

## Technical Note

### TN # 90

## Seismic and / or Strong Motion Networks

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# Description for Digital Seismic Telemetry Network

## 1. Overview

### 1.1. Seismic Instrumentation

In the following descriptions and block diagram we are describing and showing a seismic instrumentation similar to your specific requirements. Number of sites, type of sensors and digitisers may vary and are quoted specifically to your requirement and are possibly not completely identical with this proposal.

In the block diagram SN\_1, it shows the building blocks of a proposed digital seismic installation. There are 3 seismic stations with a uniaxial vertical sensor. One triaxial sensor is placed at the central site. The digital information out of the 4 seismic stations S1 up to S4 are fed into the multiple RS-232 interface and data is recorded by a SEISLOG based PC.

The information of the seismic stations S2 up to S4 are transmitted by radio. Optionally shown is e.g. Station S4 equipped additionally with a relay station (repeater station) (see also diagram SN\_3).

Diagram SN\_2 shows in more detail the components of the seismic stations S2 to S4: The highest performance GSD-18 or GSD-24, 18 or 24 Bit digitiser converts the analog signal from the sensor into digital information. From the GPS time information is received and the internal real time clock is synchronised to UTC. The digital seismic information is packed to time stamped 1 second data packages of data and then transferred through telemetry/spread spectrum to the central recording station.

For the detailed telemetry project study we could propose a special meeting with the customer.

The power supply is based on local AC. If this can not be provided, the power supply would have to base on solar power. A solar battery charger would feed then the energy from the solar panel into the batteries. From there, both, the digitiser and the transmitter are supplied. We have submitted this as an option in our quotation and are able to support the customer also in this regard. It may also be possible to purchase this locally however no guarantee could be taken for that part in such case.

### 1.2. Strong Motion Instrumentation (Sample Block Diagram)

There are triaxial accelerometers with recorders in the site (A2 to A4) and one accelerometer with recorder is placed as a free field (A1) (for Dam applications) not affected by the surrounding forces. All stations are interconnected with a central station. This makes sure that one can communicate with the recorders from only one site (see Block Diagram SN\_4). Strong Motion Recorders can of course also be placed individually and not interconnected in a network.

## 2. Transducer Sub-Units

### 2.1. Triaxial Short Period Seismometer Transducer Sub-Unit

As transducer an orthogonal oriented, triaxial (two horizontal and one vertical) surface mount seismometer CMG-40T-1 of the company GÜRALP Systems is proposed.

The CMG-40T-1 is actually based on the CMG-40T broadband-seismometer technology. Therefore it comes in the same housing and uses the same cable / pin connections as the CMG-40T. Designed for scientific studies and engineering evaluations, the GÜRALP CMG-40T-1 seismometer is well known in the marketplace. The frequency response can be found in the section V. The CMG-40T-1 is powered from a 12 VDC supply and has an output of 2 x 400 V/m/s (800 V/m/s). The dynamic range is more than 135 dB. The CMG-40T-1 uses a seismometer as sensing device. The CMG-40T-1 is more rugged compared to for instant a Mark L-4-3D. For detailed specification we refer to the data sheets.

The transducer unit is equipped with an indicator for levelling the transducer. A reference line indicating each sensor's orientation and polarity is provided. Calibration data showing the sensor response at different frequencies will be provided along with every sensor.

## **2.2. Uniaxial Short Period Seismometer Transducer Sub-Unit**

For a uniaxial seismometer stations the CMG-40-T1 single component seismometer is proposed. For detailed specification we refer to paragraph 2.1 and to the data sheets.

## **2.3. Triaxial Force Balanced Accelerometer Transducer Sub-Unit for Strong Motion Network**

As force balanced accelerometer we propose the AC-63 or the CMG-5T. For detailed specification we refer to the data sheets.

# **3. Digitiser**

## **3.1. GSD-18 Bit Digitiser**

We are quoting the GSD-18, 18 Bit Digitiser for all seismic stations as a more economical solution. Technical Data are available from the specific datasheet.

Please consider when using the 18 Bit instrument that it will allow you to either store the data in full dynamic range or within a 16 Bit format. The 16 Bit format offers an optimum between the signal quality and the use of memory.

Please take care on the specifications of the noise performance since the indications usually are given in RMS values. Having 18.5 Bit @ 100 SPS or 18 Bit @ 200 SPS ends up in noise of  $\pm 3$  counts up to  $\pm 4$  counts at 18 Bit. Knowing this, you will see that the data represented in a 16 Bit format (2 Byte format) includes a completely noise free signal. Actually the 2 Byte format (16 Bit data) is more memory friendly to store than an 18 Bit data which asks for 3, sometimes 4 Bytes ('long' data format instead of 'word' data format).

## **3.2. Optional GSD-24 Bit Digitiser**

Optionally we may quote the GSD-24 Digitiser which is a 3 channel, 24-bit digitiser with best performance. Technical Data are available from the specific datasheet.

# **4. Central Recording System**

## **4.1. System Description**

The central recording system (CRS) is a PC based system. It consists of radio receivers in the UHF band, for receiving the digital from up to 14 (maximal 19) field stations with 3-components and one field station with 6-components, which may be co-located with the CRS. The data from the field stations are transferred from the receivers to a multiple RS-232 board connected to a PC. On the central computer Windows NT operating system is installed. The management of data acquisition is performed by the SEISLOG (see paragraph 4.1.1) application software and the analysis is accomplished using the SEISAN (see paragraph 4.1.8) earthquake analysis software. SEISLOG and SEISAN were developed by the Institute of Solid Earth Physics, University of Bergen, Norway. The SEISLOG data acquisition system is used as the major data collection system in the national seismic networks of Norway, United Kingdom, Ireland and in several countries of Central America. In addition, SEISLOG is used at about 40 stations in eight other countries in Europe, Africa and Asia.

#### **4.1.1. SEISLOG**

SEISLOG is a general purpose seismic data acquisition system intended for recording of earthquakes. The system can record 1-16 channels with 12-24 bits resolution. Up to 64 channels may be supported with optional serial interface boards. A typical system consists of a standard PC with a real time operating system, at least a 1 GByte Hard Disk and 32 MB Memory and some means of communication with a processing computer.

The digitised data packets, sent from the Seismic Monitoring System, are displayed on the central computer terminal by SEISLOG. When each page of data is accumulated, it is printed out in the analogue mode. This approach of printout is recommended because it provides the least cost and most reliable method of obtaining hard copies of the signals. Alternative plotting methods are selectable. SEISLOG has flexible user defined trigger criteria which can be tailored to both local and distant earthquakes. The system can be set up with up to five different trigger criteria sets in order to independently trigger on local and distant earthquakes.

The data are transferred from SEISLOG to the processing and analysis software SEISAN (see paragraph 4.1.8) by floppy disk, tape, removable disk, modem or Ethernet.

##### **4.1.1.1. Description of SEISLOG Software for Volcano Monitoring**

SEISLOG can be tailored to monitor volcanic activity. By using the possibility to set up individual filters for each channel, it is possible to set the channel trigger level according to the frequency content for a particular station. Different parts of the network can be set up to trigger on different parameter sets so subsets of stations can monitor different parts of the network with different parameters or the whole network can be monitored with different parameter sets. Since the duration of an event is also a trigger parameter, it is then possible to store only events larger than a given limit, while still obtaining the time and duration of all (volcanic) events for statistical purposes.

##### **4.1.1.2. Early Warning System with SEISLOG**

The Early Warning System is a separate PC which performs the defined checks. Periodically the SEISLOG station is contacted and the relevant data are extracted. Warnings and Alarms based on predefined criteria can be activated.

#### **4.1.2. Recording**

The CRS records continuously the digital data stream received at a rate of 100 SPS / channel. Actually this is without applying a compression the limit of the 9600 Baud system since for the 100 SPS a bit stream of  $(10 \text{ Bit / transferred byte}) \times (3 \text{ channels}) \times (3 \text{ Bytes}) \times (100 \text{ SPS}) = 9000 \text{ Bit/s}$ .

The acquired data is stored first in files of 1 day data within the SEISLOG computer. The off-line analysis PC then retrieves this files through the Ethernet and stores the data on optical discs. Since the optical disc writing process has it's own timing specification with this approach it is secured that both the data recording and the disc writing process are running under optimal conditions. Obviously data is compressed for archiving on the optical disc.

With the approach described above the optional facility for continuous recording of the decimated data from the incoming digital streams at a user selectable rate varying from 20 SPS/channel to highest sampling rate (i.e. up to 100 SPS/channel) combined with a switch to the highest sampling rate in case of an ongoing event can be implemented easily.

#### **4.1.3. Timing System**

All the information reaching the CRS is already time stamped at the field station. This is from the redundancy point of view the much better solution than the centralised time stamping. In centralised time stamping additionally to the problem of building up a redundant 'time stamper' the different transmission delays from the field stations have to be considered. It has to be known that in the digital telemetry transmission the time delays typically may vary and therefore the 'at field time stamping' is the only really successful approach. Actually the evolution on the GPS marketplace does support this approach since the GPS units are located on a very moderate price level nowadays.

The requested drift of 15 msec per day is only possible with several GPS updates of the precise TXCO controlled real time clocks in the field units. Using this approach the requirement of maintaining the time within  $\pm 5$  msec of UTC all the time is warranted.

#### **4.1.4. Event Detection**

The CRS detects the presence of an event based on trigger parameters set by the operator. The trigger is applied to the band passed signal for all the stations selected for trigger voting. The number of stations that are selected for trigger is an operator selectable parameter. The band passed signal may be subjected to STA/LTA or a level trigger algorithm for declaring an event. This event detection builds the important base to transmit the information to the central data bank.

#### **4.1.5. Conversion Software**

GeoSIG provides the necessary software for converting the data collected by the CRS into popular processing formats such as PC-SUDS, SEG-Y, SAC, SIERRA, AH, etc. Beside the already in the SEISLOG / SEISAN package implemented data conversion we are able to write 2 additional conversions. Since the CRS is based on SEISLOG/SEISAN implicitly the full performance of this field proven software package is included.

#### **4.1.6. Analog signal monitoring**

As explained above, this is included in every 'Recording Module' and has also a high importance for the operator. The monitor based analog signal display is state-of-the art and leads the seismologists in the next century. Whereas the drum recorder based monitoring is more of a historical value, can not comply with the digital solution's features and is, compared to the PC technology prices much more expensive.

#### **4.1.7. Seismic Analysis**

GeoSIG provides the SEISAN seismic data software for each CRS. Actually in a joint approach between Bergen University and GeoSIG SEISAN is running under Windows 95 and comes as a compact, user friendly package. SEISAN is additionally daily professionally used by many seismological institutes world-wide.

#### **4.1.8. SEISAN**

SEISAN has been in operation since 1988. It is used as the main processing tool in the SEISLOG installations mentioned above. SEISAN has the advantage of being a complete system with a data base and integrated processing tools. In addition to working smoothly with data from SEISLOG, SEISAN can also process data from many well known data acquisition systems and data banks. In particular, it has been well integrated with International Seismological Centre data formats. Large amounts of data can be processed either manually or automatically.

SEISAN can calculate all normally used magnitudes. It locates earthquakes with the latest global model (IASP91) or with user selectable models. Earthquake location can be done with several thousand stations and arrival times. More than 100 types of phases can be used. The data base can be searched for more than twenty different criteria. The results are displayed in terms of the hypocentral distribution in time and space and a statistical analysis can also be carried out.

The system consists of a set of programs tied to the same database. Using the search programs it is possible to use different criteria to search the data base for particular events and work with this subset without extracting the events. Most of the programs can operate both in a conventional way (using a single file with many events), or in a database manner. Additionally, SEISAN contains some integrated research tools like coda Q, synthetic modelling and a complete system for seismic hazard analysis. The SEISAN system operates both on PC (DOS) and SUN computers. The data is organised in a database like structure using the file system. The smallest basic unit is a file containing original phase readings (arrival times, amplitude, period, azimuth, apparent velocity) for one event. The name of that file is also the event ID, which is the key to all information about the event in the database including waveform file name.

Although the database in reality only consists of a large number of sub-directories and files (all of which the user has access to), the intention is that by using the surrounding software, the user should rarely need to access the files directly, but rather do all work from the user's own directory.

The programs are mostly written in Fortran, a few in C and almost all source codes are given, so the user should be able to fix bugs and make modifications suiting his/her needs. The programs have been compiled and linked with system compilers and linkers on SUN and Microsoft Powerstation Fortran 1.0 on the PC.

#### **4.1.8.1. Description of SEISAN for analysis of Volcanic Events**

Classification of events: Data can be stored in the data base according to the users classification (e.g. type 1, 2 or 3 etc.) and tools are then readily available to make statistical analysis of the all or particular types of events (b-value, time of day or number of events / time unit).

Magnitudes:

Magnitudes can be determined and stored also if only one station is available and no location made. If a distance estimate is available,  $M_L$  or  $M_w$  can be used, however coda magnitude can also be used when no distance is available as it often the case with volcanic earthquakes.

Hypocentres:

When locations are available, epicentres and hypocentres in cross sections can be displayed.

Spectral analysis:

Interactive analysis can be done on individual events and the results are stored in the data base together with readings and other parameter data. E.g. the spectral level can be determined at different frequencies and stored. The total energy can be estimated by determining the seismic moment. If average spectral properties for a large number of events is desired, this can be done in batch mode based on the event entries in the data base. In this mode, a the spectra are made of a given number of events and the average spectra presented. It is thus e.g. possible to make average spectral levels for all events recorded in given time intervals or in a given area. All results of spectral analysis can be presented as instrument corrected acceleration, velocity or displacement.

Continuous data:

It is often desirable to work with continuous data and SEISAN can store and plot continuous data. The data is based on individual waveform files of suitable length depending on sample rate (e.g. 20 minutes pr file)

#### **4.1.9. Power Supply**

The Power Supply is project related and needs to be defined. The battery capacity depends on the customers requirement of the autonomy which has to be defined. Existing UPS systems or Solar Panels may already exist and can be integrated in the system or offered by GeoSIG.



## 5. Telemetry

### 5.1. UHF Telemetry

Although the proposed approach is basically simplex the telemetry equipment is using transceivers. E.g. every transmitter is a receiver and every receiver is also a transmitter. We are using successfully the transceivers DM-3412 from the company Dataradio Corp. Ltd.. The coded digital data (RS-232) from each field station at a baud rate of 9600 Baud is transmitted to the CRS. The used frequencies are in the UHF band (480 up to 512 MHz). The transceiver has an internal synthesiser which allows the selection of more than 200 channels within a certain transceiver band.

The required channel spacing is 25 kHz. The final frequency allocation has to be evaluated between the customer and GeoSIG. We are adding a Technical paper about the Procedure for telemetry testing and the definition of an acceptance criteria. GeoSIG insists on a professional check of the telemetry links since this is the back-bone of the complete installation. GeoSIG bases therefore on special telemetry measurement team who is capable to optimise a digital telemetry network.

The telemetry link transfers the output of the digitiser to the CRS and there the original digital waveform is reproduced. The transmitter may be located as far as 100 km from the CRS, depending on the line of sight conditions. The receiver sensitivity of the DM-3412 supporting such ranges of distances.

The telemetry uses an CCITT algorithm for the bit error rate (BER) detection, allowing the user to identify data with transmission bit errors and missing data. The implemented detection system is able to take corrupted or missing data into account so that the system does not trigger because of the corruption momentary loss of data. The design reliability is  $10^{-4}$  failure per trigger demand due to transmission errors. The BER is  $10^{-6}$  and the fade margin should be not less than 28 dB. The fade margin has to be defined between customer and GeoSIG based on the measured telemetry link conditions.

The detail specification are given in the data sheets appended. Reference is given in the Technical paper 'Telemetry Testing and Acceptance Criteria' where all the relevant technical background information about telemetry links for seismic application is documented.

### 5.2. Spread Spectrum Telemetry

The TEL-SSR1 2.4 GHz wireless RS-232 spread spectrum data transceiver provides reliable long range data communications. Using the superior frequency hopping spread technology, the TEL-SSR1 Spread Spectrum transceivers are capable of uncompressed data rates of 115.2 kBaud over distances of up to 60 km (in case line of sight is provided), meeting the data communications needs in the field of seismic applications.

The 2.4 GHz products operate at 500 mW output power, the maximum output power allowed under Part 15 rules. As well as providing long range reliable data links, the TEL-SSR1 Spread Spectrum transceiver sets up quickly and incur no ongoing fees or permissions, unlike cellular, land line communications or VHF or UHF telemetry.

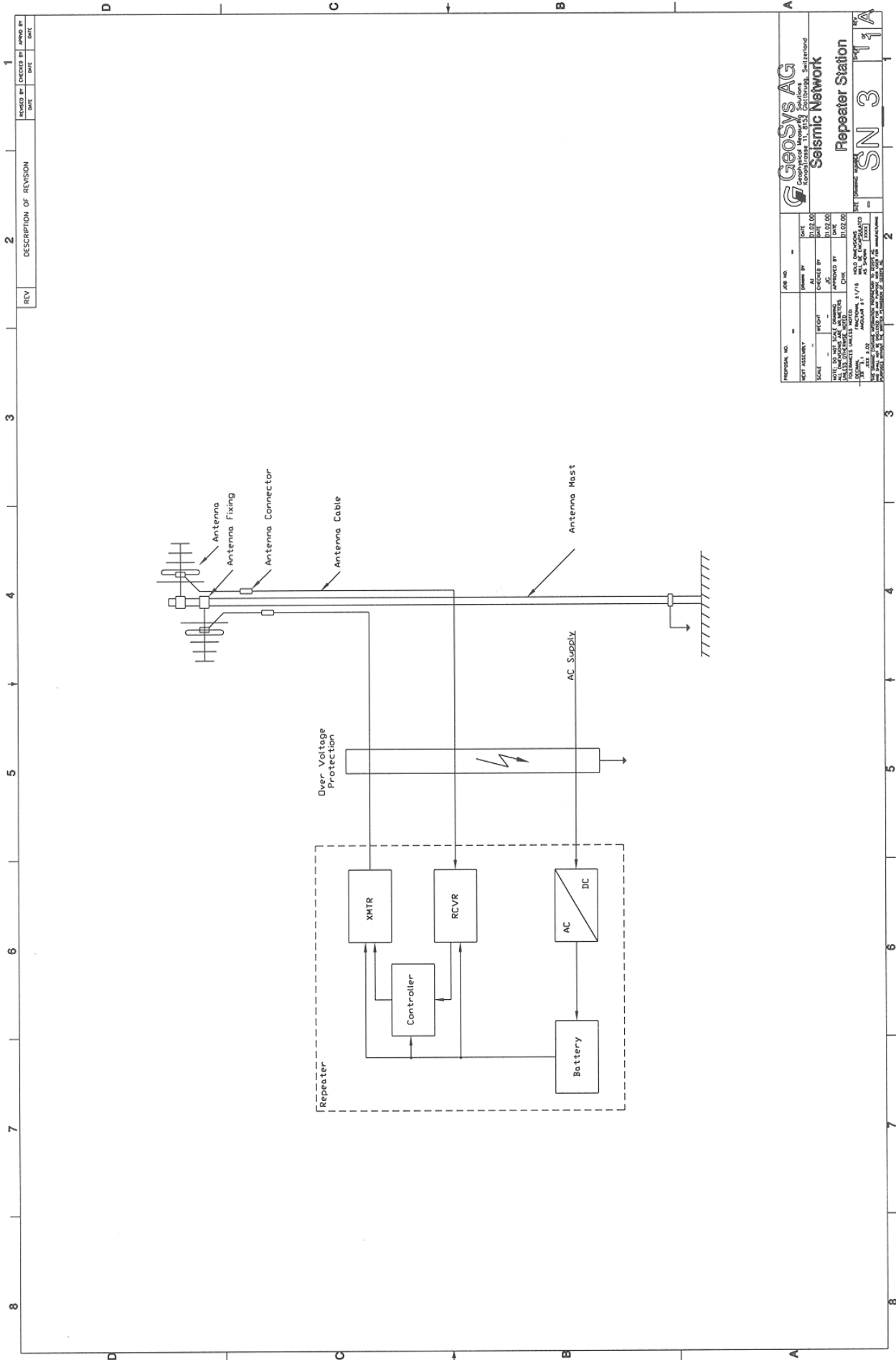
The TEL-SSR1 Spread Spectrum transceiver operates in either point to point or point to multipoint modes, depending on the application and topology of the network. Repeaters may be deployed in either mode to extend the range of the link, not by plugging two units in back to back as is the case with most radios, but by programming the units to operate as a store and forward repeater. With up to two repeaters in a link and using optional external antennas, links of 100 km and beyond are possible. <http://www.freewave.com/images/dgro.gif>

### 5.3. UHF Antenna

We include in our projects 7 element Yagi antennas with an antenna gain of 8 to 9 dBd. By using the 7 element Yagi on both sides a total antenna gain of about 17 dB can be reached in every link.







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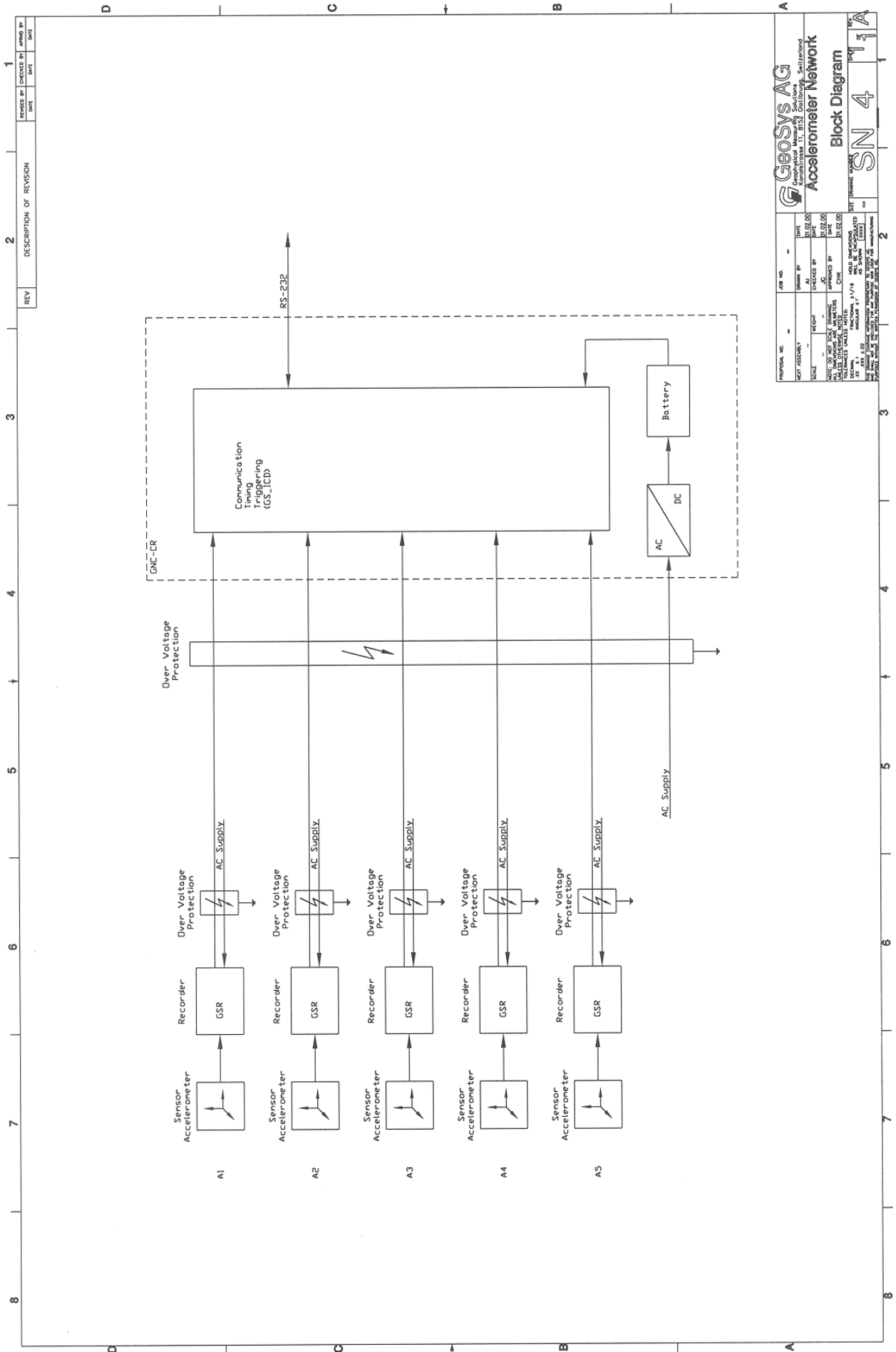
  

NO.	DESCRIPTION	DATE

**GeoSigs AG**  
Geophysical Monitoring Solutions  
Seismic Network

**Repeater Station**

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PROPOSAL NO.	JOB NO.	DATE
		01.02.00

**Geosys AG**  
Geographic Information Systems  
Accelerometer Network

SCALE	DRAWN BY	CHECKED BY	DATE
			01.02.00

NOTE: ON THE SCALE DRAWING, ALL DIMENSIONS SHALL BE INDICATED UNLESS OTHERWISE SPECIFIED.

DATE	DESCRIPTION	BY
01.02.00	ISSUED FOR MANUFACTURE AS SUPPLEMENT TO THE MAIN DRAWING	JG

**Block Diagram**  
SN 4