

ANEXO D: CARTAS DE CALIBRACIÓN
Cartas de calibración de los acelerómetros
usados.

PRODUCT DATA

DeltaTron® Accelerometers
— Types 4513, 4513-001, 4513-002, 4513-B, 4513-B-001 and 4513-B-002

The wide frequency range, low noise-to-signal ratio and choice of sensitivity from 1 to 50 mV/ms² (10 to 500 mV/g) means the Type 4513 range of accelerometers covers a wide range of measurement applications and can be used in a variety of environmental conditions.

FEATURES

- Insulated base
- Hermetically sealed
- High resolution
- Low noise
- Low-impedance output
- TEDS – 'B' types only

Description

The Type 4513 accelerometer family are piezoelectric Shear accelerometers with integral electronics. The transducers feature a 10–32 UNF side connector, an insulated base and are hermetically sealed. The transducers have a high resolution, giving an excellent signal-to-noise ratio. They can be mounted by means of a 10–32 UNF threaded stud, or adhesively mounted.

Characteristics

The piezoelectric accelerometers feature built-in preamplifiers. The sensitivity is expressed in terms of voltage per unit acceleration (mV/g).

In the Shear design, the piezoelectric element undergoes shear deformation as in the DeltaShear® design. Two rectangular slices of piezoelectric material are arranged on opposite sides of a rectangular centre post. This design gives a high degree of linearity, and excellent immunity to base bending and temperature fluctuations. The signal is collected and amplified in the built-in amplifier. The housing material is titanium.

TEDS Versions ('B' Types)

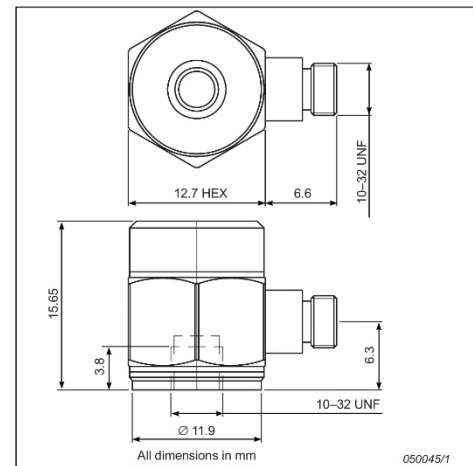
The 'B' version of each Type 4513 includes Transducer Electronic Datasheet (TEDS), containing sensor specific and application specific information, including frequency and phase response compensation. The 'B' versions are in all other aspects identical to the 'non-B' versions. The



TEDS device will survive the temperature range of the accelerometer and operate in the temperature range from –40°C to +85°C.

Calibration

The transducers are individually calibrated using state-of-the-art random FFT technology, providing an 800-point high-resolution calibration (magnitude and phase), ultimately giving a unique characterisation and securing the integrity of the vibration measurement. The sensitivity given on the calibration chart has been measured at 159.2 Hz with a 95% confidence level, using a coverage factor $k = 2$.



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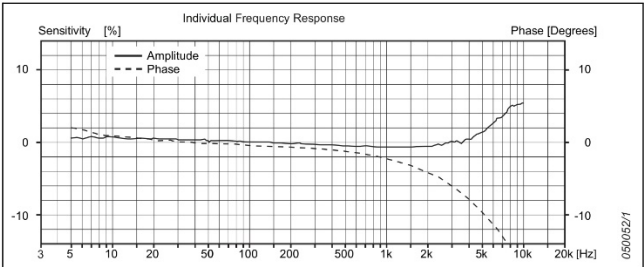
Fig. D-1

Specifications – General Purpose DeltaTron Accelerometers
Types 4513(-B), 4513(-B)-001 and 4513(-B)-002

	Units	4513/ 4513-B	4513-001/ 4513-B-001	4513-002/ 4513-B-002
Dynamic Characteristics				
Voltage Sensitivity (@ 160 Hz)	mV/ms ⁻² (mV/g)	1 +12/-8% (10 ±10%)	10 +12/-8% (100 ±10%)	50 +12/-8% (500 ±10%)
Measuring Range (±pk)	ms ⁻² (g)	4900 (500)	490 (50)	98 (10)
Frequency Response		See typical amplitude response		
Mounted Resonance Frequency	kHz	32		
Amplitude Response ±10% (typical) ^a	Hz	1 to 10000		
Residual Noise	mg	0.8	0.2	0.1
Transverse Sensitivity	%	<5		
Electrical Characteristics				
Output Impedance (typical)	Ω	20	100	200
DC Output At room temperature	V	12 ± 1		
Bias Voltage In specified temperature range	V	8 to 16		
Power Supply	mA	2 to 20		
Start-up Time	s	1	1	3
Grounding		Insulated base		
Environmental Characteristics				
Temperature Range	°C (°F)	-51 to +121 (-60 to +250)	-51 to +100 (-60 to +212)	-51 to +100 (-60 to +212)
Humidity		Hermetically sealed		
Max. Operational Shock (peak)	g pk	5000		
Base Strain Sensitivity	Equiv. g/μ strain	0.003		
Thermal Transient Sensitivity	Equiv. %/°C (%/°F)	0.24 (0.13)		
Thermal Shock Sensitivity	g/°C	0.04		
Physical Characteristics				
Dimensions		See outline drawing		
Weight	gram (oz.)	8.6 (0.3)		
Case Material		Titanium		
Connector		10-32 UNF		
Mounting		10-32 UNF threaded hole		
Mounting Torque	Nm (lb.in.)	1.7 (15)		

a. Individual frequency response calibration up to 10 kHz

All values are typical at 25°C (77°F) unless measurement uncertainty is specified.



TRADEMARKS

Teflon is a registered trademark of E.I. du Pont de Nemours and Company.

Brüel & Kjær reserves the right to change specifications and accessories without notice

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Local representatives and service organisations worldwide

COMPLIANCE WITH STANDARDS

CE Compliance with EMC Directive and Low Voltage Directive of the EU



Compliance with the EMC requirements of Australia and New Zealand

Ordering Information

Types 4513(-B), 4513(-B)-001 and 4513(-B)-002 include the following accessories:

- Carrying box
- Calibration chart
- 10-32 UNF Beryllium mounting stud, length 6.7 mm (0.26")
- 'B' versions include TEDS

OPTIONAL ACCESSORIES*

- AO-0038-D-012: Teflon® super low-noise cable, 10-32 UNF to 10-32 UNF connector 250°C (482°F), length 1.2 m (4 ft)
- AO-0531-D-050: PVC insulated flexible cable, 10-32 UNF to BNC connector 70°C (158°F), 5 m (17 ft)
- JP-0145: Plug adaptor, BNC/10-32 UNF
- UA-0186: Extension connector for 10-32 UNF cables, set of 25
- QS-0007: Tube of cyanoacrylate adhesive
- YJ-0216: Beeswax for mounting
- DB-0544: 10-32 UNF Round tip
- QA-0029: Tap for 10-32 UNF thread
- UA-0866: Cement stud 10-32 UNF 0.14 mm (0.005") (set of 25)
- UA-2064: 10-32 UNF threaded steel stud with flange, length 5.3 mm (0.2"), set of 10
- UA-2063: 10-32 UNF threaded steel studs, length 7.5 mm (0.3"), set of 10

SERVICE

- 4513-CAF: IEPE Accelerometer, Accredited Calibration
- 4513-CAI: IEPE Accelerometer, Accredited Calibration Performed as initial
- 4513-CTF: IEPE Accelerometer, Traceable Calibration
- 4513-CTI: IEPE Accelerometer, Traceable Calibration Performed as initial
- 4513-EW1: IEPE Accelerometer, Extended Warranty, one year extension

* Additional accessories and cables are available (see www.bksv.com)

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Fig. D-2

PRODUCT DATA

Piezoelectric Accelerometer Types 4507 and 4508

Accelerometer families that include both CCLD and charge variants

This family of small ThetaShear accelerometers is perfect for structural analysis applications. Each accelerometer has a lightweight titanium housing with an integrated 10–32 UNF coaxial connector, which is located on either the top (Type 4508 family) or the side (Type 4507 family). Types 4507 and 4508 are available in charge or CCLD versions, and CCLD variants are equipped with TEDS (transducer electronic datasheet).*

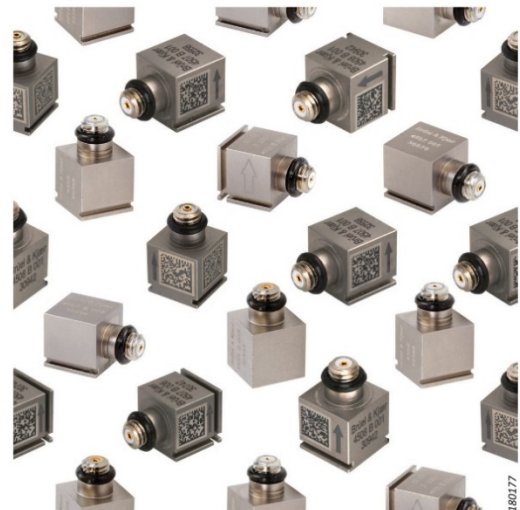
CCLD variants have an engraved data matrix code for use with the Brüel & Kjær app for multichannel test set up: Transducer Smart Setup.

CCLD accelerometers offer the following advantages:

- Connect directly to power supply
- Use inexpensive cables
- Use long cables
- >100 dB dynamic range
- Sensitivities from 10 mV/g to 1 V/g
- Hermetic connector

Charge accelerometers offer the following advantages:

- Sensitivity of 5 pC/g
- Operating temperature up to 250 °C (482 °F)



Uses and Features

Uses

- Structural analysis measurements
- Multichannel measurements
- General purpose

Features

- Titanium housing
- Integrated titanium connector with hermetic sealing
- Excellent low-frequency response
- Low sensitivity to RF (radio frequency) electromagnetic fields
- Low magnetic sensitivity
- ThetaShear design providing:
 - High sensitivity-to-weight ratio
 - Low sensitivity to environmental factors
- Mounting clips (for most variants)
- Triaxial mounting facility
- Engraved data matrix codes (on CCLD variants with TEDS only)

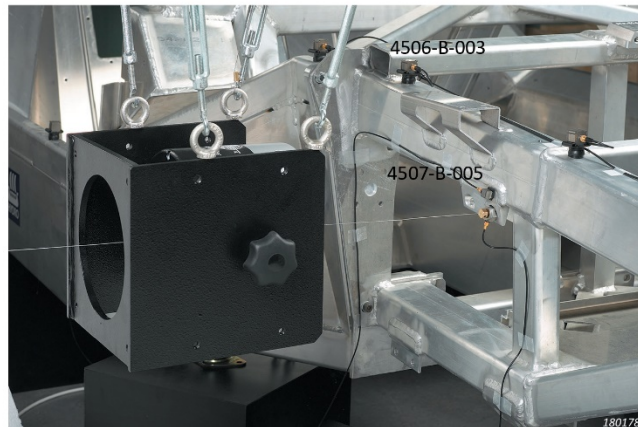
* CCLD: Constant current line drive, also known as DeltaTron® (ICP® and IEPE compatible)

Description

Applications

These accelerometers are specifically designed to withstand rough environments. A combination of high sensitivity, low mass and small physical dimensions makes them ideal for modal analysis on large, composite structures that require multiple measurement points, such as ground vehicles, aircraft and satellites. The accelerometers are easy to handle, reliable, and rugged enough for use in a wide range of environments. They can be calibrated quickly, and they have a low sensitivity to temperature transients, which is advantageous when it comes to making measurements at low frequencies.

Fig. 1
Test setup for modal analysis. Note the size of Type 4507-B-005 as compared to Type 4506-B-003

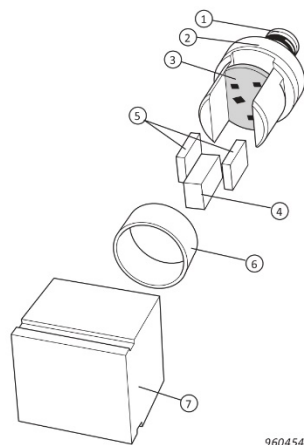


Environmental Sensitivity

Some of the most troublesome environmental factors encountered when using piezoelectric accelerometers are temperature transients. However, by careful choice of materials, mechanical design and the shear concept, the influence of these factors has been reduced to a minimum. Special effort has also been made to minimize interference from RF electromagnetic fields.

High humidity is another environmental factor that can influence the accuracy of piezoelectric transducers. Careful design and manufacturing have reduced this effect to a minimum for the Type 4507 and 4508 families. Furthermore, all CCLD variants are equipped with hermetically sealed (glass) connectors, that make them completely independent of humidity and aggressive gases.

Fig. 2
Exploded view of Type 4508-B showing the ThetaShear design and built-in CCLD preamplifier:
(1) 10–32 UNF connector
(2) Top
(3) Preamplifier
(4) Seismic mass
(5) Piezoelectric plates
(6) Clamping ring
(7) Titanium housing



ThetaShear Design

The connector is an integrated part of the accelerometer, as is the preamplifier (CCLD variants only). A slotted cylindrical stanchion holds the central seismic mass which is flanked by two piezoelectric plates and the assembly is clamped rigidly by a ring. The parts are firmly held together without the use of any bonding agent other than friction, a principle that has proved extremely reliable in Brüel & Kjær DeltaShear™ accelerometers. The entire assembly is hermetically welded to the titanium housing.

Data Matrix Codes

Data matrix codes are engraved on CCLD variants with TEDS. The codes contain information about the transducer and its orientation, and provide access to product documentation. The codes can be used with Transducer Smart Setup, a free app for iOS devices that simplifies setting up tests with multiple channels. You can read more about Transducer Smart Setup on bksv.com/smartxdsetup.

Specifications – CCLD Accelerometer Type 4508 Family (top connector)

Type Number			4508-B	4508-B-003	4508-B-001	4508-B-002	4508-B-004
General							
Weight	gram		4.8	4.9	4.8	4.8	4.8
	oz		0.17		0.17	0.17	0.17
Voltage Sensitivity (at 159.2 Hz, 4 mA supply current)	mV/ms ⁻²		10 ± 5%		1 ± 5%	100 ± 10%	50 ± 5%
	mV/g		98 ± 5%		9.8 ± 5%	980 ± 10%	490 ± 5%
Amplitude (±10%)			0.3 to 8000		0.1 to 8000	0.4 to 8000	0.2 to 8000
Frequency Range	Phase (±5°)	Hz	2 to 5000		0.5 to 5000	2 to 5000	1 to 5000
Mounted Resonance Frequency		kHz	25		25	25	25
Max. Transverse Sensitivity (at 30 Hz, 100 ms ⁻²)		%	<5		<5	<5	<5
Transverse Resonance Frequency		kHz	>18		>18	>18	>18
Max Operational Continuous Sinusoidal Acceleration (± peak)	kms ⁻²		0.7		7	0.07	0.15
	g		70	71	700	7	14
TEDS / Data Matrix Code			Yes		Yes	Yes	Yes
Electrical							
Bias Voltage (at full temp. and curr. range)		V	13 ± 1		13 ± 1	13 ± 2	13 ± 2
Power Supply	Constant current	mA	2 to 20		2 to 20	2 to 20	2 to 20
	Unloaded supply voltage	V	24 to 30*		24 to 30*	24 to 30*	24 to 30*
Output Impedance		Ω	30		30	30	30
Start-up time (to final bias ±10%)		s	<5		<50	<5	<5
Residual Noise (inherent rms broadband noise in the specified frequency range)		μV	<35		<8	<150	<80
		μg	<350		<800	<150	<160
Noise (spectral)	10 Hz	mms ⁻² /√Hz (μg/√Hz)	0.15 (15)		0.25 (25)	0.08 (8)	0.08 (8)
	100 Hz		0.035 (3.5)		0.06 (6)	0.02 (2)	0.02 (2)
	1000 Hz		0.02 (2)		0.035 (3.5)	0.01 (1)	0.01 (1)
Environmental							
Operating Temperature Range		°C	-54 to +121		-54 to +121	-54 to +100	-54 to +100
		°F	-65 to +250		-65 to +250	-65 to +212	-65 to +212
Temperature Coefficient of Sensitivity		%/°C	0.06		0.06	0.12	0.12
Temperature Transient Sensitivity (3 Hz Lower Limiting Freq. (-3 dB, 6 dB/octave))		ms ⁻² /°C	0.3		0.3	0.3	0.3
		g/°F	0.0165		0.0165	0.0165	0.0165
Magnetic Sensitivity (50 Hz, 0.038 T)		ms ⁻² /T	3		3	3	3
		g/kG	0.03		0.03	0.03	0.03
Base Strain Sensitivity (at 250 με in base plane)		ms ⁻² /με	0.005 [†]		0.005 [†]	0.005 [†]	0.005 [†]
		g/με	0.0005 [†]		0.0005 [†]	0.0005 [†]	0.0005 [†]
Max. Non-destructive Shock (± peak)		kms ⁻²	50		50	50	50
		g	5000		5000	5000	5000
Mechanical							
Case Material			Titanium ASTM Grade 2				
Piezoelectric Sensing Element			PZ 23		PZ 23	PZ 27	PZ 27
Construction			ThetaShear				
Sealing			Hermetic				
Electrical Connector			Top, 10-32 UNF-2A				
Mounting Slots (pairs)			1	0	1	1	1
Dimensions (excluding connector)		mm (in)	10 × 10 × 10 (0.4 × 0.4 × 0.4)				

* Min. +18 V DC (reduced measuring range)

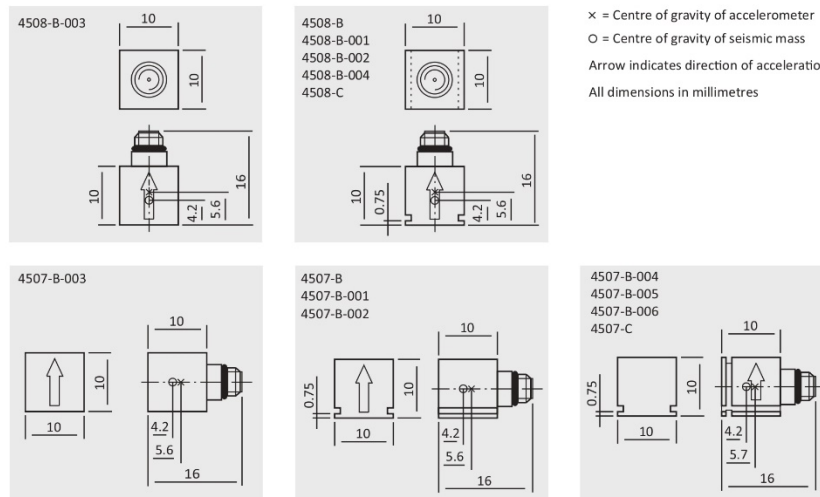
† Mounted on adhesive tape 0.09 mm thick

Note: All values are typical at 25 °C (77 °F), unless measurement uncertainty is specified. All uncertainty values are specified at 2σ, that is, expanded uncertainty using a coverage factor of 2

Polarity: Positive (for an acceleration in the direction of the engraved arrows)

Dimensions

Fig. 10 Dimensions of the variants, grouped by dimensions and arranged by family (**top**: Type 4508 family, **bottom**: Type 4507 family) and mounting slots (**left**: no mounting slots, **middle**: one pair of mounting slots, **right**: three pairs of mounting slots)



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Compliance with Standards

	<p>The CE marking is the manufacturer's declaration that the product meets the requirements of the applicable EU directives</p> <p>RCM mark indicates compliance with applicable ACMA technical standards – that is, for telecommunications, radio communications, EMC and EME</p> <p>China RoHS mark indicates compliance with administrative measures on the control of pollution caused by electronic information products according to the Ministry of Information Industries of the People's Republic of China</p> <p>WEEE mark indicates compliance with the EU WEEE Directive</p>
Safety	<p>EN/IEC 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use</p> <p>ANSI/UL 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use</p>
EMC Emission	<p>EN/IEC 61000–6–3: Generic emission standard for residential, commercial and light industrial environments</p> <p>EN/IEC 61000–6–4: Generic emission standard for industrial environments</p> <p>CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits</p> <p>FCC Rules, Part 15: Complies with the limits for a Class B digital device</p> <p>This ISM device complies with Canadian ICES–001 (standard for interference-causing equipment)</p>
EMC Immunity	<p>EN/IEC 61000–6–1: Generic standards – Immunity for residential, commercial and light industrial environments</p> <p>EN/IEC 61000–6–2: Generic standards – Immunity for industrial environments</p> <p>EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements</p> <p>Note: The above is only guaranteed using accessories listed in this document</p> <p>Types 4507-B, 4507-B-003, 4507-B-004, 4508-B and 4508-B-003: <60 mV</p> <p>Types 4507-B-001 and 4508-B-001: <10 mV</p> <p>Types 4507-B-002, 4507-B-005, 4507-B-006, 4508-B-002 and 4508-B-004: <100 mV</p>
Temperature	<p>IEC 60068–2–1 & IEC 60068–2–2: Environmental Testing. Cold and Dry Heat</p> <p>Operating Temperature:</p> <ul style="list-style-type: none"> Types 4507-B, 4507-B-001, 4507-B-003, 4507-B-004, 4508-B, 4508-B-001 and 4508-B-003: –54 to +121 °C (–65 to +250 °F) Types 4507-B-002, 4507-B-005, 4507-B-006, 4508-B-002 and 4508-B-004: –54 to +100 °C (–65 to +212 °F) Types 4507-C and 4508-C: –74 to +250 °C (–101 to +482 °F)
Mechanical	<p>Non-operating:</p> <p>IEC 60068–2–6: Vibration: 0.3 mm, 20 m/s², 10 – 500 Hz</p> <p>IEC 60068–2–27: Shock: 1000 m/s²</p> <p>IEC 60068–2–29: Bump: 1000 bumps at 250 m/s²</p>

Ordering Information

Type 4507 Family Accelerometers with side connector
Type 4508 Family Accelerometers with top connector

Each accelerometer includes the following accessories:

- Carrying box
- Individual calibration chart
- One mounting clip[†]

Order Number	TEDS	Mounting Slot Pairs	Sensitivity	
Type 4507-B-001	Yes	1	1 mV/ms ⁻²	CCLD
Type 4508-B-001				
Type 4507-B-003	Yes	0	10 mV/ms ⁻²	
Type 4508-B-003				
Type 4507-B	Yes	1		
Type 4508-B				
Type 4507-B-004	Yes	3		
Type 4507-B-006	Yes	3	50 mV/ms ⁻²	
Type 4508-B-004				
Type 4507-B-002	Yes	1	100 mV/ms ⁻²	
Type 4508-B-002				
Type 4507-B-005	Yes	3		

Type 4507-C	No	3	0.45 pC/ms ⁻²	Charge
Type 4508-C		1		

Brüel & Kjær Accessories

CABLES – CCLD ACCELEROMETERS

Please specify cable length when ordering.[†]

AO-0038	Super low-noise, single-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F)
AO-0122	Super low-noise, double-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F)
AO-0406	Low-noise double-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F), includes Adapter JP-0145
AO-0463	Flexible, single-screened cable with 10–32 UNF connectors (M), –20 to +80 °C (–4 to +176 °F)
AO-0531	Flexible cable with 10–32 UNF (M) to BNC (M) connectors, –20 to +80 °C (–4 to +176 °F)
AO-1382	Low-noise, double-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F)
AO-1419	Low-noise, single-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F)

* Types 4507-B-003 and 4508-B-003 do not include a mounting clip because the accelerometers do not have mounting slots

[†] Example: AO-0038-x-yyy
x = D (decimetres) or M (metres)
yyy = length in decimetres or metres

CABLES – CHARGE ACCELEROMETERS

Please specify cable length when ordering.[†]

AO-0038	Super low-noise, single-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F)
AO-0122	Super low-noise, double-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F)
AO-0406	Low-noise, double-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F), includes Adapter JP-0145
AO-1382	Low-noise, double-screened cable with 10–32 UNF connectors (M), max. 250 °C (482 °F)

CABLING ACCESSORIES

UA-1243	Cable markers for cables with 1.6 mm (0.06 in) cable jacket diameter, 3 × 30 pieces marked with 1, 2 or 3 (use with AO-0406 and AO-1382)
UA-1244	Cable markers for cables with 1.9 to 2.2 mm (0.07 to 0.09 in) cable jacket diameter, 3 × 30 pieces in red, green or yellow (use with AO-0038, AO-0463 and AO-0531)
JP-0192	Solder connector adapter
JP-0145	Adapter, 10–32 UNF (F) to BNC (M)

MOUNTING

QS-0007	Cyanoacrylate adhesive
UA-1407	Mounting clip, set of 100
UA-1418	Dummy accelerometers for mass loading, set of 25
UA-1475	Mounting clip with thick base, set of 100
UA-1478	Mounting clip with swivel base, set of 100
UA-1564	Mounting clip for high-temperatures, set of 5
YJ-0216	Mounting wax

CONDITIONING AND DATA ACQUISITION

Type 2647	Charge to CCLD Converter
UA-2105-060	LAN-XI Front Panel for Input Module
	Type 3050-060, 6 slots for Type 2647
Type 3050-A-060	LAN-XI Module, 6 input channels, 51.2 kHz, includes LAN-XI Front Panel UA-2100-060 (BNC)
WB-1372	CCLD Signal Conditioner

CALIBRATION

DV-0459	Mounting clip for calibration
Type 4294	Vibration Exciter

Brüel & Kjær Services

CALIBRATION SERVICES

ACC-M-CAF	Accredited calibration
ACC-M-CAI	Accredited initial calibration
ACC-M-CFF	Factory standard calibration
ACC-M-CTF	Traceable calibration

Fig. D-7