In details each unit **(A, B, C, D)** is prescribed as follows:

12.2. Section A. Receiving dipoles.

The receiving dipoles consist of: a) the actual electrodes which are put in the ground, and utilize the electrical contact with it and b) the wires that connect the electrodes with the signal-preconditioning unit.

12.2.1. Electrodes used.

Two kinds of electrodes are used with equal results. The first one is the well known **"copper – copper sulfate" non-polarizing electrode,** while the second one is **the metal casing of existing in the area, for a long period of time, boreholes.**

12.2.1.a. Non-polarizing electrodes.

The structure of this electrode is shown in the following figure **(12.2.1.a.1)**.

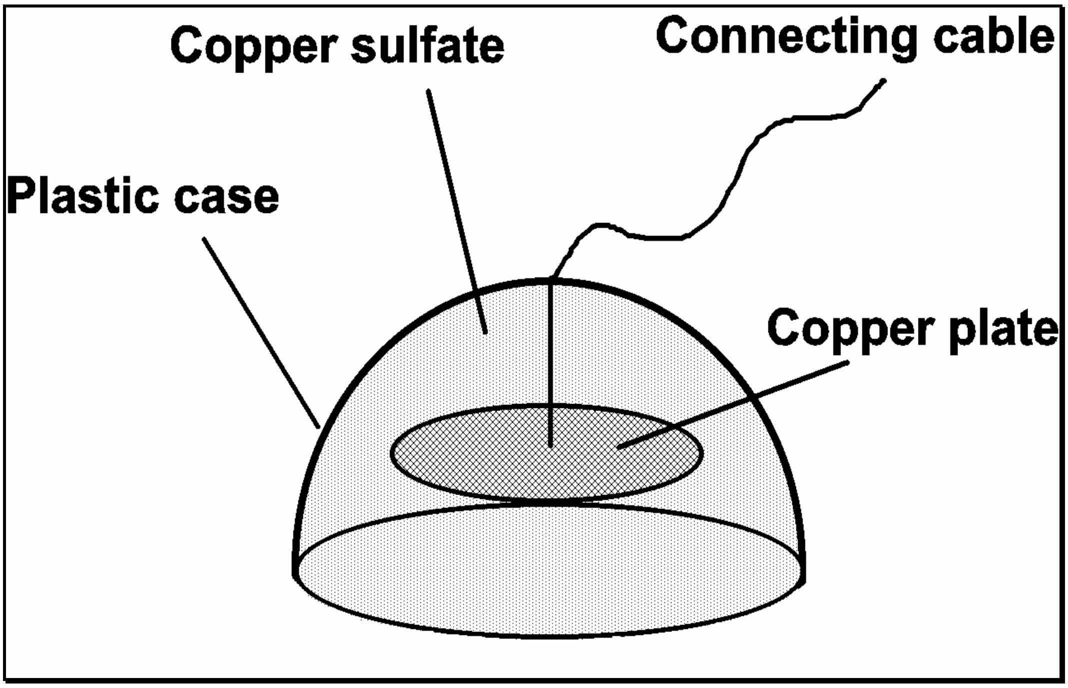

Fig. 12.2.1.a.1. Copper – copper sulfate electrode composition.

A plastic bowl, of about 35cm in diameter, is filled with copper sulfate. In this bowl, a copper disk of 20cm, in diameter, is fitted and its connection to the external circuitry is made via a connecting cable. Electrical connection with the ground is made through the lower surface of the plastic bowl. The copper sulfate remains "wet", due to ground's moisture, for a long period (it has been used continuously for three years in ATH and for more than one year in HIO) without any noticeable malfunctioning at all.

Typical "**contact resistance Rc**", measured for this type of electrode is:

$$Rc = 150 \text{ Ohm}. \qquad (12.1)$$

while the potential, developed, between the ground and the electrode is of a few mV.

12.2.1.b. Borehole metal casing.

This type of electrodes consists of the metal casing of already existing boreholes in the area, where the monitoring station will be installed. The depth extent of the boreholes is variable, but any length from 10 to 100meters is suitable. The problem that was faced with boreholes was that these are not usually located in convenient places, in order to form a typical NS – EW array. Moreover, the distance between them was either small or large thus, prohibiting the installation of a regular, of equal distant dipoles, array.

A typical electrode of "borehole type" is shown in the following figure **(12.2.1.b.1)**.

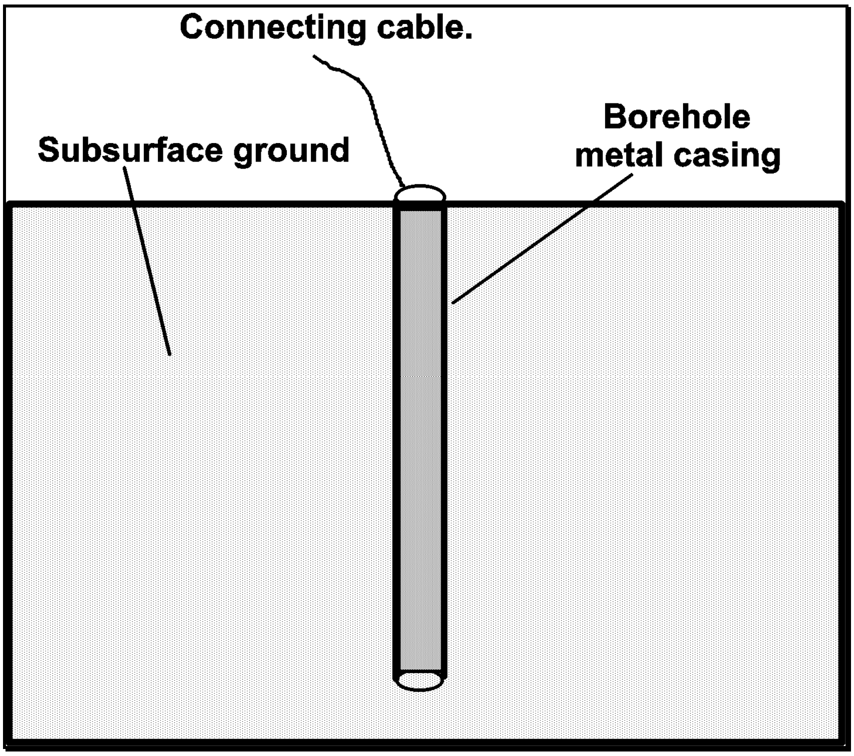

Fig. 12.2.1.b.1. Typical Borehole metal casing electrode is presented.

Typical "**contact resistance Rc**", measured, for this type of electrode is:

$$Rc = 10 \text{ Ohm} \quad (12.2)$$

An objection which arose for the use of such type of electrodes, is that a rather high parasitic, potential develops between the metal casing and the ground, because of the presence of electrolytes in the ground. Although this is correct, what actually happens is that this parasitic potential is cancelled out, in its majority, when a second electrode, of the same type, is used to form the overall receiving, electric dipole. This is shown in the following equation:

Assume that **BH1** electrode develops a parasitic potential **P1** and **BH2** electrode develops a parasitic potential **P2.** Thus, the observed potential difference **dP** between the two electrodes is:

$$dP = P2 - P1 \quad (12.3)$$

Since **BH1** and **BH2** are located in the **same ground environment,** then **P2** almost equals **P1** and therefore, the observed **dP** is expected to be very small.

Another objection which arose for the use of such type of electrodes is that, this exhibit a large amount of drifting, due to change of contact resistance, temperature, water level etc.

The opposite point of view is that, the borehole metal casing that has remained in the ground for a long time period (usually for some years) exhibits very stable behavior, as it has been observed in **PYR** and **VOL** monitoring sites.

Moreover, borehole metal casing is more or less at temperature equilibrium with the deeper, underground formations, due to its high, thermal conductivity. The fact that **differential measurements** are taken, with any pair of boreholes forming an electric dipole, **guarantees data free of any drift that takes place, simultaneously, in both borehole electrodes.**

12.2.2. Cables layout.

These consist of coaxial cable **(RG59)** of which the shield is grounded at the central **(CE)** electrode, while the inner electrode carries the signal. The length of the dipoles depends on local conditions and the presence of installation facilities. In **HIO** monitoring site, local conditions permitted a length of almost **200m** long dipoles to be installed at **NS** and **EW** directions, using non-polarizing electrodes, due to the absence of boreholes. In **PYR** monitoring site, **160m** long dipoles are used, at almost **NS** and **EW** directions, using as electrodes the metal casing of existing boreholes. In **ATH** monitoring site, **20m** dipoles are used only, with non-polarizing electrodes. The dipoles directions of **ATH** monitoring site are **SW-NE**, **SE-NW**.

Experience, obtained, from the results so far, shows that precursory, seismic electric signals can be successfully received, even with small length dipoles, provided that, an effective signal to noise separation scheme, is used. It is characteristic, that a dipole of **120m** located in Volos, Greece, at a distance of **650Km** far from the corresponding epicentral area, detected the precursory electrical signals, generated, by the earthquake in IZMIT (17^{th} August, 1999, M=7.5R).

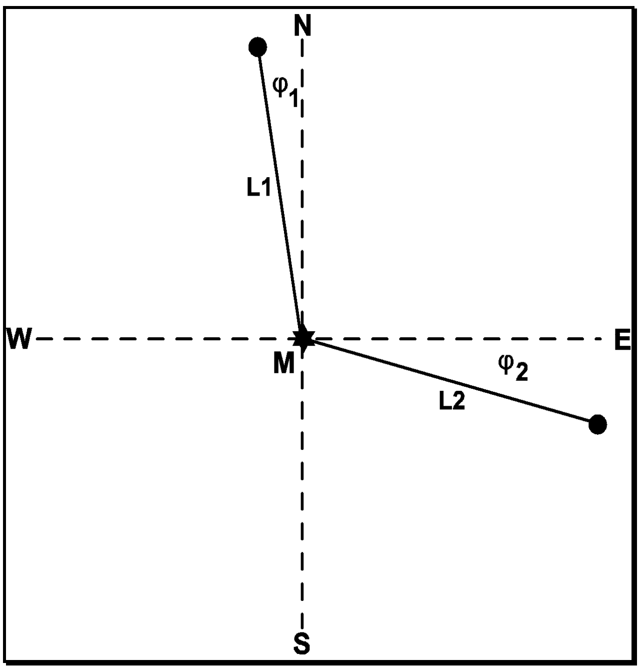

Fig. 12.2.2.1. Typical cables lay out that form the receiving dipoles. **L1** and **L2** are the lengths of the dipoles while **φ1** and **φ2** are the corresponding deviations from true **NS** and **EW** directions.

Problems, met, during the operation of the network are mainly the animal's attack to the wires. Goats and ships like very much the plastic cover of the wires.

Some times, strong winds fatigue and break the wires, thus, producing gaps of data for some hours. Finally, some careless field workers, accidentally, cut the wires during fieldwork.

Consequently, each monitoring site must be supervised by a technician, who will be responsible to repair any damage (mainly in cables), reported, by the central, monitoring, research group.

12.3. Section B. Signal pre-conditioning unit.

This is the "heart" of the monitoring hardware. The following figure **(12.3.1)** will show its importance.

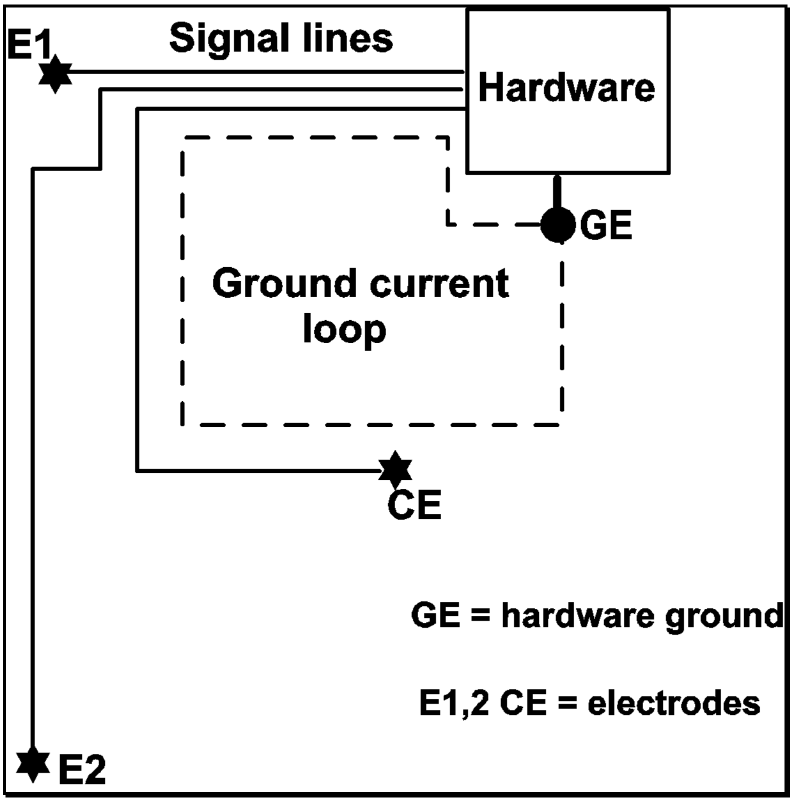

Fig. 12.3.1. Typical "wrong" installation of a monitoring site is shown. A ground current loop is generated, because of the different grounding location of the used dipoles and the main hardware.

In most cases, the field dipoles are located in a certain distance, far from the place where the rest of the registering hardware was installed. This creates a serious problem and induces severe errors in the measurements. The common electrode **CE** is grounded directly at its location, while, at the same time, it is grounded at **GE,** where the main hardware was grounded, through the grounding line of the mains AC supply lines.

The result of these two grounding locations is the generation of a **"ground current loop",** which "distorts", locally, the form of the Earth's electric field that is registered by the two dipoles. The latter, results into erroneous, data obtained and consequently, in wrong, azimuthal direction calculations, too.

Therefore, it is of primary importance to solve this technical problem before commencing into any further data registration and processing. The problem of the **galvanic isolation of the grounding** was solved by using separate, floating power supplies and optical isolators as follows:

12.3.1. Power supply.

The power supply of the preconditioning unit consists of four distinct, floating power supplies **P1, P2, P3, P4** consisting of: the secondary windings of a main transformer (primary 220VAC) of 19 VAC, the rectifying unit and a voltage regulator of 13.5V. These separate power supplies continuously charge four 12V batteries of 2Ah each. Therefore, this unit serves as a UPS system for the preconditioning unit. The power supply is shown in the following figure **(12.3.1.1)**.

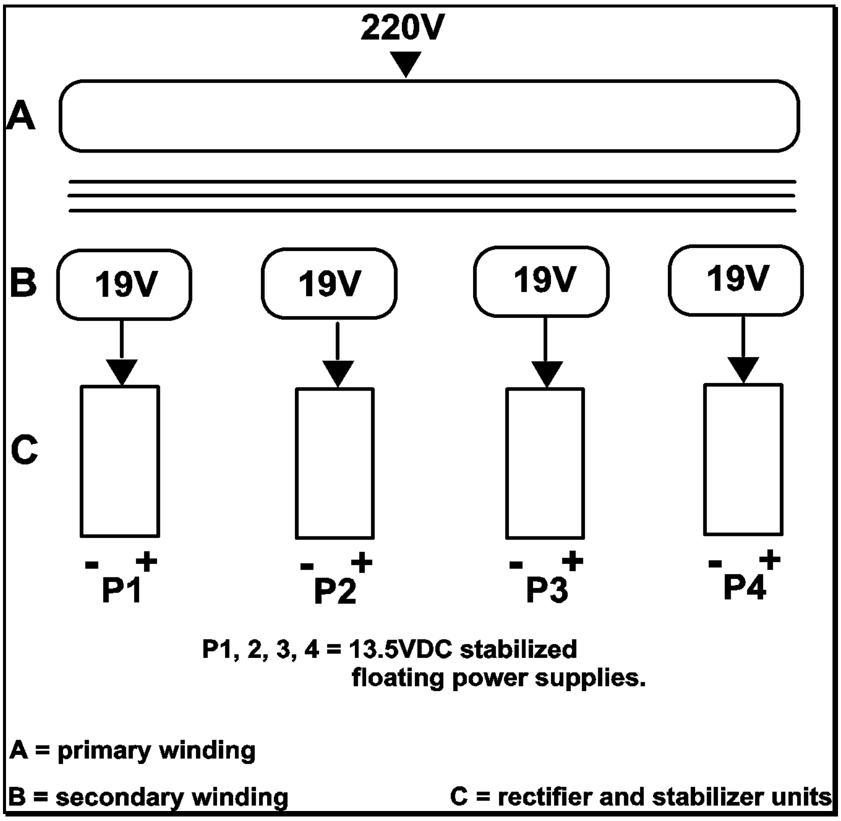

Fig. 12.3.1.1. The used power supply and UPS for the preconditioning unit.

12.3.2. Front end.

From this section and on, all operational amplifiers are considered as powered by **+ / - 9V** and by-passed in the traditional way.

The front end of the preconditioning unit **(fig. 12.3.2.1)** serves two purposes. The first one is to protect the monitoring site hardware from any lighting discharge that could destroy the entire system, while the second one is to balance out any parasitic, stable, potential, developed at the electrodes.

Lightning and overload input protection is achieved through **R1** and the pair of zener diodes **Z,** connected back to back. The combination of **R1-Z** forms a clipping system, having set the clipping level at +/- 7 volts, which is within the working dynamic range of the **Op-741.**

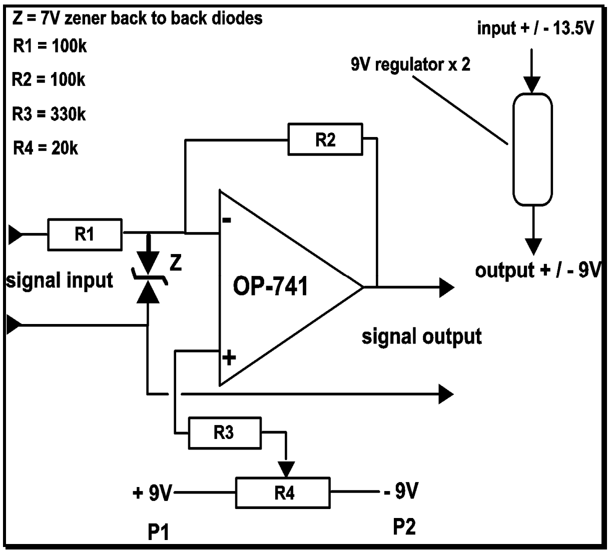

Fig. 12.3.2.1. Lightning protection and parasitic potential balance out circuit is shown.

The parasitic potential is balanced out through the **R3 – R4** system. In practice, an opposite, in sign and level, potential in respect of the parasitic one, is fed into the **Op.-741** through the potential divider **R3 – R4**. The front-end unit is powered with **+/-9V** dc, obtained, through a voltage regulator, powered, with **13.5V** from **P1** and **P2**. The double stage regulation of the power supply of the **Op.-741** serves as a protection against any excessive discharge of batteries, when a very long period of time power failure takes place.

12.3.3. Optoisolator.

This unit serves the main purpose of galvanic isolation. To this end, the **A7800** optoisolator is used. The detailed circuitry is shown in the following figure **(12.3.3.1)**. Bypassing of power of **Op. 741** and **A7800** is applied, as usual. Care must be taken for the **A7800,** for keeping the used bypassing capacitors leads as short as possible.

At the input, the signal fed from the previous section is lowered about 50 times for preventing saturation of the **A7800** since it is a low-level potential optoisolator. The original signal level is restored back through the next **Op.741**.

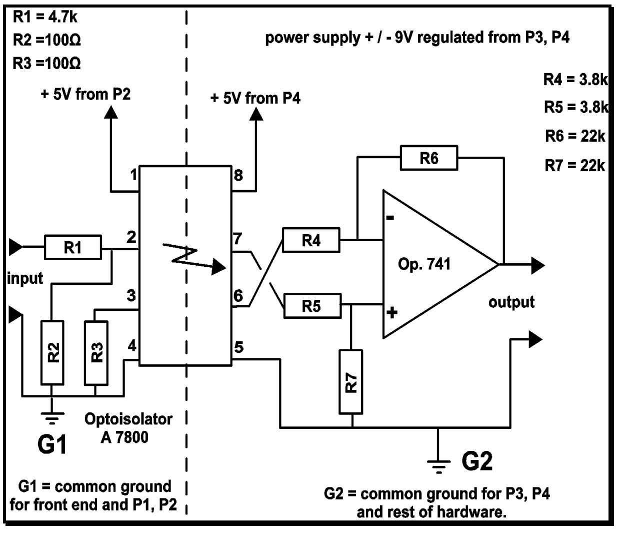

Fig. 12.3.3.1. Detailed, optical isolation circuitry, used, in the preconditioning unit.

The main feature of this unit is that the first part of the **A7800** is powered with **5Vdc,** obtained from **P2,** while the rest of the circuitry is powered from **P3** and **P4**. Consequently, there is **no galvanic connection** between the front end **(12.3.2)** and the rest of the hardware.

In case that a lightning strikes nearby and the clipping circuitry fails to operate because it has already been "evaporated", then the damage will be limited to just one **Op.741** and one **A700**. The rest of the hardware will remain safe. So far, within the 4 years period of operation, no such damage took place in any of the operating, monitoring stations.

12.3.4. Low-pass, band-pass filters.

Two filters process the optoisolated signal. The first one is a low-pass active filter while the second one is a pass-band active filter (Graeme and Tobey 1971; Mitra and Sanjit 1971; Moschytz 1975).

12.3.4.a. Low pass active filter.

The low-pass filter is implemented in figure **(12.3.4.a.1)**. The upper band limit is set to 30 seconds. In other words, signals with periods shorter than 30 seconds are rejected.

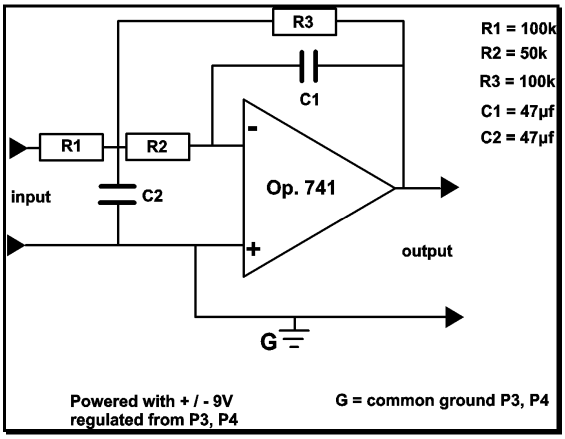

Fig. 12.3.4.a.1. Low-pass filter implementation is shown. Upper band limit is set to 30 seconds.

12.3.4.b. Band pass active filter.

The band-pass filter is implemented in figure **(12.3.4.b.1)**. The center band period is set at 24 hours.

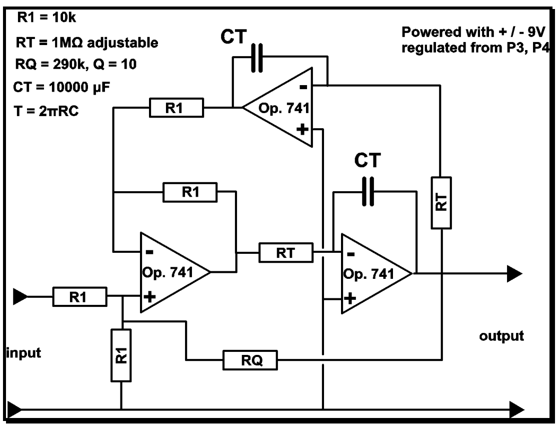

Fig. 12. 3.4.b.1. Band-pass filter implementation. Center band period is set at 24 hours.

The purpose of this filter is to extract, from the raw data, the daily, tidal, lithospheric oscillating signals, which are generated by the tidal waves. The same type of oscillating signals can be obtained from the low-pass filtered data, through the use of an FFT band-pass filter. The difference between the two methods is that **the band-pass filter generates real-time oscillating signals,** in contrast to **the FFT method that is applied “a posteriori” on a data set**. In practice, since the evolution of a preseismic signal lasts for a few days, there is no practical “predictive” difference between the two methods which are used.

12.3.5. Signal amplification.

This part of hardware **(fig. 12.3.5.1)** serves a specific reason only. It has been added so that the resolution of the registered signal increases beyond the **12 bit capabilities of the ADDA card.**

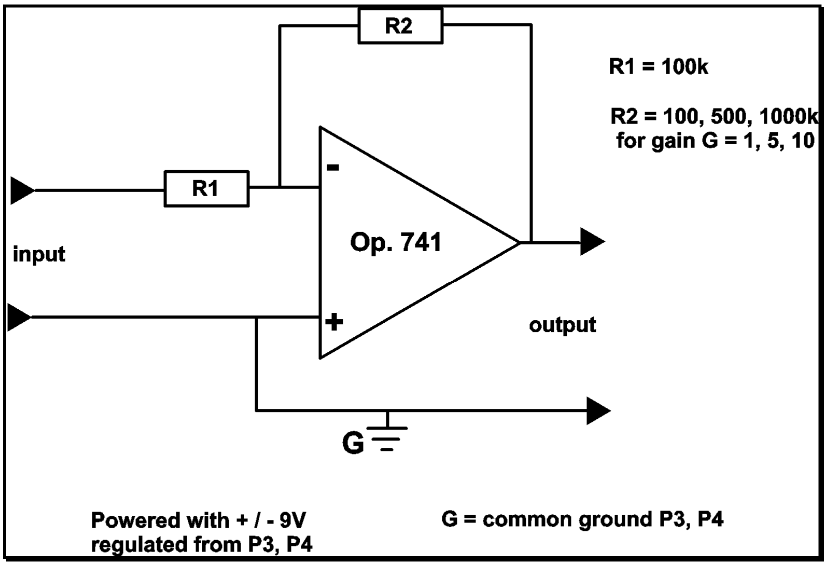

Fig. 12.3.5.1. Signal amplifier with selectable gain (1, 5, 10).

Its operation is as follows:

Let us assume that a **10mV** signal enters the system. Moreover, a +/-5V ADDA 12Bit card is used for digital conversion.

Then, each step of conversion (resolution) equals:

5000mV / 4096 (12bit) = 1.22 mV.

The 10 mV signal will correspond to **10mV/1.22mV = 8.2 steps** of conversion.

Next, the 10 mV signal is amplified 10 times and becomes 100 mV. This signal corresponds to 82 steps of conversion. During the final processing of the signal, this is divided by 10 so that the original signal amplitude is obtained.

Consequently, the resolution of the entire system (signal amplification – ADDA card – signal amplitude restoration) becomes **0.122mV/conversion step**.

In practice, the 12bit ADDA card, through the use of this amplifier, behaves as a 15bit ADDA card! In simple words, the dynamic range of the ADDA card is much better exploitated by increasing the low level signal amplitude, as long as it remains in the dynamic range of the ADDA card.

In the following figures are presented examples of recordings which were made by using this technique. The first figure **(12.3.5.2)** represents a typical 12Bit ADDA card. Its resolution is 1mV. In 4mV recording amplitude it corresponds to 4 sample amplitude levels.

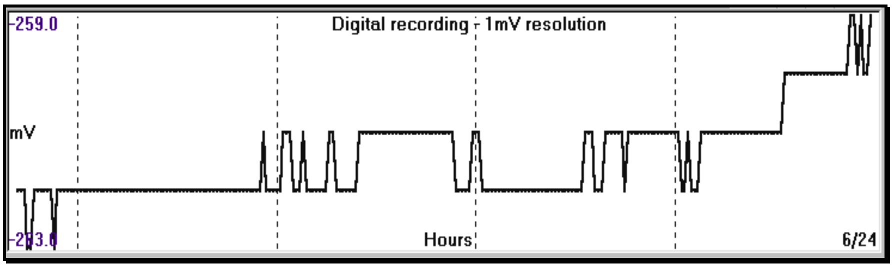

Fig. 12.3.5.2. Typical, digital recording made by a 12Bit ADDA card. Resolution = 1mV, recording amplitude = 4 mV p-p.

Next example **(fig. 12.3.5.3)** represents the digital recording made by a 12bit ADDA card after the pre-amplification of the original signal for 10 times. The increase of the achieved resolution is self-evident, between figure **(12.3.5.2)** and figure (**12.3.5.3).**

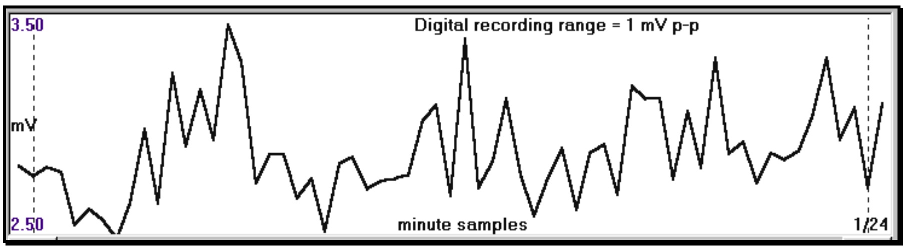

Fig. 12.3.5.3. Digital recording made by a 12Bits ADDA card and the use of an amplifier of Gain = 10. Resolution = 0.1mV. Recording amplitude = 1mV p-p.

A close-up view **(fig. 12.3.5.4)** of the previous presentation **(fig. 12.3.5.3)**, which indicates an improved resolution of 0.2 mV, is shown next.

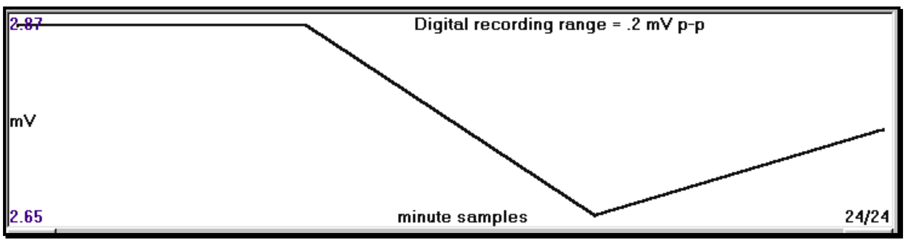

Fig. 12.3.5.4. Amplitude potential difference observed, between two random consecutive potential samples. Resolution = 0.2 mV.

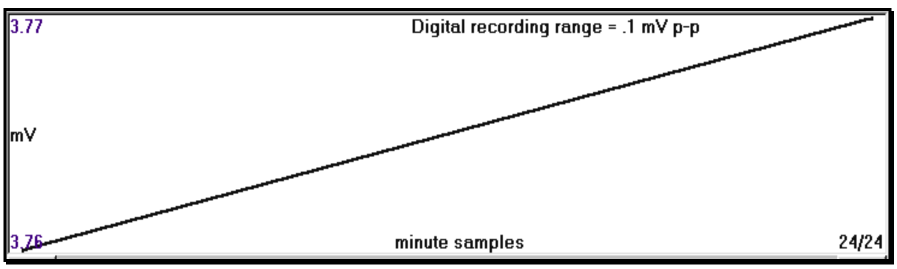

Fig. 12.3.5.5. Best resolution, observed, of 0.01 mV between two consecutive potential samples which present the least observable potential difference.

Finally, a generalized presentation, concerning the performed galvanic isolation in the preconditioning unit, is given **(fig. 12.3.5.6)**.

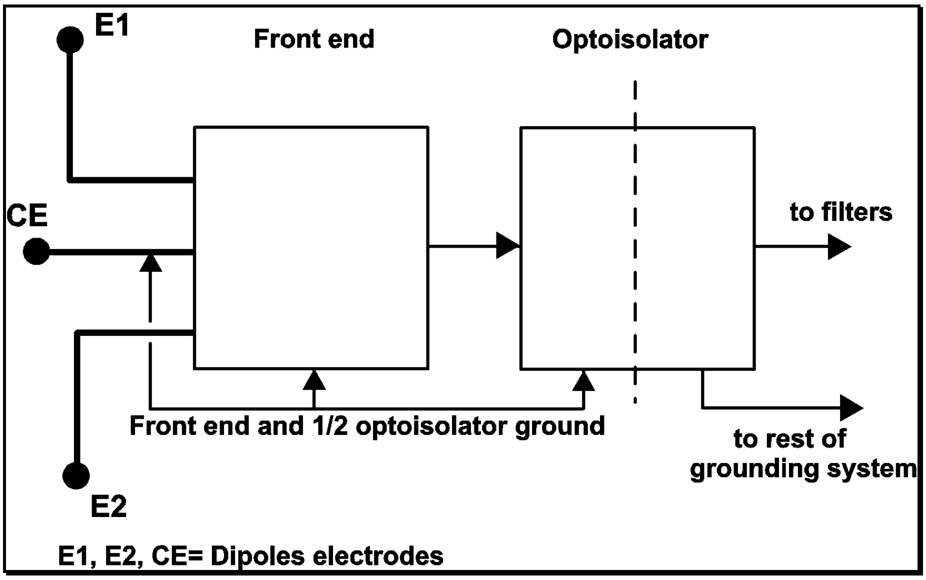

Fig. 12.3.5.6. Block diagram, representing the galvanic isolation scheme, used, in the preconditioning unit.

The dipoles, the front end and the first half of the optoisolator use, as ground, the common electrode **CE**, while the rest of the hardware uses a second common ground which does not affect the potential measurements at all. The electrical signals are transferred from the front end to the rest of the hardware, through the optoisolator, with no galvanic connection at all.

12.4. Section C. Desktop computer.

The desktop computer unit consists of: the main computer itself, the ADDA card and the communications software. We preferred this solution, to build the monitoring site, because it is a cheap one, since it does not require expensive, registering hardware. Old-fashioned computers are found almost at no cost.

12.4.1. Analog to digital conversion card.

The Decision Computer International Group 12BIT ADDA card is used, as an analog to digital conversion card. The card is readjusted from its default potential input of +/- 9V to +/- 5V. The ISA slot type was selected, since this is the most common slot, found in the majority of the old-fashioned computers.

12.4.2. Desktop computer.

The desktop computer, which is used, can be of any type capable of cooperating with ADDA cards. What is important, of its features, is the CPU frequency. Data samples of 30000 – 40000 samples / minute were achieved with frequencies of 100 – 133 MHz.

The operating system of Microsoft windows (Windows 98SE or later) was found to be very useful for implementing all the necessary programming, required. Moreover it allows a large variety of communication software to be installed and convert the computer into a host server.

Before the start of the operation of any computer, care must be taken so that:

- Any messages, at the start up of the operating system, must be turned off. Otherwise, at any power interrupt and the subsequent startup, the operator should answer all these questions, asked, by the operating system. The main idea is to automatically restart up the computer, after any power failure, in "blind mode".

- Summer time facility must be turned off to avoid time errors, due to automatic change from **winter time** to **summer time** clock and vice versa.

- A problem, sometimes, met, is "clock drifting". It is caused, either by low battery on the motherboard, or low quality motherboard. In any case, observed, typical "clock drift", is of the order of 1-2 minutes per week that is adjustable each time (daily) the host computer is visited, to download the data files.

12. 5. Modem.

Communication with the central offices is utilized by an external, typical modem and dialup operation, through public telephone network.

The entire setup of the monitoring site is shown in the following figure **(12.5.1)**.

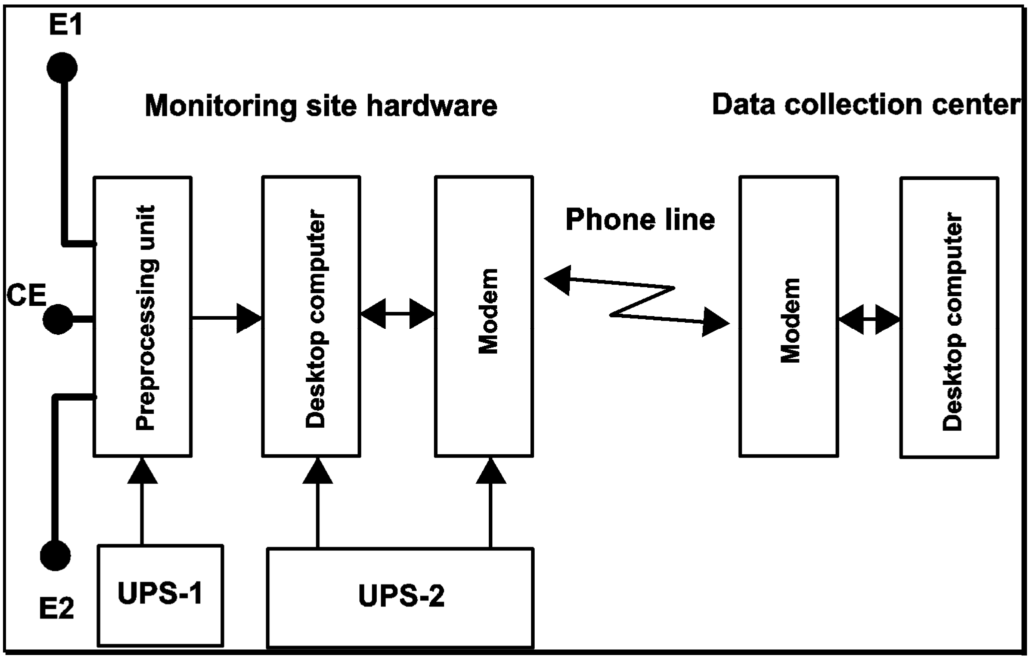

Fig. 12.5.1. The entire setup is shown of the monitoring site.

What is important in this setup is the fact, that two separate **UPS** are used. The first one **(UPS-1)** provides power to the preconditioning unit. Its operation on power failure can last for a few days since the current consumption of this unit is very low (a few mA). The second **(UPS-2)** provides with power the computer motherboard and its peripherals. Its duration depends on the batteries, which are used by the **UPS-2**. It has been found that its operation lasts for 3.5 hours with a 15Ah battery.

13. DATA DESCRIPTION CONTAINED IN CD.

Closing the presentation of this earthquake prediction methodology I think it is important to provide the interested reader with all the raw data, acquired, from the monitoring site, in operation, till the time of publishing of this book, so that he is capable of testing all the techniques, presented, herein.

The following data are provided in a CD form, in order to facilitate this test:

1. Map of Greece.
2. Geographical coordinates of the already installed three **(PYR, ATH, HIO)** monitoring sites.
3. Dipole length, its azimuthal direction and used polarity for the dipoles of each monitoring site.
4. Format of registered, preseismic, electrical signals raw data at each monitoring site.
5. Data files of registrations from **PYR, ATH,** and **HIO** monitoring sites.
6. Format of earthquakes catalog file.
7. Earthquake catalog file of the seismicity of Greece, which took place from 1901 till the day of publication of this book.
8. Format of data file of magnetic field.
9. Data files of the magnetic field variations, observed, at the Magnetic Observatory of Penteli **(MOP)**, Athens, Greece. This file spans for the period of time, covered, by the registration of the Earth's electric field in **PYR, ATH** and **HIO** monitoring sites.

It must be stressed out that all time-references are in GMT time zone mode.

I believe that, in the future, another scientist will improve this methodology or even better he will find a much more effective scheme for predicting earthquakes, based on deterministic methodologies of the laws of Physics.

In case you need help I'll be glad to answer your questions and provide clarifications to any topic, presented, in this book. Please do not hesitate to contact me.

Moreover, in case you find any error I will appreciate it very much, if you report it to me immediately at my e-mail, so that I can fix it in the next publication.

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