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ONE SOLUTION FOR REALISATION OF ELECTROLOG PROBE IN GEOPHYSICAL MESUREMENTS

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Abstract: *When testing the properties of soil in geophysical measurements (GPM),we are using different probes for measurements. This probe is an upgraded version of electrolog probe for measuring electrical resistance of soil. Some of the critical features of these probes is power consumption, resistance to interference and the number conductors from the ground surface to the probe. Here is shown an improved solution in terms of consumption electrical energy, number of cables, immunity to interference and it improves compatibility in GPM measurements.*
Keywords: ***GPM measurement / electrolog probe / measurement of the resistance of the soil / borehole.***

1. BOREHOLE GP MEASUREMENT

In the process of development wells, to determine the geological formation and physical properties of soil it is necessary to perform measurements of various geophysical quantities. These measurements are commonly called geophysical measurement (GPM). Measurements are performed using probes which are lowered to the bottom of the borehole and then lifted up at constant speed, so that the measurement and transferring of the measured parameters to the surface unit are carried out simultaneously.

Probes are consisted of: sensors to measure data of interest, electronics for processing signals from sensors and communication unit. In industrial practice it is common to connect multiple probes in series in electrical and mechanical sense, and this tread is called a string. Since the sensors that are within the measuring probes provide continuous information of the measured data, it is necessary to modify these signals before sending, in the form which is pre-defined by communication protocol.

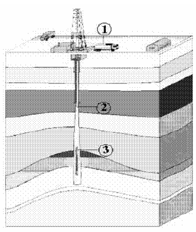

Figure 1. *GPM system for borehole testing*

The main components of GPM system are (figure.1):

1 - surface unit for analysis and monitoring of measured results

2 - cable for lowering the probe through the tested well and communication link between the measuring instruments and surface units.

3 - measuring probe.

On the other side of the electro-mechanical cable in addition to equipment for lowering and raising the probe is computed surface units.

Common versions of electrolog probes were manufactured so that the entire electronics was located on the surface in a surface unit and the major problem was that the measured signal from the bottom of the bor-hole had to pass through cables to a surface unit and electronics for signal processing which had result in entry of large disturbances in the useful signal, and signal processing on the surface has been also compromised due to the adverse impact of the surrounding devices. Also one of the problems was the large consumption of energy due cable losses because the power of the system was on the surface and the probe, which is powered, where located at the bottom of the borehole. Also one of the important factors is the number of conductors in cable because the price of cable increases with the number of conductors.

2. SOIL ELECTRICAL RESISTANCE MEASURING

The first probes that have appeared in use were designed to measure specific electric resistance (SER). They were modification of surface geo-electrical devices that are used for specific detection of electric conductance anomalies below the earth's surface. Vertical version of surface system is the first probe used in borehole measurement. Since now, probes were developed in five different families for measuring the SER. These are:

1. Electric probe
2. Inductive probe
3. Lateral probe
4. Micro-resistant probe
5. Dielectric probe

3. ELECTROLOG PROBE

The functionality principle of the probe is given in Figure 2 which is based on that we set up a controlled source of constant current between the electrodes A and B (Figure 2). As the points A and B are at a great distance from the ground surface, and in a sufficiently large distance between each other the whole system can be viewed as that the top of the probe is point source charge contained in the infinite homogeneous isotropic material. If we assume that then follows:

$$V(r) = \int_{r}^{\infty} \vec{E}\,\vec{dr}$$

$$E = JR \Rightarrow J = \frac{I}{4\pi r^2}$$

$$V(r) = \frac{IR}{4\pi r}$$

In the classic versions of electrolog probes reference electrode is located on the surface, and how this electrolog is powered with one cable, Bridle electrode has function of a reference point. When current flows from point A to B through the soil, the voltage occurs between the electrodes 16"and Bridle and 64 " and Bridle electrodes which is proportional to the resistance of the soil . By measuring this voltage, based on knowing the current through the soil we can determine the soil resistance and thus find in what type of land is probe currently testing?

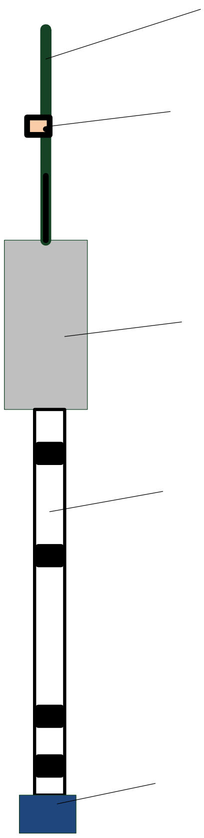

Figure 2. *Probe*

- The probe is lowered by metal shielded one-wire cable which is data and power cable in the same time. (Figure 2-mark 1).
- Five meters from the electronics there is *bridle* electrode (Figure 2-mark 2) which is common point for voltage measurement of electrodes 16“and 64”.
- 5m after that there is 1.2m length aluminium tube. This tube is casing for complete electronics of the probe (Figure2-mark 3).
- At the end of the aluminium casing 5m length four wire cable is placed which on itself has contacts for current A and B electrodes and measurement 16” and 64” electrodes. (Figure2-mark 4).
- At the end of the cable is a weight which helps moving the probe through the borehole (Figure 2-mark 5).

4. SYSTEM DESCRIPTION

Electrolog probe consists of a receiving part, transmitting part, galvanic separated power source and the input block for two-way communication with the surface unit.

Transmitting part of the probe sends controlled AC current through the ground between the electrodes A and B, and performs communication with the receiving part of the probe.

Receiving part of the probe measure voltage between electrode 16 "and 64" in relation to the bridle electrode, communicates with the transmitting part of the probe, processing results and forwards them to line drivers.

Input block is designed to power the entire probe and to perform two-way communication with the surface unit through one-wire cable at the same time.

Each part of the probe, receiving and transmitting, has a galvanic separate power supply. Power supply must be galvanic separated in order to, in the case of transmitting part, have closed circuit between the current electrodes A and B, and not to the rest of the system, in case of the receiving part to have undisturbed measurement of 16 and 64 electrode. Both of the supplies are switching type power supply, primarily because it is so easy to make galvanic separation (because we have DC input voltage, and transformers can not be directly used), and because they significantly reduce the elements power losses, so that there is no significantly heated parts which can further increase the temperature in probe, which is normally very large in the deeper wells. Block scheme of the probe is shown in Figure 3

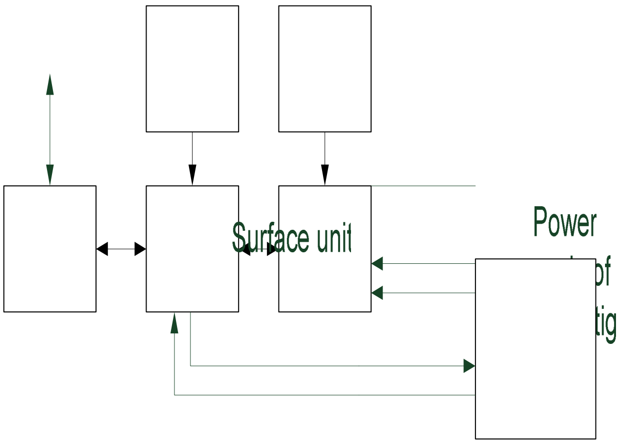

Figure 3. *Block scheme of the probe*

1. INPUT BLOCK

The input block is a subsystem for data transfer.

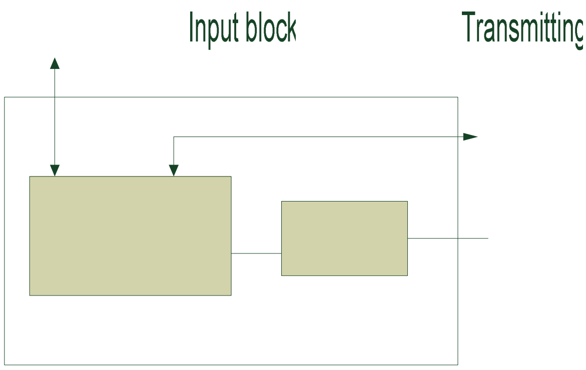

Figure 4. *Input block*

Subsystem for data transfer in borehole measurements is used primarily for transmission of measurement data from the probes to the surface computer unit, and vice versa, in the form of electrical impulses, with pre-defined voltage levels and duration in accordance with the communication protocol.

Since the electromechanical cable is usually one-wire cable with shield which is used as well as feedback cable, as is our case, the power and data are sent to the same line, with this subsystem is necessary to make the separation of the DC component and the communication signals. In order to do this easily, information which are transmitted is first processed in a signal that is suitable for transmission in the form of negative voltage impulses with predefined duration. These impulses are "impressed" in voltage (voltage drop) on the line, so we can easily detect them on the reception side. The advantages of this type of signal transmission are simple implementation and robustness of transmitting and receiving systems, as well as a correct data transfer.

2. TRANSMITTING

Key part of the transmitting part o the probe is current source. Current source is constructed as a linear current source in combination with h-bridge. With this we have achieved that we have implemented a relatively simple alternating current source. The principle on which this is achieved is presented in figure 5.

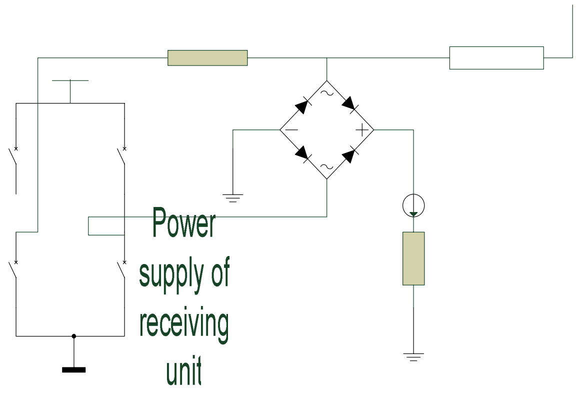

Figure 5.*Current source*

The linear part of the current source provides a constant direct current that can be selected to be in the range of 1mA to 100mA, and that thanks to the diode rectifiers and h-bridge, sensor "sees" as the alternate current source, the frequency of H-bridge switching, in this case is about 1 kHz. By measuring the voltage drops on the probe we can determine whether it is necessary to change the current range in order to make more precise measurement of resistance. Voltage is measured with precision operational amplifier that is coupled with the micro controller. When controller receives information that it is necessary to adjust the range, control signal is sent to the relays who made the change range of current.

Control of the transmitting part of the probe was done by the controller ATmega8, which has a duty to control H-bridge, communication with the receiving part of the probe and to make correction in the range of current sources if it is necessary. Current range change is done with resistors. Each resistor combination represents one range, which is selected by switching relays.

As a task that should be done is not very demanding, 8-bit controller ATmega8 with 8KB of memory with built-in module for serial communication and relatively low cost is proved to be ideal for performing this task.

Complete transmitting part of the probe was powered from separate power supply that is galvanic separated from the receiving block of the probe. We have used a flyback switching power supply that was supposed to provide a voltage of 80V and current of 200m for power source, and there are also power feeds of 20V for electronics that were after reduced to the 5V or 12V. It is important that this power supply must be galvanic separated from other power in the probes, because thus we can control the current sources closes between electrodes A and B.

3. RECEIVING PART

The second part of the probe is receiving part. Heart of receiving part is the dsPIC30F4012 controller that performs processing of measured signal and very precise 14-bit AD converter max1033.Probe measures voltage on the electrode 16 "and 64", which depends on the resistance of soil and of transmitted current that probe sends. High frequency signal which we are extracting from the electrodes 16" and 64" is a useful part of the signal from which we can calculate the resistance of the soil. HF filter eliminates DC signal from the current source which represents the own potential (OP). It should be noted that the value of SP is about mV and the accuracy and immunity to interference in the elements that perform the signal processing is of crucial importance.

In order to make accurate measurement, low-noise switching power supply was made which is galvanic separated from other power supplies in probe. Power supply of receiving part of the probe provides symmetrical voltage of + /-15V.

Voltage measured at the electrode probes (16 "and 64") was first passed through a first input buffer (Figure 6), and then each channel after the buffer leads to the HF filter that needs to separate useful signal from its own potential (OP) . HF filter is a Bessel-type with two poles. Thus, filtered signals are amplified with operational amplifier and after amplification led to 14-bit AD converter max1033.

How are signals that are measured at the reception are very small and require precise acquisition, AD converter max1033 is currently selected as the best possible solution because it has eight 14-bit channels that can measure signals of + / - 12V.It demands only one power supply of 5V and can perform acquisition of 115ksps

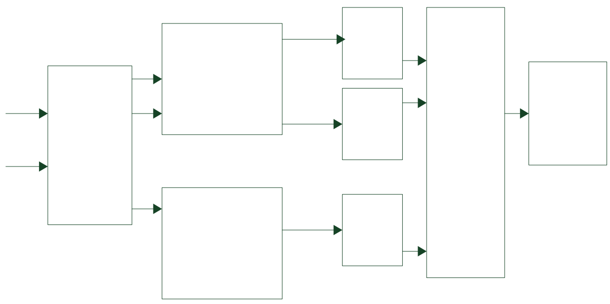

Figure 6. *Block scheme of receiving part*

One feed from the electrode of 16" probe was passed through a LF filter with 10 Hz cut-off frequency. After that, signal was amplified. After amplification it was led to a free channel AD converter max1033 (Fig. 6). This signal represents an own potential (SP).

After processing these analogue signals and converting them to digital signals, they were transferred to the controller dsPIC30F4012, which calculates resistance based on the received data and makes data packages, which are transferred by line driver to the surface unit.

5. SURFACE UNIT

For data acquisition we used the "WellScan" software which is a complete solution for control and acquisition. This software controls the mechanism by which the probe is lowered into the borehole, captures data sent by the probe and record the depth at which the probe are sending data. Software also takes care about the tension wires, which contains the probe. The interface software is simple and intuitive.

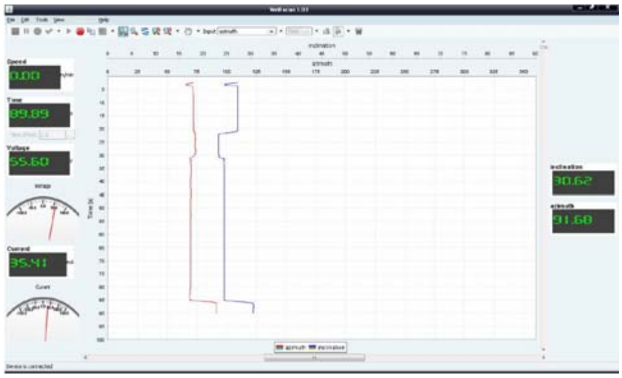

Figure 7. *WellScan software*

6. CONCLUSION

All these problems that we encountered in the classical electrolog probes we have solved in this way that we have managed to complete power supply, current source and electronics for signal processing in the pipe of the probe. We have achieved this so that the entire probe was made in the SMD technology. We got that we need only a cable with two wires, which are also power lines and lines of communication, and one Bride electrode. By placing the electronics in the probe we achieved that electronics are far enough away from the surface disturbances and bad influence, and because digital of digital data transfer to the surface was done by line driver we have avoided a bad impact of the cable that exists in classical probes.

7. REFERENCES

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Amplifier
16'
16'
HF filter
16'
64'
controller
64'
dsPIC
Amplifier

AD convertor
Input buffer
64'