GURALP SYSTEMS

GÜRALP CMG-40T

BROADBAND SEISMOMETER

- Truly portable seismometer with lifting handle, and easy access to electric connection.
- Direct velocity output broadband feedback seismometer.
- Suitable for local, regional and teleseismic recording.
- Mass clamp not required.
- Mass centering not required.
- Adjustable feet with sapphire tips to reduce analogue ground loops.
- High and low gain differential velocity outputs.
- Long period response; 10, 20, 30, 60 and 120 seconds options.

- Short period response up to 50 Hz.
- Low power consumption, 0.5 Watts.
- Stainless steel construction.

The CMG-40T portable broadband seismometer is a three-component seismometer of rugged design, designed to meet the requirements of rapid installation, minimum setting up and optimum sensitivity and dynamic range. The sensor is completely waterproof and self-contained apart from the external dc power supply and recording device. For strength and long term durability it is constructed entirely from stainless steel.

GÜRALP SYSTEMS LIMITED
3 Midas House, Calleva Park, Aldermaston,
Reading, Berks, RG7 8EA, United Kingdom.
Tel: +44 (0) 118 9819 056
Fax: +44 (0) 118 9819 943
e-mail: sales@guralp.com
Website: http://www.guralp.com

While the CMG-40T noise floor is higher than that of CMG-3ESP and CMG-3T sensors, the moderate price makes the instrument an attractive selection for several applications:

- Portable and rapid array mobilisations in which reliability, low power and installation simplicity are important.

- Permanent installation at sites which do not have seismic background close to the USGS Low Noise Model.

- Short to medium term installations in which vault temperature and tilt are not as well controlled as for permanent sites.

The standard frequency band is 0.033 Hz (30 sec) to 50 Hz with options for long period response from 20 seconds, 60 seconds and 120 seconds. The sensor system is supplied with comprehensive calibration information, including the measured frequency response of each component and a single theoretical transfer function.

MECHANICAL SYSTEM DESIGN

Mechanically, the vertical and horizontal sensor constructions are very similar. The vertical component sensor boom is supported horizontally with a leaf spring. The horizontal sensor is based on an inverted pendulum which is supported with two parallel leaf springs. The rigid construction and geometry of the sensor mass/boom eliminates spurious modes of vibration. In the closed loop mode the lowest parasitic resonance is above 450 Hz from either of the components.

The vertical and horizontal sensors are orthogonal to each other with an accuracy of better than 0.2 degrees on a single stainless steel seismometer base.

The small mass of the suspension , uniquely combined with a strong, well designed, suspension system, eliminates the requirement for a sensor mass clamp during transportation and mass centring when installed to operate as a broadband sensor. The total weight of the vertical sensor mass is 36 grams and 34 grams in the case of the horizontal sensor.

The mechanical construction of the instrument is such that it is compact, rugged and easy to use.

The CMG-40T (three-component) sensors are housed within a completely 'O' ring sealed housing and all the external components are manufactured from stainless steel.

CMG-40T can also be delivered with a waterproof connector and cabling. The waterproof connector/sensor can be immersed continuously under water down to a depth of 25 meters (other depth options are also available).

These instruments do NOT require precise leveling of the sensor package to obtain long period mechanical response and can be used without leveling the sensor case up to ±2.5 degrees of tilt.

The photograph opposite shows the posthole CMG-40T sensor system with a waterproof connector.

Construction is stainless steel and can be immersed under water down to a depth of 100 meters (other depth options are available).

An optional remote mass centering mechanism can be supplied to zero the capacitive displacement transducer.

SYSTEM DESCRIPTION

The system consists of three orthogonal miniature sensors controlled by force feedback to give velocity and mass position electrical outputs. The sensors, all of similar construction, are mounted on a common circular base surmounted by a cylindrical case containing the control and signal processing electronics. The lowest parasitic vibration is above 450 Hz. The vertical sensor is fitted with pre-stressed springs to counteract gravity. The relative motion of the mass to the frame is detected by a differential capacitor which provides the basic signal from the device.

The sensors operate with a free oscillation frequency of about 10 Hz and force feedback is supplied by a pair of coil/magnet transducers. The force transducers are arranged such that they form a constant flux feedback transducer to enhance the linearity of the feedback transducer. The feedback transducer is also used as the calibration transducer when calibration signals are applied to the system.

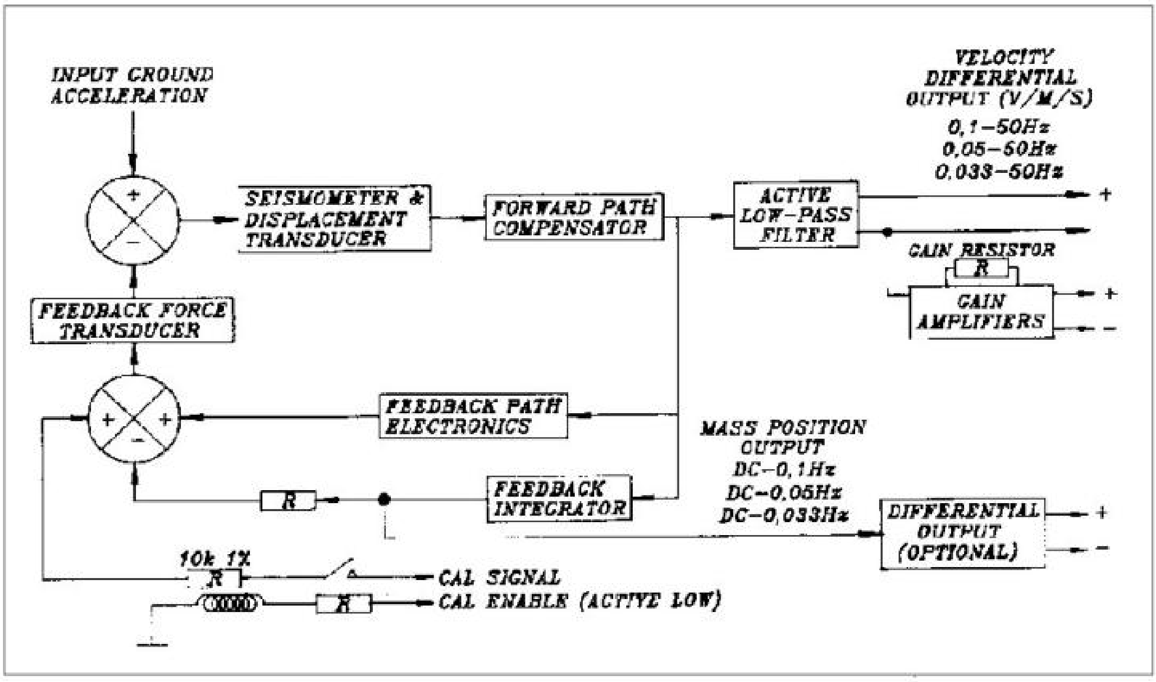
The output signals from each sensor are obtained from the feedback network which operates on the basic signal from the differential displacement capacitor transducer. Processed signals are returned to the force transducer to control the operation of the seismometer. The velocity output signal is provided on a balanced pair output circuit capable of driving up to 50 m of twin twisted and screened cable. There are also mass position outputs on single ended lines referred to signal ground.

The basic response of the system (velocity output) is flat to velocity from a specified corner frequency of fn to 50 Hz (f is the long period corner frequency). The damping coefficient of the sensor transfer function is $\zeta = 0.707$.

The standard specification corner frequency is (fn) 0.033 Hz (30 sec). Additional optional corner frequencies are 0.1 Hz (10 sec), 0.05 Hz (20 sec), 0.0166 Hz (60 sec) and 0.00833 Hz (120 sec). The high frequency low pass corner is realised with an active low pass filter.

The CMG-40T sensor system block diagram is given below. This type of broadband feedback system was suggeted by Dr. Buckner at Reading University, UK, in 1975. Ref 2.

Normally the high frequency low pass corner is realised with an active low pass filter. All the amplitude and the phase plots of the sensor and the transfer functions are supplied in the calibration sheet.

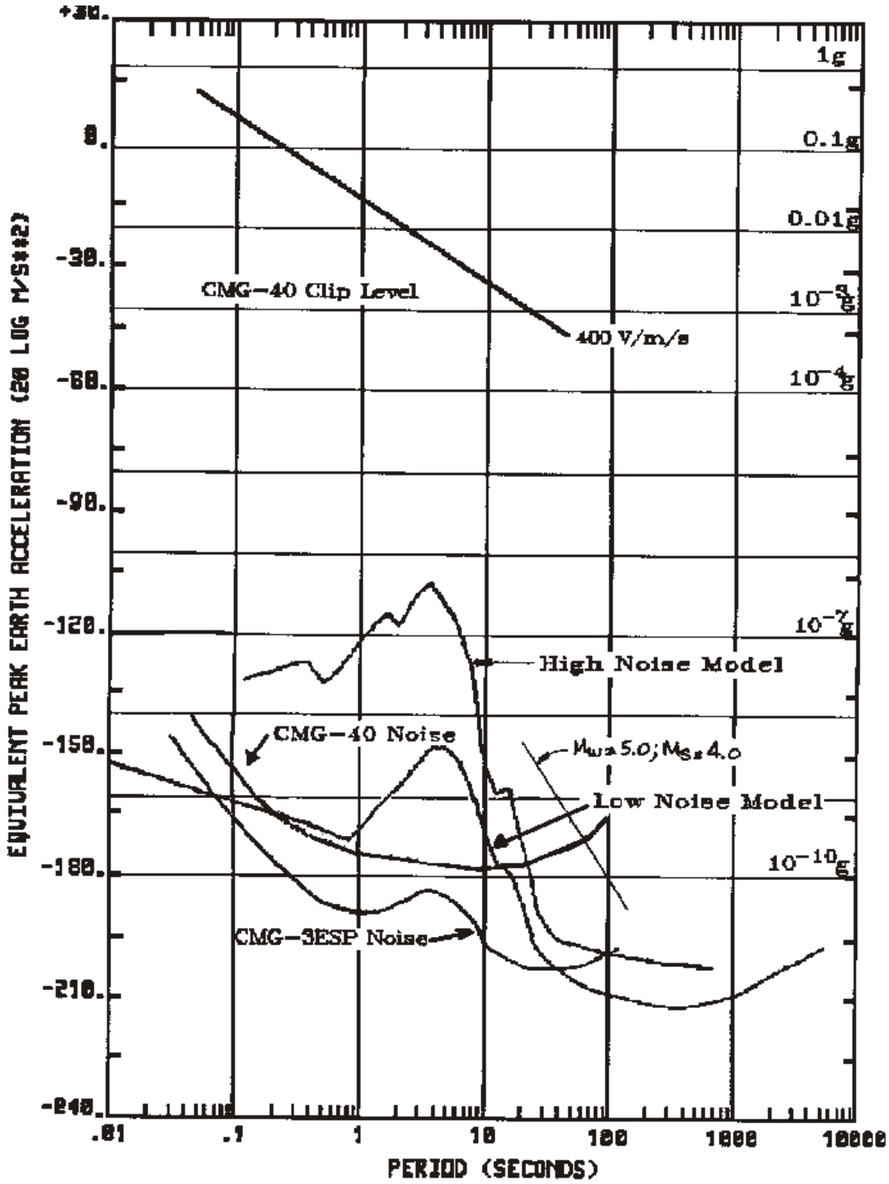


SIGNAL AND NOISE LEVELS

The CMG-40T broadband sensor has a mass of 36 grams (0.036 kilograms) and it's mass size is the smallest amongst the true broadband sensors manufactured to date. The system Brownian noise is calculated to be -180 dB (10^{-18} $m/s^4/Hz$) relative to 1 $m^2/s^4/Hz$. Ref 1.

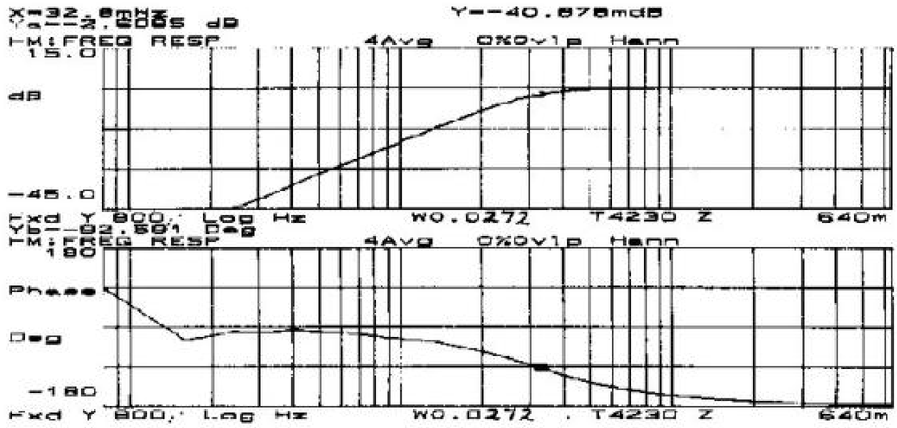
A discrete component low noise pre-amplifier circuitry (identical to the CMG-3 sensor pre-amplifier) together with a high responsivity capacitive transducer sets the electronics noise level of the system to - 172 dB relative to ground acceleration of 1 $m^2/s^4/Hz$ from 10 Hz to 0.1 Hz (10 seconds).

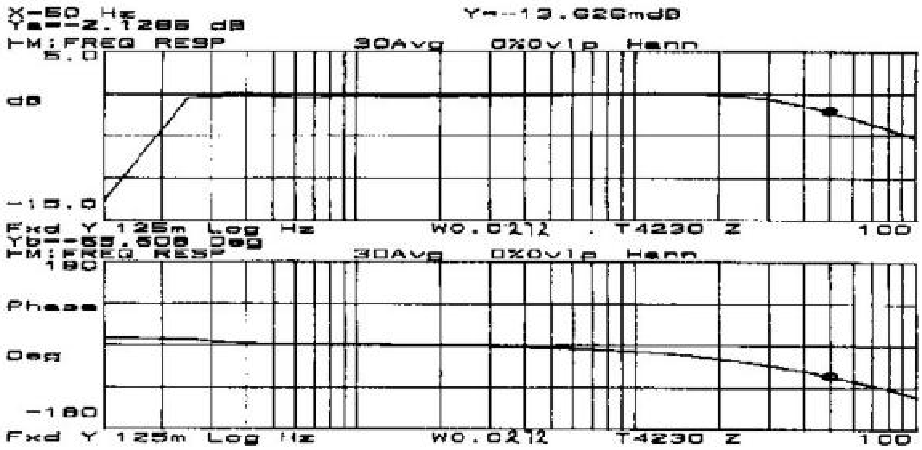
The figure below contains typical measurements of the system noise power plotted (thick line) as non-coherent power for vertical and horizontal sensors in the long period and short period bands. The power spectral estimate has been corrected for the system response and gain. The <u>L</u>ow <u>N</u>oise <u>M</u>odel is also plotted.



SENSOR FREQUENCY RESPONSE

The CMG-40T seismometer is delivered with comprehensive documentation which includes the 'Operator's Guide' and complete calibration documentation. Each CMG-40T sensor measured frequency response is provided as normalised amplitude and phase plots. The frequency plots are given as the long period and short period sections of the seismic spectrum.





As well as the measured frequency response, poles and zeros of the sensor transfer function are provided as a single transfer function.

POLES AND ZERO TABLE

WORKS ORDER NUMBER: 0272

SENSOR SERIAL NO: T4230

POLES (HZ)	ZEROS HZ
$-23.56 * 10^{-3} \pm j\ 23.56 * 10^{-3}$	0
- 50	0
	159

Normalising Factor at 1 Hz: A = - 0.314
Sensor Sensitivity: See Calibration Sheet

NOTE: The above poles and zeros apply to the vertical and horizontal sensors and are given in units of Hz. To convert to Radian/sec multiply each pole or zero with 2π. The normalising factor A should also be recalculated.

CMG-40T TRANSDUCER SYSTEM SPECIFICATION

Outputs and Response

Standard velocity output:	2 * 400 V/m/s
OPTIONAL High gain output:	2 * 4000 V/m/s **Note:** High gain outputs are user adjustable with a resistor Change.
OPTIONAL Velocity outputs:	2 * 80 V/m/s 2 * 800 V/m/s
Standard frequency band:	0.033 Hz (30 sec) to 50 Hz
OPTIONAL Frequency bands:	0.05 Hz (20 sec) to 50 Hz 0.0188 Hz (60 sec) to 50 Hz 0.008 Hz (120 sec) to 50 Hz
Clip level and measured sensor noise:	See figure. CMG-3 noise level is shown for reference.

Controls

Calibration enable:	Calibration enable line operates all the components calibration Enable.
Calibration signal:	Common to all the sensors.
Mass centring:	Screw adjustment through case.
OPTIONAL DC adjustment:	Remote operation via dc motors for posthole and downhole.

Physical

Lowest spurious resonance:	450 Hz vertical
Temp. before recentre needed:	± 10 deg. C
Mass recentring range:	± 2.5 deg from horizontal
Operating temperature range:	- 10 to + 75 deg C
Base plate and top cap:	Stainless steel
Pressure jacket material:	Stainless steel
Power/signal connector:	Milspec connector on top cap, KPT 02E-16-26P. Stainless, 1500 psi connector available.
Pressure relief valve:	On top cap
Carrying handle:	On top cap
Case diameter:	168 mm (6.61 in)
Case height with handle:	160 mm (6.29 in)
Weight:	16.7 lb (7.5 Kg)

Power

Standard power supply:	+ 12 Vdc, with internal DC/DC converter (Can operate over 10 to 36 Volts.)
Current at standard (12 V) output:	+ 42 mA
Additional cal relay current:	< 1 mA

REFERENCES

Ref 1 GURALP, C.M., 'The Design of a Three-component Borehole Seismometer' 1980, PhD Thesis, University of Reading.

Ref 2 BUCKNER, I.W., 'Design of a Horizontal Component Feedback Seismometer' 1975, PhD Thesis, University of Reading.

Ref 3 USHER, M.J., GURALP, C.M. and BURCH, R.F., 'The Design of Miniature Wideband Seismometers', 1978. Geophys. J.R. astr. Soc.