# TELEMETERING AND REMOTE CONTROL CIRCUITS FOR A 4000 m THERMAL DRILL

by

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Handling water make thermal drills rather tricky to use. People operating such a drill in very cold ice face with two main problems :

- know at any time what is going on in the drill,
- be able to operate from the control desk in surface a few apparatus located in the drill.

In order to improve reliability of our 4000 meters thermal drill, researches have been carried on about specific telemetering and remote control electronic circuits.

Purpose of this paper is to give a few informations about two tests systems designed in order to compare reliability, efficiency, implementation and use of two transmissions principles, one using a frequency division multiplexing and the other a time division multiplexing principles.

A third final system should be designed after the first field tests taking very likely into account both transmission principles.

## I - DATA AND DRIVES TO BE TRANSMITTED

A good monitoring of the 4000 meters thermal drill needs the transmission of 13 data or drives between the drill and the control desk. Sharing out of these signals is given below .

### I.1 - Data travelling up from the drill to the control desk

- 6 temperatures data from 4 transducers in the water tank, 1 transducer near the heating head and 1 transducer in the electronic tank.
- 1 position data from the position transducer of the drill suspension.
- 1 diameter data from the transducer giving the size of the borehole.

### I.2 - Drivings travelling down from the control desk to the drill

- 2 proportional drivings to operate heaters in water tank and pipe.

- 2 Go / No Go drivings to operate the pump and the electrical valve.

- 1 Go / No Go test driving used to check the overall transmission. When this test is actuated all temperatures displays are shifted by an equal amount of + 20°C, apart temperature data from the electronic tank which is set to 0°C.

  This test is intended to be used very easily while drilling in the field when the driller feels something wrong in the overall drill behaviour and wants to make sure data or drivings transmissions are not failing.

## 2 - CONNECTION BETWEEN THE DRILL AND THE SURFACE DESK

The main cable which hangs and feeds the drill is made up of 8 wires for all power supplies and a bifilar pair for data transmission.

### 2.1 - Data transmission line

The bifilar twisted pair has not been specially designed for data transmission. It is made up of two 0,34 $mm^2$ wires, teflon insulated, with no screen. Frequency cut-off of this line is of course load depending as indicated below at 3 db down :

2.5 kilohertz under 600 Ω
4.5 kilohertz under 300 Ω
8 kilohertz under 150 Ω
12 kilohertz under 100 Ω

Loading of 150 Ω has been chosen in order to be able to operate the line to about 24 kilohertz.

### 2.2 - Power supply

Among the 8 wires of the cable 6 are used to supply the heating head and 2 as a secondary power line to supply electronic driven apparatus and the electronic compartment.

Although a high voltage had been used to transmit power along the 4000 meters cable, the voltage drop is very important and the power supply level varies between 220 and 340 volts depending on heating power in the water tank and pipe.

This high power supply swing has made the electronic power supply circuit more difficult to design and increased its size.

## 3 - TRANSMISSION PRINCIPLES

As previously mentioned two very different transmissions systems have been designed and built. The first one uses a frequency division multiplexing technique (in short FDM) and the second one, which has been designed a bit later, a time division multiplexing (in short TDM). In order to save time and money the second design uses the same signal conditionners as the first one.

### 3.1 - Frequency Division Multiplexing (FDM)

In this mode of transmission :

- each data is converted into a modulated wave

- all waves are continuously sent on the transmission line by the transmitters

- the receivers convert back all waves in DC levels

- 13 frequency bands are necessary in this design.

  Main advantage of this mode of transmission is the possibility of making all transmissions channels fully independant. One channel can fail, because failure of an electronic component for instance, without any effect on the others.

  Main disadvantage is of course larger design and tuning times.

### 3.2 - Time Division Multiplexing (TDM)

In this mode of transmission :

- each data is sampled and converted into a binary word or level

- two microprocessors circuits are used acting as transmitters and receivers (drill and desk)

- transmission is operated in half-duplex mode, the reason will be given later

- modulators and demodulators are used because the length of the transmission line

- 3 frequency bands are necessary.

  Main advantage of this mode of transmission is the flexibility of software operated electronic circuits and a rather shorter design time.

  Main disadvantage is the risk of overall transmission failure if any electronic component is failing.

Figure 1 shows a very simplified block diagram of overall transmission systems including both FDM and TDM design.

Upper part of the diagram relates to the transmitter and the receiver laid in the control desk and the lower part to the corresponding circuits in the drill.

Boxes with slash indicate differences of design in the two systems : above the slash relates to the FDM circuits and below the slash to the TDM.

Other boxes represent identical circuits in both design ; monitor is of course not used in FDM.

In the lower part of the diagram, the switch between the "signal conditionners" box and the "converters or DAC" box is the test switch operated from the control desk "signal conditionners".

## 4 - THE FDM TEST SYSTEM

Three kinds of transmission channels have been designed to fulfill all requirements :

- data channel
- proportionnal driving channel
- Go / No Go driving channel.

### 4.1 - Data transmission

A simplified block diagram is given Fig. 2.

- Transmitter :

Transducer is DC supplied and signal is amplified by an instrumentation amplifier. DC signal is then sent to a voltage/frequency converter the output of which is a frequency variable square wave.

Supply of transducer, instrumentation amplifier and V/F converter constitute the signal conditionners shown Fig. 1.

The frequency variable square wave drives a frequency shift keying modulator whose output signal is sent to the transmission line after been filtered in order to shrink its frequency span.

In this test system only one amplifier has been used to drive the transmission line and all transmitted signals are mixed in front of the amplifier. In order to improve reliability it would be very easy to use one output amplifier in each channel and to mix all transmitted signals in front of the coupling transformer.

- Receiver :

The demodulator is a phase locked loop based circuit which restores the frequency variable square wave. Input filter is mandatory to avoid locking the loop on a bad frequency.

The square wave is then sent to a frequency to voltage converter restoring the DC level which is displayed.

4.2 - Proportionnal driving transmission

This circuit is very similar to the previous one ; a simplified block diagram is given Fig. 3.

- Transmitter :

Electronic circuit is the same. The only differences lies in the use of a DC supplied potentiometer at the input instead of a transducer.

- Receiver :

Electronic circuit is the same too. DC output level of the F/V converter is sent to a power controler instead of being displayed.

- Power controler :

Block diagram of this circuit is given Fig. 4. Purpose of this circuit is to transform a low power continuously tunable DC level into a proportionnal high power AC level in a heater. It has been rather difficult to design a very reliable circuit. Two problems were to be solved :

- switch on the heater as near as possible the zero crossing point of line voltage in order to avoid generation of RFI signals
- switch on the thyristors at very low operating temperature under this very low voltage level.

4.3 - Go / No Go Driving transmission

This circuit is the simplest. Block diagram is given Fig. 5.

- Transmitter :

There is no need for a filter between the modulator and the transmission line because output signal is a pure sinusoïdal wave.

- Receiver :

Binary output signal of the PLL demodulator drives a switch controler.

- Switch controler :

This circuit is used to switch on and off a reed relay used to feed a low power, line supplied, apparatus (pump or electrical valve).

A reed relay has been used instead of a thyristor because power dissipated in the load is far too small to keep a thyristor switched on at lowest operating temperature. In order to avoid fast burning of reed relay's contacts, this switch controler has been designed to switch off at zero current level in the inductive load.

A block diagram of this switch controler is given Fig. 6.

### 4.4 - Frequency bands used in the FDM test system

Informations about filters center frequencies, frequency span and use of the 13 channels are given on Table 1.

### 4.5 - Operating conditions of the FDM test system

- Temperature rangs :

-55°C to +35°C (limit temperature of laboratory test)

- Drill circuits operating voltage supply :

200 to 340 volts RMS

- Transmission accuracy :

$\pm 10^{-4}$

- Power consumption :

Drill circuits 80 watts under 220 volts
Desk circuits 60 watts under 220 volts.

## 5 - THE TDM TEST SYSTEM

### 5.1 - Time Division multiplexing principle and digital serial transmission

The device includes two microprocessor circuits for the surface desk and the drill electronics. Five (up to eight) proportional controls are sent to the drill, and simultaneously eight measurements are transmitted up to the surface, both at a rate of ten exchanges per second on the cable, in a serial mode. For this purpose, a modem circuit, working in a half-duplex asynchronous mode, transmits at 2400 Bauds, with a frequency shift keying (FSK) modulation on the three channels at 4, 8 and 16 KHz (including the reset function) (Table 2).

Half-duplex has been temporary used in this test system in order to shorten transmission working time of microprocessors too much used to measure the frequency of signals to be transmitted.

### 5.2 - Hardware design (Fig. 7)

- <u>Central processing units</u> (C.P.U.)

The two C.P.U. used are 8 bits CMOS devices (National Semiconductor : NSC 800 M) choosen for their Z 80 instructions set, low-supply current and military temperature range (working at 2 MHz). The surface electronic contains Euronorm printed circuits, specified for ruggedized applications (mechanical and temperature down to -40°C). CIMBUS cards (CMOS industrial micro-computer bus from N.S.) are installed in a water-proof 19"-3U cabinet and including : C.P.U., Memory expansion, UART for C.R.T. terminal, D.A.C. These later cards are alltogether connected on the BUS, and four other cards are used as signal conditionners and low voltages power supplies.

The drill C.P.U. board is a multi-layer C.A.D. printed circuit, using MIL grade integrated circuits. Each C.P.U. includes PROM and RAM devices (up to 64 K bytes), as well as 8 bits parallel input-output ports (P.I.O.), timers and analog to digital converters (and inversely). After, or before digital conversions, the conditionner circuits as well as the power commands (proportional or Go - No Go) are similar to the devices designed in the multiplexing frequency principle, as well as the overall test circuit.

- Serial mode of transmission (Fig. 8)

For these first tests, the system software is designed for half-duplex asynchronous mode of transmission, at 2400 Bauds rate.

After analog to digital conversions, the controls and measurements are available the 8 bits C.P.U. bus. A U.A.R.T. circuits (RCA CDP 1854) converts the 8 bits data from parallel to serial mode, in order to transmit the informations on the bifilar pair, in a time-multiplexing modulation final mode.

At the U.A.R.T. output, the binary pulses are F.S.K. modulated (EXAR : XR 2206 M), and after amplification transmitted to the 4000 m cable, using a transformer coupling (Zc = 150 Ω).

The central F.S.K. frequencies (4, 8 and 16 KHz, respectively for the transmission of the reset of drill C.P.U., the remote controls to the drill and the transmission of the measurements up to the surface desk) are 25 % (mark and space frequencies) modulated. At the reception of the FSK signal, 4 $^{th}$ order band-pas Butterworth filters (making use of switched capacitor filters integrated circuits : NS, MF 10 M) are operated from a stable clock oscillator working at 6,4 MHz.

### 5.3 - Software of the microprocessors

Three possible modes of operation are assumed by the software :

- Surface monitor and assembler dialogue with C.R.T. terminal
- Surface to drill transmission
- Complete telemetering and remote control of drill.

The software contents the following tasks, the surface desk C.P.U. software acting as the master program relative to the slave program of the drill C.P.U.

- Monitor program
- Z 80 assembler
- Specific programs including : data acquisition (analog to digital and inversely) of up to eight measurements from the drill and up to eight remote commands to the drill ; the serial communications in both directions ; C.R.T. terminal interactive dialogue with unit conversions and screen display, and the general control of the transmission (error of transmission message by C.R.C. determination and a watch-dog message if no exchange occurs on the cable for at least 0.5 s).

### 5.4 - Operating conditions of the T.D.M. test system

These operating conditions are the same as in the FDM test system concerning temperature range, drill circuits operating voltage supply. However, the overall transmission accuracy (for the complete temperature range) is about 0.5 %. About the power consumption, both drill and desk circuits draws less current (CMOS circuitry).

### 5.5 - Future extensions

Although preliminary tests need to be conducted with the drill itself, future extensions may consist of :

- depth measurement of drill
- increased accurary, presently limited to 8 bits equivalent, increased speed of transmission (exchanges per second), number of measurements and remote controls (eight each actually)
- use of a dedicated microprocessor for improved C.R.T. dialogue
- software including full-duplex mode of transmission
- automatic servo-loops and regulations for proportionnal or Go / No Go remote controls.

A much appreciated fruitful cooperation, and the software development of the Time Division Multiplexing device, have been conducted with Jean-Paul Eynard, Jack Baudoin and Fidèle Andrianandraina (joint C.N.R.S. - I.N.P.G. program).

## 5 - CONCLUDING REMARKS

The FDM system has been used for the first time in Antarctica during the field party 1987/1988 at D47. All the field tests were very good and these circuits have been successfully used again during the 1988/1989 campaign at D74 where the 4000 meters drill did reach -871 meters depth. The FDM system proved to be very reliable, accurate and easy to operate.

First test of the FDM system made during the 1988/1989 field party did point out transmissions problems although laboratory tests were good. It has not been possible to find the reason of these problems in the field, a few other laboratory tests are necessary.

| CHANNEL | FILTER CENTER FREQUENCY | FSK SPAN | USE |
|---|---|---|---|
| 1 | 350 | 332 - 368 | TRANSMISSION TEST |
| 2 | 500 | 475 - 525 | ELECT. VALVE SWITCH |
| 3 | 700 | 665 - 735 | PUMP SWITCH |
| 4 | 1000 | 950 - 1050 | Θ˚ DRILL |
| 5 | 1400 | 1330 - 1470 | Θ˚ DRILL |
| 6 | 2000 | 1900 - 2100 | Θ˚ DRILL |
| 7 | 2800 | 2660 - 2940 | Θ˚ DRILL |
| 8 | 4000 | 3800 - 4200 | Θ˚ DRILL |
| 9 | 5600 | 5320 - 5880 | HEATER |
| 10 | 8000 | 7600 - 8400 | Δ SUSPENSION |
| 11 | 11200 | 10640 - 11760 | HEATER |
| 12 | 16000 | 15200 - 16800 | Θ˚ ELECTRONIC CIRCUIT COMPARTMENT |
| 13 | 22400 | 21280 - 23520 | ø BOREHOLE |

Table 1 - Frequency bands (Hz) used in the FDM test system

| CHANNEL | FILTER CENTER FREQUENCY | FSK SPAN | USE |
|---|---|---|---|
| 1 | 4000 | 3500 - 4500 | RESET DESK DRILL |
| 2 | 8000 | 7000 - 9000 | TRANS. DRILL DESK |
| 3 | 16000 | 14000 - 18000 | TRANS. DESK DRILL |

Table 2 - Frequency bands (Hz) used in the TDM test system

_TRANSMISSION PRINCIPLES

FDM AND TDM

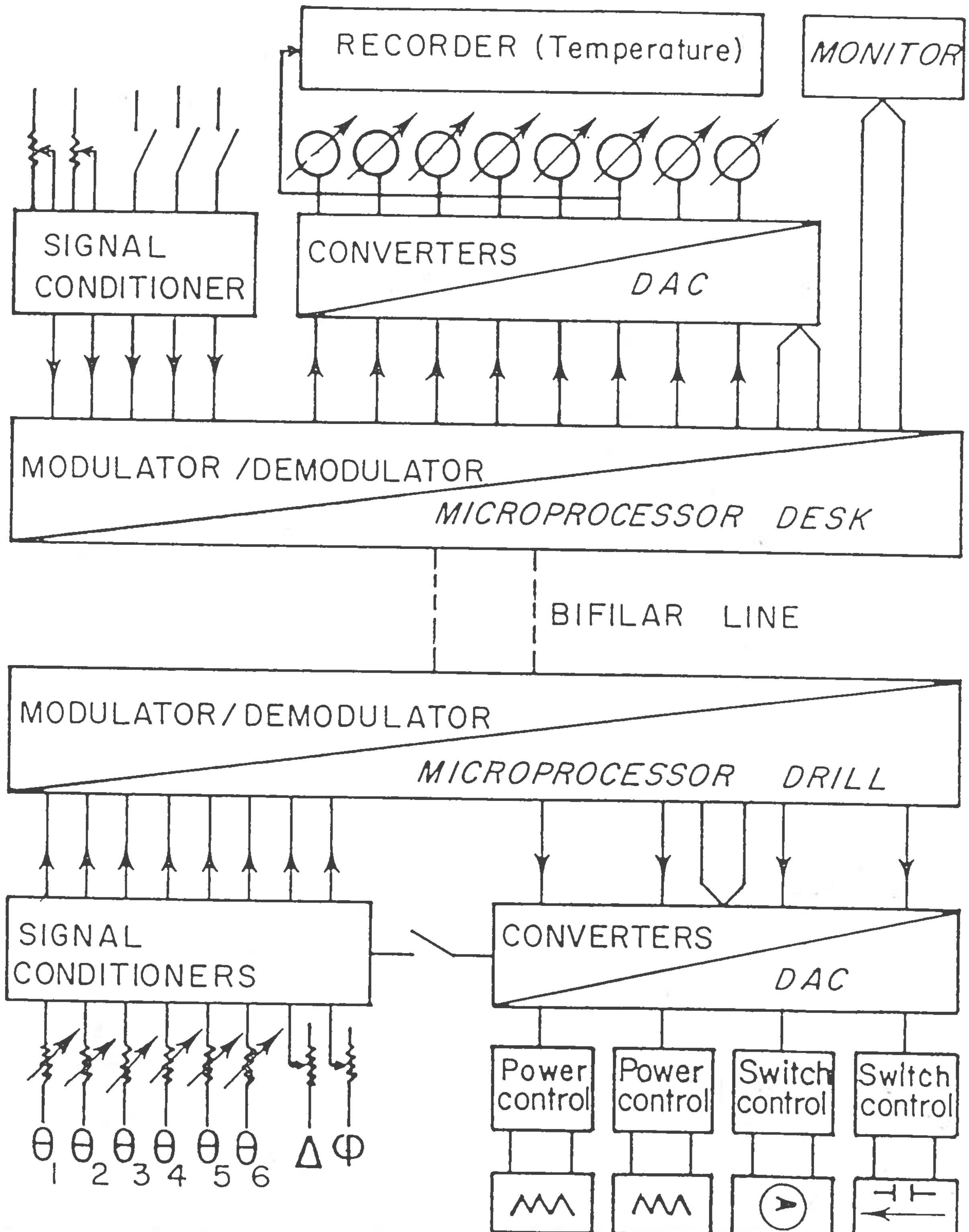



Fig.1

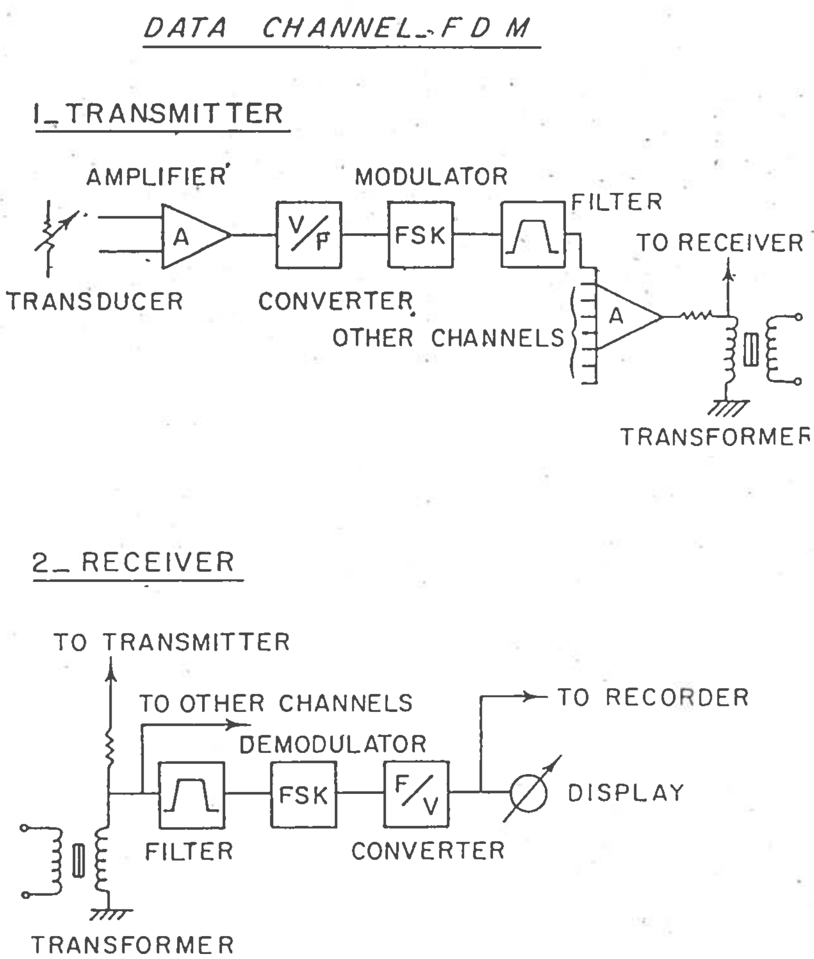

DATA CHANNEL_FDM
1_TRANSMITTER
AMPLIFIER
MODULATOR
FILTER
A
V/F
FSK
TO RECEIVER
TRANSDUCER
CONVERTER
OTHER CHANNELS
A
TRANSFORMER
2_RECEIVER
TO TRANSMITTER
TO OTHER CHANNELS
TO RECORDER
DEMODULATOR
FSK
F/V
DISPLAY
FILTER
CONVERTER
TRANSFORMER

Fig.2

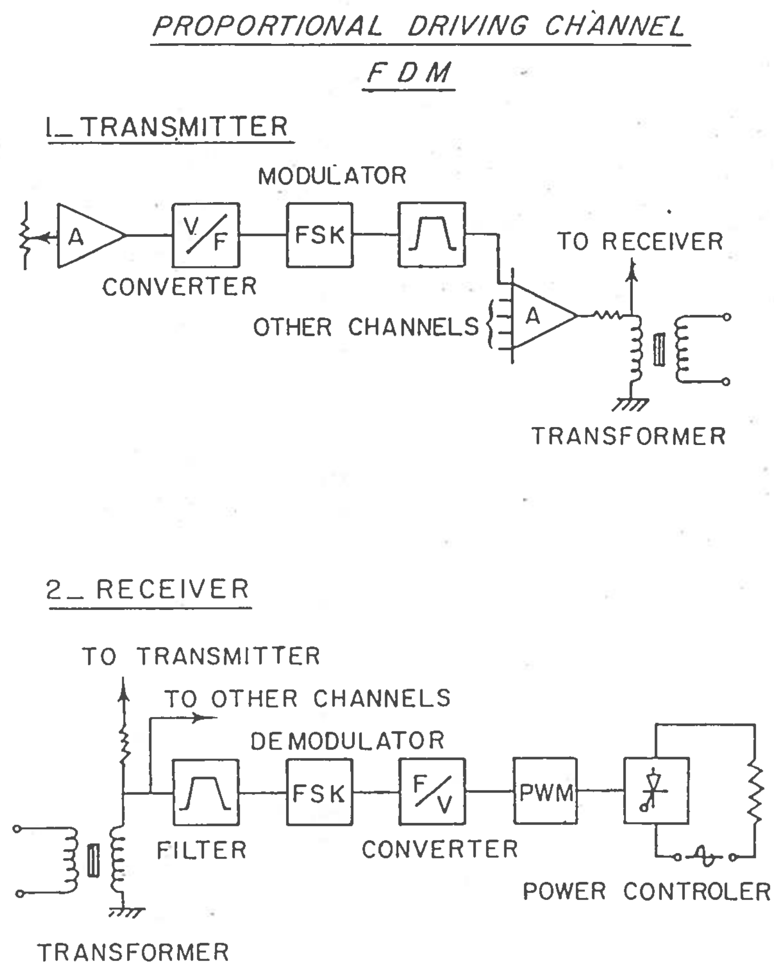

PROPORTIONAL DRIVING CHANNEL
FDM
1_TRANSMITTER
MODULATOR
A
V/F
FSK
TO RECEIVER
CONVERTER
OTHER CHANNELS
A
TRANSFORMER
2_RECEIVER
TO TRANSMITTER
TO OTHER CHANNELS
DEMODULATOR
FSK
F/V
PWM
FILTER
CONVERTER
POWER CONTROLER
TRANSFORMER

Fig.3

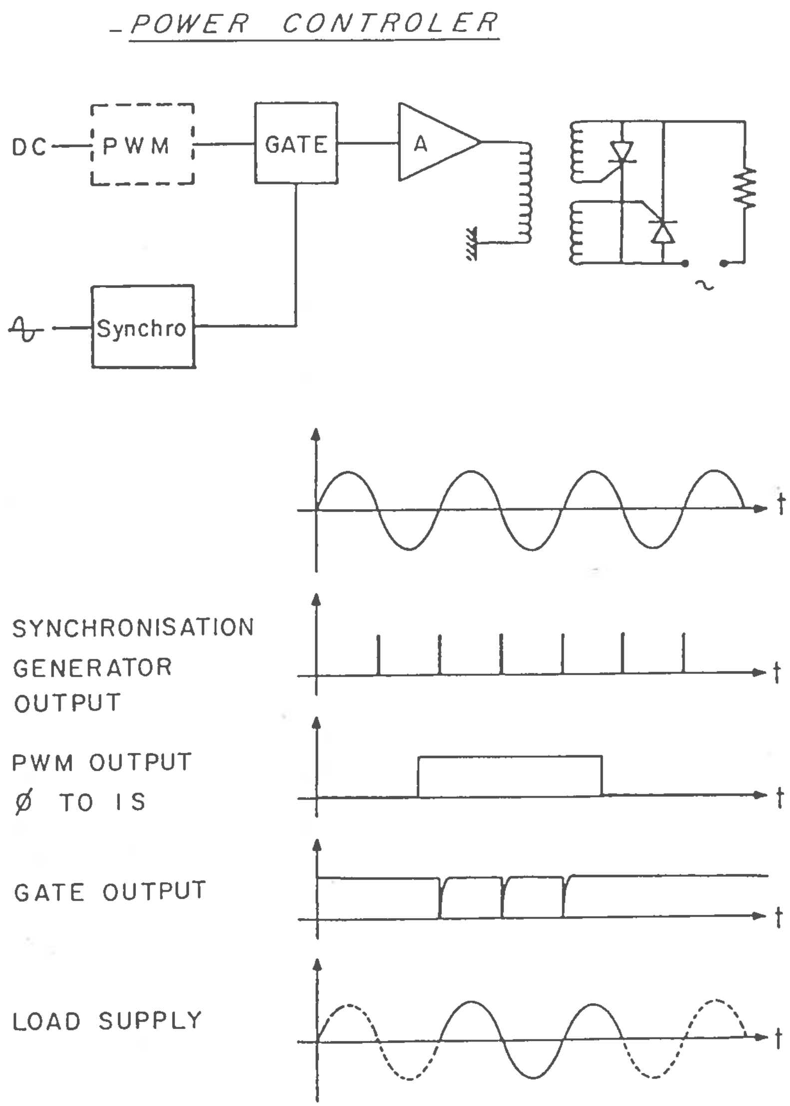

POWER CONTROLER
DC
PWM
GATE
A
Synchro
SYNCHRONISATION GENERATOR OUTPUT
PWM OUTPUT Ø TO IS
GATE OUTPUT
LOAD SUPPLY
t

Fig.4

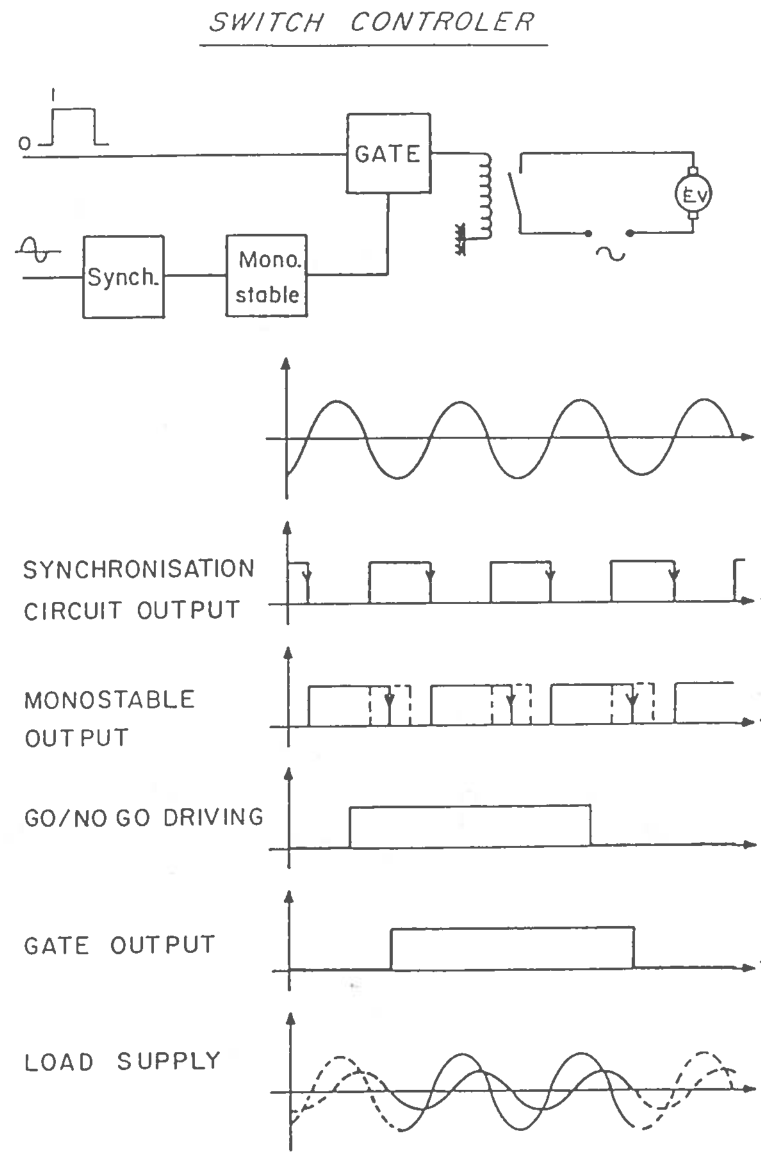
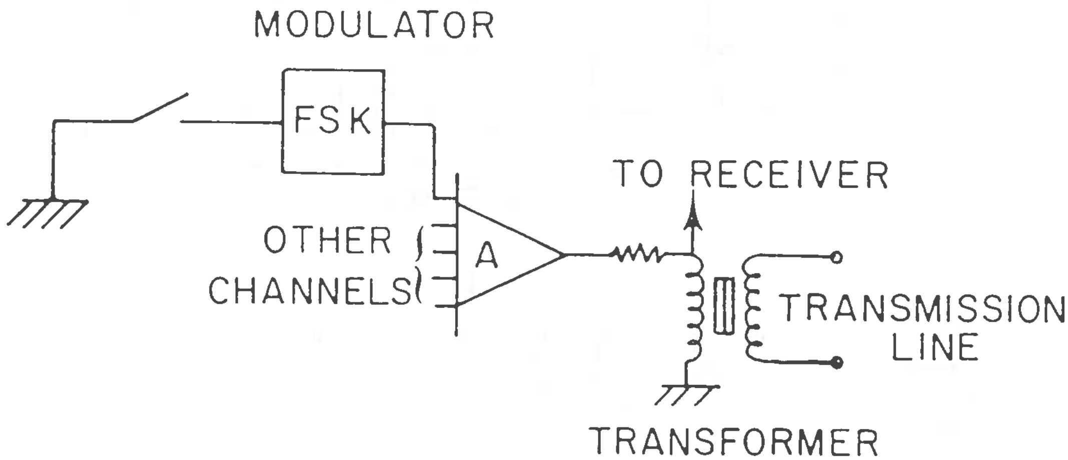

SWITCH CONTROLER
0
I
GATE
Ev
Synch.
Mono. stable
SYNCHRONISATION CIRCUIT OUTPUT
MONOSTABLE OUTPUT
GO/NO GO DRIVING
GATE OUTPUT
LOAD SUPPLY
t

Fig.6

# *GO/ NO GO DRIVING CHANNEL*

## *F D M*

### 1_TRANSMITTER




### 2_RECEIVER

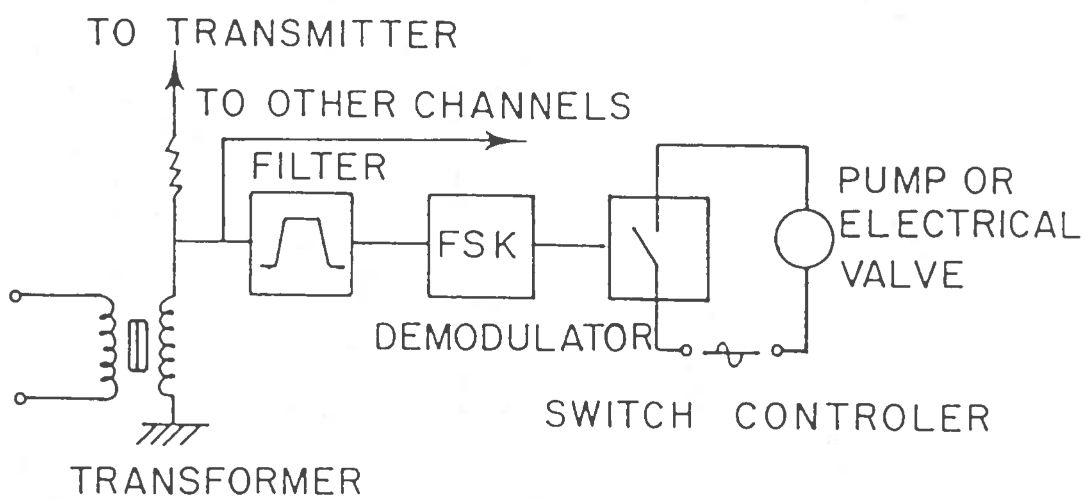



Fig.5

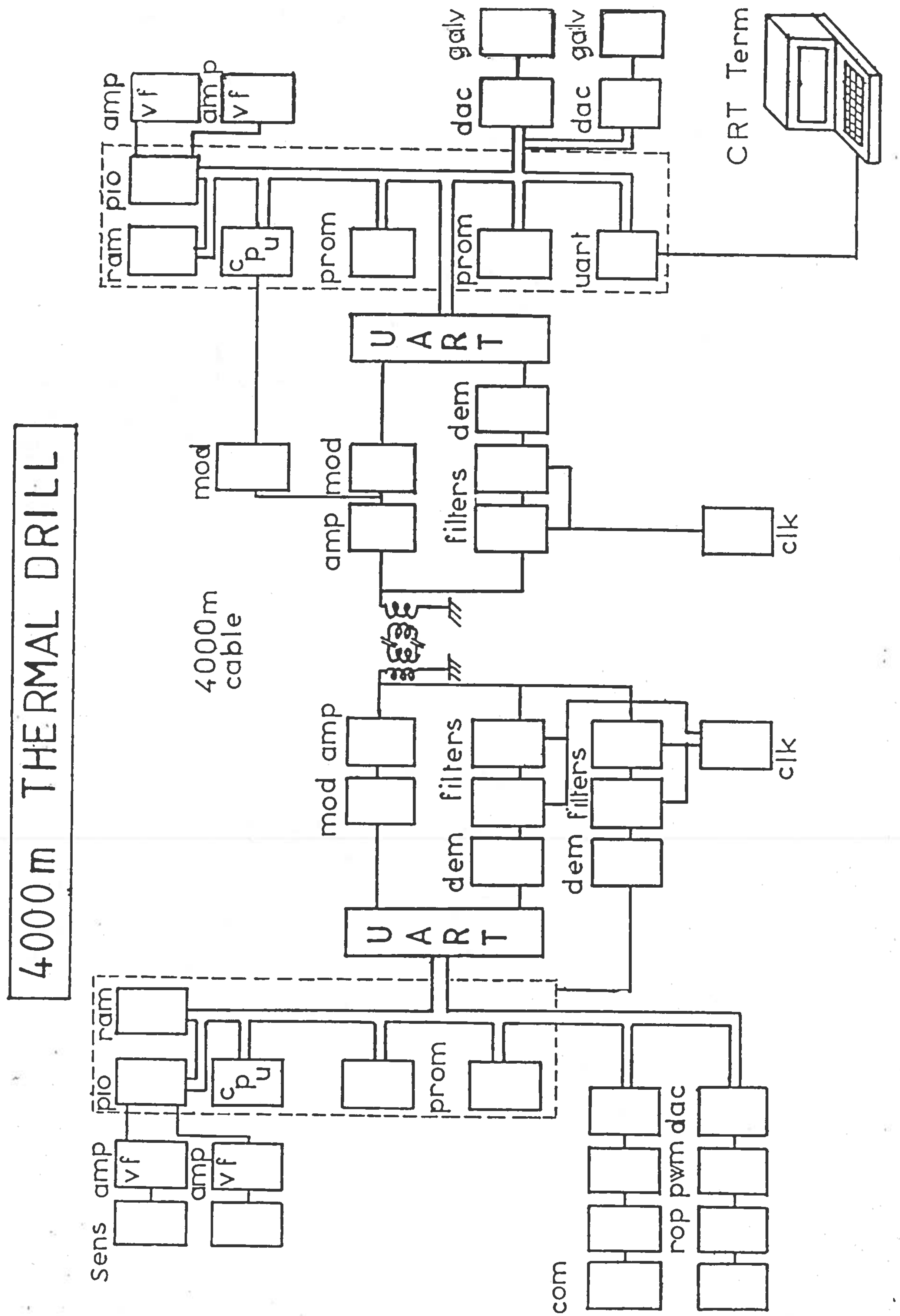

4000m THERMAL DRILL
Sens
amp
vf
amp
vf
pio
ram
cpu
prom
com
rop
pwm
dac
UART
mod
amp
filters
dem
filters
dem
clk
4000m cable
amp
mod
mod
filters
dem
clk
UART
ram
pio
amp
vf
amp
vf
cpu
prom
prom
uart
dac
galv
dac
galv
CRT Term

Fig.6

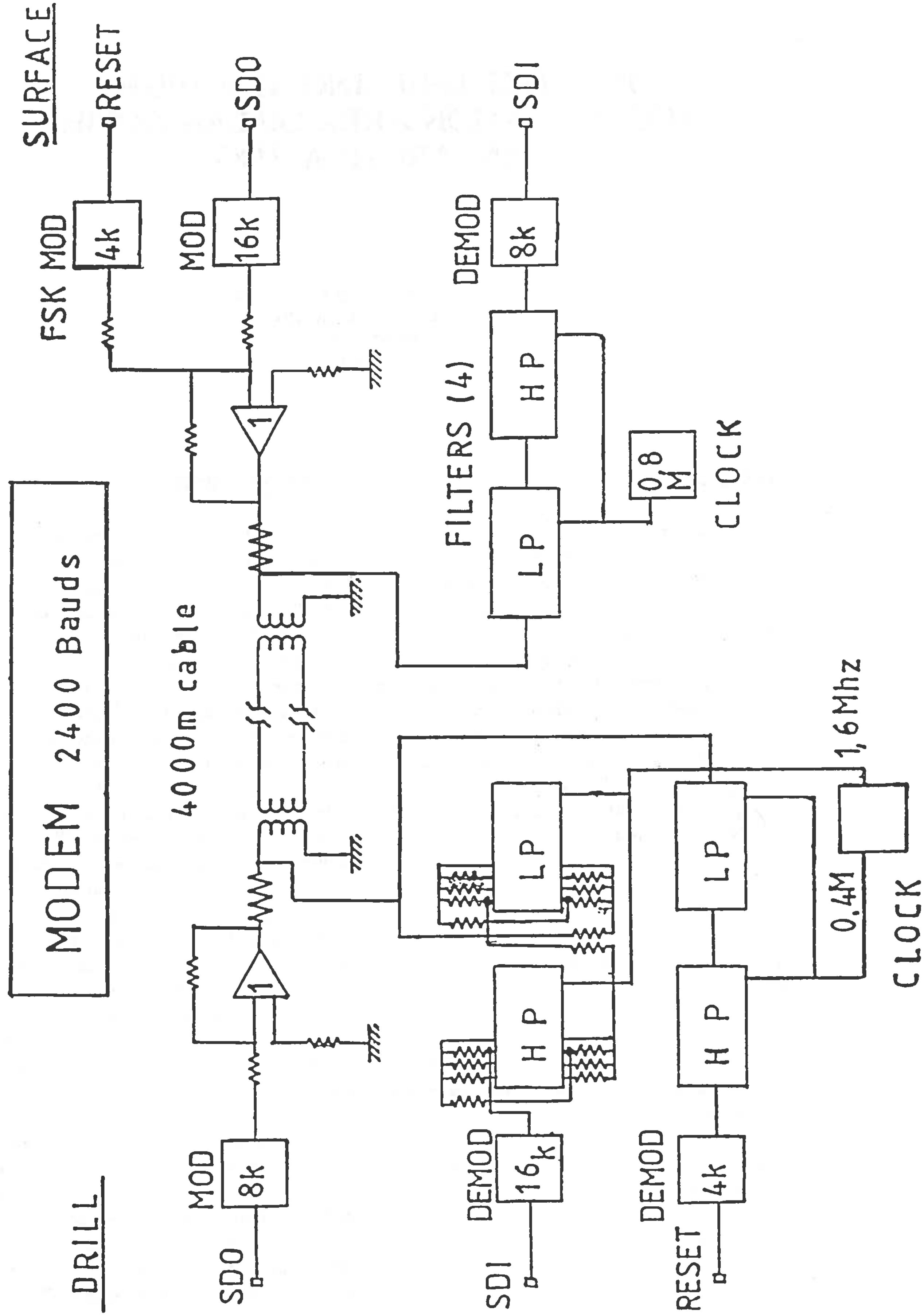

SURFACE
RESET
SDO
SDI
FSK MOD
4k
MOD
16k
DEMOD
8k
FILTERS (4)
HP
LP
0,8 M
CLOCK
MODEM 2400 Bauds
4000m cable
1,6Mhz
0,4M
CLOCK
DRILL
MOD
8k
SDO
DEMOD
16k
SDI
DEMOD
4k
RESET
LP
HP
LP
HP

Fig.7