—研究ノート—
Scientific Note

Development of High-performance Amplifier of ECM-system for Ice Core Analysis and Data Management

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氷床コア解析のための ECM 増幅器の改良とデータ処理

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要旨: これまで使用されてきた ECM (Electric Conductivity Measurement) 装置の電流増幅器の部分の改良を行った. 主な改良点は, 電流増幅器の性能向上による雑音の逓減とフローテング回路を採用し, あらゆる点の絶縁性をよくしたことである. その結果, 同じ場所での数回の測定に対して再現性のよいデータが得られた. このデータは, また, パソコンで即時処理されるようにした.

Abstract: An ECM (Electric Conductivity Measurement) apparatus was improved by reconstructing the current meter amplifier. The main improvements were reduction of noise and improvement of reproducibility, and adoption of a floating circuit. Further, the ECM amplifier was connected to personal computer for storage of data. Repeated measurements on the same sample indicated good reproducibility.

1. Introduction

ECM (Electric Conductivity Measurement) is a very simple and effective method to find impurities such as volcanic ash in an ice core (HAMMER, 1980). The development of an ECM-system was required for *in-situ* measurement for deep ice cores recovered at Dome Fuji Station, Antarctica. Since the measurement has to be done in the vicinity of a drilling system which makes cosiderable noises, minimizing the counter noise from them was necessary for the ECM-system.

In the present paper, characteristics of the new amplifier for the ECM-system and its improvement process are described.

2. Electric Circuit Design

A block diagram of the ECM system is shown in Fig. 1. The electrode, to which the voltage of DC 1250 volt is applied, is run on the cleaned surface of the ice core. Then, the small current between the electrodes is measured through the improved amplifier. In Fig. 1, the thick solid line rectangle shows the ECM amplifier. In the shaded area in Fig. 1, the circuit is "floating" when viewed from

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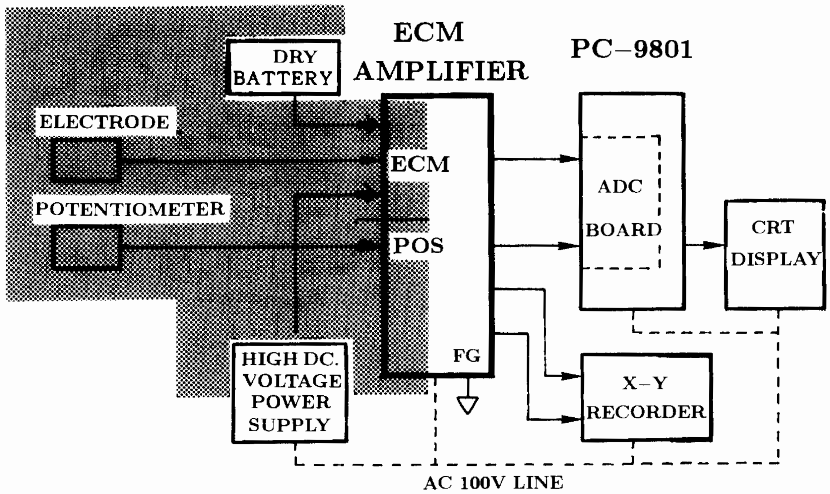


Fig. 1. *Block diagram of ECM-system. The thick solid line rectangle in the center shows the ECM amplifier. In the shaded area, the circuit is "floating" when seen from the output side of the ECM amplifier.*

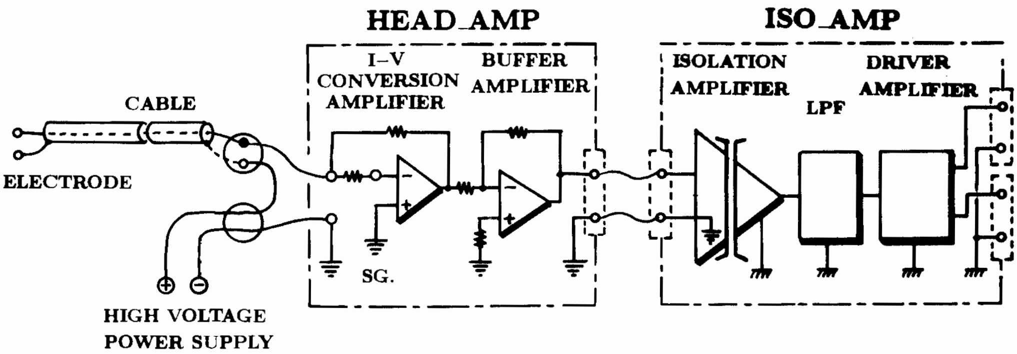


Fig. 2. *Simplified diagram of ECM amplifier.*

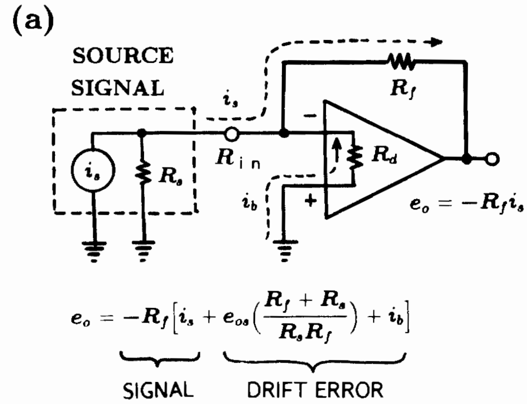
the output side of the ECM amplifier. Figure 2 shows a simplified block diagram of the ECM amplifier. The amplifier consists of a HEAD-AMP and an ISO-AMP as shown in Fig. 2. First the HEAD-AMP transforms the small electrode current linearly into voltage. The obtained voltage is transmitted to the isolation amplifier in the ISO-AMP and further to the LPF and to the driver amplifier.

The input and output are isolated from each other in the isolation amplifier. If the output works as a base, the input becomes floating. Advantages of using the isolation amplifier are as follows: (1) The grounding for output and signal are separate from each other. A ground loop is not made. If the ground loop would be made, noise would be generated through the loop; (2) The circuit is convenient to receive signal which is transmitted from the high impedance electrode at a high noise level; (3) The amplifier is easily able to reject Common Mode Voltage and Common Mode Noise. Common Mode Voltage is the voltage difference between the real signal-voltage and the input voltage (BURR-BROWN Product Data Book, 1993/1994, by Burr Brown Japan, LTD., 3-2∼3-3). As a result, an accurate signal is obtained by delimiting the noise substantially. Furthermore, this amplifier avoids failures due to electrical accidents.

The LPF is a biquadratic Chebyshev's low pass filter. The attenuation coefficient is 42 dB/oct. The cut-off frequency was set to 33 Hz considering the sliding speed of the electrode on the ice sample. The last amplifier in ISO-AMP is a driver amplifier. This can send a suitable signal to the A/D conversion board and X-Y recorder as load.

(A) Design of the HEAD-AMP (Amplifier of current meter)

The design of this amplifier is important for high quality performance of the ECM-system. Therefore, the selection and composition of the operational amplifier were paid considerable attention in order to gain maximum performance. A simpler method to measure the current is to make the voltage-drop by load-resistance R_f (in Fig. 3b) and use a non-inverting high input impedance amplifier. However, this method have many defects compared with the circuit in Fig. 3a as follows: (1) The non-inverting amplifier generates a Common Mode error; (2) The ideal amplifier of a current meter should have zero-impedance, but its R_f should be large in order to have high measuring sensitivity; (3) In a non-inverting amplifier, for the input impedance R_{CH} changes with temperature and a load which is applied to R_f fluctuates with the temperature change of R_{CH}. As a result, the output is erroneous. These problems can be resolved by the amplifier shown in Fig. 3a. In this amplifier, the open loop gain is made sufficiently large and the input impedance is minimized to the minimum. As a result, the voltage drop in the measuring circuit can be essentially avoided. In order to produce the above mentioned current meter amplifier, it is essential to use the operational amplifier which has low noise and low current drift (Analog Devices Linear Data Book, 1992/1993, by Analog



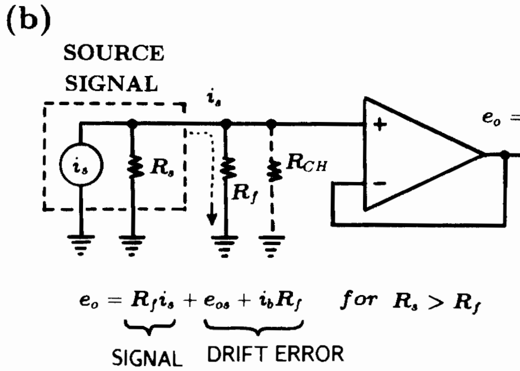


Fig. 3. Basic circuit for current meter amplifier. (a) Current meter amplifier, where, i_s: current of source signal, R_s: impedance of source signal, R_{in}: input impedance, i_b: input bias current, R_d: input impedance of internal of operational amplifier, R_f: load resistance. (b) Voltage amplifier by sampling register, where, i_s: current of source signal, R_s: impedance of source signal, R_{CH}: input impedance, R_f: load resistance.

Table 1. Main specifications of AD549J.

Input impedance	$10^{15}//0.8\Omega//pF$ (Common mode)
Input bias current	250 fA
Input current noise	0.7 fA_{P-P}
Input offset voltage	1.0 mV

Devices, Inc., 4-19~4-20). Specifications of current meter the amplifier are shown in Table 1.

(B) Mounting of the current meter amplifier

In order to gain maximum performance of the operational amplifier for current meter, layout and mounting of electric parts on a PCB (Print Circuit Board) is essential. In the case of a high input impedance circuit, the operational amplifier should be placed as close as possible to the signal source, in order to minimize leak current, intermixture of noises and stray capacity. Furthermore, the difference of electric potential between the input of amplifier input pin and other pins (or circuit patterns of parts on the PCB) may cause a parasitic current which flows in the signal channel. Therefore, if we pay no attention to the design, the current easily exceeds the input bias current of AD549J. In mounting the amplifier, in order to prevent the phenomena described above, the cable and feedback resistance, which tend to have very small leak-current, are soldered directly to the insulated Teflon stand-off. A stain on the PCB made at the time of soldering is removed by isopropyl alcohol. In order to prevent mixing of the parasitic current to the input of the amplifier a sensitive Zener diode: ESD (Electric Static Discharge) was used. Figure 4 shows the HEAD-AMP. The relationship between input current and output

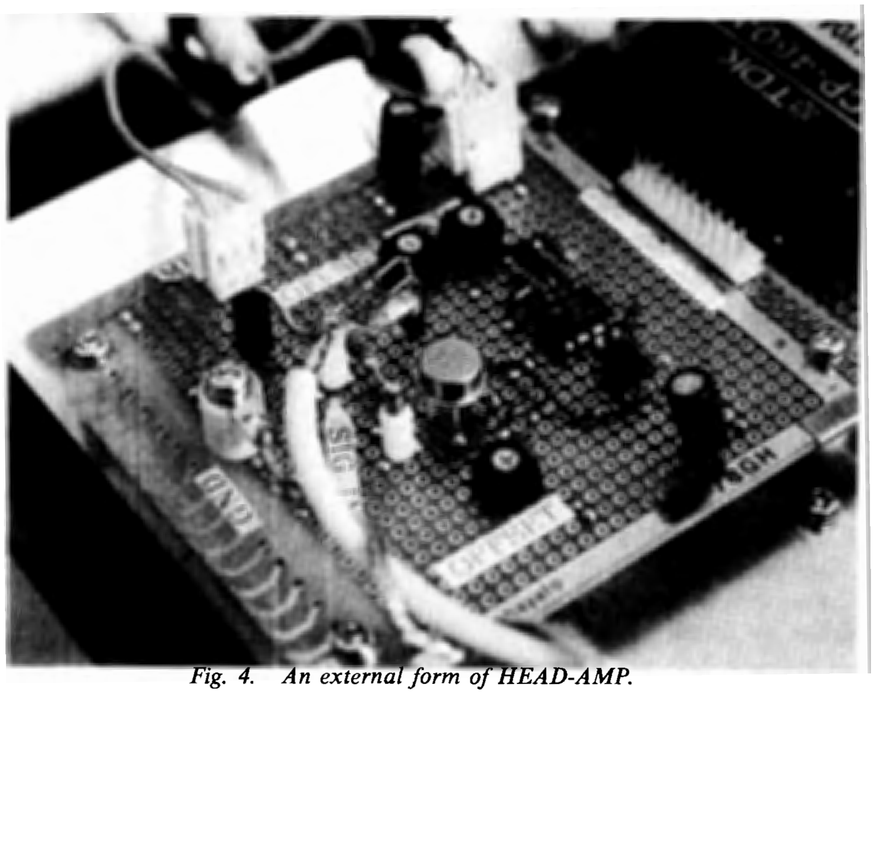


Fig. 4. An external form of HEAD-AMP.

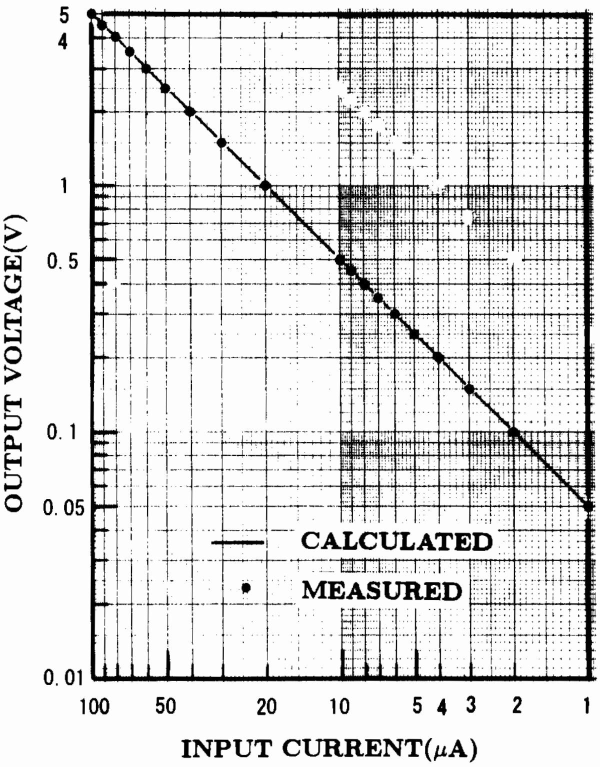


Fig. 5. Relationship between input current and output voltage.

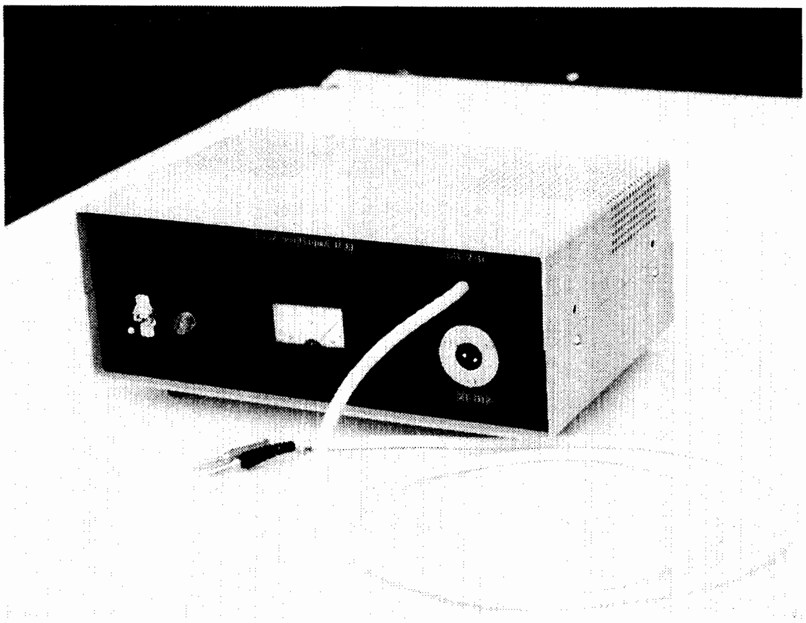


Fig. 6. An external feature of ECM amplifier.

voltage is shown in Fig. 5.

Figure 6 shows the picture of the improved ECM amplifier and electrode cable.

(C) Connection to personal computer

A personal computer was connected to the ECM amplifier in order to display and save the data measured by ECM. The computer used is a "note-type" of the NEC PC-98 series. An A/D conversion board is set in the I/O unit as a peripheral

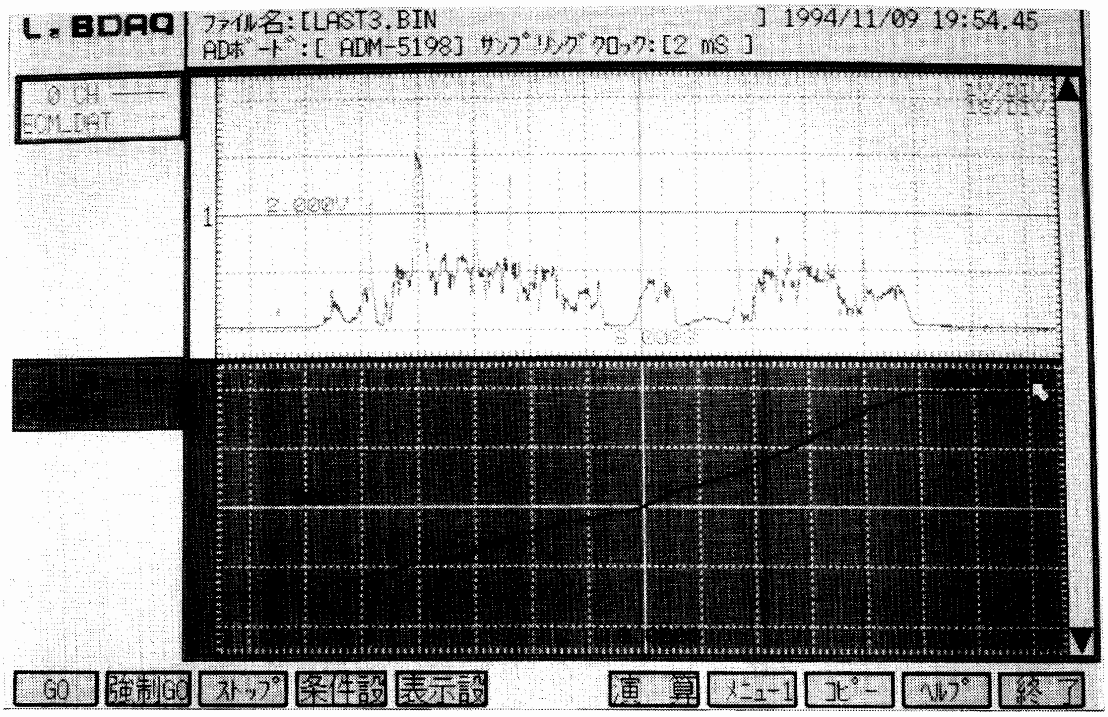


Fig. 7. An example of the result of measurement by use of the ECM-system.

device. The board is able to receive 2-channels, in this case the ECM-signal and ice core position. These data are displayed on a CRT and are saved in a computer data file. Measuring conditions, such as number of data to record and sampling rate etc. of the A/D conversion board can be adjusted by an operator watching the CRT. The maximum sampling data number to record is 16000 for 1 channel and can be increased by enlargement of the EMS (Extended Memory System) memory. The software program is made by Takamatsu Advance Inc. in Japan.

Figure 7 shows an example of the measurement result. The upper part is the ECM-signal and the lower part is a signal which shows the position (depth). Some sharp spikes in the upper figure are signals from the layer which contains an impurity artificially mixed in a thickness of 1 to 2 mm. The line in the lower figure indicates the electrode position. The position is obtained as a change of resistance of the potentiometer, which is connected to the ECM electrode. The line in the lower figure of Fig. 7 is not linear because the electrode was moved by hand of the operator. The measuring conditions are as follows:

Length of ice core	90 cm
Sampling clock of A/D converter	2 ms
Number of samplings	16000/1 channel
Vertical and horizontal scales on CRT	1 V/DIV, 1 S/DIV (ECM) and 500 mV/DIV, 1 S/DIV (position)

3. Concluding Remarks

The ECM system was made for analysis of deep ice cores taken at Dome Fuji Station, Antarctica. For improvement of the ECM, it is necessary to obtain accurate data under harsh conditions such as no grounding possible and to escape from noise from the generator and drilling system. The improved system showed reproducibility in repeated measurements. However, the system is not complete. The next improvements will be as follows: (1) The single line shield cable between the electrode and the amplifier can be replaced with a 2 line shield cable to minimize noise; (2) The ECM input connector can be replaced with a better insulated one; (3) A logarithmic amplifier should be placed between the LPF and Driver (Fig. 2) to increase resolution against weak signals.

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