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VERY BROADBAND BOREHOLE SYSTEMS

Flexible design

To ensure you achieve seismic measurement at depth

Borehole installations offer excellent performance for low-noise detection of weak seismic signals such as from local microseismic events or from regional/ teleseismic earthquakes.

We offer a range of options to assist you in achieving measurement at depth, allowing you to get closer to the seismic event and improve the accuracy of sub-surface velocities and event depths.

Our 'very broadband' borehole (VBB) system can house a weak-motion seismometer, a strong motion accelerometer, or a combination of the two.

If the borehole deviates from the vertical path we recommend our Radian system which can be installed at any angle.

The Radian can also be strung together for vertical seismic profiling (VSP). Please see our seperate Radian datasheets for more on this solution.

Through experience, we have learnt that there is a high level of complexity in successfully designing and installing borehole systems. For this reason, we strongly recommend that one of our field engineers is involved in installing Güralp borehole instruments, particularly for a first installation.

If you are considering procuring a borehole instrument we recommend an early discussion with us to explore the full range of available options.

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BOREHOLE SYSTEMS

VBB SYSTEM

Where the verticality of the cased hole is max. 12.5 ° from vertical

- **3TB** — Weak-motion seismometer
- **5TB** — Strong-motion accelerometer
- **3T/5TB** — Dual sensor combination

Suitable for a borehole casing diameter of 99 - 203 mm. The depth that can be achieved with the VBB borehole system will depend upon the conditions of the borehole itself e.g. Temperature

RADIAN SYSTEM*

'Any angle' for deviated boreholes and vertical seismic arrays

- **BOREHOLE** — Cased boreholes 60 to 140 mm; To 2000 m depth
- **POSTHOLE** — Uncased holes 55 mm Diameter; To 2000 m depth

*For details on the Radian systems please see the Radian Borehole datasheet (DAS-RAD-0002) and the Radian Posthole datasheet (DAS-RAD-0001)

VBB BOREHOLE SENSORS

A modular design that offers a range of installation possibilities. All combinations are supplied with surge protection and a strain relief mechanism to isolate the sensors in the instrument from motions in the cable.

5TB

The 5T borehole is designed for strong-motion borehole studies. It is fitted with a DC to 100 Hz accelerometer with a full scale output of 2 g as standard (other options are available).

THE INSTRUMENTS ARE SHOWN WITH THE OPTIONAL SINGLE JAW HOLE-LOCK - WHICH SECURES THE INSTRUMENT IN THE BOREHOLE AT THE DESIRED DEPTH.

3TB

The 3TB houses our 3T sensor renowned for delivering reliable, high quality performance in long period monitoring applications. Standard response of 120 s - 50 Hz, or 360 s to 50 Hz (other options are available).

3T/5TB

The 3T/5TB combines both sensors in one instrument for simultaneous monitoring of weak seismic signals and near-field, high intensity shaking. It is particularly useful where the shaking has the potential to clip the weak-motion sensor.

APPLICATIONS

- Earthquake Early Warning systems
- Strong motion seismic hazard modelling
- Studies of ground amplification / attenuation
- Structural health monitoring

APPLICATIONS

- National observatories
- Microseismic monitoring
- Robust velocity subsurface modelling
- Teleseismic earthquake monitoring
- Nuclear test ban treaty monitoring

APPLICATIONS

- Earthquake Early Warning systems
- Strong motion monitoring and modelling

BOREHOLE SYSTEM OVERVIEW

No two boreholes are the same

Fortunately, the flexibility of the VBB borehole system means instruments can be installed in boreholes with a diameter ranging between 99 mm and 203 mm.

In most cases, an optional single-jaw hole-lock will be used to secure the instrument in the borehole at the required depth. An improved skid design guarantees the stability of the instrument in the casing.

There is also the option, where the conditions are appropriate, to install the instrument using sand backfill. In these instances, the hole-lock module can be eliminated from the design, reducing the length of the system.

As standard, the instruments are supplied with surge protection and a strain relief mechanism that isolates the sensors in the instrument from motions in the cable.

Deeper deployments with data integrity

For deployments exceeding 100 metres in depth, we recommend the Downhole Minimus digitiser. Digitizing the data at source ensures that the origin can be definitively traced and not subject to attenuation during the travel to the surface; so signals are stronger and more reliable.

The Downhole Minimus, which integrates into the instrument to form a single unit, is an eight channel digitiser. It is connected via fibre optic cable to a surface interface unit which delivers advanced data processing capability and software communications, as well as allowing the user to access waveforms and state-of-health data at the installation location.

Ancillary equipment

We can provide tripods, winches and other equipment designed specifically for borehole installations. We strongly recommend that one of our field engineers is involved in installing Güralp borehole instruments, particularly for a first installation.

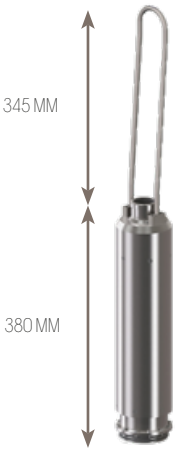
Design complexities

Due to the level of complexity in designing a successful borehole system, we have created a 'borehole questionnaire' designed to guide you through the key questions that our engineers will need to consider when designing a suitable system for your project.

You can view the questionnaire online here:
www.guralp.com/borehole-questionnaire

DOWNHOLE MINIMUS

FOR DEPLOYMENTS EXCEEDING 100 METRES, WE RECOMMEND THE INTEGRATION OF A DOWNHOLE MINIMUS DIGITISER MODULE



THE DOWNHOLE MINIMUS CONNECTS TO THE TOP OF THE BOREHOLE INSTRUMENT TO FORM A SINGLE UNIT

A SURFACE INTERFACE UNIT CONNECTS TO THE DOWNHOLE MINIMUS VIA A FIBRE-OPTIC CABLE AND DELIVERS ADVANCED DATA-PROCESSING CAPABILITY AND SOFTWARE COMMUNICATIONS

5T Borehole

The 5T Borehole (5TB) accelerometer is designed for capturing strong motion and high intensity shaking.

KEY FEATURES

- Flat acceleration output from DC to 100 Hz (200 Hz option)
- In addition to the borehole instrument with single jaw hole-lock, there is a 76 mm diameter option suitable for posthole installation with sand backfill to minimise convection
- Waterproof and durable with O-ring seals throughout
- Dual output (high and low gain) and optional high/low pass filters
- Optional electronic compass module to determine downhole attitude
- Remote DC offset zeroing
- Strain relief mechanism fully isolates the sensors from any motions in the load-bearing cable

5TB WITH SINGLE JAW HOLE-LOCK AND LIFTING BAIL

APPLICATIONS

> Earthquake Early Warning systems
> Strong motion seismic hazard modelling
> Studies of ground amplification / attenuation
> Structural health monitoring

SPECIFICATIONS

SYSTEM	
Configuration / Topology	Triaxial orthogonal (ZNE)
PERFORMANCE	
Acceleration output band	DC to 100 Hz. Options of DC to 200 Hz
Output sensitivity	2 g standard, other solutions available
Peak / Full scale output	Differential: ±20 V (40 V peak-to-peak)
Sensor Dynamic Range	156 dB
Self-noise	Below NHNM > 0.08 Hz (12.5 s)
Cross axis rejection	> 0.001 g/g
Linearity	> 77 dB vertical; > 66 dB horizontal
Lowest spurious resonance	> 400 Hz
Offset zeroing	Via remote control
Transfer function	User manual is available to download from the website. Each sensor is provided with full calibration details including measured sensitivity, measured frequency response and instrument poles and zeros
Calibration controls	Independent signal & enable lines exposed on sensor connector
POWER	
Power voltage range	10 - 36 V DC*
Power consumption (at 12 V DC)	0.5 W

**Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.*

ENVIRONMENTAL	
Operating temperature	-20 to +70 °C
PHYSICAL	
Diameter	76 mm (for installation without hole-lock) 89 mm (for installation with hole-lock)
Inner borehole diameter for installation with hole-locks	99 mm to 203 mm
Case height excl. lifting bail	240 mm without hole-lock 725 mm with hole-lock
Enclosure/Materials	Stainless steel case Gold plated contacts O-ring seals throughout
Borehole install depth	to 250 m (other options available)
Hole-lock install mechanism	Spring-loaded single jaw with passive skids or studs (>60 kg force)

For deployments exceeding 100 metres in depth, we recommend the integrated Downhole Minimus digitiser. For more information see the Borehole brochure or datasheet DAS-MIN-0003

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DAS-BHO-0005 Issue K

3T Borehole

The 3T Borehole (3TB) offers reliable, high quality performance in long period monitoring applications.

KEY FEATURES

- Covers the complete seismic spectrum with a single transfer function
- 120 s to 50 Hz or 360 s to 50 Hz, other bespoke options available on request
- Hybrid velocity-acceleration responses available offering unrivalled dynamic range.
- Single-jaw hole lock for inner borehole diameters of 99 to 203 mm, or backfill with sand to minimise convection
- Waterproof and durable with O-ring seals throughout
- Built-in inclinometer option for attitude checking at depth
- Operates with a tilt tolerance of up to 2.5 ° with an option to increase this to 12.5 °
- Strain relief mechanism fully isolates the sensors from any motions in the load-bearing cable

APPLICATIONS

> National observatories
> Microseismic monitoring
> Robust velocity subsurface modelling
> Teleseismic earthquake monitoring
> Nuclear test ban treaty monitoring

3TB WITH SINGLE JAW HOLE-LOCK

SPECIFICATIONS

SYSTEM		
Configuration / Topology		Triaxial orthogonal (ZNE)
PERFORMANCE		
Velocity output band	3T-120: 3T-360:	120s (0.0083 Hz) to 50 Hz 360 s (0.0028 Hz) to 50 Hz Contact Güralp to discuss other frequency response options
Output sensitivity		1500 V/ms^{-1} (2 x 750 V/ms^{-1}) differential standard output (full-scale clip level of 13 mm/s) Contact Güralp to discuss alternative high sensitvity (high gain) options
Peak / Full scale output		Differential: ±20 V (40 V peak-to-peak) Single-ended (e.g. mass positions): ±10 V (20 V peak-to-peak)
Sensor Dynamic Range		167 dB at 1 Hz (Full octave width across 1 Hz)
Self-noise	3T-120: 3T-360:	Below NLNM 166 s (0.006 Hz) to 10 Hz Below NLNM 200 s (0.005 Hz) to 10 Hz
Cross axis rejection		65 dB
Linearity		> 111 dB
Lowest spurious resonance		> 140 Hz
Transfer function		User manual is available to download from the website. Each sensor is provided with full calibration details including measured sensitivity, measured frequency response and instrument poles and zeros
Calibration controls		Independent signal & enable lines exposed on sensor connector
Operational tilt		Up to 2.5 ° (option to increase this to 12.5 °)

MASS / MONITORING CONTROL	
Locking	Remote auto mass lock/unlock
Mass centre	Remote automatic mass centreing
POWER	
Power voltage range	11– 30 V DC* (24 V DC recommended)
Power consumption (at 12 V DC)	3 W
**Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.*	
ENVIRONMENTAL	
Operating temperature	-20 to +75 °C
PHYSICAL	
Instrument diameter	89 mm
Inner borehole diameter	99 mm to 203 mm
Case height (exc. lifting bail)	795 mm without hole-lock 1280 mm with single jaw hole-lock
Enclosure/Materials	Stainless steel casing Gold plated contacts O-ring seals throughout
Communication / Connectors	100 bar/10 MPa waterproof connector
Hole-lock install mechanism	Spring-loaded single jaw with passive skids or studs (>60 kg force)

For deployments exceeding 100 metres in depth, we recommend the integrated Downhole Minimus digitiser. For more information see the Borehole brochure or datasheet DAS-MIN-0003

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DAS-BHO-0001 Issue R

3T/5T Borehole

The 3T/5T Borehole (3T/5TB) seismometer offers exceptional dynamic range achieved with this dual sensor 3T/5T instrument, designed specifically for borehole applications.

KEY FEATURES

- Total realised dynamic range of over 200 dB with exceptionally low noise floor
- Single-jaw hole lock for inner borehole diameters of 99 to 203 mm, or backfill with sand to minimise convection
- Operates with a tilt tolerance of up to 2.5 ° with an option to increase this to 12.5 °
- Waterproof and durable with O-ring seals throughout
- Built-in inclinometer option for attitude checking at depth
- Hole-lock units with cable pass-through available, allowing installation in boreholes already containing an instrument
- Strain relief mechanism fully isolates the sensors from any motions in the load-bearing cable

APPLICATIONS

> Earthquake Early Warning systems
> Strong motion monitoring and modelling

3T/5TB WITH SINGLE JAW HOLE-LOCK

SPECIFICATIONS

SYSTEM		
Configuration / Topology		Two sensors, each with triaxial, orthogonal (ZNE) components
PERFORMANCE		
Velocity output band (3T)		120s (0.0083 Hz) to 50 Hz or 360 s (0.0028 Hz) to 50 Hz Contact Güralp to discuss other frequency response options
Acceleration output band (5T)		DC to 100 Hz. Option of DC to 200 Hz
Output sensitivity	3T sensor: 5T sensor:	1500 V/ms^{-1} (2 x 750 V/ms^{-1}) differential standard output (full-scale clip level of 13 mm/s) 2 g standard, other options available Contact Güralp to discuss alternative high sensitvity (high gain) options
Peak / Full scale output		Differential: ±20 V (40 V peak-to-peak) Single-ended (e.g. mass positions): ±10 V (20 V peak-to-peak)
Sensor Dynamic Range	3T sensor: 5T sensor:	167 dB at 1 Hz (Full octave width across 1 Hz) > 156 dB
Self-noise	3T-120 sensor: 3T-360 Sensor: 5T sensor:	Below NLNM 166 s (0.006 Hz) to 10 Hz Below NLNM 200 s (0.005 Hz) to 10 Hz Below NHNM > 0.08 Hz (12.5 s)
Cross axis rejection	3T sensor: 5T sensor:	65 dB > 0.001 g/g
Linearity	3T sensor: 5T sensor:	> 111 dB > 77 dB vertical; > 66 dB horizontal
Lowest spurious resonance	3T sensor: 5T sensor:	> 140 Hz > 400 Hz
Offset zeroing (5T)		Via remote control
Transfer function		User manual is available to download from the website. Each sensor is provided with full calibration details including measured sensitivity, measured frequency response and instrument poles and zeros

Calibration controls	Remote calibration on both 3T and 5T sensors
Operational tilt	Up to 2.5 ° (option to increase this to 12.5 °)
MASS / MONITORING CONTROL	
Locking (3T)	Remote auto mass lock/unlock
Mass centre (3T)	Remote automatic mass centring
POWER	
Power voltage range	11– 30 V DC* (24 V DC recommended)
Power consumption (at 12 V DC)	3 .5 W
**Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.*	
ENVIRONMENTAL	
Operating temperature	-20 to +70 °C
PHYSICAL	
Instrument diameter	89 mm
Inner borehole diameter	99 mm to 203 mm
Case height (exc. lifting bail)	1075 mm without hole-lock 1560 mm with single-jaw hole lock
Enclosure/Materials	Stainless steel case Gold plated contacts O-ring seals throughout
Communication / Connectors	100 bar/10 MPa waterproof connector
Hole-lock install mechanism	Spring-loaded single jaw with passive skids or studs (>60 kg force)

For deployments exceeding 100 metres in depth, we recommend the integrated Downhole Minimus digitiser. For more information see the Borehole brochure or datasheet DAS-MIN-0003

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DAS-BHO-0006 Issue K

Downhole Minimus

A downhole digitiser that converts the data at source for stronger and more reliable signals. Suitable for all borehole applications and strongly recommended for installations exceeding 100 metres depth.

DOWNHOLE MINIMUS

SPECIFICATIONS

SENSOR INPUTS	
Primary digitisation channels	Eight at 24 bits Differential input: 40 V peak-to-peak (± 20 V). Also compatible with single-ended inputs: 20 V peak-to-peak (± 10 V)
Secondary channels	Six analogue channels for sensor mass positions, two internal calibration channels
Internal environmental channels	Humidity Temperature Supply voltage MEMS accelerometer (three component) Magnetometer (three component)
Input impedence	50 kΩ
PERFORMANCE	
ADC converter type	Delta-sigma
ADC conversion delay	6 µs
Output format	32-bit
Dynamic Range	>142 dB at 100 samples per second
Gain drift	3 ppm / °C
Common-mode rejection	>110 dB
DATA PROCESSING	
Output rates available	1 sample per hour up to 5000 samples per second for primary channels, user-selectable Multiple independent data streams at different sample rates for all channels (transmission and recording) Up to 500 samples per second for environmental channels
Decimation filters	÷2, ÷3, ÷4, ÷5 decimation (Causal / Acausal)
Out-of-band rejection	>194 dB
Data transmission mode	Continuous and trigger modes
Triggered data	Retrievable using event table in digitiser's web page. User selectable pre and post event time.
Trigger modes	STA/LTA, Threshold
Output streams	Direct output of PGA, PGV and PGD without external software
Selectable gain	Unity, ×2, ×4, ×8, ×12, ×64
TIMING AND CALIBRATION	
Timing source precision	Accuracy when GNSS locked ±50 ns. Typical drift when unsynchronised (without GNSS) <1 ms per day
Timing source at the surface	Stratum 1: GNSS (GPS and GLONASS, BeiDou optional), PTP (Precision Time Protocol)
Calibration signal generator	Triangle, Step or Broadband noise with adjustable amplitude.

OPERATION AND POWER USAGE	
Operating temperature	-20 to +60 °C
Relative humidity range	zero to 100 %
Power supply	9 - 36 V DC* Or mains 90 - 250 V AC
Power consumption at 12 V DC	Dependent upon installations parameters
**Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.*	
SOFTWARE	
Operating system	Windows and Linux compatible
Communication technologies supported	Ethernet (10/100/1000BASE-T) Optional Power over Ethernet (PoE)
USER INTERFACE	
Configuration and control	(Ethernet) Güralp Discovery - free download, web browser interface.
DATA COMMUNICATION	
Data recording formats	miniSEED (metadata stored in dataless SEED format)
Data streaming protocols (via Ethernet)	GCF (Scream!), GDI-link[1] and SEEDlink[1] ([1]metadata sent in RESP, StationXML and dataless SEED file formats)
Memory and storage	Dual redundant 16 GB microSD cards Option for 64 GB or 128 GB
RAM	256 MB
PHYSICAL CHARACTERISTICS	
Casing type	Environmentally sealed, hard anodised aluminium
Environmental sensor	Humidity and temperature
Dimensions	Diameter 89 mm Height without lifting bail 350 mm Height with lifting bail 725 mm
Connector type	MIL-DTL-26482 Series 1: 2 × Ethernet Power Ethernet - 8P8C (RJ45) Power - 10 pin GNSS - 10 pin (GPS)
Global navigation satellite system (GNSS)	Compact, encapsulated, waterproof, precision timing GPS/GLONASS (BeiDou optional) receiver
Communication / Connectors	100 bar/10 MPa waterproof connector up to 1000 metres
Surface Interface Unit dimensions	512* mm × 376 mm × 432 mm *Allow additional 350 mm for cable connectors

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