Bureau International des Poids et Mesures

Consultative Committee for Acoustics, Ultrasound, and Vibration (CCAUV)

Strategy 2019 to 2029

Consultative Committee for Acoustics, Ultrasound, and Vibration (CCAUV)

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Strategic Planning Working Group (SPWG)

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Organization of the Report

- Executive Summary
- Terms of Reference
- Baseline
- Stakeholders
- Future Scan
- Rationale for Various Activities
- Required Key Comparisons and Pilot Studies
- Resource Implications for Piloting Laboratories
- Summary
- Document Revision Schedule
- Bibliography and Supporting Documents

Terms of Reference for the SPWG

- Establish a view on emerging requirements for CCAUV metrology, the way these are driven by societal and industrial stakeholder needs and the key enabling technologies providing solutions to the highlighted challenges;
- Provide input within the area of AUV into the CC Strategy Document; "Future Needs in Metrology" documents; which will be the basis for the strategic plan proposed to the CGPM;
- Provide expert input and advice to the CC Strategy Document identifying future pilot studies and Key Comparisons;
- Advise the CCAUV on the optimal operational structure, e.g. for information gathering, collation and dissemination;
- Share information on national priorities (e.g. roadmapping) for emerging metrology helping NMIs to formulate improved metrological programs;
- Identify areas suitable for collaboration, thereby allowing impact to be accelerated;
- Monitor and respond to developments within other CCs, including the future of the SI, which might impact on the area of CCAUV.

General Information of CCAUV

- Established in 1999
- President: Dr. Takashi Usuda (NMIJ), since 2014
- 18 members, 12 observers, and
- Meets every 2 years
- Last meeting was held 24 to 27 November 2019
- 51 participants at last meeting (experts included)
- 16 CC-KCs and 24 RMO-KCs carried out from 1999 to 2019
- 4 Pilot Studies were carried out from 1999 to 2019
- There are 51 types of CMCs. 1244 CMC entries are published in KCDB of which 890 are linked to a Key Comparison supported by the CCAUV

A-U-V Designations

(A)	**Acoustics**	
	Airborne Sound	Airborne sound is sound that is transmitted through the air.
(U)	**Ultrasound and Underwater Acoustics**	
	Ultrasound	Ultrasound is sonic energy at a frequency above the human hearing range (20 kHz) whose applications are both in industrial and medical applications.
	Underwater Acoustics	Underwater acoustics is the study of the propagation of sound in aquatic environments.
(V)	**Vibration**	
	Sinusoidal Acceleration	Acceleration measurements using sinusoidal steady state mechanical excitation
	Shock Acceleration	Acceleration measurements using transient impact
	Inertial Acceleration (under consideration)	Acceleration measurements by static rotation.

Stakeholders

Stakeholder	**Application**
Metrological bodies	High precision metrology Precursor to other stakeholders
Health	Hearing assessment Objective audiology Diagnostics (imaging) Therapy Cleaning and materials processing Occupational Safety Patient Safety Human body comfort (vibration)
Industry	Industrial design Equipment manufacturers Automotive Aerospace Testing Health and safety Cleaning procedures Robotics and machine tool Secondary Calibration and Test Laboratories

Stakeholders

Stakeholder	Application
Consumer Electronics	Mobile devices Fitness Tracking
Trade	Added value in performance of products
Environment	Marine noise pollution Climate change monitoring Air-borne environmental noise Earth quake monitoring Carbon capture and storage Public transportation Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) International Monitoring System (IMS)
Society	Environmental protection Psychological influence and human health Music and entertainment
Academia	Universities Research Institutes
Energy	Offshore oil and gas Marine renewable energy Biofuel production Wind

Stakeholders

Stakeholder	**Application**
Standards Organizations	Standards Development
Legal Metrology	Regulators and Administration
Defense	Defense and security
Ocean science and marine applications	Ocean processes (e.g. currents and temperature) Hydrographic mapping Positioning, Navigation Communication Sonar Echo-sounding Geophysical survey

Action for 2021: Consider identifying stakeholder links to topic areas A and/or U, V

Future Scan

- In strategic planning, it is the participants that benefit the most
- Future scan discussions provide a forum for discovery of international needs and topics for cooperation between NMIs
  - Development of Standards
  - Bilateral Comparisons
  - Pilot Studies
  - Key Comparisons

Future Scan – Driving future KCs

- New or evolving applications are driving incremental needs for widening frequency range or power levels in AUV Key Comparisons.
  - This information drives our planning of future Key Comparisons and extending the range of repeats
- But there are also applications that are driving more fundamental change and which are not yet reflected in our future KCs
  - Digitization
  - Inertial Sensors

Future Scan: Digitization

(example referenced in 2017 report)

(example referenced in 2019 report)

ANALOG DEVICES

Single-Axis, High-*g*, *i*MEMS® Accelerometers

ADXL78

FEATURES

Complete acceleration measurement system on a single monolithic IC
Available in ±35 *g*, ±50 *g*, or ±70 *g* output full-scale ranges
Full differential sensor and circuitry for high resistance to EMI/RFI
Environmentally robust packaging
Complete mechanical and electrical self-test on digital command
Output ratiometric to supply
Sensitive axes in the plane of the chip
High linearity (0.2% of full scale)
Frequency response down to dc
Low noise
Low power consumption (1.3 mA)
Tight sensitivity tolerance and 0 *g* offset capability
Largest available prefilter clipping headroom
400 Hz, 2-pole Bessel filter
Single-supply operation
Compatible with Sn/Pb and Pb-free solder processes
Qualified for automotive applications

APPLICATIONS

Vibration monitoring and control
Vehicle collision sensing
Shock detection

GENERAL DESCRIPTION

The ADXL78 is a low power, complete single-axis accelerometer with signal conditioned voltage outputs that are on a single monolithic IC. This product measures acceleration with a full-scale range of ±35 *g*, ±50 *g*, or ±70 *g* (minimum). It can also measure both dynamic acceleration (vibration) and static acceleration (gravity).

The ADXL78 is the fourth-generation surface micromachined *i*MEMS® accelerometer from ADI with enhanced performance and lower cost. Designed for use in front and side impact airbag applications, this product also provides a complete cost-effective solution useful for a wide variety of other applications.

The ADXL78 is temperature stable and accurate over the automotive temperature range, with a self-test feature that fully exercises all the mechanical and electrical elements of the sensor with a digital signal applied to a single pin.

The ADXL78 is available in a 5 mm × 5 mm × 2 mm, 8-terminal ceramic LCC package.

FUNCTIONAL BLOCK DIAGRAM

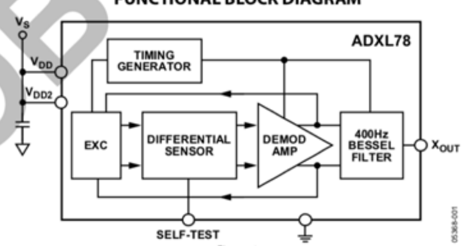


Figure 1.

ANALOG DEVICES

Dual-Axis, 60 *g* to 480 *g* Sensor with SPI and PSI5

Data Sheet **ADXL251**

FEATURES

User selectable sensor *g* ranges: ±60 *g*, ±120 *g*, ±240 *g*, ±480 *g*
Dual x-axis and y-axis sensor
Compliant to PSI5 Version 2.1 airbag substandard
- **Synchronous operation**
  - **PSI5-P10P-500/3L and others**
- **Daisy-chain operation with bidirectional communication**

Application level serial peripheral interface (SPI) communication
Selectable 16-bit or 10-bit sensor data
Independently programmable *g* range and time slot for each axis
Independent fault discrimination for each axis
Fully differential analog signal chain
0.25 µs data interpolation routine
User selectable, continuous auto-zero operation
High resistance to electromagnetic interference (EMI) and radio frequency interference (RFI)
SPI mode supply voltage: 3.3 V and 5 V, +5%
PSI5 mode supply voltage range: 4.5 V to 11.0 V
Qualified for automotive applications

APPLICATIONS

Front impact crash sensing
Side impact crash sensing

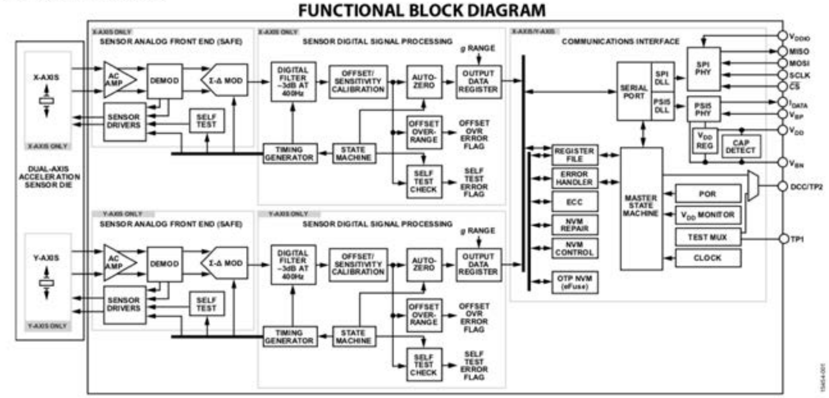
GENERAL DESCRIPTION

The ADXL251 is a dual-axis, integrated satellite sensor with user selectable *g* ranges, compliant to the PSI5 Version 2.1 airbag substandard, and backwards compliant to PSI5 Version 1.3. The ADXL251 (x-axis/y-axis) enables low cost solutions for front impact and side impact airbags, as well as satellite sensor and electronic control unit (ECU) main sensor applications. Acceleration data is sent to the control module via a digital, 2-wire current loop PSI5 bus. Communication via the SPI bus is also available for ECU applications.

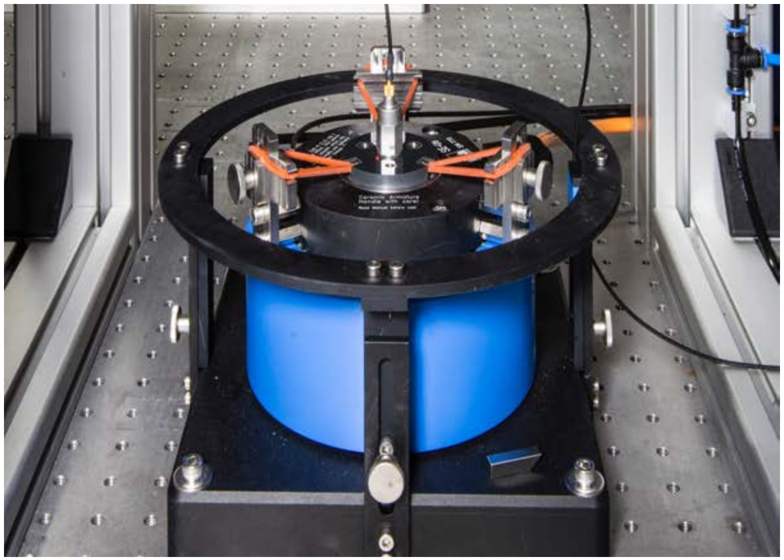
The device uses an ECC protected one time programmable (OTP) memory. The sensor *g* range is configurable to provide full-scale measurement of ±60 *g*, ±120 *g*, ±240 *g*, or ±480 *g* acceleration. The user can program each axis independently with multiple *g* ranges in different time slots. In PSI5 mode, there are four programmable time slots available. The device transmits 16-bit or 10-bit acceleration data to the control module, and can be configured to include either a 1-bit parity check, or a 3-bit cyclic redundancy check (CRC).

The ADXL251 is available in a 4 mm × 4 mm LFCSP package and is specified to operate over the full automotive temperature range, −40°C to +125°C.

FUNCTIONAL BLOCK DIAGRAM



Future Scan: Inertial



Air Bearing Shaker for Vibration Calibration of Reference Accelerometers

Calibration of MEMS Inertial Measurement Unite (IMUs)

Future Scan: Digitization/Inertial

Why should we feel a sense of urgency?

- Inertial Measurement Units are manufactured in the billions per year.
- Most of their applications do not (presently) have life and limb at stake.
- “Nobody is coming to ask us for inertial calibrations.”
- Change is coming: Devices are steadily increasing in performance, new technologies are developing (optical based), and new applications are on the horizon.
- Example: Autonomous vehicles – “IMUs are the heart of the vehicle.”
- Life and limb will be at stake in these new applications and the accuracy of the devices will require calibrations with low uncertainty.

Future Scan: Digitization/Inertial

Considerations by CCAUV regarding pilot studies or new key comparisons to address this include:

- A digital-based standard reference transducer, preferably one that is commercially available and not subject to international restrictions that would inhibit comparisons between countries.
- The development of a standard testing protocol, preferably through ISO, and its adoption by a sufficient number of NMIs
- For gravity-based measurements, the inclusion of an uncertainty due to the gravitational acceleration as taught in ISO 16063-16 and/or the development of CMCs for local gravitational acceleration at the NMIs.

Key Comparisons: Airborne Sound

Sub-area/ Reference No.	**Description**	**Rationale**	**How far the light shines**	**Expected start**
Airborne sound	Comparison of Laboratory Standard Microphones type LS2	Repeat of CCAUV.A-K4	Free-field sensitivity in the frequency range 1 kHz to 30 kHz	2020
Airborne sound	Comparison of Laboratory Standard Microphones type LS1	Repeat of CCAUV.A-K5	Pressure sensitivity in the frequency range 2 Hz to 20 kHz	2022
Airborne sound	Comparison of Working Standard Microphones type WS3 (Pilot study)	Extension of the frequency range up to 150 kHz	Free-field sensitivity in the frequency range 10 kHz to 150 kHz	2020
Airborne sound	Comparison of Laboratory Standard Microphones type LS1/LS2 (pilot study)	Calibration in a diffuse field	Diffuse-field sensitivity in the frequency range 2 Hz to 20 kHz	2020
Airborne sound	Calibration of LS1/LS2/WS3 microphones (pilot study)	Calibration using optical techniques	Pressure and free-field sensitivity in the combined frequency range 1 Hz to 200 kHz	2022

Key Comparisons: Ultrasound

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Ultrasound	Ultrasonic power	Repeat of CCAUV.U-K3	Transducer electro-acoustic radiation conductance and transducer ultrasonic output power, 0.01 W – 15 W*	2023
Ultrasound	Comparison of reference hydrophone calibrations	Repeat of CCAUV.U-K4	End-of-cable loaded hydrophone sensitivity, in nV/Pa, over the frequency range 0.5 MHz – 20 MHz*	2024

Key Comparisons: Underwater Acoustics

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Underwater Acoustics	Comparison of pressure calibration of hydrophones	Extension of CCAUV.W-K2 to low frequencies	Free-field hydrophone sensitivity in V/Pa over the frequency range 20 Hz to 1 kHz	2020
Underwater Acoustics	Comparison of free-field calibrations vector sensors (pilot study)	Comparison of particle velocity standards	Free-field sensitivity in $Vm^{-1}s$ over the frequency range 20 Hz to 10 kHz	2022
Underwater Acoustics	Comparison of free-field calibrations of hydrophones	Repeat of CCAUV.W-K2	Free-field hydrophone sensitivity in V/Pa over the frequency range ~250 Hz to 2 MHz	2025
Underwater Acoustics	Comparison of pressure calibration of hydrophones	Extension of CCAUV.W-K2 to low frequencies	Hydrophone pressure sensitivity in V/Pa over the frequency range 2 Hz to 1 kHz	2026

Key Comparisons: Sinusoidal Acceleration

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Sine-excitation	Comparison of primary calibration in magnitude and phase	Coverage of traditional calibration services in acceleration CCAUV.V-K3	0.1 Hz to 40 Hz This will be a regular KC to be repeated in 10 y intervals	2025
Sine-excitation	Comparison of primary calibration of magnitude and phase	Coverage of traditional calibration services in acceleration CCAUV.V-K5	10 Hz to 20 kHz This will be a regular KC to be repeated in 10 y intervals	2027
Angular vibration	Primary calibration of magnitude	Increasing number of NMIs with the capability and demand for CMCs	Depending on the global demand this may become a regular KC	2022

Key Comparisons: Shock

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Shock excitation	Primary calibration according to ISO 16063-13 (peak ratio)	Increasing number of NMIs with the capability and demand for CMCs CCAUV.V-K4	500 m/s^2 to 5000 m/s^2 This will ultimately be a regular KC to be repeated in a 10-year interval.	2026
Shock excitation	High intensity (up to 100 km/s^2) primary calibration according to ISO16063-43 (pilot study)	The parameter identification is needed for broad band excitation calibration	A pilot study is needed to ensure the applicability of the parameter identification for KC. This will enable subsequent KCs.	2022

SPWG Recommendations

- CCAUV should hold discussion at the general meeting to identify pilot laboratories for Key Comparisons that are currently listed as TBD or TBC in this report

- CCAUV should form a liaison relationship with the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), similar to its relationships with ISO, IEC, IMEKO.

- CCAUV should consult with other CCs to examine the use of g_n, the physical constant for the standard acceleration of gravity defined in CODATA, expressing concern of its expanding use over the SI unit for acceleration (m/s^2).

Thank You!