



KIRBY MISPERTON A WELLSITE

KM8 PRODUCTION WELL

SURFACE SEISMOMETER SPECIFICATION



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Executive Summary

The surface seismic monitoring equipment deployed is a Nanometrics Compact Post-hole seismometer (sensor) coupled with a Nanometrics Centaur Data logger. There are a total of 12 units deployed in the area around the KMA wellsite. The specification for the equipment used is detailed in appendix 1 and 2 and includes equipment details, manufacturer and accuracy..

The equipment was tested using an in-built self-calibration feature. This ensures that the sensors are within tolerance having survived shipping from the factory and burial under the ground in North Yorkshire. The result of these calibrations is shown in appendix 3.

Appendix 1 – Nanometrics Centaur Specification

The **best** digital recorder on the market
just got **better**

Centaur

A truly modern digital recorder that meets
today's field deployment challenges



**Whether your
deployment is portable
or permanent, stand-
alone or networked,
the choice of digital
recorder has never
been easier.**

You'll get the reliability and exceptional performance you've come to expect from our popular Centaur digital recorder, now with expandable memory and even lower power requirements. Available in both 3- and 6-channel versions, as well as with a high-gain option, the Centaur is ideal for multidisciplinary science involving mixed sensor applications.

High performance, simplified

The 3-channel version requires less than 1 watt with telemetry. And the onboard 8GB memory is expandable up to 64GB by adding an internal SD card.

Reliability

- Redundant, fail-safe data archive with field swap capability
- Rugged, waterproof field enclosure for harsh environments, rated for continuous submersion (IP68)
- Excellent protection for ESD & lightning

Exceptional performance

- True 24-bit performance available in 3- or 6-channel configurations
- Sample rates of up to 5000 sps to support high-frequency applications
- Full digitizer/sensor response files generated on-demand
- Fully configurable digital filtering

Onboard data processing

- Advanced bandpassed triggering
- Derived data products including PGA, PGV and PGD
- Acquisition and data management of high-precision GPS data (BINEX) and other data formats



Centaur

SPECIFICATIONS

Specifications subject to change without notice

SENSOR INPUTS

Channels	Available with 3 or 6 channel inputs
Sampling	Simultaneous on all 3 or 6 channels
Resolution	24 bits per channel, full 24-bit range to clip level
Input Impedance	40kΩ (standard digitizer) 1.8MΩ (high-gain digitizer)
Input voltage range (peak-to-peak)	40V, 20V, 10V, 4V, 2V, 1V (standard) 10V, 5V, 2.5V, 1V, 0.5V, 0.25V (high-gain)

SENSOR COMPATABILITY

Sensor Types	Broadband active and short period passive seismometers and geophones
Control Lines	6 per connector – typically used for Cal enable, mass centre, mass lock/unlock, XYZ/UVW select
Sensor Power	Supply power pass-through to sensor (9-36VDC, 1A) Over-current and surge protected
Auto Mass Centering	Configurable thresholds, intervals, retries
Serial Interface	Supports digital management of Nanometrics sensors

DIGITIZER PERFORMANCE

Type	True 24-bit ADC per channel
Preamp Gain	Standard: 1x, 2x, 4x, 10x, 20x, 40x High Gain: 4x, 8x, 16x, 40x, 80x, 160x
Sample Rates	1, 2, 5, 10, 20, 40, 50, 80, 100, 125, 200, 250, 500, 1000, 2000, 5000sps
Dual Sample Rates	A second sample rate can be selected from the sample rates above
Anti-Alias Filters	Attenuation: 140dB at output Nyquist, 0dB at 80% Nyquist frequency
Digital Filters	User-configurable low-pass and high-pass 1st to 5th order, 0.1 mHz to Nyquist Different filters may be configured for primary and secondary sample rates and Sensor A and B
Accuracy	Nominal gain accuracy within ±0.5%
Dynamic Range	142dB @ 100sps, 135dB @ 500sps (full-scale peak to RMS shorted-input noise)

CALIBRATION

Signal Source	16-bit DAC with 30ksps output
Attenuator Selectable	1x, 10x, 100x, 1000x attenuation
Waveforms	Playback standard .wav files Step and sine provided Users can upload custom waveforms

RECORDING (CONTINUOUS)

Formats	MiniSEED
Internal Memory	8 GB flash memory (32 or 64 GB options available)
Removable Media	SD Card up to 64 GB

RECORDING (EVENTS)

Triggers	Bandpassed STA/LTA, Threshold
Captured Data	MiniSEED, ASCII
Data Products	Peak Ground Motion (i.e PGA, PGV, PGD) statistics calculated on the instrument

STATE-OF-HEALTH INPUTS

Channels	3 singled-ended inputs, ±5V range, 50KΩ input impedance
Sampling Interval	Configurable from 60 to 3600 seconds
Accuracy	18 bits effective resolution

DATA RETRIEVAL

File Transfer	Via Ethernet, optional WiFi or Ethernet-connected DSL, VSAT, cellular, radio
Media Exchange	SD card field-swappable during continuous recording with no loss of data

DATA STREAMING

Continuous	Seismic data and State-of-Health data
Formats	SeedLink, Nanometrics NP
Events	Triggered event data: email, secure file transfer, other options available

TIMING

Timing System	Internal DCX0 clock disciplined to GPS or external NTP or PTP (Precision Time Protocol) source [Can also act as a PTP master]
Timing Accuracy	<5µsec (GPS Always on) <100µsec (GPS duty cycled)
GPS Receiver	Internal 14-channel receiver
GPS Power	Selectable: Always on or Duty Cycled

COMMUNICATIONS

Web-based UI	Supports standard PC, tablet and mobile devices
Interfaces	10/100 Base-T Ethernet, WiFi (optional), Serial via USB
IP Addressing	Static, dynamic (DHCP) or link-local IP
Protocols	UDP/IP unicast/multicast, HTTP data streaming

LOCAL USER INTERFACE

Removable Media	SD card protected in waterproof media bay
External LEDs	System status, Ethernet link, Time quality, Media card status, Sensor A & B
Buttons	WiFi wakeup, media eject, system shutdown

POWER

Power Supply	9-36VDC isolated input
Protection	Electronic resettable fuse design, lightning surge, reverse battery and short circuit protection
Battery Manager	User-configurable low voltage shutdown and restart thresholds

POWER USAGE (GPS DUTY CYCLED)

3 chan. (standard)	810 mW, 960 mW with 10 Base-T Ethernet
6 chan. (standard)	1.2W, 1.35 W with 10 Base-T Ethernet
High Gain	Add 0.2W for every 3 high-gain channels

CONNECTORS

Sensor	26-pin Mil. circular, shell size 16, female
Power	3-pin Mil. circular, shell size 8, male
Ethernet	Watertight RJ-45
USB	2.0 Type A receptacle behind media bay door
GPS Antenna	TNC (female) with 3.3V supply for active antenna
State-of-Health	4-pin Mil. circular, shell size 8, female

PHYSICAL CHARACTERISTICS

Housing	Aluminum
Weather Resistance	Rated to IP-68 with connectors mated
Humidity	0 to 100%
Operating Temperature	-20°C to +60°C (Ultra-low temperature option available. Please contact Nanometrics.)
Storage Temperature	-40°C to +70°C
Weight	1.9kg (3-channel), 2.0kg (6-channel)
Size	196 mm (L) x 137 mm (W) x 88 mm (H)

Appendix 2 – Nanometrics Trillium Compact PH Specification

Nanometrics' industry-leading portfolio of **Trillium** seismometers now includes a **Trillium Compact Posthole** for quick and easy deployment



Trillium COMPACT PH

Compact Posthole Seismometer



Don't let your seismometer limit you

The Trillium Compact Posthole is a small, ruggedized, waterproof member of the industry-leading family of Trillium seismometers.

Forget complex deployments

At just 3.3kgs (or just over 7lbs) and with the installation convenience comparable to a geophone, the Trillium Compact PH is the obvious choice for those who don't want their experiments to be limited – by a complex deployment of bulky instrumentation, by the overburden, by the effects of moisture, by thermal instability, by high power consumption or by installation technique.

No vault required

Its corrosion, scratch and chip-resistant stainless steel enclosure, waterproof connector and rating to IP68 for full submersion in water makes the Trillium Compact PH ideal for direct burial, even in arid, polar or wet environments.

Ultra-low power consumption

Both variants of the Trillium Compact PH – the 120s and 20s – boast ultra-low power consumption, at <180mW and <195mW respectively. And its optional transport case doubles as a thermal insulating cover for surface deployments.

The Trillium Compact PH is rugged enough to be buried directly in an ice shelf, light enough for easy portability on a volcano, and intuitive enough to be deployed in minutes. Because no one wants to be limited by their seismometer.



Trillium COMPACT PH

SPECIFICATIONS

Specifications subject to change without notice.

TECHNOLOGY

Topology	Symmetric triaxial
Feedback	Force balance with capacitive transducer
Mass Centering	Not required

PERFORMANCE

Sensitivity/120s	750V-s/m nominal $\pm 0.5\%$ precision
Bandwidth/120s	-3dB points at 120s and 100Hz
Sensitivity/20s	750V-s/m nominal $\pm 0.5\%$ precision
Bandwidth/20s	-3dB points at 20s and 100Hz
Off-axis Sensitivity	$\pm 0.5\%$
Transfer Function	Lower corner pole frequency within $\pm 0.5\%$ of nominal provided High-frequency poles within 1db of nominal up to 45Hz No peak in response at high frequency
Clip Level	26 mm/s from 0.1 Hz to 10 Hz
Oper. Tilt Range/120 s	$\pm 2.5^\circ$
Oper. Tilt Range/20 s	$\pm 10^\circ$
Parasitic Resonances	None below 200Hz
Dynamic Range	>152dB @ 1Hz

INTERFACE

Connector/Downhole	16-pin, underwater SubConn MCBH16MSS, top-mounted
Velocity Output	$\pm 20V$ peak (40V peak-to-peak differential) Selectable XYZ or UVW mode
Mass Position Output	Single voltage output representing maximum mass position 3-channel mass positions available through serial port
Calibration Input	Single voltage input and one active high control signal to enable all 3 channels Remote calibration in XYZ or UVW mode Independent channel selection by serial port

DIGITAL COMMAND & CONTROL INTERFACE

Digital Interface	RS-232 compatible serial IP (SLIP) Onboard web server standard HTTP
Digital Commands	XYZ, UVW mode switching Calibration channel selection (off, enable all, U, V, or W) Short/long period mode Firmware updates State-of-health request
Digital Data Outputs	Independent mass position values Instrument temperature Factory sensitivity User calibration data (poles and zeros) Instrument serial number and firmware revision

POWER

Supply Voltage	9 to 36VDC isolated inputs
Power Consumption	<180mW typical (model TC120-PH2) <195mW typical (model TC20-PH2)
Protection	Reverse-voltage and over-voltage protected Self-resetting over-current protection revision

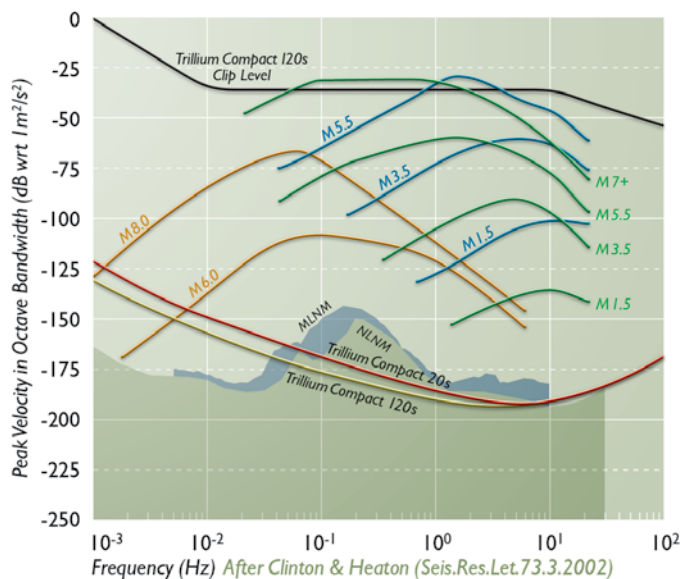
PHYSICAL

Diameter	97 mm
Height	Body & connector: 160 mm On fixed studs: 167 mm On optional 70 mm spikes: 230 mm
Weight	3.3 kg
Housing	Stainless steel surface, resistant to corrosion, scratches & chips
Levelling	Optional bubble level Optional tripod deployment cradle for rapid levelling
Alignment	Vertical scribe marks for north-south Case-top north-south guide for straight-edge, line, or laser level
Weather Resistance	Rated to IP68 for full submersion

ENVIRONMENTAL

Operating Temp.	-20°C to +60°C (Ultra-low option available. Contact Nanometrics.)
Storage Temp.	-40°C to +70°C
Shock	100 g half sine, 5 ms without damage, 6 axes No mass lock required for transport
Magnetic	Insensitive to natural variations of the earth's magnetic field

THE EARTHQUAKE SPECTRUM



- Local events ~10 km Several seconds to 30 Hz
- Regional ~100 km 30 seconds to 10 Hz
- Teleseismic ~3000 km 3600 seconds to 2 seconds

Note: Sensor noise floors and earth noise models have been converted to equivalent peak amplitudes using a full octave bandwidth assuming Gaussian distribution and 95% probability.

Appendix 3 – Seismometer Calibration Data

Station	Component	RMS	Within Tolerance	Date of Calibration
1	U	5.719	Yes	10/26/2017 13:37
1	V	5.738	Yes	10/26/2017 13:37
1	W	5.703	Yes	10/26/2017 13:37
2	U	5.734	Yes	10/29/2017 15:11
2	V	5.740	Yes	10/29/2017 15:11
2	W	5.646	Yes	10/29/2017 15:11
3	U	5.498	Yes	10/29/2017 16:11
3	V	5.397	Yes	10/29/2017 16:11
3	W	5.422	Yes	10/29/2017 16:11
4	U	5.881	Yes	10/29/2017 13:33
4	V	5.852	Yes	10/29/2017 13:33
4	W	5.862	Yes	10/29/2017 13:33
5	U	5.692	Yes	10/29/2017 10:35
5	V	5.653	Yes	10/29/2017 10:35
5	W	5.700	Yes	10/29/2017 10:35
6	U	5.400	Yes	10/29/2017 12:27
6	V	5.514	Yes	10/29/2017 12:27
6	W	5.448	Yes	10/29/2017 12:27
7	U	5.361	Yes	10/29/2017 11:58
7	V	5.386	Yes	10/29/2017 11:58
7	W	5.425	Yes	10/29/2017 11:58
8	U	5.456	Yes	10/27/2017 15:58
8	V	5.423	Yes	10/27/2017 15:58
8	W	5.386	Yes	10/27/2017 15:58
9	U	5.665	Yes	10/28/2017 15:35
9	V	5.593	Yes	10/28/2017 15:35
9	W	5.662	Yes	10/28/2017 15:35
10	U	5.770	Yes	10/27/2017 11:27
10	V	5.769	Yes	10/27/2017 11:27
10	W	5.648	Yes	10/27/2017 11:27
11	U	5.364	Yes	10/27/2017 11:02
11	V	5.361	Yes	10/27/2017 11:02
11	W	5.410	Yes	10/27/2017 11:02
12	U	5.858	Yes	10/28/2017 13:12
12	V	5.635	Yes	10/28/2017 13:12
12	W	5.722	Yes	10/28/2017 13:12