ROYAL OBSERVATORY, HONG KONG

TECHNICAL NOTE NO. 72

A REAL-TIME

RAINFALL DATA ACQUISITION SYSTEM

by

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FIGURES

PLATES

1. INTRODUCTION

In 1978, at the request of the Geotechnical Control Office (GCO), the Royal Observatory designed an electronic system (Lam and Li 1979) in which rainfall data from a network of about 20 tipping-bucket rain-gauges could be telemetered back to a central control office. For each rain-gauge, the accumulated amount of rainfall was output to a calculator printer every 15 minutes. In 1981, the Royal Observatory improved the design and the collection of real-time rainfall data from these gauges was handled by a microprocessor-based central system at GCO. This system became operational in May 1982. Since then, rainfall data were also relayed to the Royal Observatory via telephone wires. The data were displayed on a terminal and a line-printer in the Central Forecasting Office and at the same time archived by the Royal Observatory main computer system for subsequent analysis. GCO increased the number of rain-gauges in the network to 42 in 1983 and starting from June the same year the time resolution of rainfall data was improved to 5 minutes.

In 1983, the Royal Observatory implemented public advisory services on landslips and floods. Since a majority of the GCO telemetering rain-gauges were concentrated in urban areas in Hong Kong Island and Kowloon, the Royal Observatory identified a need to increase the existing coverage of rainfall data to outlying islands and the New Territories. Consequently, it was decided to implement at the Royal Observatory a separate real-time rainfall data acquisition system (RDAS) consisting of 20 telemetering rain-gauges.

This report describes the RDAS, which is designed to :

(1) receive and monitor inputs from a network of 20 rain-gauges each connected to the Royal Observatory by a pair of telephone wires ;

(2) transmit rainfall data accumulated over a fixed time interval to the Royal Observatory main computer system for subsequent display at the Central Forecasting Office and for archival by the computer ; and

(3) store raw data on magnetic tapes for subsequent analysis of short-duration rainfall.

Item (3) above is a feature not found in the GCO system. The raw data include the time at which a tip of the rain-gauge bucket occurs. This enables an estimation of the rainfall rate under intense rain situations (Donnelly 1977).

2. DESIGN OBJECTIVES

The design objectives are as follows :-

(1) Signals representing rainfall collected by a tipping-bucket rain-gauge should be distinguished from random noises which might be present in telephone wires.

(2) The effect of contact-bounce occurring in the rain-gauge should be eliminated.

(3) Updated rainfall data should be sent to the main computer every 5 minutes.

(4) Rainfall data accumulated over the past quarter of an hour and over the past hour, and that recorded since midnight should be displayed on a line-printer and on an optional video monitor.

(5) The time at which a signal (i.e. a contact closure resulting from a tip of the bucket) is received from a rain-gauge should be recorded on a magnetic tape.

(6) Power back-up at the central control should allow for at least ten minutes of continuous and uninterrupted operation immediately after an AC power stoppage. The system clock should be backed up by separate batteries for at least six hours.

(7) Lightning and transient protection should be provided at field sites and at the central control.

3. THE DESIGN

(a) Tipping-bucket rain-gauge

The mechanism by which this type of rain-gauge operates is described in the Guide to Hydrological Practices published by the World Meteorological Organization (1974). Essentially rainwater is funnelled into one of the two buckets which rest on a pivot in such a way that when a given amount of rain (normally 0.5 mm) has been collected in the bucket, it tips and momentarily closes a magnetic reed switch. The tipping action discharges the water and at the same time causes the other bucket to start collection. The momentary closure of the reed switch indicates that the given amount of rain has fallen.

Casella type W5698/1 rain-gauges (Plate 1) are used in the RDAS.

(b) Transmission of rainfall information

Low-speed, dedicated telephone lines for data transmission are available in Hong Kong. In the GCO system, land lines are used for transmission. As shown schematically in Fig. 1, the closure of the reed switch in the rain-gauge causes a dc pulse to be generated. The pulse is sensed at the receiving end of the lines. In this design, noise on the telephone lines can sometimes switch on the relay at the receiving end of the lines and produce a false trigger.

A solution to the problem is to employ digital transmission. In the RDAS, the electrical pulse generated by the contact closure is converted into a data stream with a pre-defined bit pattern (i.e. a series of 'lows' (0's) and 'highs' (1's)) for transmission over the telephone lines. The probability of random noise having the same encoded bit pattern as the data stream diminishes with increased complexity in the bit pattern.

In the design shown in Fig. 2, closure of the switch in the rain-gauge is relayed through a pair of cables to an interface box, which is of width 270 mm, height 135 mm and depth 200 mm and is placed in a nearby building at the field site. The interface box (Plate 1) consists of an electronic counter and a microprocessor controller. The electronic counter (Plate 2) displays on light-emitting diodes (LED) the cumulative rainfall for trouble-shooting purpose. By the use of flip-flops, the counter also outputs a positive square pulse of 2-second duration. The flip-flops remain deactivated during this period and the effect of bouncing in the switch, which normally lasts for no more than 2 seconds after tipping of the bucket, is thus eliminated. The duration over which the rainfall amount is accumulated is selectable and can be either one minute or one hour.

The conversion of the generated square pulse into a serial data stream is achieved by microprocessor controller (Plate 3). The square pulse enters as an external interrupt to the MK38P70 microprocessor (Mostek Corporation 1978), which is triggered by the rising edge of the square wave to produce a 12-bit data stream at 400 baud. A low-speed modem provides a 1-kHz carrier for the signal and this is output to the telephone wires through an isolation transformer (Fig. 2).

The circuit diagrams and brief descriptions of the field electronic equipment can be found in Appendix 1. In order to protect the electronics against transients and lightning, a line filter and a large capacitor are

provided at the AC power input and a 'tranzorb' surge suppressor is provided at the input from the rain-gauge. The site equipment is completely self-starting on the resumption of electricity supply after power failure.

(c) Reception of rainfall information

On entry through telephone wires into the Royal Observatory and then through an isolation transformer, the 1-kHz carrier wave is demodulated by a low-speed modem. As shown schematically in Fig. 2, the serial data stream is restored and fed into an MK38P70 microprocessor controller (Plate 4), the functions of which are to recognize the pre-defined bit pattern and then output a square pulse of one-second duration to an interface to the Z-80-based microprocessor central control system. The detection of the square pulse by the interface is described in Section 3(d).

The circuit diagram of the MK38P70 controller together with a brief description of the theory of operation is included as Appendix 2. A line filter and an interference suppressor are provided at the AC power input to protect the equipment from effects of transients and lightning.

(d) Processing of data

In the existing configuration, there are two interfaces between the microprocessor controller and the Z-80 central control system. They are similar to one another and each one serves 16 positions (16 rain-gauges). The TTL level at each of these positions is interrogated by the Z-80 system every 3/4 of a second and a change from the normally 'low' TTL level to a 'high' TTL level indicates that 0.5 mm of rain has fallen on that rain-gauge. The choice of this duration of less than one second is to ensure that the one-second square pulse from the microprocessor controller (see Section 3(c) can be detected.

The circuit diagram and a brief description of the interface are given in Appendix 3.

In the Z-80 system, random-access memories (RAM) have been allocated for each rain-gauge to keep account of rain fallen since the start of the following periods :-

(i)   latest clock 5-minute period (i.e. since the 0th, 5th, 10th, ..., 50th or 55th minute of the hour) ;

(ii)   latest quarter period (i.e. since the 0th, 15th, 30th or 45th minute of the hour) ;

(iii)   latest clock hour period (i.e. since the 0th minute of the hour) ;

(iv)   midnight last night ; and

(v)   3 p.m. the previous day.

The last value gives a 24-hour total coinciding with the practice of manual observation in the conventional rainfall network maintained by the Royal Observatory.

The software of the Z-80 system is written in Z-80 assembler language and resident on Erasable Programmable Read-only Memories (EPROM's) in the system. Once the rainfall information from a rain-gauge is detected, a value of 0.5 (mm) is added to the rainfall total of the particular rain-gauge. At the same time, the time at which such information comes in will be written onto a computer-compatible tape. The time corresponds to that at which the tipping of the bucket occurs, within an error of 3/4 of a second. Information stored in this manner enables the rainfall intensity during intense rainfall situation to be estimated in subsequent analysis (Donnelly 1979). The format of the message transmitted to the computer-compatible tape is given in Appendix 4 and the transmission is done at a high speed of 9600 bauds to ensure no loss of data. The reason for the high speed data transmission is given in the description of the software structure in Appendix 5.

At the end of each clock 5-minute period, the rainfall detected by each rain-gauge (which is zero if there has been no tipping of the bucket) during the period will be transmitted at 300 bauds, via a RS-232C serial interface, to the main computer. The form of the message is given in Appendix 4.

At the end of each quarter of the hour, the following are output to a line-printer :-

    (i)   the quarterly total ;

    (ii)   the cumulative total since the start of the latest clock hour ; and

    (iii) the cumulative total since midnight last night.

The form of the message is given in Appendix 4. The message is transmitted to the line-printer, at 600 bauds and also via a RS-232C serial interface.

At 3 p.m. each day, the rainfall accumulated over the past 24 hours will also be output to the line-printer in a similar manner to the above (see Appendix 4).

The 3 p.m. total will be set to zero immediately after 3 p.m. each day, while all the other rainfall totals mentioned above will be set to zero at midnight each day.

(e) Hardware configuration of the
Z-80 central control system

A block diagram of the Z-80 central control system is shown in Fig. 3.

The system is built on the Mostek MD series microcomputer modules (Mostek Corporation 1980) and is designed around a Z-80 microprocessor (module : CPU2A). The system software resides on two 2K-byte EPROM's (Erasable Programmable Read-only Memory). Volatile memory space is available from a 32K-byte Dynamic Random Access Memory (DRAM) board.

A Parallel Input/Output (PIO) module provides 30 data lines, one for each rain-gauge (There are 32 lines in a PIO module, but two of these are used as control lines to reset the latches on the interface described in Section 3(c). Another PIO module can be added to provide extra data lines without any significant modification in the software.

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For output of data to the peripherals and the Royal Observatory main computer system, two Serial Input/Output (SIO) modules are used. Each of these modules provides two RS-232C channels. Three of the four available SIO channels are separately connected to a line-printer, the Royal Observatory main computer system and a computer-compatible tape recorder (for 1/2-inch, 9-track and 1600 bpi tape, Innovative Data Technology Series 1050). The fourth channel is left unused and can accommodate an additional output device, such as a video terminal.

The Z-80 system is timed by a clock module (BCLK) with a built-in battery back-up for at least five days, thus obviating the need to adjust the time after a power failure, which normally lasts for no more than several hours. The time can be adjusted using a video terminal connected to a duplex Universal Asynchronous Receiver Transmitter (UART) module (Fig. 3) through which interaction between the operator and the Z-80 system can be established.

The complete set-up of the central control system and the peripherals is shown in Plate 5.

(f) Power supply

Two Sola type 50600 uninterruptible power supply provides continuous 600 VA AC power for at least 12 minutes. The central control system is self-starting on resumption of power after complete failure.

4. DISCUSSIONS

The essential parts of the central control system of the RDAS were implemented in November 1983 and eight rain-gauges became operational in December 1984. Fig. 4 shows a map indicating the locations of these gauges.

At the time of writing this report, the system has been running continuously for three months. Apart from some necessary modifications in the software during initial operation, there have been no major faults of any sort.

Work is in progress to incorporate into the microprocessor transmitter controller at the field site an automatic rainfall recorder (Lee and Chiu 1984) which stores rainfall data on an EPROM (Erasable Programmable Read-only Memory). The power supply to the equipment at field site will be backed up by batteries. These measures will ensure that rainfall data will not be lost in case of telephone line failures and power stoppages at the field site.

The following are kept on file and may be made available to those interested :-

(i) computer programs for the Z-80 central control system and for the microprocessor controllers ; and

(ii) layouts of the printed circuit boards for the microprocessor controllers and the electronic counter.

Enquiries should be addressed to :

Hydrometeorology Section,
Royal Observatory, Hong Kong,
Nathan Road, Kowloon,
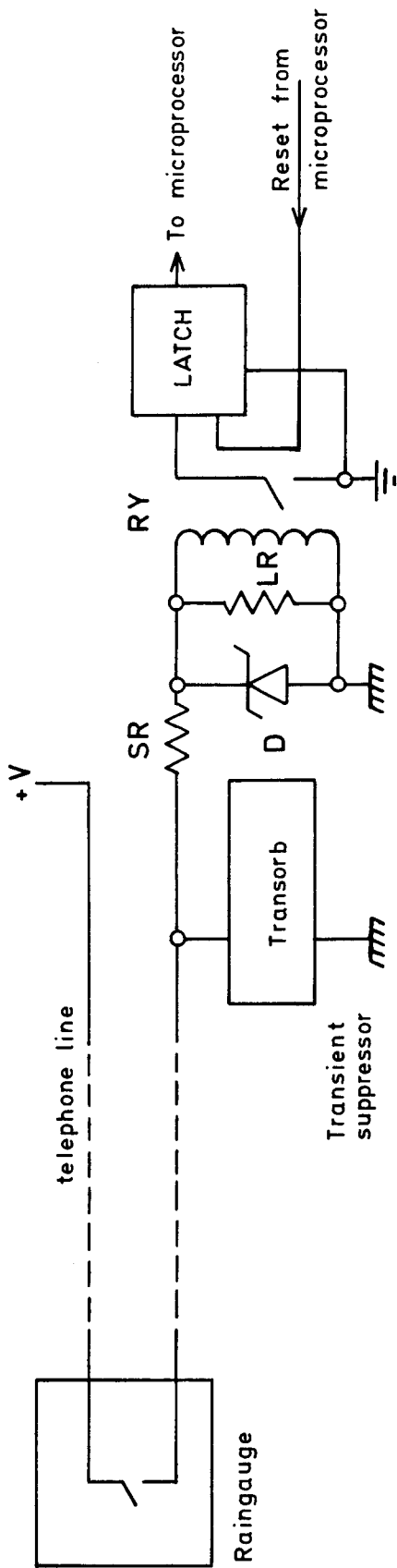Hong Kong.

5. ACKNOWLEDGEMENT

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1. Donnelly, D.P.   1979   Digital Raingauge Recorder, J. of Appl. Met., Vol. 16, pp. 205-207.

2. Lam, H.K. and P.C.S. Li   1979   A Remote Recording Digital Tilting-Bucket Raingauge, Royal Observatory Technical Note No. 47.

3. Lee, B.Y. and M.C. Chiu   1984   A Microprocessor-based Rainfall Recorder, Royal Observatory Technical Note No. 71

4. Mostek Corporation   1978   Mostek F8 Microprocessor System - Programming Manual

5. Mostek Corporation   1980   MD Series Microcomputer Modules - Operations Manuals

6. World Meteorological Organization   1974   Guide to Hydrological Practices, WMO Report No. 168

Fig. 1 Transmission and reception in the Geotechnical Control Office rainfall data acquisition system

D – zener diode

SR – current-limiting resistor

LR – shunting resistor

RY – relay
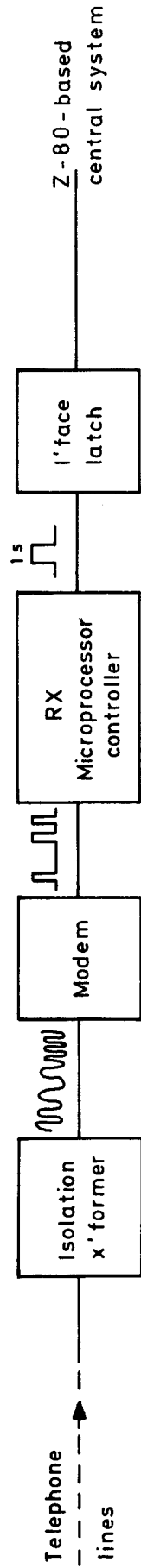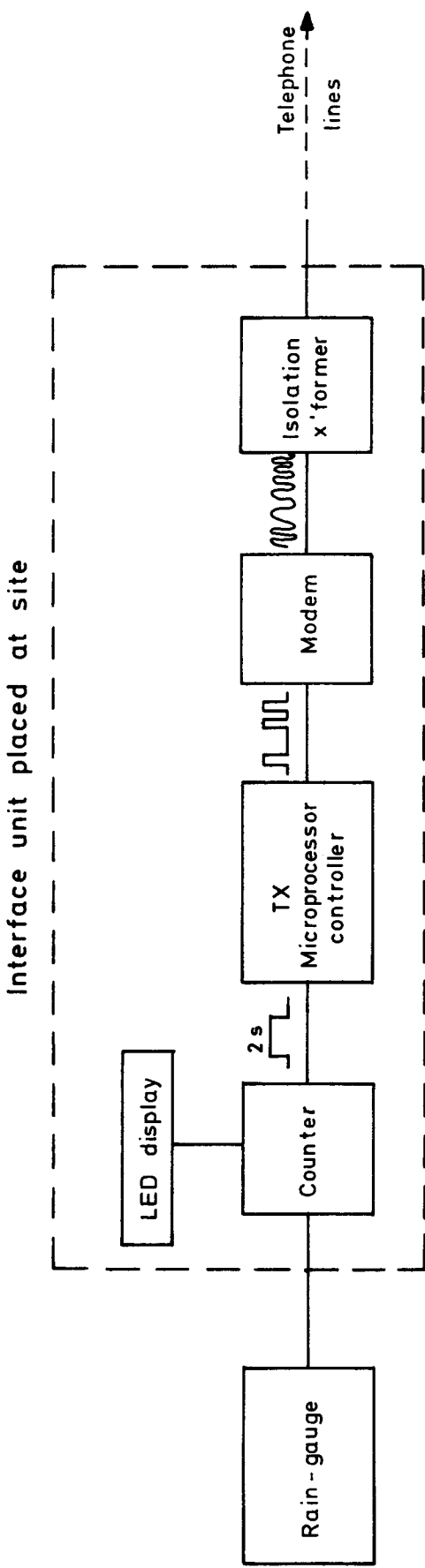
Fig. 2 Transmission and reception in the Royal Observatory rainfall data acquisition system
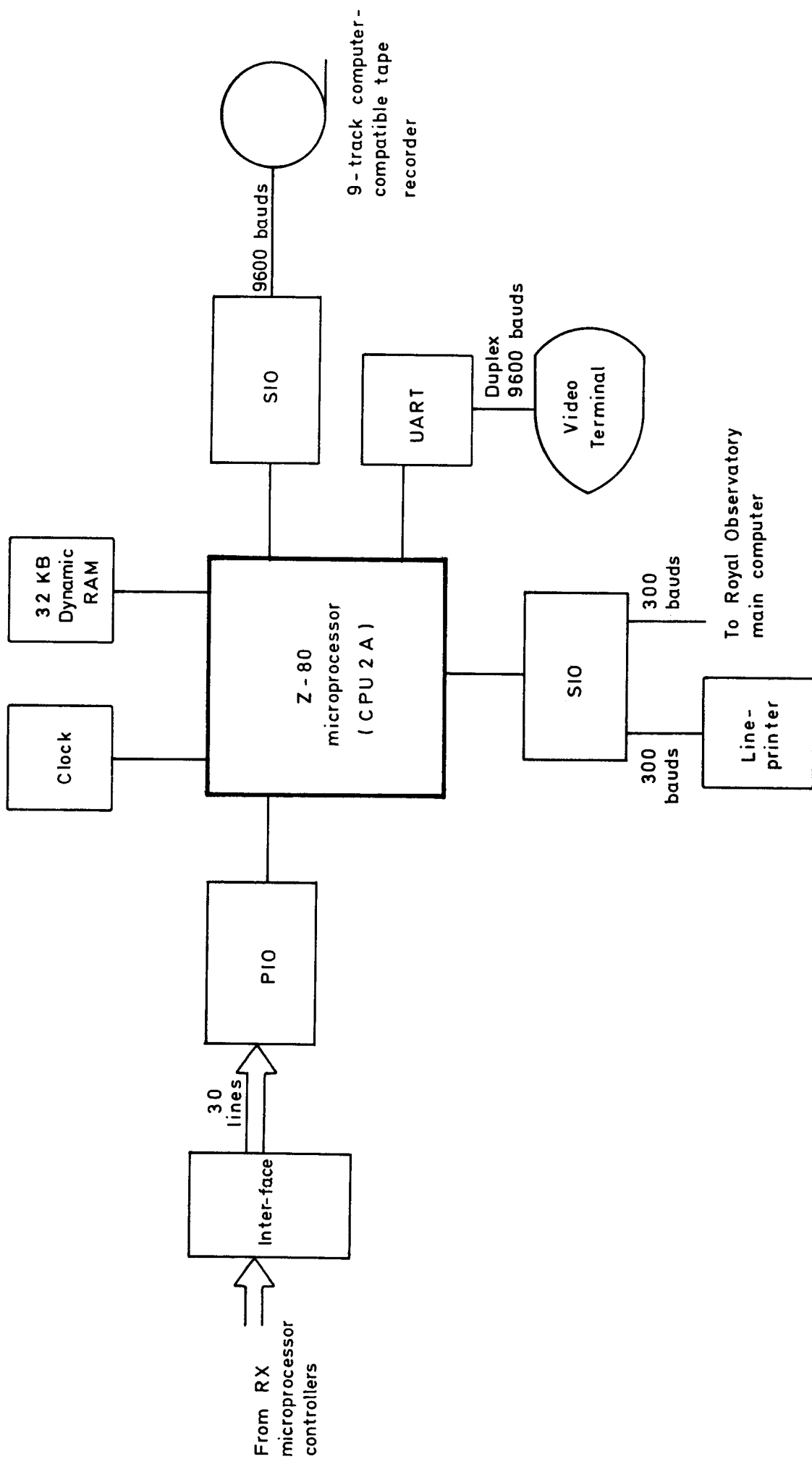
Fig. 3 Hardware configuration of the Z-80 central control system
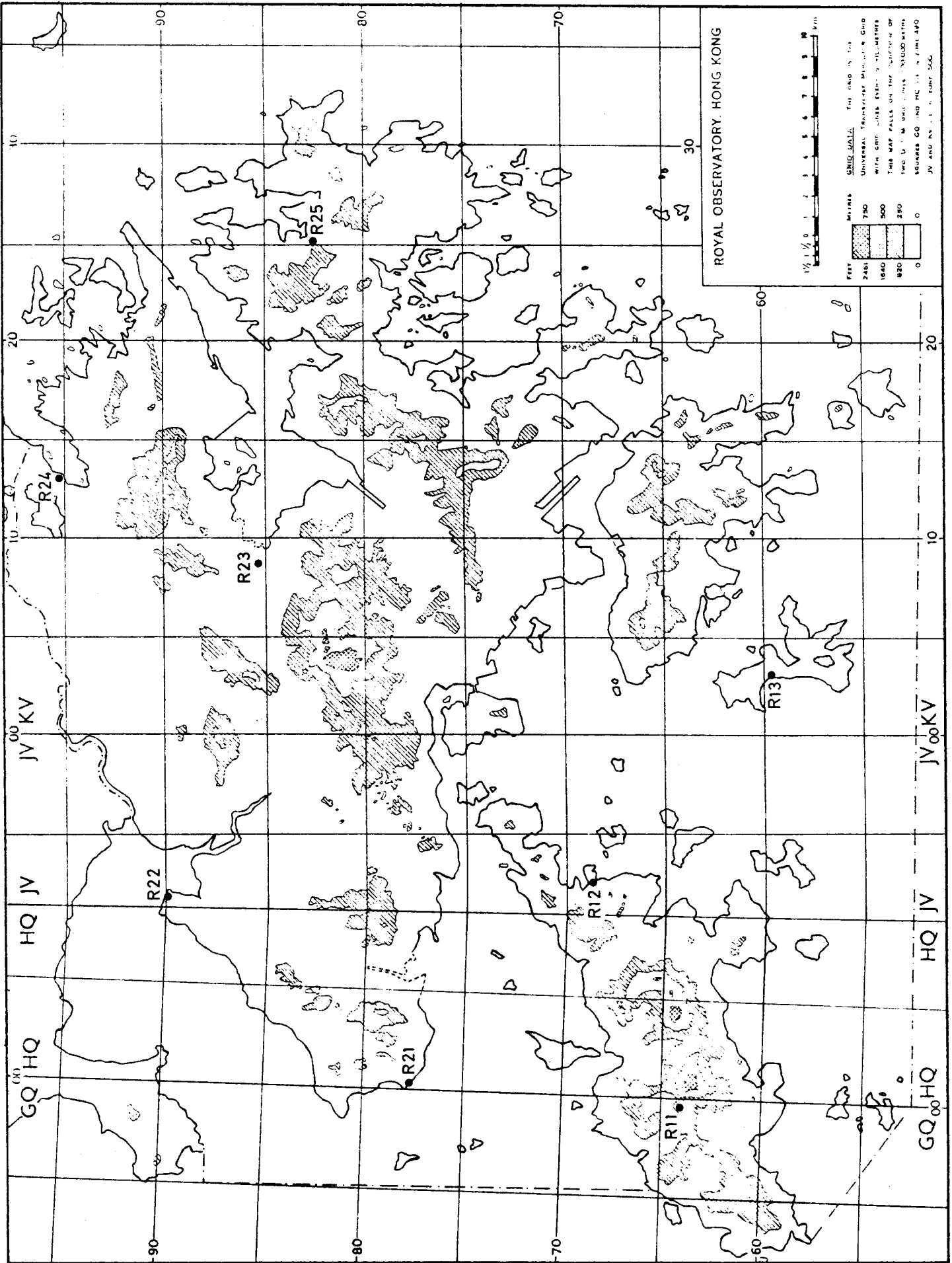
Fig. 4 Locations of rain-gauges of the Royal Observatory rainfall data acquisition system (as at 1 February 1984)

R.O. 128

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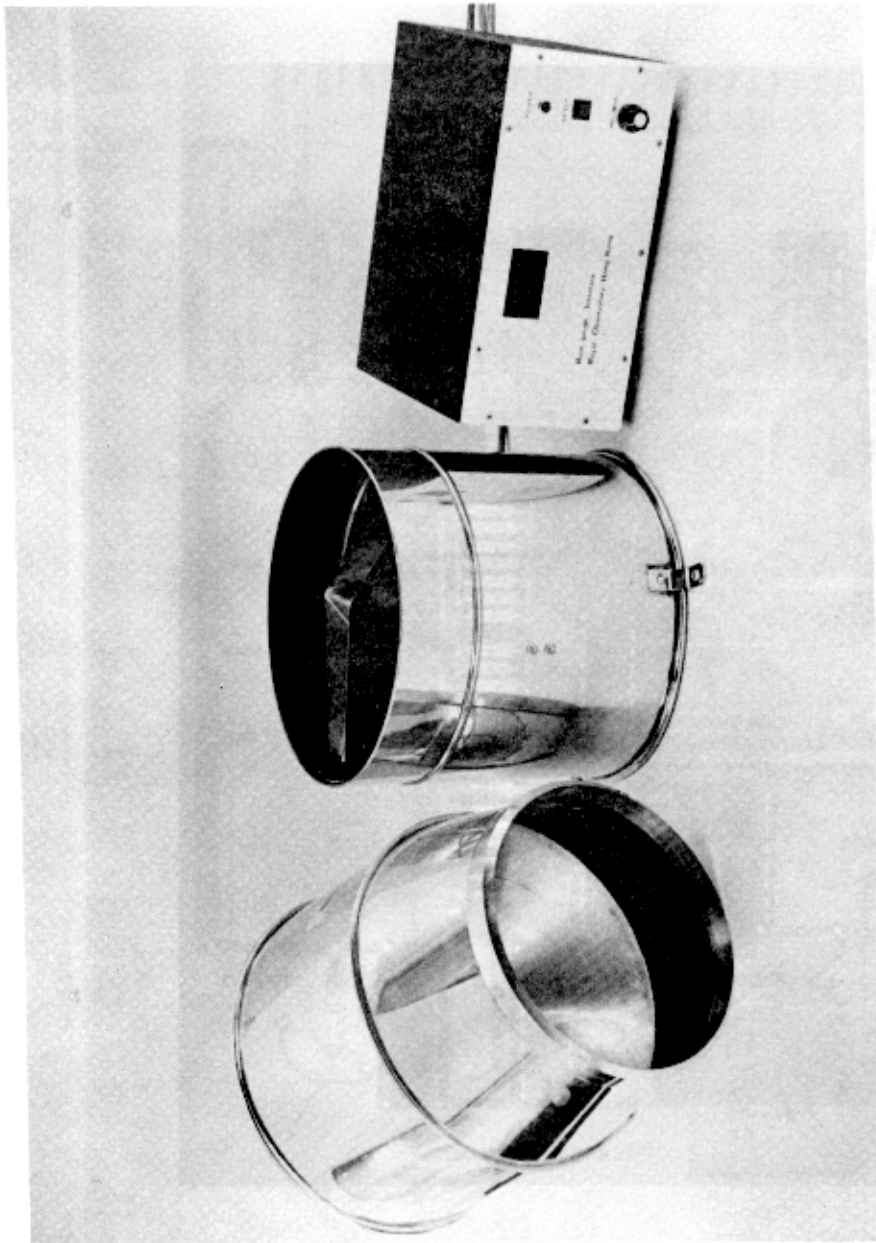
Plate 1. A tipping-bucket rain-gauge connected to an interface box
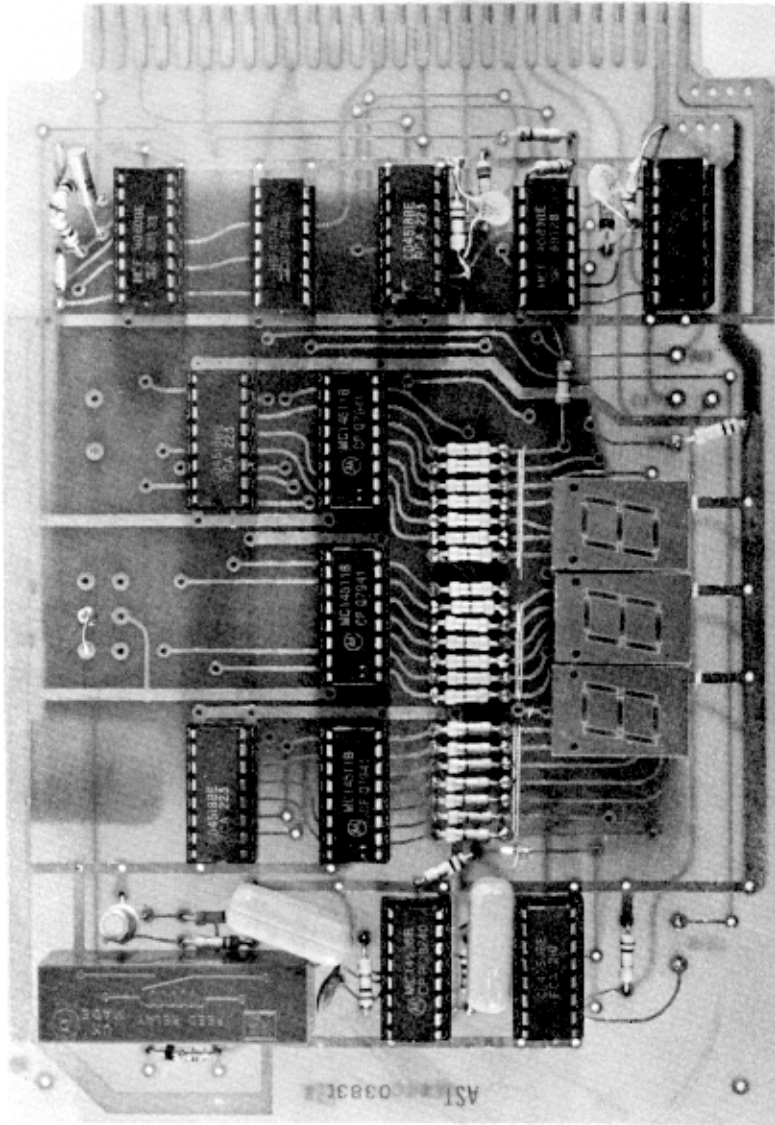
Plate 2. An electronic counter
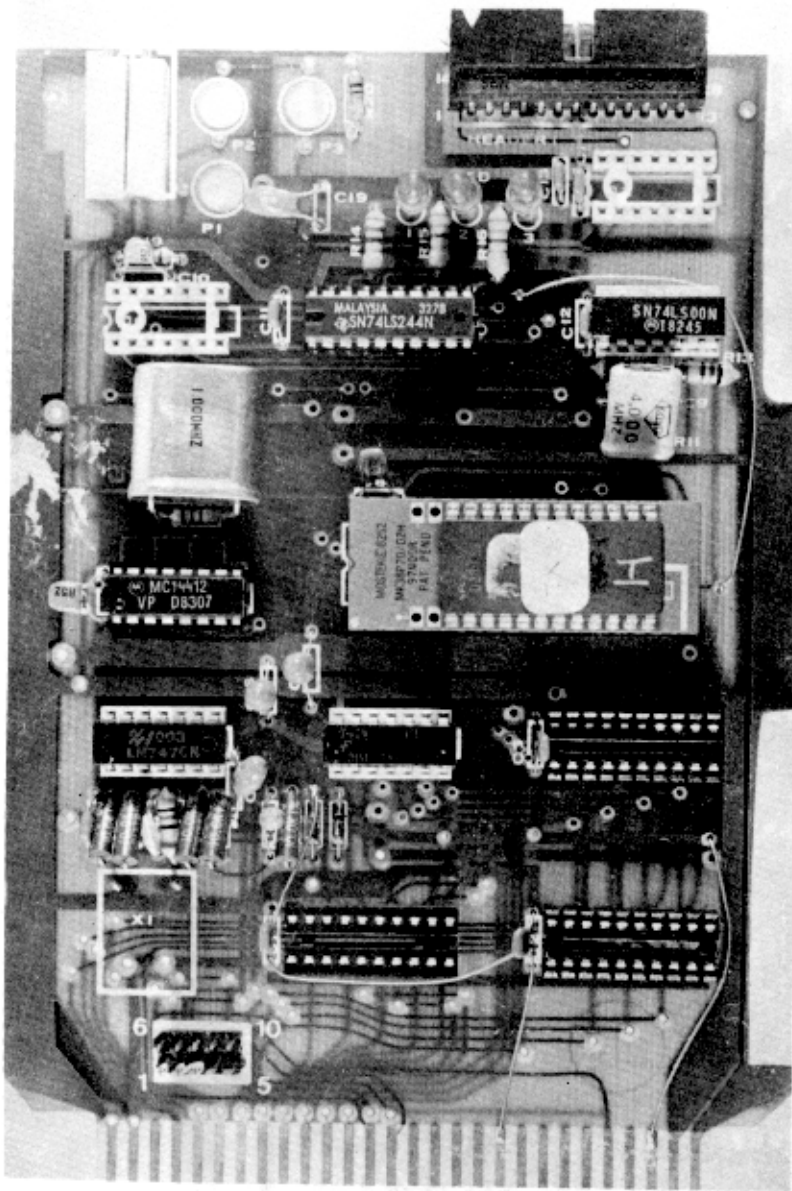
Plate 3. A microprocessor transmitter controller
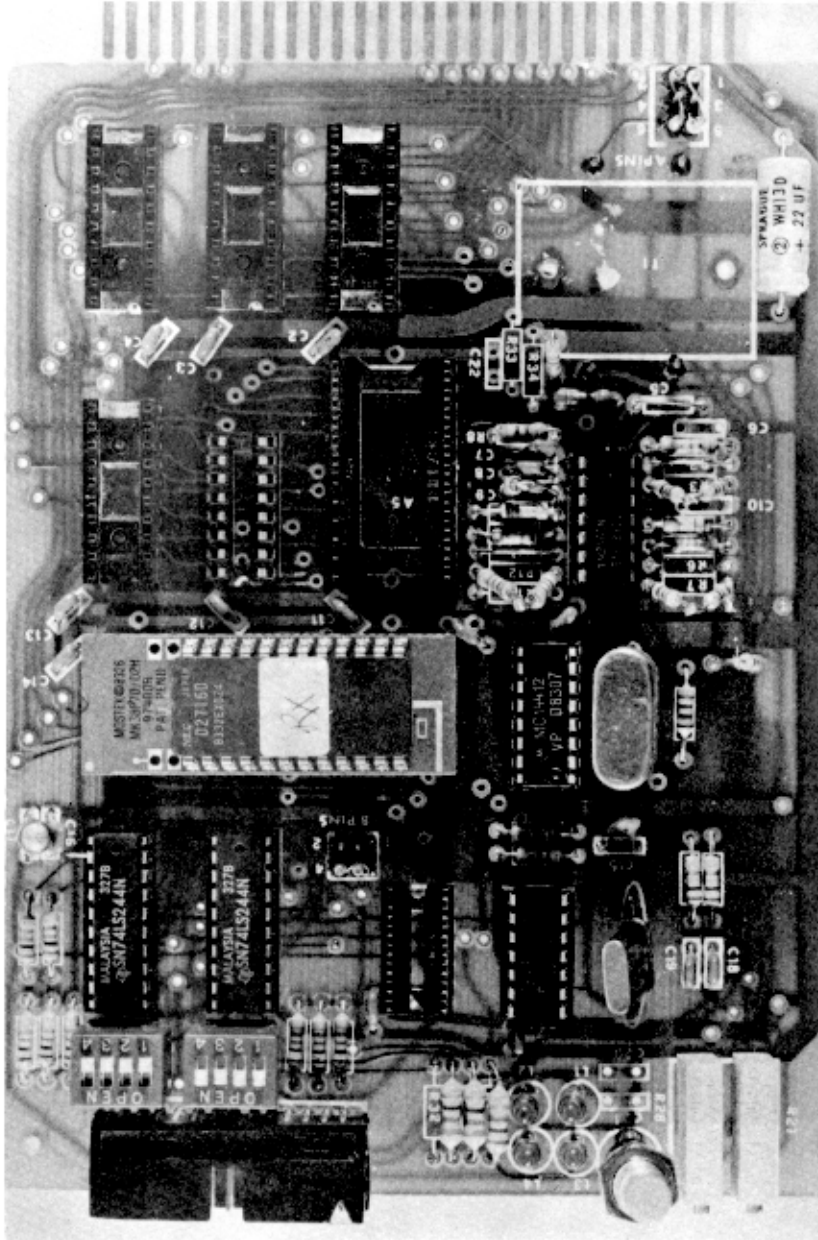
Plate 4. A microprocessor receiver controller
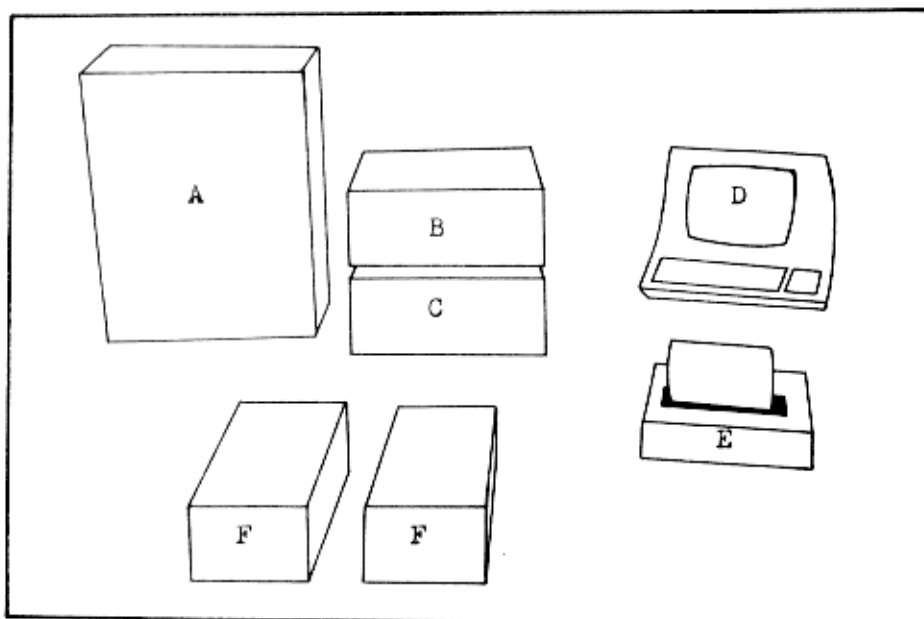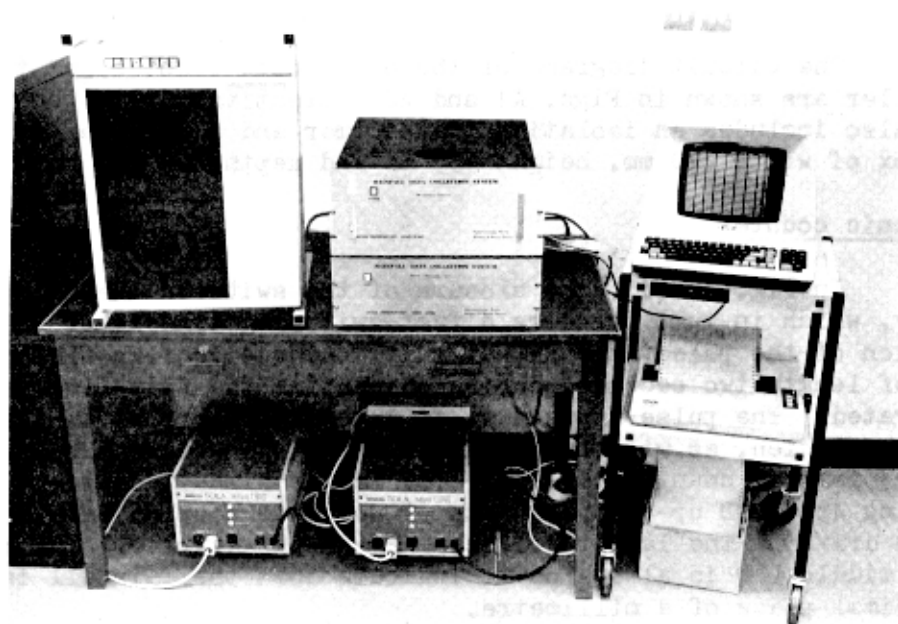
A. Communication recorder (tape drive)

B. Microprocessor receiver controllers and interface to CPU

C. Central Processing Unit (Z-80 system)

D. Terminal

E. Line-printer

F. Uninterruptible power supplies

Plate 5.   The central control system and peripherals

APPENDIX 1

OPERATING PRINCIPLES OF
THE INTERFACE UNIT PLACED AT FIELD SITE

The circuit diagrams of the electronic counter and the microprocessor controller are shown in Figs. A1 and A2 respectively. The entire equipment, which also includes an isolation transformer and a dc power supply, is housed in a box of width 270 mm, height 135 mm and depth 200 mm.

Electronic counter

In Fig. A1 (i), the closure of the switch in the rain-gauge triggers a relay, which in turn triggers a fast-switching transistor (2N2222). On reception of the pulse, the R-C circuit in the 4538 flip-flop enables a square pulse of length two seconds, during which time the flip-flop remains deactivated. The pulse is used as an external interrupt to the microprocessor controller which, as will be explained later, generates 5 pulses (for 0.5 mm buckets) for the counter circuit. The latter circuit consists of three cascading 4518 BCD up-counters each of which is coupled to a 4511 BCD-to-7-segment driver. The latter drives a HP7653 LED display. The decimal point in the middle LED is always 'on' to indicate that the rainfall is expressed to one decimal place of a millimetre.

Fig. A1 (ii) shows the circuit to reset the LED displays. There are three reset positions in the switch on the front panel : manual, hour and minute. The timing is achieved in the following manner : a 4060 14-stage binary counter converts signals from a 32768-Hz quartz crystal into one-second pulses. These pulses are cascaded by two by a 4013 flip-flop. These are further cascaded by a factor of 10 by a 4518 counter and then by a factor of 3 by another 4518 counter. Pulses from the latter are thus each separated by 60 seconds. In a similar manner, a further factor of 60 is achieved by having another two 4518 counters down the line to produce pulses separated by 60 minutes. These pulses are passed (at different times) to the 'reset' position of the counter circuit in Fig. A1 (i).

Microprocessor transmitter controller

In the microprocessor transmitter controller, the rising edge of the incoming square pulse triggers an external interrupt in the Mostek MK38P80 microprocessor. The software, written in assembler language, is resident in the EPROM (Erasable Programmable Read-only Memory) which is inserted on the back of the microprocessor. The interrupt activates a routine which provides a serial data stream with a pre-defined bit pattern to be output at 400 bauds to a MC14412 low-speed modem. The latter then modulates the data stream with different mark and space frequencies (1270 and 1070 Hz respectively). The modulated signal is amplified by LM744 operational amplifiers before entering into the primary coil of a 600-ohm 1:1 isolation transformer (type RS 217-826). The secondary coil of the transformer is connected to a pair of telephone wires which transmit the data back to the Royal Observatory Headquarters.

On the detection of a square pulse, the microprocessor also outputs 5 pulses (for 0.5 mm bucket) to the on-site electronic counter to update the accumulated rainfall on the LED display.

The microprocessor is timed by an oscillator circuit which makes use of three NAND-gates in 74LS00. The 74LS14 Schmitt triggers at the reset position serve to transform slow-changing input signals into sharply defined, jitter-free output signals.

Fig. A3 shows the design of the microprocessor software.

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Fig. A1 (i) Electronic counter – flip-flop, counter and display circuits

Rain-gauge

2N 2222
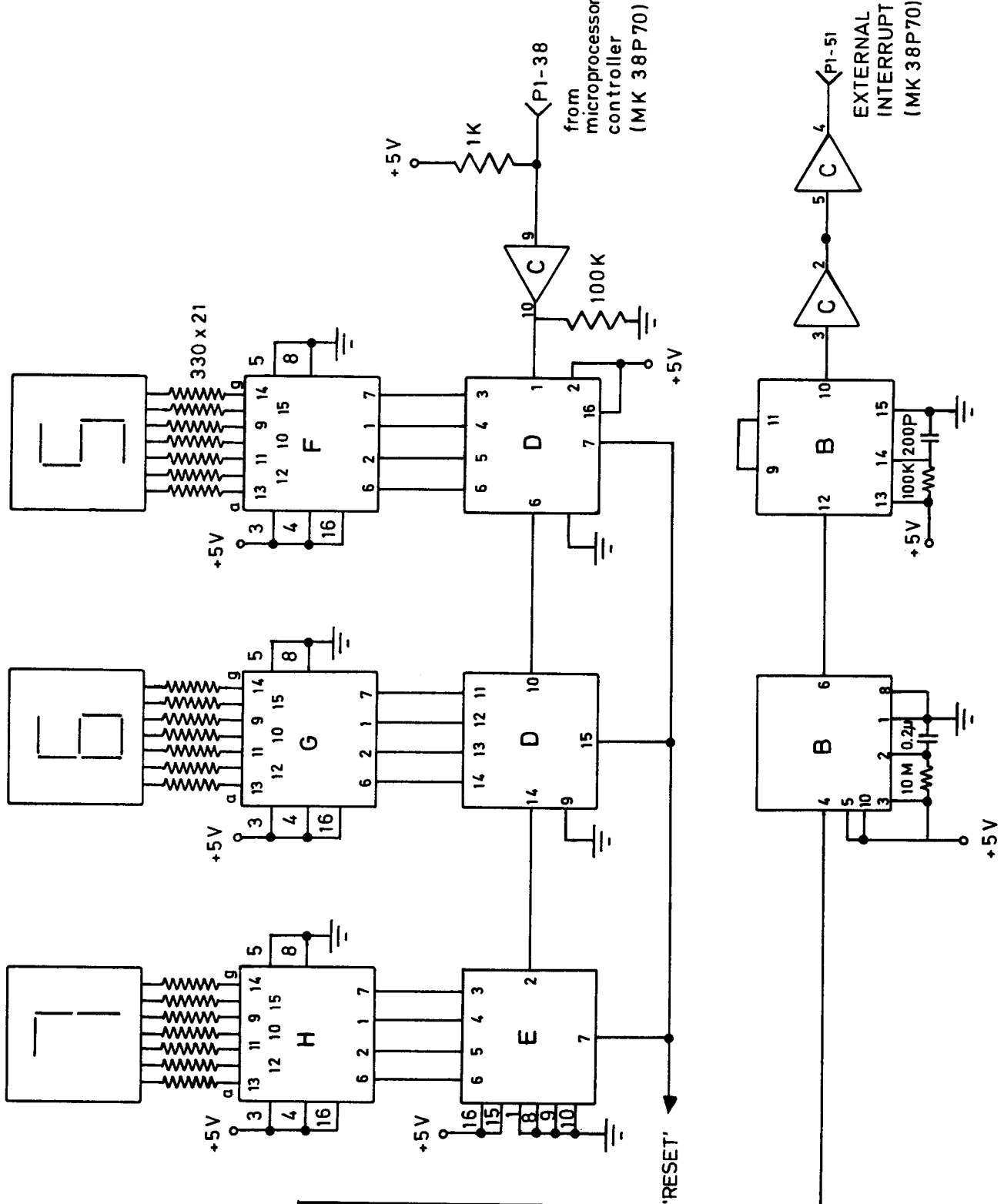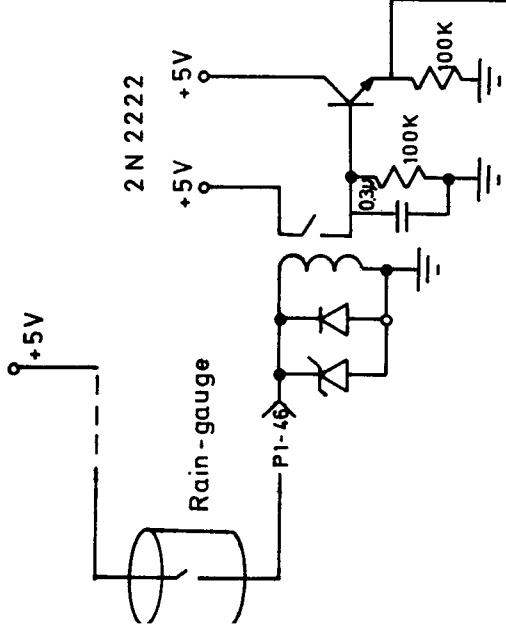
B – 4096 (16 pins) master–slave
      flip-flops

C – 4050 (16 pins) hex buffers
      Pin 1 – +5V
      Pin 8 – Gnd
      Pin 7, 9, 11 – Gnd

D – 4518 (16 pin) dual up–counters
E –

F
G – 4511 (16 pin) BCD-to-7-segment
H   latch decoder and
        driver

LED display – HP 7653 common
              cathode type

from
microprocessor
controller
(MK 38P70)

EXTERNAL
INTERRUPT
(MK 38P70)

'RESET'

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Fig. A1 (ii) Electronic counter - reset circuit
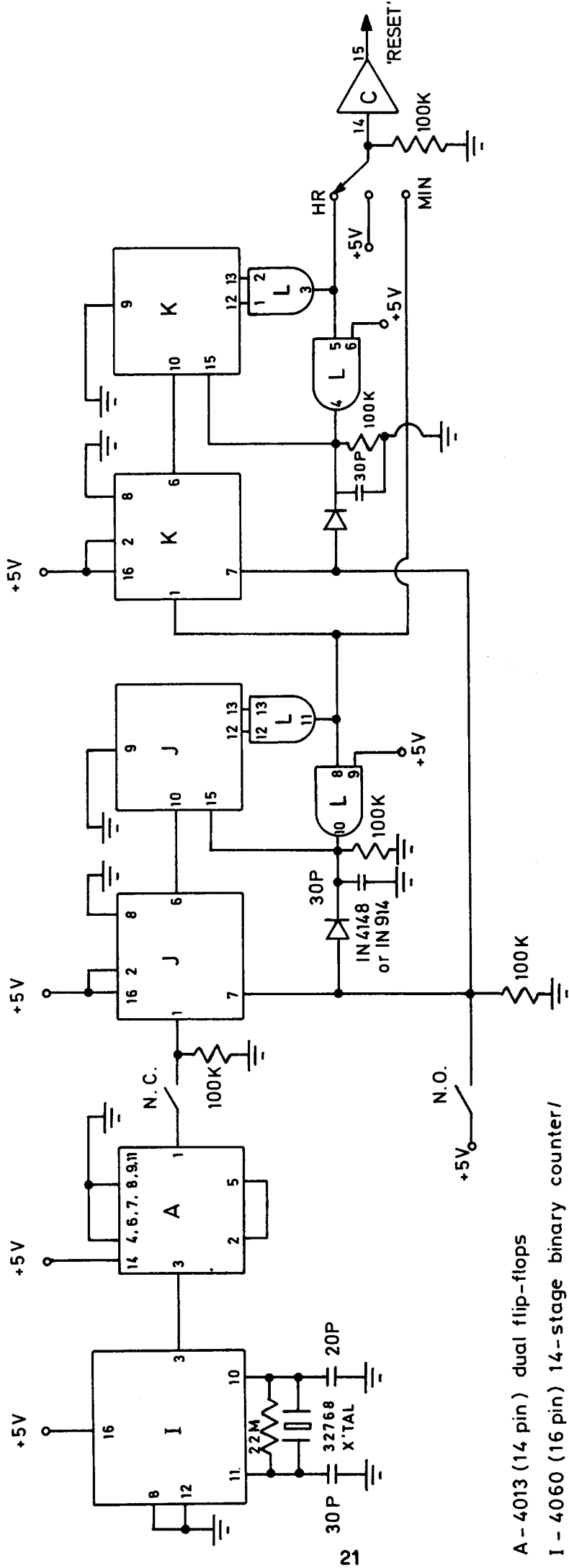
A - 4013 (14 pin) dual flip-flops

I - 4060 (16 pin) 14-stage binary counter/
divider and oscillator

J -
K - 4518 (16 pin) dual up-counters

L - 4081 (14 pin) dual 2-input AND gate
Pin 14 - +5 V
Pin 7 - Gnd

21
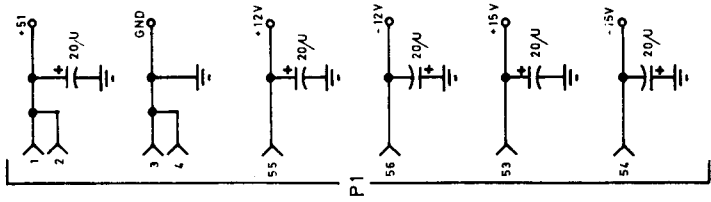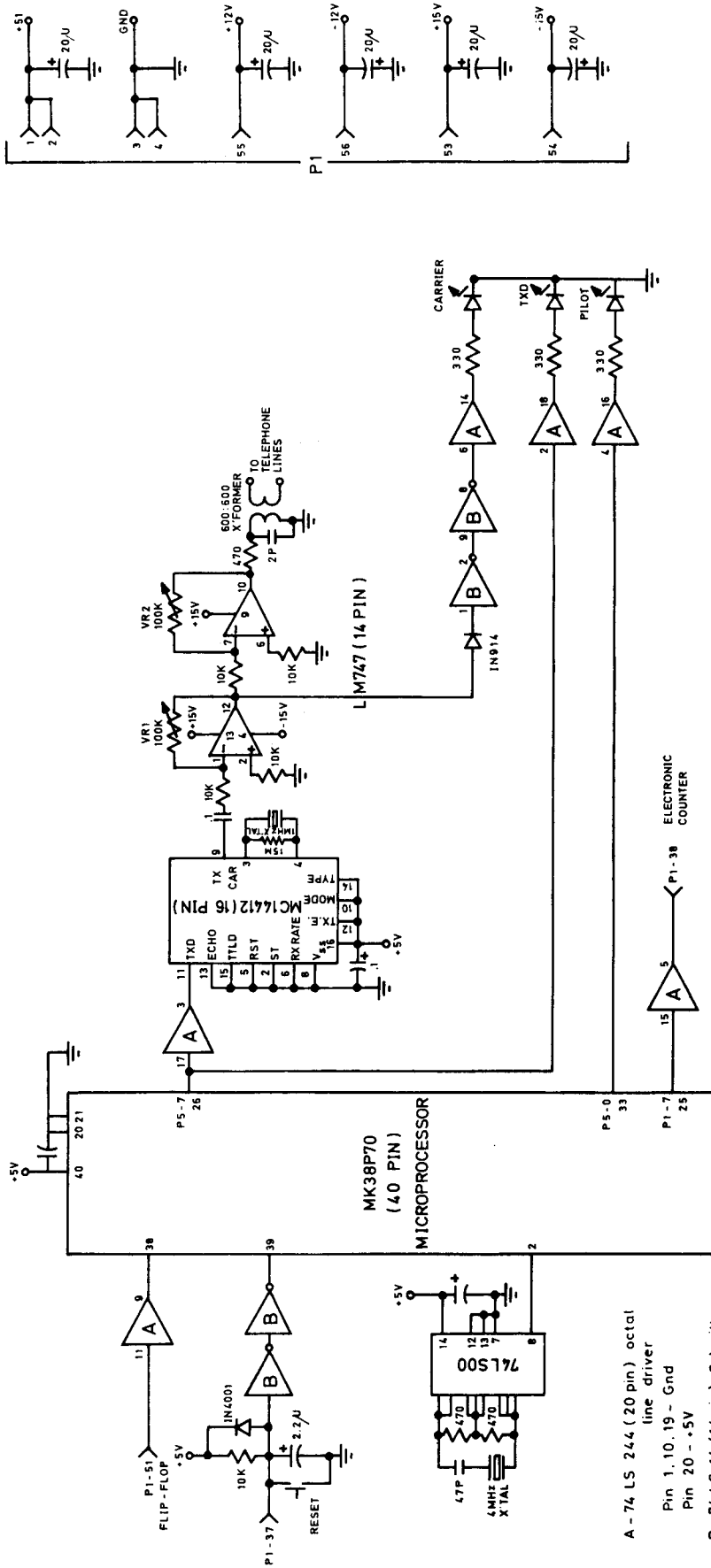
Fig. A2 Circuit diagram for microprocessor transmitter controller

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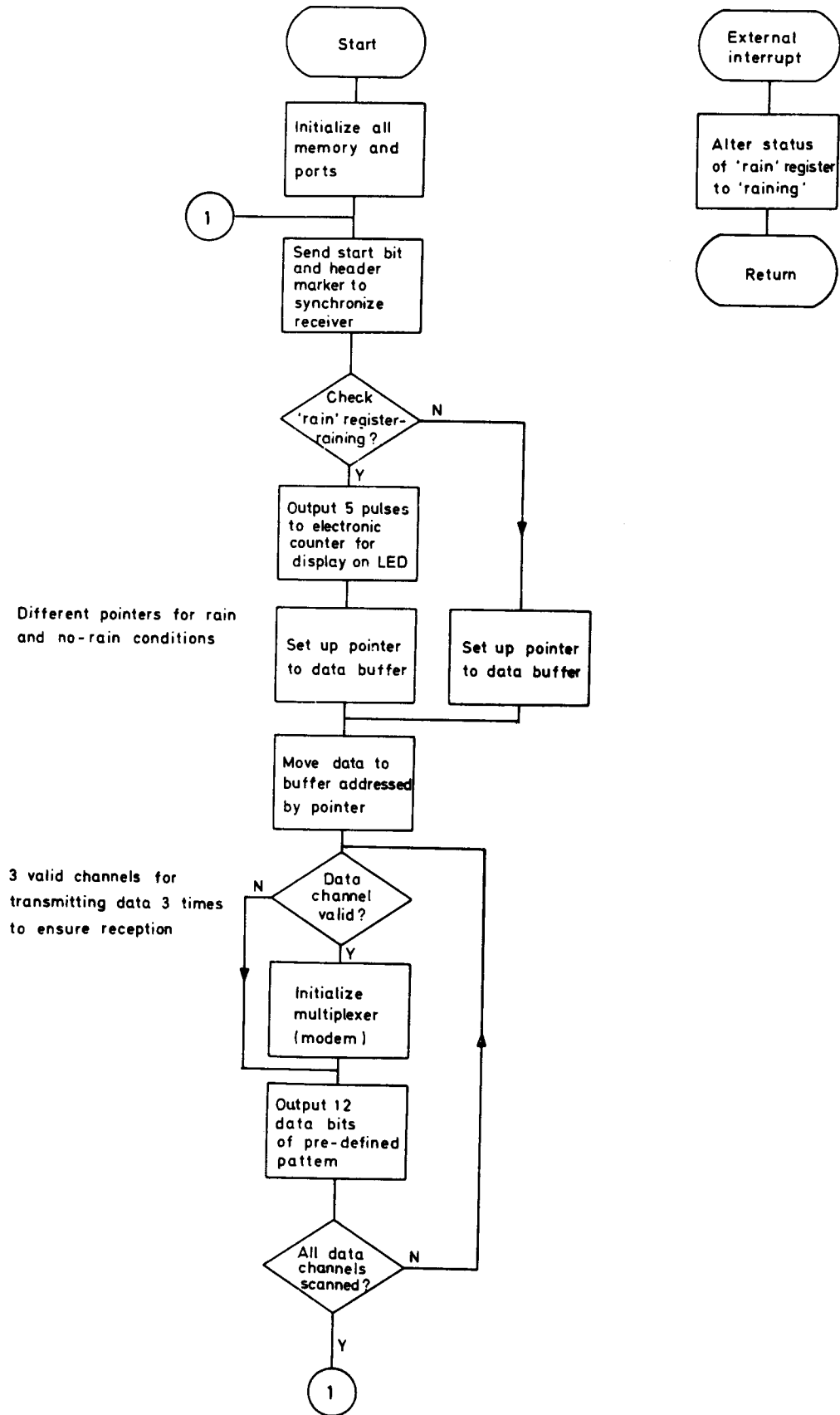
Fig. A3 Flowchart for the software of the microprocessor transmitter controller

APPENDIX 2

OPERATING PRINCIPLES OF
THE RECEIVING MICROPROCESSOR CONTROLLER

The circuit diagram for the receiving microprocessor controller
is given in Fig. A4.

Microprocessor receiver controller

The signal on the telephone wires consists of mark and space
frequencies (1270 and 1070 Hz respectively). It first passes through
a 600-ohm 1:1 isolation transformer at the input of the microprocessor
receiver controller. It is then amplified by LM3900 operational amplifiers
before arriving at the MC14412 low-speed modem for demodulation. The data
stream with a pre-defined bit pattern for rainfall information is then
decoded by the MK38P70 microprocessor. The software is programmed in
assembler language and is resident in an EPROM (Erasable Programmable
Read-only Memory) inserted on the back of the microprocessor. On
recognition of the data stream, the microprocessor sends out a square
pulse of one-second duration. This pulse is then latched on the interface
to the Z-80 central control system.

The microprocessor is timed by an oscillator circuit which makes
use of three NAND-gates in 74LS00. The 74LS14 Schmitt triggers at the
reset position serve to transform slow-changing input signals into sharply
defined, jitter-free output signals.

Fig. A5 shows the design of the microprocessor software.
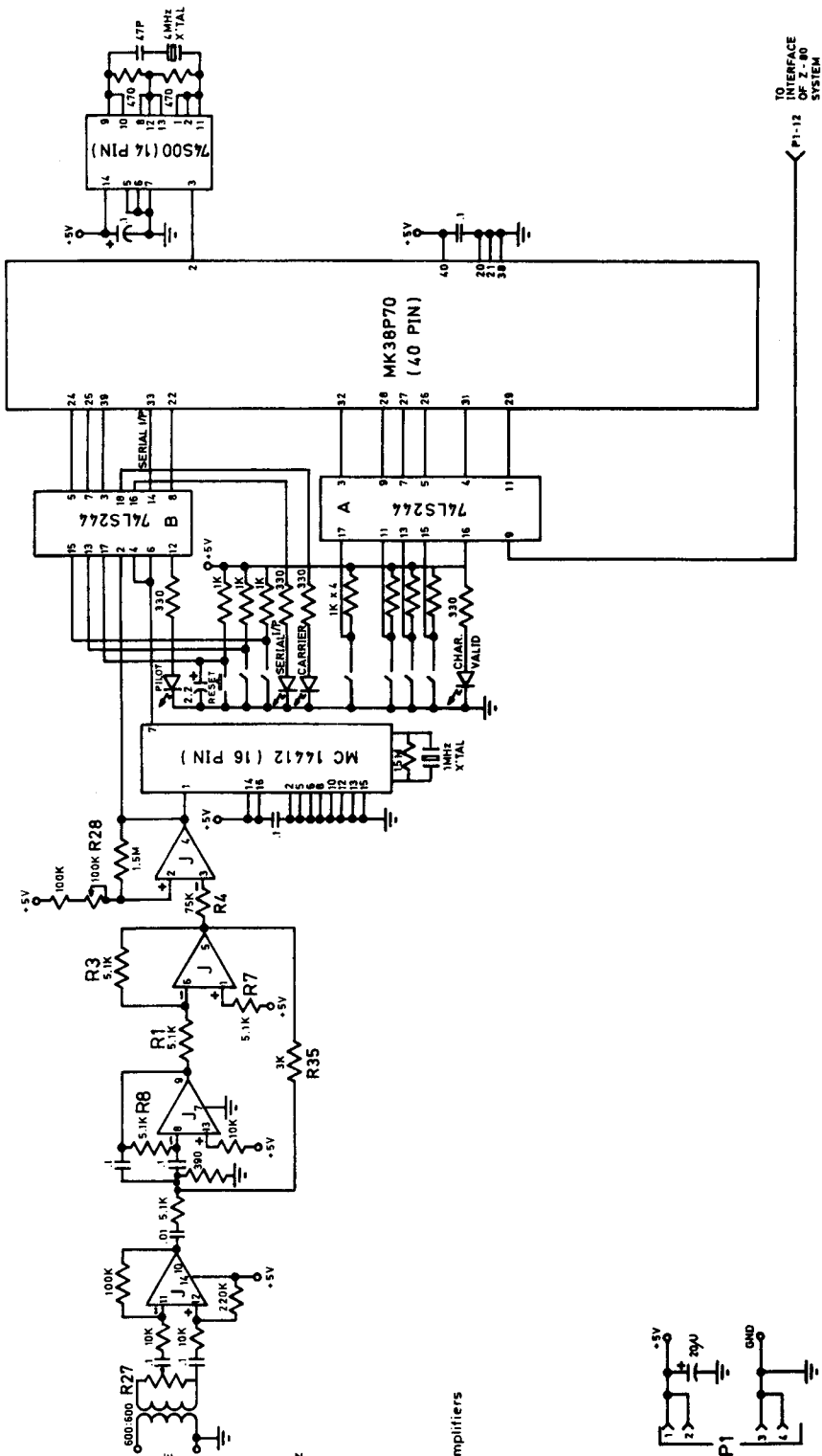
Fig. A4 Circuit diagram for microprocessor receiver controller

MARK : 1270 Hz
SPACE : 1070 Hz

A – 74 LS 244 (20 pin) octal line drivers
B   Pin 1, 10, 19 – Gnd
          Pin 20 – +5 V

J – LM 3900 (14 pin) quad operational amplifiers
          Pin 7 – Gnd
          Pin 14 – +5 V

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Microprocessor receiver controller

Start

Initialize all memory, ports and 1-s timer

Transmitted data at 400 bauds

Start bit detected ? — N

Y

Check header marker

Header marker correct ? — N

Y

Start bit detected ? — N

Y

Collect 12 data bits

Does data received match pre-defined pattern? — N

Y

Output 1-s pulse to interface to central Z-80 system

End of 1 s ? — N

Y
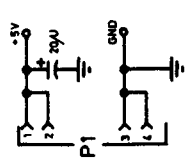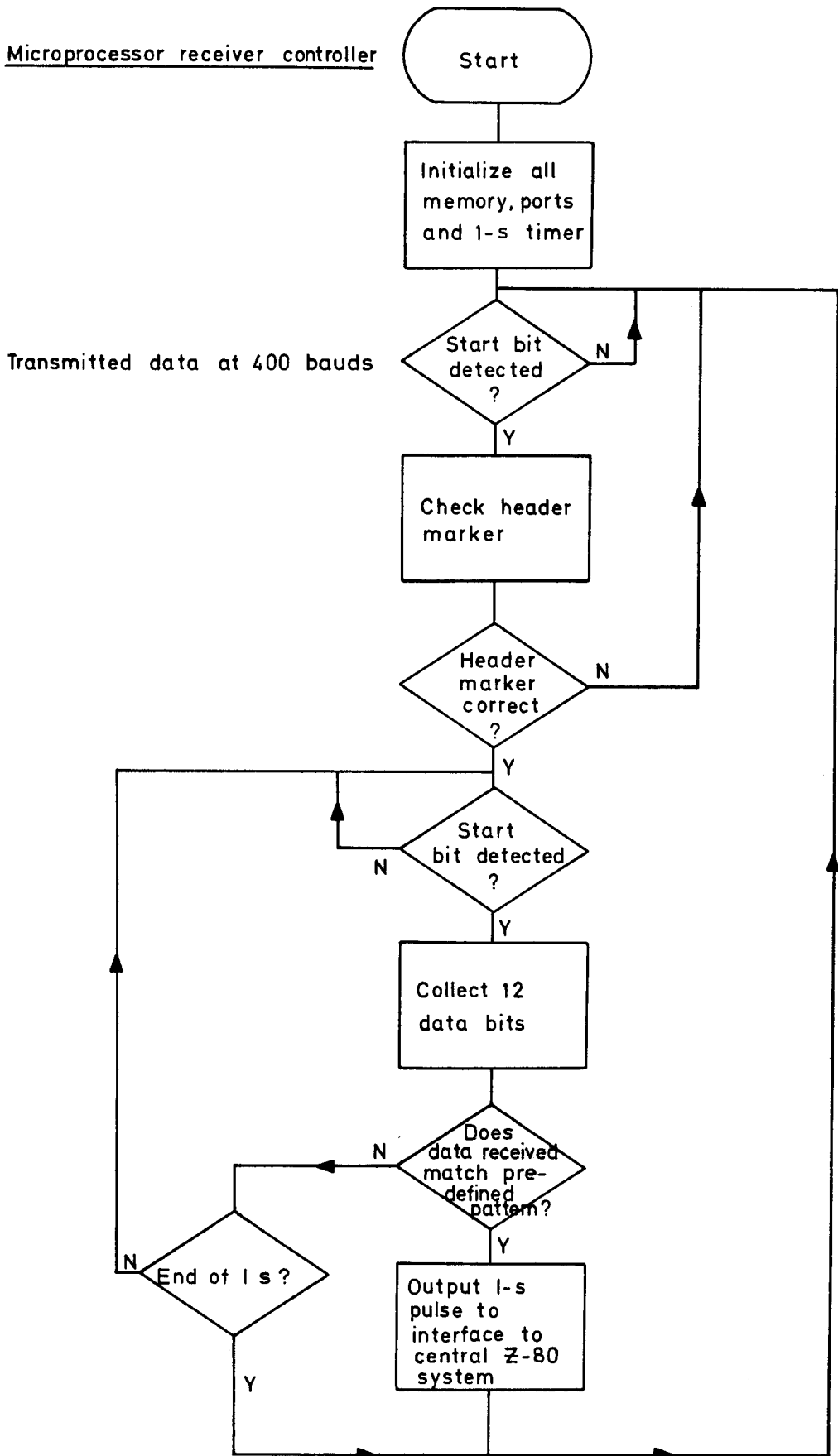
Fig. A5 Flowchart for the software of the microprocessor receiver controller

APPENDIX 3

OPERATING PRINCIPLES OF THE INTERFACE
TO THE Z-80 CENTRAL CONTROL SYSTEM

The circuit diagram for the interface to the Z-80 central control system is shown in Fig. A6.

Outputs from the microprocessor receiver controller enter through a relay and are latched to a 74LS240 line driver by a 74LS279 set-reset latch. The latch is reset at 3/4-second intervals under the control of the software in the Z-80 system, which comes through the PIO module (Section 3(e)).

P1-12
from microprocessor controller

A   18
2

Relay   14   2
6,8

4.7K   +5V

B   2,11,16   3   4   1   8   +5V

C   2   18

J1   18   To PIO of Z-80 system

J1-16   'Reset' from central Z-80 system

An interface board serves 16 lines (i.e. 2 I/O ports) from the PIO board. One of these lines is used as 'reset'. The board consists of two 74 LS 244's, four 74 LS 279's, two 74 LS 240's, fifteen 5V relays, fifteen pull-up resistors and fifteen zener diodes.
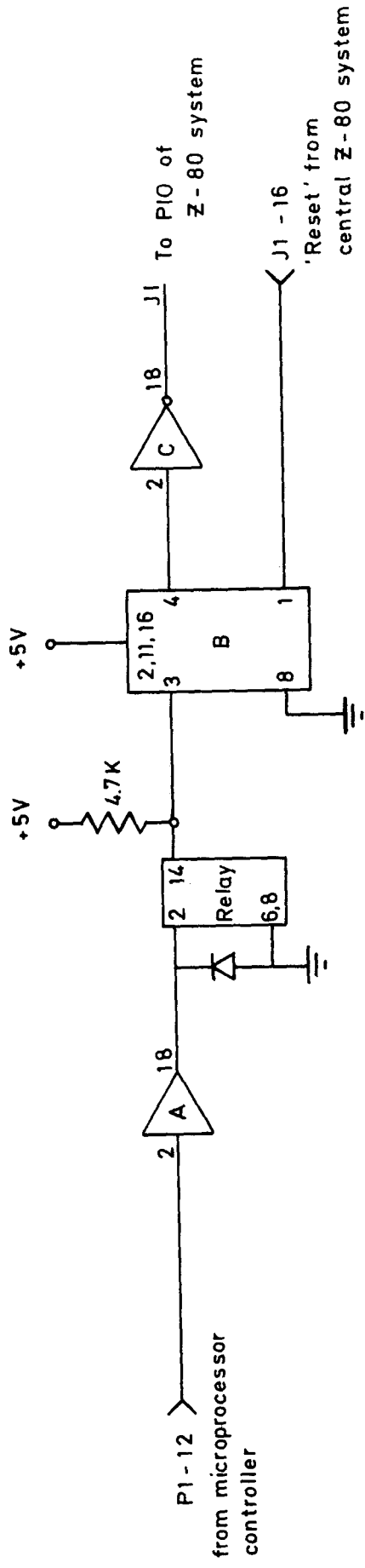
A - 74 LS 244 (20 pin) octal line driver
Pin 1,10,19 - Gnd
Pin 20 - +5V

B - 74 LS 279 (16 pin) quad set-reset latch
Pin 8 - Gnd
Pin 2,11,16 - +5V

C - 74 LS 240 (20 pin) octal inverting line driver
Pin 1,10,19 - Gnd
Pin 20 - +5V

Fig. A6 Circuit for the interface between the microprocessor receiver controller and the Z-80 system

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APPENDIX 4

FORMATS OF OUTGOING MESSAGES
FROM THE Z-80 CENTRAL CONTROL SYSTEM

All the messages are in ASCII codes. Each character consists of one start bit, eight data bits and one stop bit.

Message to the computer-compatible tape recorder :

```
SOH CRLF
YYMMDDHHMM CRLF
SO1 Nxxxxxx CRLF
ETX
```

where
SOH = 'start of header' in ASCII ;
ETX = 'end of text' in ASCII ;
CRLF = carriage return and line feed in ASCII ;
SO1 = 3-letter station code in ASCII ;
YYMMDDHHMM = time in ASCII at which transmission takes place ;
xxxxxx = time in hour, minute and second (HHMMSS) in ASCII.

Transmission is done every time a tipping of the buckets of the rain-gauge is detected. The transmission speed is 19200 bauds.

Message to the main computer :

```
SOH CRLF
YYMMDDHHMM CRLF
SO1 xxxxx CRLF
ETX
```

where
SO1 = 3-letter station code in ASCII ;
YYMMDDHHMM = time in ASCII at which transmission takes place ;
xxxxx = five numerals indicating the value of the parameter correct to one decimal place. A decimal point is always implied between the 4th and 5th numerals. Leading zeroes are blanked.

Transmission is done every five minutes at 300 bauds.

Messages to the line-printer :

A sample of the printout on the line-printer is shown in Fig. A7.

Transmission is done every quarter of an hour at 600 bauds.

STN	Q	H	D	STN	Q	H	D	STN	Q	H	D
R11	0	0	1.0	R12	0	0	1.0	R13	0	0	1.0
R21	0	0	1.0	R22	0	0	1.0	R23	0	0	1.0
R24	0	0	2.0	R25	0	0	5.0	RXX	0	0	1.5
RXX	0	0	1.5	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0				

RAINFALL DATA FROM R.O.H.K. RAINGAUGE NETWORK
DATE : 3 NOV 1983   TIME : 14:30

STN	Q	H	D	STN	Q	H	D	STN	Q	H	D
R11	0	0	1.0	R12	0	0	1.0	R13	0	0	1.0
R21	0	0	1.0	R22	0	0	1.0	R23	0	0	1.0
R24	0	0	2.0	R25	0	0	5.0	RXX	0	0	1.5
RXX	0	0	1.5	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0				

RAINFALL DATA FROM R.O.H.K. RAINGAUGE NETWORK
DATE : 3 NOV 1983   TIME : 14:45

STN	Q	H	D	STN	Q	H	D	STN	Q	H	D
R11	0	0	1.0	R12	0	0	1.0	R13	0	0	1.0
R21	0	0	1.0	R22	0	0	1.0	R23	0	0	1.0
R24	0	0	2.0	R25	0	0	5.0	RXX	6.0	6.0	7.5
RXX	0	0	1.5	RXX	.5	.5	.5	RXX	0	0	0
RXX	.5	.5	.5	RXX	0	0	0	RXX	.5	.5	.5
RXX	0	0	0	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0				

RAINFALL DATA FROM R.O.H.K. RAINGAUGE NETWORK
DATE : 3 NOV 1983   TIME : 15:00

STN 24H TOTAL FROM 1500		STN 24H TOTAL FROM 1500		STN 24H TOTAL FROM 1500	
R11	1.0	R12	1.0	R13	1.0
R21	1.0	R22	1.0	R23	1.0
R24	2.0	R25	5.0	RXX	8.0
RXX	1.5	RXX	.5	RXX	0
RXX	.5	RXX	0	RXX	.5
RXX	0	RXX	0	RXX	0
RXX	0	RXX	0		

RAINFALL DATA FROM R.O.H.K. RAINGAUGE NETWORK
DATE : 3 NOV 1983   TIME : 15:00

STN	Q	H	D	STN	Q	H	D	STN	Q	H	D
R11	0	0	1.0	R12	0	0	1.0	R13	0	0	1.0
R21	0	0	1.0	R22	0	0	1.0	R23	0	0	1.0
R24	0	0	2.0	R25	0	0	5.0	RXX	.5	6.5	8.0
RXX	0	0	1.5	RXX	0	.5	.5	RXX	0	0	0
RXX	0	.5	.5	RXX	0	0	0	RXX	0	.5	.5
RXX	0	0	0	RXX	0	0	0	RXX	0	0	0
RXX	0	0	0	RXX	0	0	0				

Fig. A7 Sample printout of the message to the line-printer

SOFTWARE DESIGN FOR THE Z-80 CENTRAL CONTROL SYSTEM

Essentially, the software consists of a main program and a timer interrupt routine.

The main program (Fig. A8) continuously (i) looks for any control signal input by the operator from the video terminal (VDU) and arranges the following actions to be taken :

a) to set time,

b) to set a threshold rainfall value for alarm,

c) to silence/re-activate alarm,

d) to toggle display of status of data lines on the video terminal, and

e) to initiate transfer of data to tape recorder ; and (ii) monitors the time and at appropriate time intervals outputs rainfall data summaries to the line-printer, video terminal and the main computer.

The time-interrupt routine (Fig. A9) operates at regular intervals of about 25 ms. Once every 3/4 of a second (i.e. 30 time-interrupts) has elapsed, all data lines will be scanned. A change in the status of any particular data line from 'low' TTL level to 'high' TTL level indicates that 0.5 mm of rain has fallen on the corresponding rain-gauge. A value of 0.5 (mm) is immediately added to each of the totals accumulated since the start of the following time periods :-

(i)   latest clock 5-minute period (i.e. since the 0th,
        5th, 10th, ..., 50th or 55th minute of the
        hour) ;

(ii)   latest quarter period (i.e. since the 0th, 15th, 30th
        or 45th minute of the hour) ;

(iii)   the latest clock hour period (i.e. since the 0th minute
        of the hour) ;

(iv)   midnight last night ; and

(v)   3 p.m. the previous day.

The time at which a change in the status of the data line is detected is also logged on a 9-track computer-compatible tape. If the threshold rainfall value for alarm is reached, signals will be sent (every 3/4 of a second) to the video terminal and can be heard of as 'beeps', if the alarm is already in a ready state.

As a built-in feature in the microprocessor, a time-interrupt is given a high priority over the main program. Execution of the main program is suspended when a time-interrupt comes in. This ensures that there is no loss of incoming data even during transmission of messages to the main computer and the peripherals. The contents of all working registers used by the main program are saved before the time-interrupt is served, and are restored afterwards.

Main   Program

```
                        ╭──────────╮
                        │   Start   │
                        ╰──────────╯
                             │
                    ┌────────────────┐
                    │ Initialize all │
                    │ memory and     │
                    │ I/O  ports     │
                    └────────────────┘
                             │
                    ┌────────────────┐
                    │ Initialize all │
                    │ rainfall input │
                    │ and  control   │
                    │ lines          │
                    └────────────────┘
                             │
                    ┌────────────────┐
                    │ Output 'start' │    Message to indicate
                    │ message to     │    start-up time after reset
                    │ line-printer   │    or stoppage of system
                    └────────────────┘
                             │
      ⎛1⎞──────────►         │
                             ▼
                          ╱Any╲
                         ╱ input ╲
                        ╱ from     ╲  Y
                        ╲ keyboard?╱────────────► ⎛2⎞
                         ╲ (VDU) ╱
                          ╲   ╱
                           │ N
                           ▼
                        ╱'MM'╲
                     N ╱changed from╲
      ◄──────────────╲   last ?   ╱
                        ╲        ╱
                         ╲    ╱
                          │ Y
                          ▼
                         ⎛3⎞
```
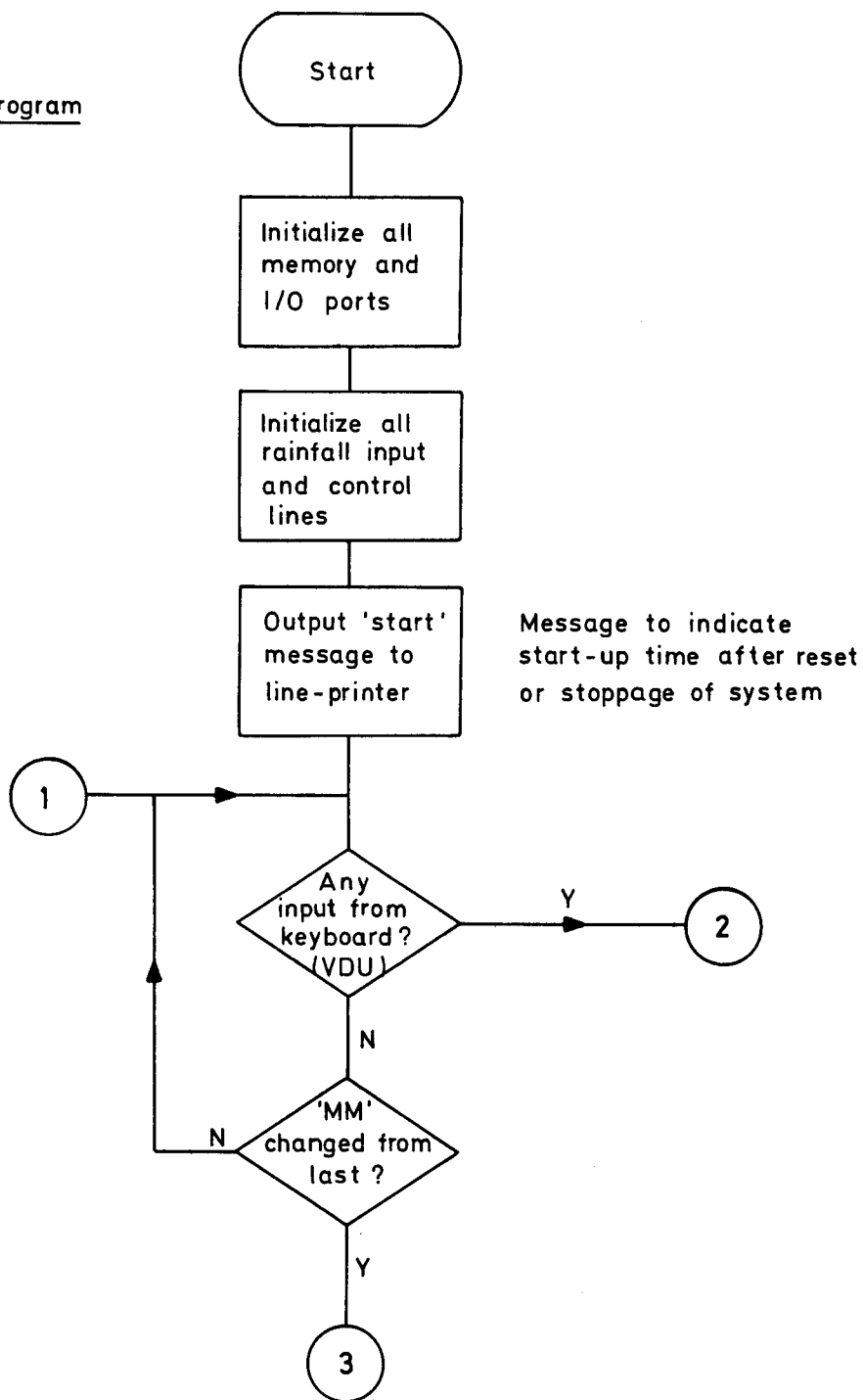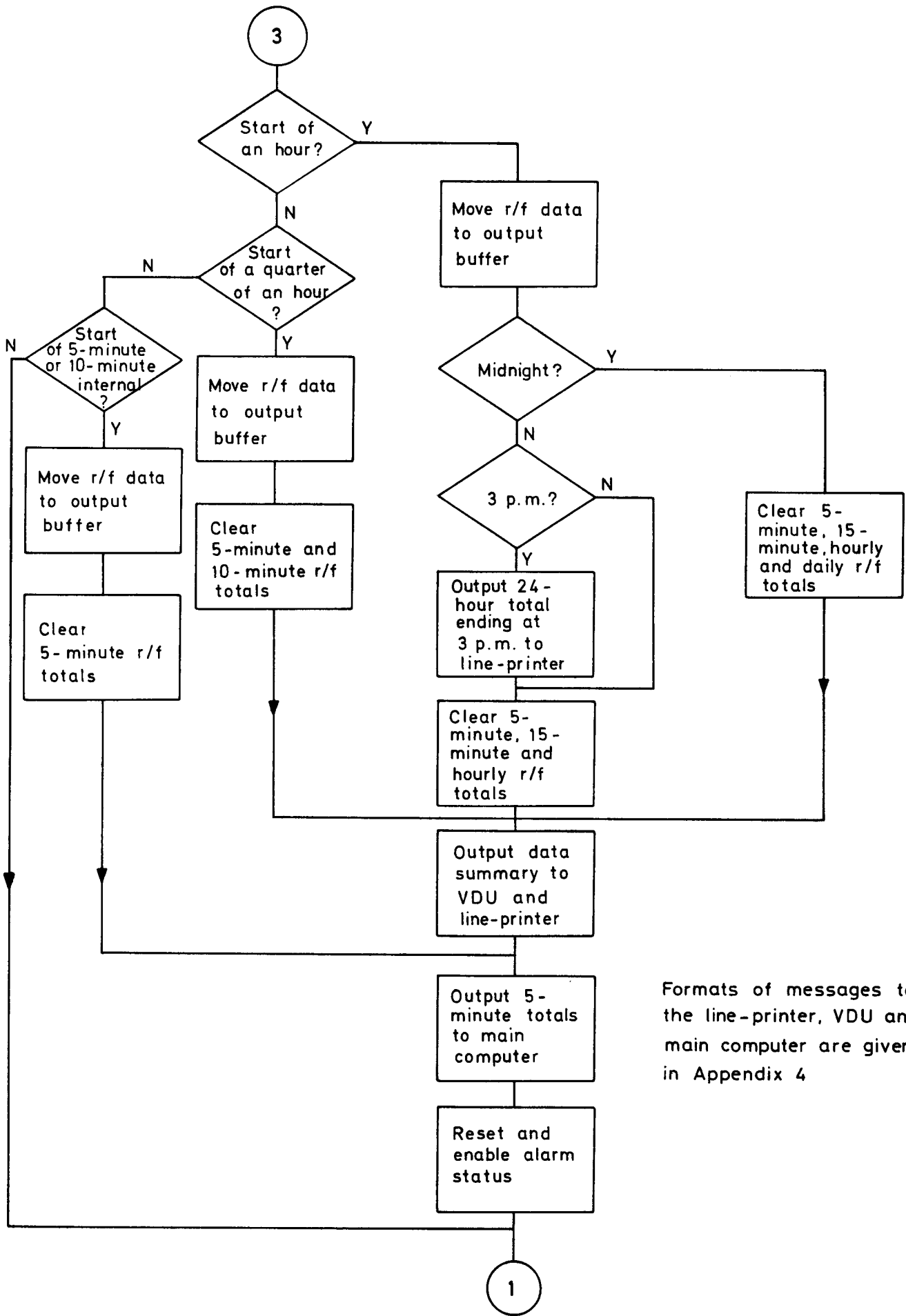
Fig. A8 Flowchart for the main program of the Z-80 system software

Fig. A8 (cont'd)

Input from keyboard
detected

②

Set time?

N

Y

Adjust
YYMMDDHHMMSS
keyed in
from VDU

Set
alarm
threshold
?

N

Y

Change rainfull
alarm threshold
to keyed-in
value

Normally 15.0 mm

Silence alarm?

N

Y

Deactivate alarm

Transfer
data to tape
?

N

Y

Set flag to
signal transfer
of data if any

Display
status of data
line on VDU
?

N

Y

Set flag to
display status
of data line
on VDU

For trouble-shooting
purpose

①

Moniter input from
keyboard again

Fig. A8 (cont'd)

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Every 25 ms

Time interrupt

Save all working registers

Rain-gauges scanned once every 0.75 s

0.75 s time out? — N

Maximum 60 lines

Y

Scan rain-gauge data lines and display status on VDU

Tip of the bucket for every 0.5 mm of rain fallen. An 'input' is a change of line status from 'Low' to 'High'

Any input? — N

Y

Update 5-minute, 15-minute, hourly, daily and 3 p.m. totals

Computer-compatible tape recorder stores data on magnetic tape. See Appendix 4 for format of message.

Output time of tipping in the gauge to tape recorder

Send reset signal to interface

Rainfall threshold exceeded? — N

Y

Sound alarm on VDU if alarm line is active
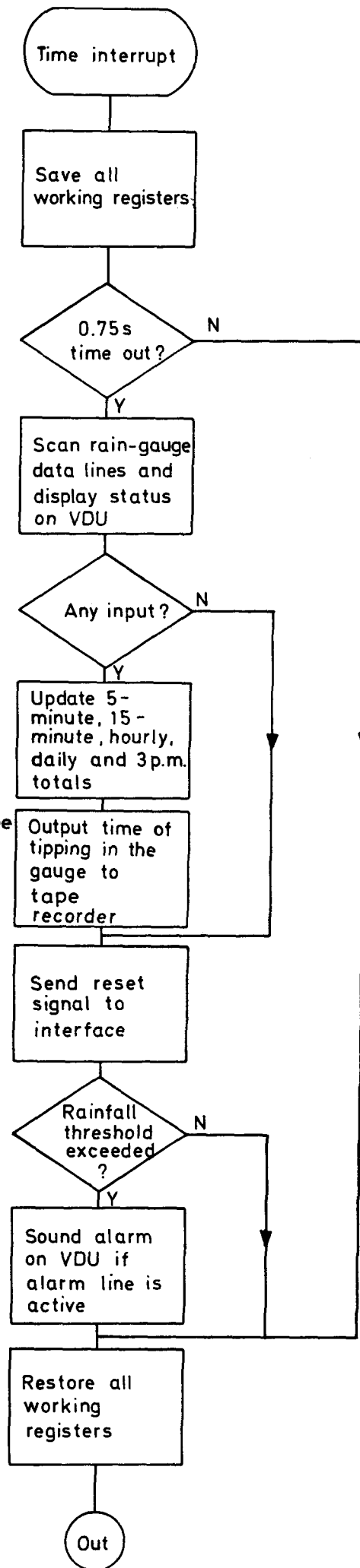
Restore all working registers

Out

Fig. A9 Flowchart for the time-interrupt routine of the Z-80 system software

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