Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa
UNIVERSITAT POLITÈCNICA DE CATALUNYA

ETSEIAT
Grau en Enginyeria en Tecnologies Industrials

Design of a bench to allocate accelerometers and gyroscopes on a sailplane

Annex A: Material Diagrams

Author:
Oscar Castro Ruiz

Director:
Ricardo Villar
Co-director:
Rafael Weyler

[12-06-2015]

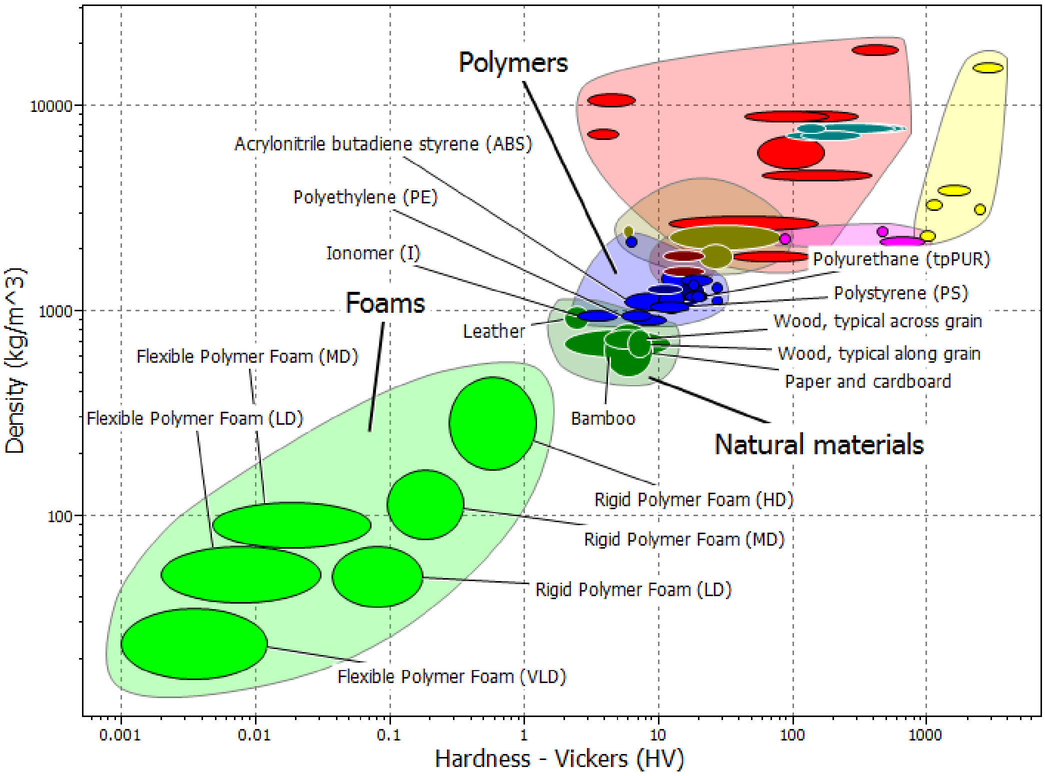
Annex A

This is the annex in charge of providing all the information needed of the materials used or that would be use in the fabrication of the benches.

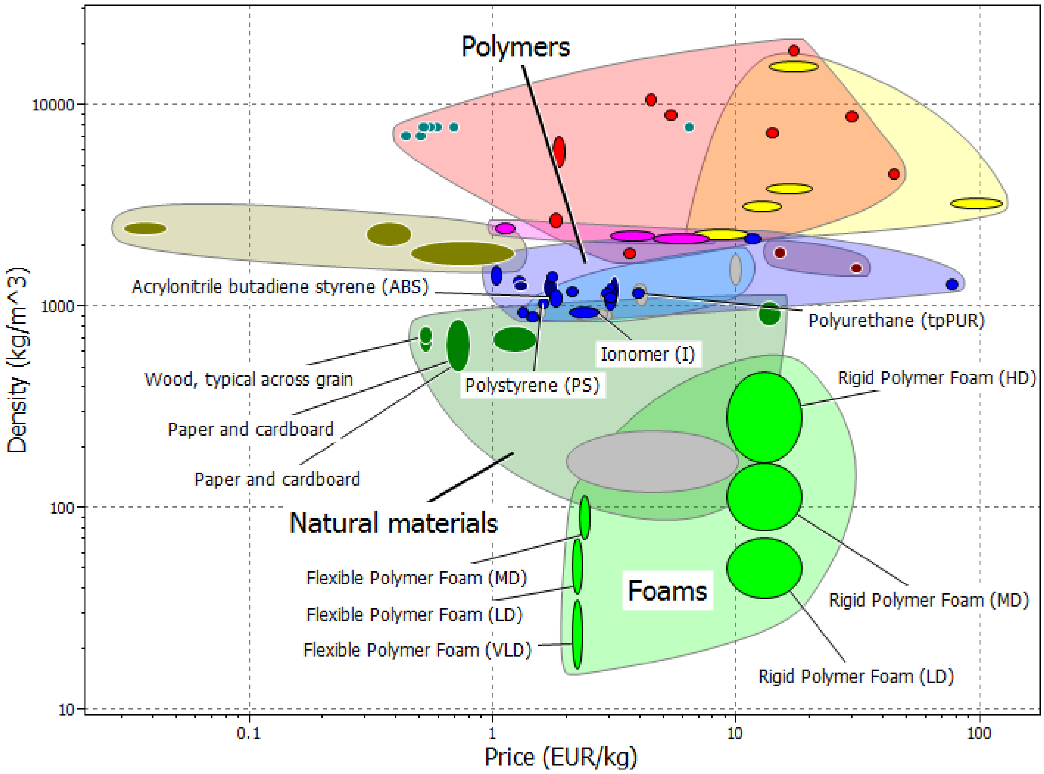
All the information below is an extract of the database available in UPC 'CES EduPack'.

Diagrams

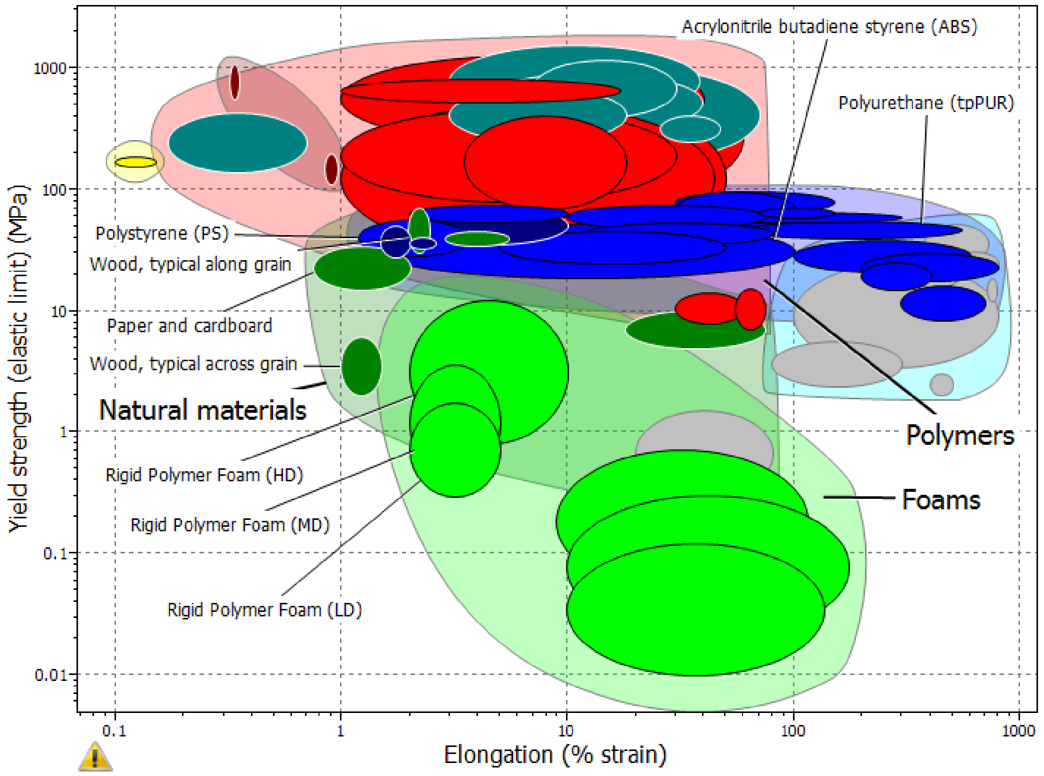
Density – Hardness



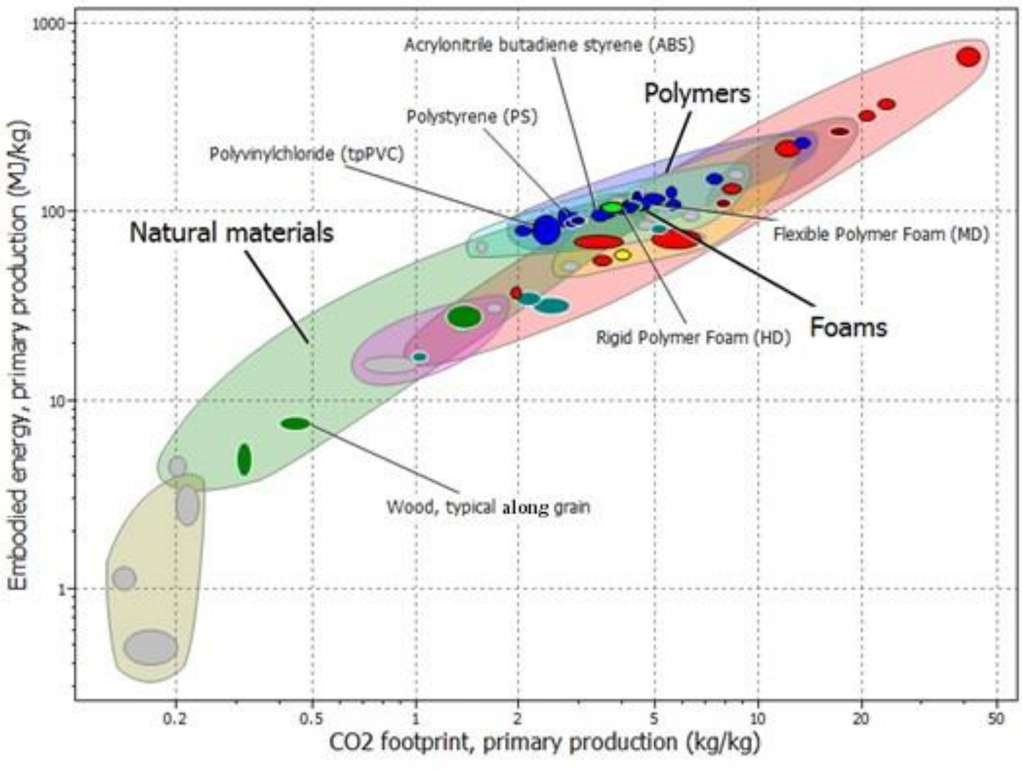
Density – Price



Yield Strength – Elongation



Embodied energy – CO_2 footprint



Basic information of the materials

Acrylonitrile butadiene styrene (ABS)

Description

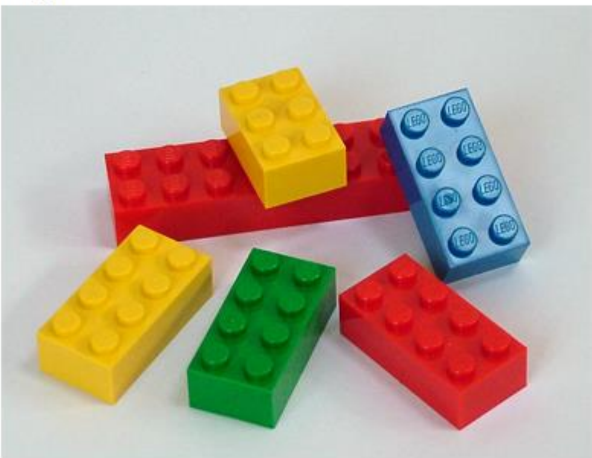
The material

ABS (Acrylonitrile-butadiene-styrene) is tough, resilient, and easily molded. It is usually opaque, although some grades can now be transparent, and it can be given vivid colors. ABS-PVC alloys are tougher than standard ABS and, in self-extinguishing grades, are used for the casings of power tools.

Composition (summary)

Block terpolymer of acrylonitrile (15-35%), butadiene (5-30%), and Styrene (40-60%).

Image



Caption

The picture says a lot: ABS allows detailed moldings, accepts color well, and is non-toxic and tough enough to survive the worst that children can do to it.

General properties

Density	1.01e3	-	1.21e3	kg/m^3
Price	1.73	-	1.9	EUR/kg

Mechanical properties

Young's modulus	1.1	-	2.9	GPa
Shear modulus	0.319	-	1.03	GPa
Bulk modulus	3.8	-	4	GPa
Poisson's ratio	0.391	-	0.422	
Yield strength (elastic limit)	18.5	-	51	MPa
Tensile strength	27.6	-	55.2	MPa
Compressive strength	31	-	86.2	MPa
Elongation	1.5	-	100	% strain
Hardness - Vickers	5.6	-	15.3	HV
Fatigue strength at 10^7 cycles	11	-	22.1	MPa
Fracture toughness	1.19	-	4.29	MPa.m^0.5
Mechanical loss coefficient (tan delta)	0.0138	-	0.0446	

Thermal properties

Glass temperature	87.9	-	128	°C
Maximum service temperature	61.9	-	76.9	°C
Minimum service temperature	-123	-	-73.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.188	-	0.335	W/m.°C
Specific heat capacity	1.39e3	-	1.92e3	J/kg.°C
Thermal expansion coefficient	84.6	-	234	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e21	-	3e22	µohm.cm
Dielectric constant (relative permittivity)	2.8	-	3.2	
Dissipation factor (dielectric loss tangent)	0.003	-	0.007	
Dielectric strength (dielectric breakdown)	13.8	-	21.7	1000000 V/m

Optical properties

Transparency	Opaque			
Refractive index	1.53	-	1.54	

Processability

Castability	1	-	2	
Moldability	4	-	5	
Machinability	3	-	4	
Weldability	5			

Eco properties

Embodied energy, primary production	* 91	-	102	MJ/kg
CO2 footprint, primary production	* 3.27	-	3.62	kg/kg
Recycle	✓			

Recycle mark

Supporting information

Design guidelines

ABS has the highest impact resistance of all polymers. It takes color well. Integral metallics are possible (as in GE Plastics' Magix.) ABS is UV resistant for outdoor application if stabilizers are added. It is hygroscopic (may need to be oven dried before thermoforming) and can be damaged by petroleum-based machining oils. ASA (acrylic-styrene-acrylonitrile) has very high gloss; its natural color is off-white but others are available. It has good chemical and temperature resistance and high impact resistance at low temperatures. UL-approved grades are available. SAN (styrene-acrylonitrile) has the good processing attributes of polystyrene but greater strength, stiffness, toughness, and chemical and heat resistance. By adding glass fiber the rigidity can be increased dramatically. It is transparent (over 90% in the visible range but less for UV light) and has good color, depending on the amount of acrylonitrile that is added this can vary from water white to pale yellow, but without a protective coating, sunlight causes yellowing and loss of strength, slowed by UV stabilizers. All three can be extruded, compression molded or formed to sheet that is then vacuum thermo-formed. They can be joined by ultrasonic or hot-plate welding, or bonded with polyester, epoxy, isocyanate or nitrile-phenolic adhesives.

Technical notes

ABS is a terpolymer - one made by copolymerizing 3 monomers: acrylonitrile, butadiene and styrene. The acrylonitrile gives thermal and chemical resistance, rubber-like butadiene gives ductility and strength, the styrene gives a glossy surface, ease of machining and a lower cost. In ASA, the butadiene component (which gives poor UV resistance) is replaced by an acrylic ester. Without the addition of butyl, ABS becomes, SAN - a similar material with lower impact resistance or toughness. It is the stiffest of the thermoplastics and has excellent resistance to acids, alkalis, salts and many solvents.

Typical uses

Safety helmets; camper tops; automotive instrument panels and other interior components; pipe fittings; home-security devices and housings for small appliances; communications equipment; business machines; plumbing hardware; automobile grilles; wheel covers; mirror housings; refrigerator liners; luggage shells; tote trays; mower shrouds; boat hulls; large components for recreational vehicles; weather seals; glass beading; refrigerator breaker strips; conduit; pipe for drain-waste-vent (DWV) systems.

Tradenames

Claradex, Comalloy, Cycogel, Cycolac, Hanalac, Lastilac, Lupos, Lustran ABS, Magnum, Multibase, Novodur, Polyfabs, Polylac, Porene, Ronfalin, Sinkral, Terluran, Toyolac, Tufrex, Ultrastyr

Polystyrene (PS)

Description

The material

Polystyrene is an optically clear, cheap, easily molded polymer, familiar as the standard "jewel" CD case. In its simplest form PS is brittle. Its mechanical properties are dramatically improved by blending with polybutadiene, but with a loss of optical transparency. High impact PS (10% polybutadiene) is much stronger even at low temperatures (meaning strength down to -12C). The single largest use of PS is a foam packaging.

Composition (summary)

(CH(C6H5)-CH2)n

Image

Caption

Polystyrene is water-clear, easily formed and cheap.

General properties

Density	1.04e3	-	1.05e3	kg/m^3
Price	1.53	-	1.68	EUR/kg

Mechanical properties

Young's modulus	1.2	-	2.6	GPa
Shear modulus	0.5	-	0.9	GPa
Bulk modulus	2.9	-	3.1	GPa
Poisson's ratio	0.383	-	0.403	
Yield strength (elastic limit)	28.7	-	56.2	MPa
Tensile strength	35.9	-	56.5	MPa
Compressive strength	31.6	-	61.8	MPa
Elongation	1.2	-	3.6	% strain
Hardness - Vickers	8.6	-	16.9	HV
Fatigue strength at 10^7 cycles	14.4	-	23	MPa
Fracture toughness	0.7	-	1.1	MPa.m^0.5
Mechanical loss coefficient (tan delta)	0.012	-	0.0175	

Thermal properties

Glass temperature	73.9	-	110	°C
Maximum service temperature	76.9	-	103	°C
Minimum service temperature	-123	-	-73.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.121	-	0.131	W/m.°C
Specific heat capacity	1.69e3	-	1.76e3	J/kg.°C
Thermal expansion coefficient	90	-	153	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e25	-	1e27	µohm.cm
Dielectric constant (relative permittivity)	3	-	3.2	
Dissipation factor (dielectric loss tangent)	0.001	-	0.003	
Dielectric strength (dielectric breakdown)	19.7	-	22.6	1000000 V/m

Optical properties

Transparency	Optical Quality		
Refractive index	1.57	-	1.59

Processability

Castability	1	-	2
Moldability	4	-	5
Machinability	3	-	4
Weldability	5		

Eco properties

Embodied energy, primary production	86	-	99	MJ/kg
CO_2 footprint, primary production	2.7	-	3	kg/kg
Recycle	✓			

Recycle mark

Supporting information

Design guidelines

PS comes in 3 guises: as the simple material ('general purpose PS'); as the high impact variant, blended with polybutadiene; and as polystyrene foam, the most familiar and cheapest of all polymer foams. All are FDA approved for use as food containers and packaging. General purpose PS is easy to mold. Its extreme clarity, ability to be colored, and high refractive index give it a glass-like sparkle, but it is brittle and cracks easily (think of CD cases). It is used when the optical attractiveness and the low cost are sought, and the mechanical loading is light: cosmetic compacts, transparent but disposable glasses, cassettes of all kinds. Medium and high impact polystyrenes trade their optical for their mechanical properties. Medium impact PS, translucent, appears in electrical switch gears and circuit breakers, coat hangers and combs. High impact PS - a blend of PPO and PS, is opaque, but is tough and copes better with low temperatures than most plastics; it is found in interiors of refrigerators and freezers, and in food trays such as those for margarine and yogurt. Other styrene blends, like Kraton, have low tensile strength and higher elongation than SBR or natural rubber. PS can be foamed to a very low density (roughly 1/3 of all polystyrene in foamed). These foams have low thermal conduction and are cheap, and so are used for house insulation, jackets for water boilers, insulation for disposable cups. They crush at loads that do not cause injury to delicate objects (such as TV sets or to the human body), making them good for packaging.

Technical notes

Polystyrene, PS, is - like PE and PP - a member of the polyolefin family of moldable thermoplastics. In place of one of the H-atoms of the polyethylene it has a C_6H_5 - benzene ring. This makes for a lumpy molecule which does not crystallize, and the resulting material is transparent with a high refractive index. The benzene ring absorbs UV light, exploited in the PS screening of fluorescent lights, but also causing the polymer to discolor in sunlight. All grades of PS have excellent electrical resistance and dielectric strength, exploited in switchgear.

Typical uses

Toys; light diffusers; lenses and mirrors; beakers; cutlery; general household appliances; video/audio cassette cases; electronic housings; refrigerator liners.

Tradenames

Aim, Bapolan, Comalloy, Dylite, Lastirol, NSC, Polystyrol, Styron, Styropor, Vestyron

Wood

Description

The material

Wood has been used to make products since the earliest recorded time. The ancient Egyptians used it for furniture, sculpture and coffins before 2500 BC. The Greeks and the peak of their empire (700 BC) and the Romans at the peak of theirs (around 0 AD) made elaborate boats, chariots and weapons of wood, and established the craft of furniture making that is still with us today. More diversity of use appeared in Mediaeval times, with the use of wood for large-scale building, and mechanisms such as pumps, windmills, even clocks, so that, right up to end of the 17th century, wood was the principal material of engineering. Since then cast iron, steel and concrete have displaced it in some of its uses, but timber continues to be used on a massive scale, particularly in buildings.

Composition (summary)

Cellulose/Hemicellulose/Lignin/12%H_2O

Image

Caption

Wood remains one of the world's major structural materials, as well finding application in more delicate objects like furniture and musical instruments. The bridge is oak; the body of a violin is spruce, the fingerboard is ebony, the bridge is rosewood and the bow is pernambuco.

General properties

Density	660	-	800	kg/m^3
Price	0.498	-	0.557	EUR/kg

Mechanical properties

Young's modulus	0.5	-	3	GPa
Yield strength (elastic limit)	* 2	-	6	MPa
Tensile strength	4	-	9	MPa
Elongation	1	-	1.5	% strain
Hardness - Vickers	4	-	8	HV
Fatigue strength at 10^7 cycles	* 1.5	-	2.5	MPa
Fracture toughness	* 0.5	-	0.8	MPa.m^0.5

Thermal properties

Maximum service temperature	117	-	137	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.15	-	0.19	W/m.°C
Specific heat capacity	1.66e3	-	1.71e3	J/kg.°C
Thermal expansion coefficient	* 31.8	-	42.5	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Poor insulator

Optical properties

Transparency	Opaque

Eco properties

Embodied energy, primary production	7	-	8.2	MJ/kg
CO2 footprint, primary production	0.4	-	0.49	kg/kg
Recycle	✗			

Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa
UNIVERSITAT POLITÈCNICA DE CATALUNYA

ETSEIAT
Grau en Enginyeria en Tecnologies Industrials

Design of a bench to allocate accelerometers and gyroscopes on a sailplane

Annex B: Flight Manual

Author:
Oscar Castro Ruiz

Director:
Ricardo Villar
Co-director:
Rafael Weyler

[12-06-2015]

Flight Manual

for the Sailplane LS1 - d

Edition: 01 Jan., 2003

This Flight Manual should be carried in the sailplane at all times.

This Flight Manual is issued for the sailplane

Model: **LS1 - d**

Serial No. ________

Manufacturer: Rolladen-Schneider Flugzeugbau GmbH
Mühlstr. 10
63329 Egelsbach
Germany

Type Support: DG-Flugzeugbau GmbH
Otto-Lilienthal-Weg 2
76646 Bruchsal
Fon: +49(0)7251-30200
Fax: +49(0)7251-3020200
Email: info@ls-flugzeugbau.de

Owner:

Pages 1-___ approved by Luftfahrt-Bundesamt:

Contents

List of Pages

Page	Edition	Edition (TB)	Edition (TB)	Edition (TB)
1	01.01.03			
2	01.01.03 (15)			
3	01.01.03			
4	01.11.72 (15)	01.01.03 (57)		
5	01.01.03 (57)			
6	01.11.72 (13)	01.01.03 (43)		
7	01.01.03 (13)			
8	01.11.72 (13)	01.01.03 (50)		
9	01.01.03 (50)			
10	01.01.03			
11	01.01.03 (33)			
12	01.01.03(56)			
13	01.01.03 (43)			
14	01.01.03			
15	01.01.03			
16	01.01.03			
17	01.01.03 (43)			
18	01.01.03			
19	01.01.03			
20	01.01.03 (15)			
21	01.11.72 (15)	01.01.03 (57)		
22	01.01.03 (57)			
23	01.01.03 (43)			
24	01.01.03			
25	01.01.03			
26	01.01.03			
27	01.01.03			
28	01.01.03			

Page numbering as of 2003. Numbers in brackets indicate page modifications by Technical Bulletins, some of which were in English language also.

List of Pages continued

Page	Edition (TB)	Edition (TB)	Edition (TB)	Edition (TB)
29	01.01.03 (13)			
30	01.01.03 (13)			
31				
32	01.01.03 (43)			
33	01.11.72 (13)	01.01.03 (57)		
34	01.11.72 (13)	01.01.03 (43)		
35	01.01.03 (13)			
36	01.11.72 (13)	01.01.03 (50)		
37	01.01.03 (37)			
38	01.01.03 (40a)			
39	01.01.03 (46)			
40	01.01.03 (56)			
41	01.01.03 (56)			
42	01.01.03 (56)			

Operating Data and Limitations

Airspeed Limits

Never Exceed	240 km/h	(149 mph,	130 Kt.)
Aero Tow	160 km/h	(99 mph,	86 Kt.)
Winch Launch	120 km/h	(75 mph,	65 Kt.)

Note:
The structural design limit of the aircraft is reached, when it is exposed to a gust of 10 m/s (1980 ft/min; 19.6 Kt.) and travelling at a speed of 240 km/h (149 mph; 130 Kt.). Thus, any additional pull-up under these circumstances would lead to exceeding the design limit of the aircraft.

All control surfaces can be moved 100% of possible travel up to 160 km/h (99 mph; 86 Kt.).
At speeds between 160 and 240 km/h (99 to149 mph; 86 to 130 Kt.), control movements should be limited to 1/3 of possible travel.

Cloud Flying permitted with appropriate instrumentation.
(See page 18)

Aerobatic Flight not permitted.

Weight Limits

Empty Weight	**approx.**	**200 kg**	**440 lbs**
Maximum Gross Weight		**341 kg**	**752 lbs**
Maximum Weight of Nonlifting Parts		**212 kg**	**467 lbs**

Inflight C.G. Limits

Horizontal reference line:
Under side of fuselage boom

Datum Line:
Leading edge of wing at root rib

Maximum Forward Inflight C.G.
210 mm [8.268 in] aft of Datum

Maximum Rearward Inflight C.G.
350 mm [13.78 in] aft of Datum

Empty Weight C.G. Limits

For empty weight C.G. Limits see page 4.

Empty Weight C.G. range

Weight kg	from mm	to aft of Datum mm	kg	mm	mm
190	665	708	221	592	658
191	652	707	222	591	657
192	650	705	223	589	655
193	648	703	224	587	654
194	645	701	225	585	653
195	643	699	226	584	651
196	641	697	227	582	650
197	639	696	228	581	649
198	637	694	229	579	647
199	635	692	230	577	646
200	632	691	231	576	645
201	630	689	232	573	644
202	628	687	233	571	642
203	626	685	234	568	641
204	624	684	235	566	640
205	622	682	236	564	639
206	620	681	237	561	637
207	618	679	238	559	636
208	616	677	239	556	635
209	614	676	240	554	634
210	612	674	241	552	633
211	610	673	242	550	631
212	608	671	243	547	630
213	607	670	244	545	629
214	605	668	245	543	628
215	603	667	246	541	627
216	601	665	247	538	626
217	599	664	248	536	625
218	598	662	249	534	623
219	596	661	250	532	622
220	594	660			

Datum: Leading edge at root rib

Horizontal
Reference line: Under side of fuselage boom

Empty Weight C.G. range

Weight lbs	from in	to aft of Datum in
419	25.78	-27.874
421	25.66	-27.835
423	25.59	-27.756
425	25.51	-27.677
428	25.39	-27.598
430	25.31	-27.520
432	25.23	-27.441
434	25.15	-27.402
437	25.07	-27.323
439	25.00	-27.244
441	24.88	-27.205
443	24.80	-27.126
445	24.72	-27.047
448	24.60	-26.969
450	24.48	-26.929
452	24.37	-26.850
454	24.25	-26.811
456	24.13	-26.732
459	24.01	-26.654
461	23.89	-26.614
463	23.78	-26.535
465	23.66	-26.496
467	23.58	-26.417
470	23.46	-26.378
472	23.34	-26.299
474	23.22	-26.260
476	23.15	-26.181
478	23.03	-26.142
481	22.91	-26.063
483	22.79	-26.024
485	22.71	-25.984
487	22.59	-25.906
489	22.52	-25.866
492	22.40	-25.787
494	22.32	-25.748
496	22.20	-25.709
498	22.12	-25.630
500	22.00	-25.591
503	21.92	-25.551
505	21.81	-25.472
507	21.73	-25.433
509	21.61	-25.394
511	21.53	-25.354
514	21.45	-25.276
516	21.33	-25.236
518	21.26	-25.197
520	21.18	-25.157
522	21.06	-25.079
525	20.98	-25.039
527	20.90	-25.000
529	20.82	-24.961
531	20.74	-24.921
534	20.63	-24.843
536	20.55	-24.803
538	20.47	-24.764
540	20.39	-24.724
542	20.31	-24.685
545	20.23	-24.646
547	20.15	-24.606
549	20.07	-24.528
551	20.00	24.488

Datum: Leading edge at root rib

Horizontal
Reference line: Under side of fuselage boom

Weak Link in tow cable

For winch launch and aero tow :

500 kg 1102 lbs

Hotellier Control System Connectors

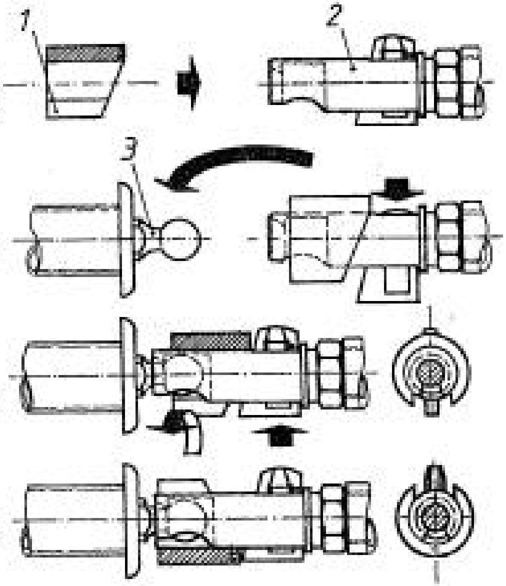
Prior to assembly, everybody should be familiar with the functioning of the Hotellier control system connectors (a.k.a. ball snap joints or clip and ball coupling). With the locking plate fully pressed, each connector <2> must be engaged **fully** on the ball <3>. During securing, the locking plate moves slightly backwards. Using the securing sleeve <1>, installation is possible only with the slot facing down. After proper connection and turning the sleeve by 180 degrees, the joint is secured, see also sketch. The sleeve always stays on the connector!

sleeve installation

Connection

Locked

Locked and secured



Warning: With connectors unsecured, the locking plate may open under load temporarily ! The locking plate should never be greased !

Normal Procedures

Adjustment of Rudder Pedals:

Forward Adjustment: Disengage latch, push both pedals forward with feet and re-engage latch.
Rearward Adjustment: Disengage latch, pull pedals rearward to desired position and re-engage latch.

Canopy Emergency Jettison:

Pull both canopy locks near forward canopy frame backward and turn inward. Lock pins in open position by turning outward again.

Parachute Static Line:

Attach to red marked tube potion at left rear of pilot seat.
When using a parachute with separate harness, make sure **not** to route connector around landing gear drive rod, as this makes emergency exit impossible.

Winch Launch

Maximum winch launch speed = 120 km/h, 75 mph, 65 Kt.

Attention:

Keep control stick during take off roll in normal position, not fully forward. Apply forward pressure when entering transition, because of pitch-up tendency especially with rear C.G. positions.

Aero tow only at nose hook (when installed)

Maximum aero tow speed = 160 km/h, 99 mph, 86 Kt.

Minimum aero tow speed not below 90 km/h, 56 mph, 49 Kt., with full water ballast tanks not below 100 km/h, 62 mph, 54 Kt.

Tow cable length = 30 to 60 m, 100 to 200 ft

Initial aileron effectiveness may be considerably increased by slight extension of air brakes. They should be retracted and locked before leaving ground.

Landing gear

Landing gear can be operated at all permissible speeds.

Handle forward and locked:	Gear extended
Handle rearward and locked:	Gear retracted

Caution:

When pushing backwards and applying wheel brake, landing gear may unlock and fold. This results in a bended drive rod.

Free Flight

Stall speed around 65 to 60 km/h 37 to 40 mph
32 to 35 Kt.
with full water tanks 75 to 70 km/h, 47 to 43 mph,
40 to 38 Kt.

Minimum sinking speed at 80 km/h (50 mph, 43 Kt.)

Best glide ratio at 90 –100 km/h
(56-62 mph, 49-54 Kt.)

Flight polar see page 32

High Speed Flight

Trim carefully in high speed flight. Otherwise excessive pitch-up may result from inadvertent freeing of stick.
It is recommended to hold the stick with both hands during high speed flight to avoid oversteer.
In trimmed flight the stick should be free for short periods only to avoid speed oscillation.

High Speed Reduction

If red line speed should be exceeded for any reason, extend air brakes carefully. Air brakes can be fully extended and retracted at 240 km/h (149 mph, 149 Kt.)

Landing

Landing gear should always be extended, even during emergency landings.

Final approach speed about 90 km/h (56 mph, 49 Kt). Air brakes allow wide control of glide angle. Touch down recommended with air brakes half extended.

Avoid side slip with air brakes extended, because of T-tail shaking due to air brake turbulence.

Minimum speed with air brakes fully extended increases to
70-75 km/h (43-47 mph, 38-40 Kt)
with full water ballast 80-90 km/h (50-56 mph, 43-54 Kt)

Wheel Brake

Wheel brake is coupled to air brake system and brake operation starts with air brakes almost fully extended.

The wheel brake is an emergency brake and should be used sparingly to avoid excessive wear.

Emergency Procedures

Stalls

After entering stall, the plane starts oscillating around the longitudinal axis.

Aileron effectiveness is still existent, but with a certain delay.

A larger rudder deflection yields in spinning.

Spinning

C.G. position has a marked effect on spinning characteristics.

With forward C.G. position, after one turn of spinning the plane transfers into spiral dive. Cautiously pull-out with airbrakes extended.

With intermediate C.G. position, normal spinning occurs. With all controls in normal position, spinning terminates on its own.

With rearward C.G. position, spinning should be terminated using the following method:

1. Rudder against direction of rotation
2. Stick in normal position until rotation stops
3. Rudder in normal position and cautious pull-out

Rain and Icing

Raindrops, frost and icing can change airfoil considerably resulting in totally different flight characteristics.

Minimum speed increases. Therefore, increase approach speed to landing during rain.

Weight and Balance

Minimum Cockpit Load (Pilot and Parachute) **75 kg, 165 lbs**.

For lower cockpit load, weight deficiency must be compensated by appropriate lead weight cushion in seat. When trim box is existent, this must be used for trimming.

1 trim weight of 3.2 kg, 7 lbs in the trim box compensates 5 kg, 11 lbs of weight deficiency.

When cockpit load is above 90 kg, 198 lbs, all trim weights must be removed from the trim box.

Maximum Cockpit Load (Pilot and Parachute) 110 kg, 242 lbs, when not reduced by maximum all-up weight (312 kg, 688 lbs)

Cockpit Loading Plan

Should be updated during each annual inspection and change of equipment by inspector.
Maximum Cockpit Load is calculated from Maximum Weight of Non-Lifting Parts (212 kg, 467 lbs) and from maximum all-up Weight 341 kg, 752 lbs.

Date of Inspection	Max. Weight of Pilot + Parachute	Max. Weight of Pilot, Parachute Waterballast	Minimum Cockpit Load	Inspector

Cockpit Loading Plan

Should be updated during each annual inspection and change of equipment by inspector.
Maximum Cockpit Load is calculated from Maximum Weight of Non-Lifting Parts (212 kg, 467 lbs) and from maximum all-up Weight 341 kg, 752 lbs.

Date of Inspection	Max. Weight of Pilot + Parachute	Max. Weight of Pilot, Parachute Waterballast	Minimum Cockpit Load	Inspector

Minimum Equipment

Airspeed Indicator, range 50 – 250 km/h (31 –155 mph, 27 – 135 Kt.)
For colour marking: see page 25

Altimeter

Four piece seat belt harness

Seat cushion or parachute in compressed form should not be thinner than 80 - 100 mm (3 - 4 in)

Checklist, Type Placard, Weight and Balance Plan and operating placards

Flight Manual

In addition for Cloud Flying:

Turn and Bank Indicator or Artificial Horizon

Compass compensated

Variometer with appropriate range

Minimum equipment must be approved for use in gliders

Flight Control Travel Limits

Elevator deflection

Up	60 ± 2 mm	1.575 ± 0.08 in
Down	40 ± 2 mm	2.362 ± 0.08 in
Radius	230 mm	9.055 in

Rudder deflection

Both sides	200 ± 10 mm	7.874 ± 0.394 in
Radius	420 mm	16.535 in

Aileron deflection

Up	75 ± 5 mm	2.953 ± 0.197 in
Down	32 ± 3 mm	1.260 ± 0.118 in
Radius	168 mm	6.614 in

Tyre pressure

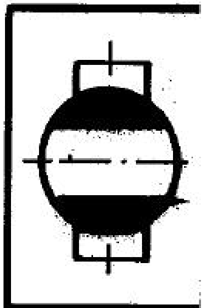
Without water ballast 3 bars, 44 psi
With water ballast 3.5 bars, 51 psi

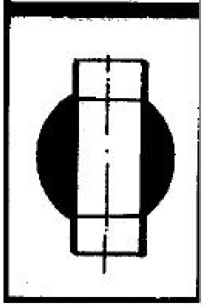
Placards

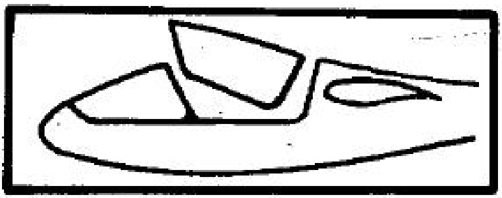
LS1 CHECKLIST

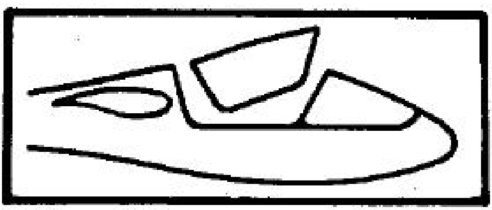
This sailplane must be operated in compliance with operating limitations as stated in the form of markings, placards and Flight Manual

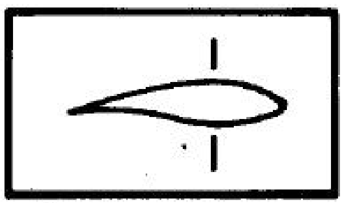
1. Secure main pins
2. Secure horizontal tail
3. Connect controls
4. Connect air brakes
5. Connect parachute static line
6. Lock air brakes
7. Test controls
8. Lock canopy
9. Check tow release



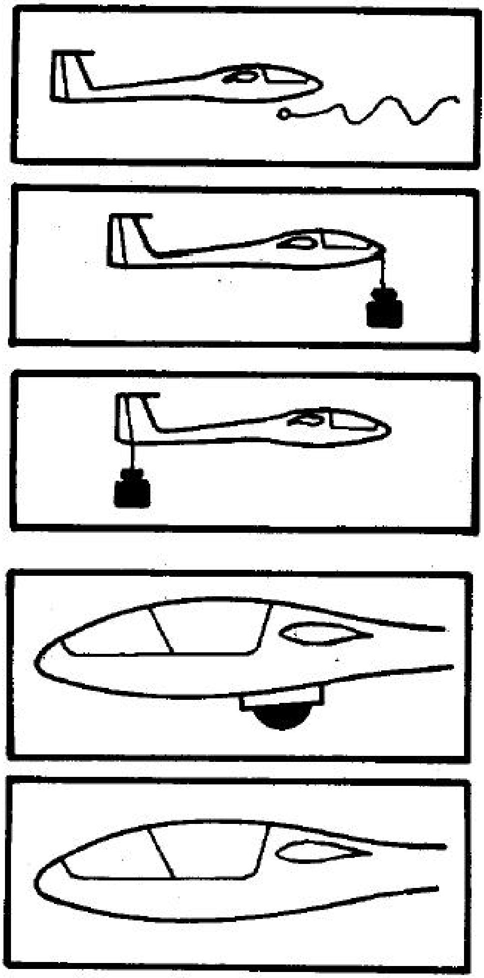








Placards



Colour Markings of Airspeed Indicator

green arc	80 –	160 km/h
	50 –	99 mph
	43 -	86 Kt.
yellow arc	160 -	240 km/h
	99 -	149 mph
	86 -	130 Kt.
red radial	240 km/h	
	149 mph	
	130 Kt.	

Filling of Water Ballast

1) After rigging, connect both tubes to root ribs and disconnect from fuselage system for filling. Close discharge valve.

2) Lay one wingtip on the ground, fill water tank using funnel and tube with intended amount.
In no case fill more than 30 litres (8 US gallons, 7 Imp. gallons), because during connection to fuselage system this will overspill into the fuselage.

3) Connect tube to fuselage system in baggage compartment.

4) Lay second wing on the ground, fill same amount with identical procedure.

Discharge of Water Ballast

Open discharge valve
(Complete discharge takes about two minutes)

Leave valve open after discharge to avoid pressure increase in system.

Contents

Maintenance and Care

Even though the LS1 is made of fiberglass, you should protect it from humidity as you would with other sailplanes.

Protect the aircraft from intense heat, as it may lead to surface deterioration.

Dust particles, insects and paint damage at the leading edge of the wing reduce performance significantly.

Taping of upper aileron gaps and wing-fuselage connection is necessary for control surface effectiveness and performance.

The canopy should not be taped, as it might interfere with an emergency exit.

Tyre pressure 3 bars (44 psi), increase to 3.5 bars (51 psi) with water ballast.
The C.G. hook is exposed to dirt, therefore it requires frequent cleaning and lubrication.

The static pressure pickups at the fuselage behind the wing or below the canopy front end must be kept clean. Any constriction will produce erroneous airspeed indication.

Air brake boxes are air tight and water tight. Any moisture collected in the box must be wiped using a sponge as soon as possible.

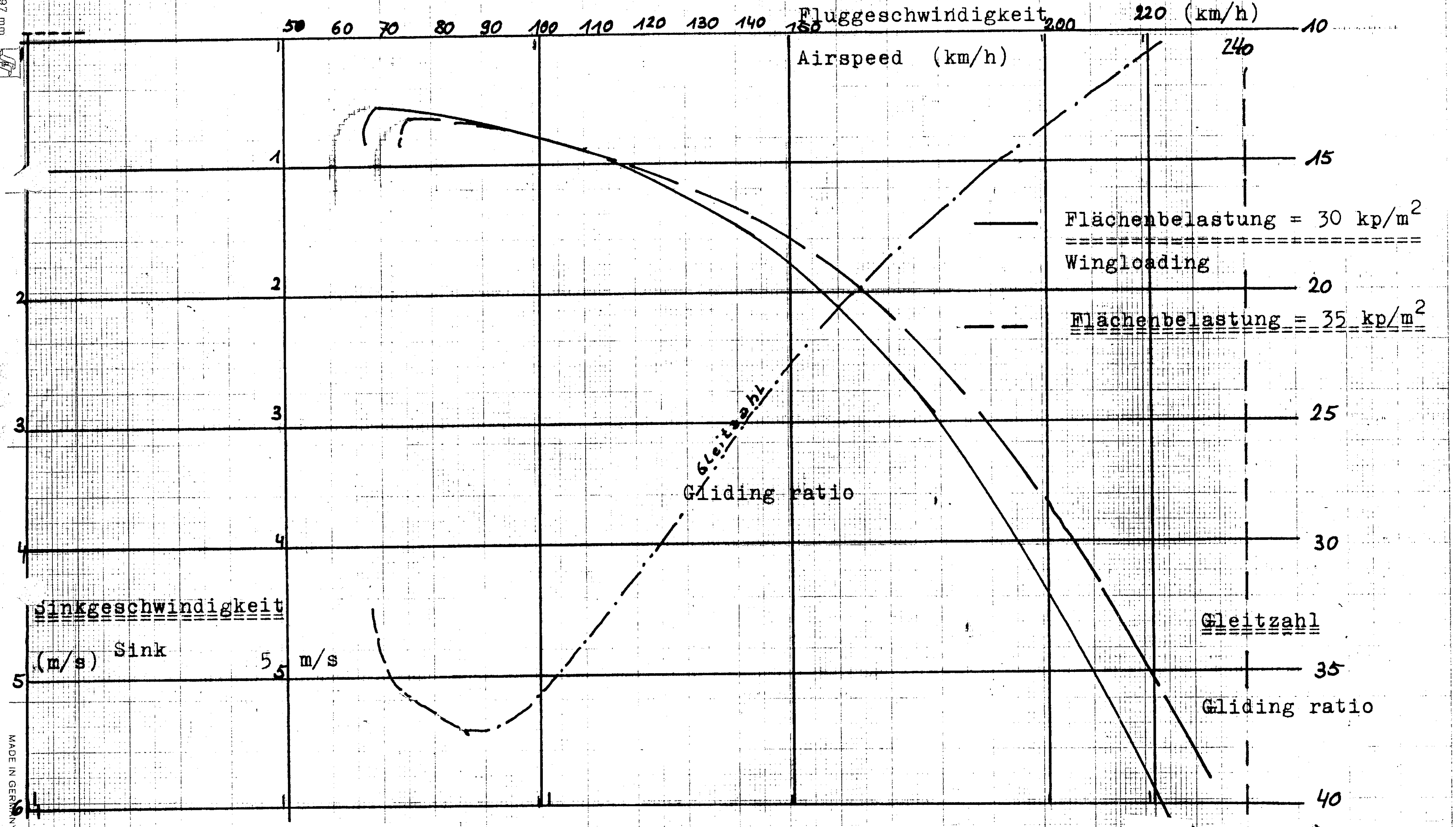
Rigging

1. Clean all pins and matching bushes
2. Insert left spar end into fuselage and watch for angle of dihedral to avoid fuselage shell damage.
3. Insert right spar end into fuselage and watch for angle of dihedral, undersides of spar ends must be parallel.
4. Insert right main pin partly to align right side by tapered portion.
5. Adjust dihedral to allow full insertion of left main pin.
6. Fully insert right main pin. Secure both main pins behind spring loaded pegs.
7. Connect aileron and air brake systems with ball snap joints (L'Hotellier quick connectors).
8. Turn LS securing sleeves half a turn. See also page 10 for detailed information and sketch of connectors and securing procedure.
9. Install horizontal tail and fix at under side with bolt. Use safety needle to tighten bolt before securing against fixed peg.
10. Install total energy unit, battery and barograph.
11. Connect automatic parachute to red marked portion at main bulkhead using special loop only.
12. Tape wing-fuselage intersection gaps on upper and lower sides.

De-Rigging

1. Unscrew horizontal tail bolt and pull off from fuselage
2. Turn LS-sleeves half a turn (slot in downward position), unlock air bakes.
3. Disconnect control system ball snap joints (L'Hotellier quick connectors).
4. Support wing tips until unlocked main pins can be turned. Keep this wing position to avoid damage to fuselage shell and remove main pins.
5. Remove left wing without altering angle of dihedral.
6. Remove right wing.

LS1 **Flug- und Gleitwinkelpolare** Performance Curve



LS1 Repair Instructions

Construction method:

1. Wings, horizontal tail, ailerons, rudder

   These parts consist of an approximately 7 mm thick GRP-foam sandwich without any ribs. This means, that the foam is covered by GRP layers on outer and inner sides.

2. Fuselage, vertical tail fin, seat

   These parts are made from several GRP-layers, altogether about 2.5 mm thick.

Materials:

Resin:	Epikote 162	Deutsche Shell Chemie
Hardener:	Laromin C 160	BASF

Mixture ratio: 100 parts of weight resin
38 parts of weight hardener

The mixture ratio is essential for material properties. Stir mixture thoroughly until all optical inhomogeneities have disappeared. If filler material is required, add only after stirring.

Processing temperature not below 20º Centigrade (68º Fahrenheit)

Repair regions must be heat treated at 55º Centigrade (131º Fahrenheit) for at least 15 hours.

LS1 Repair Instructions continued

Filler Materials:

Microballon: 100 parts of weight Resin
38 parts of weight hardener
40 parts of weight microballon

Cotton flocks: 100 parts of weight Resin
38 parts of weight hardener
25 parts of weight cotton flocks

Foam: PVC foam Conticell C60

Fibre glass fabric (Maker Interglas)
Qualities 92110
92125
92145

Gelcoat:

PE-Vorgelat 3-6910 (Lesonal)
PE Hardener 7-2050
PE Thinner 6-3026

Mixture ratio 100 parts of weight Vorgelat
10 parts of weight hardener
add thinner required for spraying

OR

Scheufler UP-Vorgelat white T35
Hardener SF2
Thinner SF

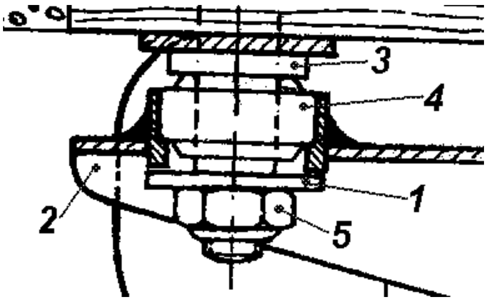
Mixture ratio 100 parts of weight Vorgelat
2 parts of weight hardener (for brushing-on)
10 parts of weight thinner, then
2-3 parts of weight hardener (for spraying)

Repairs

Whenever a damage or defect should arise -even cracks in paint may be an indication – contact the manufacturer immediately for advice, help and instructions. There is no better way to ensure correct and sound elimination.

Axial Securing of Control Surfaces

Rudder:
The rudder is fixed against lifting at the lower bearing by one large washer, see sketch. After assembly and tightening self-locking nut with maximum torque of 1 mkg (7.23 ftxlb) the rudder should have slight axial play. Max. axial play 1 mm (0.039 in)



1 Securing washer
2 Fuselage bracket
3 Rudder bolt
4 Lower rudder bearing
5 Self-locking nut

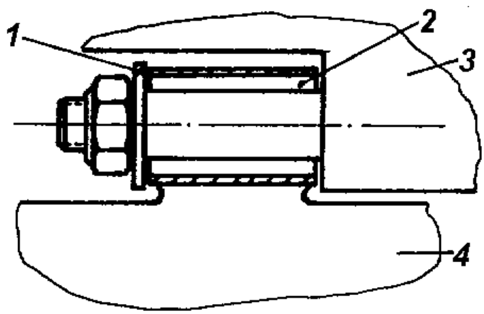
Adjustment of axial play possible by use of washers:

Increase axial play: Washers with internal diameter of 6 mm (0.236 in) inserted before axial securing washer.

Decrease axial play: Washers with internal diameter of 8 mm (0.315 in) inserted before axial securing washer.

Aileron:

Same principle as described above.



1 Securing washer
2 Needle roller bearing (not depicted)
3 Wing
4 Aileron

Check presence of axial securing large washers regularly during annual inspections.

Important Warning:
Unless regularly polished with hard wax after each cleaning, sanded gelcoat shows distinctive weathering marks due to changes of temperature, ultra violet radiation and humidity (Wax at least twice a year!).

Cleaning and Care Recommendations according to paint manufacturer Lesonal dated 07.07.81:

Suitable:
- Water with washing-up liquid, added in recommended quantities
- Car polish with or without silicone.
- Car hardwax.

Suitable with Reservations:
- Tar remover for cars based on petrol or white gasoline.
- Alcohol, like spirit or isopropyl alcohol.

Reservations are, that these liquids should only be used for wiping off, not for soaking with rags.

Unsuitable:
- Strong solvents and thinners (Acetone)

These items may decompose gelcoat and cause local shrinking.

Completely unsuitable:
- Trichlorethylene
- Carbon tetrachloride or similar hydrocarbon chlorides

These liquids destroy the gelcoat.

Other over the counter products must be tested before being used!

Inspection Sequence to Increase Service Life

1. **General**
   Results of supplementary serviceability tests at main spar booms for wings proved, that service life of FRP sailplanes may be increased to 12.000 hours if airworthiness of each single sailplane (in addition to annual inspections) is checked according to a special multi-step inspection programme.

2. **Schedule**
   When the sailplane has reached 3000 hours service life an inspection according to the programme mentioned under 3. Must be carried out. If the result of the inspection is positive or found defects repaired properly, the service life of this sailplane will be increased by 3000 hours to 6000 hours (1. Step).

   The inspection routine should be repeated when reaching 6000 hours. With a positive result or found defects repaired properly, service life will be increased by another 3000 hours to 9000 hours (2. Step).

   The inspection routine should be repeated when reaching 9000 hours. With a positive result or found defects repaired properly, service life will be increased by 1000 hours each to 10000 hours (3. Step), 11000 hours (4. Step) and 12000 hours (5. Step).

3. The valid **Inspection Programme** should be requested from the manufacturer stating serial number and service time.

4. Inspections should be carried out at the manufacturer or an adequately licences repair shop.

5. Results of inspections must be recorded in an inspection report, commenting to each inspection step. If inspections are not carried out at the manufacturer, a copy of the report must be sent to them for analysis.

6. This inspection does not affect annual inspections.

Weight and Mass Balance of Control Surfaces
(Check whenever change of weight is suspected)

Weight and mass balance should be within given limits for safety against danger of flutter.

Control Surface	Radius mm / *in*	Horizontal Reference Line	Weight at rear edge of reference line kg / *lbs*	All-up weight kg / *lbs*
Elevator	230 *9.055*		xx)	Not specified
Rudder	420 *16.535*	Centreline of section	0.040 *0.088*	Not specified
Aileron	169 *6.654*	Upper side of section	0.300 – 0.415 *0.661 – 0.91*	1.860 – 2.680 *4.101 – 5.90*

xx) Elevator C.G. should be between 19 to 25 mm (0.748 to 0.984 in) aft of flange of bushes. Due to system springs the elevator C.G. position cannot be measured at the fuselage, but must be done separately.

Measuring Technique: Flight control surface should be supported at two bearing points without any tension or friction. Weight at rear edge should be measured with reference line at level position.

TB-AD-Repetitive Inspections List

Serial Number:	Reg. Signs:	Year of Manuf.:

List opened date: ____________ Signature: Page No. 1

TB LBA-AD	Components concerned	Steps / Modification	Interval	Date Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector
	C.G. hook *G: ___* *S/N.: _______*	*Overhaul*	*2000 take-offs*					
	Nose hook *E: ___* *S/N.: _______*	*Overhaul*	*2000 take-offs*					
	Seat belt harness ______ *S/N.: ________________* *S/N.: ___________*	*Overhaul* *Exchange* *Webbing*	*12 years*					
TB 37 *LBA-AD* *79-44*	*Axially securing washers at laterally fixed control bearings*	*Check for existence*	*Each annual inspection*					

TB-AD-Repetitive Inspections List

Serial Number: | Reg. Signs: | Year of Manuf.:

List opened date: _____________ Signature: Page No. 2

TB LBA-AD	Components concerned	Steps / Modification	Interval	Date Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector
~~*TB 52 LBA-AD 93-001 Rev.3*~~	~~*LS securing sleeves **red** for L'Hotellier connectors*~~	~~*Inspect for proper retaining and function*~~	~~*Each annual inspection*~~					
TB 56 LBA-AD 93-001 Rev.3	*LS securing sleeves **white** for L'Hotellier connectors*	*Inspect for proper retaining and function*	*Each annual inspection*					

TB-AD-Repetitive Inspections List

Serial Number: | Reg. Signs: | Year of Manuf.:

List opened date: _____________ Signature: Page No. 3

TB LBA-AD	Components concerned	Steps / Modification	Interval	Date Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector	Datum Fl.-hours Stamp Inspector

Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa
UNIVERSITAT POLITÈCNICA DE CATALUNYA

ETSEIAT
Grau en Enginyeria en Tecnologies Industrials

Design of a bench to allocate accelerometers and gyroscopes on a sailplane

Annex C: x-IMU User Manual

Author:
Oscar Castro Ruiz

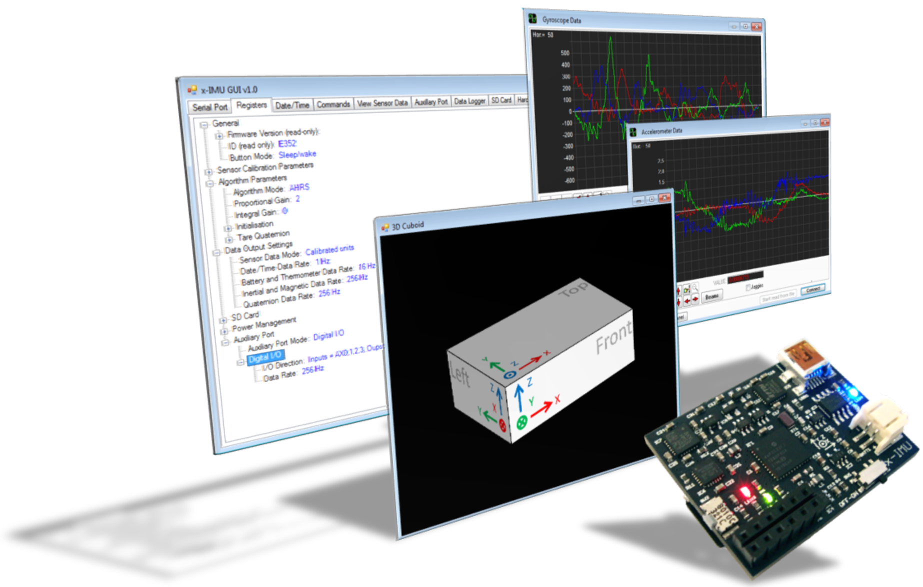
Director:
Ricardo Villar
Co-director:
Rafael Weyler

[12-06-2015]

x-IMU User Manual 5.2

x-io Technologies

November 1, 2013



Disclaimer

The x-IMU and associated software are provided in an 'as in' condition. No warranties, whether express, implied or statutory, including but not limited to implied warranties of merchantability and fitness for a particular purpose apply. x-io Technologies shall not in any circumstances, be liable for special, incidental or consequential damages, for any reason whatsoever.

Contents

1 x-IMU overview

The x-IMU was designed to be the most versatile Inertial Measurement Unit (IMU) and Attitude Heading Reference System (AHRS) product available. Its host of on-board sensors, algorithms and configurable 8-channel auxiliary port make the x-IMU both a powerful sensor and controller. Communication is enabled via USB or Bluetooth for wireless applications. The on-board SD card, battery charger (via USB), real-time clock/calendar and motion trigger wake up also make the x-IMU an ideal stand-alone data logger.

The open source x-IMU GUI allow users configure all internal x-IMU settings, view sensor data in real-time and export data to software such as MATLAB and Microsoft Excel. Custom user software may be developed using the x-IMU API.

1.1 x-IMU Features

On-board sensors

- Triple axis 16-bit gyroscope - Selectable range up to ±2000°/s
- Triple axis 12-bit accelerometer - Selectable range up to ±8 g
- Triple axis 12-bit magnetometer - Selectable range up to ±8.1 G
- 16-bit thermometer
- 12-bit battery voltage level
- Factory calibrated
- Temperature compensated (gyroscope only)
- Selectable data rates up to 512 Hz

On-board algorithms

- IMU and AHRS algorithms provide real-time measurement of orientation relative to the Earth
- Internal states updated at 512 Hz
- Algorithm 'initialise' and 'tare' commands can be sent in real-time
- Complete sensor calibration algorithms for user maintenance

Connectivity

- USB
- Bluetooth - Class 1, 100m range, SPP
- Micro SD card - Supports FAT16/32 and SDHC
- UART (see auxiliary port mode)

Power options

- USB
- LiPo battery - On-board charging via USB
- External source from 3.6 V to 6.3 V
- Low power consumption - 50 mA to 150 mA dependent on settings and usage, 130 μA sleep mode

Low profile

- Dimensions: 33 × 42 × 10 mm (57 × 38 × 21 mm with plastic housing and battery)
- Weight: 12g (100 g with plastic housing and battery)

Other features

- Motion triggered wake-up and sleep timer
- Real-time clock and calendar
- Configurable command button
- Configurable 8 channel auxiliary port

Auxiliary port modes

- External power in from 3.6 V to 6.3 V
- 3.3 V power out up to 100 mA
- Digital I/O mode - 8 channels, controlled via USB or Bluetooth
- Analogue input mode - 8 channels, 12-bit resolution, 0 to 3.3 V
- PWM output mode - 4 channels, 1 to 65,535 Hz; controlled via USB or Bluetooth
- ADXL345 bus mode - 4 external triple-axis, 16g, 13-bit resolution accelerometers
- UART mode - 3.3 V, 2400 to 921.6k baud, substitutes Bluetooth

1.2 x-IMU Software

The x-IMU GUI (Graphical User Interface) provides interface to all features and functionality of the x-IMU via the x-IMU API. The x-IMU GUI is open source and so is intended to serve as a comprehensive template for those using the x-IMU API to develop their own applications. Additional open source software examples using the x-IMU API for various applications can be found on the x-IMU Examples webpage.

Features

- View, edit and backup all internal x-IMU settings
- Real-time 2D and 3D data graphics
- Control panels for auxiliary port
- Data logger and file converter for exporting data; e.g. to MATLAB, Microsoft Excel, etc.
- Magnetic calibration tools
- Firmware bootloader to access new features in future x-IMU firmware versions

2 Getting started

1. Install the USB drivers or pair the x-IMU as a Bluetooth device.
2. Download and install the latest version of the x-IMU GUI.
3. Connect to the x-IMU via the serial port tab page of the x-IMU GUI.

3 Hardware overview

Figure 1: x-IMU and battery in plastic housing

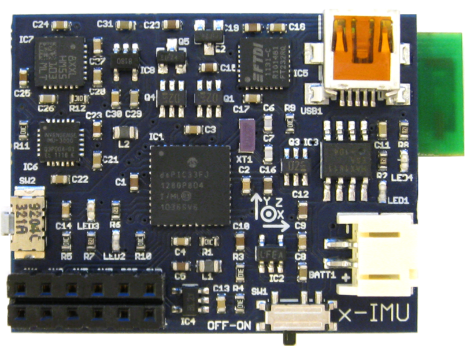


Figure 2: x-IMU top

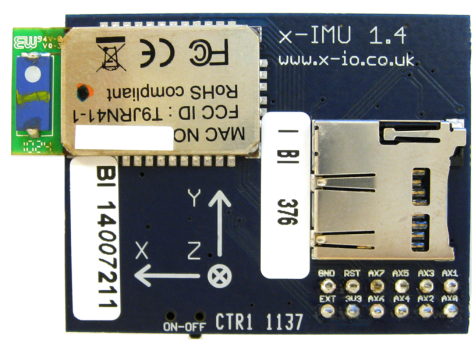


Figure 3: x-IMU bottom

3.1 Power switch

The power switch is used to switch the battery and USB power on or off. The battery and USB power is completely disconnected when the switch is in the *off* position. The x-IMU may be powered by an external supply via the auxiliary port if the power switch must be in the *off* position.

3.2 Command button

The command button that allows the execution of commands while the x-IMU is operating as a standalone device. See the command button section for more information.

3.3 LEDs

3.3.1 Status LED (Green)

The green LED indicates the status of the x-IMU. It will remain lit while the device is sampling and sending data and will otherwise be extinguished; for example, during the execution of some commands. In sleep mode the green LED will blink once every 3 seconds. The green LED will flash rapidly while the on-board bootloader is active.

3.3.2 SD card LED (Amber)

The amber LED indicates SD card activity. See the SD card LED section for more information.

3.3.3 Bluetooth LED (Blue)

The blue LED indicates the state of the Bluetooth connection and power status. See the Bluetooth LED section for more information.

3.3.4 Charging LED (Red)

The red LED indicates the charging state of the battery. The red LED will remain lit while the battery is charging and will be extinguished once the battery is charged. See the battery and charging section for more information.

3.4 USB socket

The USB mini-B socket is used to connect the x-IMU to a computer via a standard *USB A to mini B (5 pin)* type cable. See the USB section for more information.

3.5 Micro-SD card socket

The micro SD card socket is used to log all data generated by the x-IMU to an SD card. The x-IMU supports standard SD and SDHC cards formatted as either FAT16 or FAT32. The file must be closed before the SD card is removed or the x-IMU switched of otherwise the current file will corrupt and data lost. See the SD card section for more information.

3.6 Bluetooth module

The on-board Bluetooth module is used to connect the x-IMU to a Bluetooth host. See the Bluetooth section for more information.

3.7 Battery connector

The on-board battery connector allows the x-IMU to be powered by any single-cell Lithium Polymer (LiPo) battery. The battery is automatically charged while the x-IMU is connected to a USB host. See the battery and charging section for more information.

3.8 Auxiliary port header

The auxiliary port that can be configured to one of many modes. The auxiliary port connector is a 2×6, 2.54 mm pitch female header socket. The socket pins include: ground, external power input, 3.3 V output, hard reset and 8 I/O lines. See the auxiliary port section for more information.

4 Software overview

4.1 x-IMU GUI

4.1.1 Tab page: Serial port

The serial port tab page is used to manage the USB or Bluetooth connection between the software and the x-IMU. The USB and Bluetooth connections will each appear as a separate serial port; see the USB section and Bluetooth section for more information and how to find the serial port name assigned to each connection.

To connect to the x-IMU, the user first select the correct serial port name the x-IMU appears as in the *Port name* drop down list. If the name does not appear in the list, the user can either press the *Refresh List* button to update the drop down list or type in the port name directly. The *Open Port* button may then be pressed to connect to the device.

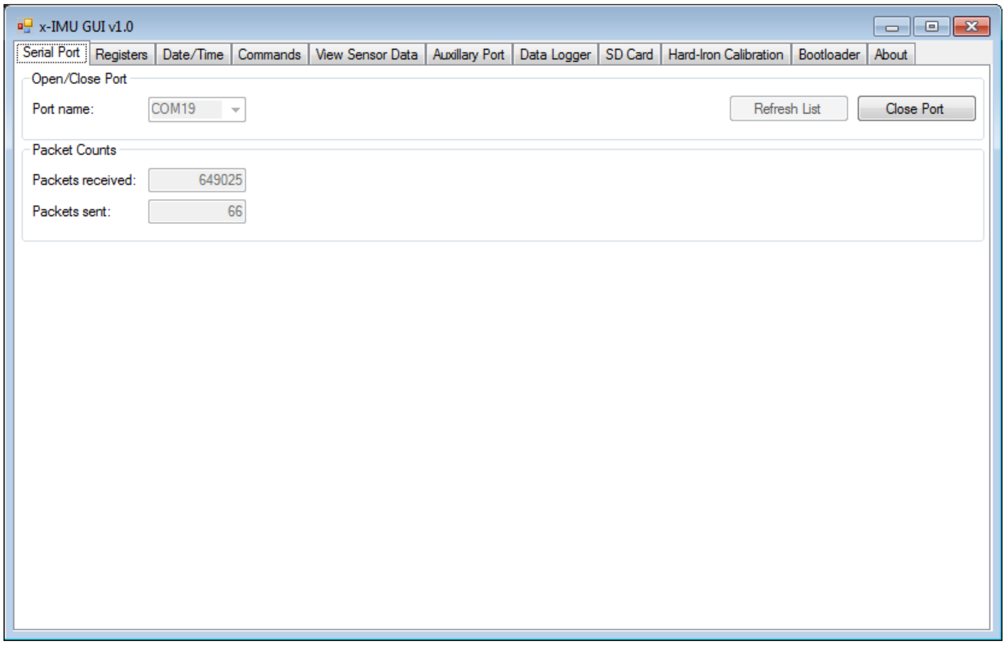


Figure 4: x-IMU GUI serial port tab page

4.1.2 Tab page: Registers

The registers tab page allows the user to view, edit and back up all internal settings on the x-IMU; see the registers section for more information on x-IMU registers. All registers are organised into sections within a tree view where the end node of each branch is an individual register name and text box or drop down list containing the register value. Register values that have been read directly from the x-IMU or loaded from file will appear as blue text. Any registers values then edited will appear as red text. A right click on any register will show the action menu.

To read all register on the x-IMU, the user should right click anywhere in the registers tab page and select *Read all registers*. The software will then read each register and update the values in the tree view. Individual registers or groups of registers may be read by first selecting a register or group within the tree view and then selecting *Read this register only* or *Read all registers in this group only*. Register values in the tree view may be written to the x-IMU using the *Write all registers*, *Write this register only* and *Write all registers in this group only* options in the action menu.

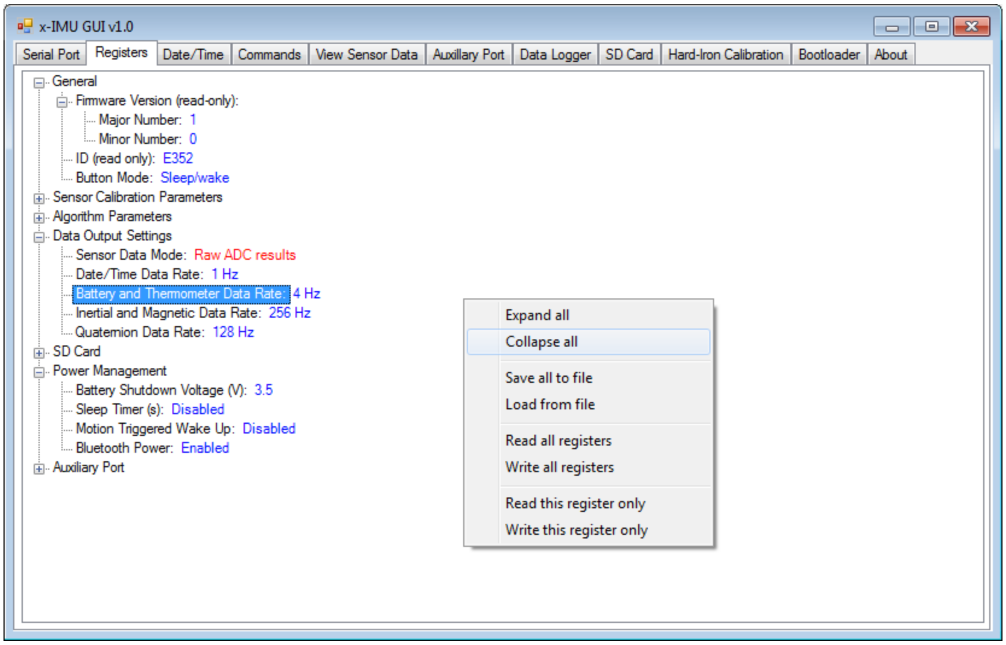


Figure 5: x-IMU GUI registers tab page with (right click) action menu

4.1.3 Tab page: Date/time

The date/time tab page allows the user to view and set the date and time of the x-IMU's real-time clock and calendar. The *Received date/time* text box displays the date and time each time it is received from the x-IMU. The *Read Date/Time* button may be used to read the current date and time of the x-IMU; this is of use if date/time data rate has been disabled. Pressing the *Set Date/Time* button will set the x-IMU date and time equal to computer date and time.

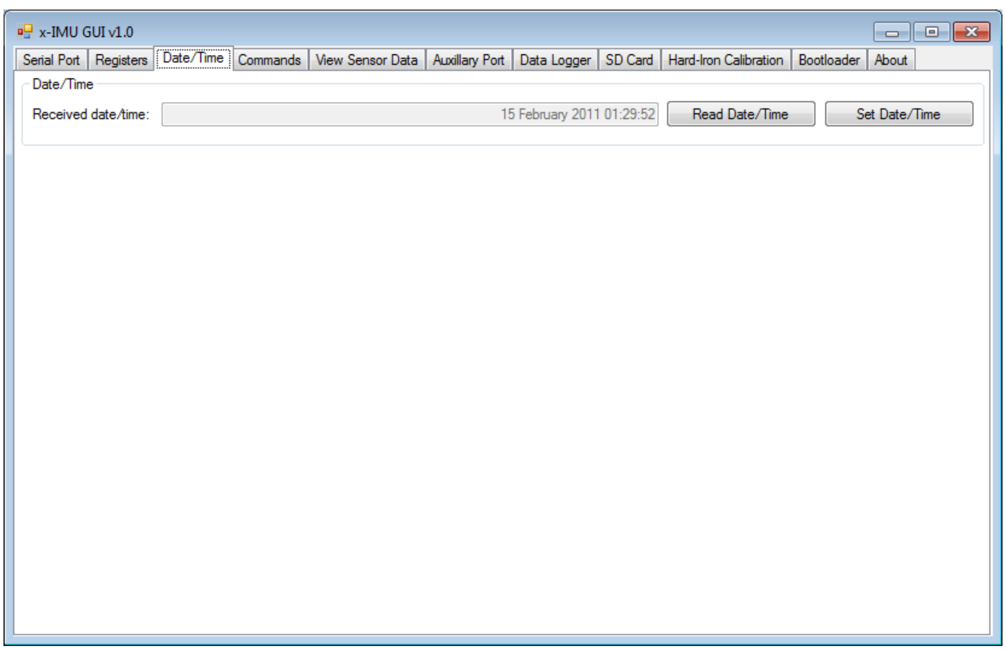


Figure 6: x-IMU GUI date/time tab page

4.1.4 Tab page: Commands

The commands tab page is used to send commands to the x-IMU. See the commands section for more information on individual commands. Once the x-IMU has processed a command it will echo the command back and it will appear in a message box. To suppress these message boxes, un-check the *Display received command messages in message box* check box.

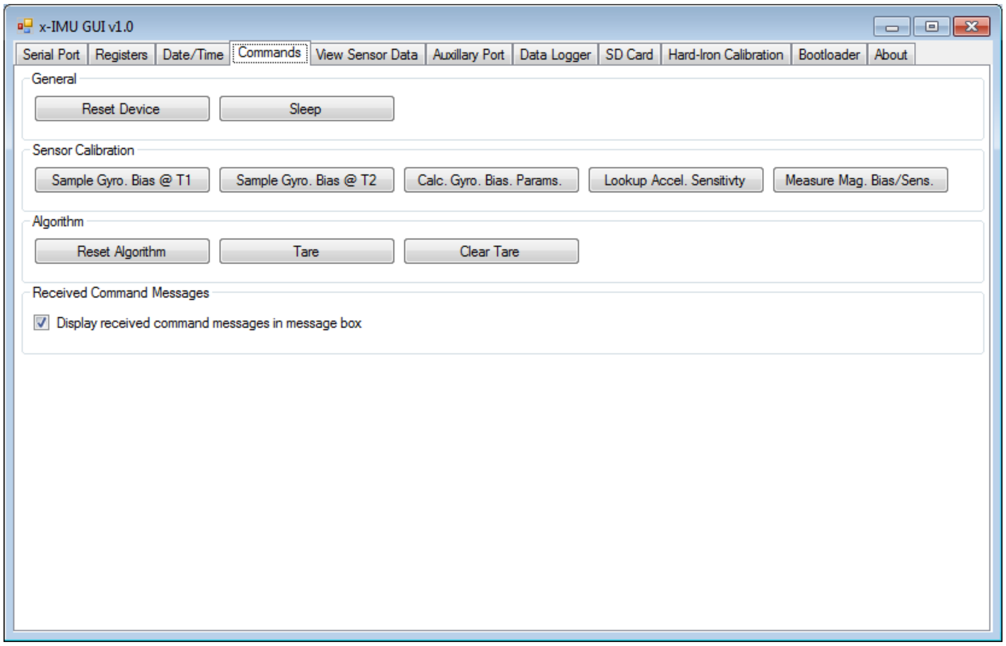


Figure 7: x-IMU GUI date/time tab page

4.1.5 Tab page: View sensor data

The view sensor data tab page contains buttons to show or hide separate real-time data graphic windows for incoming x-IMU sensor data.

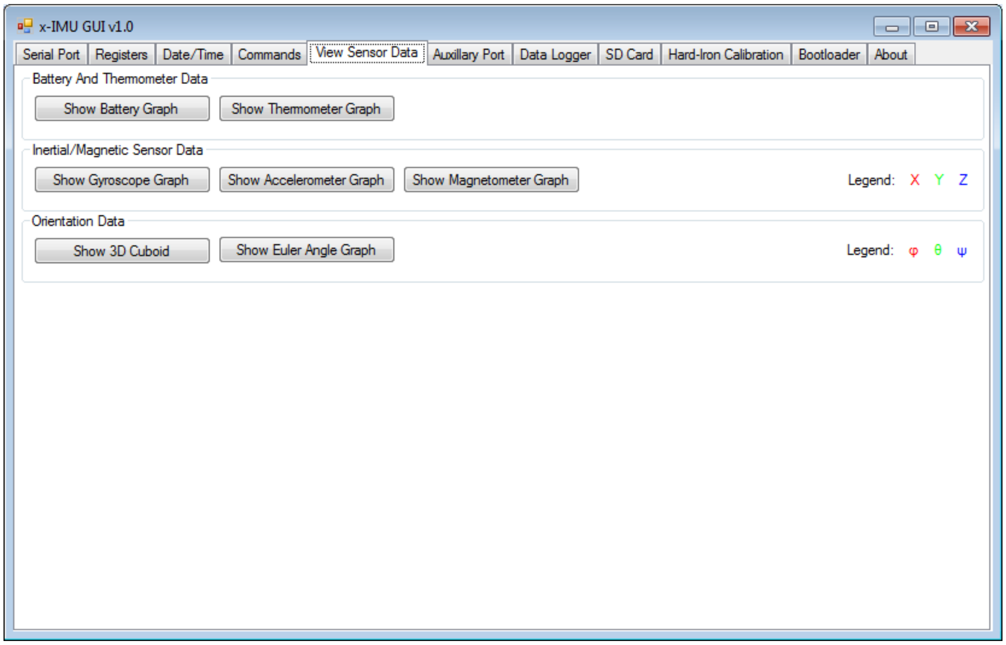


Figure 8: x-IMU GUI view sensor data tab page

The data from individual sensors is displayed in real-time data graphs as seen in Figure 8. The controls bar at the bottom of each graph allow the view and scaling to be adjusted.

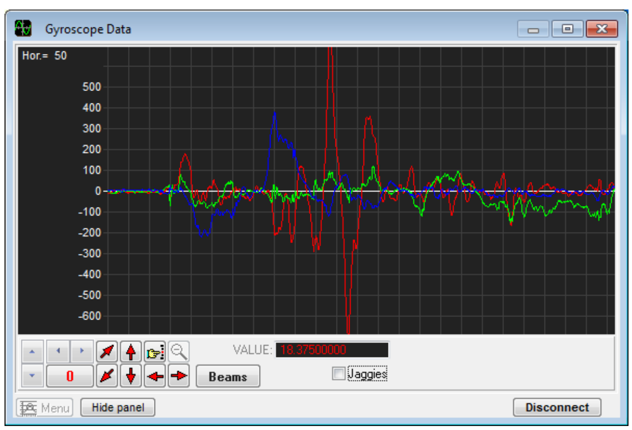


Figure 9: x-IMU GUI gyroscope data window

Orientation data received may be displayed in a graph as ZYX Euler angles and displayed as the orientation of a 3D cuboid as seen in figure 10. The cuboid is displayed in a screen coordinate frame where the x-axis is aligned to the width of the screen (left to right), the z-axis aligned to the height (bottom to top) and the y-axis projects into the screen. To align the motion of the physical x-IMU and 3D cuboid displayed on the screen, the user should first align the axes of the physical x-IMU to the screen coordinate frame and then use the *algorithm tare* command.

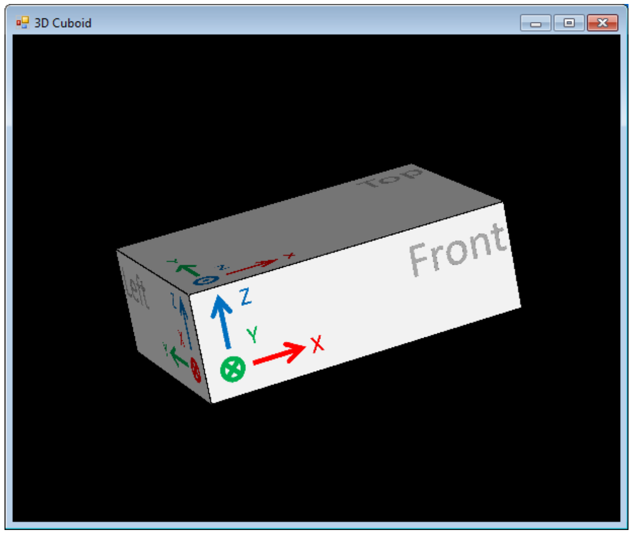


Figure 10: x-IMU GUI 3D cuboid window

4.1.6 Tab page: Auxiliary port

The auxiliary port tab page contains buttons to show or hide individual control windows for the different modes of the auxiliary port.

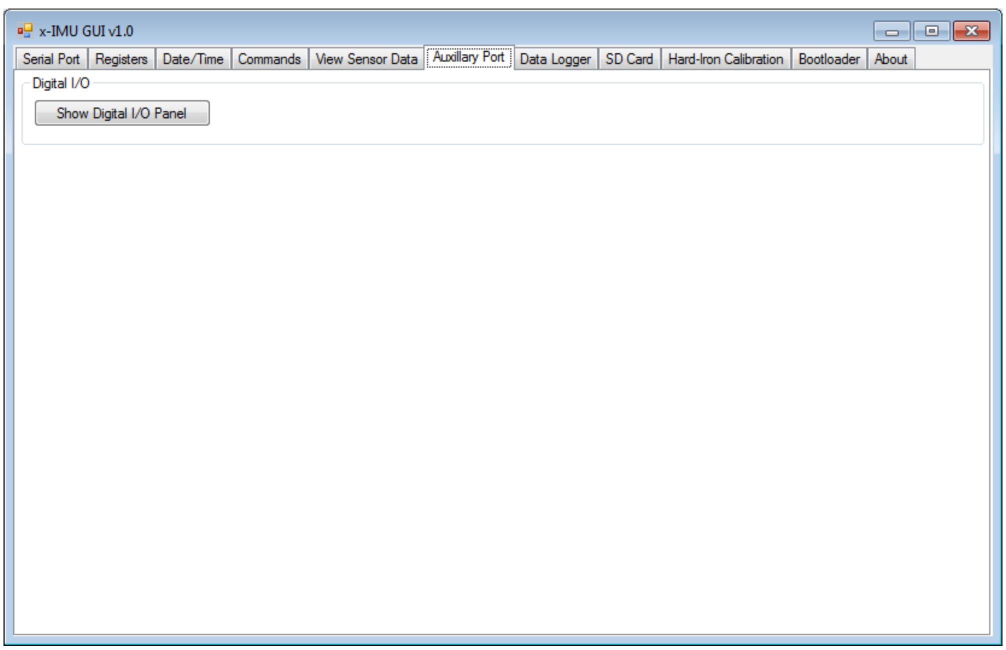


Figure 11: x-IMU GUI auxiliary port tab page

Digital I/O control panel The digital I/O control panel displays the state and mode of each channel of the auxiliary port when in digital I/O mode as shown in figure 12. Each channel is represented by a check box. If the channel mode is output then the check box is enabled and may be checked or un-checked to set the channel high or low respectively. If the channel is an input the check box is disabled and will be checked or un-checked if the channel is high or low respectively.

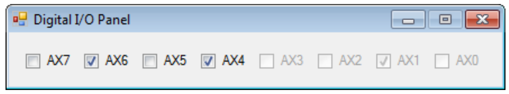


Figure 12: x-IMU GUI digital I/O control panel

4.1.7 Tab page: Data logger

The data logger tab allows the user to log incoming real-time data to file. These files may be imported to user software such as Microsoft Excel and MATLAB. The user may select the location and first part of the file name in the *File path* text box. This file name will be extended with an appropriate description and extension when the individual data files are created. For example, if a file name of `myFile` is specified, Euler angle and date/time data will be saved to `myFile_EulerAngles.csv` and `myFile_DateTime.txt`.

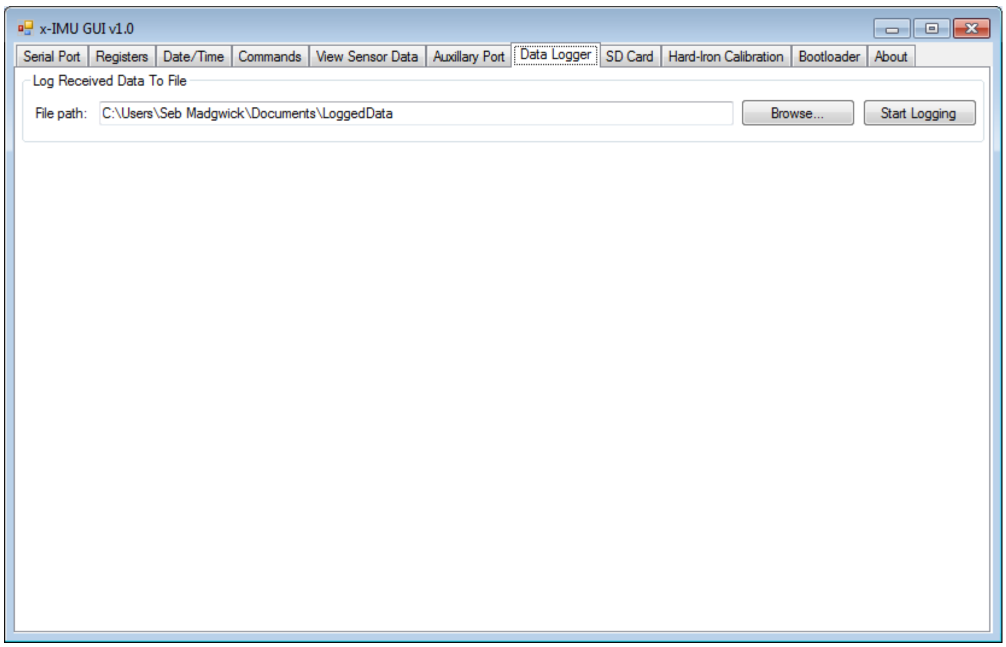


Figure 13: x-IMU GUI data logger tab page

The *Start/Stop Logging* button is used to start and stop the data logger. When logging is stopped, a report window will be presented detailing the number of each type of packet logged and the specific data files created; as shown in figure 14.

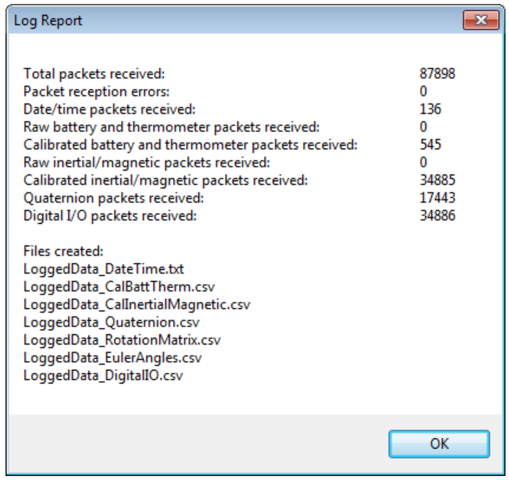


Figure 14: x-IMU GUI data logger report

4.1.8 Tab page: SD card

The SD card tab page allows the user to convert binary files (`.bin`) saved to the SD card in to readable data files. These files may be imported to user software such as Microsoft Excel and MATLAB. The location and file name must be specified in the *File path* text box. The file conversion will start when the *Convert* button is clicked. This process occurs in the background and may take a while if a large binary file is specified.

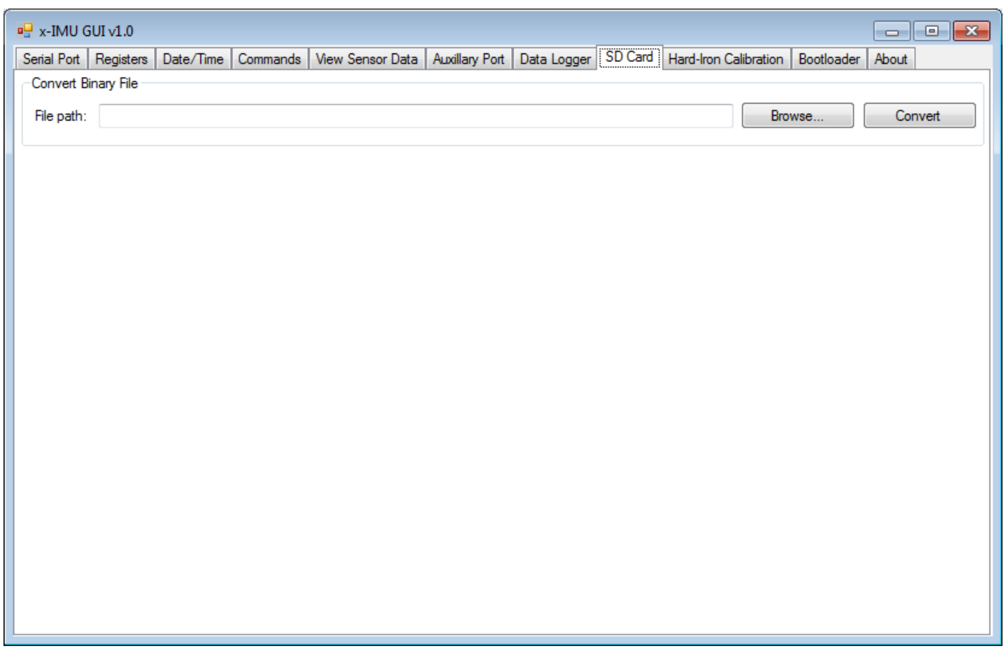


Figure 15: x-IMU GUI SD card tab page

Once the conversion is complete, a report window will be presented detailing the number of each type of packet read and the specific data files created; as shown in figure 16.

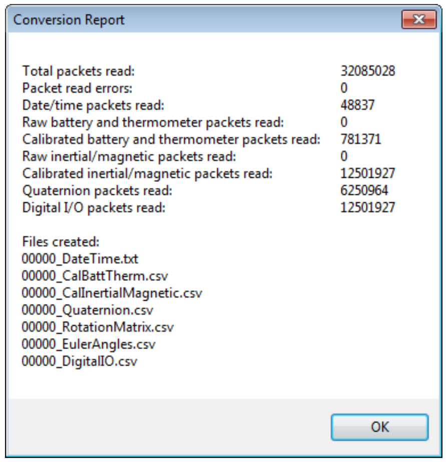


Figure 16: x-IMU GUI binary file conversion report

4.1.9 Tab page: Hard-iron calibration

The hard-iron calibration tab page provides all the functionality required for the user to calibrate for hard-iron interferences affecting the x-IMU. It is necessary to re-calibrate hard-iron parameters whenever the x-IMU's magnetic characteristics are changed; for example, when the x-IMU if fitted to a battery or mounting that includes ferromagnetic elements. The 3 group boxes, *Step 1 - Clear Hard-Iron Bias Registers*, *Step 2 - Collect Hard-Iron Calibration Dataset* and *Step 3 - Run Hard-Iron Calibration Algorithm* represent the 3 steps that must be performed in order. See the magnetometer hard-iron calibration section for more information.

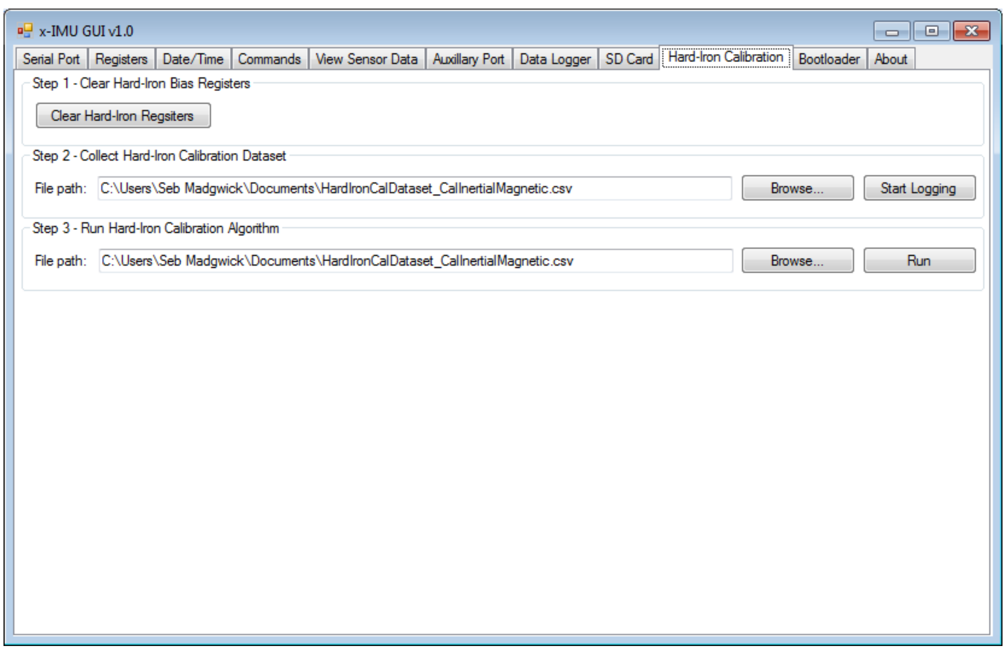


Figure 17: x-IMU GUI hard-iron calibration tab page

4.2 x-IMU API

The x-IMU API (Application Programming Interface) is a code library that contains all the classes, data structures and methods required to interface to all features and functionality of the x-IMU. The x-IMU API is an open source project written in C# and targets Microsoft .NET 3.5. Documentation for use of the API is represented by the XML comments throughout the source code which is accessed automatically by Visual Studio's IntelliSense. The open source x-IMU GUI serves as a comprehensive template for use of all features of the x-IMU API. See the x-IMU Examples web page for further open-source examples and applications.

5 USB

The x-IMU streams all communication data simultaneously and identically via USB, Bluetooth and to a file on the SD card. The USB and Bluetooth connections are also be used to send commands, read/write registers and control the auxiliary port outputs from the host software application. As both USB and Bluetooth connections appear as serial ports, use of either communication channel is identical.

The x-IMU can be connected to a computer via a standard USB *A to mini B (5 pin)* type cable. The on-board FTDI USB chip is widely used USB interface with drivers available for Windows, Mac OS X and Linux. Once the drivers have been installed and the x-IMU connected to the computer, the x-IMU will appear as a serial port and be assigned an available port name; for example *COM2*. The computer may then communicate with the x-IMU by opening this serial port. This is achieved via the *serial port* tab page of the x-IMU GUI.

The USB connection is a reliable communication channel that cannot be comprised by user settings; the x-IMU will not enter sleep mode due to the sleep timer or low battery voltage detection while the USB is connected. The USB connection can be used to power the x-IMU and is used by the on-board charging circuit to charge the battery if connected. The on-board USB interface is powered directly by the USB connection so that the x-IMU will remain detectable and the serial port may be held open by the computer even while the x-IMU is switched off or in sleep mode.

5.1 Installing USB drivers

The Windows USB drivers can be downloaded from the x-IMU webpage. Drivers for other operating systems are available of the FTDI website. To install the Windows drivers, simply run the `.exe` file. This will automatically detect specific Windows operating system being used and install the correct drivers. Once the drivers have been installed and the x-IMU connected to the computer, the x-IMU will appear as a serial port and be assigned an available port name; for example *COM2*. The port name assigned to the x-IMU USB connection can be confirmed at any time by viewing the computer's *Ports* in Windows device manager; as shown in Figure 18.

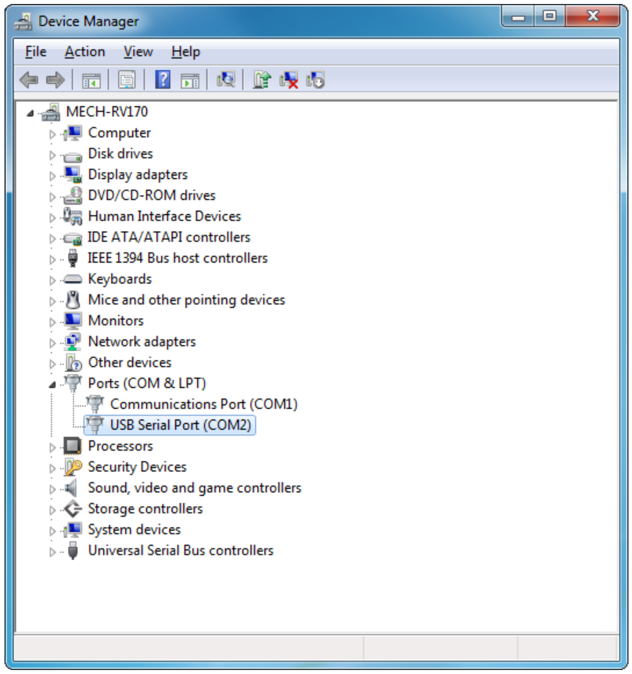


Figure 18: Confirming the port name assigned to the x-IMU USB connection

Windows serial mouse bug Windows may misinterpret the constant stream of data from the x-IMU as the behaviour of a serial mouse when the x-IMU USB is connected. This will lead to the mouse cursor being 'hi-jacked' by apparent random behaviour. If this happens the x-IMU should be unplugged and reconnected while switched off or in sleep mode for the first few seconds of connection. The 'hi-jacked' activity may leave the mouse buttons disabled which can be undone by entering and then leaving the *Ctrl + Alt + Del* screen.

5.2 USB bandwidth

It is possible for the user to define data output rates so that the amount of data being generated by the x-IMU exceeds the bandwidth of a communication channel. If the USB bandwidth is exceed, the USB transmit buffer will overrun and some data will be lost. When this happens a *USB transmit buffer overrun* error will be generated. As this error is sent immediately after the buffer has overrun, the error will be successfully transmitted. This error can be avoided by reducing the data output rates.

All data sent to the x-IMU via USB is buffered in the USB receive buffer before being processed. The time required to process the received data is dependent on the data. If data is sent to the x-IMU via USB at a rate at a rate greater than it can be processed then the receive buffer will overflow and some data will be lost. When this happens a *USB receive buffer overrun* error will be generated.

6 Bluetooth

The x-IMU streams all communication data simultaneously and identically via USB, Bluetooth and to a file on the SD card. The USB and Bluetooth connections are also be used to send commands, read/write registers and control the auxiliary port outputs from the host software application. As both USB and Bluetooth connections appear as serial ports, use of either communication channel is identical.

The on-board Bluetooth radio is a class I device with a maximum range of 100 m. The radio uses the Serial Port Profile (SPP) to enable connection to any Bluetooth host without the need to install specific drivers. Once paired with a Bluetooth host, the x-IMU will appear as a serial port and be assigned an available port name; for example *COM3*. The computer connects to the x-IMU via Bluetooth by opening this serial port. This is achieved via the *Serial Port* tab page of the x-IMU GUI. The Bluetooth connection will be lost when the x-IMU is switch off, enters sleep mode or is out of range. The connection status of the x-IMU is indicated by the Bluetooth LED. The Bluetooth radio can be completely disabled by the user via the *Bluetooth power* register to reduce power consumption.

6.1 Pairing the x-IMU with a Bluetooth host

As with any Bluetooth device, the x-IMU must first be paired with the host computer before a Bluetooth connection can be made. This pairing process is the same for all Bluetooth devices and will be familiar those who have used other Bluetooth devices such as printers or mobile phones.

To pair the x-IMU with a host computer, the host computer's Bluetooth must be enabled and the x-IMU must be switched on and the Bluetooth power enabled so that the Bluetooth LED is flashing. The user may then use the host computer to search for and the x-IMU to be paired with the computer. The x-IMU will appear with the name "x-IMU-ABCD" where the characters "ABCD" are the *device ID* of the x-IMU. For example, Figure 19 shows how this is done in Windows 7 having right clicked the Bluetooth icon the task bar.

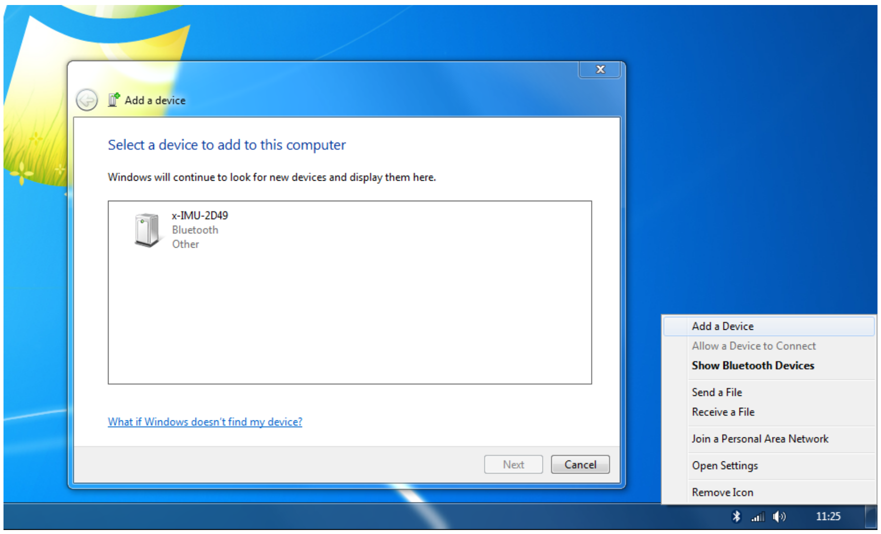


Figure 19: Searching for the x-IMU as a new Bluetooth device in Windows 7

Once the x-IMU has been found by the host computer, it can be added. This will require the user to enter the x-IMU's Bluetooth pass code: "1234". The x-IMU Bluetooth pairing will be assigned an available serial port name by the host computer; for example *COM3*. For example, Figure 20 shows this being done in Windows 7.

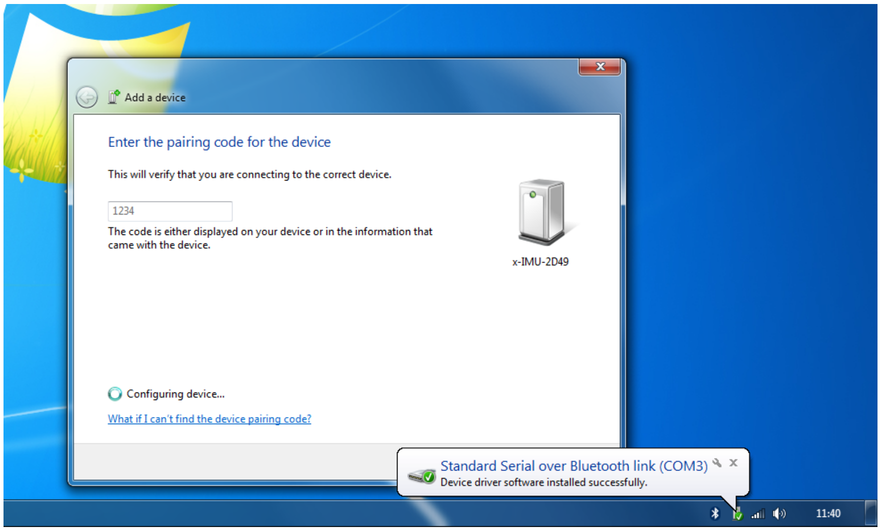


Figure 20: Adding the x-IMU as a new Bluetooth device in Windows 7

The port name assigned to the x-IMU Bluetooth pairing can be confirmed at any time by viewing the services of the x-IMU. For example, Figure 21 shows how this is done in Windows 7 having right clicked the x-IMU Bluetooth device icon.

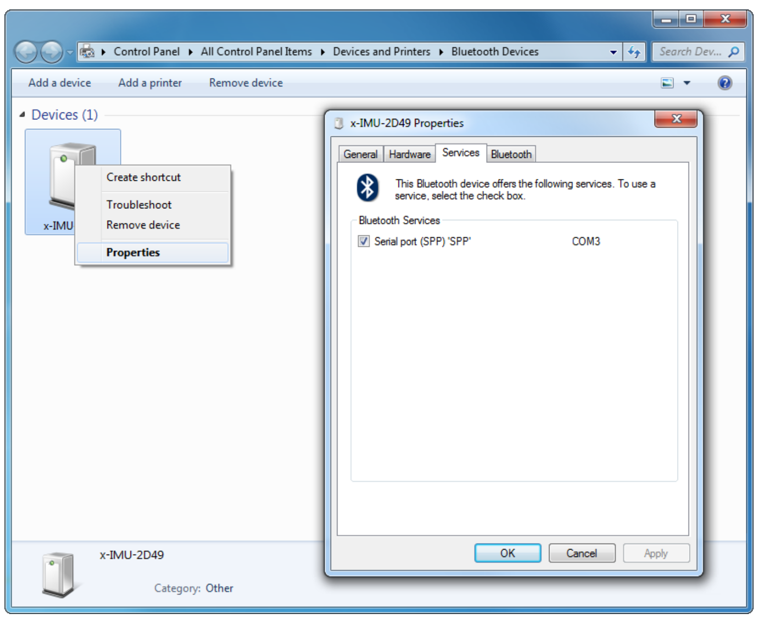


Figure 21: Confirming the port name assigned to the x-IMU Bluetooth pairing

6.2 Bluetooth LED

The blue Bluetooth LED indicates the Bluetooth radio state. The LED behaviour and associated Bluetooth radio states are detailed in table 1.

LED behaviour	Bluetooth state
Off	Switched off. Power to the radio is completely disconnected
Flashing (1 Hz)	Fully powered and discoverable
On	Fully powered and connected

Table 1: Bluetooth LED states

6.3 Bluetooth bandwidth

It is possible for the user to define data output rates so that the amount of data being generated by the x-IMU exceeds the bandwidth of a communication channel. If the Bluetooth bandwidth is exceed, the Bluetooth transmit buffer will overrun and some data will be lost. When this happens a *Bluetooth transmit buffer overrun* error will be generated. As this error is sent immediately after the buffer has overrun, the error will be successfully transmitted. This error can be avoided by reducing the data output rates.

All data sent to the x-IMU via Bluetooth is buffered in the Bluetooth receive buffer before being processed. The time required to process the received data is dependent on the data. If data is sent to the x-IMU via Bluetooth at a rate at a rate greater than it can be processed then the receive buffer will overflow and some data will be lost. When this happens a *Bluetooth receive buffer overrun* error will be generated.

6.4 Optimising Bluetooth performance

The practical range and quality of the Bluetooth connection are dependent on a number of factors. A poor Bluetooth connection will be unable to handle higher data output rates and so result in missing data and *Bluetooth transmit buffer overrun* errors. The use of lower data output rates can help achieve a more reliable Bluetooth communication channel.

The x-IMU uses a class I Bluetooth radio which represents a maximum range of 100 m. However, the practical performance is also limited by computer's Bluetooth class; for example a class II Bluetooth dongle (representing a range of 10 m) will limit the x-IMU's operating range to 10 m. Performance also varies between Bluetooth dongle brands; a dongle from a reputable brand may be expected to perform better than a low-cost, 'budget' product. Bluetooth is a radio system and so the location of the antennae (usually built into the dongle) should be given consideration. For example, a miniature Bluetooth dongle plugged in to the back a desktop PC can be expected to achieve worse performance than if the dongle was fixed to a front USB port with line-of-sight to the x-IMU.

6.5 Connecting to multiple x-IMUs via Bluetooth

A single Bluetooth host/master (e.g. Bluetooth dongle) can connect to up to 7 Bluetooth slaves (e.g. x-IMUs) simultaneously. Each x-IMU is assigned a separate serial port name and operates independently. However, the bandwidth will be limited to that of the single Bluetooth host.

7 SD card

The x-IMU streams all communication data simultaneously and identically via USB, Bluetooth and to a file on the SD card. The SD card may therefore be used in conjunction with the USB and/or Bluetooth or as the sole communication channel allowing the x-IMU to function as a standalone data logger. Data is logged to the SD card on separate files binary files that are automatically created each time the x-IMU is switched on, reset or wakes up. Logging is only then stopped once the x-IMU is reset or enters sleep mode.

The binary files (`.bin`) created may be read form the SD card on to any PC and then converted to individual Comma Separated Variable (`.csv`) files using via the x-IMU GUI *SD Card* tab page. Alternatively the x-IMU Binary File Converter may be used for command-line-based or automated conversion of multiple files. Converted CSV and text files can be directly imported into programmes such as MATLAB and Microsoft Excel. The x-IMU MATLAB Library includes all the tools required to import, structure and plot x-IMU data.

The x-IMU supports standard SD cards and SDHC cards[1]. Cards may be formatted as FAT16 (usually cards equal or less than 2 GB) and FAT32 (for card greater than 2 GB). For reliable performance it is recommended that the SD card is formatted prior to each use.

7.1 Creating and closing files

The x-IMU automatically creates a new file on the SD card each time the x-IMU is switched on, reset or wakes up. If an SD card is not accessible at this point, the x-IMU will not create a file and the SD card will not be used. The new file name is created as the 5 digit number stored in the *SD card new file name* register. For example, `00000.bin`. The number stored in this register is automatically incremented each time a new file is created. This ensures that each file created by the x-IMU is given a unique file name until the maximum file name of `65535.bin` is reached, the file name will then automatically reset to `00000.bin` and start again. The user may also edit this value to any number by writing to the register. If the x-IMU attempts to create a file name that already exists on the SD card, the x-IMU automatically increment the file name and try again. If all file names have been used, the x-IMU will not create a file and the SD card will not be used.

Files must be closed before the SD card is removed or the x-IMU switched off otherwise the file will be corrupted and all data written to the file will be lost. The file is automatically closed when the x-IMU is reset or enters sleep mode. Users wishing to frequently remove the SD card may wish to have the command button configured in *sleep/wake* mode.

7.2 SD card LED

The amber SD card LED indicates SD card activity. The LED remains lit each time a burst of data is written to the SD card. If the user low defines data output rates then the LED will blink infrequently, high data output rates will mean the LED will flash rapidly. In this way the SD card LED provides an indication of SD card bandwidth performance.

7.3 SD card bandwidth

It is possible for the user to define data output rates so that the amount of data being generated by the x-IMU exceeds the bandwidth of a communication channel. The SD card bandwidth is greater than the USB and Bluetooth bandwidth and so the SD card may still provide reliable data logging when the USB or Bluetooth channel bandwidth is exceeded. If the SD card bandwidth is exceed, the SD card buffer will overrun and some data will be lost. When this happens an *SD card write buffer overrun* error will be generated. This *error* packet is sent immediately after the buffer has overrun so that the error will always be successfully logged to the SD card. This error can be avoided by reducing the data output rates. The SD card LED may be used to provides an indication of SD card bandwidth performance while access to errors is not available.

The effective bandwidth of SD card is varies between different SD card brands and may decrease significantly if the SD card becomes fragmented. It is therefore recommended that the SD card is formatted prior to each use.

7.4 Magnetic distortions from the SD card socket

The SD card socket contains a ferromagnetic mechanism that may distort magnetometer measurements in different ways dependant on whether an SD card is inserted or not. These distortions are removed from measurements through hard-iron calibration. Each x-IMU is calibrated and supplied with a dummy SD card that may be used to ensure constant SD card socket magnetic characteristics.

[1] The x-IMU has known compatibility issues with counterfeit SDHC cards. It is recommended that you only use genuine products from a reputable brand.

8 Command button

The x-IMU features a configurable command button that allows the execution of commands while the x-IMU is operating as a standalone device. The command button modes are detailed below. Only *reset* and *sleep/wake up* modes remain active while the x-IMU is in sleep mode. The command button is also used to confirm the factory reset command.

Command button modes

- *Disabled*
- *Reset* command
- *Sleep/wake up*
- *Algorithm initialise* command
- *Algorithm tare* command
- *Algorithm initialise then tare* command

9 Real-time clock and calendar

The on-board real-time clock and calendar provides accurate measurement of the date and time and is pre-programmed to account for leap-years between the year 2000 and 2099. The real-time clock and calendar data can be viewed and synchronised with the computer clock using the x-IMU via the *Date/Time* tab page.

The real-time clock and calendar data is provided by the x-IMU in the *write date/time data* packets. The data output rate of these packets may be set to *disabled*, 1 Hz, 2 Hz, 4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz, 128 Hz, 256 Hz or 512 Hz in the *date/time data rate* register. A single *date/time data* packet is always sent on device reset regardless of user settings so that the date and time are always available as the first packet written to the SD card. The real-time clock and calendar is set by sending a *write date/time data* packet to the x-IMU, once the new date and time have been set the x-IMU will respond with a *write date/time data* containing the real-time clock and calendar data. The date and time may read at any time by sending a *read date/time data* packet to the x-IMU.

9.1 Maintaining clock power

The real-time clock and calendar requires power to operate. If power is lost or the x-IMU switch off then the date and time will reset to 01/01/2000 00:00:00. Applications that require date and time to be maintained should ensure that the x-IMU is never switched off and instead take advantage of sleep mode.

10 Sensors

The x-IMU's on-board sensors include a triple axis gyroscope, triple axis accelerometer, triple axis magnetometer, thermometer and a battery voltmeter. The user may access individual sensor data as either *raw un-calibrated ADC results* or as *calibrated units* by specifying the mode in the *sensor data mode* register. The data from individual sensors is provided in either the *raw inertial/magnetic data* and *raw battery and thermometer data* packets or the *calibrated inertial/magnetic data* and *calibrated battery and thermometer data* packets. The data output rate of these packets may be set to *disabled*, 1 Hz, 2 Hz, 4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz, 128 Hz, 256 Hz or 512 Hz in the *battery and thermometer data output rate* and *inertial/magnetic data output rate* registers.

10.1 Battery voltmeter

The battery voltmeter allows the battery voltage to be monitored by the user application. The battery voltmeter must be correctly calibrated if the low battery voltage detection functionality is to be used. The battery voltmeter has 12-bit resolution and a range of 0 V to 6.6 V. When the power switch is in the *off* position and the x-IMU is powered from an external supply via the auxiliary port the battery voltmeter will measure the voltage of the external supply.

Raw ADC data: In raw data mode the battery voltmeter data is the ADC integer value between 0 and 4096 corresponding to a voltage between 0 V and 6.6 V. This data is provided in the *raw battery and thermometer data* packets.

Calibrated data: In calibrated data mode the battery voltmeter data is the calibrated measurement in Volts. This data is provided in the *calibrate battery and thermometer data* packets. The calibrated measurement v is calculated from the raw ADC measurements $\tilde{v}$ according to a sensitivity s_v and bias b_v as described by equation (1). Parameters b_v and s_v are defined in the battery voltmeter sensitivity and bias registers.

$$v = \frac{1}{s_v}(\tilde{v} - b_v) \tag{1}$$

10.2 Thermometer

The thermometer is built in to the gyroscope and provides a measurement of the temperature of the device. The thermometer must be correctly calibrated for calibrated gyroscope measurements to compensate for gyroscope bias temperature sensitivity. The thermometer has 16-bit resolution and has a range of -30°C to +85°C. See the IMU-3000 datasheet for further information on the thermometer's characteristics.

Raw ADC data: In raw data mode the thermometer data is the ADC integer value between $-32,768$ and $+32,767$ linearly proportional to temperature. This data is provided in the *raw battery and thermometer data* packets.

Calibrated data: In calibrated data mode the thermometer data is the calibrated temperature in °C. This data is provided in the *calibrate battery and thermometer data* packets. The calibrated measurement τ is calculated from the raw ADC measurement $\tilde{\tau}$ according to a defined sensitivity s_τ and bias b_τ as described by equation (2). Parameters b_τ and s_τ are defined in the thermometer sensitivity and bias registers.

$$\tau = \frac{1}{s_\tau}(\tilde{\tau} - b_\tau) \tag{2}$$

10.3 Gyroscope

The triple axis gyroscope provides a measurement of the angular velocities around the x, y and z axes of the x-IMU. The gyroscope must be correctly calibrated in order for the IMU and AHRS algorithms to be able to function correctly; the algorithms use measurements of angular velocities to filter out errors in the estimated orientation caused by linear accelerations and temporal magnetic distortions. The gyroscope has 16-bit resolution and a range of ±250°/s, ±500°/s, ±1000°/s or ±2000°/s selected in the gyroscope full-scale register. See the IMU-3000 datasheet for further information on the gyroscope's characteristics.

Raw ADC data: In raw data mode the gyroscope data is the ADC integer values between $-32,768$ and $+32,767$ linearly proportional to angular velocities. This data is provided in the *raw inertial/magnetic data* packets.

Calibrated data: In calibrated data mode the gyroscope data are calibrated angular velocities in °/s. This data is provided in the *calibrated inertial/magnetic data* packets. The calibrated measurements g_x, g_y and g_z are calculated from the raw ADC measurements $\tilde{g}_x$, $\tilde{g}_y$ and $\tilde{g}_z$ according to the defined sensitivities s_{g_x}, s_{g_y} and s_{g_z}, temperature of the device τ, biases at 25°C b_{g_x}, b_{g_y} and b_{g_z}, bias temperature sensitivities f_x, f_y and f_z, and bias drift compensation parameters α_x, α_y and α_z provided by the IMU and AHRS algorithms. The calibrated measurements are described by equation (3). Parameters s_{g_x}, s_{g_y}, s_{g_z}, b_{g_x}, b_{g_y}, b_{g_z}, f_x, f_y and f_z are defined in the separate gyroscope calibration parameters registers. The sensitivities and biases will be different for each full-scale measurement range.

$$\begin{bmatrix} g_x \\ g_y \\ g_z \end{bmatrix} = \begin{bmatrix} s_{g_x} & 0 & 0 \\ 0 & s_{g_y} & 0 \\ 0 & 0 & s_{g_z} \end{bmatrix}^{-1} \left(\begin{bmatrix} \tilde{g}_x \\ \tilde{g}_y \\ \tilde{g}_z \end{bmatrix} - \begin{bmatrix} b_{g_x} \\ b_{g_y} \\ b_{g_z} \end{bmatrix} - \begin{bmatrix} f_x & 0 & 0 \\ 0 & f_y & 0 \\ 0 & 0 & f_z \end{bmatrix}^{-1} \begin{bmatrix} \tau - 25 \\ \tau - 25 \\ \tau - 25 \end{bmatrix} - \begin{bmatrix} \alpha_x \\ \alpha_y \\ \alpha_z \end{bmatrix} \right) \tag{3}$$

10.4 Accelerometer

The triple axis accelerometer and provides a measurement of the accelerations along the x, y and z axes of the x-IMU. The accelerometer must be correctly calibrated in order for the IMU and AHRS algorithms to be able to function correctly; the algorithms use the accelerometer to measure the direction of gravity and provide an absolute reference for the pitch and roll components of the estimated orientation. The accelerometer has 12-bit resolution and selectable ranges from ±2 g to ±8 g. The measurement range of the accelerometer is defined in *accelerometer full scale* register. See the LSM303DLH datasheet for further information on the accelerometer's characteristics.

Raw ADC data: In raw data mode the accelerometer data is the ADC integer values between −4096 and +4095 linearly proportional to accelerations. This data is provided in the *raw inertial/magnetic data* packets.

Calibrated data: In calibrated data mode the accelerometer data are calibrated accelerations in g. This data is provided in the *calibrated inertial/magnetic data* packets. The calibrated measurements a_x, a_y and a_z is calculated from the raw ADC measurements $\tilde{a}_x$, $\tilde{a}_y$ and $\tilde{a}_z$ according to the defined sensitivities s_{a_x}, s_{a_y} and s_{a_z} and biases b_{a_x}, b_{a_y} and b_{a_z} as described by equation (4). Parameters s_{a_x}, s_{a_y}, s_{a_z}, b_{a_x}, b_{a_y} and b_{a_z} are defined in the separate accelerometer calibration parameters registers. The sensitivities and biases will be different for each full-scale measurement range.

$$\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix} = \begin{bmatrix} s_{a_x} & 0 & 0 \\ 0 & s_{a_y} & 0 \\ 0 & 0 & s_{a_z} \end{bmatrix}^{-1} \left(\begin{bmatrix} \tilde{a}_x \\ \tilde{a}_y \\ \tilde{a}_z \end{bmatrix} - \begin{bmatrix} b_{a_x} \\ b_{a_y} \\ b_{a_z} \end{bmatrix} \right) \tag{4}$$

10.5 Magnetometer

The triple axis magnetometer and provides a measurement of the magnetic flux along the x, y and z axes. The magnetometer must be correctly calibrated in order for the AHRS algorithm to be able to function correctly; the algorithm uses the magnetometer to measure the Earth's magnetic field and provide an absolute reference for the heading component of the estimated orientation. The magnetometer has 12-bit resolution and selectable ranges from ±1.3 G to ±8.1 G. The measurement range of the magnetometer is defined in *magnetometer full scale* register. See the LSM303DLH datasheet for further information on the magnetometer's characteristics.

Raw ADC data: In raw data mode the magnetometer data is the ADC integer values between −4096 and +4095 linearly proportional to magnetic flux. This data is provided in the *raw inertial/magnetic data* packets. A value of -4096 will be provided when the measurement saturates in either direction.

Calibrated data: In calibrated data mode the magnetometer data are calibrated accelerations in G. This data is provided in the *calibrated inertial/magnetic data packets*. The calibrated measurements m_x, m_y and m_z are calculated from the raw ADC measurements $\tilde{m}_x$, $\tilde{m}_y$ and $\tilde{m}_z$ according to the defined sensitivities s_{m_x}, s_{m_y} and s_{m_z}, biases b_{m_x}, b_{m_y} and b_{m_z} and hard-iron biases h_x, h_y and h_z as described by equation (5). Parameters s_{m_x}, s_{m_y}, s_{m_z}, b_{m_x}, b_{m_y}, b_{m_z}, h_x, h_y and h_z are defined in the separate magnetometer calibration parameters registers. The sensitivities and biases will be different for each full-scale measurement range.

$$\begin{bmatrix} m_x \\ m_y \\ m_z \end{bmatrix} = \begin{bmatrix} s_{m_x} & 0 & 0 \\ 0 & s_{m_y} & 0 \\ 0 & 0 & s_{m_z} \end{bmatrix}^{-1} \left(\begin{bmatrix} \tilde{m}_x \\ \tilde{m}_y \\ \tilde{m}_z \end{bmatrix} - \begin{bmatrix} b_{m_x} \\ b_{m_y} \\ b_{m_z} \end{bmatrix} \right) - \begin{bmatrix} h_x \\ h_y \\ h_z \end{bmatrix} \tag{5}$$

11 Sensor calibration

The sensitivity and bias of the gyroscope, accelerometer and magnetometer are calibrated at the factory using precision equipment. The user is recommended not to attempt to recalibrate these parameters. Please contact x-io Technologies for more information.

11.0.1 Magnetometer hard-iron calibration

Magnetic elements fixed to the x-IMU such as metal screws, the battery or electronics components may introduce hard-iron biases to magnetometer measurements. These biases must be compensated for through hard-iron calibration. Uncalibrated hard-iron distortions will cause significant errors in the x-IMUs estimated heading. Each x-IMU is fully calibrated at the factory. However, many applications may alter the hard-iron characteristics and so require the user perform hard-iron calibration using the x-IMU GUI.

Before performing hard-iron calibration, the x-IMU registers must be set to output calibrated inertial and magnetic data packets at 256 Hz. Calibration can then be performed by following steps 1, 2 and 3 indicated on the Hard-Iron Calibration tab in the x-IMU GUI. Step 2 requires the user to collect a calibration dataset where the x-IMU (and any ferromagnetic elements it is fixed to) are rotated through as many and as different orientations as possible far away from other magnetic distortions. The x-IMU should held far from all objects in a room for the duration of the dataset collection.

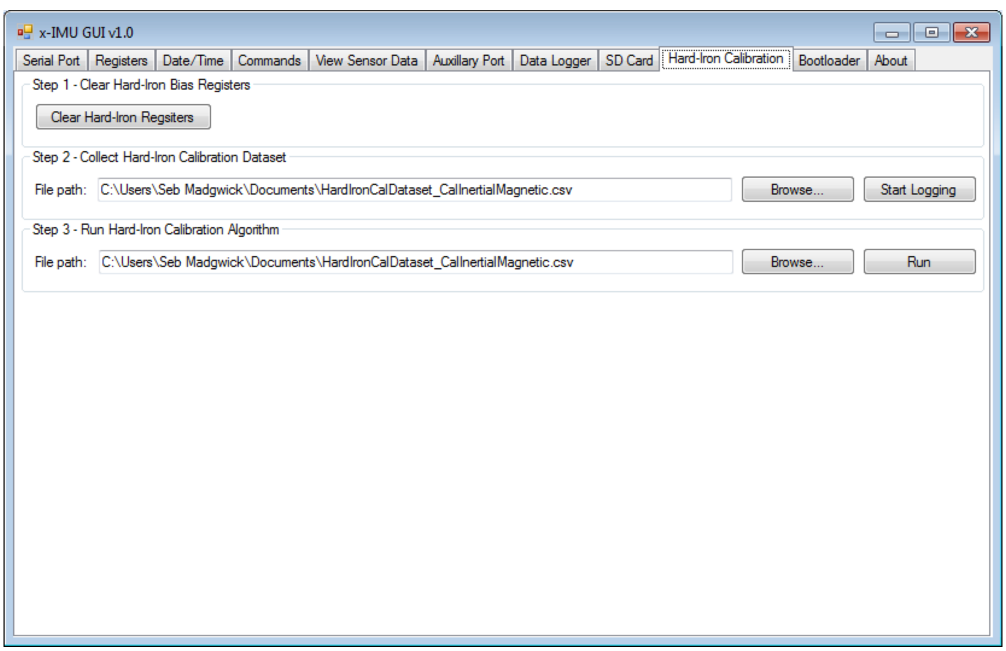


Figure 22: x-IMU GUI hard-iron calibration tab page

The SD card socket will have different magnetic characteristics depending if an SD card is secured in the socket or not. Each x-IMU is calibrated at the factory with a dummy SD card inserted to reduce the need for user calibration.

12 IMU and AHRS algorithms

The x-IMU features an sensor fusion algorithm that use the on-board sensors to compute a measurement of orientation relative to the Earth. The algorithm can operate in either IMU or AHRS mode. IMU mode uses only the gyroscope and accelerometer. In this mode, the head component of the measurement orientation will slowly drift over time. However, magnetic distortions or interference will have no effect on the sensor as the magnetometer is not used. IMU mode is of use in application that require only an accurate measurement of the pitch and roll components of an orientation or do not need an absolute measurement of heading. AHRS mode uses all of the on-board sensors so that the measurement of orientation is free from drift.

The sensor fusion algorithm has a number of associated commands. The Initialise command will cause the algorithm to reinitialise so that the proportional gain (Kp) governing how quickly the algorithm output converges to the accelerometer and magnetometer measurements, starts at a high value and is ramped down to the operating value. The Tare command will save the current orientation so that all algorithm becomes relative to this datum. A Tare operation is saved to non-volatile memory and so will remain in effect even if the device is reset. A Clear Tare command will cancel this operation and clear the memory.

13 Power management

The x-IMU may be powered via USB, an external power supply or a single cell lithium polymer (LiPo) battery cell which will be charged automatically while the x-IMU is connected to a USB port.

13.1 External supply

The x-IMU may be powered by a 3.5 to 6.3 V external supply via the auxiliary port. The supply should be connected to the *GND* and *EXT* pins of the auxiliary port. This power supply is only enabled while the power switch is in the *off* position. In this situation, the battery voltmeter will measure the voltage of the external supply.

13.2 Battery and charging

The x-IMU has a standard connector for a 3.7 V single cell Lithium Polymer (LiPo) battery cell. These batteries are widely available in range of capacities, for example 1000 mAh and 2000 mAh. The battery life is dependent on user settings and usage. See the tips on minimising power consumption section.

The x-IMU has an on-board battery charger specially designed for LiPo battery cells. The battery is charged automatically while the x-IMU is connected to a USB port. The red charging LED will remain lit while the battery is charging. Charging stops automatically once complete. The x-IMU may be used as normal while the battery is charging. It is not necessary for the connected computer to have the USB drivers installed for charging, however the charging process will be faster if the drivers are installed.

13.3 Sleep mode

In sleep mode, the x-IMU remains powered but all on-board components are shutdown. This allows the device to be powered down without removing power from essential components; for example, the real time clock and calendar. The green status LED will blink once every 3 seconds to indicate that the device is in sleep mode. Sleep mode is enabled through the sources listed below. The x-IMU will reset upon wake up so that the same behaviour may be expected when the devices is powered on, reset or awakened. The wake up sources are listed below.

Sleep mode enable sources:

- Command button in sleep/wake mode
- Sleep command via USB, Bluetooth or UART
- Low battery voltage detection
- Sleep timer
- Sleep/wake mode

Wake up sources

- Command button in sleep/wake mode
- Motion trigger wake up

13.4 Low battery voltage detection

The calibrated battery voltmeter is used to trigger sleep mode when the battery voltage falls below a specific level defined in the *battery shutdown voltage* register. This allows the x-IMU to execute critical tasks prior to power failure; for example closing the file on the SD card and notifying the user or host software with a *low battery* error. By entering sleep mode prior to power failure the x-IMU also ensures that the date and time of the real-time clock and calendar are not lost. The low battery voltage detection is disabled while USB is connected.

13.5 Sleep timer

The sleep timer will trigger sleep mode after the period of time defined in the *sleep timer* register has elapsed. The sleep timer countdown starts when the x-IMU starts up and may be reset by the sources listed below. These sources enable the detection of motion, the user or the host software to prevent the x-IMU from entering sleep mode. The sleep timer is disabled by specifying a *sleep timer* register value of 0 seconds. The sleep timer is disabled while USB is connected.

Sleep timer reset sources

- *reset sleep timer* command
- Motion trigger wake up

13.6 Motion triggered wake up

The motion trigger wake up is enabled via the *motion trigger wake up* register and may be either *disabled* or set to a *low* or *high* sensitivity. Motion is detected using accelerometer. If motion is detected while the x-IMU is in sleep mode then the x-IMU will wake up. While the x-IMU is not in sleep mode the motion trigger wake up is used to reset the sleep timer and thus postpone sleep while motion persists.

For example, if the sleep timer is set to 20 seconds and there is motion is detected at least once every 20 seconds the motion trigger wake up will prevent the sleep timer from expiring and the x-IMU will not enter sleep mode. However, if no motion is detected for 20 seconds the x-IMU will enter sleep mode. If motion is then detected while in sleep mode, the x-IMU will wake up.

13.7 Tips for minimising power consumption

Battery powered applications require that power consumption is minimised in order to extend the battery life. The x-IMU is designed to optimise power consumption according to user settings. The user may therefore expect a considerable reduction in power consumption and extended battery life simply by using register settings appropriate to their application.

Tips

- Set data output rates of unused data to *disabled*.
- Use the minimum data output rates required by application.
- Set algorithm mode to *disabled* if the IMU and AHRS algorithms are not required.
- Disable Bluetooth power if not Bluetooth is unused.
- Use the sleep timer and motion trigger wake up to automatically enter sleep mode during periods of inactivity.

14 Auxiliary port

The x-IMU features an auxiliary port that can be configured to one of many modes. The auxiliary port connector is a 2 × 6, 2.54 mm pitch female header socket. The socket pins include: ground, an external power input, 3.3 V power output, hard reset and 8 I/O channels. The pins are annotated in Figure 23 and summarised in table 2.

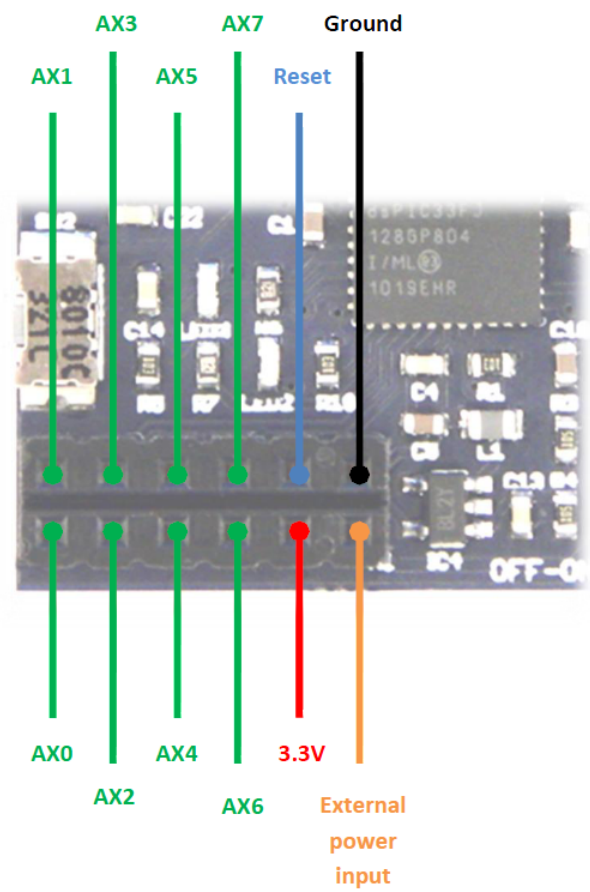


Figure 23: Auxiliary port pins

Pin	Description	Min/Max
GND	Common ground	N/A
EXT	External power input	3.5 V to 6.3 V
RST	Hard reset (active low)	0 V to 3.3 V
3V3	3.3 V power output	100 mA
AX0 to AX7	I/O channels	0 V to 3.3 V, 4 mA source/sink

Table 2: Auxiliary port pins

The mode of the auxiliary port is set by the *auxiliary port mode* register. If the x-IMU receives a packet associated with a specific axillary port mode while the axillary port is not in that mode the x-IMU will respond with an *incorrect auxiliary port mode* error. For example, this will happen if the x-IMU receives a *digital I/O packet* to change a digital output channel while the axillary port mode is *disabled*.

Auxiliary port modes

- Disabled
- Digital I/O
- Analogue input
- PWM output
- ADXL345 bus
- UART
- Sleep/wake mode

14.1 Disabled

When *disabled*, all auxiliary port channels are configured as high-impedance inputs. The auxiliary port in *disabled* when the x-IMU is in sleep mode. Table 3 summarises the auxiliary port pin assignments when disabled.

Pin	I/O	Description
AX0	Input	Unused
AX1	Input	Unused
AX2	Input	Unused
AX3	Input	Unused
AX4	Input	Unused
AX5	Input	Unused
AX6	Input	Unused
AX7	Input	Unused

Table 3: Auxiliary port pin assignments when disabled

14.2 Digital I/O mode

In *digital I/O mode* each pin of the auxiliary port functions as either a digital input or output. The direction of each pin is defined within the *digital I/O direction* register. Digital input data is provided in either the *digital I/O data* packets received from the x-IMU. The data output rate of these packets may be set to *on change only*, 1 Hz, 2 Hz, 4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz, 128 Hz, 256 Hz or 512 Hz in the *digital I/O data output rate* register. Digital outputs are set by sending a *digital I/O data* packet to the x-IMU.

Pin	I/O	Description
AX0	Input/Output	Digital I/O
AX1	Input/Output	Digital I/O
AX2	Input/Output	Digital I/O
AX3	Input/Output	Digital I/O
AX4	Input/Output	Digital I/O
AX5	Input/Output	Digital I/O
AX6	Input/Output	Digital I/O
AX7	Input/Output	Digital I/O

Table 4: Auxiliary port pin assignments in digital I/O mode

14.3 Analogue input

In *analogue input mode* all 8 pins of the auxiliary port function as analogue inputs. Each analogue input channel sas a 12-bit resolution and a range of 0 V to 3.3 V. The user may access analogue input data as either *raw un-calibrated ADC results* or as *calibrated units* by specifying the mode in the *analogue input data mode* register. Analogue input data is provided in either the *raw analogue input data* or *calibrated analogue input data* packets. The data output rate of these packets may be set to *disabled*, 1 Hz, 2 Hz, 4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz, 128 Hz, 256 Hz or 512 Hz in the *analogue input data output rate* register.

Raw ADC data: In raw data mode the analogue input data is the ADC integer value between 0 and 4096 corresponding to a voltage between 0 V and 3.3 V. This data is provided in the *raw analogue input data* packets.

Calibrated data: In calibrated data mode the analogue data is the calibrated measurement in Volts. This data is provided in the *calibrate analogue data* packets. The calibrated measurement a_n is calculated from the raw ADC measurements $\tilde{v}$ according to a sensitivity s_{a_n} and bias b_{a_n} as described by equation (6). Parameters s_{a_n} and b_{a_n} are defined in the analogue input *sensitivity* and *bias* registers.

$$a_n = \frac{1}{s_{a_n}}(\tilde{a_n} - b_{a_n}) \tag{6}$$

Pin	I/O	Description
AX0	Input	Analogue input channel AX0
AX1	Input	Analogue input channel AX1
AX2	Input	Analogue input channel AX2
AX3	Input	Analogue input channel AX3
AX4	Input	Analogue input channel AX4
AX5	Input	Analogue input channel AX5
AX6	Input	Analogue input channel AX6
AX7	Input	Analogue input channel AX7

Table 5: Auxiliary port pin assignments for analogue input mode

14.4 PWM output mode

In *PWM output mode* four pins of the auxiliary port function as digital PWM outputs. Unused pins are configured as high-impedance inputs. The PWM frequency may be set from 3 Hz to 65,535 Hz in the *PWM frequency* register. The duty cycle of each of the four PWM output channels are set by sending a *PWM data* packet to the x-IMU. The x-IMU echo back the packet as confirmation after the duty cycles have been set.

Pin	I/O	Description
AX0	Output	PWM output channel AX0
AX1	Input	Unused
AX2	Output	PWM output channel AX2
AX3	Input	Unused
AX4	Output	PWM output channel AX4
AX5	Input	Unused
AX6	Output	PWM output channel AX6
AX7	Input	Unused

Table 6: Auxiliary port pin assignments for PWM output mode

14.5 ADXL345 bus mode

This section is currently unavailable but can be updated on request.

Pin	I/O	Description
AX0	Output	ADXL345 A SPI CS
AX1	Input	SPI CLK
AX2	Output	ADXL345 B SPI CS
AX3	Input	SPI DIN
AX4	Output	ADXL345 C SPI CS
AX5	Input	SPI DOUT
AX6	Output	ADXL345 D SPI CS
AX7	Input	Power enable

Table 7: Auxiliary port pin assignments for ADXL345 bus mode

14.6 UART mode

In *UART mode* four pins of the auxiliary port function as a configurable UART with hardware flow control. The *Bluetooth power* will automatically be disabled when *UART mode* is enabled. Commination via the auxiliary port UART is identical to that via the virtual serial ports enabled by the Bluetooth or USB connection. The UART baud rate may be set to 2400, 4800, 7200, 9600, 14400, 19200, 38400, 57600, 115200, 230400, 460800 or 921600 baud in the *UART baud rate* register. The UART hardware flow control can be enabled or disabled in the *UART hardware flow control* register.

Pin	I/O	Description
AX0	Output	RX
AX1	Input	Unused
AX2	Output	TX
AX3	Input	Unused
AX4	Output	CTS
AX5	Input	Unused
AX6	Output	RTS
AX7	Input	Unused

Table 8: Auxiliary port pin assignments for UART mode

14.6.1 UART bandwidth

It is possible for the user to define data output rates so that the amount of data being generated by the x-IMU exceeds the bandwidth of a communication channel. If the UART bandwidth is exceed, the UART transmit buffer will overrun and some data will be lost. When this happens a *UART transmit buffer overrun* error will be generated. As this error is sent immediately after the buffer has overrun, the error will be successfully transmitted. This error can be avoided by reducing the data output rates or increasing the *UART baud rate* register.

All data sent to the x-IMU via UART is buffered in the UART receive buffer before being processed. The time required to process the received data is dependent on the data. If data is sent to the x-IMU via UART at a rate at a rate greater than it can be processed then the receive buffer will overflow and some data will be lost. When this happens a *UART receive buffer overrun* error will be generated.

14.7 Sleep/wake mode

In *Sleep/wake mode* three pins of the auxiliary port function as an interface to control the sleep/wake state of the x-IMU remotely. This may be useful in logging applications where access to the command button. Separate inputs are assigned for sleep and wake signals to prevent accidental double triggering reverting an intended action. An output signal indicates the sleep state of the x-IMU and can be used to drive an LED.

Pin	I/O	Description
AX0	Output	Sleep (active low, with internal pull-up)
AX1	Input	Unused
AX2	Output	Wake (active low, with internal pull-up)
AX3	Input	Unused
AX4	Output	Sleep state (wake = driven low, sleep = pull-up)
AX5	Input	Unused
AX6	Output	Unused
AX7	Input	Unused

Table 9: Auxiliary port pin assignments for Sleep/Wake mode

15 Communication protocol

Documentation for the communication protocol used to interface to the x-IMU via serial is not provided. However, an example generic C++ library is available on the x-IMU webpage and the x-IMU API source code written in C# provides a compressive library for all functionally of the x-IMU.

16 Commands

Commands are executed by either sending a *command* packet to the x-IMU USB or Bluetooth or by pressing the command button which may be configured to execute a specific command. Commands are sent using the x-IMU GUI via the *commands* tab page. Once a command has been executed, the x-IMU will echo the *command* packet back to the host as confirmation. As all communication from the x-IMU to the host computer is logged to the SD card, all command confirmations will be logged on the SD card. If a *command* packet is sent containing an invalid command code the x-IMU will respond with an *invalid command* error.

Sending a *command* packet to the x-IMU will cause the x-IMU to momentarily pause sensor sampling and processing while the received data is processed. This may cause discrepancies in the otherwise fixed data output rates.

16.1 Individual commands

16.1.1 Null command

Command code: `0x0000`

Description: A *null command* is a valid command code but will result in no action. As all commands sent to the x-IMU are echoed back to the sender, a null command may be used by the host software to confirm communication with the x-IMU.

16.1.2 Factory reset

Command code: `0x0001`

Description: A *factory reset* command code is used to reset the x-IMU to its original state prior to factory calibration so that all registers return to their default values. The user must press the command button within 3 seconds of sending a *factory reset* command in order to confirm the request else the x-IMU will respond with a *factory reset failed* error. The x-IMU requires several seconds to reconfigure on-board components during the execution of a factory reset.

16.1.3 Reset

Command code: `0x0002`

Description: A *reset* command causes a software reset of the x-IMU. The x-IMU will close any open files on the SD card before reset, in this way the reset command may be of use to users wishing to break up a logging session into multiple files. The reset command is used to put the x-IMU into bootloader mode in order to upload new firmware. A *reset* command is sent by the x-IMU to the host computer as confirmation of reset, power on and wake up.

16.1.4 Sleep

Command code: `0x0003`

Description: A *sleep* command will put the device into sleep mode. The x-IMU will close any open files on the SD card before entering sleep mode. The x-IMU may be taken out of sleep mode by using the command button configured in *sleep/wake* mode or using the motion triggered wake up functionality.

16.1.5 Reset sleep timer

Command code: `0x0004`

Description: The *reset sleep timer* command will reset the sleep timer countdown and so postpone sleep. An example usage of this command is to create behaviour where the x-IMU will automatically enter sleep mode when communication with the host software ends or connection is lost.

16.1.6 Sample gyroscope axis at 200 dps

Command code: `0x0005`

Description: The *sample gyroscope axis at 200 dps* command is used to calibrate the gyroscope sensitivity parameters. This command should be sent while the x-IMU rotating at either $+200°/s$ or $-200°/s$ around either its x, y or z axis. The x-IMU will automatically detect the axis and direction of rotation. The mean gyroscope output will then be measured over approximately 8 seconds before being stored to the corresponding register. A *calculate gyroscope sensitivity* command will then be executed. The execution of the *sample gyroscope axis at 200 dps* command will be aborted if a gyroscope axis is detected as not being at approximately $\pm 200°/s$ and a *gyroscope axis not at 200 dps* error will be generated. See the gyroscope sensitivity calibration section for more information.

16.1.7 Calculate gyroscope sensitivity

Command code: `0x0006`

Description: The *calculate gyroscope sensitivity* command is used to execute the on-board gyroscope sensitivity calibration algorithm. The algorithm uses the sampled gyroscope bias register values previously obtained by the *sample gyroscope axis at 200 dps* command to update the gyroscope sensitivity parameters registers. See the gyroscope sensitivity calibration section for more information.

16.1.8 Sample gyroscope bias at temperature 1

Command code: `0x0007`
Description: The *sample gyroscope bias at temperature 1* command is used to calibrate the gyroscope bias parameters. This command should be sent while the x-IMU is stationary and at the lowest temperature the device is required to operate at. The x-IMU will measure the mean temperature and gyroscope output over approximately 16 seconds, store the results to the sampled temperature 1 registers and then trigger a *calculate gyroscope bias parameters* command. The execution of the *sample gyroscope bias at temperature 1* command will be aborted if the gyroscope is detected as not being stationary and a *gyroscope not stationary* error will be generated. See the gyroscope bias calibration section for more information.

16.1.9 Sample gyroscope bias at temperature 2

Command code: `0x0008`
Description: The *sample gyroscope bias at temperature 2* command is used to calibrate the gyroscope bias parameters. This command should be sent while the x-IMU is stationary and at the lowest temperature the device is required to operate at. The x-IMU will measure the mean temperature and gyroscope output over approximately 16 seconds, store the results to the sampled temperature 2 registers and then trigger a *calculate gyroscope bias parameters* command. The execution of the *sample gyroscope bias at temperature 2* command will be aborted if the gyroscope is detected as not being stationary and a *gyroscope not stationary* error will be generated. See the gyroscope bias calibration section for more information.

16.1.10 Calculate gyroscope bias parameters

Command code: `0x0009`
Description: The *calculate gyroscope bias parameters* command is used to execute the on-board gyroscope bias calibration algorithm. The algorithm uses the sampled gyroscope bias register values previously sampled by the *sample gyroscope bias at temperature 1* and *sample gyroscope bias at temperature 2* commands to calculate the gyroscope bias parameters and update the gyroscope bias parameters registers. See the gyroscope bias calibration section for more information.

16.1.11 Sample accelerometer axis at 1 g

Command code: `0x000A`
Description: The *sample accelerometer axis at 1 g* command is used to calibrate the accelerometer bias and sensitivity parameters. This command should be sent while the x-IMU stationary and orientated with either its x, y or z axis at either +1 g or −1 g. The x-IMU will automatically detect the axis and direction of gravity. The mean accelerometer output will then be measured over approximately 8 seconds before being stored to the sampled accelerometer axis registers. A *calculate accelerometer bias and sensitivity* command will then be executed. The execution of the *sample accelerometer axis at 1 g* command will be aborted if a accelerometer axis is detected as not being at approximately ±1 g and a *accelerometer axis not at 1 g* error will be generated. See the accelerometer calibration section for more information.

16.1.12 Calculate accelerometer bias and sensitivity

Command code: `0x000B`

Description: The *calculate accelerometer bias and sensitivity* command is used to execute the on-board accelerometer bias and sensitivity calibration algorithm. The algorithm uses the sampled accelerometer axes register values previously obtained by the *sample accelerometer axis at 1 g* command to calculate the accelerometer bias and sensitivity and update the accelerometer calibration parameters registers. See the accelerometer calibration section for more information.

16.1.13 Measure magnetometer bias and sensitivity

Command code: `0x000C`

Description: The *measure magnetometer bias and sensitivity* command is used to run an on-board magnetometer calibration algorithm. The x-IMU uses the magnetometer's internal field generator to measure the mean magnetometer bias and sensitivity over approximately 16 seconds independent of external magnetic interference. The magnetometer sensitivity and bias registers and then automatically updated. This command should be used each time the magnetometer full-scale range is changed. The execution of this command will be aborted if a magnetometer axis saturates and a *magnetometer saturation* error will be generated. See the magnetometer calibration section for more information.

16.1.14 Algorithm initialise

Command code: `0x000D`

Description: The *algorithm initialise* command will re-start the algorithm from initial conditions. This command can be used to 'force' the algorithm to converge to steady state conditions if previous distortions to magnetic or other extreme sensor measurements have left the IMU or AHRS algorithm output at an erroneous orientation. See the IMU and AHRS algorithms section for more information.

16.1.15 Algorithm tare

Command code: `0x000E`

Description: The *algorithm tare* command is used to set the algorithm datum orientation and store the reference quaternion to the *tare quaternion* registers. These registers may be then be cleared using the *algorithm clear tare* command. See the IMU and AHRS algorithms section for more information.

16.1.16 Algorithm clear tare

Command code: `0x000F`

Description: The *algorithm clear tare* command is used to clear the *tare quaternion* registers and return the datum orientation to alignment with the Earth coordinate frame. See the IMU and AHRS algorithms section for more information.

16.1.17 Algorithm initialise then tare

Command code: `0x0010`

Description: The *algorithm initialise then tare* command will perform an *algorithm initialise* and then *algorithm tare* once the initialisation is complete. See the IMU and AHRS algorithms section for more information.

17 Errors

Error are sent by the x-IMU to warn the user or host software of any internal errors that have occurred. Error data is sent in *error* packets. The x-IMU GUI will display these errors in message boxes for user acknowledgment. As all data packets generated by the x-IMU are logged to the SD card, the SD card will contain a record off errors.

17.1 Individual errors

17.1.1 No error

Error code: `0x0000`

Description: No error. This error code is used within internal processes and will never appear to the user.

17.1.2 Factory reset failed

Error code: `0x0001`

Description: A *factory reset failed* error is sent if the user fails to press the command button within 3 seconds of sending a *factory reset* command and the execution of the command was aborted.

17.1.3 Low battery

Error code: `0x0002`

Description: A *low battery* error is sent when the low battery voltage detection detects that the battery voltage has fallen below the specific level defined in the *battery shutdown voltage* register. This message is sent immediately before the x-IMU enters sleep mode. See the low battery voltage detection section for more information.

17.1.4 USB receive buffer overrun

Error code: `0x0003`

Description: A *USB receive buffer over* error will be sent if the USB receive buffer overruns and data to be received was lost. This occurs when data is transmitted to the x-IMU at a rate greater than the rate it can be processed. Consider reducing the rate at which data is sent to the x-IMU if this error occurs repeatedly. See the USB bandwidth section for more information.

17.1.5 USB transmit buffer overrun

Error code: `0x0004`

Description: A *USB transmit buffer overrun* error will be sent if the USB transmit buffer overruns and data due to be transmitted was lost. This will occur when the communication channel bandwidth is unable to cope with the amount of data being transmitted. Consider using lower data output rates if this error occurs repeatedly. This error may be ignored in applications where USB data is not essential and the SD card is the intended data output. In such applications, the user need only be concerned with *SD card write buffer overrun* errors. The x-IMU will attempt to transmit data via USB while the USB is detected as connected, if the USB is connect but the associated serial port not open then the USB transmit buffer will continue to overrun until the port is opened or the USB disconnected. See the USB bandwidth section for more information.

17.1.6 Bluetooth receive buffer overrun

Error code: `0x0005`

Description: A *Bluetooth receive buffer over* error will be sent if the Bluetooth receive buffer overruns and data to be received was lost. This occurs when data is transmitted to the x-IMU at a rate greater than the rate it can be processed. Consider reducing the rate at which data is sent to the x-IMU if this error occurs repeatedly.

17.1.7 Bluetooth transmit buffer overrun

Error code: `0x0006`

Description: A *Bluetooth transmit buffer overrun* error will be sent if the Bluetooth transmit buffer overruns and data due to be transmitted was lost. This will occur when the communication channel bandwidth is unable to cope with the amount of data being transmitted. Consider using lower data output rates if this error occurs repeatedly. *Transmit buffer overrun* errors may be expected in the Bluetooth communication channel quality deteriorates; for example, if out of range. This error may be ignored in applications where USB data is not essential and the SD card is the intended data output. In such applications, the user need only be concerned with *SD card write buffer overrun* errors.

17.1.8 SD card write buffer overrun

Error code: `0x0007`

Description: An *SD card buffer over* error will be sent if the SD card buffer is overrun and data to be written to the SD was lost. Consider using lower data output rates if this error occurs repeatedly. An occurrence of this error may go unnoticed while the USB and Bluetooth are not used. The red SD card LED indicates SD card activity, if this LED behaviour approaches that of being solidly on then it is likely that the this error is occurring.

17.1.9 Too few bytes in packet

Error code: `0x0008`

Description: A *too few bytes in packet* error will be sent if the received packet does not contain enough bytes to be valid. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.10 Too many bytes in packet

Error code: `0x0009`

Description: A *too many bytes in packet* error will be sent if the received packet does not contains too many bytes to be valid. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.11 Invalid checksum

Error code: `0x000A`

Description: An *invalid checksum* error will be sent if the received packet contains a valid number of bytes but contains an invalid checksum. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.12 Unknown packet header

Error code: `0x000B`

Description: An *Unknown packet header* error will be sent if the received packet contains a valid number of bytes and checksum but the header is not recognised. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.13 Invalid number of bytes for packet header

Error code: `0x000C`

Description: An *invalid number of bytes for packet header* error will be sent if the received packet contains a valid number of bytes, checksum and packet header but the number of bytes does not match that expected for the specific packet header. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.14 Invalid register address

Error code: `0x000D`

Description: An *invalid register address* error will be sent if the read or write register packet contains an invalid register address. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.15 Register read-only

Error code: `0x000E`

Description: A *register read-only* error will be sent if the write register packet represents an attempt to write a read-only register.

17.1.16 Invalid register value

Error code: `0x000F`

Description: An *invalid register value* error will be sent if the write register packet contains an invalid register value for the specific address. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.17 Invalid command

Error code: `0x0010`

Description: An *invalid command* error will be sent if the command code within the command packet is not valid. This error is only relevant to users developing their own communication software and not using the x-IMU API or x-IMU GUI.

17.1.18 Gyroscope axis not at 200 dps

Error code: `0x0011`

Description: A *gyroscope axis not at 200 dps* error will be sent if an axis is detected as not being at approximately ±200°/s during the execution of a *sample gyroscope axis at 200 dps* command and the execution of the command was aborted. See the gyroscope sensitivity calibration section for more information.

17.1.19 Gyroscope not stationary

Error code: `0x0012`

Description: A *gyroscope not stationary* error will be sent if the gyroscope was detected as not being stationary during the execution of a *sample gyroscope bias* commands and the execution of the command was aborted. See the gyroscope bias calibration section for more information.

17.1.20 Accelerometer axis not at 1g

Error code: `0x0013`

Description: A *accelerometer axis not at 1g* error will be sent if an axis is detected as not being at approximately ±1 g during the execution of a *sample accelerometer axis at 1 g* command and the execution of the command was aborted. See the accelerometer calibration section for more information.

17.1.21 Magnetometer saturation

Error code: `0x0014`

Description: A *magnetometer saturation* error will be sent if the measurements taken during the execution of the *measure magnetometer bias and sensitivity* command were detected as having saturated and the execution of the command was aborted. See the magnetometer calibration section for more information.

17.1.22 Incorrect auxiliary port mode

Error code: `0x0015`

Description: An *incorrect auxiliary port mode* error will be sent if an auxiliary port action is requested while the auxiliary port is not in the correct mode for that action. For example, an *incorrect auxiliary port mode* error will be sent if a *digital IO data* packet is received while the auxiliary port mode is *disabled*. See the auxiliary port section for more information.

17.1.23 UART receive buffer overrun

Error code: `0x0016`

Description: A *UART receive buffer over* error will be sent if the UART receive buffer overruns and data to be received was lost. This occurs when data is transmitted to the x-IMU at a rate greater than the rate it can be processed. Consider reducing the rate at which data is sent to the x-IMU if this error occurs repeatedly. See the UART bandwidth section for more information.

17.1.24 UART transmit buffer overrun

Error code: `0x0017`

Description: A *UART transmit buffer overrun* error will be sent if the UART transmit buffer overruns and data due to be transmitted was lost. This will occur when the communication channel bandwidth is unable to cope with the amount of data being transmitted. Consider using lower data output rates if this error occurs repeatedly. This error may be ignored in applications where UART data is not essential and the SD card is the intended data output. In such applications, the user need only be concerned with *SD card write buffer overrun* errors. See the UART bandwidth section for more information.

18 Registers

All x-IMU settings are stored within a bank of registers in non-volatile flash memory and loaded each time the x-IMU starts up. Each register has a 16-bit address and 16-bit value. These values may be viewed, modified, read, written and backed up to file using the x-IMU GUI via the *Registers* tab page.

18.1 Reading registers

Any register may be read by sending a *read register* packet containing register address to be read. The x-IMU will respond with a *register write* packet containing the register address and value. If the *read register* packet contains an invalid register address then the x-IMU will respond with an *invalid register address* error. The x-IMU will automatically send all register values on start up so that settings are stored as the first packets written to the SD card.

18.2 Writing registers

A register may be written by sending a *register write* packet containing the register address to be written to and the new register value. The x-IMU will respond with a *register write* packet containing the register address and confirmed value. If the value written is different from the current register value then the x-IMU will save the new value to the flash memory and perform any required actions (e.g. reconfigure the IMU-3000 for a different *gyroscope full-scale* range. If the *write register* packet contains an invalid register address then the x-IMU will respond with an *invalid register address* error. If the *register write* packet contains a register value that is invalid for the specified address then the x-IMU will respond with an *invalid register value* error. If a *register write* packet contains a register address that is read-only then the x-IMU will respond with a *register read-only* error.

18.3 Individual registers

18.3.1 Firmware version major number

Address:	`0x0000`
Value:	0 to 65534. Read-only.
Description:	The major number of the current firmware version loaded on the x-IMU.

18.3.2 Firmware version minor number

Address:	`0x0001`
Value:	0 to 65534. Read-only.
Description:	The minor number of the current firmware version loaded on the x-IMU.

18.3.3 Device ID

Address:	`0x0002`
Value:	`0x0000` to `0xFFFF`. Read-only.
Description:	The 4 digit hexadecimal ID of the x-IMU taken as the last 2 bytes of the Bluetooth MAC address.

18.3.4 Button mode

Address:	`0x0003`
Value:	`0x0000` = Disabled `0x0001` = *Reset* command `0x0002` = *Sleep/wake up* `0x0003` = *Algorithm initialise* command `0x0004` = *Algorithm tare* command `0x0005` = *Algorithm initialise then tare* command
Description:	The command to be executed when the command button is pressed. See the commands section for more information and details of individual commands.

18.3.5 Battery voltmeter sensitivity

Address:	`0x0004`
Value:	Q11.5 signed fixed point value between −1024 and +1023.969.
Description:	Calibrated sensitivity of the battery ADC in lsb/V. See parameter s_v in the battery voltmeter section. The typical calibrated value is 621 lsb/V.

18.3.6 Battery voltmeter bias

Address:	`0x0005`
Value:	Q8.8 signed fixed point value between −128 and +127.9961.
Description:	Calibrated bias of the battery ADC in lsb. See parameter b_v in the battery voltmeter section. The typical calibrated value is 0 lsb.

18.3.7 Thermometer sensitivity

Address:	`0x0006`
Value:	Q10.6 signed fixed point value between −512 and +511.9844.
Description:	Calibrated sensitivity of the thermometer in lsb/°C. See parameter s_τ in the thermometer section. The typical calibrated value is provided as 280 lsb/°C in the IMU-3000 datasheet.

18.3.8 Thermometer bias

Address: `0x0007`
Value: Q16.0 signed fixed point value between −32768 and +32677.
Description: Calibrated bias of the thermometer in lsb. See parameter b_τ in the thermometer section. The typical calibrated value is provided as $-23,000$ lsb in the IMU-3000 datasheet.

18.3.9 Gyroscope full-scale

Address: `0x0008`
Value: `0x0000` = ±250°/s
`0x0001` = ±500°/s
`0x0002` = ±1000°/s
`0x0003` = ±2000°/s
Description: Full-scale range of the gyroscope. Each full-scale range will have different associated sensitivity and bias values. The gyroscope should therefore be recalibrated when the full-scale range is changed. See the gyroscope calibration section for more information.

18.3.10 Gyroscope x-axis sensitivity

Address: `0x0009`
Value: Q9.7 signed fixed point value between −256 and +255.9922.
Description: Calibrated sensitivity of the gyroscope x-axis in lsb/°/s. See parameter s_{g_x} in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *calculate gyroscope sensitivity* command. See the gyroscope sensitivity calibration section for more information.

18.3.11 Gyroscope y-axis sensitivity

Address: `0x000A`
Value: Q9.7 signed fixed point value between −256 and +255.9922.
Description: Calibrated sensitivity of the gyroscope y-axis in lsb/°/s. See parameter s_{g_y} in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *calculate gyroscope sensitivity* command. See the gyroscope sensitivity calibration section for more information.

18.3.12 Gyroscope z-axis sensitivity

Address: `0x000B`
Value: Q9.7 signed fixed point value between −256 and +255.9922.
Description: Calibrated sensitivity of the gyroscope z-axis in lsb/°/s. See parameter s_{g_z} in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *calculate gyroscope sensitivity* command. See the gyroscope sensitivity calibration section for more information.

18.3.13 Gyroscope sampled x-axis at +200 dps

Address: `0x000C`
Value: Q16.0 signed fixed point value between $-32,768$ and $+32,767$.
Description: Sampled gyroscope x-axis output in lsb when rotating at +200°/s, obtained through the execution of the *sample gyroscope axis at 200 dps* command. This value is used by the gyroscope sensitivity calibration algorithm to calculate the *gyroscope x-axis sensitivity*. See the gyroscope sensitivity calibration section for more information.

18.3.14 Gyroscope sampled y-axis at +200 dps

Address: `0x000D`
Value: Q16.0 signed fixed point value between $-32,768$ and $+32,767$.
Description: Sampled gyroscope y-axis output in lsb when rotating at $+200°/s$, obtained through the execution of the *sample gyroscope axis at 200 dps* command. This value is used by the gyroscope sensitivity calibration algorithm to calculate the *gyroscope y-axis sensitivity*. See the gyroscope sensitivity calibration section for more information.

18.3.15 Gyroscope sampled z-axis at +200 dps

Address: `0x000E`
Value: Q16.0 signed fixed point value between $-32,768$ and $+32,767$.
Description: Sampled gyroscope z-axis output in lsb when rotating at $+200°/s$, obtained through the execution of the *sample gyroscope axis at 200 dps* command. This value is used by the gyroscope sensitivity calibration algorithm to calculate the *gyroscope z-axis sensitivity*. See the gyroscope sensitivity calibration section for more information.

18.3.16 Gyroscope sampled x-axis at -200 dps

Address: `0x000F`
Value: Q16.0 signed fixed point value between $-32,768$ and $+32,767$.
Description: Sampled gyroscope x-axis output in lsb when rotating at $-200°/s$, obtained through the execution of the *sample gyroscope axis at 200 dps* command. This value is used by the gyroscope sensitivity calibration algorithm to calculate the *gyroscope x-axis sensitivity*. See the gyroscope sensitivity calibration section for more information.

18.3.17 Gyroscope sampled y-axis at -200 dps

Address: `0x0010`
Value: Q16.0 signed fixed point value between $-32,768$ and $+32,767$.
Description: Sampled gyroscope y-axis output in lsb when rotating at $-200°/s$, obtained through the execution of the *sample gyroscope axis at 200 dps* command. This value is used by the gyroscope sensitivity calibration algorithm to calculate the *gyroscope y-axis sensitivity*. See the gyroscope sensitivity calibration section for more information.

18.3.18 Gyroscope sampled z-axis at -200 dps

Address: `0x0011`
Value: Q16.0 signed fixed point value between $-32,768$ and $+32,767$.
Description: Sampled gyroscope z-axis output in lsb when rotating at $-200°/s$, obtained through the execution of the *sample gyroscope axis at 200 dps* command. This value is used by the gyroscope sensitivity calibration algorithm to calculate the *gyroscope z-axis sensitivity*. See the gyroscope sensitivity calibration section for more information.

18.3.19 Gyroscope x-axis bias at 25 degrees Celsius

Address: `0x0012`
Value: Q13.3 signed fixed point value between -4096 and $+4095.875$.
Description: Calibrated bias of the gyroscope x-axis at 25 °C in lsb. See parameter b_{g_x} in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *Calculate gyroscope bias parameters* command. See the gyroscope bias calibration section for more information.

18.3.20 Gyroscope y-axis bias at 25 degrees Celsius

Address: `0x0013`
Value: Q13.3 signed fixed point value between −4096 and +4095.875.
Description: Calibrated bias of the gyroscope y-axis at 25 °C in lsb. See parameter b_{g_y} in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *Calculate gyroscope bias parameters* command. See the gyroscope bias calibration section for more information.

18.3.21 Gyroscope z-axis bias at 25 degrees Celsius

Address: `0x0014`
Value: Q13.3 signed fixed point value between −4096 and +4095.875.
Description: Calibrated bias of the gyroscope z-axis at 25 °C in lsb. See parameter b_{g_z} in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *Calculate gyroscope bias parameters* command. See the gyroscope bias calibration section for more information.

18.3.22 Gyroscope x-axis bias temperature sensitivity

Address: `0x0015`
Value: Q5.11 signed fixed point value between −16 and +15.99951.
Description: Calibrated bias temperature sensitivity of the gyroscope x-axis in lsb/°C. See parameter f_x in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *Calculate gyroscope bias parameters* command. See the gyroscope bias calibration section for more information.

18.3.23 Gyroscope y-axis bias temperature sensitivity

Address: `0x0016`
Value: Q5.11 signed fixed point value between −16 and +15.99951.
Description: Calibrated bias temperature sensitivity of the gyroscope y-axis in lsb/°C. See parameter f_y in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *Calculate gyroscope bias parameters* command. See the gyroscope bias calibration section for more information.

18.3.24 Gyroscope z-axis bias temperature sensitivity

Address: `0x0017`
Value: Q5.11 signed fixed point value between −16 and +15.99951.
Description: Calibrated bias temperature sensitivity of the gyroscope z-axis in lsb/°C. See parameter f_z in the gyroscope section. The value of the parameter can be accurately evaluated through calibration using the *Calculate gyroscope bias parameters* command. See the gyroscope bias calibration section for more information.

18.3.25 Gyroscope sample 1 - Temperature

Address: `0x0018`
Value: Q8.8 signed fixed point value between −128 and +127.9961.
Description: Sampled temperature of gyroscope in °C, obtained through the execution of the *Sample gyroscope bias at temperature 1* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.26 Gyroscope sample 1 - x-axis bias

Address: `0x0019`
Value: Q13.3 signed fixed point value between −4096 and +4095.875.
Description: Sampled gyroscope x-axis output in lsb, obtained through the execution of the *Sample gyroscope bias at temperature 1* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.27 Gyroscope sample 1 - y-axis bias

Address: `0x001A`
Value: Q13.3 signed fixed point value between −4096 and +4095.875.
Description: Sampled gyroscope y-axis output in lsb, obtained through the execution of the *Sample gyroscope bias at temperature 1* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.28 Gyroscope sample 1 - z-axis bias

Address: `0x001B`
Value: Q13.3 signed fixed point value between −4096 and +4095.875.
Description: Sampled gyroscope z-axis output in lsb, obtained through the execution of the *Sample gyroscope bias at temperature 1* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.29 Gyroscope sample 2 - Temperature

Address: `0x001C`
Value: Q8.8 signed fixed point value between −128 and +127.9961.
Description: Sampled temperature of gyroscope in °C, obtained through the execution of the *Sample gyroscope bias at temperature 2* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.30 Gyroscope sample 2 - x-axis bias

Address: `0x001D`
Value: Q13.3 signed fixed point value between −4096 and +4095.875.
Description: Sampled gyroscope x-axis output in lsb, obtained through the execution of the *Sample gyroscope bias at temperature 2* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.31 Gyroscope sample 2 - y-axis bias

Address: `0x001E`
Value: Q13.3 signed fixed point value between −4096 and +4095.875.
Description: Sampled gyroscope y-axis output in lsb, obtained through the execution of the *Sample gyroscope bias at temperature 2* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.32 Gyroscope sample 2 - z-axis bias

Address: `0x001F`

Value: Q13.3 signed fixed point value between −4096 and +4095.875.

Description: Sampled gyroscope y-axis output in lsb, obtained through the execution of the *Sample gyroscope bias at temperature 2* command. This value is used by the gyroscope bias calibration algorithm in the calculation the gyroscope bias parameters. See the gyroscope bias calibration section for more information.

18.3.33 Accelerometer full-scale

Address: `0x0020`

Value: `0x0000` = ±2 g
`0x0001` = ±4 g
`0x0002` = ±8 g

Description: Full-scale range of the accelerometer. Each full-scale range will have different associated sensitivity and bias values. The accelerometer must therefore be recalibrated when the full-scale range is changed. See the accelerometer calibration section for more information.

18.3.34 Accelerometer x-axis sensitivity

Address: `0x0021`

Value: Q12.4 signed fixed point value between −2048 and +2047.938.

Description: Calibrated sensitivity of the accelerometer x-axis in lsb/g. See parameter s_{a_x} in the accelerometer section. The value of the parameter can be accurately evaluated through calibration using the *calculate accelerometer bias and sensitivity*command. See the accelerometer calibration section for more information.

18.3.35 Accelerometer y-axis sensitivity

Address: `0x0022`

Value: Q12.4 signed fixed point value between −2048 and +2047.938.

Description: Calibrated sensitivity of the accelerometer y-axis in lsb/g. See parameter s_{a_y} in the accelerometer section. The value of the parameter can be accurately evaluated through calibration using the *calculate accelerometer bias and sensitivity*command. See the accelerometer calibration section for more information.

18.3.36 Accelerometer z-axis sensitivity

Address: `0x0023`

Value: Q12.4 signed fixed point value between −2048 and +2047.938.

Description: Calibrated sensitivity of the accelerometer z-axis in lsb/g. See parameter s_{a_z} in the accelerometer section. The value of the parameter can be accurately evaluated through calibration using the *calculate accelerometer bias and sensitivity*command. See the accelerometer calibration section for more information.

18.3.37 Accelerometer x-axis bias

Address: `0x0024`

Value: Q8.8 signed fixed point value between −128 and +127.9961.

Description: Calibrated bias of the accelerometer x-axis in lsb. See parameter b_{a_x} in the accelerometer section. The value of the parameter can be accurately evaluated through calibration using the *calculate accelerometer bias and sensitivity*command. See the accelerometer calibration section for more information.

18.3.38 Accelerometer y-axis bias

Address: `0x0025`
Value: Q8.8 signed fixed point value between −128 and +127.9961.
Description: Calibrated bias of the accelerometer y-axis in lsb. See parameter b_{a_y} in the accelerometer section. The value of the parameter can be accurately evaluated through calibration using the *calculate accelerometer bias and sensitivity*command. See the accelerometer calibration section for more information.

18.3.39 Accelerometer z-axis bias

Address: `0x0026`
Value: Q8.8 signed fixed point value between −128 and +127.9961.
Description: Calibrated bias of the accelerometer z-axis in lsb. See parameter b_{a_z} in the accelerometer section. The value of the parameter can be accurately evaluated through calibration using the *calculate accelerometer bias and sensitivity*command. See the accelerometer calibration section for more information.

18.3.40 Accelerometer sampled x-axis at +1 g

Address: `0x0027`
Value: Q12.4 signed fixed point value between −2048 and +2047.938.
Description: Sampled accelerometer x-axis output in lsb when orientated to measure +1g, obtained through the execution of the *sample accelerometer axis at 1 g* command. This value is used by the accelerometer calibration algorithm to calculate the value of the *accelerometer x-axis sensitivity* and *accelerometer x-axis bias*. See the accelerometer calibration section for more information.

18.3.41 Accelerometer sampled y-axis at +1 g

Address: `0x0028`
Value: Q12.4 signed fixed point value between −2048 and +2047.938.
Description: Sampled accelerometer y-axis output in lsb when orientated to measure +1g, obtained through the execution of the *sample accelerometer axis at 1 g* command. This value is used by the accelerometer calibration algorithm to calculate the value of the *accelerometer y-axis sensitivity* and *accelerometer y-axis bias*. See the accelerometer calibration section for more information.

18.3.42 Accelerometer sampled z-axis at +1 g

Address: `0x0029`
Value: Q12.4 signed fixed point value between −2048 and +2047.938.
Description: Sampled accelerometer z-axis output in lsb when orientated to measure +1g, obtained through the execution of the *sample accelerometer axis at 1 g* command. This value is used by the accelerometer calibration algorithm to calculate the value of the *accelerometer z-axis sensitivity* and *accelerometer z-axis bias*. See the accelerometer calibration section for more information.

18.3.43 Accelerometer sampled x-axis at -1 g

Address: `0x002A`
Value: Q12.4 signed fixed point value between −2048 and +2047.938.
Description: Sampled accelerometer x-axis output in lsb when orientated to measure -1g, obtained through the execution of the *sample accelerometer axis at 1 g* command. This value is used by the accelerometer calibration algorithm to calculate the value of the *accelerometer x-axis sensitivity* and *accelerometer x-axis bias*. See the accelerometer calibration section for more information.

18.3.44 Accelerometer sampled y-axis at -1 g

Address: `0x002B`

Value: Q12.4 signed fixed point value between −2048 and +2047.938.

Description: Sampled accelerometer y-axis output in lsb when orientated to measure -1g, obtained through the execution of the *sample accelerometer axis at 1 g* command. This value is used by the accelerometer calibration algorithm to calculate the value of the *accelerometer y-axis sensitivity* and *accelerometer y-axis bias*. See the accelerometer calibration section for more information.

18.3.45 Accelerometer sampled z-axis at -1 g

Address: `0x002C`

Value: Q12.4 signed fixed point value between −2048 and +2047.938.

Description: Sampled accelerometer z-axis output in lsb when orientated to measure -1g, obtained through the execution of the *sample accelerometer axis at 1 g* command. This value is used by the accelerometer calibration algorithm to calculate the value of the *accelerometer z-axis sensitivity* and *accelerometer z-axis bias*. See the accelerometer calibration section for more information.

18.3.46 Magnetometer full-scale

Address: `0x002D`

Value:
`0x0000` = ±1.3 G
`0x0001` = ±1.9 G
`0x0002` = ±2.5 G
`0x0003` = ±4.0 G
`0x0004` = ±4.7 G
`0x0005` = ±5.6 G
`0x0006` = ±8.1 G

Description: Full-scale range of the magnetometer. Each full-scale range will have different associated sensitivity and bias values. The magnetometer therefore must be recalibrated when the full-scale range is changed. See the magnetometer bias and sensitivity calibration section for more information.

18.3.47 Magnetometer x-axis sensitivity

Address: `0x002E`

Value: Q12.4 signed fixed point value between −2048 and +2047.938.

Description: Calibrated sensitivity of the magnetometer x-axis in lsb/G. See parameter s_{m_x} in the magnetometer section. The value of the parameter can be accurately evaluated through calibration using the *Measure magnetometer bias and sensitivity* command. See the magnetometer bias and sensitivity calibration section for more information.

18.3.48 Magnetometer y-axis sensitivity

Address: `0x002F`

Value: Q12.4 signed fixed point value between −2048 and +2047.938.

Description: Calibrated sensitivity of the magnetometer y-axis in lsb/G. See parameter s_{m_y} in the magnetometer section. The value of the parameter can be accurately evaluated through calibration using the *Measure magnetometer bias and sensitivity* command. See the magnetometer bias and sensitivity calibration section for more information.

18.3.49 Magnetometer z-axis sensitivity

Address: `0x0030`
Value: Q12.4 signed fixed point value between −2048 and +2047.938.
Description: Calibrated sensitivity of the magnetometer z-axis in lsb/G. See parameter s_{m_z} in the magnetometer section. The value of the parameter can be accurately evaluated through calibration using the *Measure magnetometer bias and sensitivity* command. See the magnetometer bias and sensitivity calibration section for more information.

18.3.50 Magnetometer x-axis bias

Address: `0x0031`
Value: Q8.8 signed fixed point value between −128 and +127.9961.
Description: Calibrated bias of the magnetometer x-axis in lsb. See parameter b_{m_x} in the magnetometer section. The value of the parameter can be accurately evaluated through calibration using the *Measure magnetometer bias and sensitivity* command. See the magnetometer bias and sensitivity calibration section for more information.

18.3.51 Magnetometer y-axis bias

Address: `0x0032`
Value: Q8.8 signed fixed point value between −128 and +127.9961.
Description: Calibrated bias of the magnetometer y-axis in lsb. See parameter b_{m_y} in the magnetometer section. The value of the parameter can be accurately evaluated through calibration using the *Measure magnetometer bias and sensitivity* command. See the magnetometer bias and sensitivity calibration section for more information.

18.3.52 Magnetometer z-axis bias

Address: `0x0033`
Value: Q8.8 signed fixed point value between −128 and +127.9961.
Description: Calibrated bias of the magnetometer z-axis in lsb. See parameter b_{m_z} in the magnetometer section. The value of the parameter can be accurately evaluated through calibration using the *Measure magnetometer bias and sensitivity* command. See the magnetometer bias and sensitivity calibration section for more information.

18.3.53 Magnetometer x-axis hard-iron bias

Address: `0x0034`
Value: Q5.11 signed fixed point value between −16 and +15.99951.
Description: Calibrated hard-iron bias affecting the magnetometer x-axis in G. See parameter h_x in the magnetometer section. The hard-iron bias parameters will change when the x-IMU's local magnetic environment is altered; for example, when the x-IMU is fixed to the battery. See the magnetometer hard-iron calibrations section for more information.

18.3.54 Magnetometer y-axis hard-iron bias

Address: `0x0035`
Value: Q5.11 signed fixed point value between −16 and +15.99951.
Description: Calibrated hard-iron bias affecting the magnetometer y-axis in G. See parameter h_x in the magnetometer section. The hard-iron bias parameters will change when the x-IMU's local magnetic environment is altered; for example, when the x-IMU is fixed to the battery. See the magnetometer hard-iron calibrations section for more information.

18.3.55 Magnetometer z-axis hard-iron bias

Address: `0x0036`
Value: Q5.11 signed fixed point value between −16 and +15.99951.
Description: Calibrated hard-iron bias affecting the magnetometer z-axis in G. See parameter h_x in the magnetometer section. The hard-iron bias parameters will change when the x-IMU's local magnetic environment is altered; for example, when the x-IMU is fixed to the battery. See the magnetometer hard-iron calibrations section for more information.

18.3.56 Algorithm mode

Address: `0x0037`
Value: `0x0000` = Disabled
`0x0000` = IMU
`0x0001` = AHRS
Description: IMU and AHRS algorithm mode. See the IMU and AHRS algorithms section for more information. The algorithm will automatically re-initialise when the value of this register is changed. If the algorithm is not required then the *algorithm mode* can be set to *Disabled* to reduce power consumption.

18.3.57 Algorithm gain Kp

Address: `0x0038`
Value: Q5.11 signed fixed point value between 0 and +15.99951.
Description: Algorithm proportional feedback gain. The proportional gain governs the rate at which the algorithm output converges to an orientation assumed by the accelerometer and magnetometer; lower values 'trust' the gyroscope data more and the accelerometer and magnetometer less and higher values will 'trust' the gyroscope less and the accelerometer and magnetometer more. See the IMU and AHRS algorithms section for more information.

18.3.58 Algorithm gain Ki

Address: `0x0039`
Value: Q1.15 signed fixed point value between 0 and +0.9999695.
Description: Algorithm integral feedback gain in units of 1/1000. The integral gain governs the rate at which the algorithm compensates for gyroscope bias drift. In most situations it is recommended that users ensure accurate gyroscope bias temperature sensitivity calibration and use an integral feedback gain of 0 to avoid algorithm output oscillations and instabilities. See the IMU and AHRS algorithms section for more information.

18.3.59 Algorithm initial proportional gain

Address: `0x003A`
Value: Q5.11 signed fixed point value between 0 and +15.99951.
Description: Initial algorithm proportional feedback gain used during algorithm initialisation. The effective proportional gain will ramp down from the *algorithm initial proportional gain* to the *algorithm proportional gain* over the *algorithm initialisation period*. See the IMU and AHRS algorithms section for more information.

18.3.60 Algorithm initialisation period

Address: `0x003B`
Value: Q5.11 signed fixed point value between 0 and +15.99951.
Description: Algorithm initialisation period in seconds. The effective proportional gain will ramp down from the *algorithm initial proportional gain* to the *algorithm proportional gain* over the *algorithm initialisation period*. See the IMU and AHRS algorithms section for more information.

18.3.61 Algorithm minimum valid magnetic field magnitude

Address: 0x003C
Value: Q5.11 signed fixed point value between 0 and +15.99951.
Description: The minimum valid magnetic field magnitude (in G) that may be used by the algorithm in the estimation of heading. Magnetic fields of an invalid magnitude will be ignored by the AHRS algorithm so that heading is determined from gyroscope measurements alone. See the IMU and AHRS algorithms section for more information.

18.3.62 Algorithm maximum valid magnetic field magnitude

Address: 0x003D
Value: Q5.11 signed fixed point value between 0 and +15.99951.
Description: The maximum valid magnetic field magnitude (in G) that may be used by the algorithm in the estimation of heading. Magnetic fields of an invalid magnitude will be ignored by the AHRS algorithm so that heading is determined from gyroscope measurements alone. See the IMU and AHRS algorithms section for more information.

18.3.63 Tare quaternion (element 0)

Address: 0x003E
Value: Q1.15 signed fixed point value between −1 and +0.9999695.
Description: Quaternion stored to compute the algorithm output after a tare operation has been preformed. The tare quaternion can be set using the *algorithm tare* command and cleared using the *clear tare* command. See the IMU and AHRS algorithms section for more information.

18.3.64 Tare quaternion (element 1)

Address: 0x003F
Value: Q1.15 signed fixed point value between −1 and +0.9999695.
Description: Quaternion stored to compute the algorithm output after a tare operation has been preformed. The tare quaternion can be set using the *algorithm tare* command and cleared using the *clear tare* command. See the IMU and AHRS algorithms section for more information.

18.3.65 Tare quaternion (element 2)

Address: 0x0040
Value: Q1.15 signed fixed point value between −1 and +0.9999695.
Description: Quaternion stored to compute the algorithm output after a tare operation has been preformed. The tare quaternion can be set using the *algorithm tare* command and cleared using the *clear tare* command. See the IMU and AHRS algorithms section for more information.

18.3.66 Tare quaternion (element 3)

Address: 0x0041
Value: Q1.15 signed fixed point value between −1 and +0.9999695.
Description: Quaternion stored to compute the algorithm output after a tare operation has been preformed. The tare quaternion can be set using the *algorithm tare* command and cleared using the *clear tare* command. See the IMU and AHRS algorithms section for more information.

18.3.67 Sensor data mode

Address: 0x0042
Value: 0x0000 = Raw ADC results
0x0001 = Calibrated measurements
Description: Data output mode of on-board sensors. See the sensors section for more details.

18.3.68 Date/time data output rate

Address: `0x0043`

Value:
`0x0000` = Disabled (sent on reset/wake only)
`0x0001` = 1 Hz
`0x0002` = 2 Hz
`0x0003` = 4 Hz
`0x0004` = 8 Hz
`0x0005` = 16 Hz
`0x0006` = 32 Hz
`0x0007` = 64 Hz
`0x0008` = 128 Hz
`0x0009` = 256 Hz
`0x000A` = 512 Hz

Description: Output rate of the *date/time data* packets. Data rates can be reduced or disabled to reduce power consumption.

18.3.69 Battery and thermometer data output rate

Address: `0x0044`

Value:
`0x0000` = Disabled
`0x0001` = 1 Hz
`0x0002` = 2 Hz
`0x0003` = 4 Hz
`0x0004` = 8 Hz
`0x0005` = 16 Hz
`0x0006` = 32 Hz
`0x0007` = 64 Hz
`0x0008` = 128 Hz
`0x0009` = 256 Hz
`0x000A` = 512 Hz

Description: Output rate of the *battery and thermometer data* packets. Data rates can be reduced or disabled to reduce power consumption.

18.3.70 Inertial and magnetic data output rate

Address: `0x0045`

Value:
`0x0000` = Disabled
`0x0001` = 1 Hz
`0x0002` = 2 Hz
`0x0003` = 4 Hz
`0x0004` = 8 Hz
`0x0005` = 16 Hz
`0x0006` = 32 Hz
`0x0007` = 64 Hz
`0x0008` = 128 Hz
`0x0009` = 256 Hz
`0x000A` = 512 Hz

Description: Output rate of the *inertial and magnetic data* packets. Data rates can be reduced or disabled to reduce power consumption.

18.3.71 Quaternion data output rate

Address: 0x0046

Value: 0x0000 = Disabled
0x0001 = 1 Hz
0x0002 = 2 Hz
0x0003 = 4 Hz
0x0004 = 8 Hz
0x0005 = 16 Hz
0x0006 = 32 Hz
0x0007 = 64 Hz
0x0008 = 128 Hz
0x0009 = 256 Hz
0x000A = 512 Hz

Description: Output rate of the *quaternion data* packets. Data rates can be reduced or disabled to reduce power consumption.

18.3.72 SD card new file name

Address: 0x0047

Value: 00000 to 65535

Description: The file name used to be used when the next file is created on the SD card. See the SD card section for more information.

18.3.73 Battery shutdown voltage

Address: 0x0048

Value: Q4.12 signed fixed point value between 3.5 and +7.999756.

Description: Minimum voltage threshold for the device to shutdown. See the low battery voltage detection section for more information.

18.3.74 Sleep timer

Address: 0x0049

Value: 0 to 65535

Description: Sleep timer value in seconds. Once this period has elapsed, the x-IMU will enter sleep mode. A value of 0 seconds will disable the sleep timer. See the sleep timer section for more information.

18.3.75 Motion trigger wake up

Address: 0x004A

Value: 0x0000 = Disabled
0x0001 = Low sensitivity
0x0001 = High sensitivity

Description: Enables the sensitivity of the motion trigger wake up. See the motion trigger wake up section for more information.

18.3.76 Bluetooth power

Address: 0x004B

Value: 0x0000 = Disabled
0x0001 = Enabled

Description: Enables or disables Bluetooth. The Bluetooth can be disabled to reduce power consumption.

18.3.77 Auxiliary port mode

Address:	`0x004C`
Value:	`0x0000` = Disabled
	`0x0001` = Digital I/O
	`0x0002` = Analgoue input
	`0x0003` = PWM output
	`0x0004` = ADXL345 bus
	`0x0005` = UART
	`0x0006` = Sleep/wake
Description:	Sets the auxiliary port mode. See the auxiliary port section for more information.

18.3.78 Digital I/O direction

Address:	`0x004D`
Value:	`0x0000` = All channels are inputs
	`0x0001` = Channels 0, 1, 2, 3, 4, 5 and 6 are inputs, 7 is an output
	`0x0002` = Channels 0, 1, 2, 3, 4 and 5 are inputs, 6 and 7 are outputs
	`0x0003` = Channels 0, 1, 2, 3 and 4 are inputs, 5, 6 and 7 are outputs
	`0x0004` = Channels 0, 1, 2 and 3 are inputs, 4, 5, 6 and 7 are outputs
	`0x0005` = Channels 0, 1 and 2 are inputs, 3, 4, 5, 6 and 7 are outputs
	`0x0006` = Channels 0 and 1 are inputs, 2, 3, 4, 5, 6 and 7 are outputs
	`0x0007` = Channel 0 is an input, 1, 2, 3, 4, 5, 6 and 7 are outputs
	`0x0008` = All channels are outputs
Description:	Sets the direction of the auxiliary port channels when in digital I/O mode.

18.3.79 Digital I/O data output rate

Address:	`0x004E`
Value:	`0x0000` = Disabled (On change only)
	`0x0001` = 1 Hz
	`0x0002` = 2 Hz
	`0x0003` = 4 Hz
	`0x0004` = 8 Hz
	`0x0005` = 16 Hz
	`0x0006` = 32 Hz
	`0x0007` = 64 Hz
	`0x0008` = 128 Hz
	`0x0009` = 256 Hz
	`0x000A` = 512 Hz
Description:	Output rate of the *digital I/O data* packets. Data rates can be reduced or disabled to reduce power consumption.

18.3.80 Analogue input data mode

Address:	`0x004F`
Value:	`0x0000` = Raw ADC results
	`0x0001` = Calibrated measurements
Description:	Data output mode of analogue input. See the analogue input section for more information.

18.3.81 Analogue input data output rate

Address:	`0x0050`
Value:	`0x0000` = On change only
	`0x0001` = 1 Hz
	`0x0002` = 2 Hz
	`0x0003` = 4 Hz
	`0x0004` = 8 Hz
	`0x0005` = 16 Hz
	`0x0006` = 32 Hz
	`0x0007` = 64 Hz
	`0x0008` = 128 Hz
	`0x0009` = 256 Hz
	`0x000A` = 512 Hz
Description:	Output rate of the *analogue input* packets. Data rates can be reduced or disabled to reduce power consumption. See the analogue input section for more information.

18.3.82 Analogue input sensitivity

Address:	`0x0051`
Value:	Q12.4 signed fixed point value between $-2,048$ and $+2047.938$.
Description:	Calibrated sensitivity of the analogue input ADC in lsb/V. The typical value is 1241.188 lsb/V. See the analogue input section for more information.

18.3.83 Analogue input bias

Address:	`0x0052`
Value:	Q8.8 signed fixed point value between -256 and $+127.9961$.
Description:	Calibrated bias of the battery ADC in lsb. The typical value is 0 lsb. See the analogue input section for more information.

18.3.84 PWM frequency

Address:	`0x0053`
Value:	3 to 65535
Description:	Frequency of the PWM output in Hz. See the PWM section for more information.

18.3.85 ADXL345 bus data mode

Address:	`0x0054`
Value:	`0x0000` = Raw ADC results
	`0x0001` = Calibrated measurements
Description:	Data output mode of ADXL345 bus.

18.3.86 ADXL345 bus data output rate

Address: `0x0055`

Value:
`0x0000` = On change only
`0x0001` = 1 Hz
`0x0002` = 2 Hz
`0x0003` = 4 Hz
`0x0004` = 8 Hz
`0x0005` = 16 Hz
`0x0006` = 32 Hz
`0x0007` = 64 Hz
`0x0008` = 128 Hz
`0x0009` = 256 Hz
`0x000A` = 512 Hz

Description: Output rate of the *ADXL345 bus data* packets. Data rates can be reduced or disabled to reduce power consumption.

18.3.87 ADXL345 A x-axis sensitivity

Address: `0x0056`

Value: Q10.6 signed fixed point value between −512 and +511.9844.

Description: Calibrated sensitivity of the ADXL345 A x-axis in lsb/g. The typical value is 256 lsb/g. The typical value is 256 lsb/V.

18.3.88 ADXL345 A y-axis sensitivity

Address: `0x0057`

Value: Q10.6 signed fixed point value between −512 and +511.9844.

Description: Calibrated sensitivity of the ADXL345 A y-axis in lsb/g. The typical value is 256 lsb/g.

18.3.89 ADXL345 A z-axis sensitivity

Address: `0x0058`

Value: Q10.6 signed fixed point value between −512 and +511.9844.

Description: Calibrated sensitivity of the ADXL345 A z-axis in lsb/g. The typical value is 256 lsb/g.

18.3.90 ADXL345 A x-axis bias

Address: `0x0059`

Value: Q8.8 signed fixed point value between −256 and +127.9961.

Description: Calibrated bias of the ADXL345 A x-axis in lsb. The typical value is 0 lsb.

18.3.91 ADXL345 A y-axis bias

Address: `0x005A`

Value: Q8.8 signed fixed point value between −256 and +127.9961.

Description: Calibrated bias of the ADXL345 A y-axis in lsb. The typical value is 0 lsb.

18.3.92 ADXL345 A z-axis bias

Address: `0x005B`

Value: Q8.8 signed fixed point value between −256 and +127.9961.

Description: Calibrated bias of the ADXL345 A z-axis in lsb. The typical value is 0 lsb.

18.3.93 ADXL345 B x-axis sensitivity

Address: `0x005C`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 B x-axis in lsb/g. The typical value is 256 lsb/g.

18.3.94 ADXL345 B y-axis sensitivity

Address: `0x005D`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 B y-axis in lsb/g. The typical value is 256 lsb/g.

18.3.95 ADXL345 B z-axis sensitivity

Address: `0x005E`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 B z-axis in lsb/g. The typical value is 256 lsb/g.

18.3.96 ADXL345 B x-axis bias

Address: `0x005F`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 B x-axis in lsb. The typical value is 0 lsb.

18.3.97 ADXL345 B y-axis bias

Address: `0x0060`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 B y-axis in lsb. The typical value is 0 lsb.

18.3.98 ADXL345 B z-axis bias

Address: `0x0061`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 B z-axis in lsb. The typical value is 0 lsb.

18.3.99 ADXL345 C x-axis sensitivity

Address: `0x0062`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 C x-axis in lsb/g. The typical value is 256 lsb/g.

18.3.100 ADXL345 C y-axis sensitivity

Address: `0x0063`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 C y-axis in lsb/g. The typical value is 256 lsb/g.

18.3.101 ADXL345 C z-axis sensitivity

Address: `0x0064`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 C z-axis in lsb/g. The typical value is 256 lsb/g.

18.3.102 ADXL345 C x-axis bias

Address: `0x0065`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 C x-axis in lsb. The typical value is 0 lsb.

18.3.103 ADXL345 C y-axis bias

Address: `0x0066`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 C y-axis in lsb. The typical value is 0 lsb.

18.3.104 ADXL345 C z-axis bias

Address: `0x0067`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 C z-axis in lsb. The typical value is 0 lsb.

18.3.105 ADXL345 D x-axis sensitivity

Address: `0x0068`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 D x-axis in lsb/g. The typical value is 256 lsb/g.

18.3.106 ADXL345 D y-axis sensitivity

Address: `0x0069`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 D y-axis in lsb/g. The typical value is 256 lsb/g.

18.3.107 ADXL345 D z-axis sensitivity

Address: `0x006A`
Value: Q10.6 signed fixed point value between −512 and +511.9844.
Description: Calibrated sensitivity of the ADXL345 D z-axis in lsb/g. The typical value is 256 lsb/g.

18.3.108 ADXL345 D x-axis bias

Address: `0x006B`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 D x-axis in lsb. The typical value is 0 lsb.

18.3.109 ADXL345 D y-axis bias

Address: `0x006C`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 D y-axis in lsb. The typical value is 0 lsb.

18.3.110 ADXL345 D z-axis bias

Address: `0x006D`
Value: Q8.8 signed fixed point value between −256 and +127.9961.
Description: Calibrated bias of the ADXL345 D z-axis in lsb. The typical value is 0 lsb.

18.3.111 UART baud rate

Address:	`0x006E`
Value:	`0x0000` = 2400 baud
	`0x0001` = 4800 baud
	`0x0002` = 7200 baud
	`0x0003` = 9600 baud
	`0x0004` = 14400 baud
	`0x0005` = 19200 baud
	`0x0006` = 38400 baud
	`0x0007` = 57600 baud
	`0x0008` = 115200 baud
	`0x0009` = 230400 baud
	`0x000A` = 460800 baud
	`0x000B` = 921600 baud
Description:	Baud rate of the auxiliary port UART. See the UART section for more information.

18.3.112 UART hardware flow control

Address:	`0x006F`
Value:	`0x0000` = Disabled
	`0x0001` = Enabled
Description:	Hardware flow control enable/disable of the auxiliary port UART. See the UART section for more information.

Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa
UNIVERSITAT POLITÈCNICA DE CATALUNYA

ETSEIAT
Grau en Enginyeria en Tecnologies Industrials

Design of a bench to allocate accelerometers and gyroscopes on a sailplane

Annex D: MSR255 Datasheet

Author:
Oscar Castro Ruiz

Director:
Ricardo Villar
Co-director:
Rafael Weyler

[12-06-2015]

universal data loggers

Swiss made

MSR 255 with ext. sensors

MSR 255 Data Logger
Robust multi-talent with LCD screen

With up to five different sensors, four additional analogue inputs and an easy to read LCD screen the compact MSR 255 offers maximum possible flexibility and user-friendliness.

The measuring tasks undertaken by the user define the way in which the MSR 255 is configured: There is a choice of temperature, humidity, air pressure and light sensors (fitted internally within the case or externally on a cable) together with a sensor for measuring acceleration in all three co-ordinate axes. Acceleration values can be measured at 3200 Hz and saved at a frequency of approx. 50 Hz following digital filtration. In addition, the voltage of four further external analogue channels or sensors can also be recorded. The analogue inputs feature an alarm output, multiple output switching power supply and an input for starting and stopping data recording.

The memory capacity of the MSR 255 is over 2 million measurement parameters. Thanks to its high-capacity lithium polymer battery the data logger is ideal for long-term data acquisition applications. The 4-row backlit LCD display has four individually configurable views. All acquired data can be quickly transferred to a PC or laptop via the USB interface.

Technical data

Housing:	Anodised aluminium industrial case (standard IP60, optional IP67 protection class), top-hat rail snapper (TS 35)
Size & weight:	78 x 62 x 38 mm, approx. 222 g
Memory capacity:	Over 2 000 000 measurement parameters.
Operation:	Two keys for selecting functions and controlling data recording
Display:	Four row LCD matrix display
LED:	3 colour LED to indicate data recording, alarm and charge condition
Integrated sensors:	Selection of different sensors for temperature, relative humidity, pressure, light and 3-axis acceleration/position
Measurement rate (MR):	1 /s to every 12 h (acceleration up to 3200 /s)
Storage rate (SR):	1 /s to every 12 h (acceleration up to 50 /s)
Power supply:	Rechargeable lithium polymer battery 2300 mAh
PC software:	Free Setup, Reader, Viewer- & Online software (Windows XP / Vista / 7 / 8)
Interface:	USB (Mini-B)
Operating conditions:	• Temperature -20…+65 °C
Storage conditions:	• Temperatur +5…+45° C (ideal storage condition for the battery) • 10…95% relative humidity, non-condensing
Standards:	The MSR 255 complies with EU-Directives RoHS/WEEE

Measurement parameters for the sensors (internal and external)

Your MSR 255 data logger can be fitted with up to five different sensors. If required, you may select from the following external sensors in place of the corresponding internal ones: temperature, relative humidity, air pressure and light. The available cable lengths are: 0.15 m, 0.4 m, 1.0 m and 1.6 m.

Measured parameters	Working range	Accuracy	Measurement/ storage rate
Temperature	int.: -20…+65°C	±0.5°C (-10…+65°C)	1/s to every 12 h
	ext.: -55…+125°C	±0.5°C (-10…+65°C) ±2°C (-55…+125°C)	
Relative humidity with integrated temperature	0…100% rel. humidity -20…+65°C	±2% rel. humidity (10…85%, 0…+40°C) ±4% rel. humidity (85…95%, 0…+40°C)	1/s to every 12 h
Air pressure absolute, with integrated temperature	0…2000 mbar absolute -20…+65°C	±2.5 mbar (750…1100 mbar absolute, +25°C)	1/s to every 12 h
	optional: 0…14 bar absolute -20…+65°C	±50 mbar (1…10 bar absolute, +25°C)	1/s to every 12 h
3-axis-acceleration	±15 g	±0.15 g (+25°C)	Acceleration: 50/s (3,200/s) Position: 1/s up to every 12 h
Light	0…65 000 lx	max. sensitivity at 500 nm	1/s to every 12 h

Additional analogue inputs for connecting third-party sensors

It is possible to expand the range of possible applications for which your MSR 255 can be used by specifying four analogue inputs. These additional inputs allow external sensors for a wide range of measuring tasks to be connected. If required, these third-party sensors can be powered by the logger's internal battery. The power can be automatically turned on before measurements take place with a pre-settable lead time. This allows any necessary warm-up periods for the sensors to be taken into consideration.

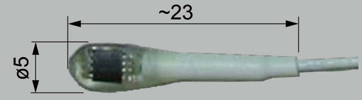
Analogue Inputs	Technical data
Including an alarm output, multiple output switching power supply and an input for starting and stopping data recording. 	**4 analogue inputs** with freely selectable input configuration: 0…20 mA; 4…20 mA; 0…3.0 V; 0.5…4.5 V; 0…5.0 V; 1.0…6.0 V; 0…10.0 V; 0…12.0 V; 0…24.0 V **Resolution:** 12 Bit **Measurement/storage rate:** 1/s to every 12 h

Its flexibility makes the autonomous MSR 255 data logger ideally suited for the most diverse documentation and monitoring applications in industry and science.

Configure your ideal MSR 255 today –
We will be pleased to provide you with prices and terms of delivery!

universal data loggers

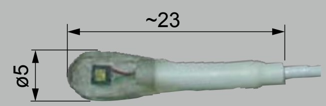
Options:



External temperature sensor

External humidity sensor

External air pressure sensor



External light sensor

MSR Electronics GmbH
Mettlenstrasse 6a
CH-8472 Seuzach
Switzerland

Tel. +41 52 316 25 55
Fax +41 52 316 35 21
info@msr.ch
www.msr.ch

Distributor:

07.14