ON DIGITAL DATA ACQUISITION AND PROCESSING IN GEOTHERMAL WELL LOGGING

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ABSTRACT

A study is made on the application and adaptation of digital computers to the conventional analog method of well-logging, as a means for data acquisition, and ultimately of processing the same data. The present system of digital well-logging in Iceland is presented in which a custom-built hardware is adapted into the logging truck for data collection, and processing is done on a central computer in the office via a reformatter for system compatibility. The essential factors and requirements based on that system together with the necessary hardware are taken into account since they too are essential to any system taken into consideration for application. An experiment is done with an HP-85 computer as the central device in a simulated temperature measurement for data acquisition, processing and plotting. The mechanics are explained with reference to the hardware, software, speed limitations, and memory capacity. The procedure for other measurements is also discussed. The alternative use of an HP-87 desktop computer and integrated data acquisition units is also presented.

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1 INTRODUCTION.

1.1 Scope of work.

This report is a result of the author's six-month Fellowship training with the United Nations University and its asssociated institution - Orkustofnun - the National Energy Authority of Iceland, under the UNU Geothermal Training Programme held at Reykjavik, Iceland, from April to October, 1983.

The first five weeks of the training comprised an introductory lecture course which dealing with the various and general aspects of geothermal energy development and was attended by all UNU Fellows.

The next five weeks were devoted to specialized training in different fields in geothermal development. The author attended the specialized training in Reservoir Engineering and Borehole Geophysics. The Borehole Geophysics course included lectures on resistivity logs, temperature logs, nuclear logs, production logs, cement bond logs and perforations of well casings. The lectures were supported by actual logging operations in the field for a real grasp on its practical side, and by seminars and tutorials for detailed discussions on some important aspects.

The Reservoir Engineering course included lectures on well - testing, tidal-leakage-boundary, reservoir mechanics, two-phase reservoirs, well performance, and reservoir operations. These too, were augmented by seminars, tutorials and practical field operations.

A two-week field excursion to many places in Iceland followed. This showed how geothermal energy is and will be fully utilized.

Few weeks were used in part by exposure to and "hands-on" the practical aspects of well-logging, and the remaining weeks, in working the project which is described in this report.

This project dealt with the applicability of computer technology, particularly microcomputers and necessary peripherals, as a system for data collecting and data processing to well-logging, deriving experience from the present system used in Iceland.

The theory behind and the experiment done in this project particularly with the HP-85 was conceived by Hordur Halldorsson of the Orkustofnun Electronics Laboratory in 1981 although it has never been applied in practice. This training will be particularly important for the author, as he will be involved in computerising geothermal well logging data for PNOC in the Philippines in the near future. At present all well log data in the Philippines is treated by hand.

1.2 Well logging

In borehole geophysics, a log is defined as record of sequential data which includes all techniques of lowering sensing devices in a borehole and recording some physical parameters that may be interpreted in terms of the characteristics of the rocks, the fluids contained in the rocks, and the construction of the well (Keys and McCary, 1971). The sequential data are obtained by moving a probe either up or down the well at a constant speed and the signal is sent to the surface and recorded. The conventional method of collecting these data is using an analog system through which the signal is processed and fed to a chart recorder which plots the data directly on the chart.

Much technological progress has been made since the first electric log was run in 1927 in France. Many useful logs have been developed along with log interpretation, chart books, equations, and techniques such as cross-plotting, F overlays, etc. Most are designed to provide well site evaluation of the well and the reservoir. The logs however, require proper interpretation by the log analyst and obtaining a fairly accurate log analysis depends on his experience, skill, and intuition. As many factors are involved, the analyst is therefore prone to making mistakes and the tedious hand calculations needed are very time consuming.

It is said that one of the "pitfalls" in log analysis is inaccurate log data (Elliot, 1983). A study made by a major company (Neinast and Knox, 1973) indicated that more than fifty percent of all well logs are erroneous.

Developments in microprocessor technology, however, have led to advances that make it feasible to harness computer power for data collecting and data processing of well logs. Therefore the reduction, if not the entire elimination of erroneous logs may be looked forward to.

1.3 Logging equipment: Analog system.

In general, all well logging equipment consists of three parts (Stefansson and Steingrimsson, 1980): the downhole sonde, transmission line, and the registration unit. Fig. 1 shows a block diagram of a logging equipment scheme. Different sondes or probes for different measurement purposes can be connected to the lower end of the cable via the cablehead. Power and signal are transmitted to the surface through the cable which could have one or several conductors inside a steel armour. Continuous registration is achieved using a slip ring assembly with fairly good electrical contacts so as to provide stable

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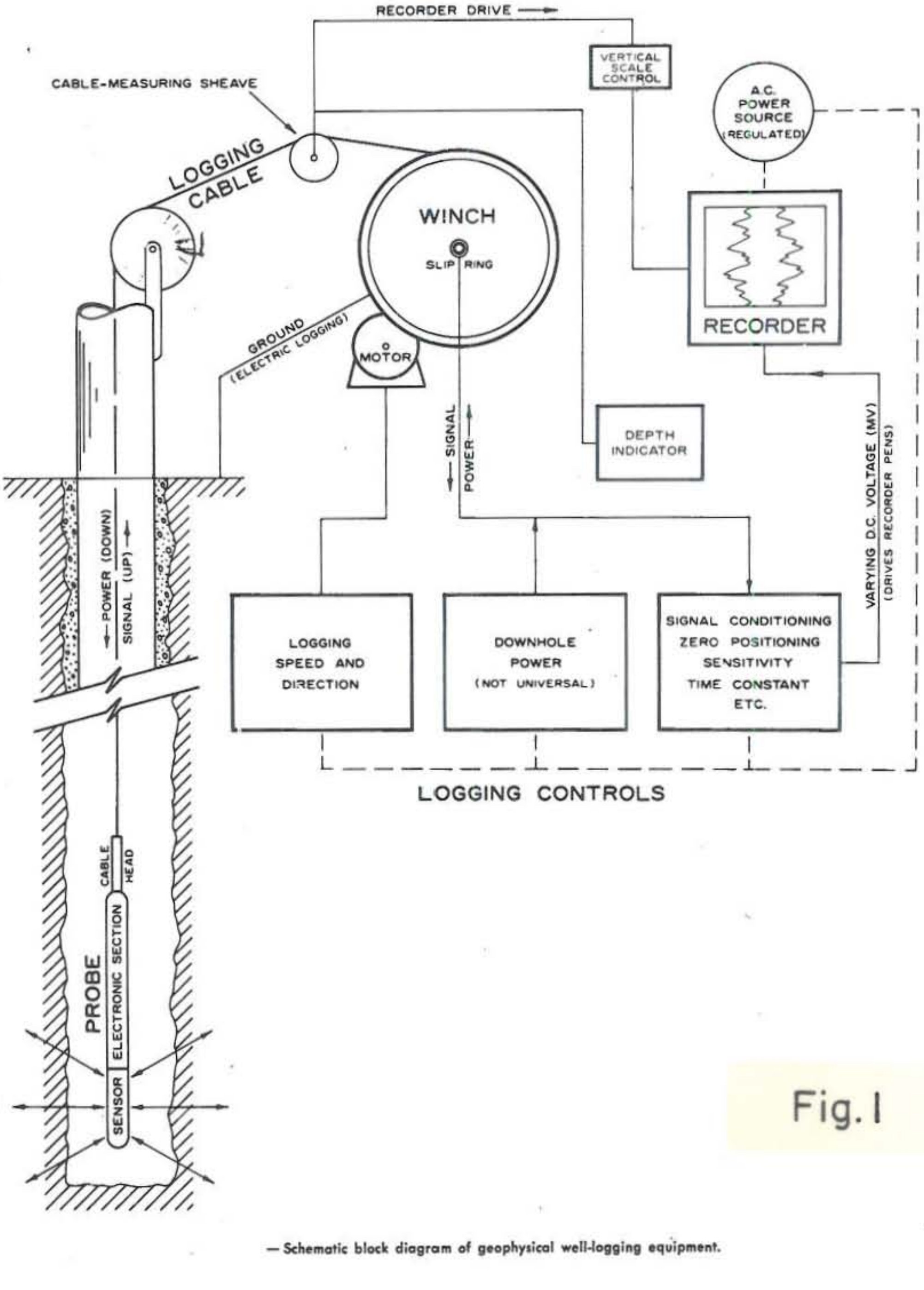

Fig. I

— Schematic block diagram of geophysical well-logging equipment.

power for the sonde and feed an undistorted signal to the registration unit while the cable drum is rotating and feeding/retrieving the line with respect to the sonde.

A cable measuring sheave measures the line outside the cable drum. A depth indicator is mechanically connected to a depth encoder which could be preset to any indicated value desired. The recorder is also mechanically coupled to the depthometer in order to drive the chart in synchronism with the line being fed. A vertical scale control provides vertical resolution control of the log by varying the chart drive speed.

A motor or a hydraulic draworks power the rotation of the drum wherein the logging speed, as well as the direction can be controlled.

Different probes require different surface signal processors and different power requirements. Different surface modules, however, are easily adapted to the system by the use of the NIMS (Nuclear Instrument Module System), an international trade standard using a 19" bin and the NIMS modules plugged into the bin which itself has an integrated power supply, and also provides interconnection between the modules, as well as the logging cable.

Most probes transform a signal to frequency variations before feeding it into the line. This is necessary since the line has considerable length which could cause some problems in the transmission of the signal to the surface. By converting the measuring signal to a frequency modulated signal, noise, cable resistance and capacitance, and other factors that could affect the measured parameter are reduced considerably. At the surface, surface modules convert frequency signals into DC (direct current) voltages for the recorder which consequently drive the recorder pens.

1.4 Digital data acquisition, registration, and processing system.

In the previously described logging scheme, the data is in analog form which is recorded directly on an analog recorder. With the present technology, however, it is feasible and desirable to register the data digitally on magnetic tapes or any other form of digital data storage, in order to have these data accessible for computer manipulation; e.g. correction, before it is plotted in any desired scale. The registration would involve digitizing the logging signal at some specified intervals along with the depth relative to the signal. It is the ability of a computer to process huge amounts of data such as these, that makes this an advantageous system. Such a system exists in Iceland and is briefly taken up in this report as a reference example to show the need for a more efficient system.

A more advantageous system involves immediate processing of the logging data at the wellsite. This requires a physically small computer yet with sufficient capability, to be mounted on the truck. The computer could process the data and record or plot it at the wellsite. The computerized logging system configuration of Dresser Atlas (1980) is shown in Fig. 2.

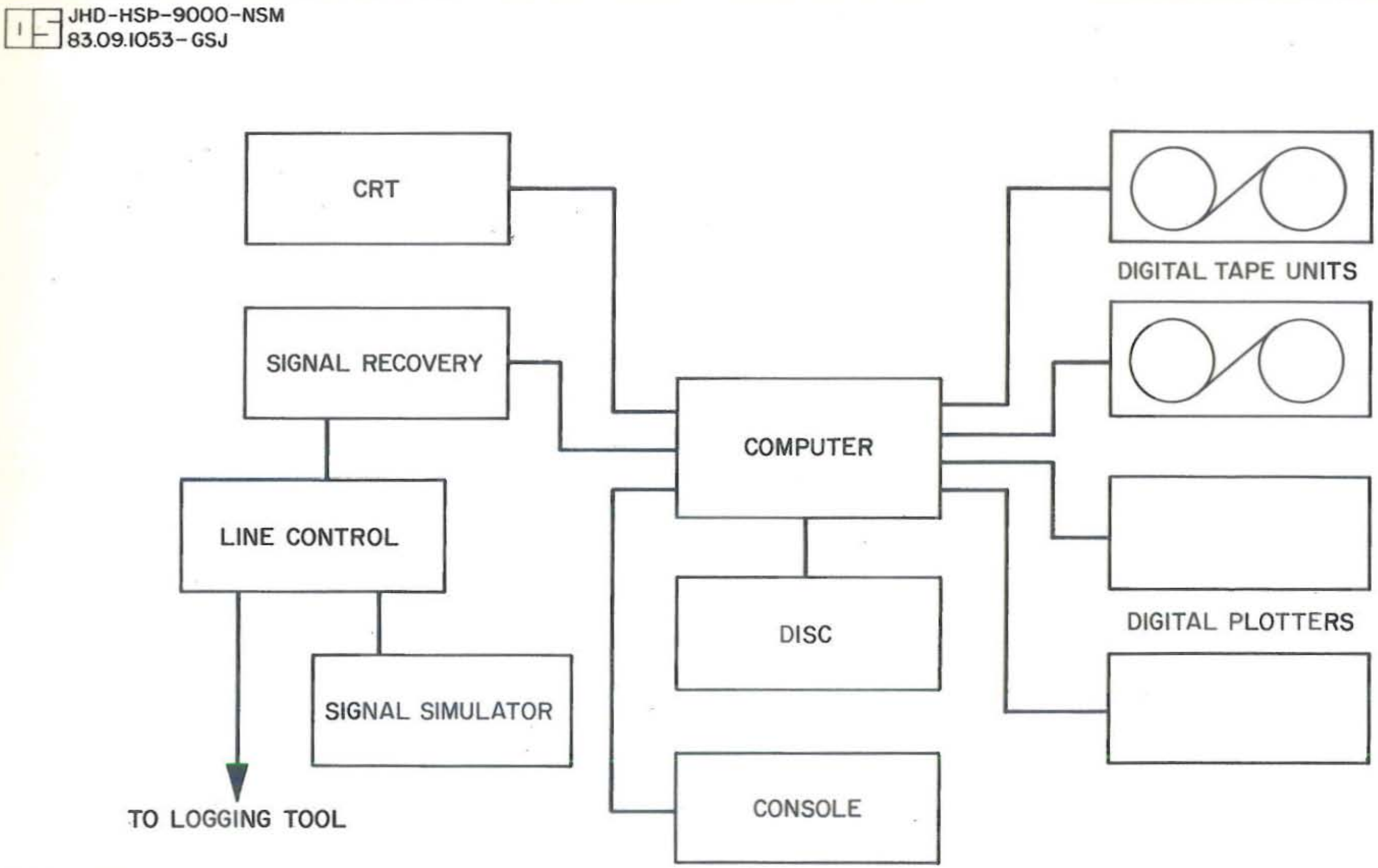

Fig. 2 DRESSER ATLAS' STANDARD COMPUTERIZED LOGGING SYSTEM "D" HARDWARE CONFIGURATION

2 PRESENT SYSTEM OF DATA COLLECTION AND PROCESSING IN ICELAND

2.1 Operation

Most of the data in this chapter are from the UNU lecture of Hordur Halldorsson on data registration, 1983.

Orkustofnun, the National Energy Authority of Iceland, has built and is employing a system for digital data collecting which is run in parallel with the conventional analog method. The main idea behind the system is to sample or read measurement signals between fixed distance intervals and record this on a tape in digital form.

The system was built with a digital tape recorder from Datel Systems,Inc. model LPS 16 as a base unit. It was built to satisfy the following conditions:

1) It should be possible to record general information on the tape, e.g. information on type of log, date, etc.; the purpose of which is to put a label on the information contained in the tape.

2) The system should be able to receive calibration signals at any time during the execution of the log. This is necessary for the final processing of the data registered.

3) It should be possible to select sampling intervals from 20 to 80 cm to allow flexibility due to different parameters being measured.

4) The logger should have at least four analog inputs. This is the largest number of parameters registered by the present Icelandic system.

5) It should have sufficient recording rate for different logging speeds and sampling intervals. Table 1 shows the time lapse between intervals for maximum logging speeds of different logging parameters with sampling intervals of 20 and 40 cm.

6) Depth and data should be visible on a display during logging to insure proper operation and checking.

Fig. 3 shows the block diagram of the data collection system which operates in the following principle: The signal coming from the logging line is sent either to a voltage amplifier or an especially constructed ratemeter (1). The ratemeter has the same function as the conventional one. The signal from the probe which is in the form of frequency variations is transformed into DC voltages with certain time constants. The main difference is that this ratemeter has a higher maximum output voltage, i.e. 5 volts for the different full scale frequency setting.

When the downhole probe in use does not send information by frequency variation but in voltage form, e.g. E-log, an amplifier (2) is used instead of the ratemeter.

The depth control (3) is also a custom-built part of the system which has the function of giving signals at every 10 cm of depth interval during logging, plus a signal for telling the direction of the logging. This depth control is an opto-coupled, i.e. light interrupted signal which is in parallel with the mechanical depthometer in the truck.

The keyboard (4) consists of switches for entering label data on the tape. Also, in order to select the measurement intervals and the number of channels to be recorded, a function selector (5) is provided on the panel. A multiplexer (6) can read up to sixteen channnels of analog signal, one at a time and feed the multiplexed signal to the analog-to-digital (A/D) converter (7). The A/D converter digitizes the analog signal from the input. The digital signal consists of combinations of logical high and

TABLE 1 - Logging parameters and time lapse between measurement interval.

LOGGING PARAMETER	MAX LOGGING SPEED (meters/min.)	MINIMUM INTERVAL (cm.)	TIME LAPSE BETWEEN INTERVAL (millisec)
temperature	40	40	600
caliper	20	20	600
gamma-gamma	15	40	1600
neutron-neutron and nat. gamma	15	40	1600
E-log	35	40	680
sonic	15	40	1600

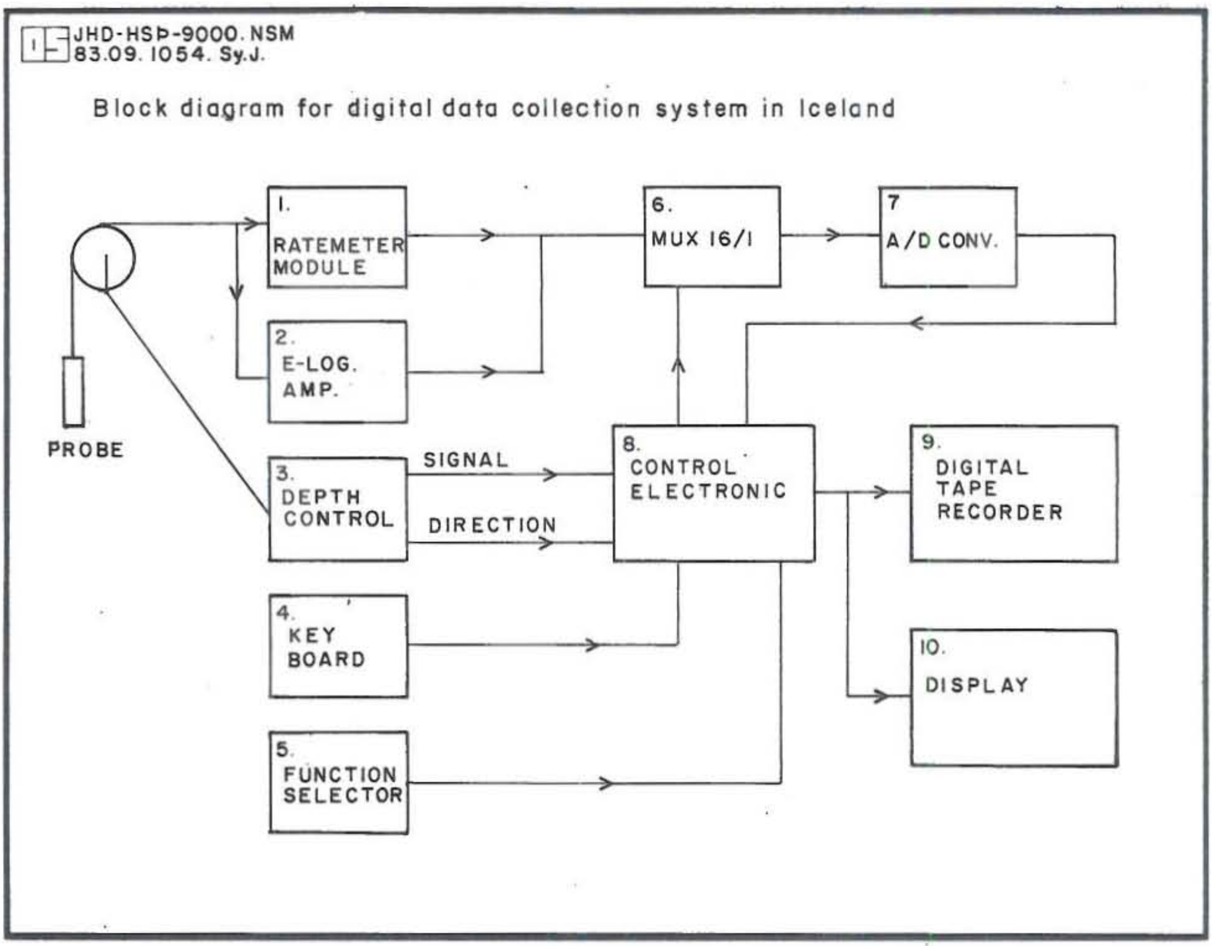

Fig. 3

low signals which is recorded on the tape through the control electronics (8) and can be monitored in the display in the form of hexadecimal figures.

The management of the flow of signals is performed by the control electronics (8). This controls the interval of registration of the measurement signal and depth signal with that coming from the depth control. The measurement signals are registered for every interval selected, while the depth information is recorded at every sixty-fourth interval and for every change of logging direction. The control electronics also control the sequence in multiplexing multi-input signals, read the digital signal into the tape, control the measurements of sampling intervals with the function selector, and send the data to the display.

2.2 Resolution

The analog to digital converter used has 12 outputs of either a logical high (1) or a low (0) signal. The A/D converter is represented by that in Fig. 4. Each output (A0 to A11) could have only one of two conditions: either a logical '1' or '0'; i.e. 5 volts or 0 volt.

Each output is called a bit (from the words binary digit), the whole output being composed of 12 bits. This is also equivalent to three hexadecimal digits. If the output is taken as a binary counter that count up to twelve digits in binary, the maximum count that would be attained, in base ten would be:

$$X_{max} = 2^{12} = 4096$$

Thus there would be 4096 different possible combinations of 0's and 1's in the twelve-bit output. This can be regarded as the resolution of measurement in the whole system. An

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Schematic representation of a 12-bit analog digital converter

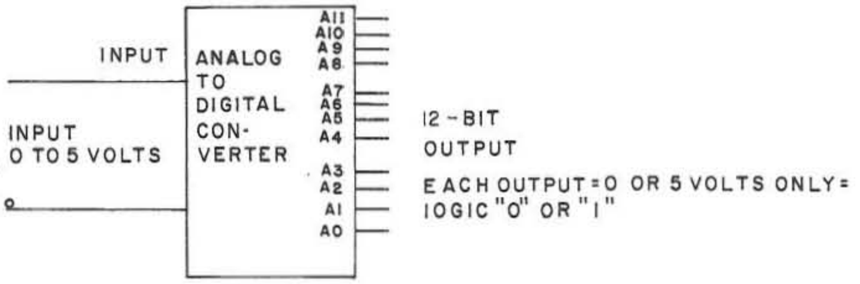

Fig. 4

input of zero to five volts in the analog to digital converter gives up to 4096 different values in binary which are recorded on the tape.

The depth counter has a 15-bit resolution plus one direction bit. Data signals for the depth are stored as a 16 bit word.

2.3 Data Processing.

The data recorded on the tape is processed at the central office in Reykjavik. Fig. 5 shows a simple flow diagram for the processing of the collected data. The data is read by a digital tape reader similar to the recorder on the truck, and the data transferred to a floppy disc via a Cromemco developmental computer, which also reformats, using a reformatter software, the data into a floppy disc format used by the VAX central computer. The file in the VAX floppy disc can now be manipulated at will. It is calibrated against some calibration coefficients that were recorded at the start of the log. It is furthermore possible to correct the data with other logging data on file, e.g. neutron-neutron log correction from caliper log due to the effect of hole size on neutron-neutron measurements.

The data can then be plotted using a Tektronix plotter interfaced to the computer with the appropriate plotting program. The plotted data can now be seen as absolute values of the parameter being measured. This can be a very great help to the analyst compared with the usually tedious job of interpreting data from an uncorrected log from conventional logging. Also the logs can be presented on any scale desired.

An example of a neutron-neutron log recorded both in digital and analog form is shown in Fig 6. The analog curve is taken out directly from the analog recorder on the truck. The digital log has three curves -labeled 1, 2, and

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FLOW DIAGRAM FOR THE LOG DATA PROCESSING IN ICELAND

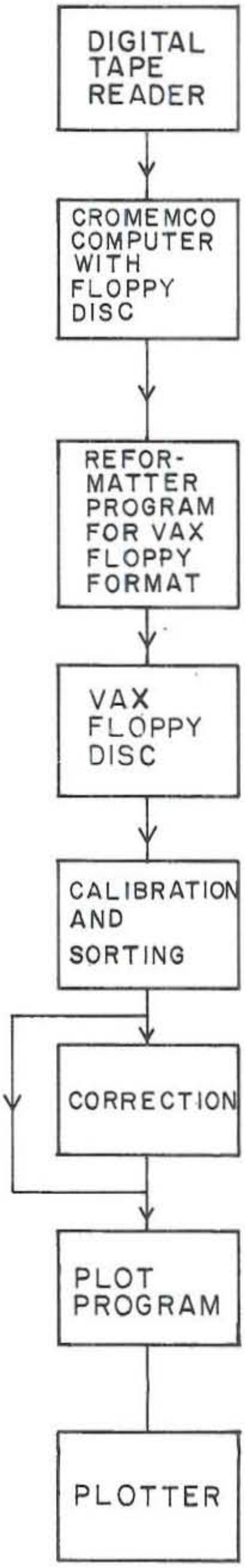
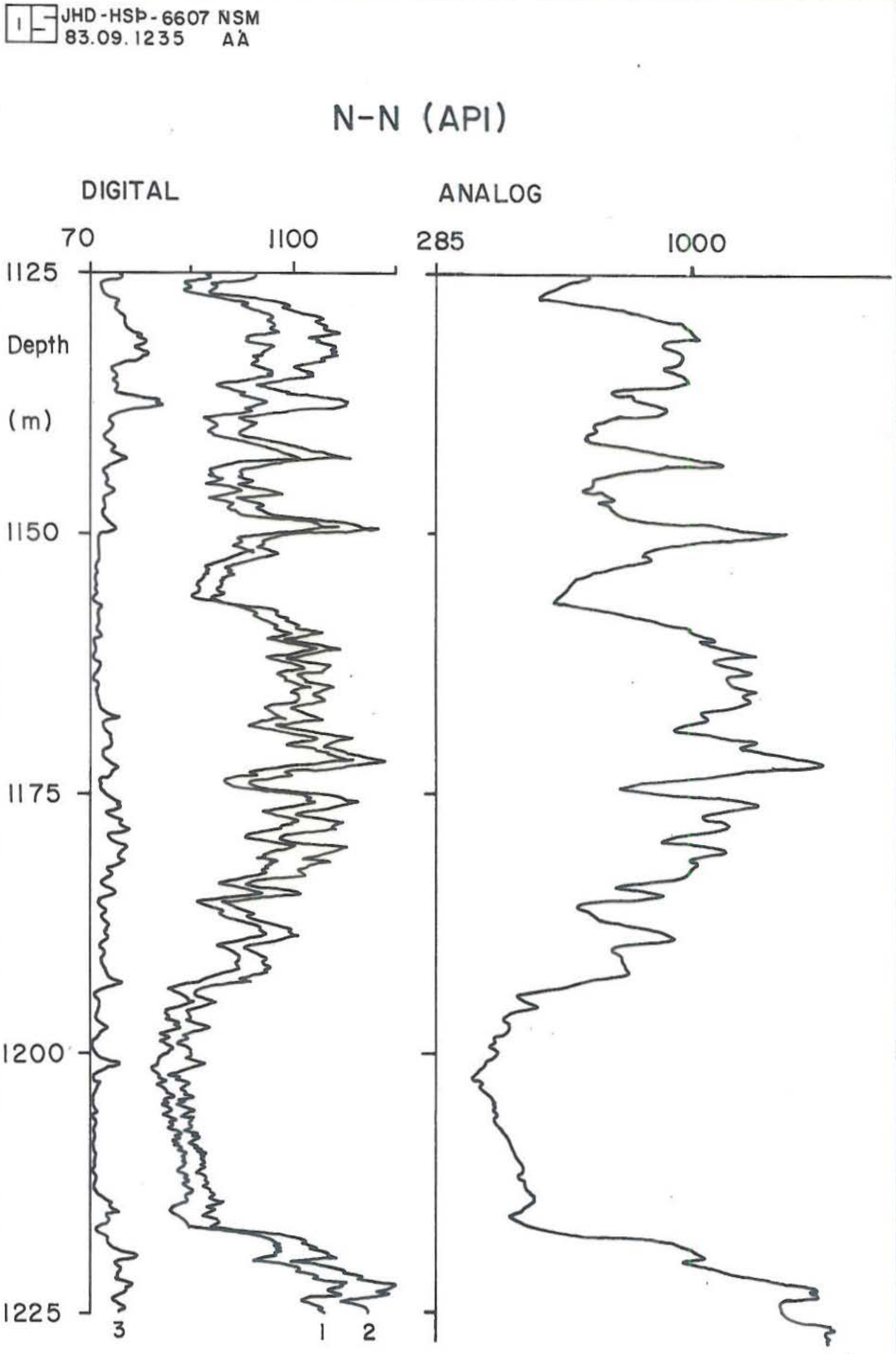


Fig. 5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N-N (API)
DIGITAL
ANALOG
70
1100
285
1000
1125
Depth
(m)
1150
1175
1200
1225
3
1
2

Fig.6

3 in the figure. The digital log has been plotted out by a digital plotter from the data on the tape which was recorded simultaneously with the analog curve. Curve 1 is just a plot of the raw data from the digital tape. It can be seen that it is very similar to to the curve from the analog log except that they are not of the same horizontal scale. Curve 2 shows the corrected neutron-neutron log. Correction is necessary due to the effect of well size on neutron logging. The curve, labelled 3 in the figure, is the correction obtained from caliper logging data. An addition of curves 1 and 3 gives the corrected log shown in curve 2.

2.4 Drawbacks and Future Plans.

Although the system now used in Iceland has been proven to be very succesful, it has some disadvantages which can be overcome with the present technology. The drawbacks are: 1) the data recorded are seen on the display as hexadecimal numbers which cannot be understood easily so that the analog system is always run in parallel with it; 2) the processing of data is cumbersome as can be seen from the length of the process involved; 3) recording of comments is limited since only hexadecimal numbers can be entered into it; and 4) the system is not user friendly; e.g. it would only accept hexadecimal figures and there is no interactive communication between it and the user.

With the present technology and reasonable cost, however, it is possible to overcome these drawbacks and greatly enhance the logging efficiency. A computer from DIGITAL, model MICRO PDP/11 is being planned to replace the old system at Orkustofnun (NEA). In this system, all data would be calibrated before it is recorded on a Winchester disc. While all software development can be done in the central office on the Digital VAX computer, the system can also be used independent of it. During logging, a CRT (cathode-ray tube) would show the calibrated signal along with the depth and the logging speed. The system is user friendly since the logger could interact actively through a log oriented computer program. In addition, the instrument works faster than the old system. The new system configuration is shown in Fig. 7.

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An incoming system for Iceland's digital well-logging scheme.

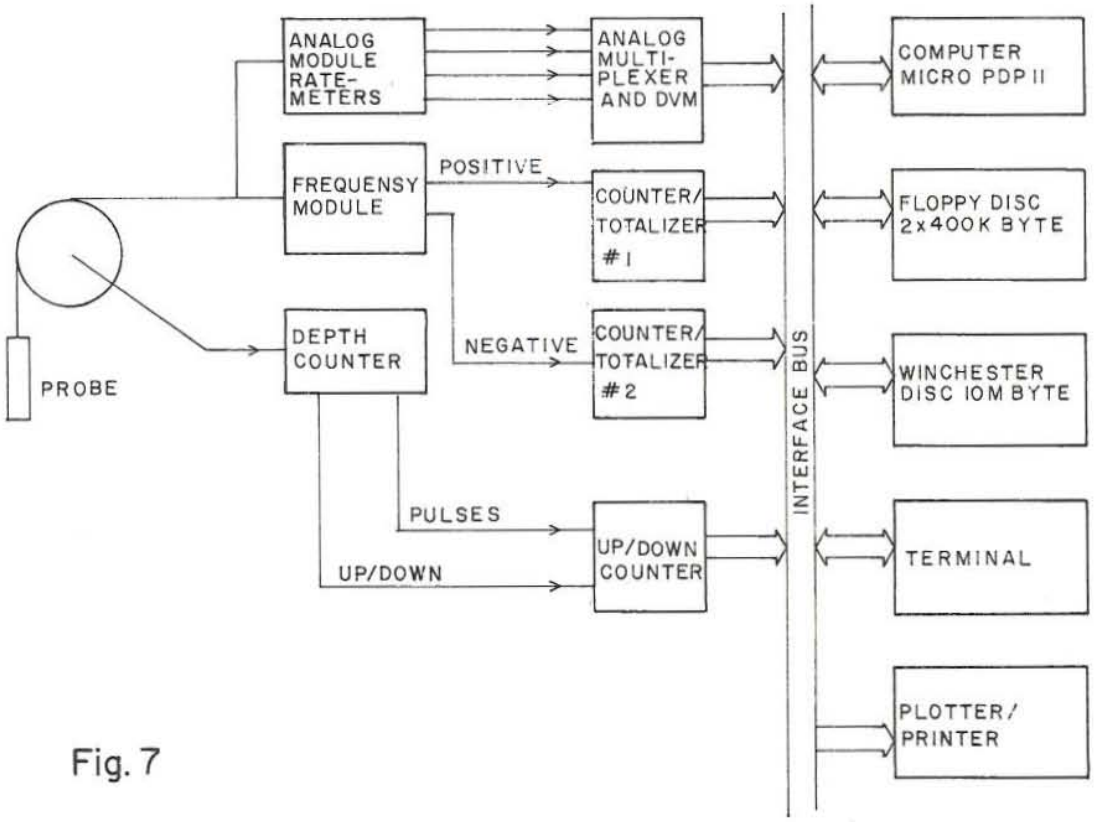

Fig. 7

3 REQUIREMENTS FOR A DATA LOGGER

3.1 Introduction

The digital logging equipment presently in effective use in Iceland as discussed in the previous chapter can lead us to a selection and system design of a computer-based data logging/acquisition unit that would be adaptable to the conventional analog system.

3.2 Types of measurement

Most of the measurements done in well logging translate the signal into either one of two forms: voltage variation, or frequency variation. In the conventional system, both forms are converted into analog (i.e. voltage) signal that drives the recorder pens. In an E-log a constant current is used to generate a potential difference between the 16" and 64" points on the probe, and the mud pit. This voltage is then proportional to the resistivity. In temperature logging, the temperature transducer is usually an element whose resistance varies with temperature. In the downhole tool, the resistance variation is converted into a frequency variation via a voltage-controlled oscillator (vco). This method of transmitting the measurement parameter makes the signal independent of the resistance and capacitance of the logging line, which are not negligible considering the length of the cable. The processed signal at the surface is therefore a more accurate representation of the measured downhole parameter. Caliper logs operate on the same principle; i.e. a resistance varies with the variation in hole diameter which is also translated into frequency variations. In nuclear logs radioactive pulses are counted by a Geiger-Mueller tube or a scintillation counter if gamma radiation is involved. He3 detector is used for neutron detection. All are fed to the line as pulses. Sonic signals are more complex as these involve timing as well as voltage amplitudes. The first arrival signal (forerunner), however, is available as an integrated output from the surface processor and could be taken as a voltage amplitude signal. The same is true for the travel time of the transmitted and first arrival signal.

3.3 Calibration of the results

The measured data are usually not in the form of absolute values. A reference value must be established to convert them into a calibrated log. Calibration of the Gearhart-Owen temperature tool is done in the laboratory and does not need frequent nor field calibrations. The calibration done by a two point method related to the linearity of the response of the sensor. The relationship between temperature and frequency of the transmitted signal is found to be

$$f = 36 (T + 17.778)$$

where the frequency, f is in Hz, and the temperature T in°C (from H. Halldorsson, UNU lecture 1983).

Therefore an oscillator frequency setting of 640 Hz would indicate 0°C and 5320 Hz would yield 130°C. The frequency can be measured by a frequency counter. This has been done and the result will be shown later in this report. With an interface to the computer, the corresponding temperature can be calculated and stored.

Calibration of other measurements are usually done in the field and calibration signals act as correction constants. For a caliper tool for instance, frequency variations do not respond linearly throughout the whole range of the caliper opening. Therefore, two points in each range should be selected, the slope of each line so obtained is calculated and used as a constant in the calculation of the actual caliper opening. The computer should be fast enough to detect the range, calculate the result and store the linearized data.

Nuclear logs are usually calibrated in API (American Petroleum Institute) units. Calibration is usually done before and after logging. An average value of the calibration signals must be calculated by the computer which is used in the final processing of the data.

3.4 Log resolution

A log is typically presented in a graph of measured parameter versus depth. The resolution therefore concerns both the degree of measurement accuracy and the depth interval at which the measurements are done. For an analog system, measurements are normally done continuously with depth and the depth resolution depends on the speed of the chart in the recorder. In a digital system, this is not possible as is explained in the following text.

3.4.1 Measurement resolution

For the system in Iceland, the analog signal is converted into a digital signal of 12-bit byte. The analog signal is set to have a variation of 0-5 volts. This gives an output of 2^{12} or 4096 bit combinations in digital form. This means that for every combination, a corresponding voltage change of

$$\Delta V = \frac{5}{4096}$$

$$\Delta V = 0.001222 \text{ V}$$

or 1.222 mV should be made to effect a change of one bit in the output.

Taking a temperature measurement, as an example, the resolution can be examined in the following: The G.O. probe transmits its measurement signal to the surface in a frequency modulated form, and converted at the surface, with the proper full scale frequency selection, into 0 to 5 volt D.C. signal for the A/D converter. Fig. 8 shows the signal conversion flow diagram.

The relationship between the frequency transmitted from the probe and the actual temperature is characteristic of the probe and is given by:

$$f = 36\ T + 640$$

where f = frequency in Hz
T = temperature in °C

A temperature range of 0 to 130°C, would, from the above relationship correspond to 640 and 5320 Hz respectively. The full scale selector of the custom-built ratemeter is set to 8000 Hz; i.e. 5 volts output for an 8000 Hz input on the frequency to voltage converter.

As has been calculated previously, 1.222 mV causes one bit change. Translating this into the corresponding frequency change for a full scale of 8000 Hz;

$$\Delta f = \frac{8000\ \text{Hz} \cdot 1.222\ \text{mV}}{5\ \text{V}} = 1.95\ \text{Hz}$$

This corresponds to a temperature change of;

$$\Delta T = \frac{(\ 640 + 1.95\ ) - 640}{36} = 0.054\ ^\circ\text{C}$$

Therefore, the registered digital data has a resolution of 0.054°C of temperature increment. This resolution is unnecessarily good owing to the fact that the instrument would be very tedious to calibrate with a better accuracy than ±0.1°C. For a computer-based data logging system, the measurement resolution would depend largely on the peripheral device that would measure the signal and feed

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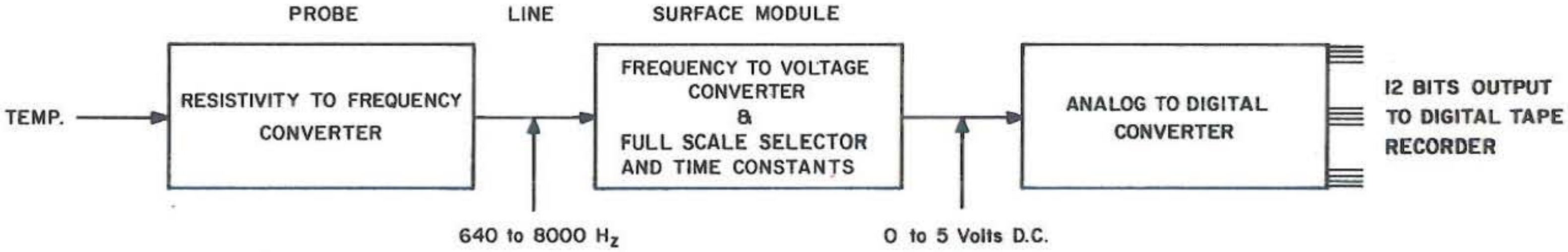

FLOW DIAGRAM IN THE CONVERSION OF TEMPERATURE INTO DIGITAL SIGNAL

Fig. 8

it to the computer. In the temperature simulation done in this project, an HP universal counter model 5316A is used which has a best case resolution of ±0.00012 Hz at 1 KHz and an input of 1 V rms for a gate time of 1 second. Increasing the gate time will decrease the least significant digit displayed and hence the resolution. This resolution is far too great for this purpose and gate time can be increased to achieve fast reading which is important in this case.

3.4.2 Depth resolution

A true continuous measurement is not possible in a digital logging system although it can be made to appear as a continuous log. Measurements are taken at some predetermined intervals as a function of depth. The smaller the sampling interval, the better is the resolution with depth. Therefore, it is desirable to have as small a sampling interval as possible. In this regard, the limit of the data acquisition system is in the speed of the measurement and its mass storage capacity. Therefore, a compromise is obtained by optimizing the sampling interval to approach the usefulness of a continuous log.

A sampling interval of for example 20 cm, i.e. measurement is read every 20 cm of depth, would yield a total registered number of 15,000 measurements for a single type of log in a 3000-m well. If three logging parameters were run simultaneously, the total registered information on the computer's mass storage would be 60,000 if the information on depth is included. For a computer that uses eight bytes of memory space for a number, e.g. HP-85, 60,000 numbers would use 480,000 bytes or approximately 467K bytes of data storage space. In actual practice however, the depth information is not necessarily registered often. Although the use of several discs would solve the storage problem, this would create a general operating problem; e.g. logging would be stopped to put a new disc, etc.

Newer type of disc drives particularly the Winchester disc drives could store up to 12 Megabytes of data and can easily be employed when desired.

3.5 E - log amplifier

In electric logs, the probe is just a passive device, i.e. no active electrical components are involved. The signal translated to the surface is in analog form and the amplitude is very small. This requires the signal to be multiplied by about twenty times. Moreover, the signal has its ground reference to the mudpit and not to the logging truck ground. This necessitates the amplifier to be isolated from the truck. This can be realized by using independent batteries in the amplifier.

In electric logging, a converter sends the current to the probe by continuous reversal; i.e. alternating current to eliminate the effect of polarization. The converter also synchronously receives the signal from the probe. This process creates a noise which is critical, due to the small amplitude of the signal. An insulating instrumental amplifier, which is suited to this purpose, is described in the next chapter.

3.6 Ratemeter and time constants

A ratemeter is the surface instrument that receives the frequency translated signal coming from the downhole probe. As its name implies, it counts the number of events per unit time - given in counts per second. It is used to count pulses from tools that translate their signal into pulse frequency form, whether recurrent pulses such as those from caliper and temperature tools, or random pulses from nuclear tools. The pulses are counted against a certain time constant and converted to analog form for the recorder.

A single time constant is defined as the output response time needed to reach 63.2 % of the ultimate input value provided that the input is a step function, i.e. if the signal goes from zero up to its maximum value instantaneously. The time constant parameter can be illustrated by a simple R-C circuit as shown in Fig. 9.

The voltage output of this circuit is an exponential response and is given by:

$$Vout = Vin \left(1 - e^{-\frac{t}{RC}} \right)$$

where t is the time in seconds, R is the resistance in ohms, and C is the capacitance in farads. The product of R and C gives what is known as the RC time constant of the circuit.

If the time $t = R \cdot C$, then

$$Vout = Vin\,(1 - e^{-1}) = 0.632\ Vin$$

This means that in one RC the voltage output reached 63.2 % of the step function input. After five time constants, i.e. 5RC the output reaches 99.3 % of the total change in the input. Fig. 10 shows the exponential response curve of the circuit.

The necessary ratemeter for a digital logging system is described in the next chapter.

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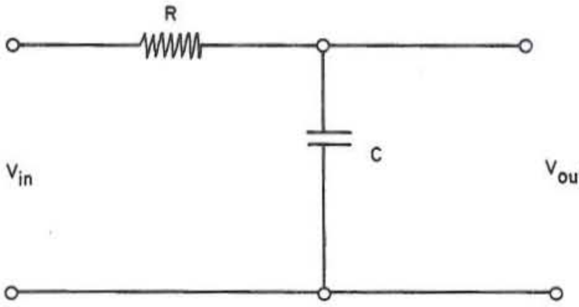

A simple R-C circuit

Fig. 9

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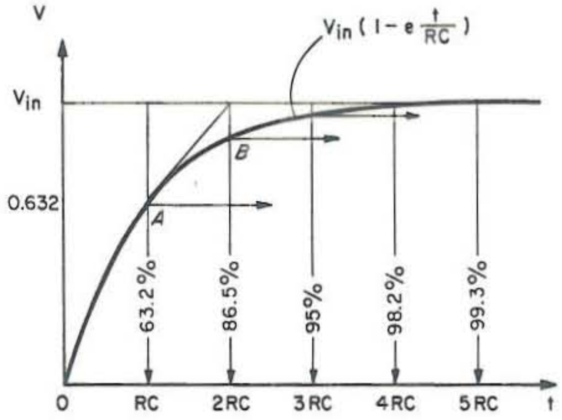

Exponential response curve

Fig. 10

4 NECESSARY CONTROL UNITS AND SIGNAL INTERFACES

4.1 Depth control

The data in the data logger storage should be depth correlated. This is of prime importance or else any data collected would be meaningless. Therefore, a depth encoder is incorporated into the system. It sends pulses for fixed depth intervals. Moreover, the depth encoder should be able to tell the logging direction; i.e. up or down. The pulses would be counted up or down, depending on the logging direction, by a counter/totalizer. The output of the counter is interfaced to the computer as a depth signal.

4.1.1 Depth encoder

An applicable depth encoder and counter are shown schematically in Fig. 11. The major part of the encoder is an optoelectronic device. Infrared light is emitted by an infrared emitter and is detected by a photosensitive semiconductor. Interruption of the light path between the infrared emitter and detector causes a signal pulse on the detector. The detector and emitter are usually housed in a single package with a slot in the light path between the detector and the emitter as shown in Fig. 12. A code wheel which passes through the slot interrupts the light path. The code wheel could be of any material but a transparent film with opaque codes imprinted on it is preferable.

Up/down counting is accomplished by using two opto-detectors. Their detection priorities determine the way of counting; i.e. count up or count down. Information from the two opto-detectors is decoded by a logic circuit illustrated in Fig. 13. Its output will be an up/down (logic high/low) signal, and the count pulses. The two opto-devices are mounted with respect to each other, so that the output from them (buffered by N8 and N9) shall be 90-electrical degrees out of phase with each other. This is

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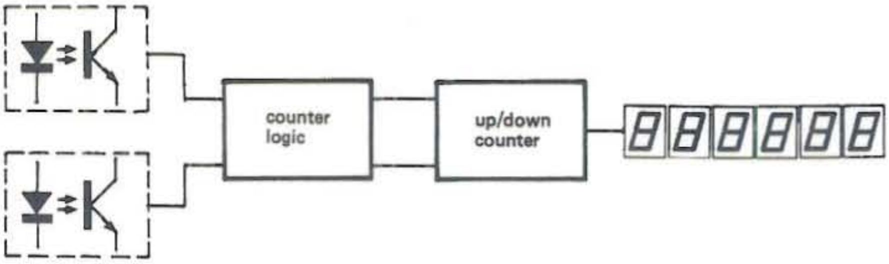
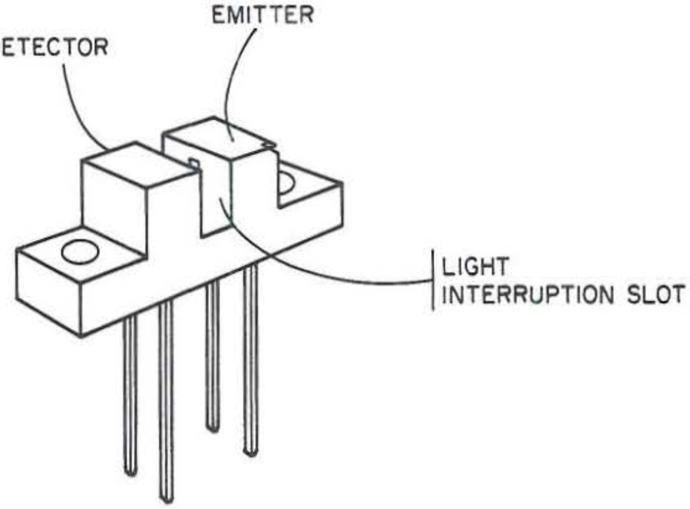


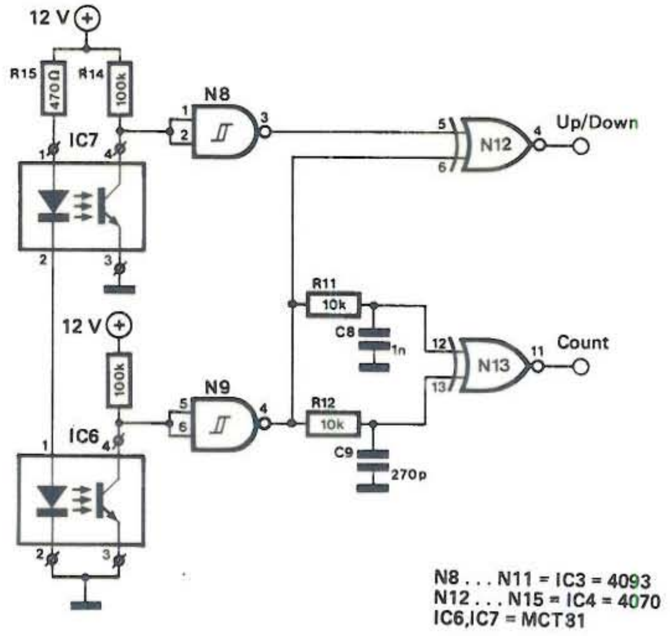
AN OPTO-COUPLED DEPTH ENCODER AND COUNTER

Fig. 11



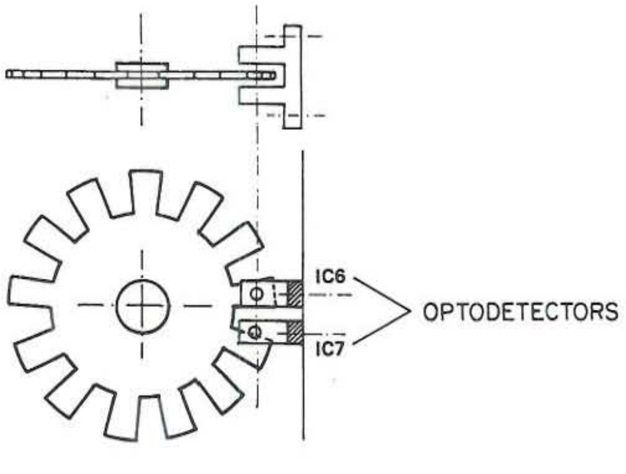
OPTO-EMITTER AND DETECTOR ON A SINGLE PACKAGE

Fig. 12



DECODER LOGIC CIRCUIT FOR UP/DOWN COUNTING

Fig. 13



RELATIVE POSITIONING OF TWO OPTO-DETECTORS
FOR A 90° PHASE DIFFERENCE IN THEIR OUTPUTS

Fig. 14

illustrated in Fig. 14. This means that when one is fully covered, the other is in dark-to-light transition. The pulse flow chart is shown in Fig. 15, with a as count up and b as count down.

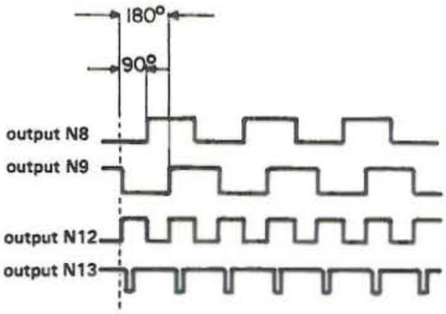
The count pulse is delayed slightly from the up/down pulse as can be seen from the timing diagram in Fig. 15-a, by way of an RC (resistor/capacitor) network. This is necessary for the up/down condition to be established before the count pulse is counted; i.e. added or subtracted. Fig. 15-b shows the waveform when the code wheel turns in the opposite direction. The counter pulses do not coincide with the positive up/down pulse which is opposite to that in Fig. 15-a when the wheel turns in the other direction.

The code wheel is mechanically linked to the logging line measuring sheave, in the same one which drives the paper chart of the analog recorder during logging.

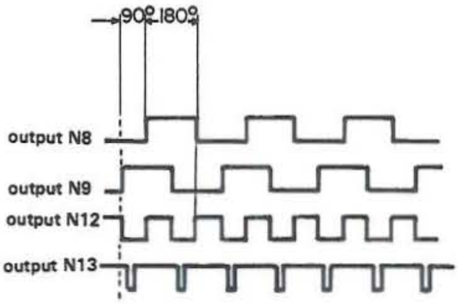
4.1.2 Depth counter

A requirement for a logging counter is a preset facility; i.e. the possibility of programming any number that would serve as an initial value for counting. This is very convenient especially if the probe is already deep in the well when the power to the counter is turned on or in case of power breakdown. This could be synchronized with the mechanical depthometer.

The circuit in Fig. 16 is suitable for this purpose. Presetting capability is obtained through the use of diodes D1 to D24, and thumbwheel switches connected to DT1 to DT6. Counting and decoding is done by the IC (Integrated Circuit) type MK 503989N.



a) COUNT UP



b) COUNT DOWN

PULSE TIMING DIAGRAM FOR UP/DOWN COUNTING

Fig. 15

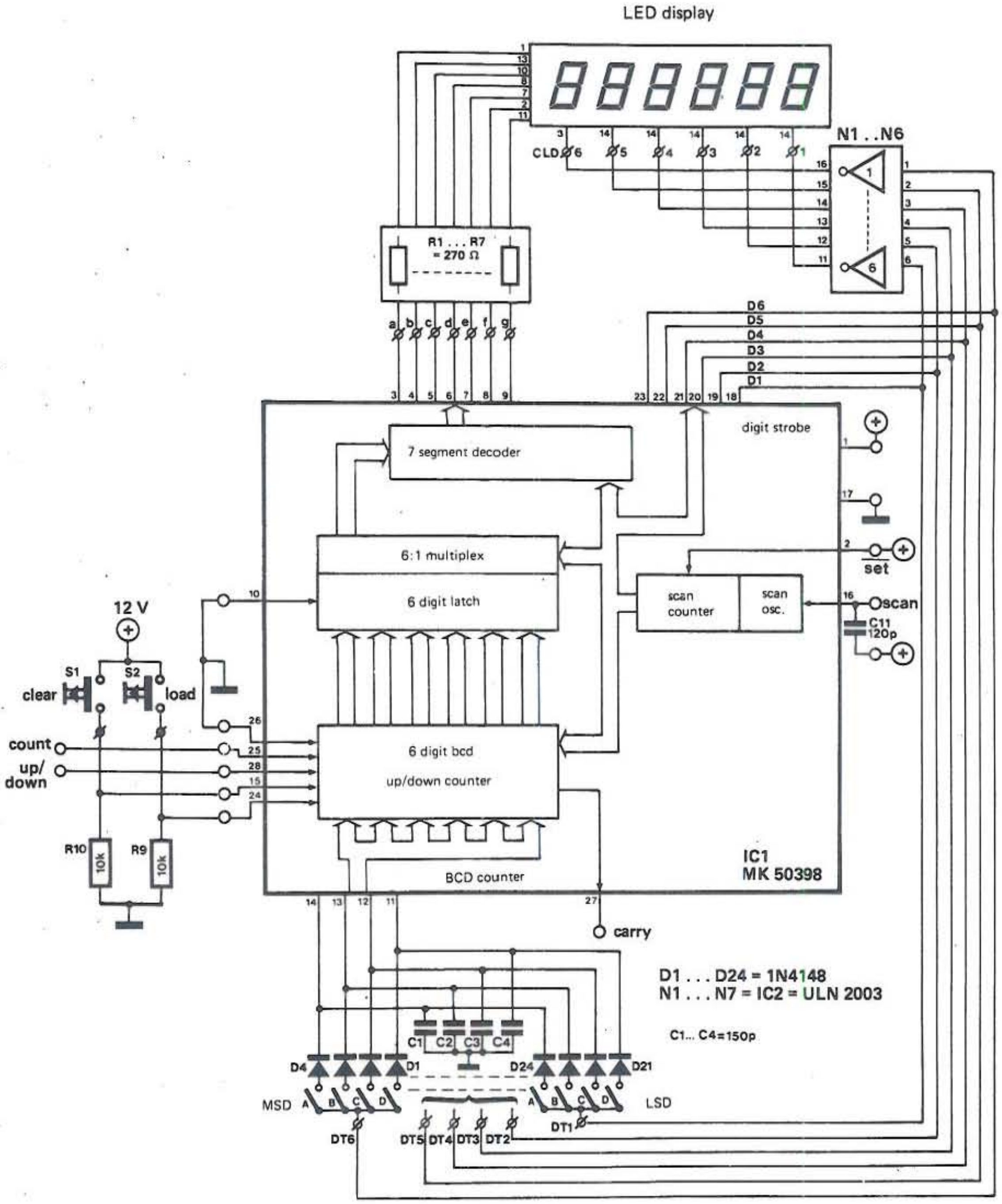

LED display
N1 . . N6
CLD
R1 . . . R7
= 270 Ω
a b c d e f g
D6
D5
D4
D3
D2
D1
digit strobe
7 segment decoder
6:1 multiplex
6 digit latch
scan counter
scan osc.
set
scan
C11
120p
12 V
S1
S2
clear
load
count
up/down
6 digit bcd
up/down counter
BCD counter
R10
R9
10k
10k
IC1
MK 50398
carry
D1 . . . D24 = 1N4148
N1 . . . N7 = IC2 = ULN 2003
C1... C4=150p
C1
C2
C3
C4
D4
D1
D24
D21
MSD
LSD
A
B
C
D
DT6
DT5
DT4
DT3
DT2
DT1

Fig. 16

4.2 E-Log amplifier

An E-log amplifier that meets the needs stated is the one shown in Fig. 17. Its active device is mainly the AD 521 IC (Integrated Circuit) manufactured by Analog Devices Co. It is an instrumentation amplifier with differential inputs and an accurately programmmable input/output gain relationship.

An instrumentation amplifier is a precision differential gain device optimized for operation in a real world environment, and is intended to be used whenever acquisition of a useful signal is difficult (Data-Acquisition Databook, 1982).

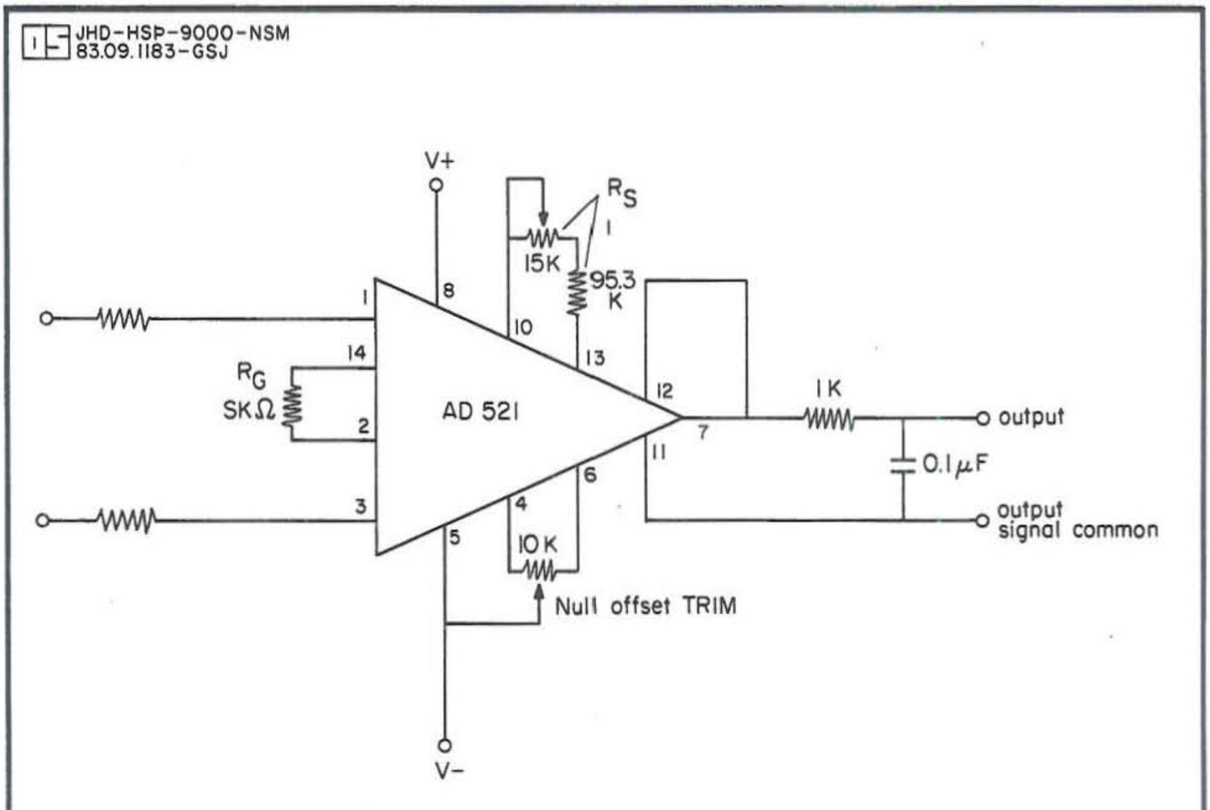
The complete amplifier shown in Fig. 17 has a voltage gain of 20, i.e. output voltage is equal to 20 times the input. This amplifier is characterized by high input impedance, balanced differential inputs, low bias currents and high common-mode rejection ratio (CMMR). The gain is determined by resistors Rs and Rg where gain, A is

$$A = \frac{Rs}{Rg}$$

Referring to the figure, when Rs is trimmed to have a value: Rs = 100 K ohms and Rg = 5 K ohms the amplification is

$$A = \frac{100\ K}{5\ K} = 20$$

A resistor of 1 K ohms and a capacitor of 0.1 microfarad in the output circuit introduces a very small time constant just to smooth out the output signal. The time constant TC is :



E-LOG Amplifier Schematic Diagram

Fig. 17

$$TC = R \cdot C$$

where R is the resistance of the resistor in ohms, C is the capacitance of the capacitor in farads, and the time constant TC is in seconds.

The time constant of the circuit is therefore

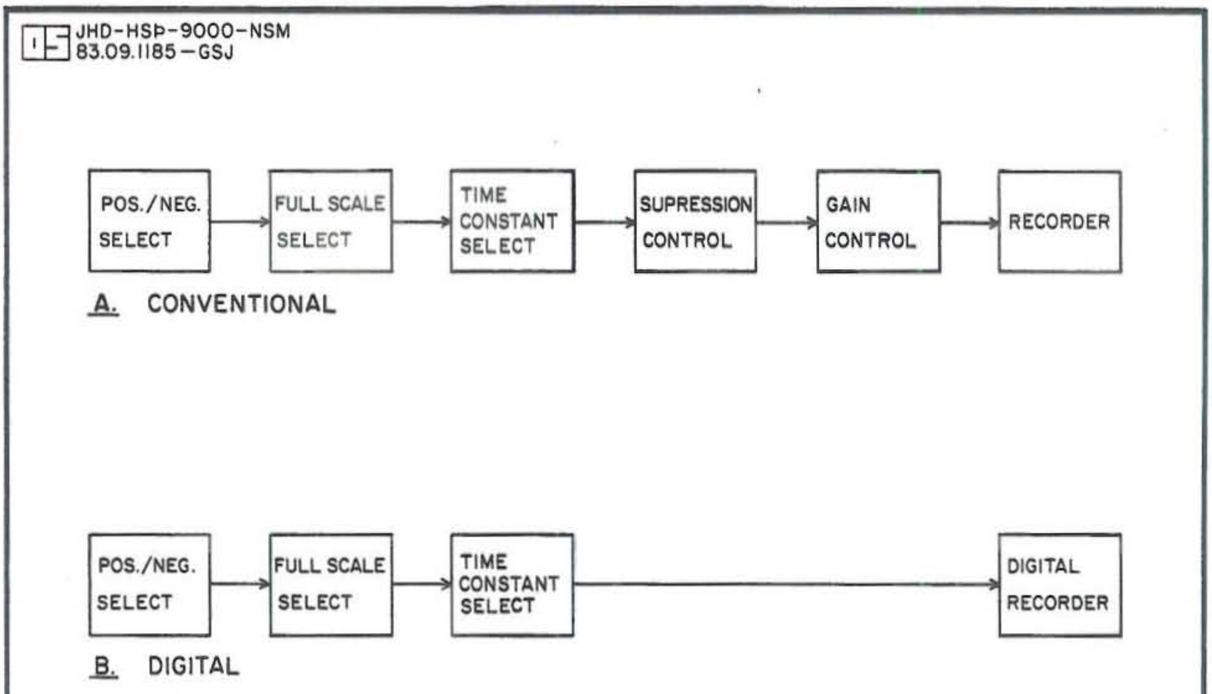
$$TC = 1 \times 10^3 \cdot 0.1 \times 10^{-6} = 0.1 \text{ milliseconds}$$

In the E-log, the mudpit and the ground for the NIM modules are not the same. This necessitates that the amplifier be isolated and have its own power supply which can be readily supplied by batteries.

4.3 Ratemeter

The ratemeter needed for digital logging is similar to the conventional one but with a few exceptions. As with the conventional ratemeter, it should change the frequency into some full scale value, time constants must be selectable, and an input and output for calibration must be provided. Different probes have different frequency responses and ranges so that a frequency range selection is required. Also, the pulses could either be positive or negative depending on the tool and should be selectable on the ratemeter. A suppression and gain control is unnecessary as their main function is calibrating the record on the paper chart in the conventional system. A ratemeter that satisfied the above requirements has been built in Iceland and is presently in use for their digital data acquisition system. Fig. 18 summarizes the necessary controls for a ratemeter for both the conventional and digital logging.

The ratemeter designed and built at Orkustofnun (NEA) is shown in Fig. 19 and it is suitable for any digital data acquisition system needing a ratemeter.



COMPARISON OF NECESSARY CONTROLS IN A) CONVENTIONAL B) FOR DIGITAL RATEMETERS

Fig. 18

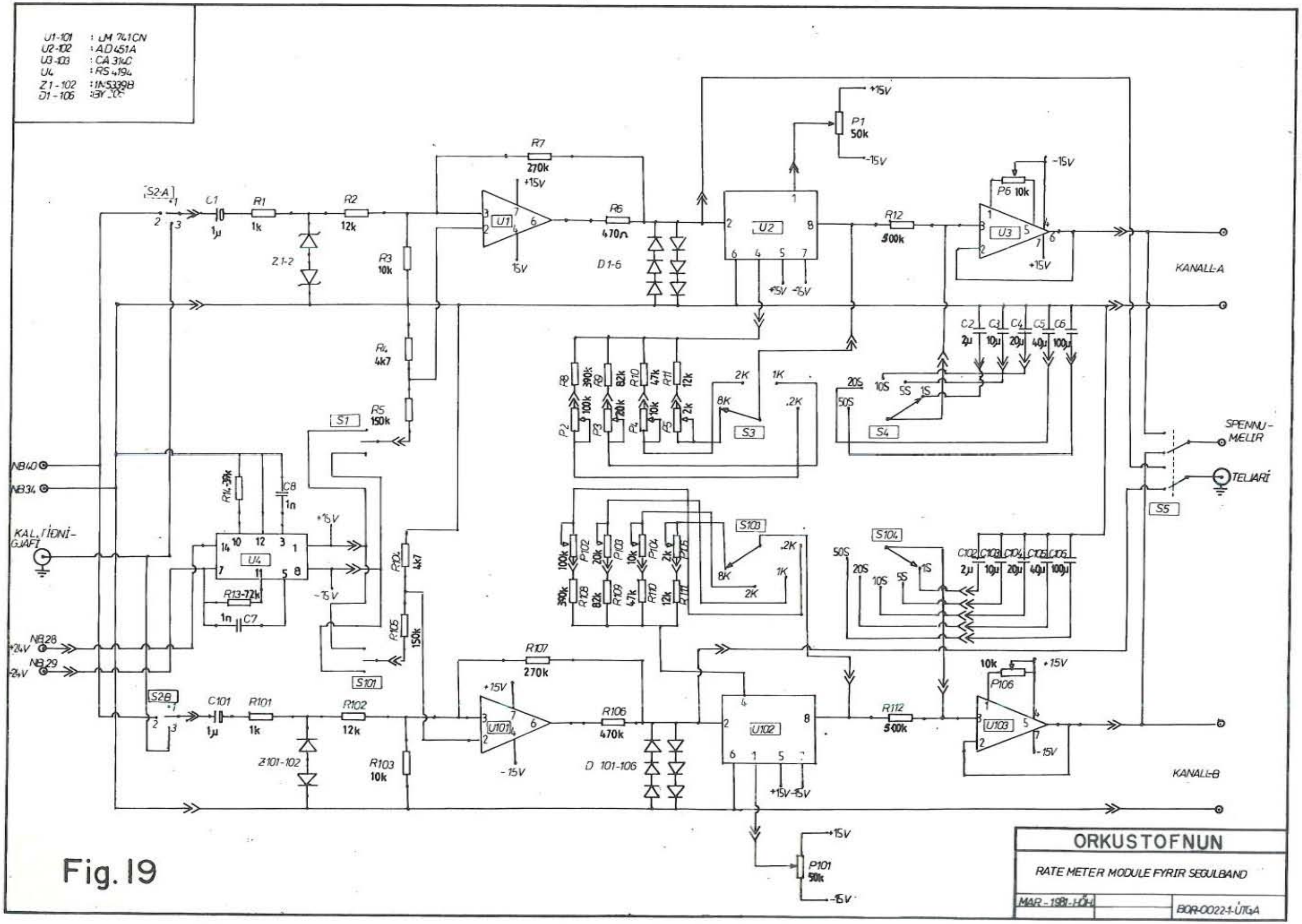

U1-101 : LM 741CN
U2-102 : AD451A
U3-103 : CA 314C
U4 : RS 4194
Z1-102 : 1N5339B
D1-106 : BY 206
S2-A
C1
1µ
R1
1k
R2
12k
Z1-2
R3
10k
R4
4k7
R5
150k
S1
R7
270k
+15V
U1
15V
R6
470Ω
D1-6
U2
+15V -15V
P1
50k
-15V
R12
500k
U3
P6 10k
KANALL-A
C2 C3 C4 C5 C6
2µ 10µ 20µ 40µ 100µ
R8 390k
R9 82k
R10 47k
R11 12k
P2 100k
P3 20k
P4 10k
P5 2k
2K 1K 8K .2K
S3
20S 10S 5S 1S 50S
S4
SPENNU-MELIR
TELJARI
S5
NB40
NB34
KAL. FIDNI-GJAFI
NB28
+24V
NB29
-24V
R14-39k
C8
1n
U4
R13-72k
1n C7
-15V
S101
R104 4k7
R105 150k
S2B
C101
1µ
R101
1k
R102
12k
Z101-102
R103
10k
R107
270k
U101
-15V
R106
470k
D 101-106
U102
+15V -15V
P101
50k
R112
500k
U103
10k
P106
KANALL-B
R108 390k
R109 82k
R110 47k
R111 12k
P102 100k
P103 20k
P104 10k
P105 2k
S103
S104
C102 C103 C104 C105 C106
ORKUSTOFNUN
RATE METER MODULE FYRIR SEGULBAND
MAR-1981-HÖH
BOR-0022-1-ÚTG.A

Fig. 19

5 THE HP-85 AS A DATA LOGGER

5.1 Introduction

An HP-85 has been tried as a base unit for a data collecting system. Some peripherals are interfaced to the computer to make it a complete data logger. A simulated temperature log has been performed in the laboratory. The hardware and the software used in the operation of the system will be discussed.

5.2 Input/Output interface

The Hewlett-Packard HP-85 in its original form, is a microcomputer which could just accept data from one peripheral device; i.e. a human being. A peripheral device is an external device, communicating with the computer. When a human as a peripheral device acts as the source he uses the keyboard as a means of input of the data into the computer. The computer acknowledges to the human being the condition of the input data through the cathode ray tube.

When communication with other peripheral devices is desired, some way other than the keyboard which is only effective for human beings must be used. An input/output interface is needed to communicate with the peripheral devices. The peripheral devices could be a disc drive, a printer, a voltmeter, a frequency counter, a plotter, etc. The interface is the hardware link that is needed to allow efficient communication of the computer with peripheral devices.

5.3 Interface standards and function of the interface

Interfacing computers to other devices has been greatly simplified by the use of interface standards. The hardware problem of hooking up devices in order to have a communication between them has been simplified. Communication is performed by software. There are several I/O interface standards in use in the computer industry. For this purpose, only the HP-IB, an interface bus developed by Hewlett-Packard and adopted by the IEEE (Institute of Electrical and Electronics Engineers, Inc.) as the IEEE 488-1978 interface standard will be discussed. This standard is also called the GPIB for General Purpose Instrument Bus.

The function of the interface is to provide compatibility in four major areas (HP-85 I/O Programming Guide, 1980b)

1. Mechanical compatibility
2. Electrical compatibility
3. Data compatibility
4. Timing compatibility

Fig. 20 shows the interface functional diagram and its role between the computer and the peripheral device.

5.3.1 Mechanical and electrical compatibility

Mechanical compatibility is achieved through standard plugs and connectors which provide the mechanical link between the computer and the peripheral device. Electrical compatibility means that the interface must change the voltage and current levels used by the computer to those used by the peripheral device. The interface causes the level changes to be the same for both computer and peripheral device.

5.3.2 Data compatibility

Another requirement of the interface is that the data sent by one device must be understandable to the other. Since different devices use different forms of codes, a form of

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INTERFACE FUNCTIONAL DIAGRAM

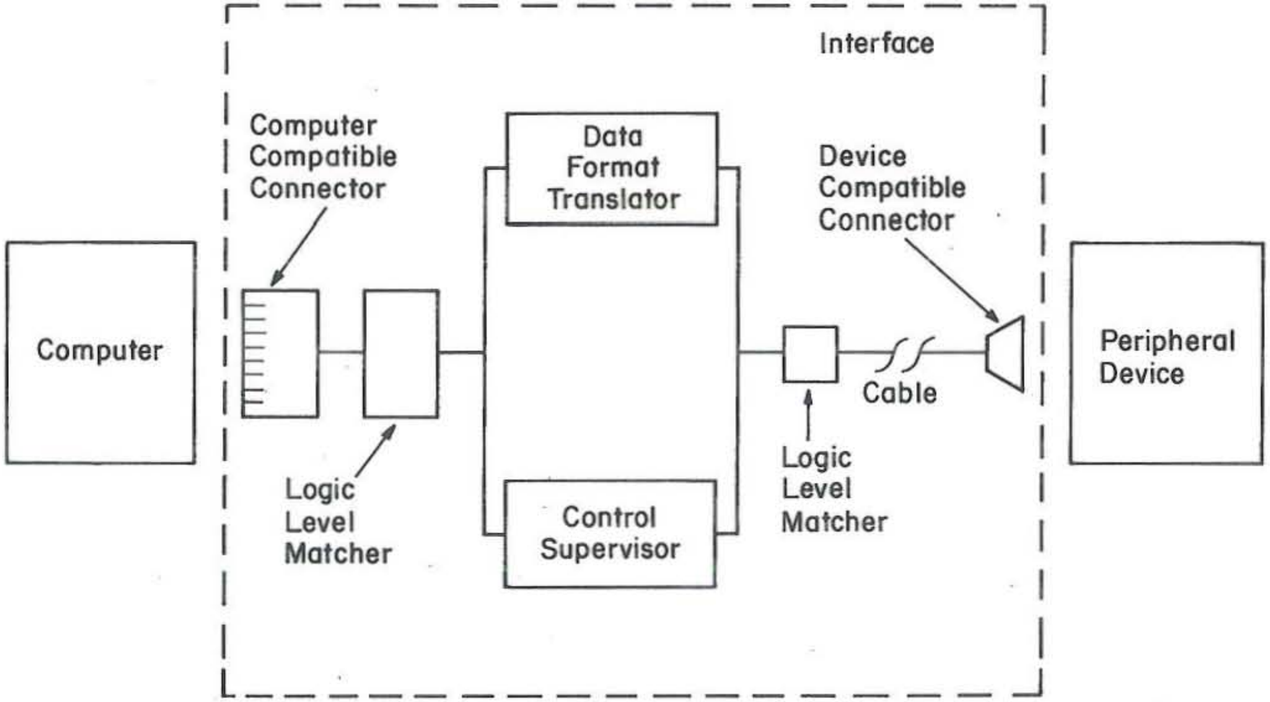


Fig. 20

translation is supplied by the interface itself although the computer can perform this function through programming.

5.3.3 Timing compatibility

Computers and peripheral devices have different range of operating speeds so that an orderly mechanism is required for the succesful transfer of data. This timing mechanism is referred to as "handshake". Fig. 21 illustrates the general concept of handshaking. The process could be summarized as follows:

1. The receiver signals that it is ready for a data item, then waits for a signal from the sender telling that the data is available.

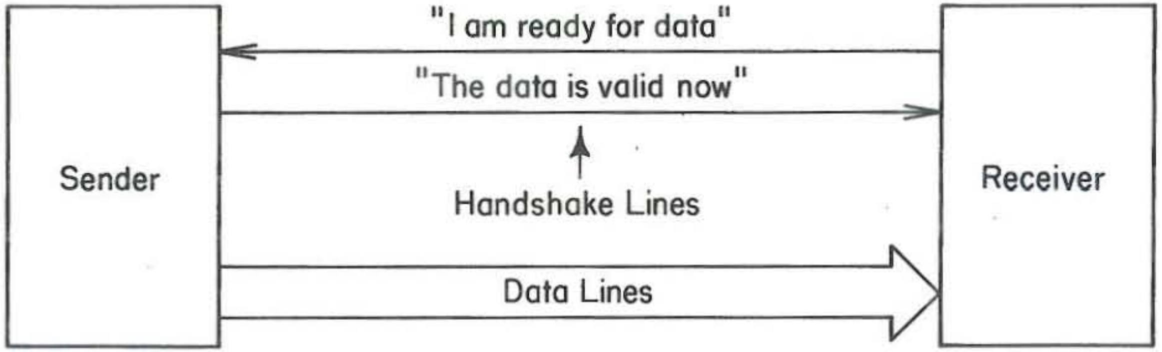
2. The receiver outputs an item of data and signals the receiver when the data is available.

3. When this data-available signal is recognized, the receiver inputs the data and signals that it is busy with this input operation.

4. The sender waits until the receiver is ready before it makes a new item of data available. When the receiver is ready, the process repeats.

5.3.4 Peripheral device addressing

With the possibility of connecting several peripheral devices to a computer, it is necessary to specify with which device it should communicate. Communication with the peripheral devices occurs one at a time. The selection process is called addressing. This uses a device selector code and then this code is addressed in the I/O statements of the computer program.



CONCEPT OF HANDSHAKING-TIMING MECHANISM OF COMPUTERS AND PERIPHERAL DEVICES

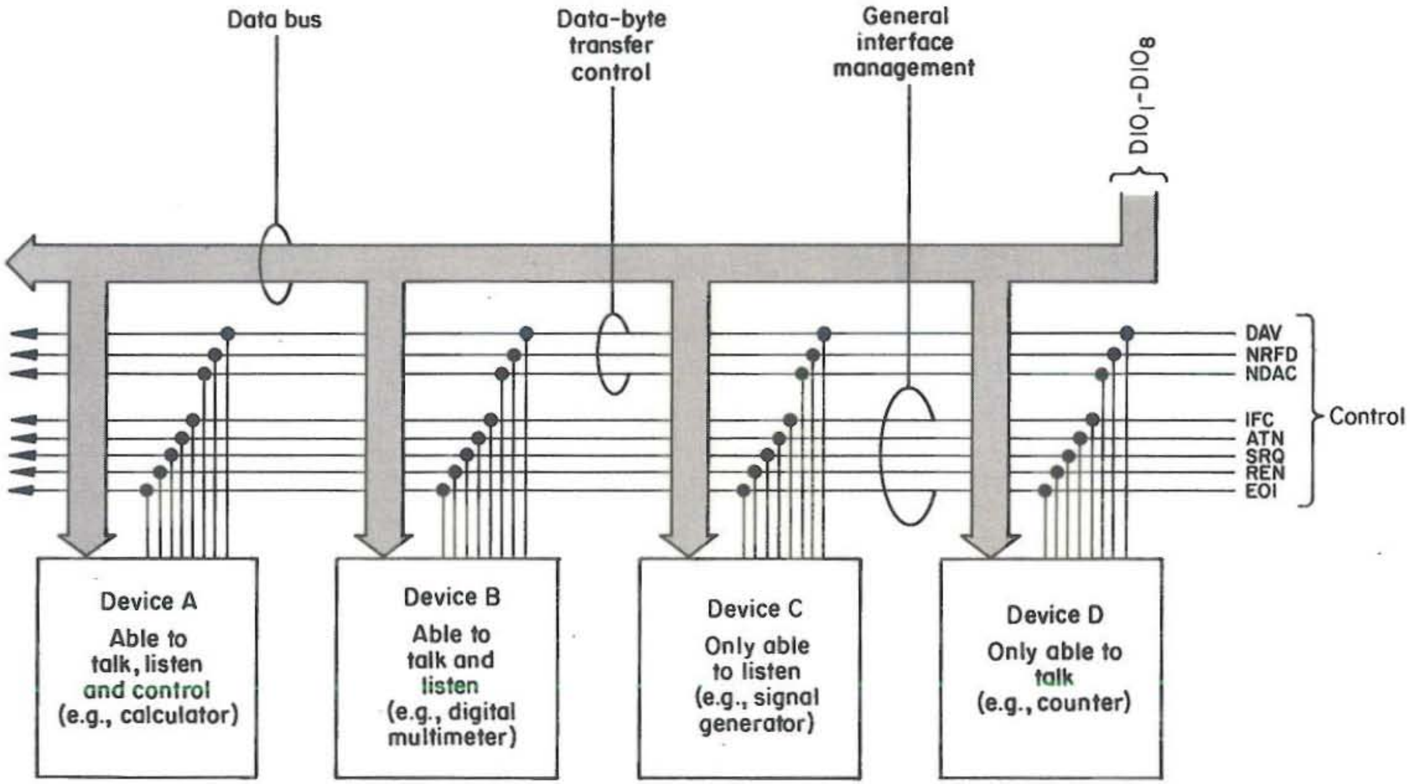
Fig. 21

5.4 The HP-IB (IEEE-488-1978) interface standard

5.4.1 General system description

HP-IB stands for Hewlett Packard Interface Bus. The HP-IB concept has greatly simplified many of the things which in the past have made instrument interfacing to the computer a cumbersome hardware task. Even so, software errors can occur if the system designer does not completely understand the bus system or the capabilities of the instruments and devices being interfaced. The purpose of HP-IB, as with other standards, is to provide the previously described compatibility requirements between all devices adhering to that standard.

The organization of the HP-IB is analogous to a committee in which a system controller acts as the chairman. This is set on the interface itself and cannot be changed under program control. It is possible however, to designate an active controller, and this may be any device capable of directing HP-IB activities, such as a computer. The system cotroller assumes the role of active controller when it is turned on but this could be passed on to other devices on the bus. For the HP-IB, the device designated to "speak" is called the active talker, and there can be only one active talker at any time. The act of authorizing an active talker is called addressing to talk, and is performed by the active controller. The message delivered by the active talker is called a data message, and delivering it is the primary function of the HP-IB. Fig. 22 shows the general configuration of the HP-IB bus. Table 2 is a description of the lines used by the bus.



GENERAL CONFIGURATION OF THE HP-IB BUS

Fig. 22

Table 2 - The HP-IB (IEEE-488) Interface Bus Lines Description.

THE HP-IB (IEEE-488) BUS LINES	
DESIGNATION	DESCRIPTION
DIO_1 - DIO_8	DATA INPUT/OUTPUT: Eight data transfer lines; also called the data bus.
ATN	ATTENTION: Issued only by the controller, to gain the attention of the bus devices before beginning a handshake sequence and to denote address or control information on the data bus.
DAV	DATA VALID: Issued by a talker to notify the listeners that the data has been placed on the DIO lines
EOI	END OR IDENTITY: Issued by a talker to notify the listeners that the data byte currently on the DIO lines is the last one. The controller issues is together with ATN to initiate a parallel poll sequence.
IFC	INTERFACE CLEAR: Issued only by the controller to bring all active bus devices to a known state.
NDAC	NOT DATA ACCEPTED: Issued by a listener while fetching data from the DIO lines.
NRFD	NOT READY FOR DATA: Issued by all listeners and released by each listener as it becomes ready to accept data.
REN	REMOTE ENABLE: Grounded to the main control over the system.
SRQ	SERVICE REQUEST: Issued by any device needing service from the controller.

5.4.2 Basic system operation

Message bytes are carried on the eight DIO signal lines in a bit-parallel, byte-serial form, asynchronously and bidirectionally. Three lines - DAV, NRFD, and NDAC - manage the transfer of data on the eight signal lines from a talker or the controller to one or more listener devices.

The DAV (Data Valid) line indicates the availability and validity of information on the signal lines. The NRFD (Not Ready for Data) line signals whether a device is ready to receive data. NDAC (Not Data Accepted) indicates that a device is receiving data.

ATN (Attention), one of the five control lines, is central to the operation of the interface. It specifies how data on the eight signal lines are to be interpreted and which devices must respond. When the controller sets the ATN line true, the specific response of devices on the bus is elicited by sending talker or listener addresses from the controller down the eight data lines. While the ATN line is held true, all devices must listen to the addresses. When the controller sets the ATN line false, only the devices that were specifically addressed receive or transmit data. Only one talker can transfer data at a time.

Data transfer rate of the bus is up to 1 Mbytes per second. This fast transfer is due to the bit-parallel mode of information communication. However, a maximum of 15 devices can be supported. This limitation is due to the electrical specifications for the line driver and receiver circuits. Also, the total cable length connecting all the instruments on one bus should not exceed 20 meters. Voltage levels on the various lines do not change instantaneously but require a certain amount of time proportional to the lengh of the cable. This limit insures that the bus will operate properly at its rated maximum speed.

5.5 HP-85 and peripherals for simulated data collection and registration

The equipment set-up for the system is illustrated in Fig. 23. A description of each piece of equipment in the system follows.

5.5.1 HP-85 desktop computer

The HP-85 desktop computer has a read/write memory of 16K bytes built into it (HP-Technical Data, 1980a). It is expandable to 32K bytes with an expansion module that can be plugged in at a provided port. The computer is programmable in BASIC language. A tape cartridge is included with a capacity of 210K bytes for data storage or 195K bytes for program storage. A built-in thermal printer is provided with a paper width of 108 mm. Each character set printed is composed of 5 by 7 dot matrix and 32 chraracters per line. Graphics resolution is 2.63 dots per mm. The visual display is CRT with a size of 127 mm (diagonal).

5.5.2 I/O ROM and 82937A HP-IB interface

If the HP-85 is to act as a system controller, the HP-IB Interface Module 82937A and the I/O ROM (Read Only Memory) must be fitted into their appropriate slots (HP-technical data, 1980c). The I/O ROM is plugged into one of six spaces in the ROM drawer, which in turn fits into one of the four slots in the back of the computer. The 82937A HP-IB module plugs into one of the slots.

The BASIC language is augmented with straightforward I/O commands through the I/O ROM. Any I/O system requires program statements or subprograms called I/O drivers to pass data and commands among instruments. This capacity is provided by the I/O ROM so that only simple BASIC commands are to be used by the programmer.

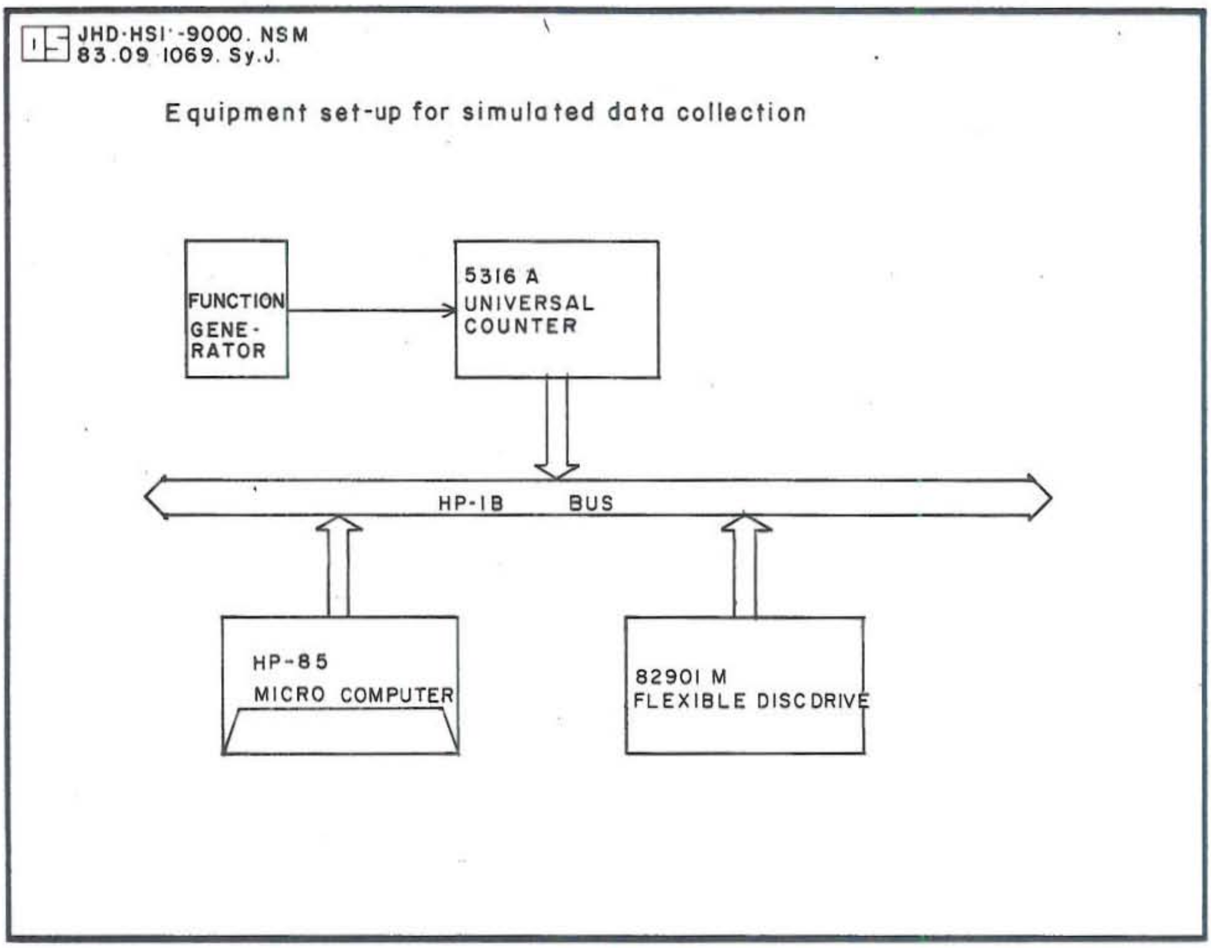

JHD-HSI'-9000. NSM
83.09 1069. Sy.J.
Equipment set-up for simulated data collection
FUNCTION GENE-RATOR
5316 A UNIVERSAL COUNTER
HP-IB BUS
HP-85 MICRO COMPUTER
82901 M FLEXIBLE DISCDRIVE

Fig. 23

The HP 82937A is the HP-IB hardware and software interface that permits bidirectional, asynchronous communication of up to 14 compatible instruments. It uses an interface processor to provide efficient management of the interface bus protocol. It can achieve data transfer rates of up to 25K bytes per second which is the absolute maximum.

5.5.3 HP 82901M flexible disc drive unit

Due to higher speed and more storage capacity than the tape cartridge, a disc drive model 82901M is employed for data storage. The tape cartridge however is convenient for storing the programs to be executed. HP 82901M is a 5-1/4" flexible disc dual drive which supplies up to 540K bytes of fast random access storage. Each disc provides 270K bytes of formatted storage.

5.5.4 HP 5316A universal counter

The Hewlett-Packard Universal Counter Model 5316 measures signals over a range of DC to 100 MHz. It measures frequency, period, time interval average, time interval holdoff, ratio (A/B), and the pulse totalization function with manual or external gating. It is externally programmable via the Hewlett Packard Interface Bus (HP-IB). It is this feature that makes it possible and useful as a measurement tool for the data collecting system. For the following simulated run, it is applied as a frequency counter. It could give a data output rate via the HP-IB of 7 readings per second maximum for the shortest gate time.

The above mentioned counter is a laboratory type counter with a very high degree of accuracy so that it is used for calibration purposes at Orkustofnun. A less accurate counter with the same interface bus would be sufficient for logging purposes. The above counter would be too expensive for purposes other than laboratory work such as calibration. It was so used just because of its availability at the Orkustofnun Electronics Laboratory.

5.6 Software

Computer programming is in the enhanced BASIC language of HP. Two programs were made: one for data collecting and one for plotting the collected data. The programs were not well refined due to time constraints on the preparation of this report but they serve their purpose well.

Shown on Fig. 24 is the flow chart for data collection and Fig.26 is the computer program itself. Fig. 25 shows the plotting flow chart and also in Fig.26 the actual program. The flow charts explain how the programs operate.

5.7 Results

On running the data collection program, the display on the CRT looks like that on Fig. 27. Two examples of plotted data are shown in Fig. 28.

5.8 Time analysis

Using the HP-85's internal timer, it has been possible to scrutinize the speed limitations of the system. Timer commands of the computer were inserted at appropriate points in the program to determine how long a time it would take to execute certain statements in the program. With this method, the following observations were made:

1) It takes an average of 40 milliseconds for the computer (which acts as the controller) to set up the counter into its frequency mode.

JHD-HSP-9000. NSM.
83.09. 1070. Sy.J.

Temperature data collection flowchart

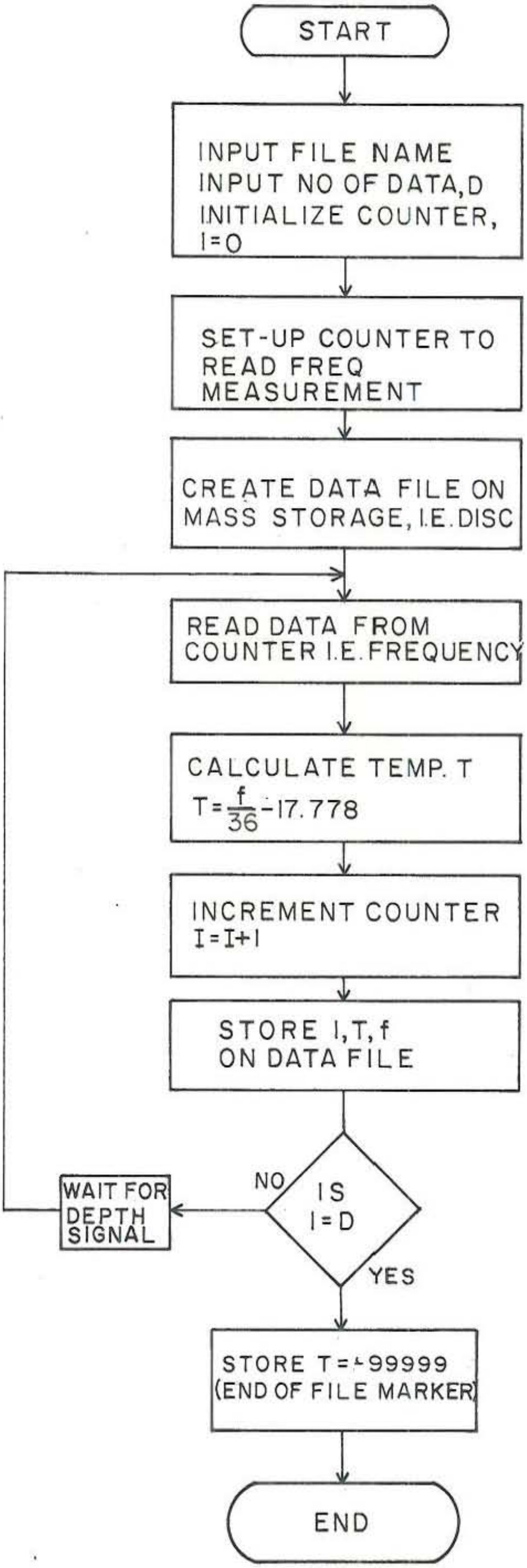


Fig. 24

JHD-HSÞ-9000.NSM
83.09.1071. Sy.J.

PLOT ROUTINE

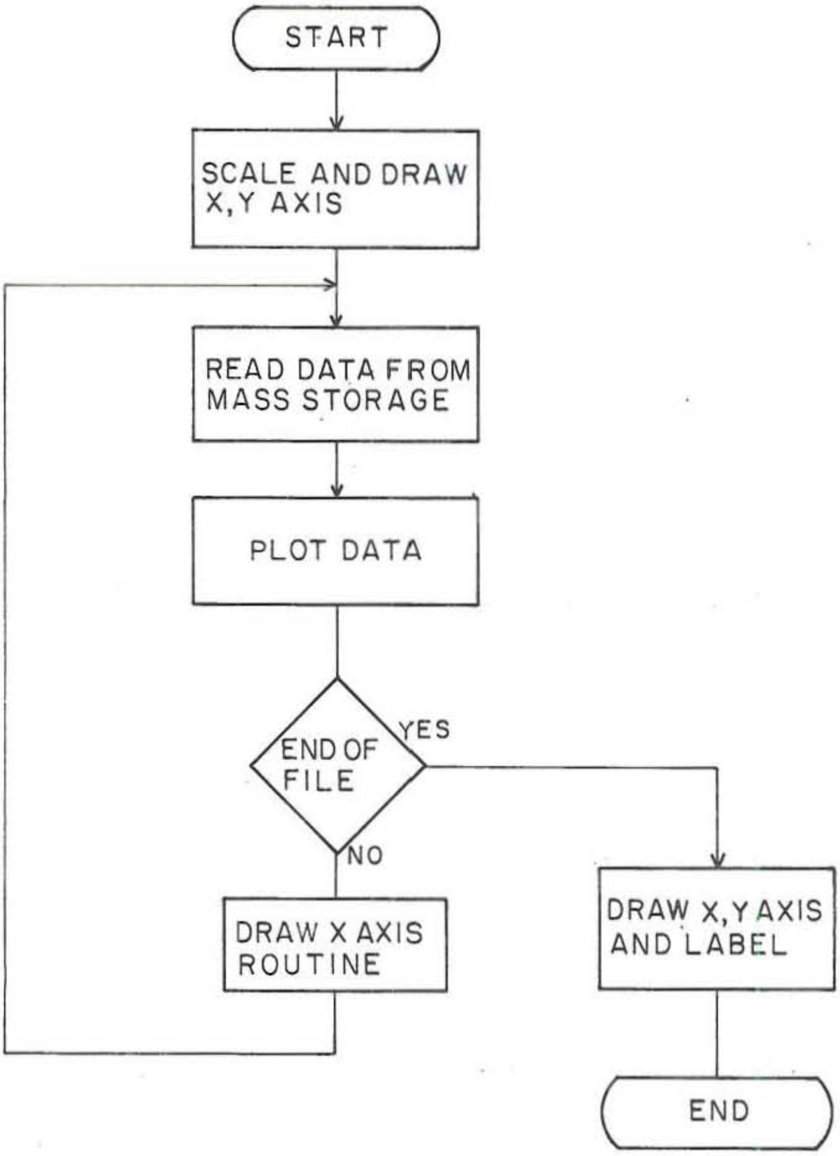


Fig. 25

DATA PLOTTING PROGRAM

```
 10 ! DATA PLOTTER,"DATPL9"
 20 DISP "FILE NAME?"
 30 INPUT F$
 40 ASSIGN# 1 TO F$
 50 GCLEAR
 60 SCALE 0,200,-30,150
 70 XAXIS 0,10,0,200
 80 YAXIS 0,10,0,140
 90 FOR J=20 TO 150 STEP 20
100 LDIR 0
110 MOVE 5,J-5
120 LABEL VAL$(J)
130 NEXT J
140 LDIR 90
150 FOR J=0 TO 200 STEP 20
160 MOVE J+5,-30
170 LABEL VAL$(J)
180 NEXT J
190 FOR J=10 TO 140 STEP 10
200 MOVE 100,J
210 DRAW 102,J
220 NEXT J
230 MOVE 45,140
240 LDIR 0
250 LABEL "TEMP FROM DATA ",F$
260 READ# 1 ; I,F,T
270 MOVE 0,T
280 M=0
290 N=1
300 M=M+1
310 READ# 1 ; I,F,T
320 IF I=-9999 THEN 540
330 IF M=N*200 THEN 360
340 DRAW I,T
350 GOTO 300
360 COPY
370 GCLEAR
380 SCALE M,M+200,-30,150
390 XAXIS 0,10,M,M+200
400 LDIR 90
410 FOR J=M TO M+200 STEP 20
420 MOVE J+5,-30
430 LABEL VAL$(J)
440 NEXT J
450 FOR K=0 TO 100 STEP 100
460 FOR A=10 TO 140 STEP 10
470 MOVE M+K,A
480 DRAW M+K+2,A
490 NEXT A
500 NEXT K
510 N=N+1
520 MOVE M,T
530 GOTO 300
540 COPY
550 GCLEAR
560 SCALE M,M+200,-30,150
570 XAXIS 0,10,M,M+40
580 MOVE M+40,3
590 DRAW M+47,0
600 DRAW M+40,-3
```

PROGRAM FOR DATA COLLECTION

```
  1 ! DATA COLLECTOR
 10 DISP "FILE NAME?"
 20 INPUT F$
 30 DISP "NO.OF DATA?"
 40 INPUT D
 50 CREATE F$,50
 60 ASSIGN# 1 TO F$
 70 OUTPUT 720 ;"WA1SR1GA1"
 80 DISP USING 90
 90 IMAGE X,"DATA",4X,"FREQ",6X,
    "TEMP"
100 FOR I=1 TO D
110 ENTER 720 ; F
120 T=F/36-17.778
130 DISP USING 140 ; I,F,T
140 IMAGE 2X,3Z,3X,4Z.2D,3X,3Z 2
    D
150 PRINT# 1 ; I,F,T
160 NEXT I
170 PRINT# 1 ; -9999,-9999,-9999
180 END
```

```
610 DRAW M+40,3
620 MOVE M+5,-20
630 LDIR 0
640 LABEL "DEPTH,m"
650 YAXIS M+10,10,0,140
660 FOR J=20 TO 140 STEP 20
670 MOVE M+14,J-5
680 LABEL VAL$(J)
690 NEXT J
700 MOVE M+12,140
710 DRAW M+10,148
720 DRAW M+8,140
730 DRAW M+12,140
740 MOVE M+43,30
750 LDIR 90
760 LABEL "TEMPERATURE,C"
770 COPY
780 BEEP @ DISP "END OF";F$;"FIL
    E"
790 END
```

Fig. 26

```
FILE NAME?
?
TEMP
NO.OF DATA?
?
100
 DATA     FREQ       TEMP
  001    1049.64    011.38
  002    1063.68    011.77
  003    1081.17    012.25
  004    1081.18    012.25
  005    1081.19    012.25
  006    1081.19    012.26
  007    1081.19    012.26
  008    1063.12    011.75

  009    0997.30    009.92
  010    0993.80    009.83
  011    0995.35    009.87
  012    1080.47    012.23
  013    1080.47    012.24
  014    1080.49    012.24
  015    1081.13    012.25
  016    1081.21    012.26
  017    1081.21    012.26
  018    1081.19    012.25
  019    1081.21    012.26
  020    1081.20    012.26
  021    1081.20    012.26
  022    1081.20    012.26
  023    1081.19    012.26

  024    1081.21    012.26
  025    1081.20    012.26
  026    1081.20    012.26
  027    1081.15    012.25
  028    1081.11    012.25
  029    1081.16    012.25
  030    1081.16    012.25
  031    1081.17    012.25
  032    1081.15    012.25
  033    1081.19    012.26
  034    1081.20    012.26
  035    1081.20    012.26
  036    1081.18    012.25
  037    1081.18    012.25
  038    1081.20    012.26

  039    1762.20    031.17
  040    1765.51    031.26
  041    1833.32    033.15
  042    2018.85    038.30
  043    1869.55    034.15
  044    1584.17    026.23
  045    1538.36    024.95
  046    1556.75    025.46
  047    1671.73    028.66
  048    1753.97    030.94
  049    1794.68    032.07
  050    1873.63    034.27
  051    1940.66    036.13
  052    2004.12    037.89
  053    2031.21    038.64

  054    2087.04    040.20
  055    2157.09    042.14
  056    2179.65    042.77
  057    2222.76    043.97
  058    2257.59    044.93
  059    2295.04    045.97
  060    2313.58    046.49
  061    2324.23    046.78
  062    2348.75    047.47
  063    2395.68    048.77
  064    2527.12    052.42
  065    2687.18    056.87
  066    2708.57    057.46
  067    2708.57    057.46
  068    2708.56    057.46

  070    2710.65    057.52
  071    2747.17    058.53
  072    2787.27    059.65
  073    2852.71    061.46
  074    3026.66    066.30
  075    3236.69    072.13
  076    3455.75    078.22
  077    3679.39    084.43
  078    3796.28    087.67
  079    3848.57    089.13
  080    3925.76    091.27
  081    4046.23    094.62
  082    4152.41    097.57
  083    4279.46    101.10
  084    4346.89    102.97

  085    4354.62    103.18
  086    4355.71    103.21
  087    4425.12    105.14
  088    4476.17    106.56
  089    4571.43    109.21
  090    4596.53    109.90
  091    4543.34    108.43
  092    4619.77    110.55
  093    4658.73    111.63
  094    4712.08    113.11
  095    4712.61    113.13
  096    4712.65    113.13
  097    4743.91    114.00
  098    4743.91    114.00
  099    4743.91    114.00

  100    4743.88    114.00
```

Fig. 27

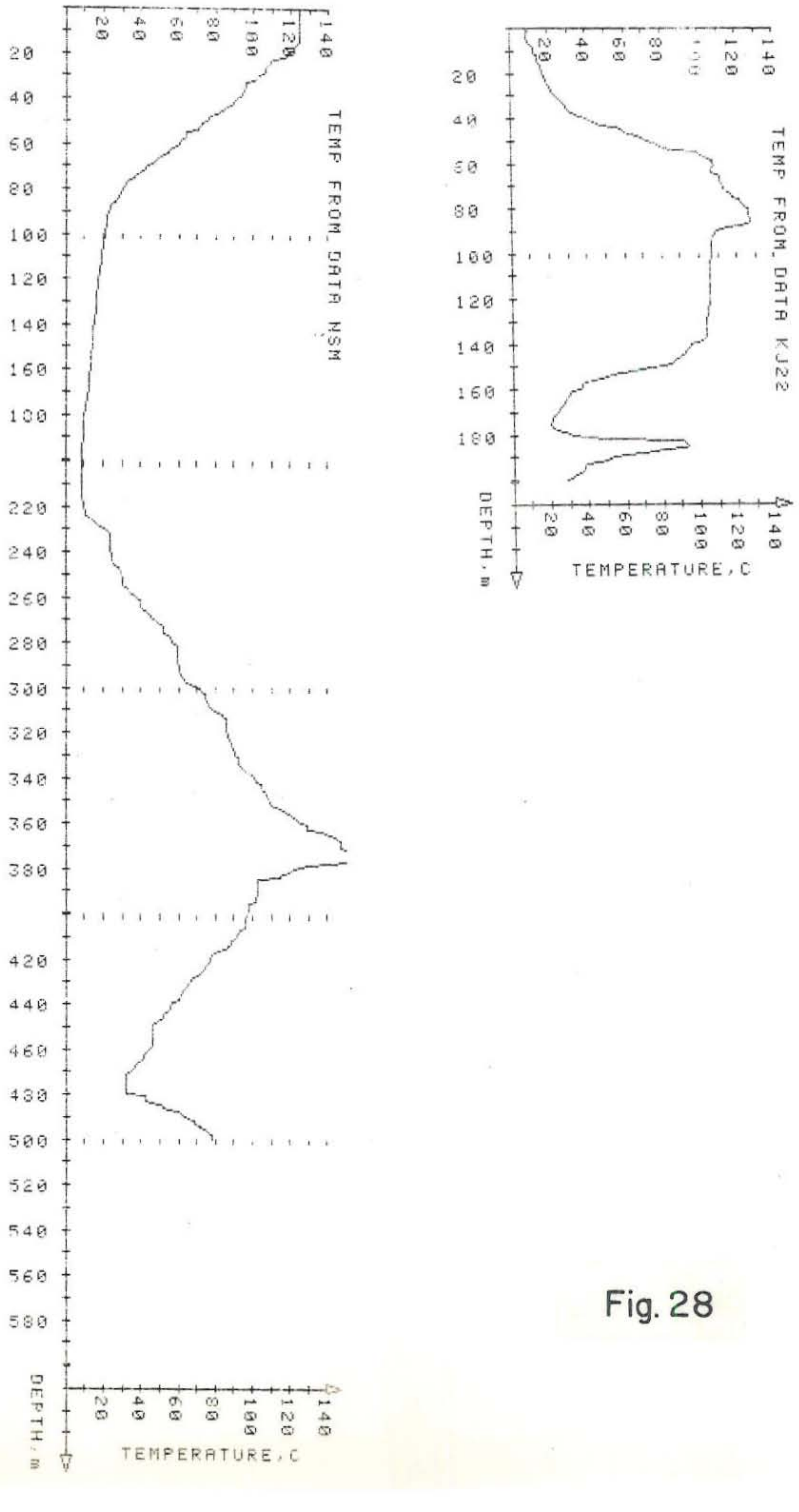

TEMP FROM DATA NSM
TEMP FROM DATA KJ22
TEMPERATURE, C
DEPTH, m
20
40
60
80
100
120
140
160
180
220
240
260
280
300
320
340
360
380
420
440
460
480
500
520
540
560
580

Fig. 28

2) With the gate time of the counter set to a minimum, i.e. the fastest measurement time, the total time for the computer to take the data averaged 160 milliseconds.

3) Conversion of the data into the corresponding temperatures by computer calculation took approximately 9 milliseconds.

4) The memory is not dimensioned so that a default state of 256-byte buffer is used as data storage. The 256-byte transfer to the floppy disc took an average of 1.14 seconds.

Disregarding the set-up time of the logging counter, the total time for the whole system to gain access and to calculate the data took 169 milliseconds. In order to see the significance of this figure, it can be seen from Table 1 wherein for the system in Iceland, temperature measurement is given a maximum logging speed of 40 m/min and a measurement interval of 40 cm. The time lapse between an interval is 600 milliseconds. Hence 169 milliseconds of data collection time is still tolerable. But if the measurement interval is reduced to 10 cm, with the same logging speed of 40 m/min., then the time for the probe to go into the next measurement point would be only 150 milliseconds; in which case no measurement would be done since the computer is still in the act of acquiring and processing the data supposed to be from the last measurement point. However, a 10 cm measurement interval is unneccessary short in usual logging operations Nevertheless, the use of a ratemeter and an interface compatible digital voltmeter would make for a very fast measurement since voltage measurement would be almost instantaneous unlike frequency measurement, which requires gate time to read its value.

In the program used, the computer first stores the data on a 256 byte buffer memory before it is transferred on to the disc. On the HP-85, a single number e.g. 1, 10, 100, 1000, etc., consumes 8 bytes of memory storage. Hence a total of

32 data numbers would fill the buffer. The act of transfer into the disc drive interrupts the whole system including the measurement function since only one thing at a time could be done by the computer notwithstanding communication through the interface bus itself. The transfer of the 256 byte data into the disc took an average of 1.14 seconds.

With reference again to the temperature logging just recently mentioned, the time (for a 40 cm interval) it takes for the probe to go from one measuring point to the next is 600 milliseconds. If the above program were to be used, then there would be a point whenever the buffer memory is filled, that no measurement can be taken in because of the 1.14 second transfer time.

It is however possible to dimension the computer's memory in such a way so as to fully utilize its full capacity before the data is transferred to the disc drive. The HP-85 has a full RAM (random-access-memory) of 32K bytes which is equal to 32,768 bytes (since 1K byte = 1024 bytes). Parts of these are used by the ROMs (read-only-memory) for the BASIC interpreter, I/O, etc., and a part is used by the program itself. In this particular case, the ROMs and the data collection program used a total of 3,386 bytes of RAM. Therefore, 29,382 bytes of the memory are still free for use for data storage.

By utilizing the memory's full available capacity, logging can be done without measurement skip, up to a certain depth depending on the number of parameters measured and stored. Logging can be stopped or slowed down to enable the data to be transferred to the disc, without losing measurements at that point.

5.9 Other measurements

The same set-up can be used for measuring other parameters employing frequency variations as the method of information transmission. Differences will just lie on the software for the data registration and plotting. Following are examples of how such other measurements would be done using the same system set-up.

5.9.1 Caliper measurement

For a caliper tool, in which the frequency is not linear for all ranges in arm opening, a program must be prepared in such a way that it will correct the gathered data with respect to the actual arm opening. An actual caliper log calibration is shown in Fig. 29. As can be seen, the pen deflection is not linear for an equal caliper arm opening. This is illustrated in Fig. 30.

Looking at each diameter range as a linear function of that frequency range, say D2 to D3 as a function of F2 to F3, it can be shown that any diameter of that range will be given by:

$$D = \frac{(f-f2)(D3-D2)}{(f3-f2)} + D2$$

where: D = diameter between D2 and D3 range, f = measured frequency

In general, for any frequency and diameter range; the diameter is calculated as:

$$D = \frac{(f - f_{n-1})(D_n - D_{n-1})}{(f_n - f_{n-1})} + D$$

where f_n is the frequency at a diameter D_n and f is the measured frequency.

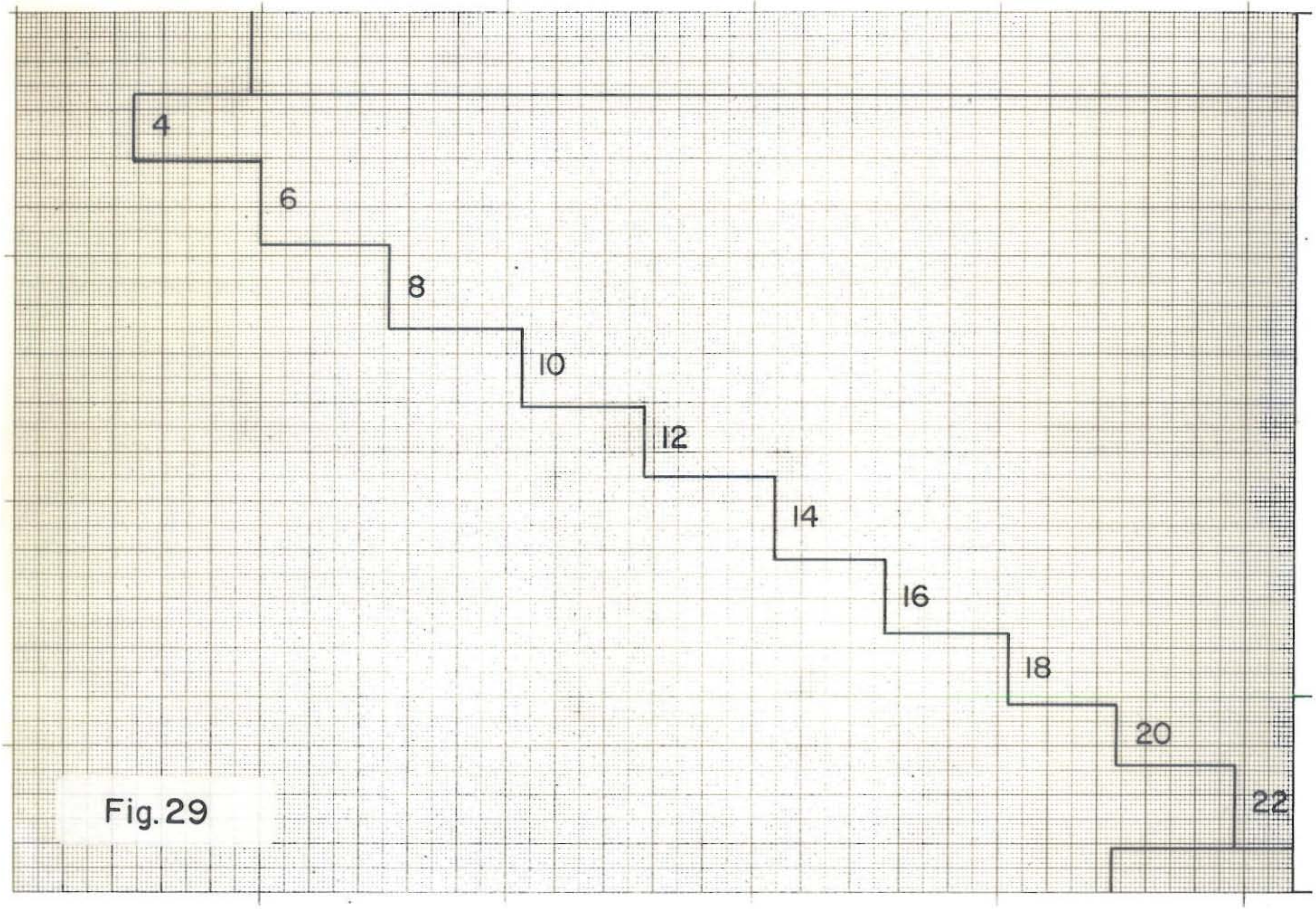


Fig.29

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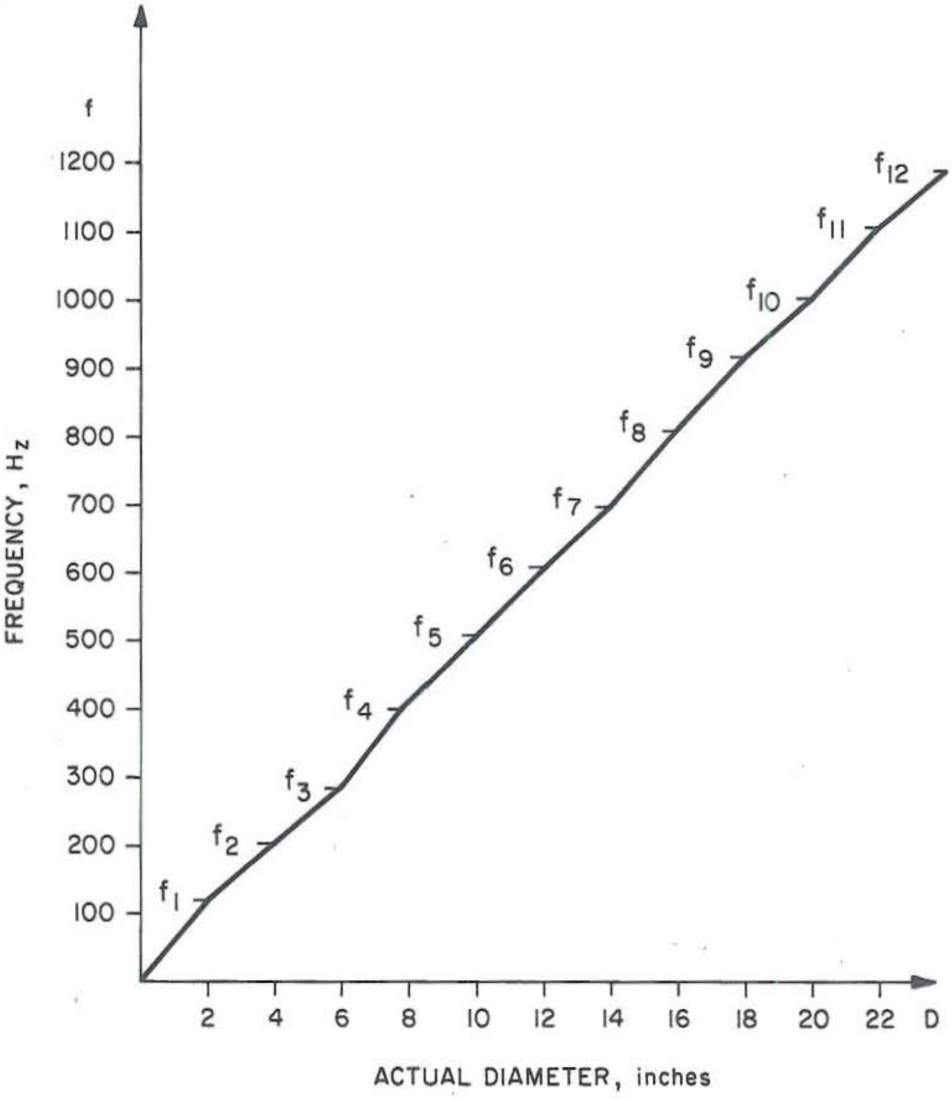


FREQUENCY RESPONSE ON LINEARLY INCREASING CALIPER OPENING

Fig. 30

During logging, calibration will be done by reading f_1 to f_n and D_1 to D_n and using these for actual diameter calculations. Fig. 31 shows a flowchart for a computer program that would apply in this type of measurement. The program first stores the corresponding frequencies for the different diameters during calibration, and then uses these data to linearize the measured frequencies to get the actual diameter values in accordance with the previously derived formula. It is also possible to take the calibration data after logging and process the measured frequency data afterwards.

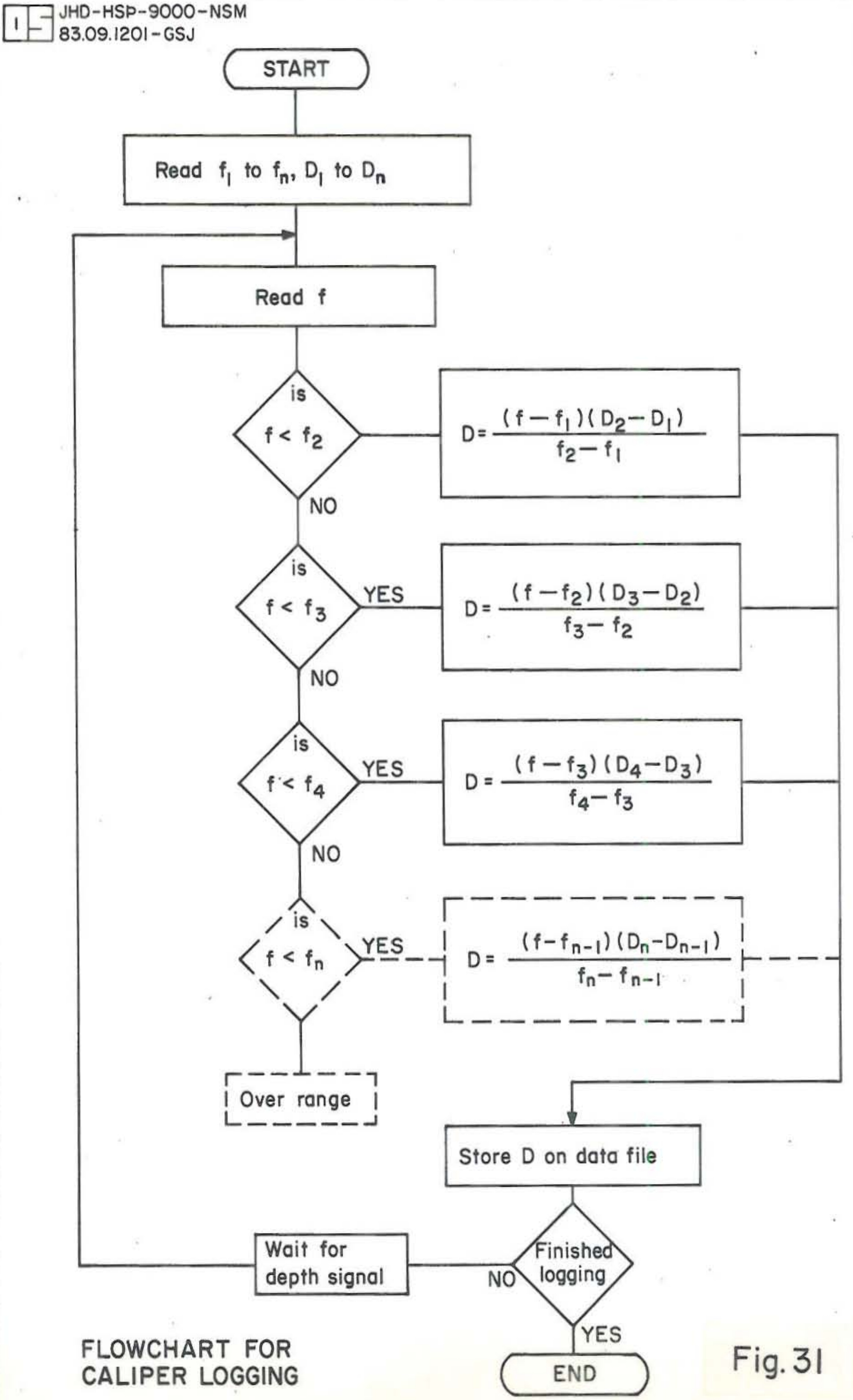
5.9.2 Nuclear logs

In nuclear logs, i.e. natural gamma, gamma-gamma and neutron-neutron where the output pulses are relatively few; i.e. low frequency, most specially the natural gamma radiation where the counted pulses are less than 20 per second and occur very randomly, it is convenient to use the HP 5316A in a totalizer mode. It can be programmed to count (totalize) the number of pulses during each measuring interval, say n. The internal clock of the computer could be set to measure the time interval between measuring points, Δt. The frequency is then calculated as:

$$f = \frac{n}{\Delta t}$$

where n = the counted pulses, Δt = the time between the start and end of counting. Similarly, the logging speed can be calculated as:

$$v = \frac{\Delta s}{\Delta t}$$



FLOWCHART FOR CALIPER LOGGING

Fig. 31

where Δs = the distance between two measuring points, and Δt = the time between each measuring interval.

5.9.3 E-log, sonic log, etc.

For logs that use analog signal translation, a digital voltmeter (DMM) such as HP 3438 A needs to be added to the system. The same is interfaceable to the computer via the HP-IB, although several of these are needed for simultaneous measurements of different parameters on a single run or a multiplexer can be used in order to use only one instrument.

5.10 Data processing

As long as the registered data are recorded on the disc, these could be processed and manipulated at will without any degradation or alteration to the original data. A similar computer and disc drive in the office plus a plotter should complete this simple system. With this, raw data can be collected in the field while the processing is done in the office. Any other way, the system could be made very flexible to suit any particular need.

6 USE OF HP-87 COMPUTER AND INTEGRATED DATA ACQUISITION UNITS

6.1 Introduction

The availability of an HP-87 computer at the author's section at the PNOC-EDC, Geothermal Division in the Philippines prompted the author to do a brief study on the applicability of this computer as a substitute for the HP-85 used previously.

Measurement, test, and control instruments have recently been available as modular units capable of being integrated into a single mainframe which in turn can be interfaced to a computer that acts as the controller. This is ultimately more practical than having several discrete instruments do the job.

6.2 Model HP-87 computer

HP-87 is one of the Series 80 personal computers manufactured by Hewlett-Packard Co. HP-85 and HP-87 have the same built-in operating system and both use the similar HP's enhanced BASIC. The main physical difference is that the HP-87 does not have an internal printer and a tape cartridge for mass storage. Also the 87's CRT is 10 inches diagonal which is twice as big as that of the HP-85. The HP-87 would need an external mass storage unit to be useful. Perhaps the most interesting difference is in their memory capacities which is a big factor especially for data acquisition. The HP-85 has a random-access-memory (RAM) with an expanded maximum of 32K bytes whereas an HP-87 has a built-in user memory of 128K bytes and can be expanded up to 640K bytes. This memory has 20 times the maximum capacity of HP-85. With this advantage, it would be possible to log continuously without stopping - which is necessary when the computer's internal memory is used up, since enough memory space is available. The data would not be transferred to a non-volatile storage media, such as a flexible disc, until the end of the logging operation. A comparison of memory spaces between an HP-85 and an HP-87 is shown in Fig. 32.

6.3 Data acquisition units

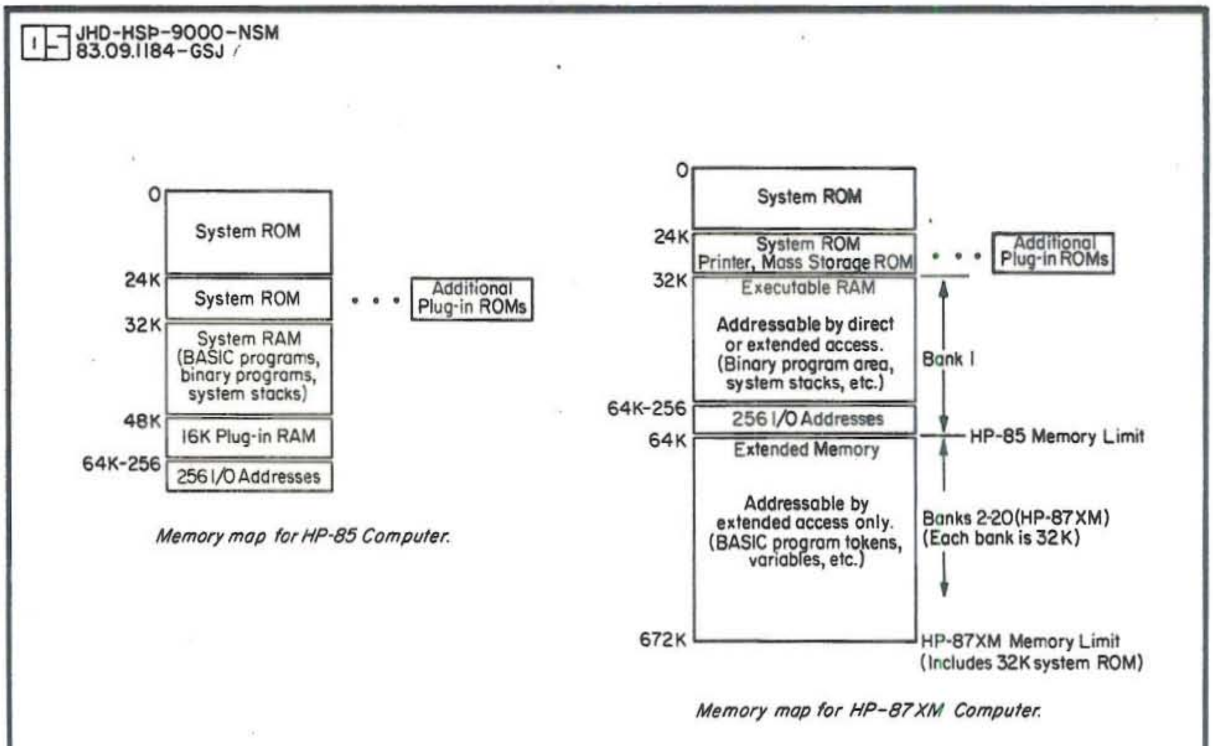
These are units which combine on a single mainframe the capabilities of several discrete instruments. These capabilities range from testing, measuring and controlling certain physical parameters. By plugging-in the appropriate modules, the unit can be custom configured to suit any particular requirement of the above capabilities. Its versatility and flexibility makes it widely used in varied areas, from industrial automation to laboratory research and development. Its measurement capabilities, however, make it desirable for well-logging application.

With the availability of these mainframes, it appears more practical to use a data acquisition unit and specify the modules needed than to use several instruments (e.g. digital voltmeters, frequency counters, etc.) to perform the same function.

Several models are available from Hewlett-Packard Co. but a suitable selection for measurements in well-logging is HP's Multiprogrammer model 6942A. This model has a built-in HP-IB bus which means that it could be interfaced and controlled by a bus compatible computer.

Card modules that suit well-logging purposes are available for the Multiprogrammer 6942A. These include a counter timer with an up-down counting facility that would do the depth measurement, getting its information from the depth control such as that described in Chapter 3 of this report. A frequency counter or totalizer card is also available for frequency or pulse counting measurements, as well as analog to digital cards which would handle the analog logging signals and convert them into digital information for the computer. All of which are controllable by the computer via the HP-IB bus. The 6942 A Multiprogrammer mainframe could handle up to 16 of these cards, which is enough for well-logging purposes.

With the addition of software for the computer, which would direct the operation of the system, this scheme should make up a complete digital logging system.



COMPARISON OF MEMORY SPACES BETWEEN HP-85 AND HP-87XM

Fig. 32

7 CONCLUSIONS

The versatility of computers for a great variety of applications does not exclude the acquisition and processing of well-logging data. Recent advances in technology that have led to micro-miniaturization of computers with high capability make it more attractive for use in the field such as in well logging.

The conventional method of well-logging is in analog form in which processing and manipulation of the data is fairly tedious if not impossible. Digital data has the big advantage of being processed using the computer. Manipulation, correction, etc. is easily done. This would otherwise be a cumbersome task using the analog data since such a huge amount of data would be manipulated manually.

The present system in Iceland can be regarded as an early generation in the application of computer technology to data collecting and data processing in well-logging. All the equipment mounted on the logging truck was hardware developed and built just to collect and record the data on a tape. The information collected is but raw data which needs to be processed by the computer at the central office. Much information and experience however, has been gained on this system which can serve as a guide for a better design of a new and more advanced system.

Any digital system that is considered to be adapted to the conventional system needs some common hardware to make it work. The most important of these is the depth control. Since measurements in a digital system can not be made continuous as in the analog system, the depth control gives the triggerring signal to tell the computer when to do the measurement. Interfacing of this device to the computer can be achieved either by building hardware or through an integrated data acquisition unit, by specifying the manufacturer's pre-assembled specific card. If a ratemeter is used, a special one should also be made for this purpose since the conventional ratemeters are designed for the analog recorder on the logging unit. Moreover, an amplifier is required for an E-log due to its low signal level and the need for isolation.

The experiment done with the HP-85 computer simulated the conditions of actual temperature logging. Its applicability along with its limitations has been discovered in the described experiment. A compromise can be made from it if it were to be used in actual practice, such as stopping at a certain depth during logging when all of its memory space is filled up. The experiment in general showed a system design for a computer based data logging and processing scheme. It gave a clear idea on the necessary factors that need be considered in order to design a practical and cost-effective working system.

The practicality of using data acquisition units which are actually several instruments integrated into a single mainframe has been described. This simplifies and cuts cost in the over-all set-up compared to using several measuring instruments and interfacing them to the computer. The integrated data acquisition unit provides the interface between the modular instruments and the computer.

An analysis of the HP-87's capability, particularly its memory capacity based on the manufacturer's technical data, showed it to have an advantage over the HP-85 in terms of data storage.

Designing a digital data acquisition system for a well-logging unit includes the factor of system compatibility with the office equipment available or needed. The collected data which is stored in some form of non-volatile media, e.g. flexible disc, should be capable of being furthermore processed in the office by using the office central computer or by having a computer similar to that in the logging unit working independently or being tied in with the central computer.

Perhaps a more ambitious but not remote scheme is to transmit the data to the office on real-time, i.e. while logging is actually done, by using modems (modulators/-demodulators) and radio transmitters for data carrier and have the data processed directly by the central computer.

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REFERENCES

Conoly, Ed, 1982: "Buses, which tie boards to data, control and power lines form the backbone of computer systems."; Computer standards: designer's reference. Electronic Design, December 23, 1982. Hayden Publishing Co., Rochelle Park, N.J. pp. 117-138.

Data-Acquisition Databook, 1982: Volume 1; Integrated circuits. Analog Devices, Inc.

Dresser Atlas, 1980: Compensated densilog. Dresser Industries, Inc., Houston, Texas.

Eaton, John T., Davidson, Andrew W. and Frolik, William R., 1982: "Extended memory and modularity are added to the series 80 computer family"; Hewlett-Packard journal, December, 1982. Hewlett-Packard Co., USA. pp. 3-7.

Elektor Publishers, Ltd., 1981: "Revolution counter"; Elektor, September 1981. Elektor Publishers Ltd., Canterbury, England. pp. 9-07 to 9-11.

Elliot, Harry W.,Jr., 1983:"Some pitfalls in log analysis"; The log analyst, November - December 1983. Society of Professional Well Log Analysts, Houston, Texas. pp.10-24

Flanagan, Dale N. ,1982: "Hewlett-Packard's HP-87"; Interface age, August 1982. pp. 94-96.

Frost, Elton Jr. and Fertl, Walter H., 1980: "A computerized wellsite log analysis system - part 1"; The log analyst, November-December, 1980. Society of Professional Well Log Analysts, Houston, Texas. pp. 10-22.

Halldorsson, Hordur, 1983: UNU lecture notes on data registration. UNU Geothermal Training Programme, Reykjavik, Iceland.

Hewlett-Packard Co., 1980a: HP-85A desktop computer specifications. Technical data, January 1980. Hewlett-Packard Co., USA.

Hewlett-Packard Co., 1980b: HP-85 I/O programming guide, February 1981. Hewlett-Packard Co., USA.

Hewlett-Packard Co., 1980c: HP-85 I/O ROM and HP-IB interface. Technical data, June 1980. Hewlett-Packard Co., USA.

Hewlett-Packard Co., 1980d: HP-85 Owner's manual and programming guide, July 1980. Hewlett-Packard Co., USA.

Hewlett-Packard Co., 1981: Operating manual, 5316A 100 MHz universal counter, 1981. Hewlett-Packard Co., USA.

Hewlett-Packard Co., 1983a: Electronic instruments and systems catalogue, 1983. Hewlett-Packard Co., USA.

Hewlett-Packard Co., 1983b: Optoelectronics designer's catalog; Components and subsystems, 1983. Hewlett-Packard Co., USA.

Jaeger, Richard C., 1983: "Tutorial: analog data acquisition technology, Part 4 - System design, analysis, and performance." IEEE Micro, February 1983. Institute of Electronics and Electrical Engineers, Inc. New York, N.Y. pp. 52-61.

Keys, W.S. and MacCary, L.M., 1971: Techniques of water resources investigations. Washington, United States Geological Survey. Book 2, 126 p.

Laengrich, Norbert, 1981: "Instrument intelligence determines 488 bus speed"; Electronic design, Oct. 15, 1981. Hayden Publishing Co.,Inc., Rochelle Park, N.J. pp. 181-186.

National Energy Authority, : Orkustofnun well-log files. National Energy Authority, Reykjavik, Iceland.

Ogata, Katshuhiko, 1970: Modern control engineering. Sec. 6-3, first-order systems. Prentice Hall,Inc., Englewood Cliff, N.J.

Stefansson, V. and Steingrimsson B., 1981: Geothermal logging 1; An introduction to techniques and interpretation. Second edition. Report OS80017/JHD09. National Energy Authority, Geothermal Division, Reykjavik, Iceland.