ELECTRONIC TELEPHONE MONITORING UNIT

OCHUODHO SHEM J. B.Sc.

This thesis is submitted in part fulfilment for the Degree of Master of Science in Electrical Engineering in the University of Nairobi.

1986/87

This thesis is my original work and has not been presented for a degree in any other University.

OCHUODHO S.J.

This thesis has been submitted for examination with my approval as a University supervisor.

MR. HAROLD de SOUZA

ABSTRACT

The project described in this thesis attempts to enhance telephone metering by providing the telephone user with detailed call information. The Kenyan telephone network is still largely analog. Its capability is therefore limited to capturing only some of the key call parameters. The unit developed in this work offers the customer more details. A unique aspect of this unit is that it is installable at the Subscriber's end office.

In order to detect the line status precisely from the end office, it becomes necessary to transform the exchange voltage to TTL logic levels. In so doing, complete electrical isolation must be maintained between the telephone line and the intelligence circuitry.

In this project, a system capable of accurately monitoring a telephone line and producing a desired output has been designed, built and tested.

The Z80 microprocessor has been relied upon for data processing. The stored programme control (SPC) approach has been adopted to make the project more cost effective. Z80 assembler language has been used in this respect.

ACKNOWLEDGEMENTS

I am greatly indebted to the project Supervisor, Mr. Harold de Souza for his exempelary assistance, advice and tolerance throughout this work.

I further wish to record my gratitute to the staff of both the departments of Electrical Engineering, University of Nairobi, and Corporate Planning, Kenya Posts and Telecommunications , for their invaluable help and corporation, without which this work could not have come true. In particular, Mr. A.W.Omukuba's assistance and motivation is gratefully acknowledged.

Special acknowledgements go to my late Mum for her encouragement and comfort in the early stages of the project.

I also sincerely acknowledge all manner of contributions of my friends and colleagues to this end. Finally, it is a pleasure to thank Miss Judy Anyango for assisting in printing this material with such patience and care.

CONTENTS

	Page
Abstract	-ii-
Acknowledgements	-iii-
List of Appendices	-vii-
List of Abbreviations	-viii-
List of Tables	-ix-
1. GENERAL OVERVIEW	1
1.1 INTRODUCTION	1
1.2 KENYAN TELEPHONE CHARGING POLICY	3
1.2.1 Local Calls	5
1.2.2 Trunk Calls	5
1.2.3 International Calls	6
1.2.4 Automatic Call Metering	6
1.3 OBJECTIVES OF THE PROJECT	9
2. OBSERVATION AND ANALYSIS OF SUBSCRIBER LINE BEHAVIOUR	13
2.1 ELECTRICAL CHARACTERISTICS OF THE LINE	13
2.1.1 Nominal Line Voltage	13
2.1.2 Standard Supervisory Tones	13
2.2 TYPES OF TELEPHONE SETS IN USE	13
2.2.1 Magneto Telephones	16
2.2.2 C.B. Manual Telephones	17
2.2.3 C.B. Auto Telephones	17

2.2.4 Public Telephones ------------ 21

2.3 OBSERVED LINE VOLTAGE VARIATIONS --- 22

2.4 THE LINE STATUS DETECTOR -------- 22

3 DESIGN OF THE DIGIT RECEIVER AND CALL TIMING CIRCUITS ---------------------- 29

3.1 THE DIGIT RECEIVER --------------- 29

3.2 REAL TIME CLOCK GENERATION ------ 32

4. DATA PROCESSING --------------------- 39

4.1 FUNCTIONAL ANALYSIS OF THE PROPOSED METERING SYSTEM ---------------- 39

4.1.1 The Line/Processor Interface - 39

4.1.2 Signal Processing ------------ 41

4.2 OPERATING SOFTWARE ------------- 45

4.3 COMPOSITION OF THE COMPUTER ------ 45

5. INTERFACING THE DOT MATRIX PRINTER TO THE PROCESSING UNIT --------------------- 55

5.1 DESIGN OF THE SYSTEM HARDWARE --- 55

5.2 MINIATURE DOT MATRIX PRINTER SYSTEM - 57

5.3 THE EIGHT-DIGIT TRIPLEXED LIQUID CRYSTAL DISPLAY (LCD) ----------- 59

6. FABRICATION OF THE METERING UNIT ------ 64

6.1 IMPLEMENTATION OF "STAND-ALONE" CALL MONITORING SYSTEM --------------- 64

6.2 CONSTRUCTION OF THE METERING UNIT - 64

6.3 TESTS AND RESULTS ---------------- 70

6.3.1 Waveforms at Selected Test Points- 70

6.3.2 Observed Output of the Constructed meter ---------- 75

6.4 POWER SUPPLY TO THE SYSTEM ------ 79

7. CONCLUSION ---------------------------- 84

7.1 MERITS OF THE PROPOSED METER ----- 84

7.2 DRAWBACKS TO THE UNIT ----------- 86

7.3 PROPOSED AUXILIARY FUNCTIONS REALIZABLE ON THE UNIT ----------- 88

Appendices -------------------------------- 92

References -------------------------------- ~~151~~ 145

List of Appendices

Page

2A. Voltage Waveforms Plotted on a Direct Line (554077) Terminating on an Hitachi C400 Crossbar Exchange ---------------------------- 92

2B. Voltage Waveforms Observed on a University of Nairobi's PABX Extension (Ext. 2306) ------- 98

3A. Timing Diagrams for Interfacing the Micro-processor Compatible RTC i.c 146818 to a Multiplexed-bus Processor ------------------ 109

4A. CCITT Recomended Format for Local Call Handling Process ---------------------------- 111

4B. Data Processing Format for the Proposed Meter written in SDL ---------------------------- 113

4C. Operating Software for the Developed Metering System in Assembler Language --------------- 125

~~5A. Recommended Dot Matrix Printer Power Supply and the Printer Interface to the Controller i.e PG 160 1~~ ------------------------------- ~~142~~

6A. Photographed Waveforms at Selected Test Points of the Constructed Unit --------------------- 142

LIST OF ABBREVIATIONS

1. Sub A ------ Subscriber being monitored.
2. Sub B ------ Distant Subscriber.
3. K.P.& T.C.- The Kenya Posts and Telecommunications Corporation.
4. STD -------- Subscriber Trunk Dialling.
5. SPM -------- Subscriber private meter.
6. SPMI -------- Subscriber private meter interface.
7. PABX -------- Private automatic branch exchange.
8. CAMA -------- Centralized automatic message accounting.
9. LCD --------- Liquid crystal display.
10. CB ---------- Central-battery powered.
11. LSD --------- Line status detector.
12. DR ---------- Digit receiver.
13. RTC --------- Real-time clock.
14. CPU --------- Central processing unit.
15. MPU --------- Master processing unit.
16. RAM -------- Random access memory (read/write memory).
17. EPROM ------- Erasable programmable read-only memory.
18. SDL --------- Specification and description language.
19. CCITT ------ International Telegraph & Telephone Consultative Committee.
20. VDU --------- Visual display unit.
21. AMH --------- Automatic message handler.

LIST OF TABLES

		Page
1.1	Typical Sample of Selected Printout Information from Phillips' PABX	10
2.1	Selected Standard Supervisory Tones	14
2.2	Summary of Measured Voltage Variations on PABX Extension	25
3.1	Guide to Figure 3.3	38
4.1	Temporary Data Storage Format	50
5.1	Binary Data Decoding for the Triplexed LCD Driver i.c 7231A	62
5.2	Address Decoding for i.c 7231A	63
6.1	List of Components	67
6.2	Sample Print-out from Constructed Meter	76
7.1	Telephone Capacity on Digital Exchanges	87

CHAPTER ONE: GENERAL OVERVIEW

1.1: INTRODUCTION

Any Telecommunication Company will have invested a lot of money in the form of facilities in her network. A means of recovering this money has to be found. One way of doing this is to charge the user of such facility a fee as a contribution towards installation and maintenance of the network.

The system described in this Thesis is specific to the Kenyan Network. The local Telephone Administration, Kenya Posts and Telecommunications Corporation (KP&TC) charges a fee to provide service to the telephone users. Revenue so collected helps to run the Corporation. This fee, in addition, regulates the telephone traffic by discouraging unnecessary and/or lengthy conversations.

Regretably, though, one occasionally comes across a disputed telephone bill. The customer may question authenticity of the bill for lack of sufficient information about service allegedly rendered. All the telephone bill contains is the accumulated number of chargeable units and the cost accrued. The project described in this text aims to provide the customer with more detailed and convincing information.

Essentially two factors determine the cost of telephone service, namely:-

(i) the length of conversation time, and

(ii) the distance between Subscribers.

However, other factors, for example time and day of call, mean hold time, etc. are also considered in computing the actual cost. [1,2]

In manual exchanges, the telephonists are liable to err when timing calls. Moreover foul play cannot be completely ruled out. There is nothing to restrain the operator from recording one Sub's charges on another Sub's card. Worse still, a call may altogether be discarded.

Some modern exchanges are fitted with Automatic Message Accounting (AMA) facilities. Nevertheless the Kenyan network will remain largely analog for some time. In any case the Corporation envisages that even after digitization, 30% of the network will still be analog [3]. There is need therefore to develop a unit that fits on an analog network to provide call particulars that were hitherto available only from a digital network.

The unit described in this project is one such facility. A unique feature of this unit is that unlike its counterparts which, as a tradition, are to be found at the switching centre, it is installable at the Sub's premises. A consumer should have more confidence in such a device's output record.

1.2: KENYAN TELEPHONE CHARGING POLICY

For all charging purposes, telephone, exchanges are arranged in geographical groups. Each group has one common central exchange point, which is used to determine the call charges from all exchanges within the group to distant exchanges. The call charge is based on the aerial distance between the charge points.

The actual charging method depends on the type of local exchange. On manual exchanges the telephonist prepares a score card for each chargeable call. This card has call details such as the caller identity, the number called and the cost of the call [4]. In fact this method applies to all operator assisted calls whether on a manual or automanual exchange. In the latter case, each Sub is provided with a meter at the exchange which records the number of unit calls originated from the line. This meter operates periodically throughout conversation at a rate dependent on the distance. [5]

Figure 1.1 is a simplified block diagram of such a meter.

Every trunk line has a pulse generator and a counter which steps at a rate commensurate with the distance of the exchange called [6]. At the start of

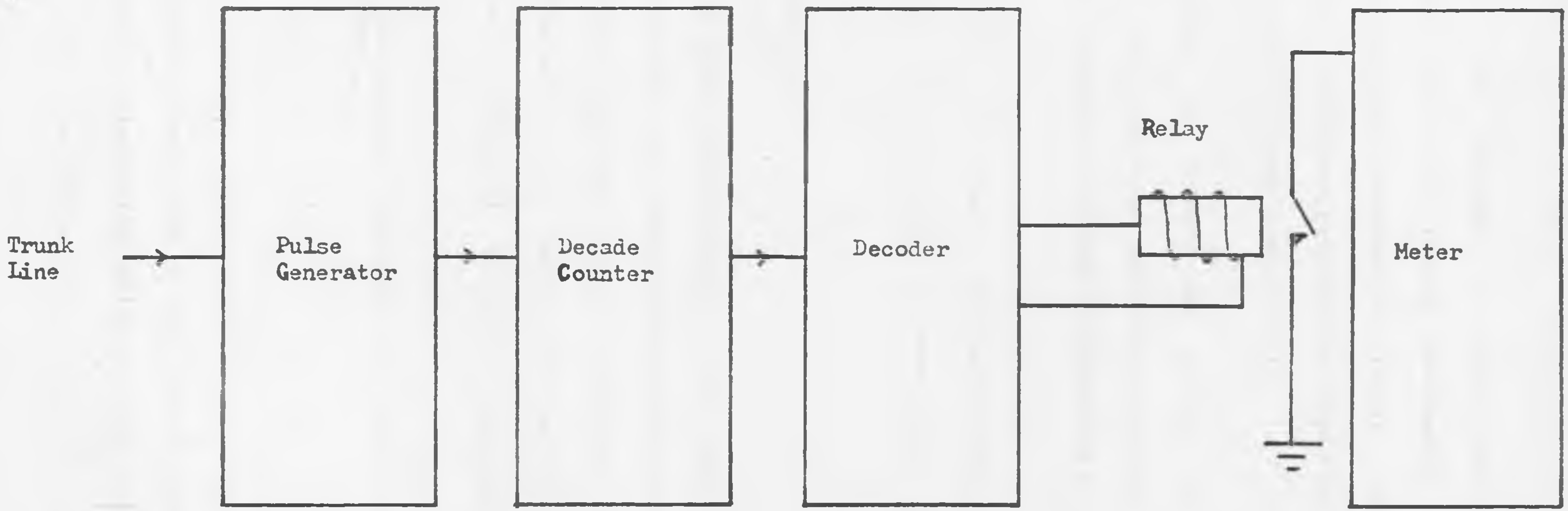


Fig. 1.1 Simplified Functional Diagram of Subscriber Meter At the Exchange

conversation, the counter is reset and enabled to count pulses from the pulse generator. After ten pulses, the decoder operates the relay. The meter is then earthed. The same process is repeated each time the counter receives the tenth pulse.

The number of times the meter is "earthed" constitutes the number of chargeable units. The meter counts upto 999999 and then automatically resets to 000000.

As already mentioned, the meter steps at a rate dependent on the distance between Subs as outlined below.

1.2.1 Local Calls

Calls between Subscribers on the same exchange or on exchanges within the same charge group are untimed. The charge for an untimed call is the unit charge, i.e 115 cents. However, local calls originating from public telephones are charged in three minutes' periods payable in advance.
There are no cheap rate periods for local calls.

1.2.2 Trunk Calls

Calls between Subscribers on exchanges in different charge groups are timed. At a number of the larger automatic exchanges in Kenya, timed calls are obtained through the Subscriber Trunk Dialling (STD).

The Subscriber dials the code for the exchange sought after a leading zero "0". The same meter records pulses for both local and trunk calls. Once every month the meters are read. Bills are then prepared on a computer sheet and posted to the customers.

Typical information to be found on this document are:-

(i) Name and number of the Subscriber.

(ii) Chargeable units of untimed calls and subsequent cost.

(iii) Chargeable units and cost of trunk calls. The dates of individual calls are indicated.

1.2.3 International Calls

International telephone service is available from exchanges in Kenya to certain countries at charge rates shown in [5]. Such service is not available from public call boxes, except in Nairobi and Mombasa where there are designated telephone booths.

1.2.4 Automatic Call Metering

Automatic Message Accounting (AMA) is available on all international directly dialled calls. Hence a Subscriber can be provided with detailed information on all calls originating from his equipment. Such information includes:-

(i) A-party number, as the caller Sub's directory number.

(ii). B-party number, as access number, country code, area code, exchange and Subscriber's number.

(iii) Date expressed as date, month and year.

(iv) Time of start of call in hours, minutes and seconds.

(v) Time of end of conversation in hours, minutes and seconds, and the date the call terminates.

(vi) Where applicable, the number of chargeable metering pulses.

Were it possible to provide such details for local and trunk calls as well, perhaps there would be fewer contested bills. The Corporation has not been silent over this shortcoming. An electromechanical meter is in use which can be fitted on a complainant's line for a period of one month. This meter, known as the Subscriber's Private Meter (SPM) gives a reading of the accumulated chargeable units. The handicap to the SPM is that an interface, the Sub's Private Meter Interface (SPMI), has to be installed at the exchange to transmit metering signals to the SPM.

The SPMI sends a 50Hz signal along the line to the SPM each time the meter at the exchange is "earthed", Figure 1.2 Relay M is connected to the supervisory C wire. Whenever a meter pulse is sent, the relay operates, closing switch S. The signal generator induces a 50Hz signal on the line. The signal is of

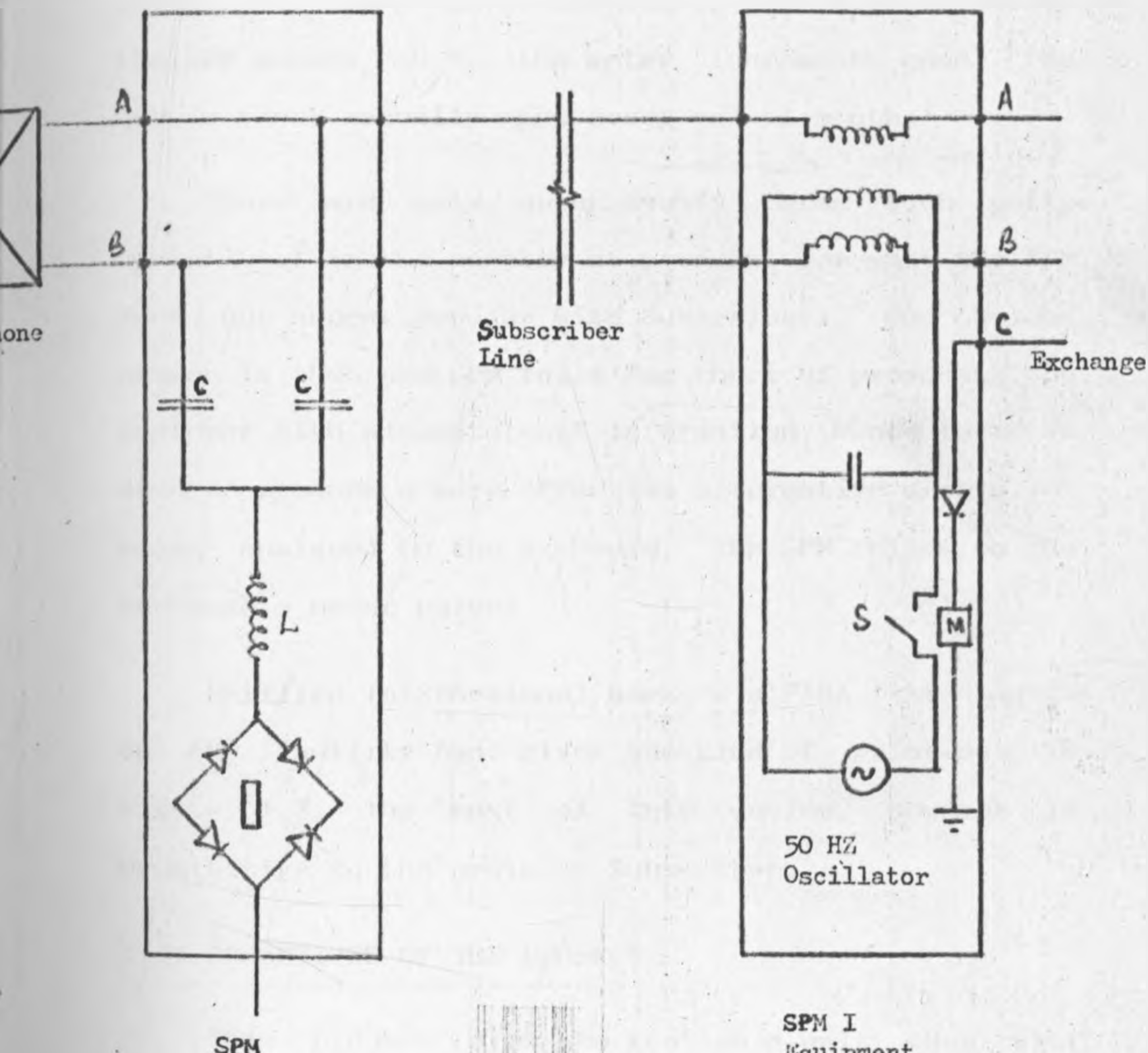


Fig 1.2 The Subscriber Private Meter

voltage 32-45 Volts r.m.s. and has a pulse duration of 180-320 ms.

The SPM detects this signal through the LC filter. The filter blocks voice and other undesired signals though. The impedence of the SPM is over 5.4k. Whenever the SPM senses 50 Hz the meter increments once. The SPM is reset manually once every end of month.

There are only about twenty three such units operational in the country at present. Somewhat the SPM does not appear popular with Subscribers. One obvious reason is that the SPM falls far short of providing the customer with adequate call information. Hence there is need to produce a more effective alternative devoid of being enslaved to the exchange. The SPM relies on the exchange's meter pulses .

Phil~~l~~ips International markets a PABX fitted with an AMA facility that gives the kind of print-out in Figure 1.3. The cost of this device, however is prohibitive to the ordinary Subscriber.

1.3: OBJECTIVES OF THE PROJECT

This project aims to realize a unit that will monitor a private Sub's line and produce an LCD display and/or a hard copy print of the following:-

a) LCD displays:-

(i) real time expressed in hours, minutes and

(cf. ETL)

CALL ACCOUNTING : SPECIFIC

ORIG	NOC	DUR	UNITS	COSTS	FIRST CALLS	LAST CALLS
2345	6	2967	103	14.42	850612 1825	850617 0910
DESTINATION		DUR	UNITS	COSTS	DATE TIME	
020211811		138	2	0.28	850612 18.25	
09454136915		726	72	10.08	850612 19 14	
35172		2103	26	3.64	850614 08 30	

ORIG : Extension number

NOC : Total number of calls made by ORIG

DUR : Duration of call(s) in seconds

UNITS : Number of metering units supplied by public exchange

COSTS : Cost of call(s) in KShs.

FIRST CALL : Date, time of first call

LAST CALL : Date, time of last call

DATE, TIME : Date, time for this call

Typical example of selected printout information (Phillips) seconds.

(ii) upto eight digits of the number called, excluding the leading "0", incase of a trunk.

(iii) the conversation time in hours, minutes and seconds.

(iv) cost of the call.

b) Printed information includes:-

(i) all numbers called, provided communication is established.

(ii) the date and time the call is initiated.

(iii) the time the call terminates, and hence the duration of the call.

(iv) the number of chargeable units and the net charge for specific calls, (where applicable).

(v) the number of units accumulated over the month.

As of necessity, the unit must identify and appropriately process free calls, namely:-

i) incoming calls.

ii) emergency calls to Police, Fire, or Ambulance.

iii) enquiries to the exchange.

Operator assisted calls, e.g manually switched calls, reversed charge calls, etc, must also be appropriately treated.

Effectively, the Subscriber should be able to analyze the behaviour of users of his equipment when he eventually gets the bill from the Corporation. In addition to giving the customer improved service, this unit keeps the Sub informed of any unauthorized calls, unreported incoming calls, etc. And as mentioned in later Chapters, the proposed unit provides the customer with auxilliary servic that was hitherto unavailable to him.

CHAPTER TWO: OBSERVATION AND ANALYSIS OF SUBSCRIBER LINE BEHAVIOUR

2.1: ELECTRICAL CHARACTERISTICS OF THE TELEPHONE LINE

2.1.1 Nominal Line Voltage

Exchange batteries have limits in the range 44-52 Volts. The positive pole is earthed. Ripple components upto 2mV psophometric may be present. Adaptive line feed circuits may connect upto 70V to the line in the near future. Depending on the resistance, current as low as 25mA may exist.

Modern exchanges give essentially constant current line feed with a nominal value of 40mA. However, when the total loop resistance is high, the feeding circuit becomes essentially constant voltage. Under certain conditions such as "line parked", current may be reduced to a lower value, even with off-hook conditions. [7]

2.1.2 Standard Supervisory Tones

Summary of selected tones is given in Table 2.1.

2.2: TYPES OF TELEPHONE SETS IN USE

A telephone instrument is necessary for transmitting and receiving speech between Subscribers. The instrument incorporates a transmitter, receiver and a

Table 2.1: Selected Standard Supervisory Tones (Source: Ref. 7)

Type of Tone	Frequency (±20% unless otherwise stated)	Cadence (±25% except where indicated)	Range Levels received at customer's termination	Type of Exchanges	Notes
DIAL TONE	33 H Z or 50HZ Rich in Harmonics	Continous	odBm to - 27dBm	Step by Step Erickson	Will be in wide spread use for several years
	350 HZ ±5% plus 440HZ ±5% (46oHZ)	Continous	odBm to - 27dBm. Each tone separately 3dB lower	C400 C23	Pipped to become more popular during next several years
BUSY TONE	400/450 HZ (460HZ)	0.375 secs. on 0.375 secs. off	odBm to 37dBm	All Exchanges	Certain PBXS have different cadence
NUMBER UNOBTA-INABLE TONE	400HZ	Continous	odBm to -37dBm	Step by Step Erickson	
	400/450HZ	Continous		C400 C23	

RING BACK TONE	400HZ/450HZ at approximately the same levels (420HZ)	0.35s on 0.22s off	0dBm to -37dBm	C400 C23	Cadence does not necessarily coincide with ringing current cadence
Type of Tone	Frequency (±20% unless other-wise stated)	Cadence (±25% except where indicated)	Range of Levels received at customer's termination	Type of Exchanges	Notes
RING BACK TONE	400HZ or 450HZ modulated by 25HZ or 17HZ	0.4s on 0.2s off	odBm to -37dBm	Step by Step Erickson	
RING-ING TONE (ENTER-ING)	25HZ at 75V RMS (21HZ) (Vpp 17V on PABX) rms	0.4s on 0.2s off	0dBm to -37dBm	All Exchanges	

Table 2.1 Cont.

signalling device by which attention is drawn to the telephone and also obtain access to other telephones through the exchange.

In all systems, signalling apparatus are provided at the Subscriber's premises and at the exchange to operate on incoming calls and to originate outgoing calls. The exact nature of the transmitting, receiving and signalling units depends on the particular type of set. The basic functions are, however, common.

There are four main types of telephone sets in use namely:--

(i) Magneto telephones

(ii) C.B. manual telephones

(iii) C.B. Auto telephones

(iv) Public telephones

2.2.1 Magneto Telephones

The magneto system is characterised by the use of low a.c. produced by means of magneto generators for signalling purposes. A Sub operates a hand generator to provide a calling signal to the exchange whenever he wants to make a call, and a clearing signal at the end of conversation.

Telephonists at the exchange use a hand generator or other power ringing device to supply ringing current which operates a magneto bell, thus providing an intermittent audible signal, incase of incoming call.

Magneto telephones are being phased out though.

2.2.2 CB Manual Telephones

Signalling from such telephones is by means of the switch hook contacts which operate under spring tension when the hand set is lifted, allowing current to flow through the telephone transmitter from the exchange apparatus and a lamp glows on the switchboard. CB telephones have no dials, instead oral instructons are given to the operator.

Power for signalling the Sub's line is obtained from a central storage battery located in the exchange. The same battery provides current for the speech path, and operates the supervisory apparatus at the exchange. [8]

2.2.3 CB Auto Telephones

Signalling from auto telephones after the handset is lifted is by means of a dial which interrupts the d.c. in the loop circuit to operate the automatic exchange equipment.

There are two distinct types of Automatic telephones:

(i) Rotary dial type.

(ii) Pushbutton keypad type.

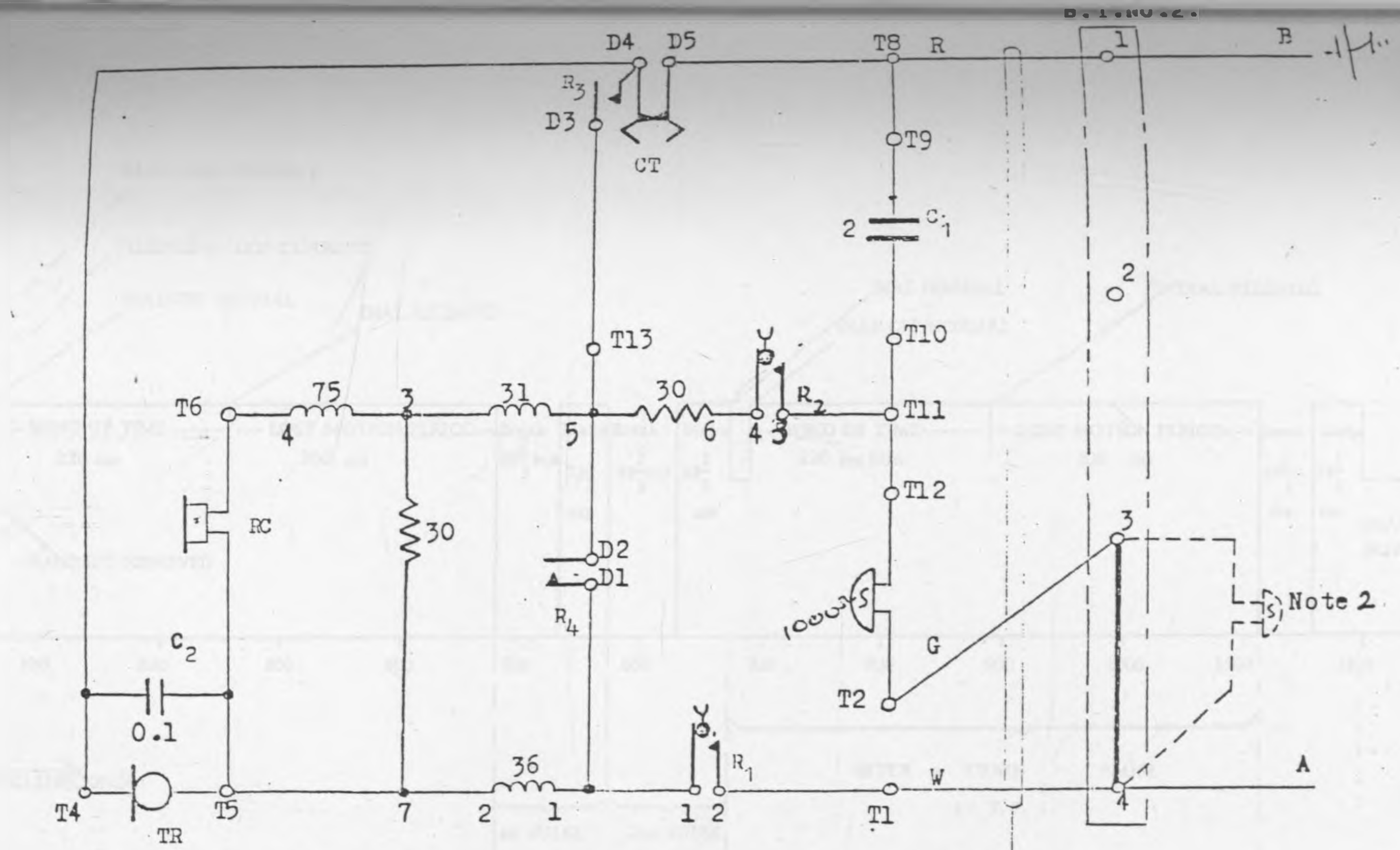
i) Rotary Dial Type

This type of telephone has ten finger holes marked 1 through 9, to 0. Figure 2.1 is a simplified circuit diagram of one of the most common telephone sets in Kenya (Type 37). When the telephone set is idle, the line is open circuited. The 2uF capacitor, C1, and the bell, S (1K), create high impedence to the 48V d.c. voltage.

On lifting the handset, the normally opened relays R1 and R2 close. When the dial plate is rotated, relays R3 and R4 operate, shorting the set. If the plate is now released it returns to normal under the influence of a spring. During this time, spring contacts, CT, open and close a number of times corresponding to the dialled digit. For example dialling digit "0" results in ten pulses.

The standard pulse frequency is ten pulses per second. Each pulse consists of "make" and "break" conditions and lasts 100ms. The nominal pulse ratio is 2:1 break/make. A minimum interdigit pause of 420ms is required for the exchange to complete the switching functions. About half this time is taken up by the Subscriber in turning the dial, and dial pulsing mechanism is arranged to introduce a delay of 200ms before each train of pulses - the "lost motion", Figure 2.2.

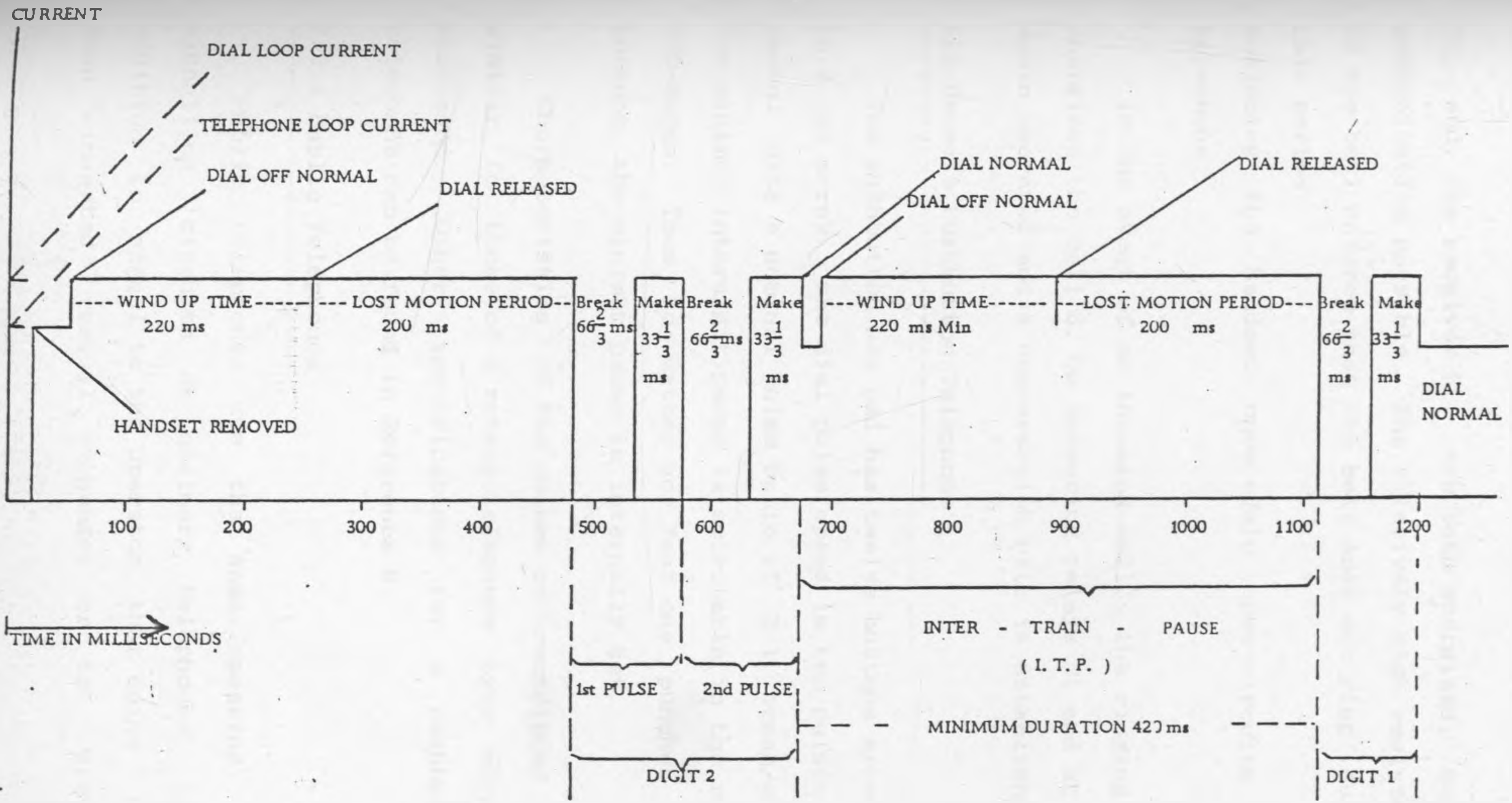
Whenever the handset is offhook, the transmitter



1. For C.B. working, recover dial and dial cord. Strap D4 and D5 and fit dummy dial.
2. To fit Extn. Bell, remove strap between terminals 3 and 4 in B.T.No.2 and connect bell as shown.

CORD INST.
EXTL.NO.25.

FIGURE 2.2 GRAPH OF OPERATION OF AN AUTOMATIC DIAL: SUBSCRIBER DIALS THE DIGIT 2 FOLLOWED BY DIGIT 1.



TR, and the receiver RC, are both energized, making communication possible. The relatively high resistance of the bell ensures that the bell does not ring during this period.
Replacing the handset once again open-circuits the telephone.

In the event of an incoming call, the ringing a.c energizes the bell S. On answering relays R1 and R2 are again operated and a conversation path is established.

ii) Decadic Pushbutton Telephone

The pushbutton key pad has twelve buttons arranged in a 4x3 array. the dial pulse speed is ten pulses per second with a nominal pulse ratio of 2:1 break/make. The minimum interdigit pause is selectable in the range 500-800ms. Thus no matter how fast one punches the buttons, the minimum pause is internally set.

Characteristics of the pulses so transmitted are similar to those of a rotary telephone type already discussed. Other specifications for a pushbutton telephone can be found in Reference 9.

2.2.4 Public Telephones

Public telephones use the same speaking and signalling circuits as ordinary telephones, with addition to signal to the operator that coins have been inserted (manual exchange) or to prevent conversation until coins are inserted, in case of automatic exchanges.

2.3: OBSERVED LINE VOLTAGE VARIATIONS

Voltage variations were monitored on a direct line terminating on a crossbar exchange (Sub number 554077). Plots of voltage variations are in Appendix 2A. However, the project design was based on measurements taken on a University of Nairobi's PABX extension (Ext. 2306). There were remarkable similarities in both cases. In particular voltage conditions varied identically, as Appendices 2A and 2B confirm.

Summary of the voltage changes is given in Figures 2.3-4 and Table 2.2.

2.4: LINE STATUS DETECTOR

From the foregoing, it is clear that voltage variations can be relied upon to predict telephone line status at the terminal equipment. In particular, the following conditions can be immediately inferred:-

i) Sub A off hook.

ii) Called party (Sub B) off hook.

iii) Incoming call.

A circuitry which can be employed to sense these conditions is outlined in Figure 2.5. This unit is referred to as the Line Status Detector (LSD). As a matter of fact, the LSD has three detectors, each

FIG. 2.3: ORIGINATING CALL

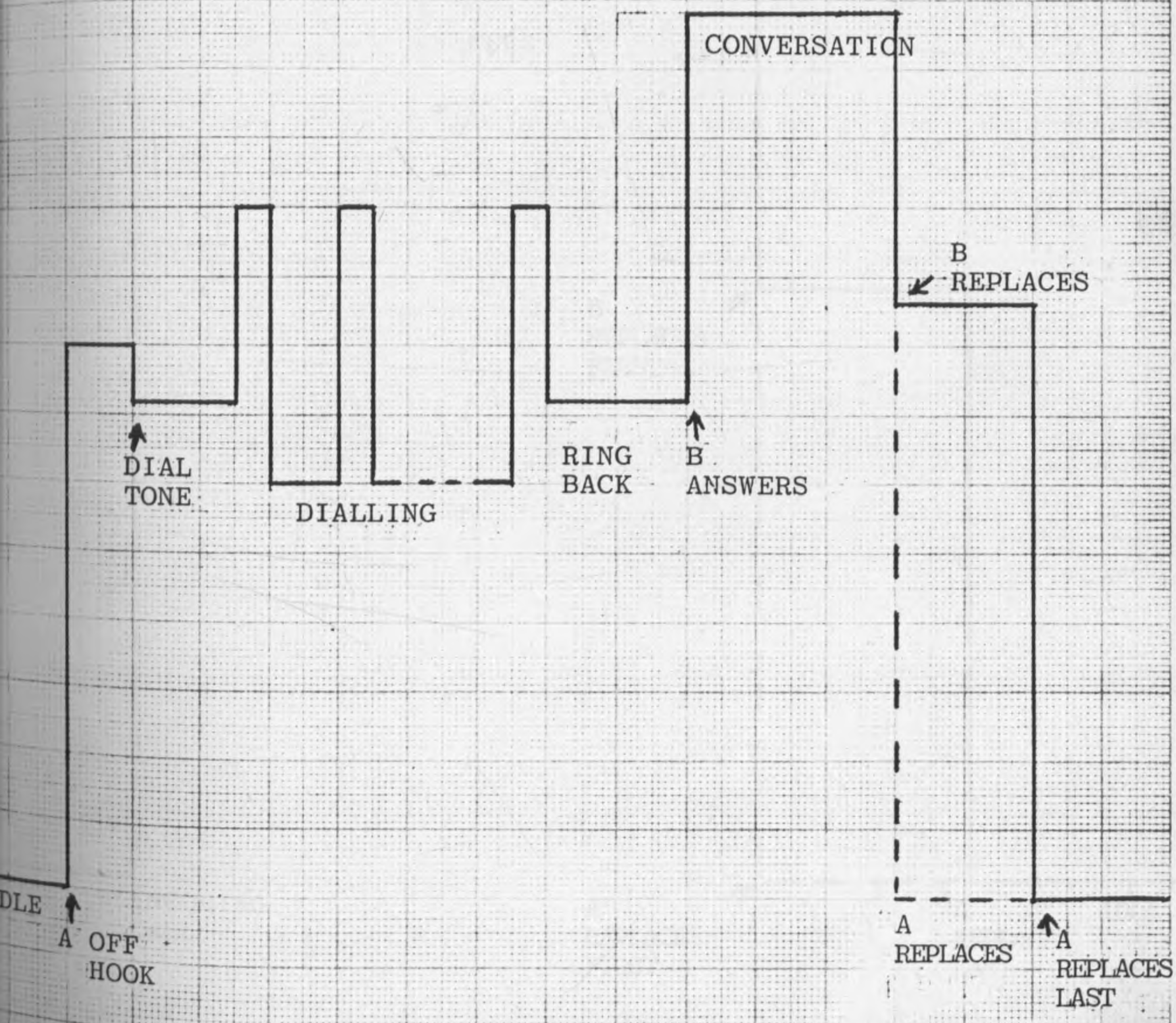


FIG. 2.4: AN INCOMING CALL

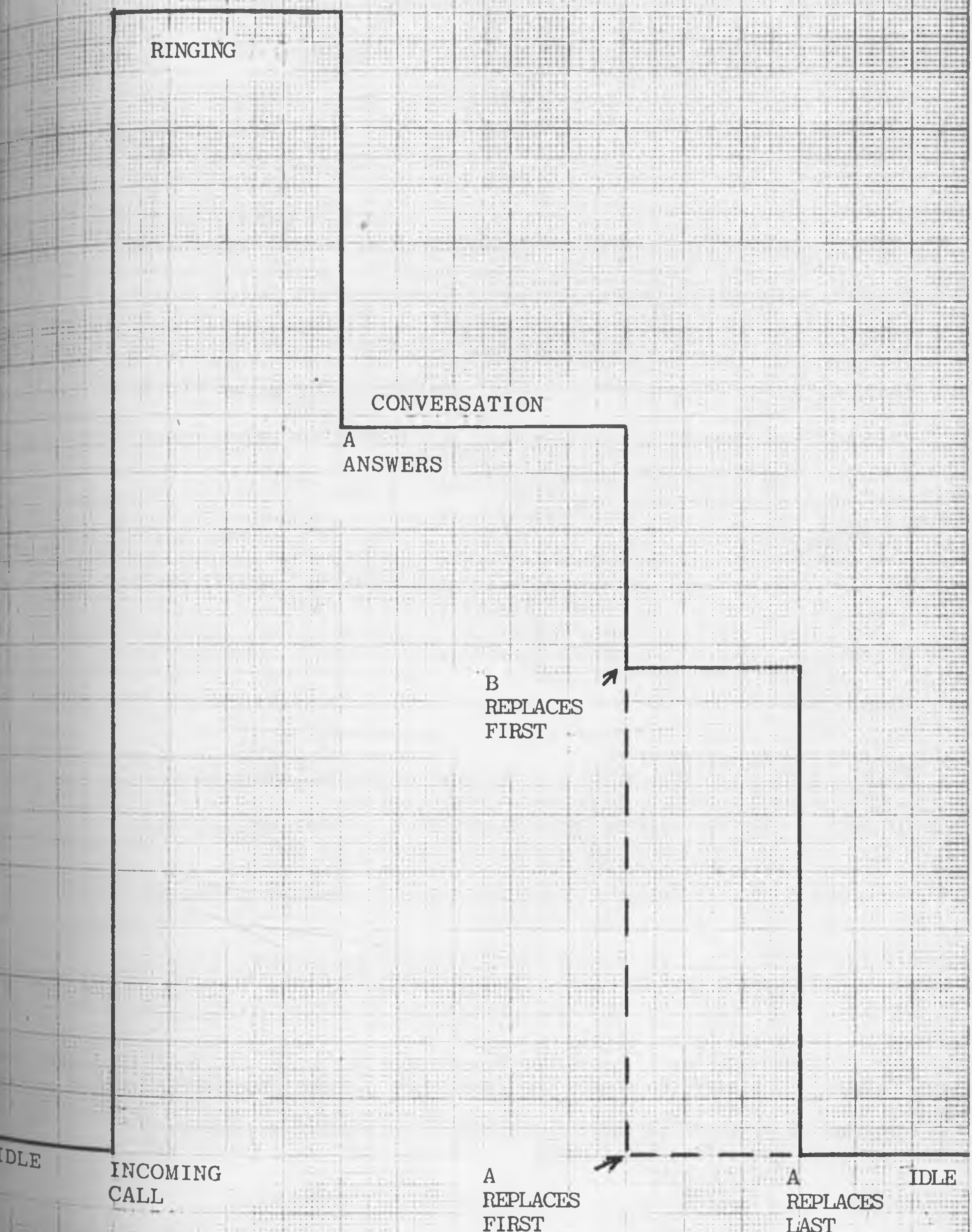


Table 2.2 Summary of Measured Voltage Variations on a PABX Extension.

Condition	Voltage (V)
a) Originating Calls	
Line idle	-49.0V
A off-hook (before dial tone)	-10.0V
A off-hook (dial tone)	-14.4V
Busy tone, no dialling	-14.4V
Called Sub engaged (busy tone)	-7.7V
Ring back	-14.0V
B replies	+14.0V
A replaces first	-49.0V
B replaces next	No change
B replaces first	-7.5V
A replaces next	-49.0V
b) Incoming Calls	
B calls (ringing tone)	+50.0V
A answers	+14.2V
A replaces first	-49.0V
B replaces next	No change
B replaces first	-7.7V
A replaces next	-49.0V

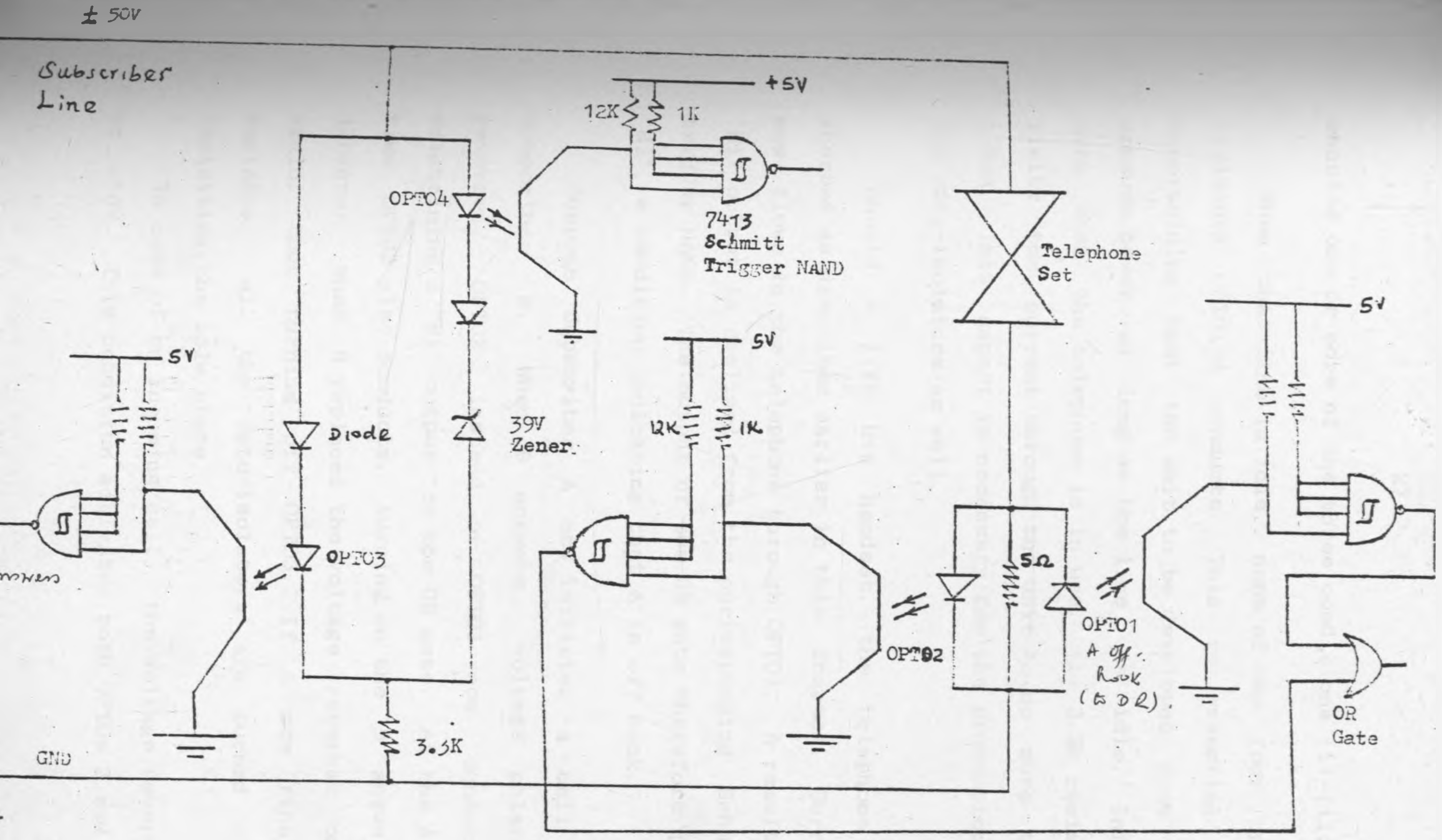


Figure 2.5 the Line Status Detector

sensing one or more of the three conditions (i)-(iii).

When the line is idle, none of the four opto-isolators OPTO1-4 conducts. This is essential in ascertaining that the unit to be developed does not consume power as long as the line is idle. Infact even when the telephone is in use, the 3.3k resistor limits the current through the unit to no more than 1.5mA. This aspect is necessary for the protection of the opto-isolators as well.

Should A lift his handset, the telephone is shorted as described earlier in this Chapter. Current now flows in the telephone through OPTO1. A resulting "Hi" output is realized from the corresponding Schmitt trigger NAND. The output of the OR gate therefore goes "Hi", a condition indicating that A is off hook.

Suppose Subscriber A now initiates a call to Subscriber B. When B answers, voltage polarity reverses. OPTO2 instead of OPTO1 now conducts, maintaining a "Hi" output for the OR gate. At the same time OPTO3 also conducts, turning on the "B answers" detector. When B replaces the voltage reverses once again, thus turning off OPTO3. If A now finally replaces, all the opto-isolators are turned off, depiciting the idle state.

In case of an incoming call, the voltage reverses to +50V. This condition activates both OPTOs 3 and 4.

On A replying, the voltage drops to +14V, thus turning off OPTO4, while turning on OPTO2. OPTO4 may appear unnecessary, however it serves two purposes:-

i) As later stated in the software section of Chapter 4, this detector is useful in confirming an incoming call.

ii) In the case of an Ericcson exchange the OR gate alone is not sufficient in predicting "A replacing" condition. With such an exchange communication is possible even after the called Sub replaces only for a specified length of time.

When the Subs finally replace their handsets, all the four opto-isolators are once again turned off.

It may be noted that when dialling commences after lifting the handset, OPTO1 is turned on and off a number of times corresponding to the dialled digit. Thispulsing aspect is useful in registering the number of the Subscriber called.

CHAPTER THREE: DESIGN OF THE DIGIT RECEIVER AND CALL TIMING CIRCUITS

3.1: THE DIGIT RECEIVER

In the previous Chapter it was mentioned that when Subscriber A dials a digit, the telephone is shorted a corresponding number of times. In particular, the output of the off-hook detector switches "on" and "off" an equivalent number of times. The digit receiver makes use of this output to capture the dialled information.

This output follows two paths. Along one path an inversion of the output also branches into two routes (Figure 3.1). One route is a direct clock input to a decade counter, IC1. The other route provides base current to transistor Q1. During dialling, Q1 is thus switched on and off.

In order to detect completion of a group of dialling pulses and to produce a signal at the end of each group, it is ncessary to have an electronic circuit equivalent to a "slugged" relay. This is formed by Q1 and IC3. The first of the dialling pulses turns Q1 hard on, discharging C2 and causing the inputs of IC3 to be at logic 1. In an idle state, C2 is held fully charged by the input current of IC3. The positive transition of IC3 output is differentiated by C3 and R4 to produce a positive pulse to logic 1, which

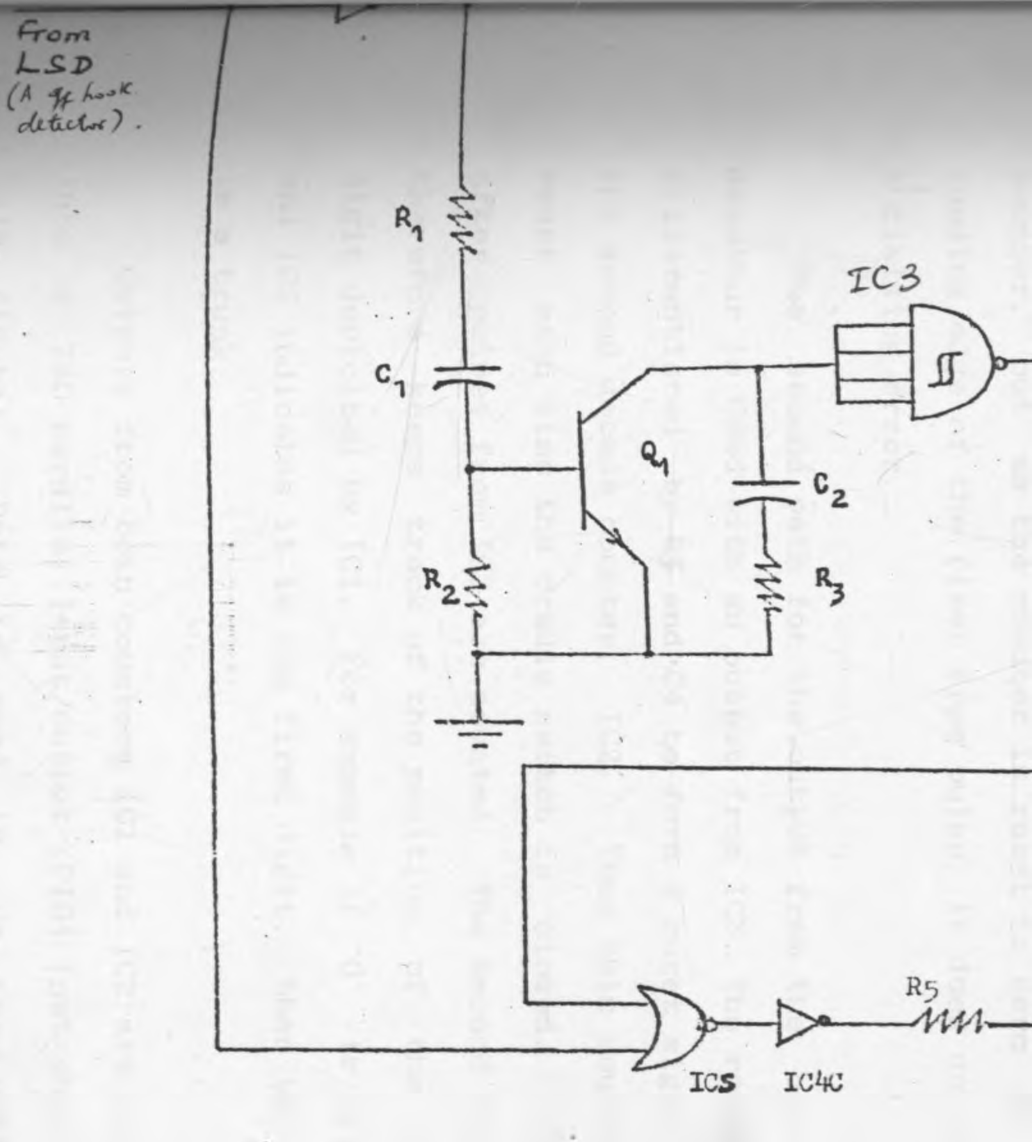
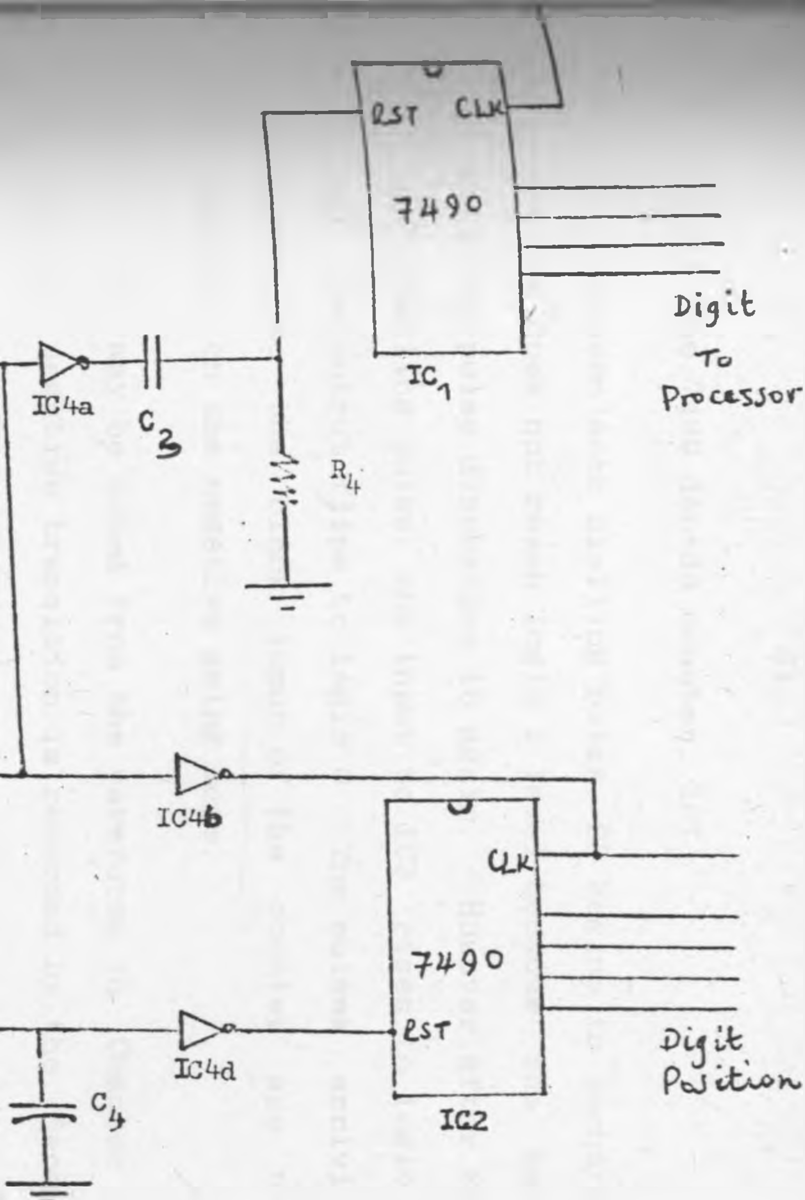


Fig. 3.1 The Digit Receiver


RST
CLK
7490
IC1
Digit
To
Processor
IC4a
C3
R4
IC4b
CLK
7490
RST
IC4d
C4
IC2
Digit
Position

resets the 7490 decade counter, IC1.

Between each dialling pulse, C2 begins to recharge but it does not reach logic 1 level because the next dialling pulse discharges it again. However after the last dialling pulse, the input to IC3 rises to logic 1 and the output flips to logic 0. The pulses arriving direct to the clock input of the counter are now sampled, on the negative going edge.

It may be noted from the waveforms in Chapter 2 that a negative transition is recorded by the decade counter, but as the counter is reset to zero on the leading edge of the first true pulse, it does not cause a dialling error.

The second path for the output from the off-hook detector is ORed with an output from IC3. The result is differentiated by R5 and C4 to form a reset signal to the second decade counter, IC2. Thus this counter is reset each time the cradle switch is closed. Thereafter pulses from IC3 are counted. The second counter therefore keeps track of the position of the first digit depicited by IC1. For example if "0" is dialled and IC2 indicates it is the first digit, then the call is a trunk.

Outputs from both counters IC1 and IC2 are latched into a Z80 parallel input/output (PIO) (not shown in this figure). Data is read in on the positive transition, provided the Chip Enable (CE) pin of the PIO is held high. The strobe input to the PIO is a negated output of IC4B. This ensures that latching is done once and only at the end of the dialling pulses. Thus by monitoring the inputs to the PIO, the directory number of the called Subscriber is trapped.

It may be noted that IC2 is reset in the event of an incoming call. However this is of no concern.

3.2 REAL TIME CLOCK GENERATION - IC 146818

The 146818 is a Real Time Clock (RTC) i.c. which combines three unique ~~feauters~~ features:- a complete time-of-day clock with alarm calendar, a programmable periodic interrupt and square wave generator, and fifty bytes of low power static RAM. This i.c can be used with a CMOS microprocessor to relieve the software of time keeping work-load and to extend the available RAM of an MPU. The RTC includes 6800 multiplexed bus interface as well. So it can be directly connected to this family of microprocessors with multiplexed Address/Data bus. [APPENDIX 3A]

Unfortunately the Z80 CPU on which this project is based has distinctly seperate data and address buses. Two optional solutions are available. Either

(i) to use a clock which is Z80 compatible, e.g the programmable timer i.c TMS 1601A, or

(ii) to construct a simple interface for the 146818.

The TMS 1601A is a forty pin chip as opposed to the 146818's only twenty four. Moreover it costs nearly four times as much as the 146818. The 146818 provides the date, month and year readings, let alone offer automatic end of month and leap year recognitions. None of these is available from the TMS 1601A. For all practical purposes, therefore, the 146818 is the most suitable RTC for this project.

Figure 3.2 shows an interface designed to fit the 146818 onto the Z80 CPU. Additional hardware is kept to a minimum. The clock is driven by a 4.194304 MHz crystal. Other time base input options are 1.048576 MHz and 32.768 KHz. A clock output (Pin 21) is available to drive the CPU.

Both the Address bus and the Data bus of the Z80 have valid data simultaneously. To multiplex the two, a tristate driver i.c is required so as to select one or the other of the two, under control of a CPU signal, as in figure 3.2. The lower six bits of the CPU (A0-A5) are driven by a Hex buffer, i.c 74367. The outputs terminate on the common Address/Data bus of the 146818. This multiplexed bus is directly connected to the Z80 data bus. The 70ns delay element is best realized with i.c 7431 drivers. However, a succession of any simple gates will

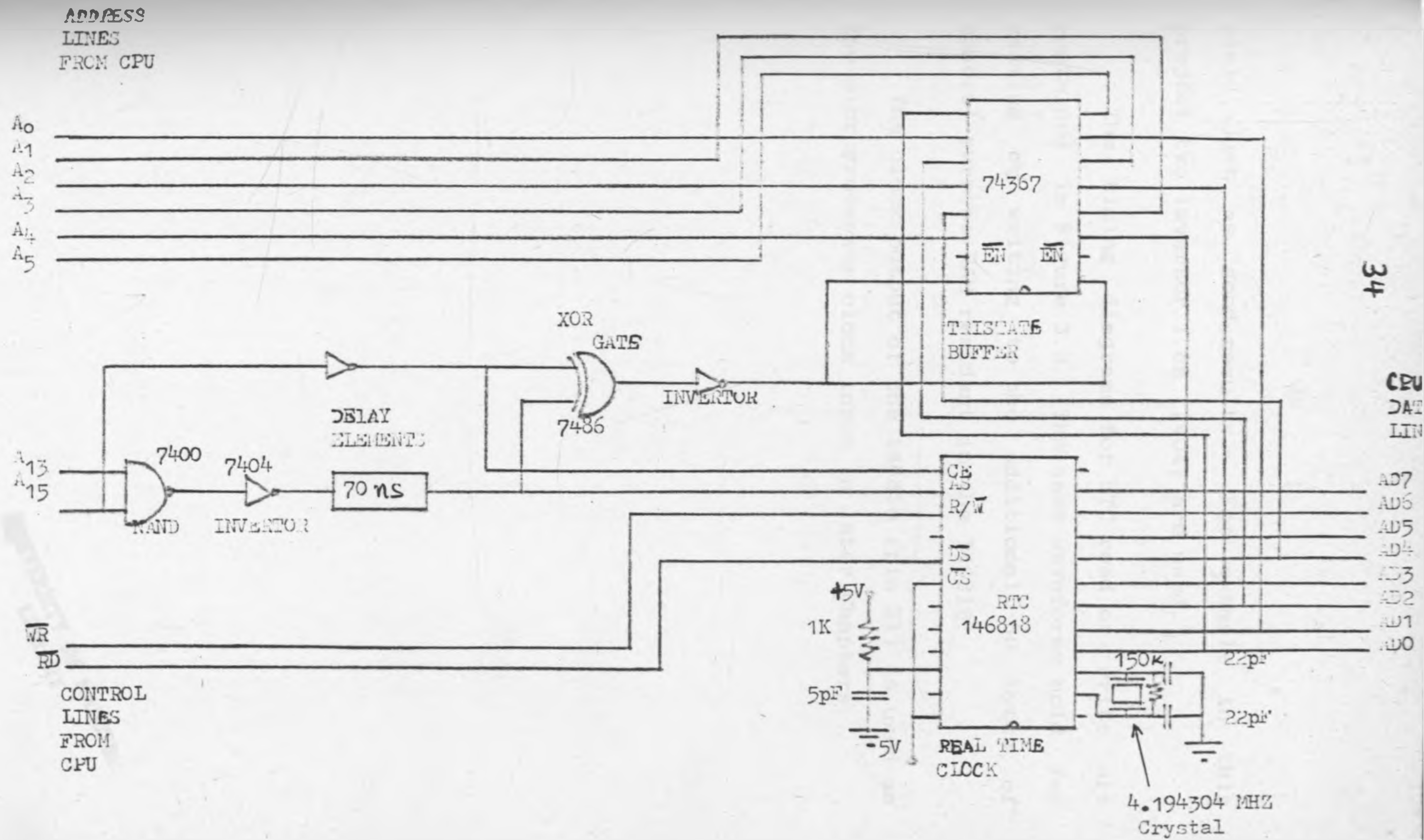
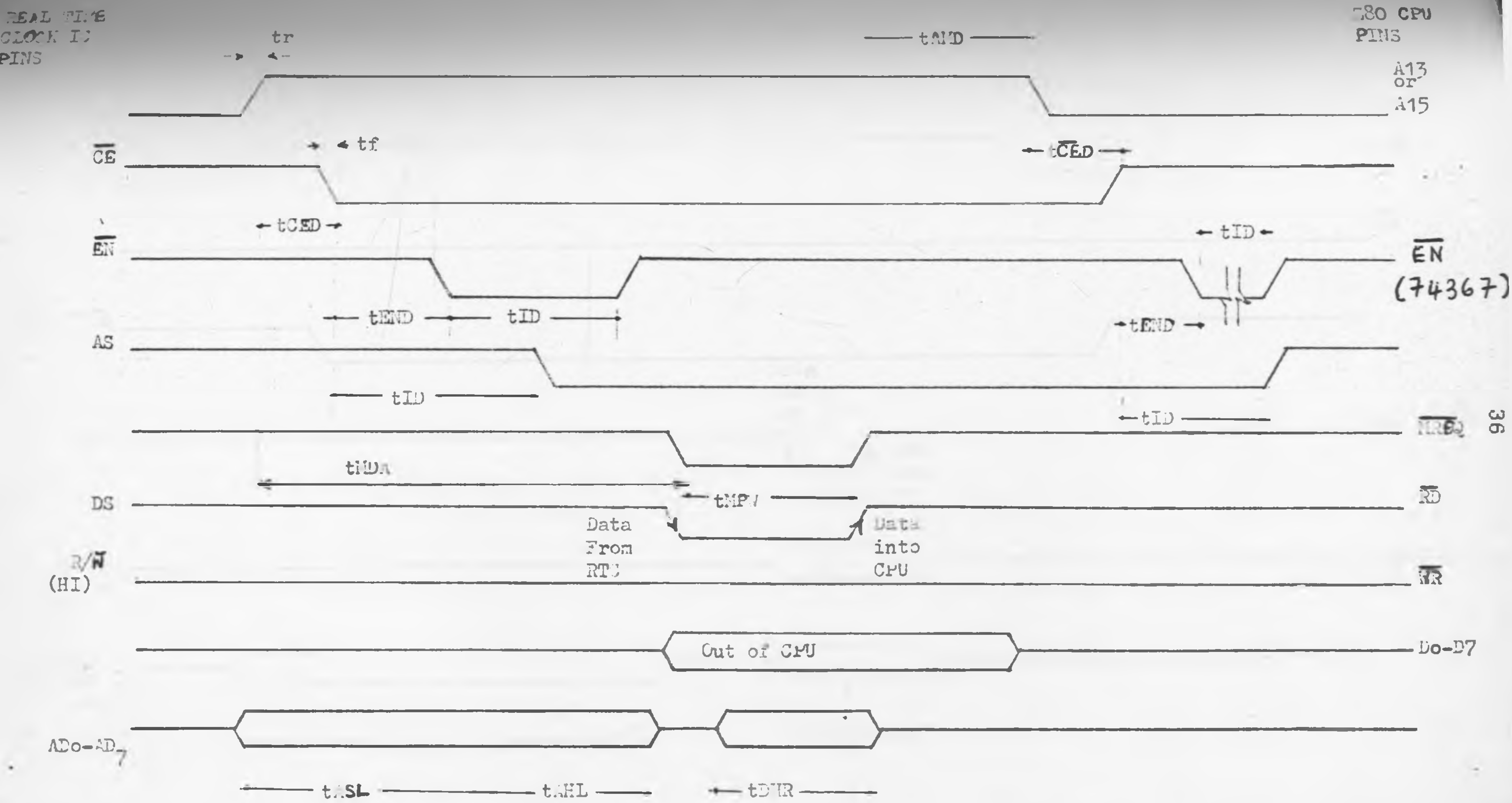


FIG. 3.2 RTC INTERFACE TO Z80 CPU

yield just as good results. For example in this project two invertor i.cs (7404) are used.

The timing diagrams for RTC read or write are contained in Figure 3.3. The same waveforms hold for reading or writing to the additional 50 bytes of general purpose RAM resident in the 146818.

The clock output of the 146818 (pin 21) is used as the microprocessor clock input in later Chapters.



-CONTINUED-

Memory Write.

Clock Readin-

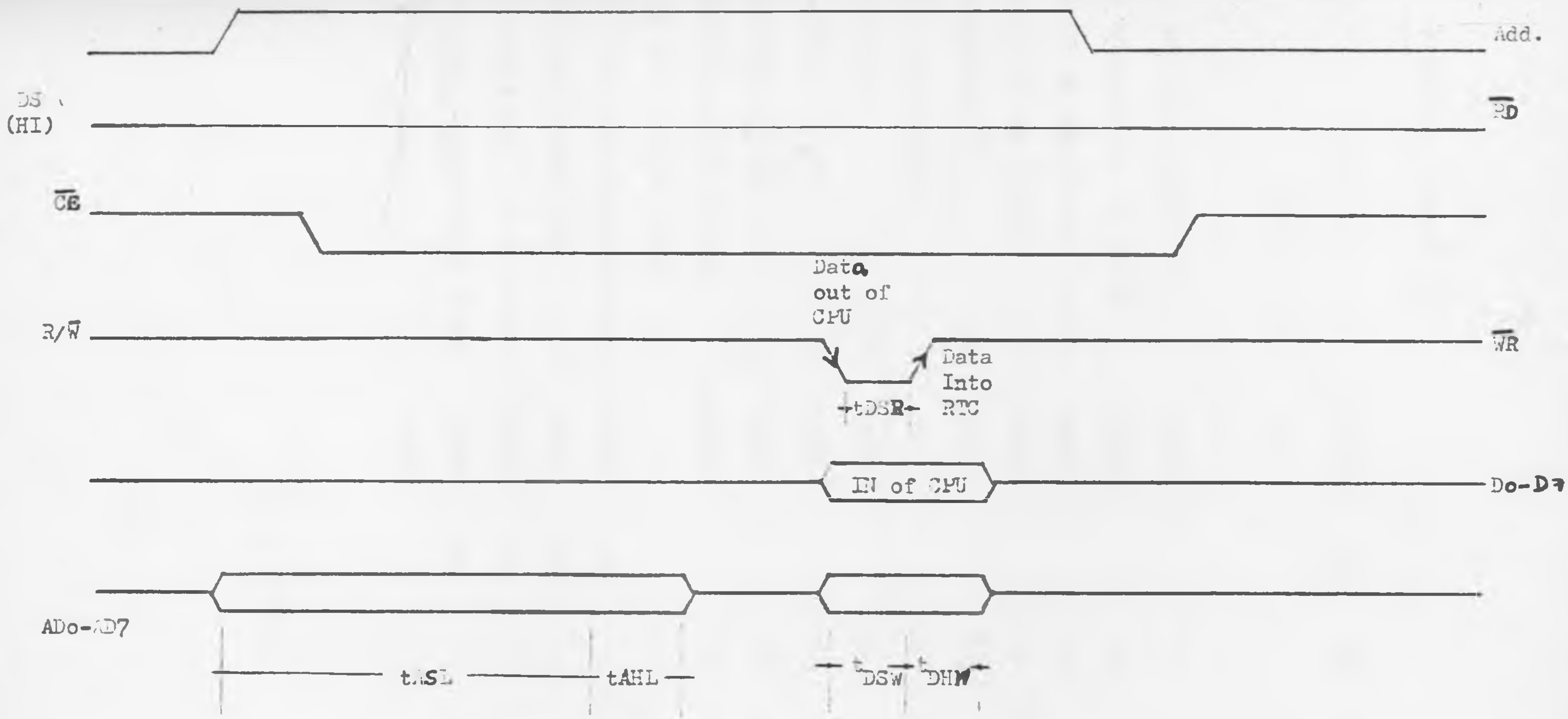


Table 3.1 Guide to Figure 3.3

Parameter	Symbol	Min	Typ	Max
Fall time	tf			30
Rise time	tr			30
Delay time address to CE (H^L)	tCED		7	15
Delay time address to CE (L^H)	tCED		11	22
Delay time CE to EN (H^L)	tEND		22	38
Delay time CE to EN (L^H)	tEND		67	135
Introduced delay	tID		19	32
MREQ delay from address	tMDA		245	250
MREQ pulse width	tMPW		500	
Delay time MREQ to WR	tWRD		250	
Delay time MREQ to ADD	tAMD		125	
Data setup time prior to RD	tDSR		120	
Multiplexed add. valid time to AS fall	tASL	50		
Multiplexed add. hold time	tAHL	20		
Read data hold time	tHDR	10		
Peripheral (CPU) data setup time	tDSW	195		
Write data hold time	tDSW	0		

CHAPTER FOUR: DATA PROCESSING

4.1: FUNCTIONAL ANALYSIS OF THE PROPOSED METERING SYSTEM

4.1.1 The Line/Processor Interface

This section describes the "stand-alone" final system arrangement. Figure 4.1 is a functional block diagram of the unit. Details of individual blocks are discussed elsewhere in this Thesis. However a summary of the functions of each sub-unit is given below.

In the previous Chapter it was shown how the LSD keeps track of the line condition by monitoring voltage variations on the Subscriber's line and accordingly transmitting this information to the master processing unit (MPU) for processing. Specifically this detector alerts the MPU in the event of:-

i) Sub A off/on hook.

ii) Sub B off/on hook.

iii) Outgoing or incoming call.

In addition the LSD captures the dialled information and conveys it to the digit receiver (DR). Infact the LSD is the bridge between the telephone and the meter.

The digit receiver receives dialling pulses from

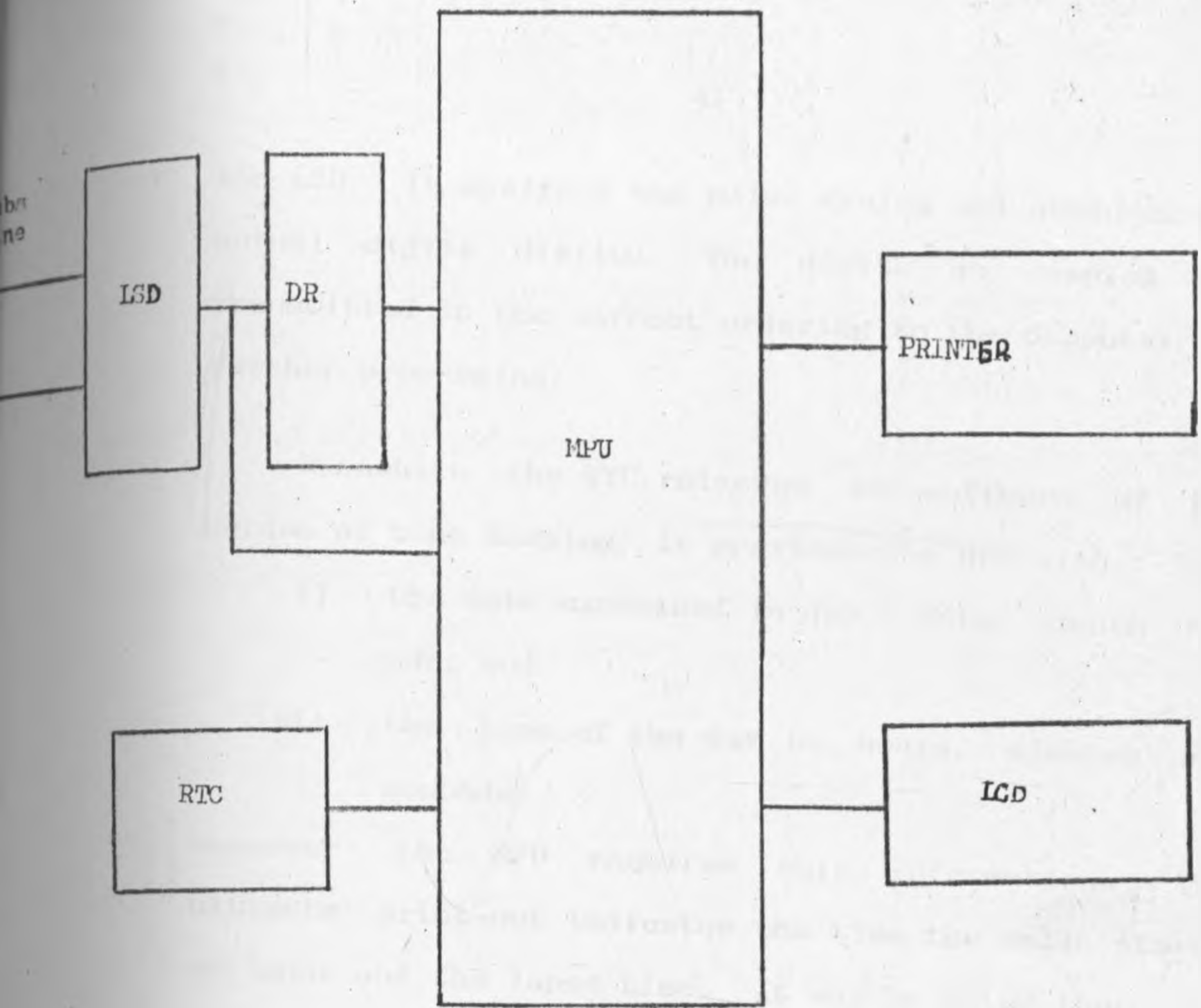


Fig 4.1 Functional Block Diagram of the Metering Unit

the LSD. It analyses the pulse trains and produces the actual digits dialled. The digits so sampled are transmitted in the correct ordering to the computer for further processing.

Meanwhile the RTC relieves the software of the burden of time keeping. It provides the MPU with :-

i) the date expressed in day, date, month and year, and

ii) the time of the day in hours, minutes and seconds,

whenever the MPU requires this information. The ultimate print-out indicates the time the call starts or ends and the lapse time. It may be noted that the time of commencement of the call is utilized by the MPU to decide whether normal or cheap rate charging is applicable.

The same RTC serves as the system clock. Thus there is no need for an additional oscillator for the CPU. The RTC used also offers 50 bytes of general purpose RAM to the user. The clock has automatic end of month and leap year recognitions.

4.1.2 Signal Processing

The MPU is the mastermind of this metering unit. All data processing is done by this sub-unit. It executes all arithmetic, logic and control manipulations.

In particular the computer (or MPU) keeps polling the LSD, DR and RTC. Data is then appropriately processed, depending on conditions arising from these three sub-units. Information so processed is output by the computer in an ordered format to a printer and/or an LCD.

Processing may be initiated in the event of one of the following :-

i) on installation/clock reset.

ii) "idle" state.

iii) end of month turnover.

iv) incoming call.

v) originating call.

i) Installation/Clock Reset

When a new unit is being connected to a Sub's line, or in case of power failure, the computer initializes any volatile memory as may be necessary. In particular provision is made such that the clock can be adjusted by pressing a button repeatedly until the required setting is obtained. The internal counters (registers) of the MPU are also appropriately reset.

ii) Idle State

As long as the line is idle, the computer keeps reading the RTC and displays the time in hours, minutes and seconds on an eight-digit LCD.

iii) End-of-month

Whenever the RTC alerts the computer of month-end turnover the computer updates certain data with regard to the new month. The counters, for example, are initialized. The accumulated number of units' counter in particular is cleared.

iv) Incoming Call

By a condition on the LSD (Chapter 2), the computer learns of existence of an incoming call. Should Subscriber A answer the call, the computer will read the RTC and send this information for on-line printing. The RTC, including date (in month and day) and time in hours, minutes and seconds, is temporarily held in RAM.

During conversation, the computer keeps scanning the LSD lest either Subscriber replaces his handset. Suppose Sub B now replaces, the computer again sends the real time for printing. The duration of the call is then computed and the result stored in RAM. When Sub A finally replaces, the call duration is printed. The number of chargeable units and the cost of the call are printed as zero, since incoming calls are not charged. The units accumulated to date are also posted for printing. The meter then once again resumes the idle state.

v) Originating Call

Whenever Sub A lifts his handset to initiate a call, the computer scans the digit receiver (DR) for the dialled information. Once sufficient digits have been dialled the computer analyzes the digits in order to recognize the call as emergency, local or trunk. The number called is temporarily held in memory. If the call is a trunk, the computer searches for the called switching centre's charge rate.

If Sub B now replaces, the RTC (including date) is printed as the time of the start of the call. In case the call is chargeable, i.e local or trunk, then metering is commenced. During conversation the meter is stepped at a predetermined rate. As soon as Sub B replaces, the meter is stopped and time is posted as before. Duration of the call, cost of the call and the number of accumulated units are all computed.

When A eventually replaces his receiver, the following information is finally printed :-

a) upto eight digits of the number called.

b) duration of the call.

c) the number of chargeable units.

d) cost of the call.

e) accumulated number of units.

The meter again initializes in readiness for the next call.

4.2: OPERATING SOFTWARE

In processing data from the LSD, DR or RTC, the MPU simulates the local exchange. That the operating program is similar to the format in which an exchange processes a call, is therefore not surprising.

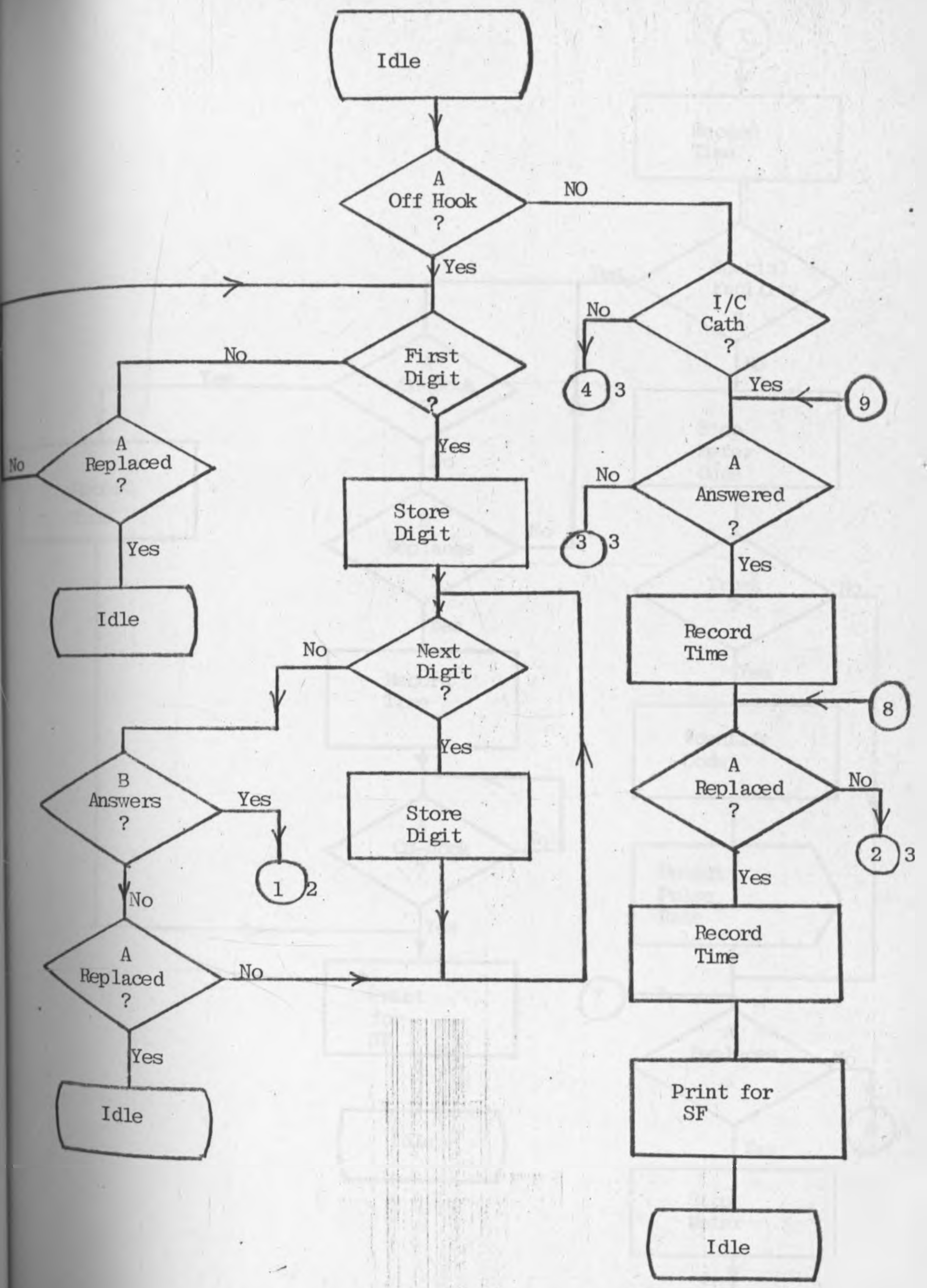
The CCITT recommended format for local call handling process is summarized in Specification and Description Language (SDL) in Appendix 4A. Appendix 4B is the data processing format for the proposed meter written in SDL. It is assumed that the Sub's line is connected to an ideal exchange. A real exchange may behave slightly different. Figure 4.2 is a flow chart format intended for a line terminating on a standard crossbar or step-by-step exchange. The same format works well for an extension of a PABX.

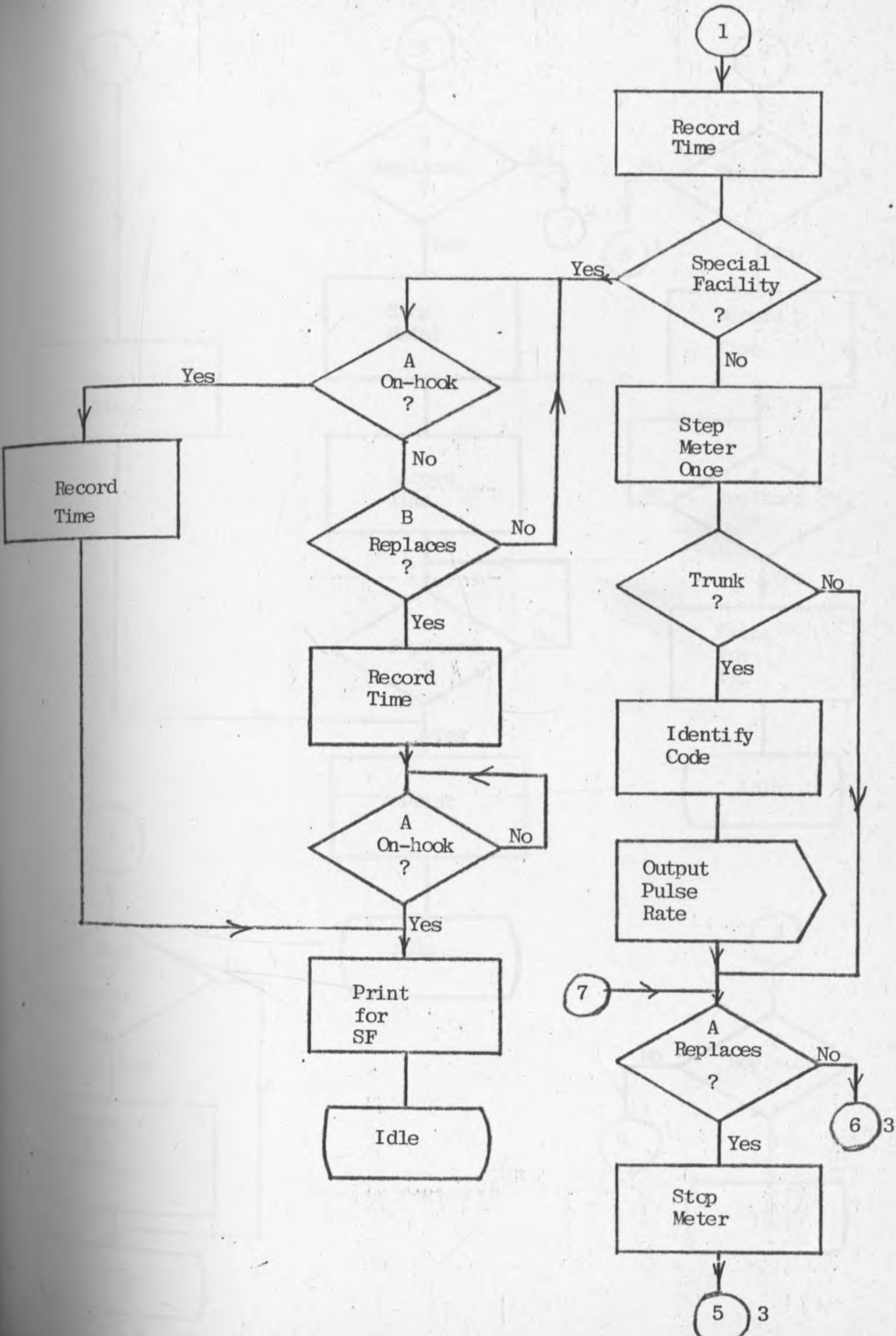
This flow chart is interprated into machine language for implementation purposes. Appendix 4C is a program written in Assembler language and is intended for the system developed in this project. A Z80 microprocessor is assumed.
Table 4.1 shows how part of the workspace RAM is utilized for temporary data storage.

4.3: COMPOSITION OF THE COMPUTER

The computer basically comprises a CPU, program ROM, area code ROM, RAM, decoder and a PIO (Figure

Fig. 4.2 A Flowchart Format for Data Processing on a PABX Extension by the Monitoring Unit


Idle
A
Off Hook
?
NO
Yes
I/C
Cath
?
No
4
3
Yes
9
First
Digit
?
No
A
Replaced
?
No
Yes
Idle
Yes
Store
Digit
A
Answered
?
No
3
3
Yes
Record
Time
8
Next
Digit
?
No
Yes
B
Answers
?
Yes
1
2
No
Store
Digit
A
Replaced
?
No
2
3
Yes
Record
Time
A
Replaced
?
No
Yes
Idle
Print for
SF
Idle


1
Record Time
Special Facility ?
Yes
No
A On-hook ?
Yes
Record Time
No
B Replaces ?
No
Yes
Record Time
A On-hook ?
No
Yes
Print for SF
Idle
Step Meter Once
Trunk ?
No
Yes
Identify Code
Output Pulse Rate
7
A Replaces ?
No
6
3
Yes
Stop Meter
5
3

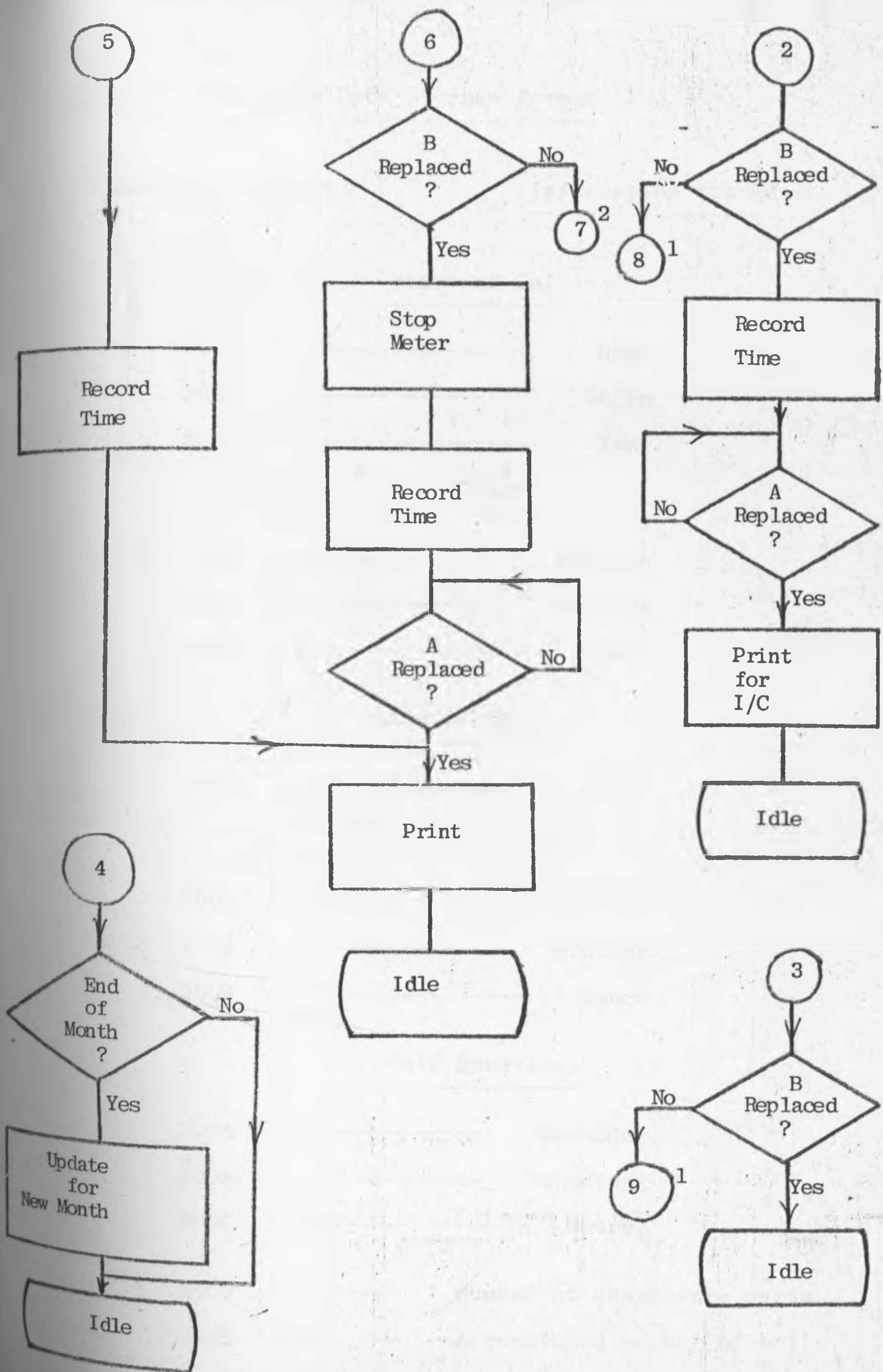

5
Record Time
6
B Replaced ?
No
7
2
Yes
Stop Meter
Record Time
A Replaced ?
No
Yes
Print
Idle
2
B Replaced ?
No
8
1
Yes
Record Time
A Replaced ?
No
Yes
Print for I/C
Idle
4
End of Month ?
No
Yes
Update for New Month
Idle
3
B Replaced ?
No
9
1
Yes
Idle

Table 4.1 Temporary Data Storage Format

Memory Location*	Information Stored
	Start of Call:
3000	Date
3001	Month
3002	Year
	Time:
3003	Seconds
3004	Minutes
3005	Hours
	End of Call:
3006	Date
	Time:
3007	Seconds
3008	Minutes
3009	Hours
	Call Duration:
300A	Seconds
300B	Minutes
300C	Hours
300D	Number of chargeable units
300E - 300F	Accumulated number of units

3010 - 3011	--	Cost of call (integral part)
3012	----------	Cost of call (fraction)
3013	----------	First digit of number called
3014	----------	Second digit
3015	----------	Third digit
3016	----------	Fourth digit
3017 - 301A	--	Reserved for 5th - 8th digits
301B	----------	Previous month
3030 - 303A	--	Area code charge rates

* -- Location numbers in Hexadecimal.

4.4). The function of each sub-unit is outlined below:-

i) The CPU

The CPU perfoms all arithmetic and logic functions of the computer described above. It also provides control signals for both internal operation of the computer and external peripherals, e.g the LCD and the printer unit. The CPU internal registers serve as metering counters.

ii) Program ROM

This EPROM contains the operating software which directs the CPU. The ROM is programmed prior to installation. It may be recalled for re-programming should tariffs change.

iii) Area Code ROM

Charge rates for different areas for both normal and cheap rate periods are resident in this ROM. Once the CPU has diagnosed the number of the Subscriber called, this ROM provides the CPU with the correct rate for meter pulses.

In case the area coding changes, though it rarely does, the ROM can be reblown. However to avoid recalling the ROM each time new centres open up, it is advisable that all planned centres as well be included during the original programming.

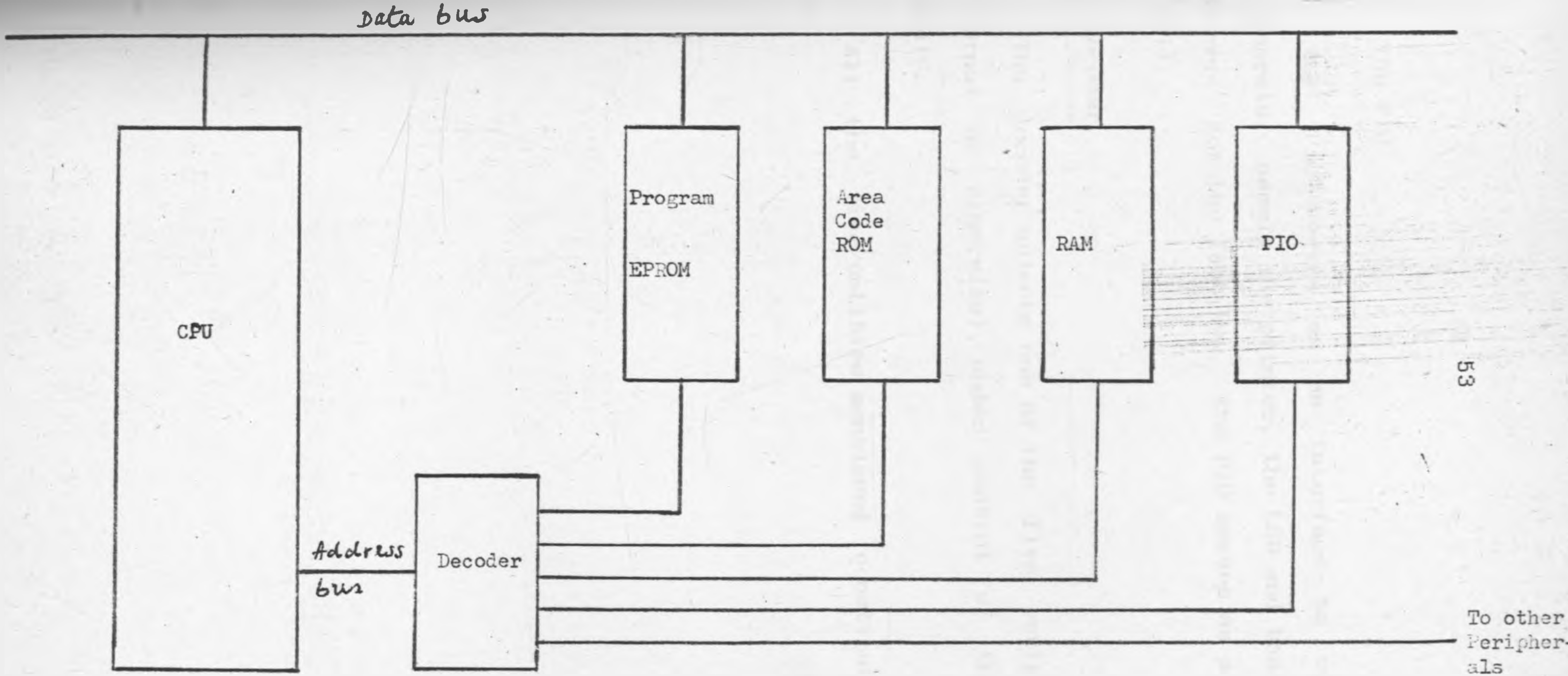


Figure 4.4 Composition of the Processor

iv) The PIO

The PIO serves as an interface to certain peripherals, namely the printer, the LSD and the digit receiver. For the last two, the PIO serves as a latch as well.

v) Decoder

The decoder selects one of the five peripherals (internal or otherwise) under control of the CPU signals.

All the five entities mentioned constitute the MPU.

CHAPTER FIVE: INTERFACING THE DOT-MATRIX PRINTER AND THE LCD TO THE PROCESSING UNIT

5.1: DESIGN OF THE SYSTEM HARDWARE

Data from both the Line Status Detector (Chapter 2) and the Digit Receiver (Chapter 3) is loaded onto the MPU for processing. The MPU is outlined in Figure 5.1. The LSD and the DR are coupled to the microprocessor IC1, through one port of the PIO, IC2. The other port forms an interface to a printer discussed in Section 5.2.

Data transfer from the LSD or DR to the PIO is under the control of a program resident in a 2716 EPROM, IC3. IC4 forms workspace memory on which temporary data storage is done. Both the microprocessor and the PIO, IC2 have a common clock input obtained from the clock output pin of the RTC (Chapter 3). In addition to cost saving, this feature solves synchronization problems which would have otherwise arisen. Thus the RTC is the system clock as well.

Peripherals connected to the microprocessor are selected in turn by outputs from a 74155 decoder, IC5. Currently only five out of eight outputs are utilized; namely to the EPROM, RAM, PIO, RTC and an LCD. The demultiplexer is vital in ascertaining that only one of these five controls the data bus at any one time.

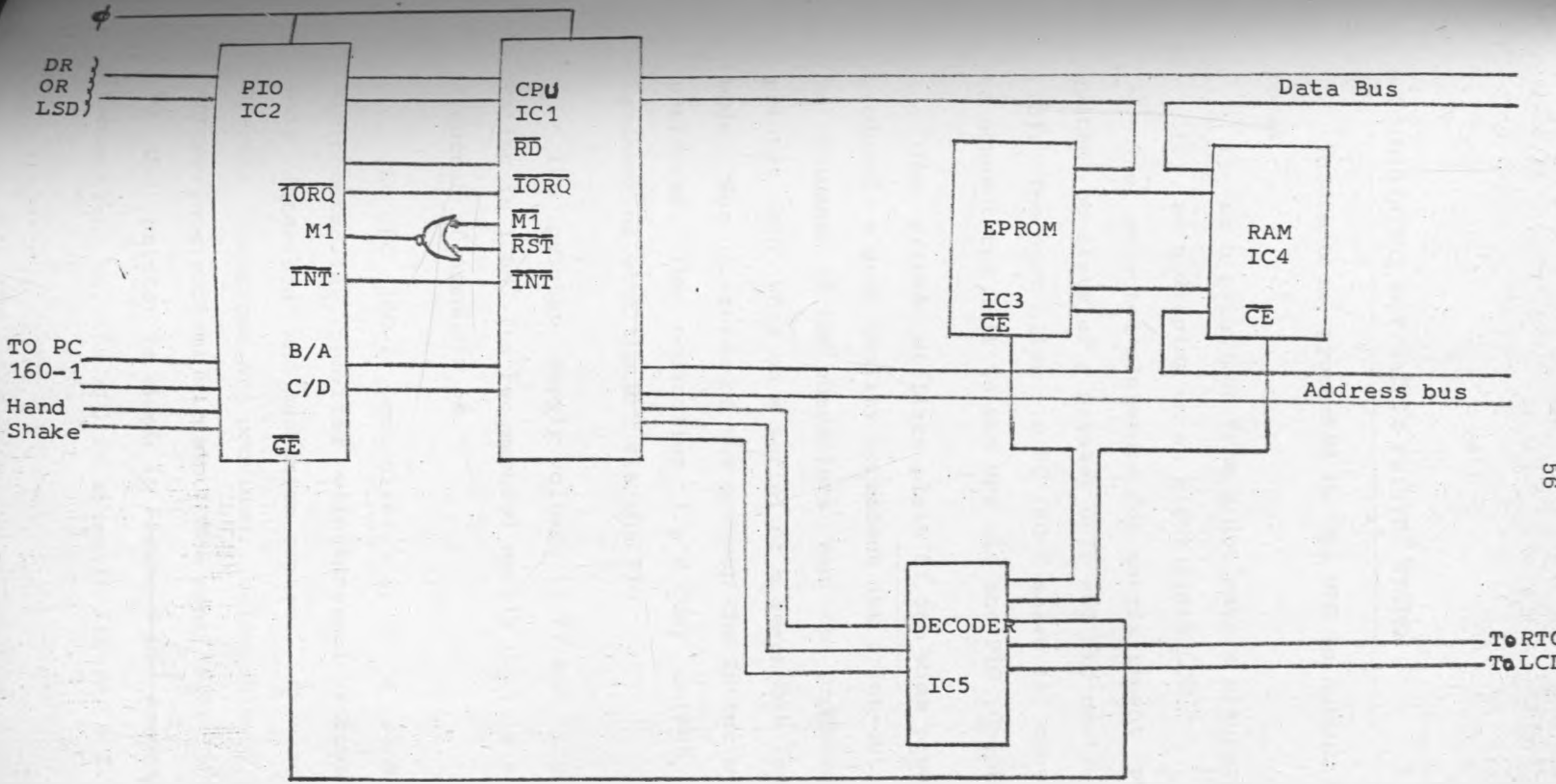


Fig. 5.1. The Master Processing Unit.

5.2: MINIATURE DOT MATRIX PRINTER SYSTEM

Information processed by the MPU is output in two forms:-

i) as a print-out from a dot matrix printer, and

ii) as a display on an eight digit LCD.

The selected miniature dot matrix impact printer system consists of a printer unit and its control i.c. [13]. The controller i.c PC 160-1 makes it convenient to connect the unit to the MPU via the PIO (Chapter 4).

The printer utilizes plain 57.5mm wide paper and produces a good quality permanent ink print-out. Upto 24 columns of 5x8 characters can be produced. The printer can work on a serial or a seven-bit parallel mode. For purposes of the project the latter mode is preferred. The controller i.c's busy output allows handshaking with the MPU via the PIO.

The printer supply voltage is 7V and its power rating is 1.5W. Its recommended supply unit is shown in Figure 5 of Appendix 5A.

The PC 160-1 controller i.c is a single-chip microcontroller provided with internal firmware for data interface and mechanism control. A variety of special functions are provided, selectable by sending appropriate control signals. The controller interface to the printer is ~~shown~~ in Ref: 13. ~~Figure 6 of Appendix 5A~~. Connection to the MPU is shown in Figure 5.2. Hand-

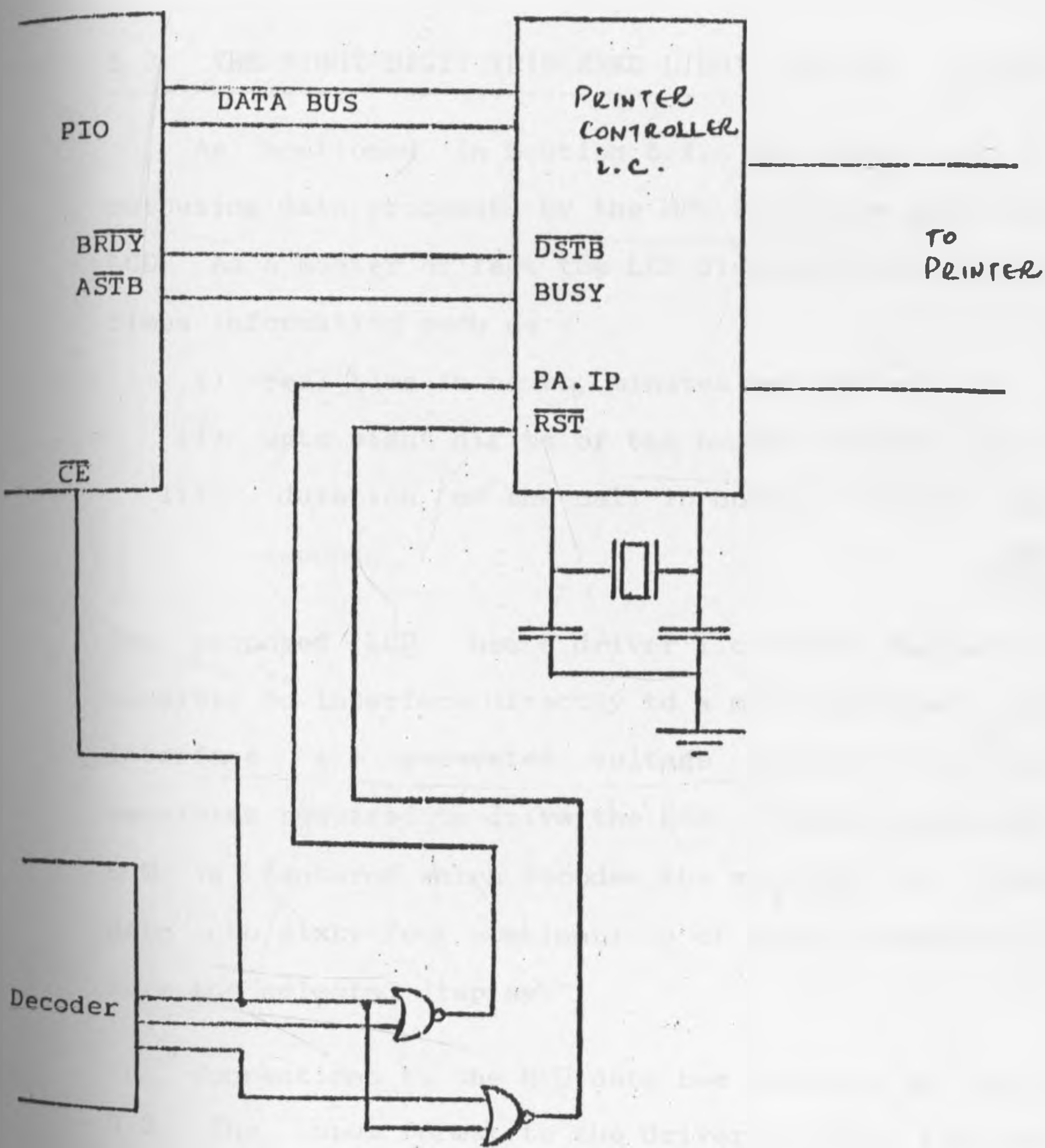


Fig. 5.2. Printer Interface to CPU

shaking is realized by connecting the busy pins of the controller i.c to the handshake pins of port B of the PIO.

5.3: THE EIGHT-DIGIT TRIPLEXED LIQUID CRYSTAL DISPLAY

As mentioned in Section 5.2, the other form of outputing data processed by the MPU is by the use of an LCD. As a matter of fact the LCD displays at different times information such as:-

i) real time in hours, minutes and seconds.

ii) upto eight digits of the number called.

iii) duration of the call in hours, minutes and seconds.

The proposed LCD has a driver i.c 7231A making it possible to interface directly to a microprocessor. The interface i.c generates voltage levels switching waveforms required to drive the LCD. A mask programmed ROM is featured which decodes the six bits of input data into sixty-four combinations of output segments to form the selected display.

Connections to the MPU data bus is shown in Figure 5.3. The input format to the driver is six parallel data bits with a three bit parallel digit select address. However in this project one annunciator control bit (AN) is not used. The remaining five data bits together with the three address bits can therefore be readily obtained from the MPU data bus.

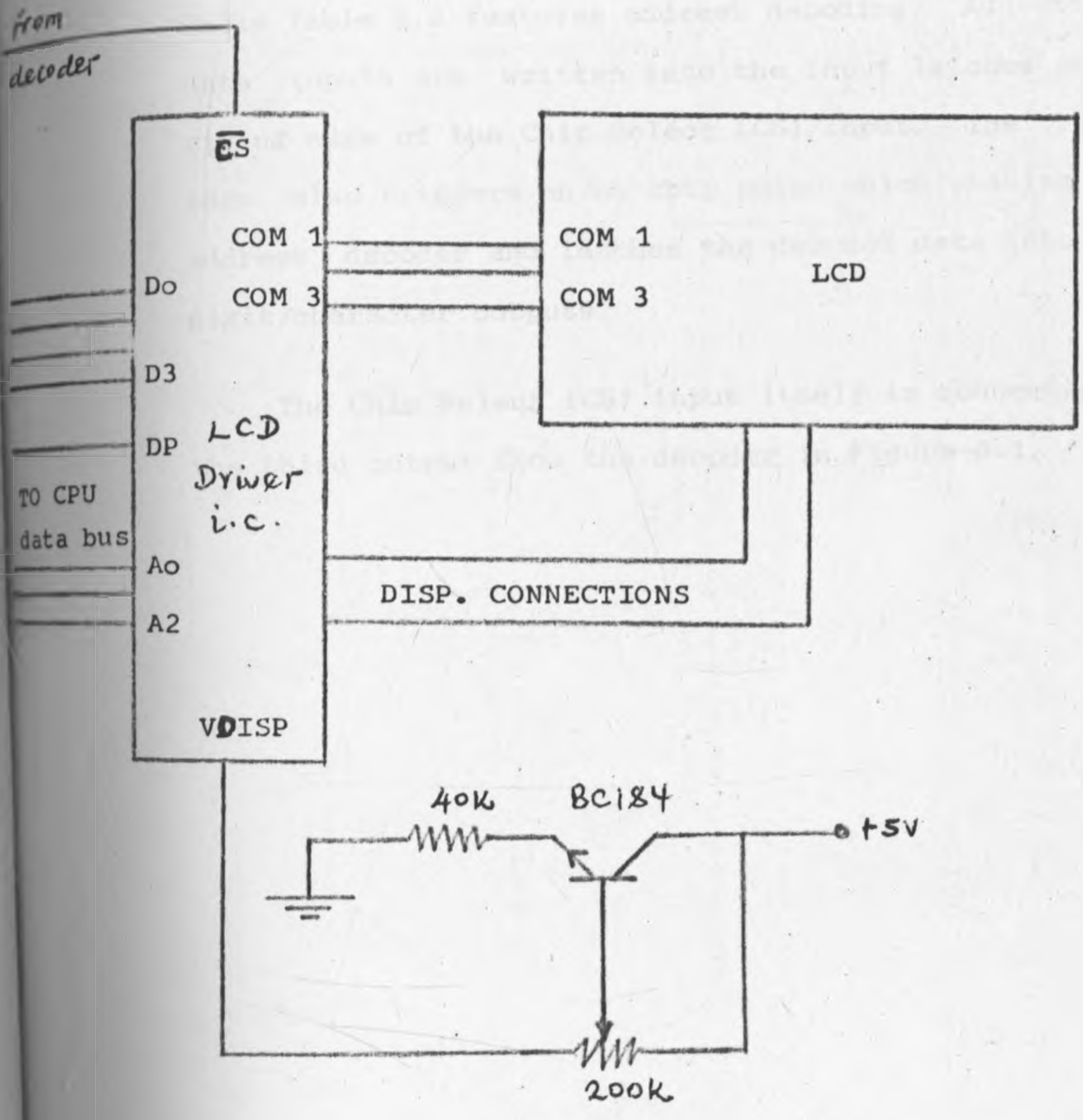


Fig. 5.3 LCD Interface to CPU.

The parallel data bits are sub-divided into four binary code bits and one annunciator (decimal point) bit. The binary data decoding is shown in Table 5.1, while Table 5.2 features address decoding. Address and data inputs are written into the input latches on the rising edge of the Chip Select (CS) input. The rising edge also triggers an on-chip pulse which enables the address decoder and latches the decoded data into the digit/character outputs.

The Chip Select (CS) input itself is connected to the third output from the decoder in Figure 5.1.

Table 5.1 Binary Data Coding for the Triplexed LCD Driver

i.c 7231A

Code Input				Display output
D3	D2	D1	D0	(HEX)
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	A
1	0	1	1	b
1	1	0	0	C
1	1	0	1	d
1	1	1	0	E
1	1	1	1	F

[Source: Ref.14]

Table 5.2 Address Decoding for i.c 7231A

Code Input			Display output
A2	A1	A0	digit selected
0	0	0	D1
0	0	1	D2
0	1	0	D3
0	1	1	D4
1	0	0	D5
1	0	1	D6
1	1	0	D7
1	1	1	D8

[Source: Ref.14]

CHAPTER SIX: FABRICATION OF THE METERING UNIT

6.1: IMPLEMENTATION OF "STAND-ALONE" CALL MONITORING SYSTEM

In this Chapter, the sub-units described in Chapters 2 to 5 are assembled to realize a single unit capable of monitoring calls that originate from or terminate on a Subscriber's line. The detailed functions of each sub-unit together with its technical specifications are described in the respective Chapters.

The circuit for the final complete product is made of Figures 6.1a and 6.1b, while Table 6.1 lists all the components required to construct the unit. The same table gives an estimated costing for the components.

6.2: CONSTRUCTION OF THE METERING UNIT

The metering unit which was actually constructed and tested utilizes a Nascom computer monitor to output information intended for the printer. Meanwhile the lower right-hand corner of the same VDU was used to simulate the LCD. The printer was not readily available. Moreover, considering the allowable research grant, the cost was prohibitive. So was the LCD.

The Nascom microcomputer was relied upon to obtain

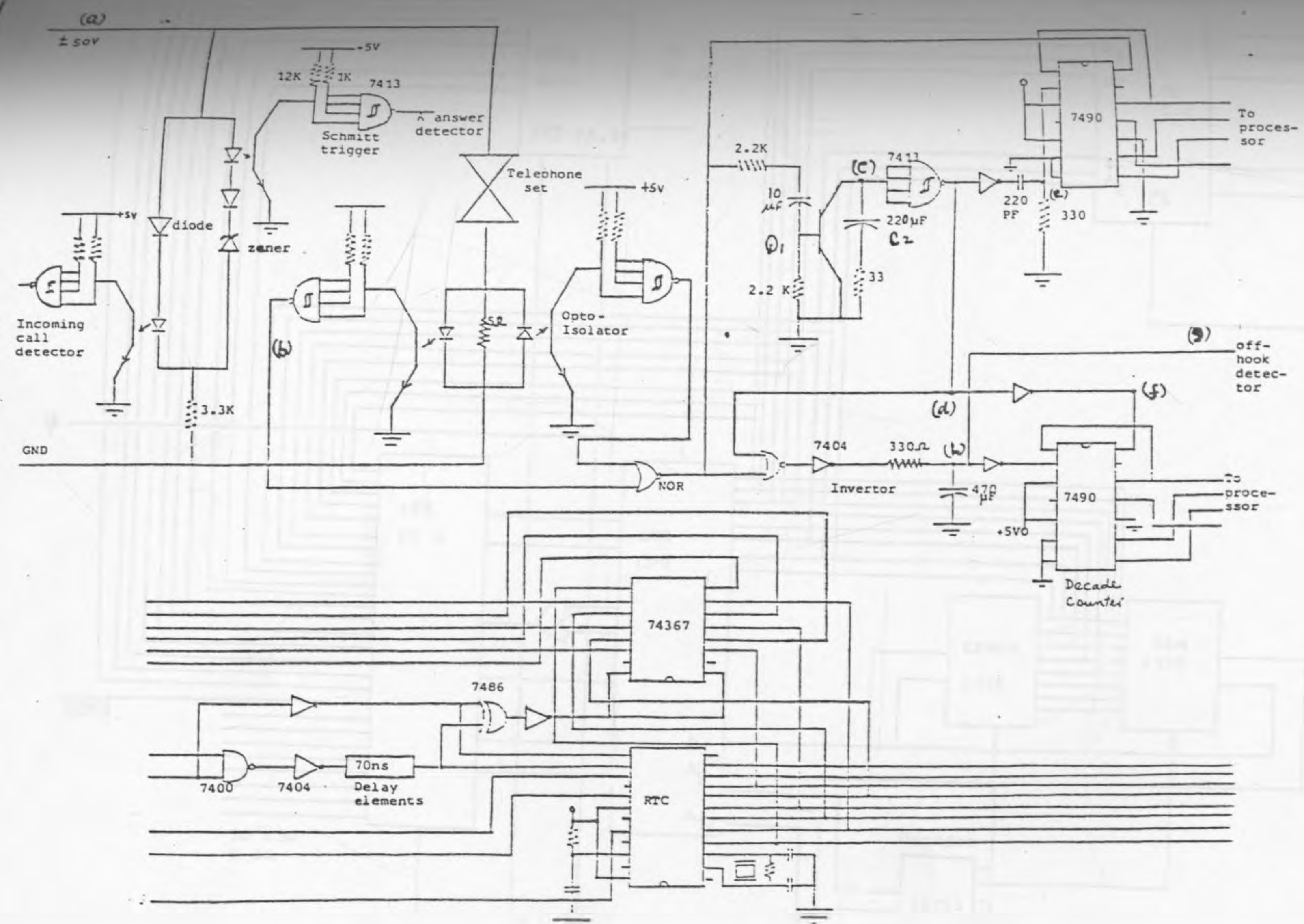


FIG. 6.1b Interface circuit diagram

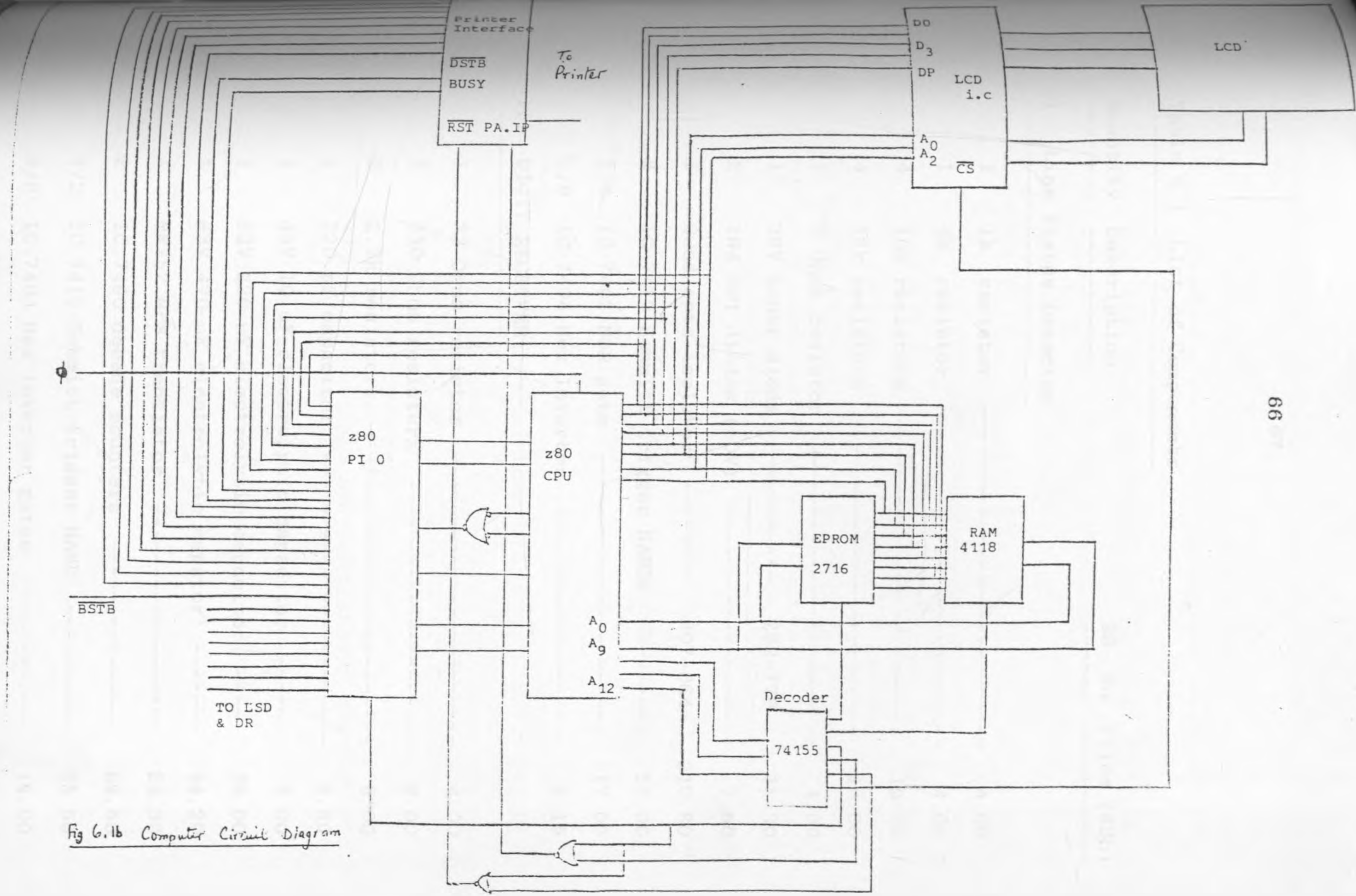


Fig 6.1b Computer Circuit Diagram

Table 6.1 List of Components

Quantity	Description	RS No	Price (KSh)
I. Line Status Detector			
1	1k resistor		4.00
1	4k resistor		4.00
4	10k resistors		16.00
4	12k resistors		16.00
1	5 Ohms resistor		4.00
1	39V Zener diode	282-779	15.30
2	1N4 001 diodes (50V)		7.50
1	Quad opto-isolator	307-064	210.80
2	IC 7413 Schmitt trigger NANDs		51.00
1/4	IC 7402 NOR gate		17.00
1/6	IC 7404 Hex Inverter		3.15
II) DIGIT RECEIVER			
1	33 Ohms resistor		4.00
2	330 Ohms resistors		8.00
2	2.2k resistors		8.00
1	220 pF capacitor		6.50
1	63V 10 uF electrolytic capacitor		8.00
1	63V 220 uF electrolytic capacitor		35.00
1	63V 470 uF electrolytic capator		44.20
1	BFY52 NPN transistor		24.30
2	IC 7490 decade counters		59.50
1/2	IC 7413 Schmitt trigger NAND		25.50
5/6	IC 7404 Hex Inverter gates		16.00

III) REAL TIME CLOCK

1	Real time clock IC 146818 -	302-003	382.50
1	IC 74367 Hex tristate buffer ----------		45.05
1/4	IC 7486 XOR gate ----------------------		23.40
1.5	IC 7404 Hex Inverters ----------------		38.30
1/4	IC 7400 NAND gate --------------------		17.00
1	4.194304 MHz oscillator --------------		289.00
1	1k resistor ----------------------------		4.00
1	150k resistor --------------------------		4.00
1	5 pF capacitor -------------------------		6.50
2	22 pF capacitors ----------------------		13.00

IV) PROCESSING UNIT

1	Z80 CPU --------------	304-532	467.50
1	Z80 PIO --------------	304-510	416.50
1	EPROM 2716 -----------	303-450	518.50
1	4118 RAM -------------	303-321	352.75
1	IC 74155 decoder ----------------------		38.25
1	IC 7402 NOR gate ----------------------		17.00
2	IC 7404 Hex Inverters ----------------		38.30

V) OTHER SUPPORT PERIPHERALS AND MISCELLENOUS COMPONENTS

1	dot matrix printer --------	301-959	2924.00
1	PC160-1 printer controller i.c	301-965	1190.00
1	paper and ink ribbon cassette	301-971	255.00
1	8-digit triplexed LCD -----	588-106	680.00
1	8-digit LCD driver 7231A --	302-514	520.20
1	6 MHz crystal ----------------------		229.50

2	5 pF capacitors ------------------------	13.00
1	BC184 NPN transistor ------------------	10.05
1	200k potentiometer --------------------	47.05
1	40k resistor ---------------------------	4.00
4	40-pin i.c sockets ------------------	328.90
2	28-pin i.c sockets ------------------	107.60
1	24-pin i.c sockets --------------------	44.20
3	16-pin i.c sockets --------------------	91.20
11	14-pin i.c sockets --------------------	432.00
1	30cm x 12cm printed circuit board ----	986.00
	TOTAL ---------	11 221.95

an acceptable output. To keep down the cost of the project even further, use was made of the on-board CPU, PIO and memory of the computer. Therefore two seperate crystals were utilized, one for the microcomputer and the other for the RTC. In case of the proposed "stand-alone" system the RTC provides timing signals for the entire system.

Figure 6.1a is a circuit diagram of the unit constructed. Excluded from the diagram are the processing unit and the VDU, both drawn from the Nascom computer.

The system software is available on a diskette. In case of the constructed unit, this program is loaded into the computer RAM. For the proposed product, it will be in-built in an EPROM (Figure 6.1b).

The circuit board layouts for both the RTC and the interface units are given in Figures 6.2a and 6.2b respectively. The RTC is designed to be directly plugged into the Nascom system.

6.3: TESTS AND RESULTS

6.3.1 Waveforms at Selected Test Points

Chapters 2 and 3 described in detail how the Line status detector and the digit receiver function. ~~Photographs of~~ Waveforms at selected test points of the constructed unit as seen on the CRO ~~were taken. Results~~ are contained in

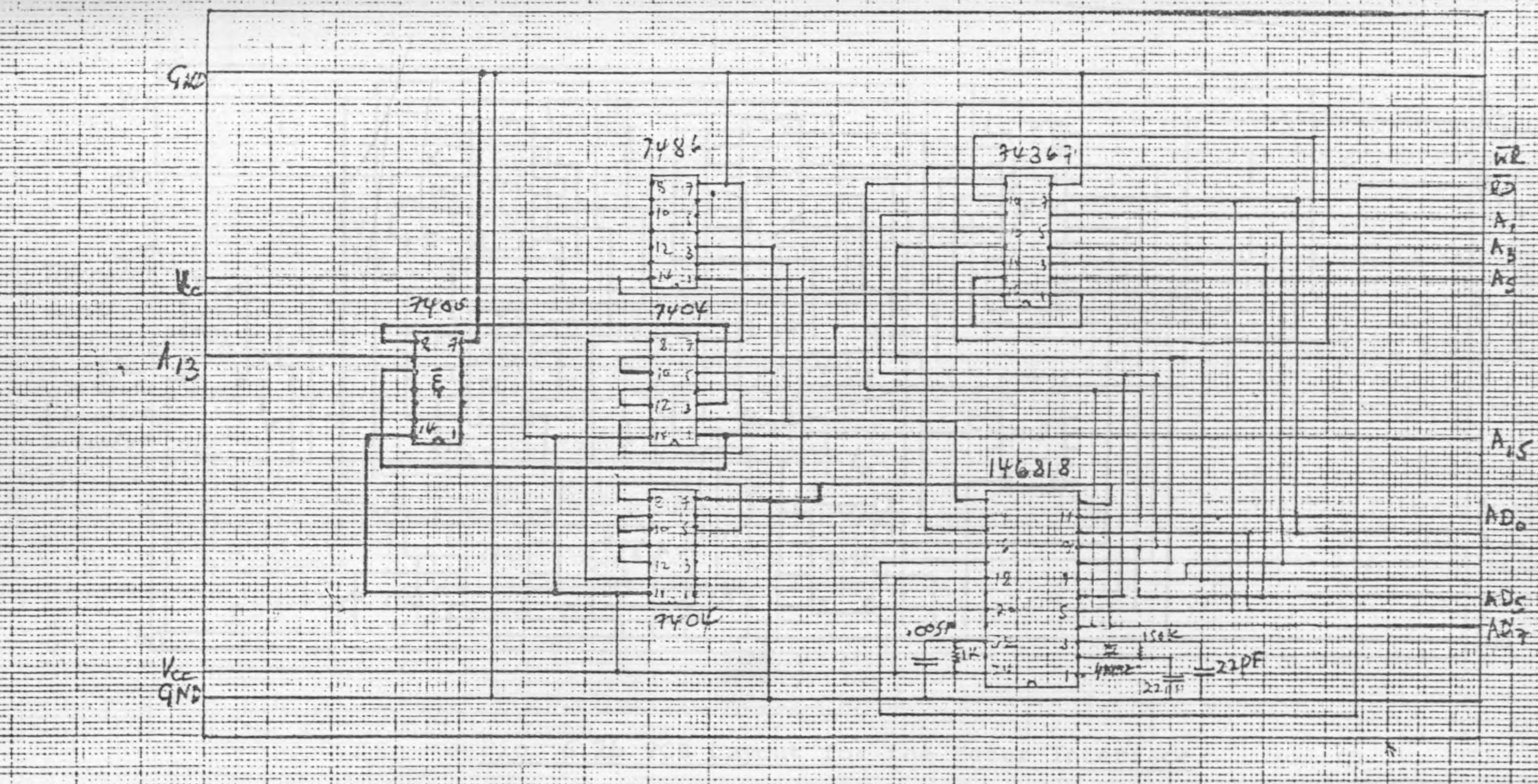


Fig. 6.2a The RTC Interface Layout.

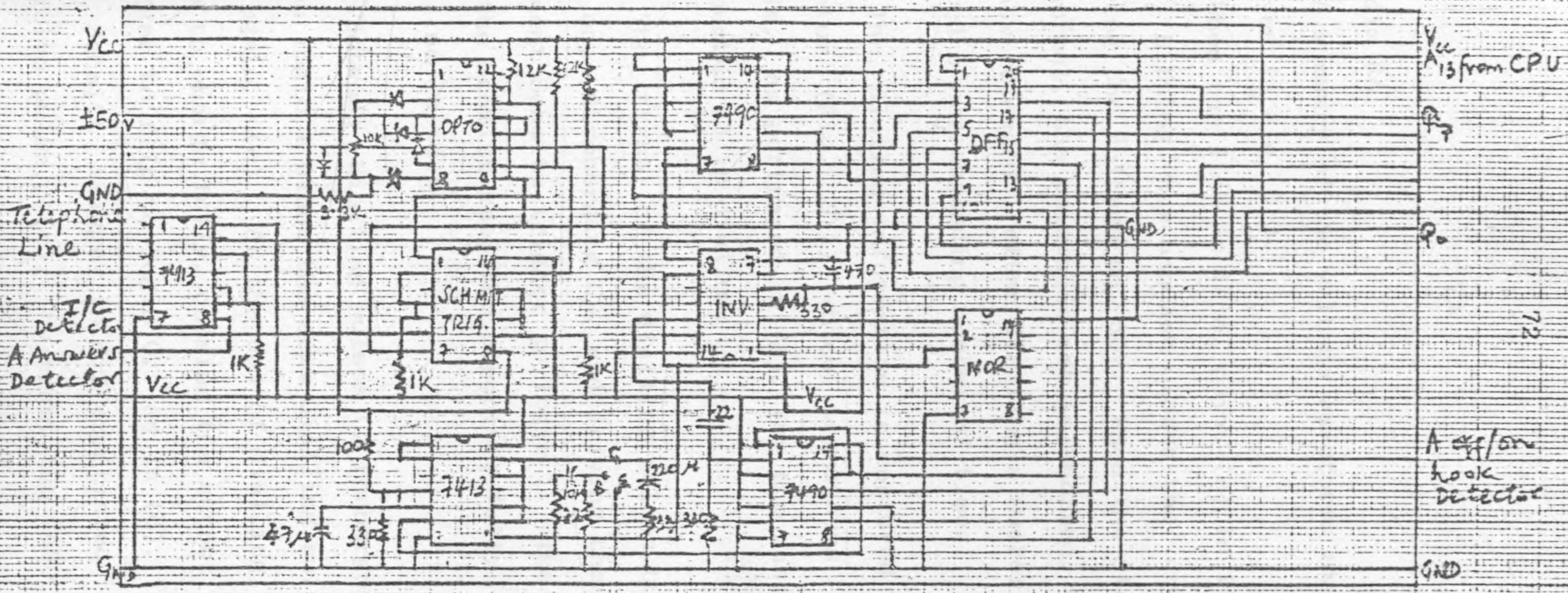


Fig. 6.2b PCB Layout for the Meter Interface.

Appendix 6A.

A summary of the voltage waveforms at these points is given in Fig. 6.3.

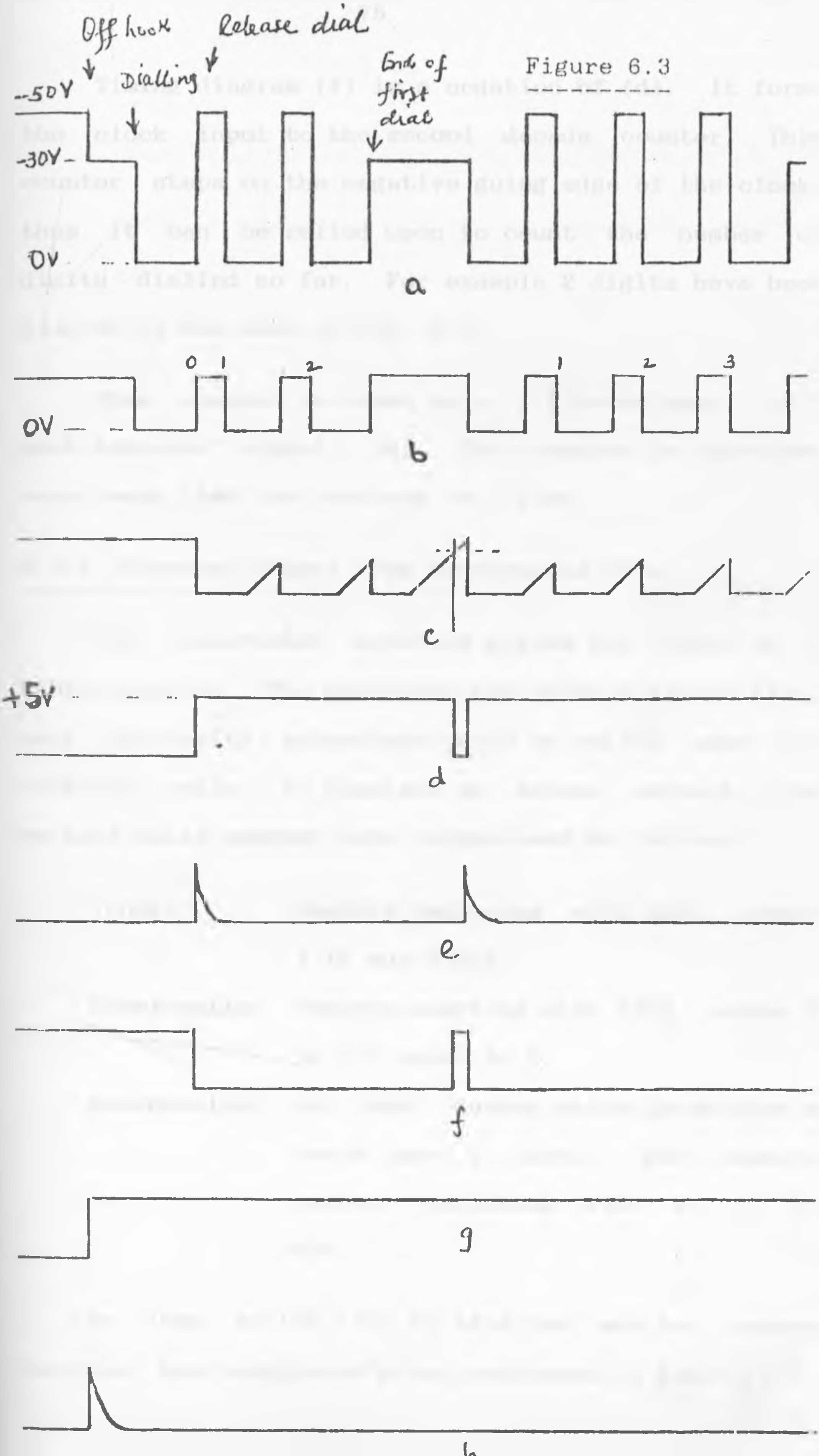
When the line is idle, point (a) in fig. 6.3 is at -50V. Lifting the handset closes the cradle switch, lowering the voltage to -30V. When the dial is rotated off normal, the telephone set is shorted. When the dial is now released, after dialling a number, the set is shorted a corresponding number of times.

The dialled information is captured by the opto-isolator (Fig. 6.1) which transforms it into TTL levels, as portrayed in (b). For the case illustrated, the number 23 is dialled.

The first of the dialling pulses turns Q1 (Fig. 6.1) on, discharging C2, and driving the inputs to the adjacent Schmitt trigger to logic 1. The input current of the Schmitt keep the capacitor fully charged when the line is idle.

Between dialling pulses C2 recharges but does not reach logic 1 since the next dialling pulse discharges it again, (c). At the end of dialling, C2 has ample time to charge fully, causing the output of the Schmitt trigger to flip to logic 0, as in (d). The output from the Schmitt trigger is differentiated to produce a positive pulse, (e), to reset the 7490 decade counter each time a new digit is received.

Figure 6.3


Off hook
Release dial
Dialling
End of first dial
-50V
-30V
0V
a
0 1 2 1 2 3
0V
b
c
+5V
d
e
f
g
h

Timing diagram (f) is a negation of (d). It forms the clock input to the second decade counter. This counter steps on the negative going edge of the clock, thus it can be relied upon to count the number of digits dialled so far. For example 2 digits have been dialled in the case of Fig. 6.3.

This counter is reset by a differentiated "off hook detector" signal, (h). This counter is therefore reset each time the receiver is lifted.

6.3.2 Observed Output From Constructed Unit

The constructed metering system was tested on a PABX extension. The extension not being a direct line, only University extensions could be relied upon for outgoing calls. To simulate an actual network, the various valid numbers were categorized as follows:-

Trunks:	Numbers beginning with 22XX, where X is any digit.
Local calls:	Numbers starting with 2YXX, where Y is not equal to 2.
Emergencies:	Any legal number which is neither a trunk nor a local. For example numbers beginning with 0, 1, 7, etc.

As long as the line is idle the monitor screen displays the background print portrayed in Table 6.2.

Table 6.2 Sample Print-out from the Constructed Meter

	TRUNK	LOCAL	SPECIAL	INCOMING	TOTAL
DATE:	MAY 10				
TIME:	10.20				
TO:	10.25				
DUR:	00.05				
UNITS:	008				008
COST:	009.18				
NO:	2222				
DATE:					
TIME:					
TO:					
DUR:					
UNITS:					
COST:					
NO:					

10.25.08

Note: *The normal charge rate for the station called is 20s. However, this particular call was made on May 10, 1987, a Sunday, during which cheap rate charging is assumed.*

The number of chargeable units
= 1 + Nearest lower integer (Duration in secs./cheap rate)
= 1 + Integer (300/40)
= 8 Units

The (1) additional unit is a must at the start of every call.

At the lower right-hand corner of the screen, real time is displayed. The clock's updating is immediately reflected on the screen, interrupted only by either an originating call or an incoming one. In case of an outgoing call, the clock display is suspended to create space for the dialled number. At this stage the Sub at his discretion may cancel the call before Sub B answers. Very often one discovers only too late that he has dialled an erroneous number. If the Sub waits for the called to answer, he ends up paying for a call he never intended. In any case the communication apparatus will have been held for no benefit.

It may be assumed at this point that the right number has been called. When the called answers, the metering unit displays the date and time of start of the call against the appropriate labels. If the call is a trunk then the lower right-hand corner continuously blinks the duration of the call throughout conversation. At the end of communication, the time the call ends, and therefore the duration, are posted on the screen. Costing is done and displayed, so are the number of chargeable units, the accumulated units and the number called. Although the University extensions are no more than four digits, the system can accommodate upto eight digits of the called number.

The sample print-out in Table 6.2 depicts such complete call information for a trunk. It may be noted that in obtaining the cost, the printed value might not precisely agree with manual computation. The number of units is multiplied by 115 cents. The difference, however, is never greater than 0.3%. In the example given the error is 0.2%. Hardware constraints limit exactness in performing this arithmetic. The fraction 0.15 is truncated to four decimal places in binary representation. Extension to eight bits would enhance accuracy, though at the expense of memory required for programming. A trade-off must therefore be made between precision and cost of implementation. The author is convinced that upto four decimal places suffices, for all practical purposes.

The only major difference between the tested unit and the proposed one is that information displayed on the screen at present, will be printed. And instead of the screen being cleared in anticipation for the next call, the printing sheet will just be scrolled up. Infact it is preferred that the background print e pretyped on the printing paper roll. Then there will be no need to reserve part of memory for the background print as in Appendix 4B. At any rate it may be unnecessary to allot seperate columns for trunks, locals, emergencies or incoming calls. It will be sufficient to tell any of these from the number printed. Alternatively, abbreviations could be printed against the number, for example TR for trunk, C for local, SP for emergency and IC for incoming calls.

For the printer, it is recommended that data be printed horizontally, rather than vertically, as in Table 6.2. Information to be printed can be summarized as:-

i) The date the call is made in month, date and year.

ii) The time call started in hours, minutes and seconds.

iii) The time the call ends in hours, minutes and seconds.

iv) Lapse time in hours, minutes and seconds.

v) Number of chargeable units.

vi) Accumulated number of units.

vii) The number called.

For special calls, (v) and (vi) are printed as zero, while for an incoming call, (vii) as well is presented as nil. Both types of calls are not chargeable. Moreover the unit is not capable of portraying the number of a caller, in case of an incoming call.

The LCD, on the other hand, displays instantaneous time, in addition to (ii) and (vii) above.

6.4: POWER SUPPLY TO THE SYSTEM

The interface as well as the processing unit has TTL i.cs which require +5V for powering. The 5 Volts can be drawn from the mains, the telephone line or a battery. The telephone line option is subject to regulations set by the local telephone company. Power for the tested unit was hooked from the Nascom power supply board, itself plugged onto the mains. An optional circuitry for tapping power directly from the telephone line is given in Figure 6.4.

Using the mains power has the disadvantage that the system will miss calls made during power failure. On the other hand if the exchange supply fails, no calls will be missed since under such circumstances calls will not be possible on the line.

However, many telephone companies do not permit any form of loading on their lines. Moreover, the printing unit requires so much power that it is only plausible to power it from the mains. For all practical purposes, therefore, the mains should be relied upon to provide power for the proposed meter. But provision should be made for a back-up power system to run the unit in case the mains fail. Although the printer may not be operated from the back-up, data can be temporarily held in RAM.

Another reason for the back-up is that the time clock resides in volatile memory. Whenever power fails, time is corrupted. It may then be necessary to reset the clock each time this happens. However, with a back-

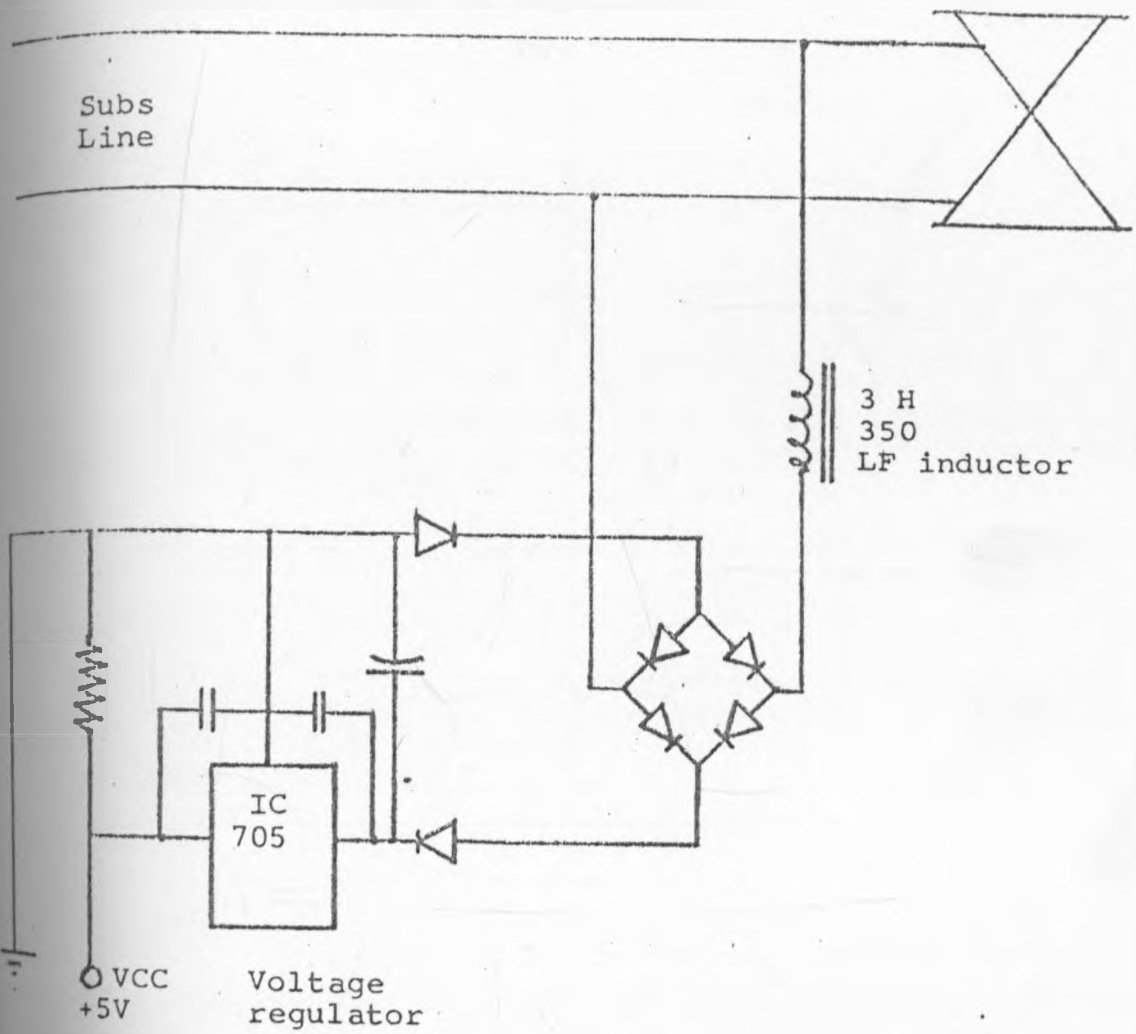
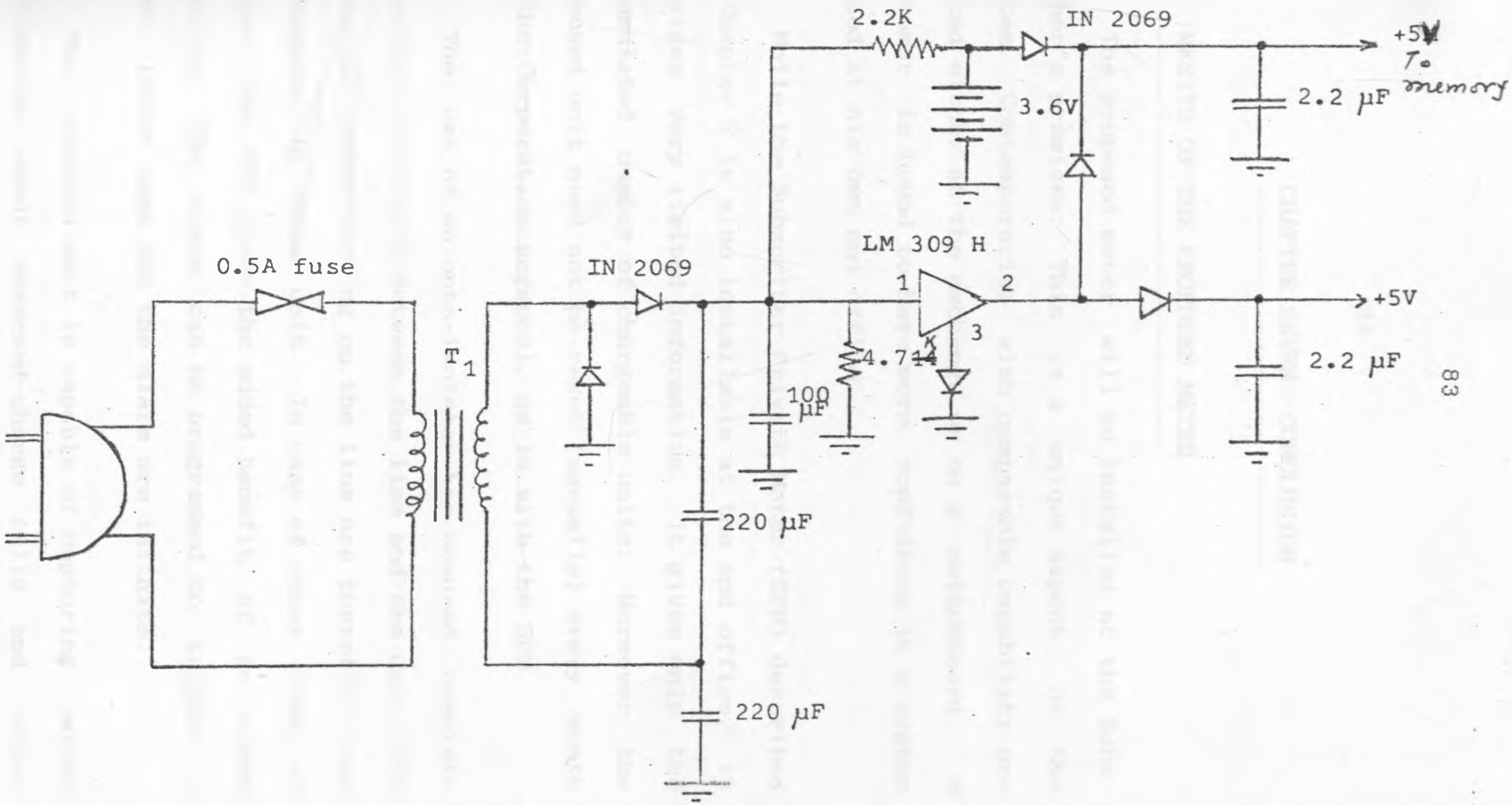


Fig. 6.4 Optional Power from Telephone Line.

up proper time keeping is certain. A proposed back-up system is shown in Figure 6.5.

Fig. 6.5. Back-up Power System.



CHAPTER SEVEN: CONCLUSION

7.1: MERITS OF THE PROPOSED METER

The proposed meter will be installed at the Subscriber's premises. This is a unique aspect of the system. Contemporaries with comparable capability are fitted either at the exchange or on a switchboard. A customer is bound to have more confidence in a system fitted at his own end office.

While the Subscriber Private Meter (SPM) described in Chapter 2 is also installable at the end office, it provides very limited information. It gives only the accumulated number of chargeable units. Moreover the proposed unit need not be reset (manually) every month by the Corporation personel, as is with the SPM.

The use of an opto-isolator has ensured complete electrical isolation between the line and the unit. The technical staff working on the line are therefore not endangered by this unit. In case of other form of danger the RTC gives the added benefit of an alarm facility. The alarm can be programmed to trigger a siren. Infact uses for the alarm are infinite.

The proposed unit is capable of capturing limited information about reversed-charge calls and other operator assisted calls. Hitherto, the Sub could not distinguish unauthorized calls that might have originated from his set. Some customers have lockable sets, though. But even with a locked equipment, unauthorized persons can still arrange to allow a reversed-charge call. He may even initiate the call through the operator. In either case the Sub ends up paying for calls he never approved.

With the proposed meter, the Sub is kept abreast with all communications involving his set. Even if information about operator-assisted calls is not complete, he is certain that his equipment was used for the time specified on the print-out. Further investigation may reveal other concealed details.

Persons entrusted to receive calls very often forget to report such calls. The meter's print-out may well serve as a reminder, however.

A final merit for the proposed unit is its capability to display the lapse time whenever a trunk call is in progress. A user is constantly reminded of the length of time he has spent on the line. He then has a clue to the ultimate costing of the call. It may even be better to progressively display the actual cost, rather than the duration. However this might not be too pleasant to the telephone company. She hopes to generate the much needed revenue to sustain herself. Any factor affecting realization of such funds will be received with mixed feelings. Whatever the case, displaying the costing instead of the lapse time will require slight modification to the software presented in Chapter 4.

Like telephone instruments, the proposed meter can either be leased or sold to Subs in need.

7.2: DRAWBACKS TO THE UNIT

The proposed meter is most useful on an analog network. With the on-going digitization, some of its funtions will be a duplication. In particular specific call details are obtainable readily from the Centralized Automatic Message Accounting (CAMA) system typical of digital exchanges. Nevertheless, digitization cannot be completed overnight. In any case it is envisaged that even after digitization, 30% of the local network will remain analog. [3]

It may also be argued that at present many exchanges, especially the smaller ones, are manual. Obviously the proposed meter is not intended for manual switchboards. Although in number there may be more manual exchanges than the automatic ones, the actual capacity is by far greater on the latter, as Table 7.1 confirms. It can therefore be expected that for a long time to come, the meter will remain a paramount entity in our network.

A definite problem with the proposed meter is

Table 7.1 Telephone Capacity on Digital Exchanges

Total capacity	208,660 lines
Automatic capacity	179,690 lines
% Automatic capacity	96%
Total working capacity	134,505 lines
Automatic working capacity	120,235 lines
% Automatic working capacity	98%

[Source: Ref.2]

that EPROMS with different in-built area codes are required for Subs in different charging areas. Moreover, the ROMs have to be recalled for reprogramming each time tarrifs change. It can only be hoped that rates do not change too often. But even if they did as often as once every year, it may be observed that under normal circumstances, the maintenance team services a Sub's line, on average, more frequently. Comparatively, therefore, it will not be too streneous to visit the Sub's premes to recall the ROMs for re-blowing.

A further demerit of the proposed meter is the added need for a back-up power. In order not to miss calls made during power failure, a back-up is a must. However, since the meter in itself is just supplementary to the exchange meter, it could well be argued that the Sub may record information about calls made during power failure. In either case, however, the clock need be reset when power is ultimately available. Provision must hence be made to reset the clock by pressing a button, as described in Chapter 6.

7.3: PROPOSED AUXILLIARY FUNCTIONS REALIZABLE ON THE UNIT

As it stands, the meter can monitor only one Sub's line. Most of the time the CPU is either idle or performing trivial functions. Modification can be done so that a larger number of lines may be scanned by a single unit. If this is achieved then instead of installing the meter at the Sub's premises, a single meter can be installed at the exchange to monitor all the lines terminating on this exchange. We shall have effectively succeded in making an analog exchange emulate the digital couterpart.

Though in so doing, the very essence of the meter being a household facility will have been lost. But transfering the unit to the exchange will even rid us of the need for the electromechanical meters currently operational. Moreover, billing can then be done along with metering. The print-out from the the system has more than adequate information required for billing purposes.

At present, telephonists can easily transfer charges from one Sub to another. They may altogether discard the costing, hence denying the Corporation of earned revenue. Unless tampered with, the proposed meter will record all calls payable, or otherwise, to the Corporation. At the same time the unit ensures that no charges are posted, deliberately or otherwise, to the wrong customer.

As a further development to the unit, a simple keyboard may be provided, so that simple computations can be perfomed. Results can be read from the 8-digit LCD, or altogether printed on the dot matrix printer.

The unit can also be interfaced with a cassette player to serve as an Automatic Message Handler (AMH), so that in the absence of anybody at the Sub's premises, a caller may leave behind a recorded message. The Line Status Detector (LSD) can be trusted to trigger the recorder when desired. The same arrangement can be employed to provide "Music-on-Hold". A number of modern PABXs have this facility. Whenever the called officer is still too occupied to attend to the call, the caller is sent a musical tone. The same could be achieved with the proposed meter. Certainly one cannot expect a private Sub to buy a PABX.

Finally, the meter could be adopted to provide a "locking" facility to the telephone instrument. Until recently a number of cunsumers did not favour the push-button telephones for its lack of a "lock". The rotary counterparts could be locked with a padlock. Fortunately, today a push-button telephone can be housed in a lockable casing, to disallow unauthorized calls. However, even with such "locking" facilities, some enlightened persons still "tap" calls by tapping the cradle switch. The proposed meter can be provided with a suitable circuitry (with mainly resistive elements) to permit only incoming calls while blocking outgoing ones, whenever desired.

On the whole, the proposed meter seeks to provide the telephone user with improved service. Some of these facilities have been hitherto unavailable to him. The meter attempts to integrate some of the facilities that have been available before from different peripherals. For example a single player can be connected to the meter to realize both "Music-on-hold" and AMH facilities. Other auxilliary functions that can be intergrated by the system are contained in Ref. 10.

From the foregoing, it may appear that design of the meter has laid too much emphasis on the individual Subscriber. It was indeed the intention of the project to give the telephone user satisfactory service. However the meter is no less useful to the telephone company. A case in mind is a disputed bill which resulted from an unauthorized call made fom a Sub"s instrument. With the meter, the Corporation need not go to pains to convince the customer that the call actually originated from his set. Other benefits the Corporation may reap from the proposed unit have been discussed elsewhere in this Thesis.

Thus the meter attempts to provide not only satisfactory, but also impartial service to both the Subscriber and the telephone company.

APPENDIX 2A

Voltage Waveforms Plotted on a Direct Line (554077), Terminating on an Hitachi C400 Crossbar Exchange

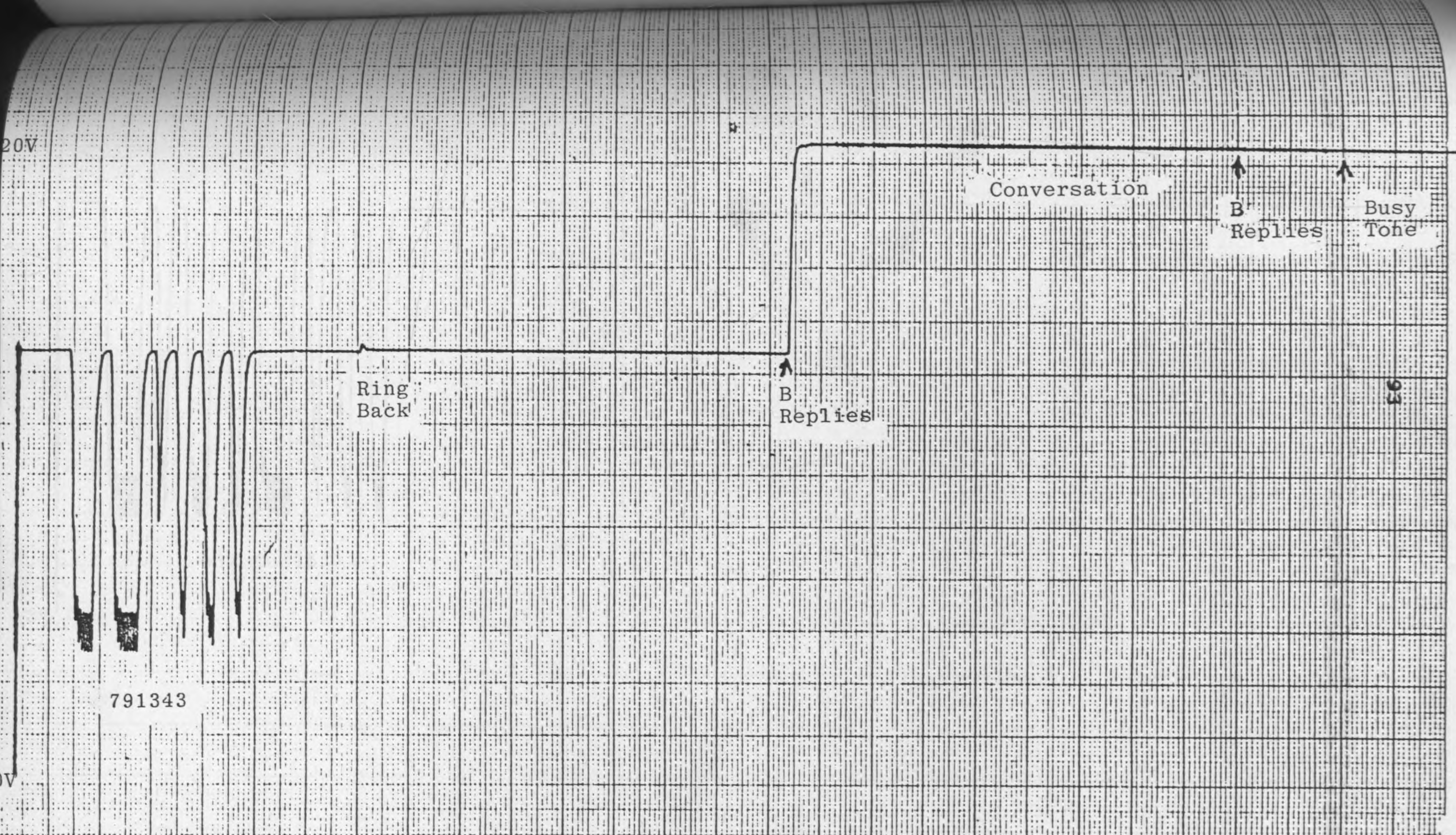


FIG. 2.51: OUTGOING CALL TO 791343

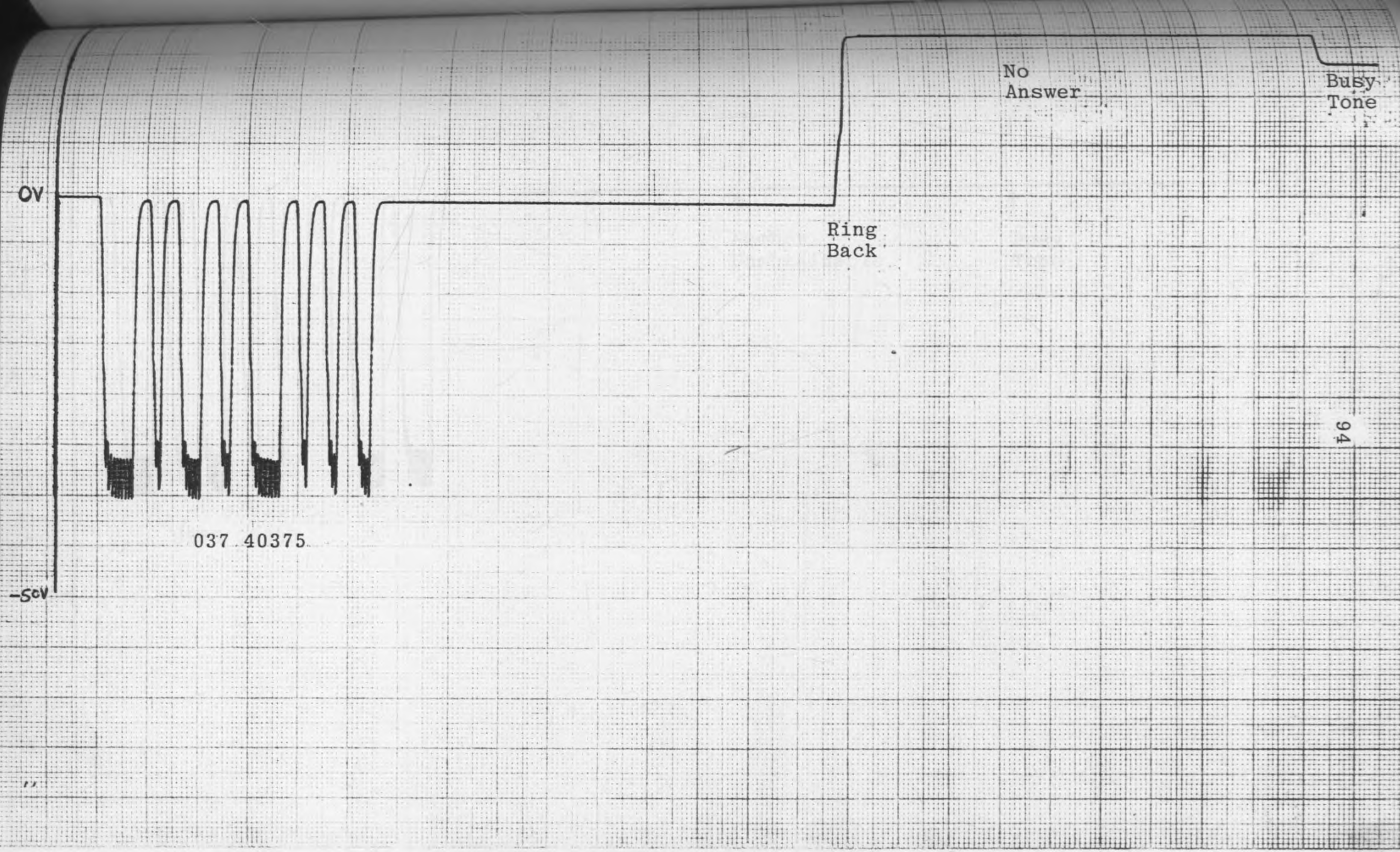


FIG. 2.52: OUTGOING TRUNK TO 037-40375 (NKR)

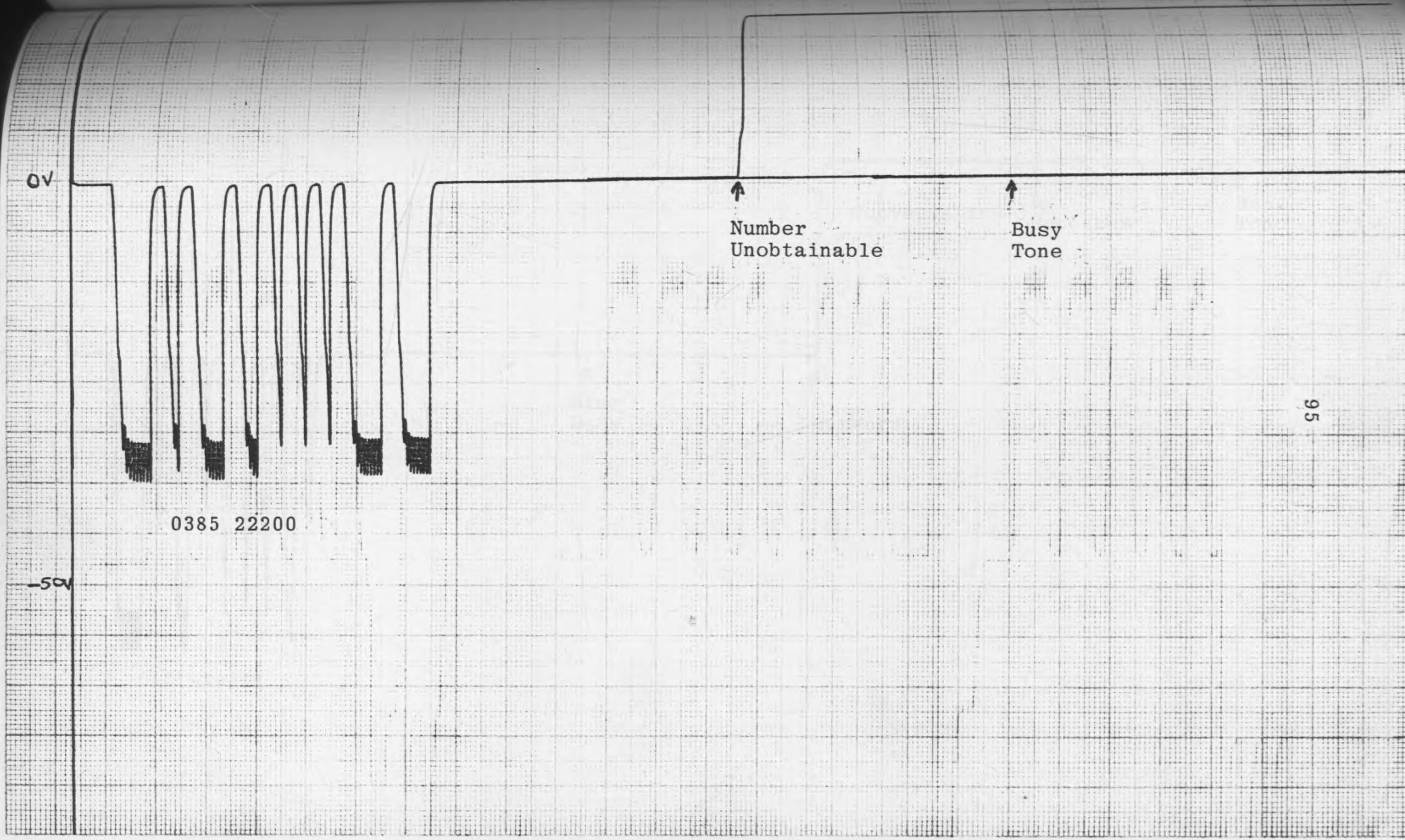


FIG. 2.53: OUTGOING TRUNK TO 0385-22200 (HMA)

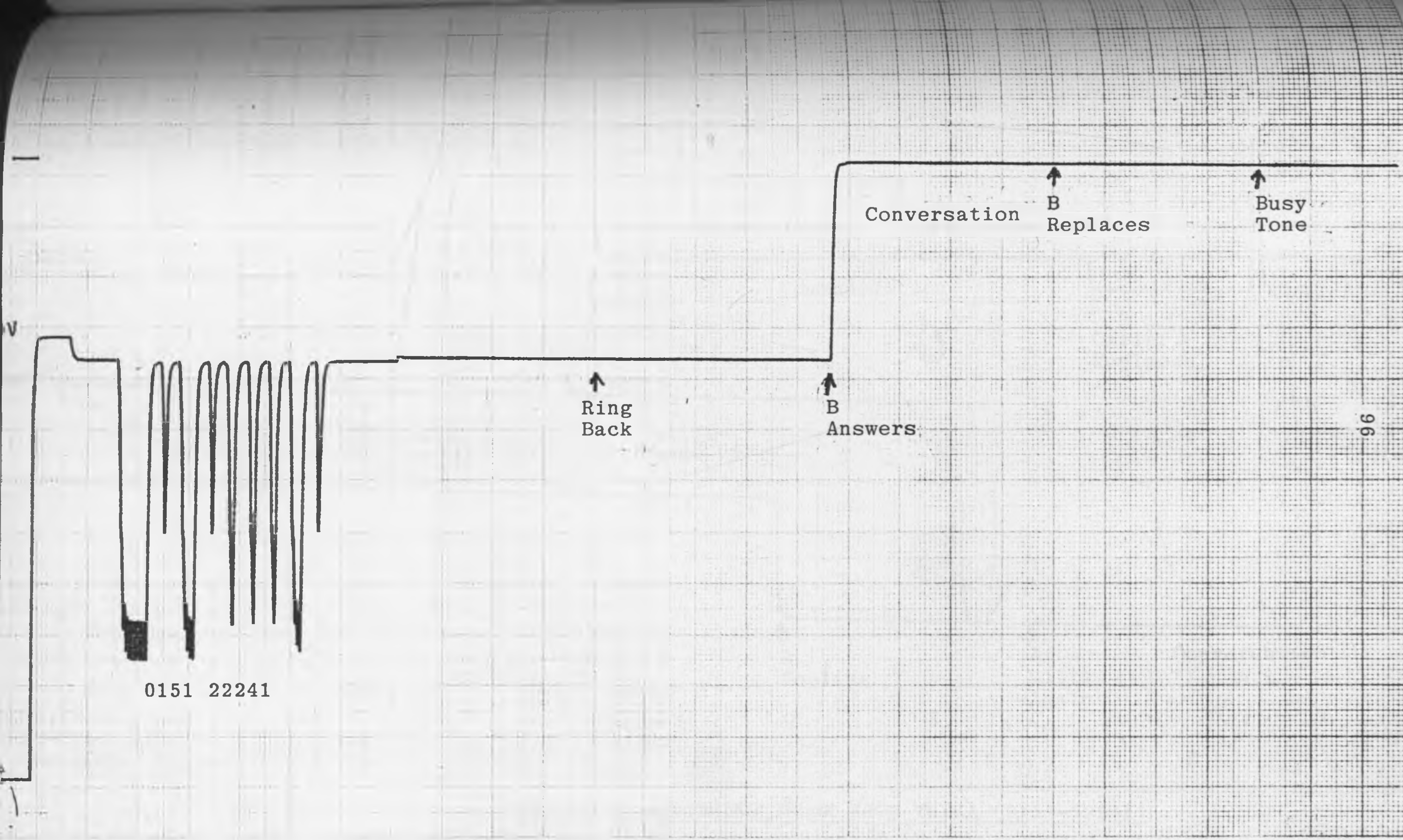


FIG. 2.54: OUTGOING TRUNK TO 0151-22241

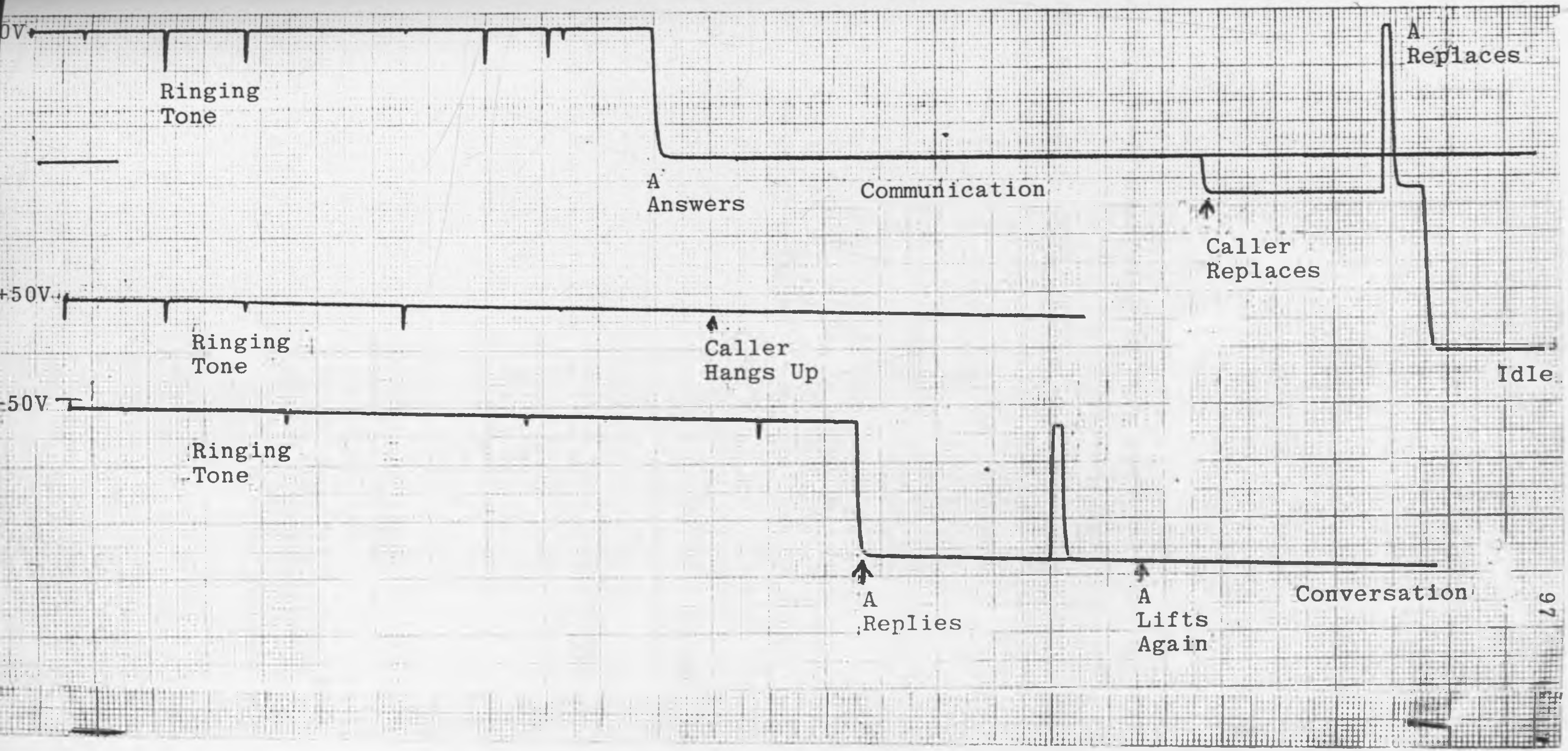


FIG. 2.55: INCOMING TRUNK FROM THIKA (0151-22241)

APPENDIX 2B

Voltage Waveforms Observed on a University of Nairobi's PABX Extension (Ext. 2306)

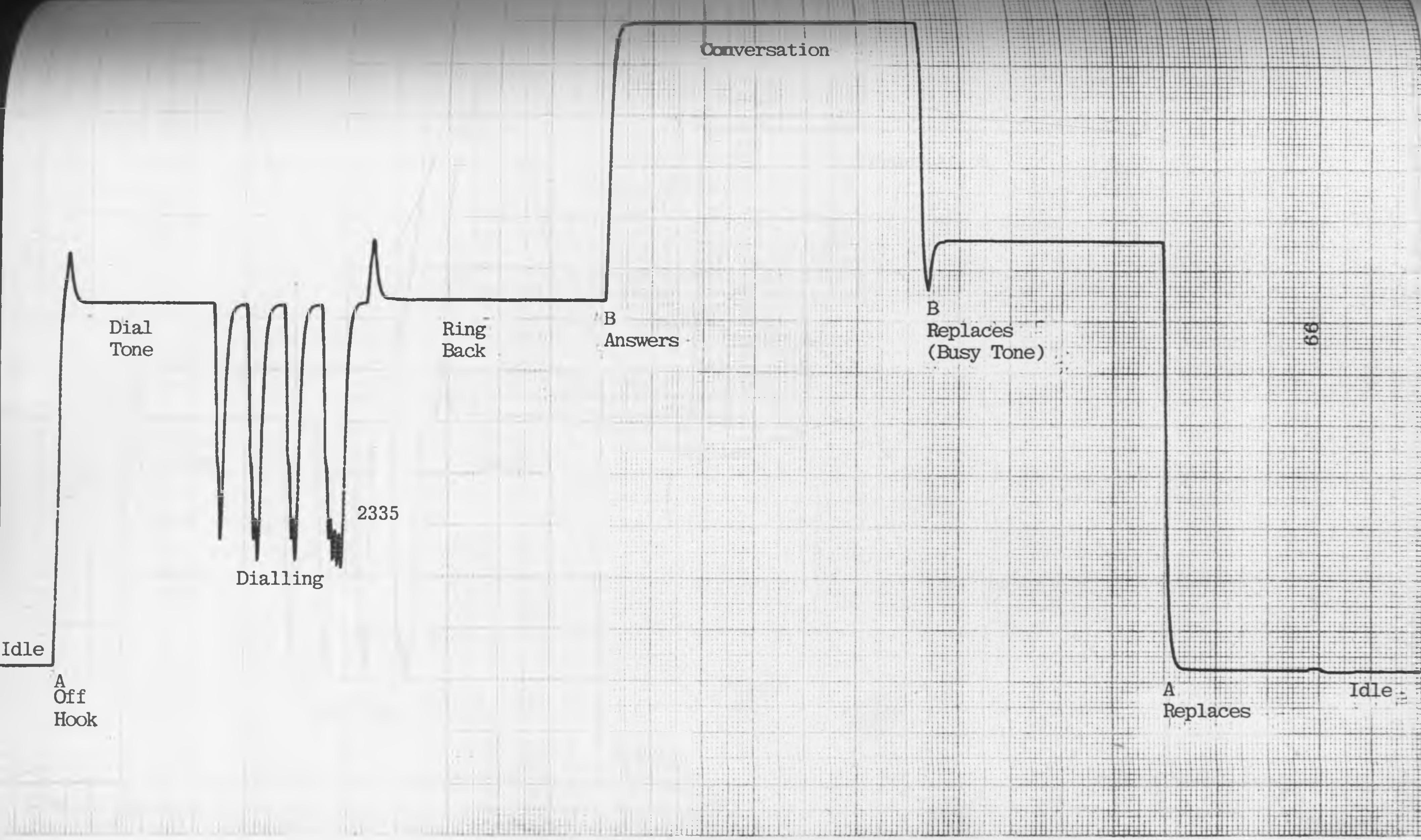


FIG. 2.56: OUTGOING TO EXTENSION 2335

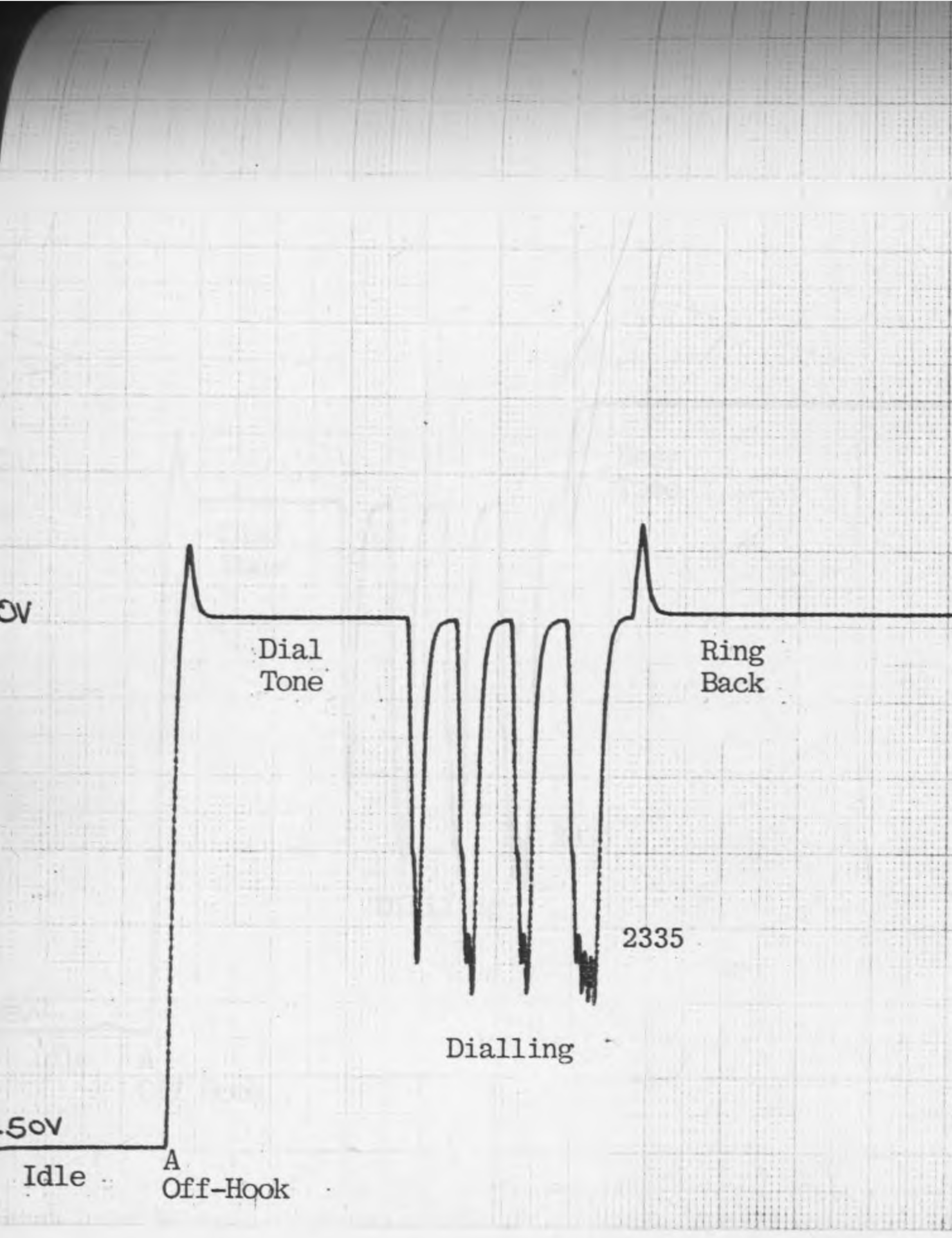
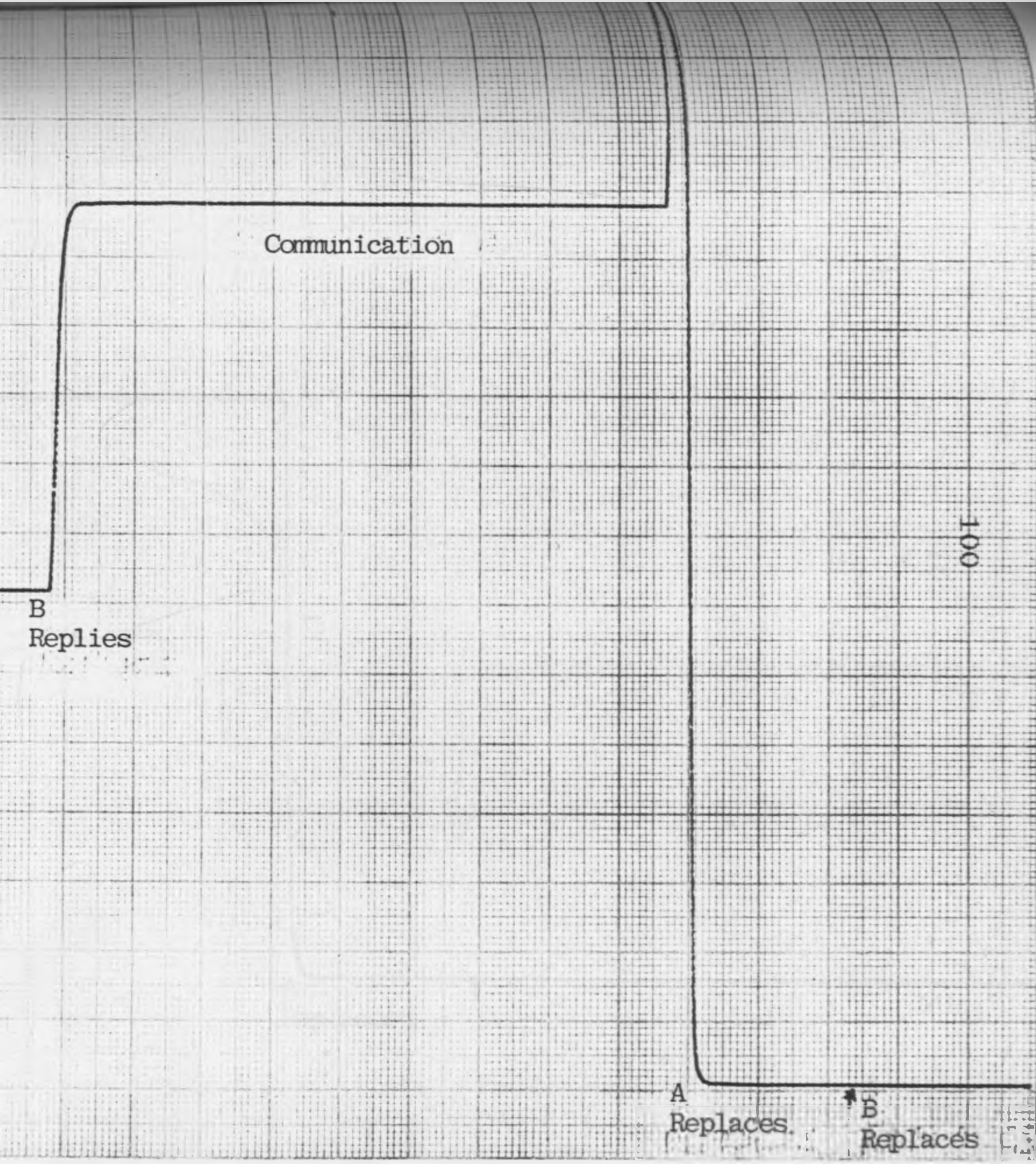


FIG. 2.57:



OUTGOING TO EXTENSION 2335 (A REPLACES BEFORE B)

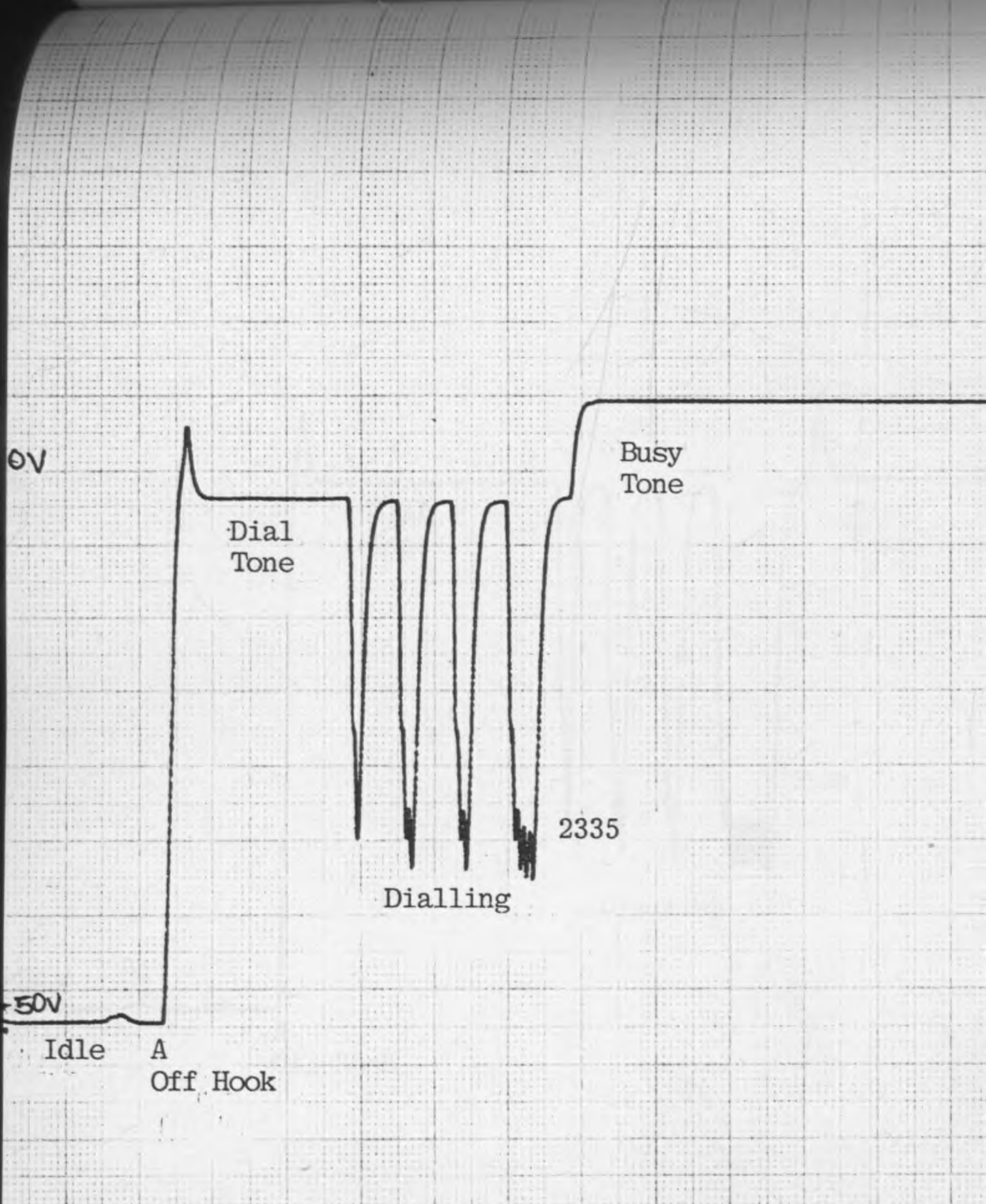
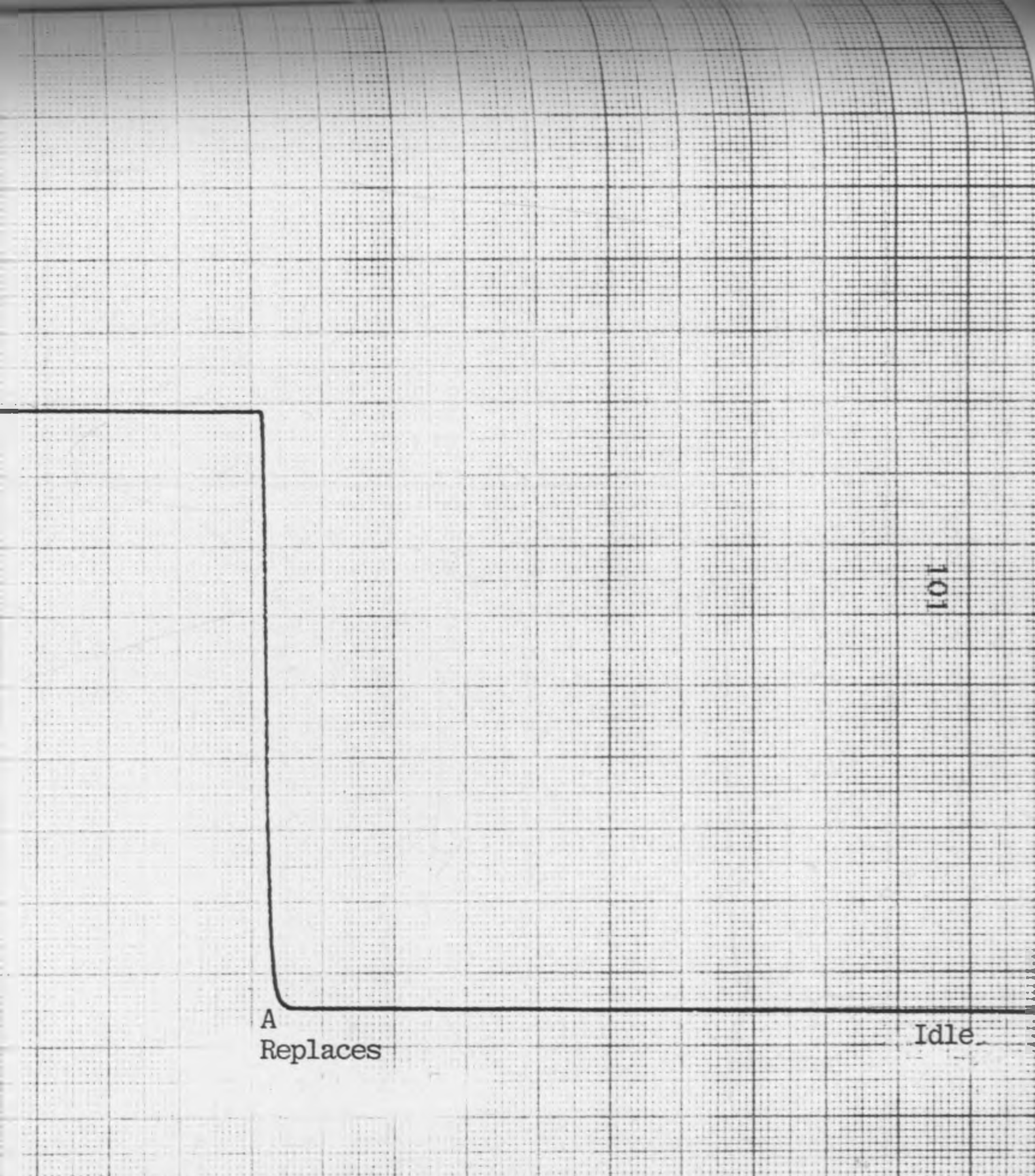


FIG. 2.58:



OUTGOING/CALLED SUB BUSY

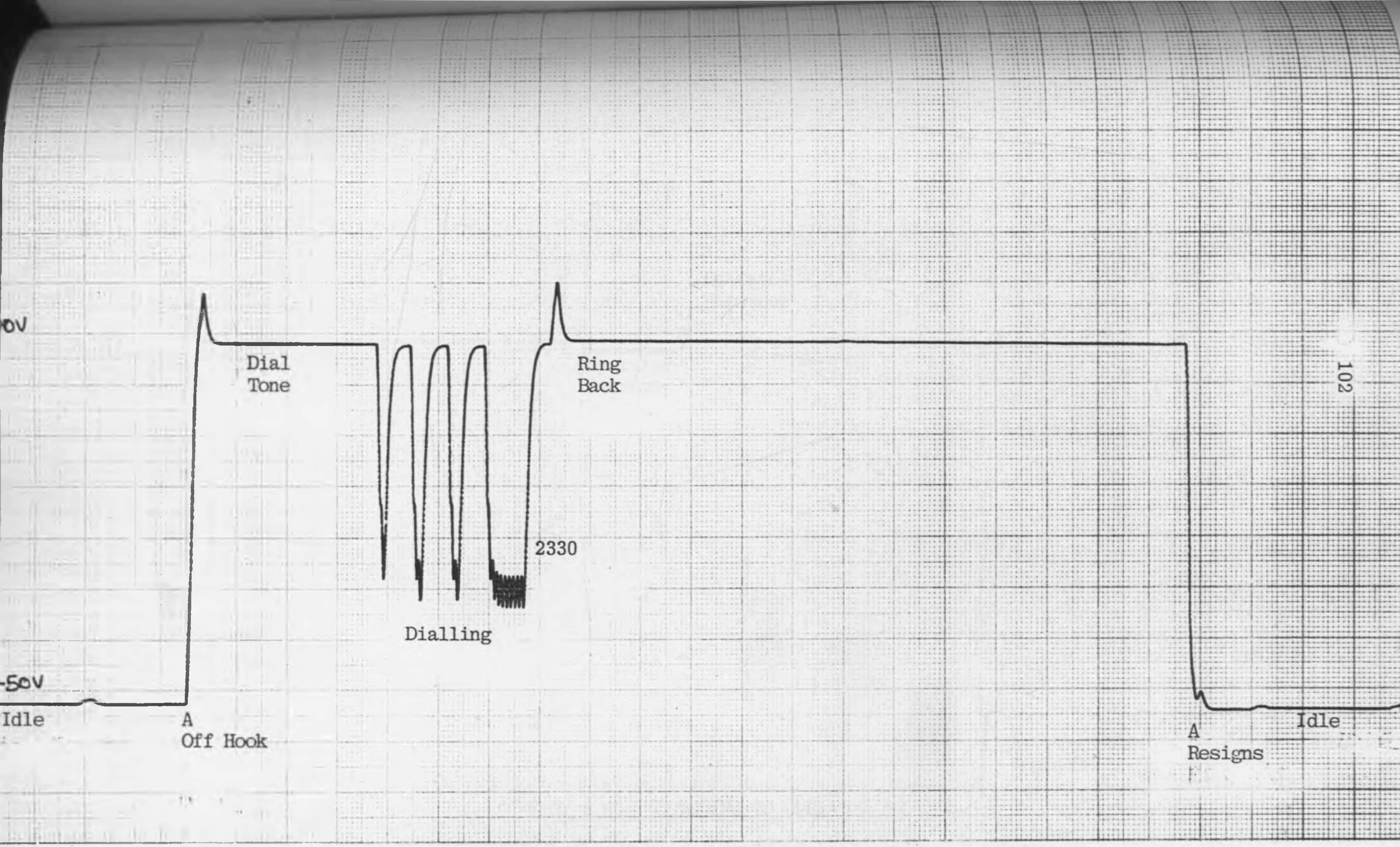


FIG. 2.59: OUTGOING CALL UNANSWERED

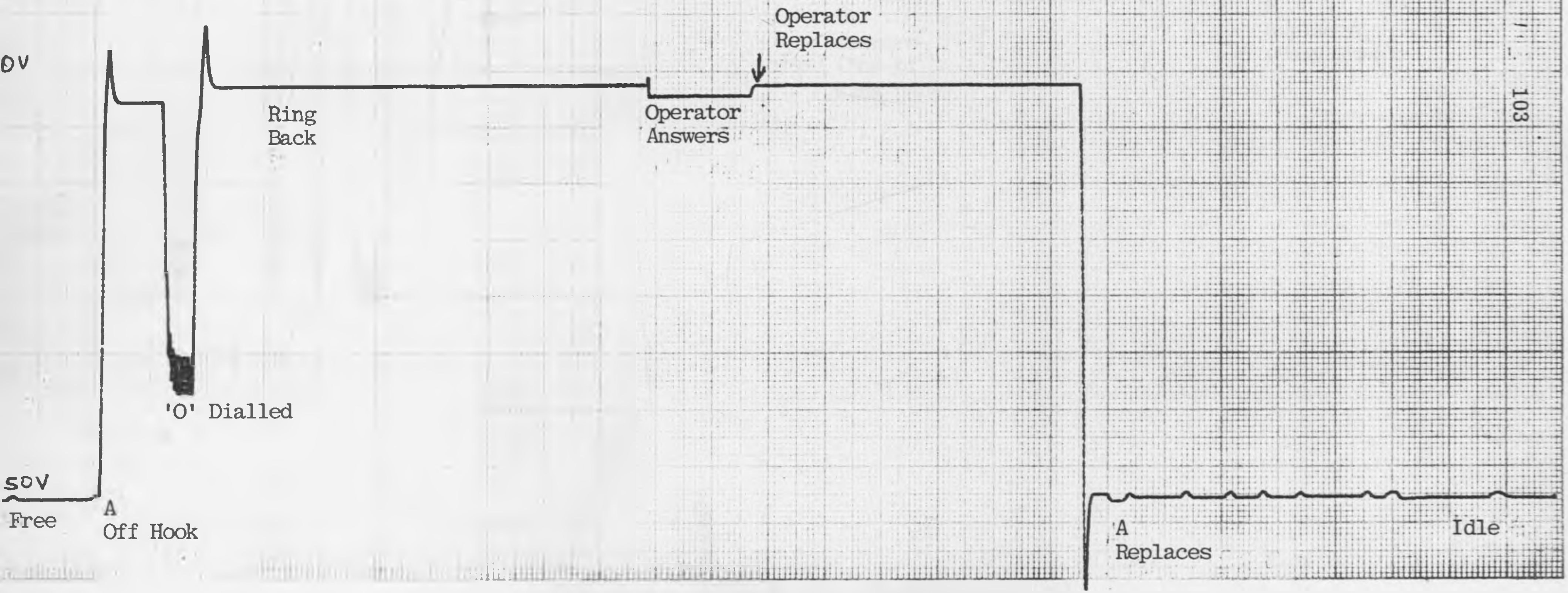


FIG. 2.60: OUTGOING TO OPERATOR ('O')

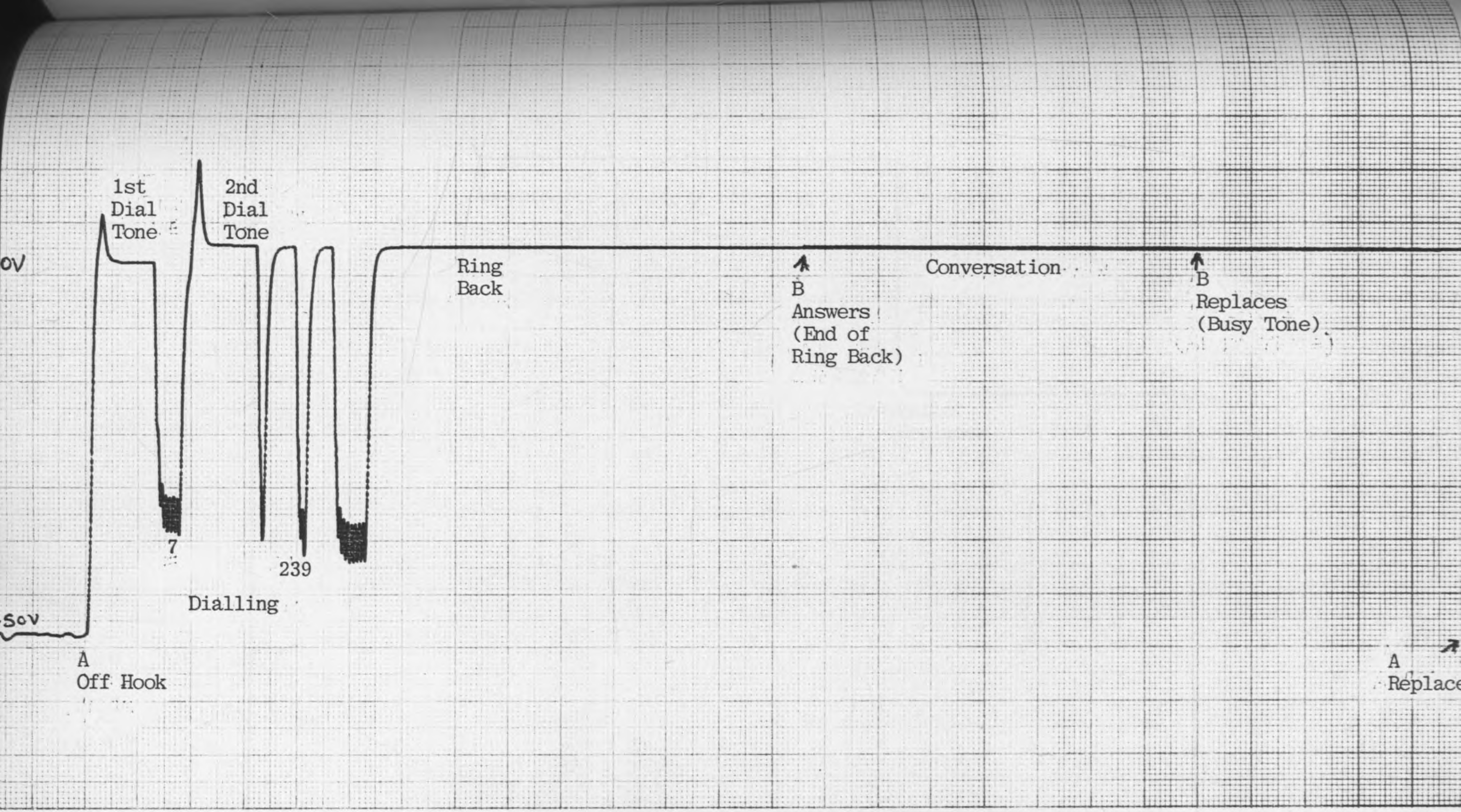


FIG. 2.61: OUTGOING CALL TO CHIROMO (7-239)

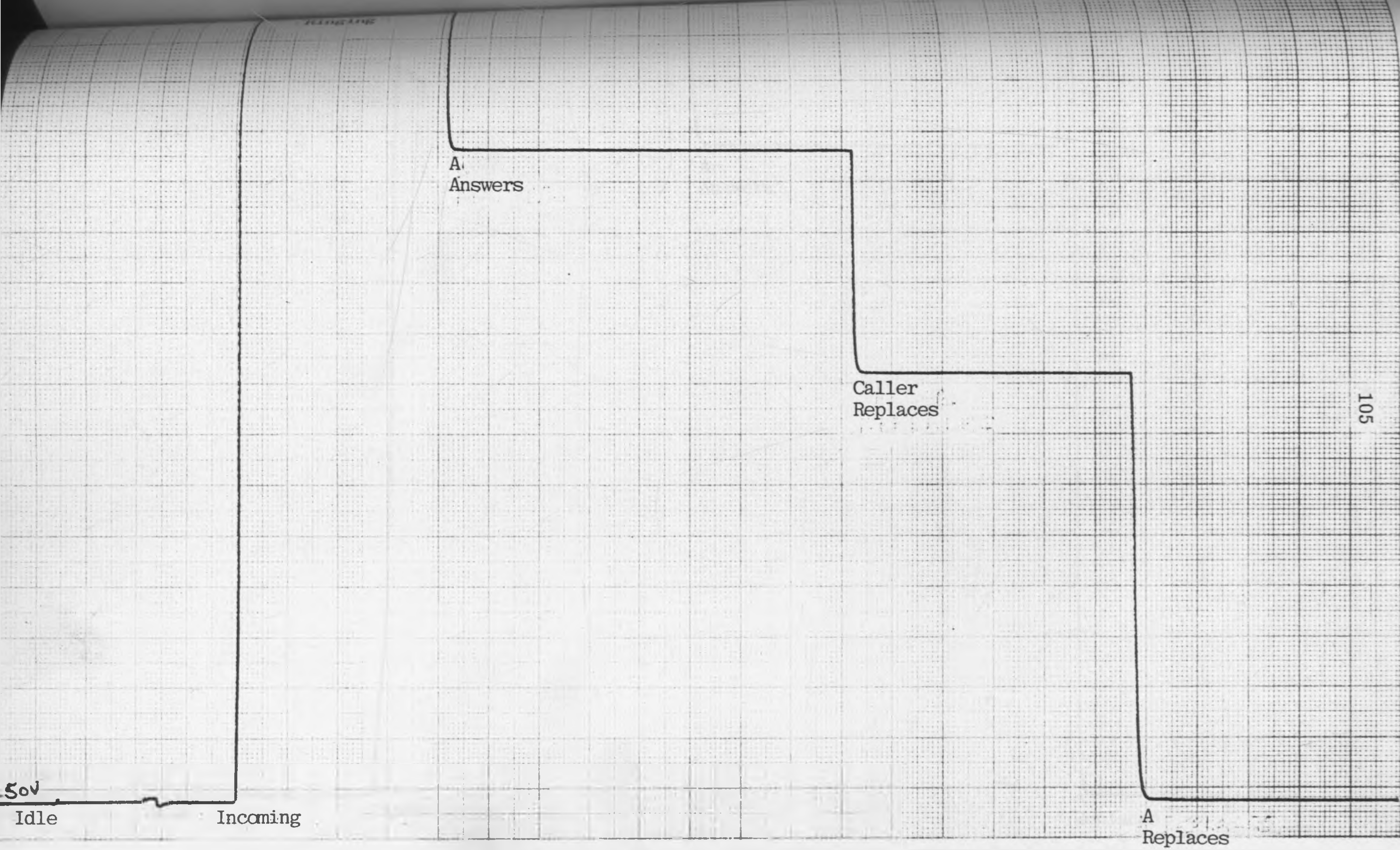


FIG. 2.62: INCOMING FROM EXT. 2335

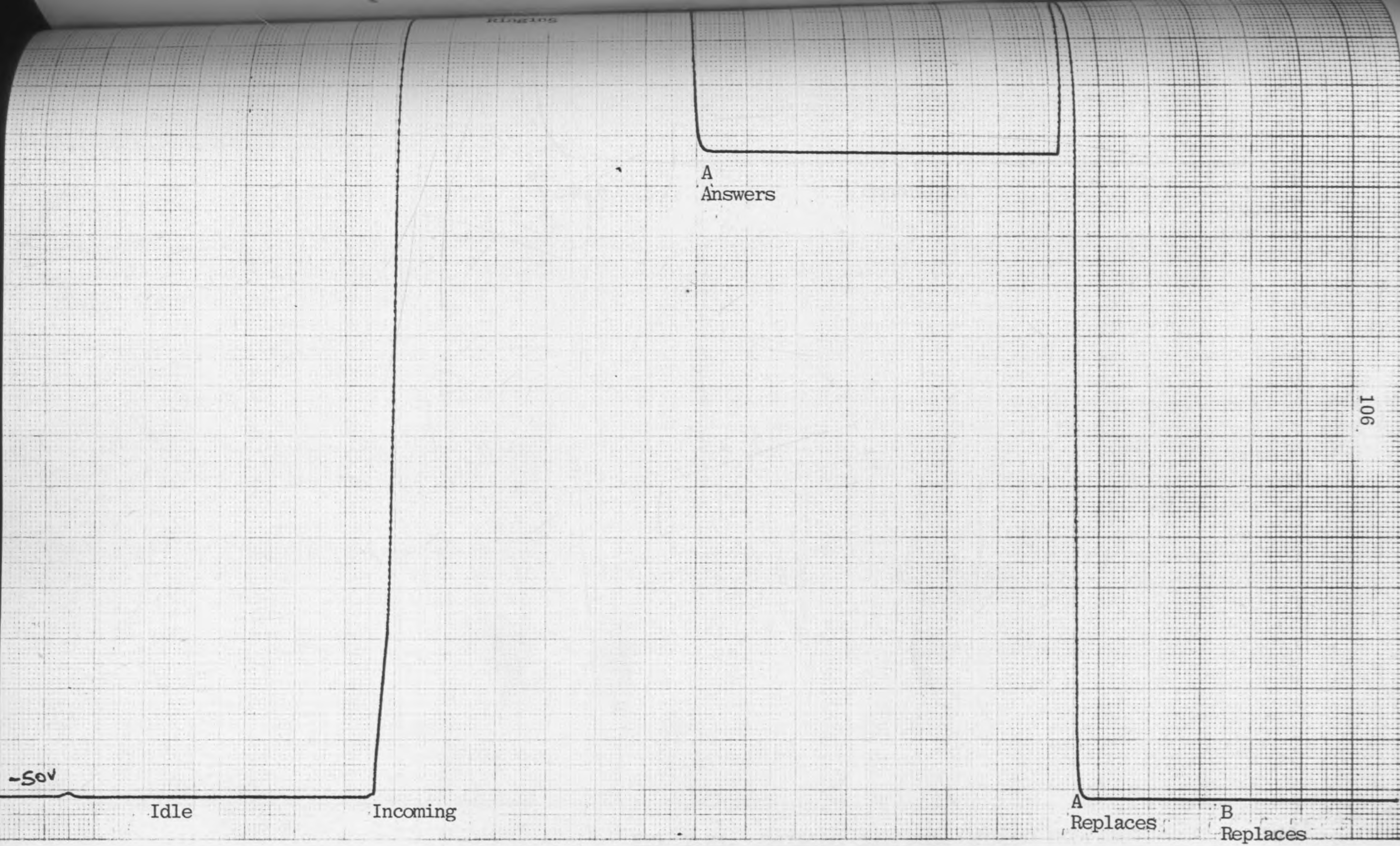


FIG. 2.63: INCOMING/A REPLACES BEFORE B

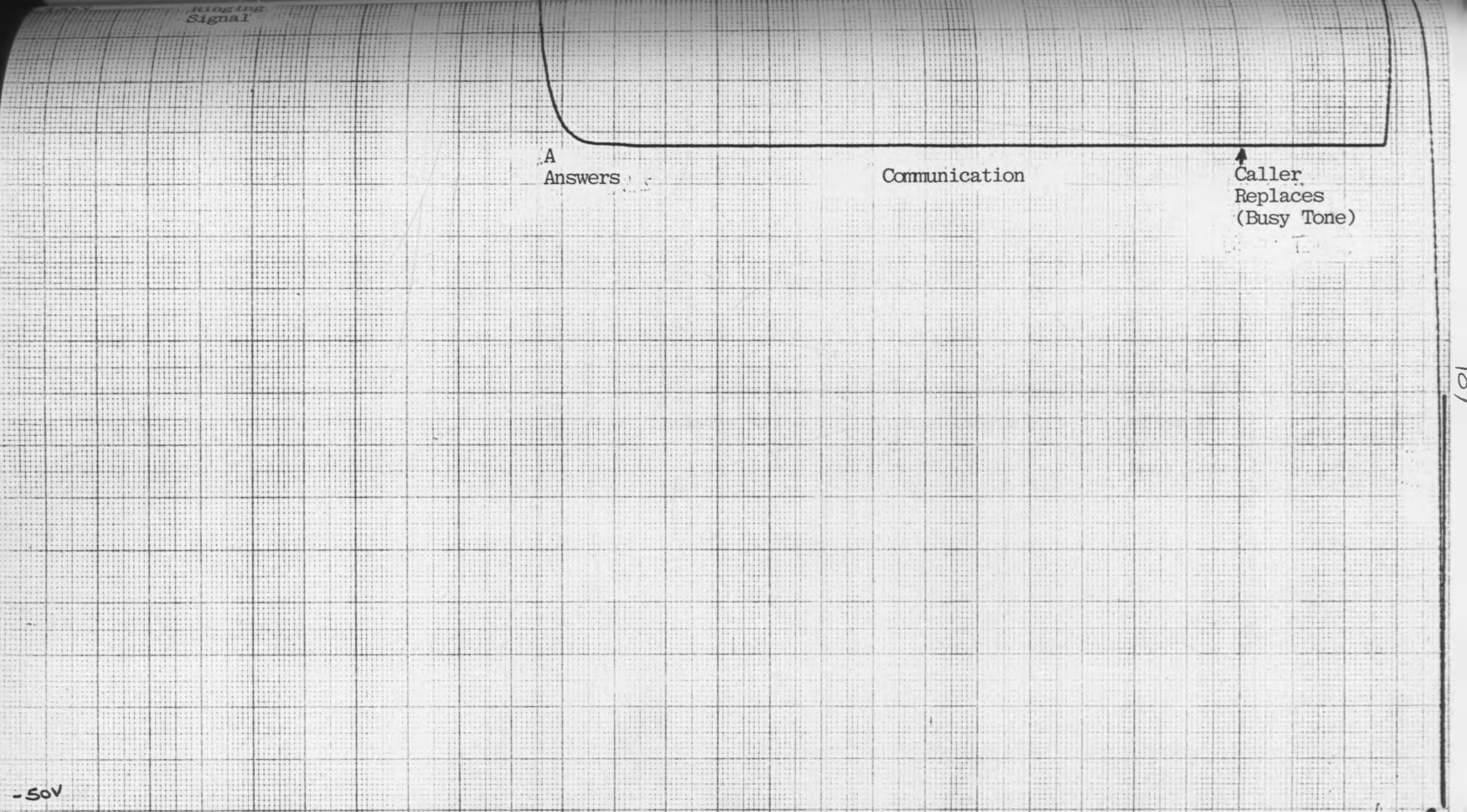


FIG. 2.64: INCOMING CALL FROM CHIROMO (EXT 239)

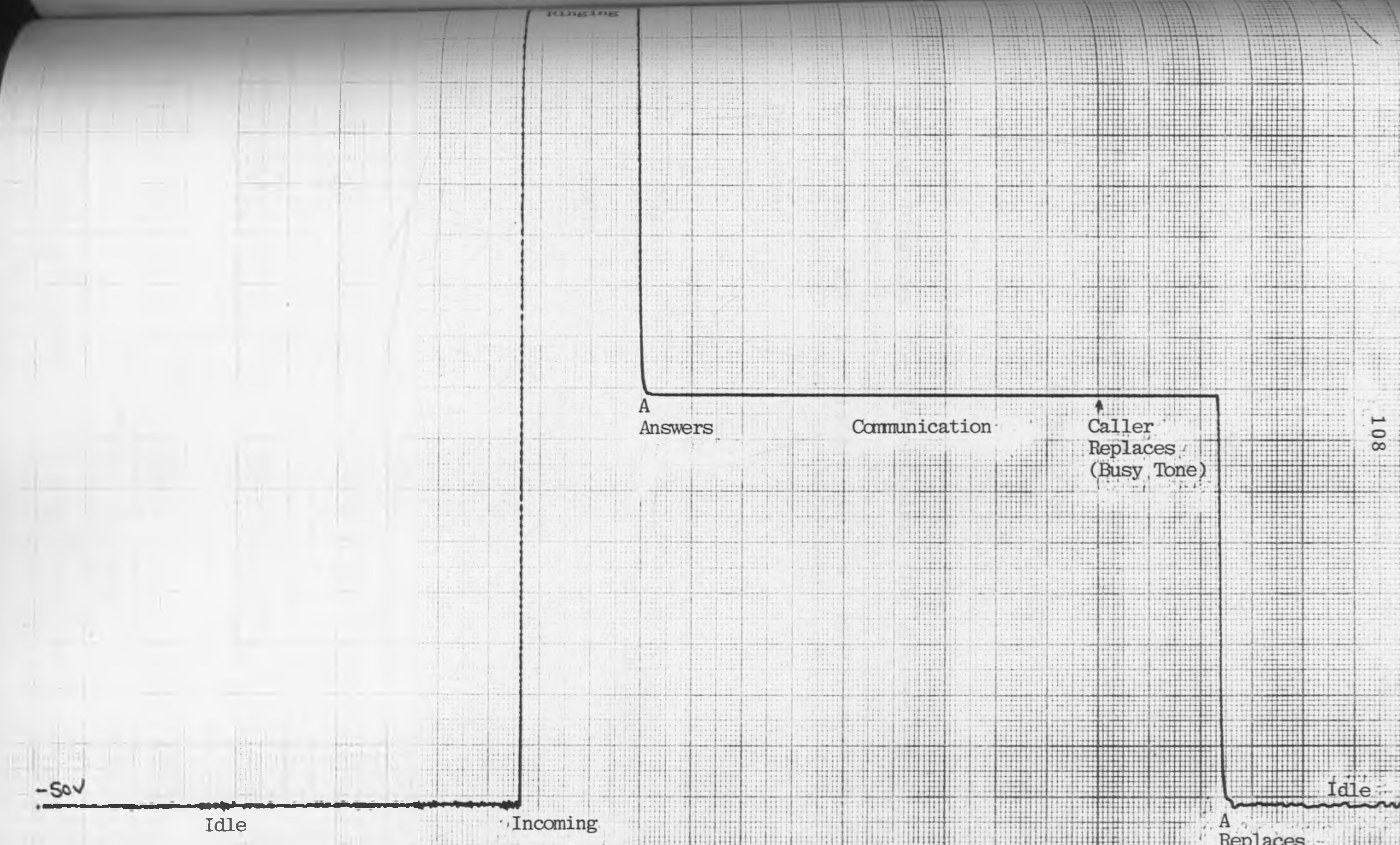


FIG. 2.65: INCOMING CALL FROM DIRECT NO. 21683 THRO' OPERATOER

APPENDIX 3A

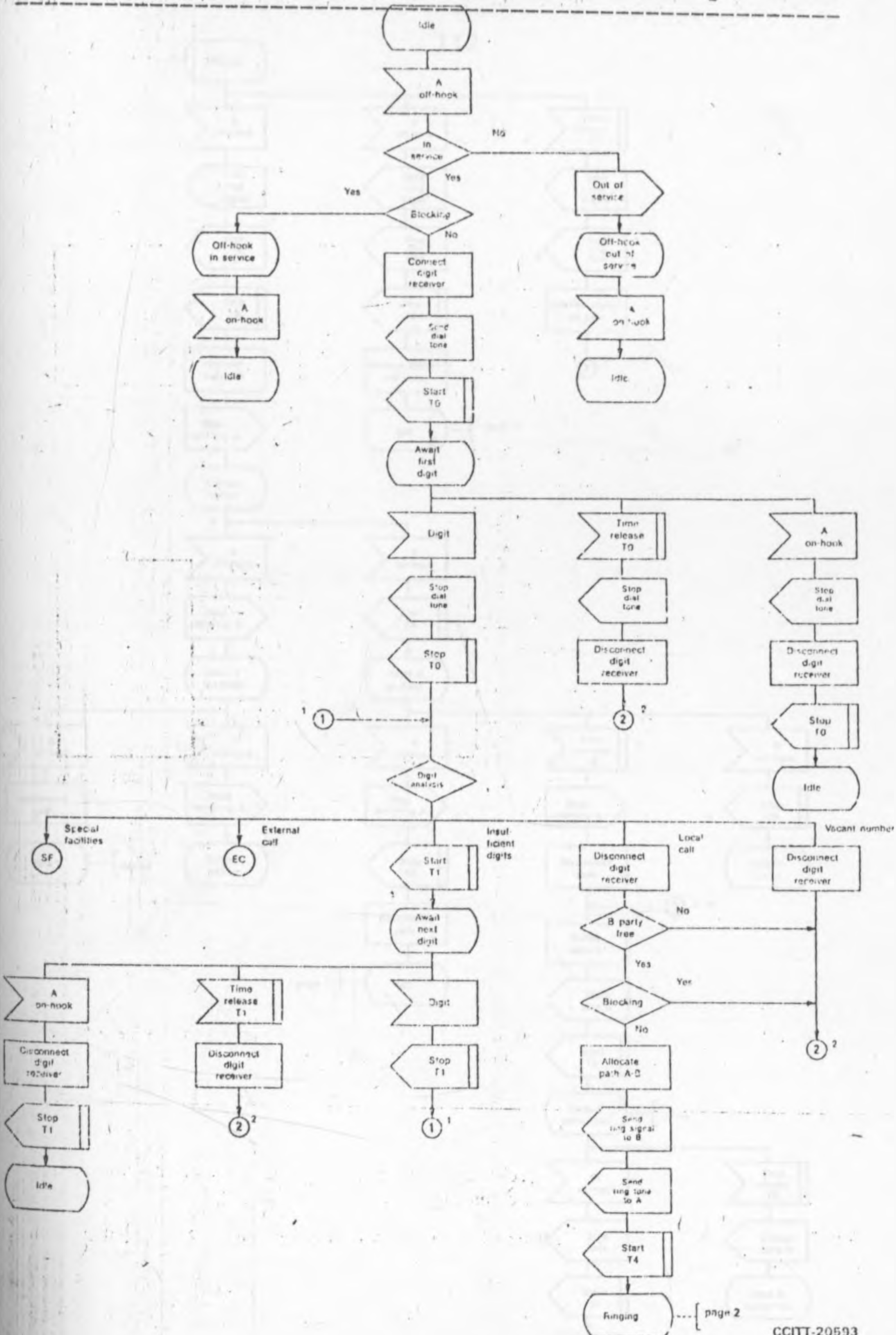
Timing Diagrams for Interfacing the Microprocessor Compatible RTC i.c 146818 to a Multiplexed bus Processor

Parameter	Conditions	Symbol	Min.	Typ.	Max.	Unit
Oscillator Startup	1MHz 4MHz	t_{RC}	–	–	100	ms
	32 kHz		–	–	1000	
Reset Pulse Width		t_{RWL}	50	–	–	us
Reset Delay Time		t_{RLH}	50	–	–	us
Power Sense Pulse Width		t_{PWL}	50	–	–	us
Power Sense Delay Time		t_{PDH}	50	–	–	us
IRQ Release from DS		t_{RDS}	–	–	20	us
IRQ Release from RES		t_{RR}	–	–	20	us
VRT Bit Delay		t_{VRD}	–	–	20	us

[REF. 11]

APPENDIX 4A

CCITT Recomended Format for Local Call Handling Process



Note – The numbers beside the connectors refer to the pages where the corresponding connectors are to be found.

FIGURE A-2 (Page 1 of 2)

Local call handling process without state pictures

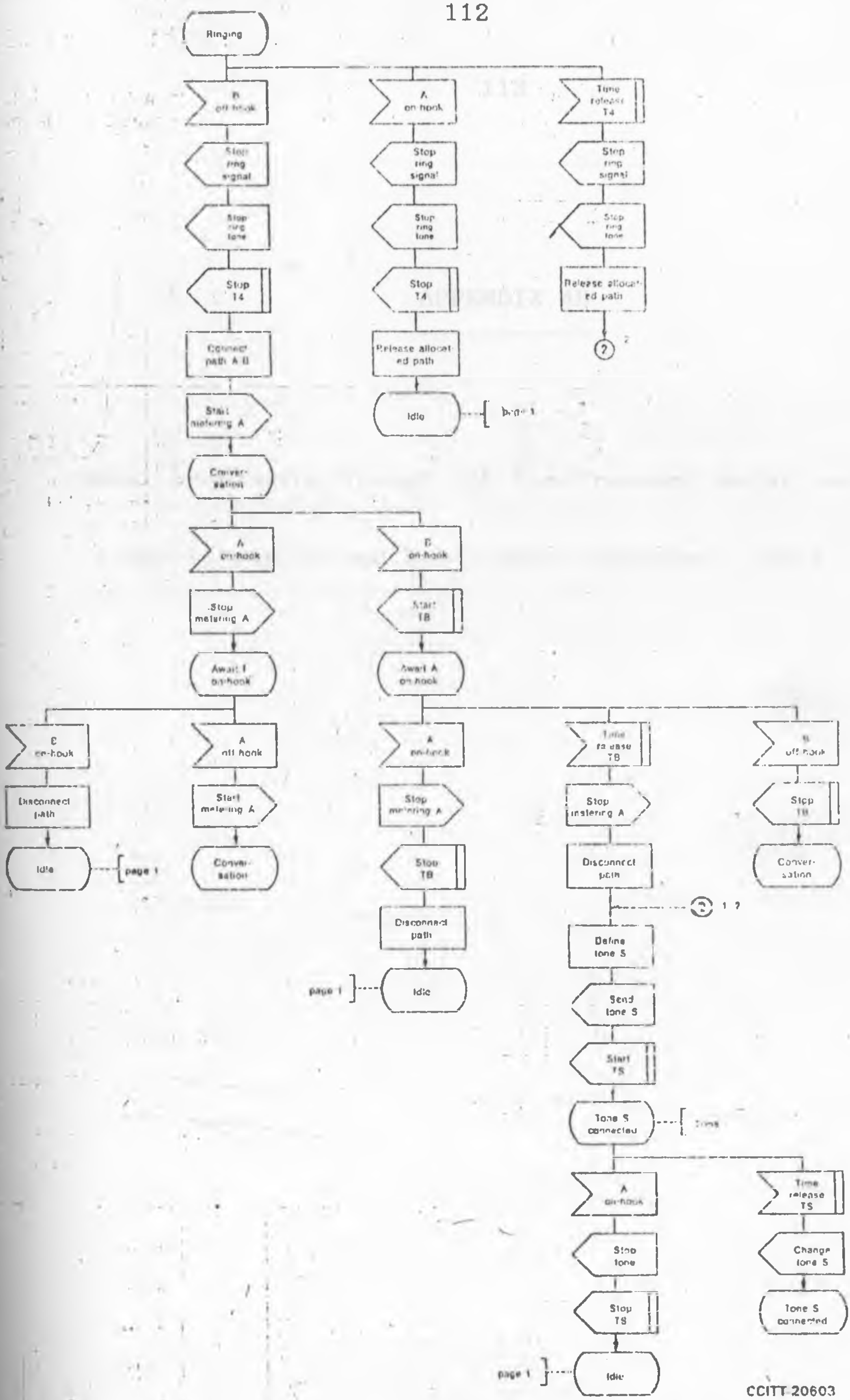
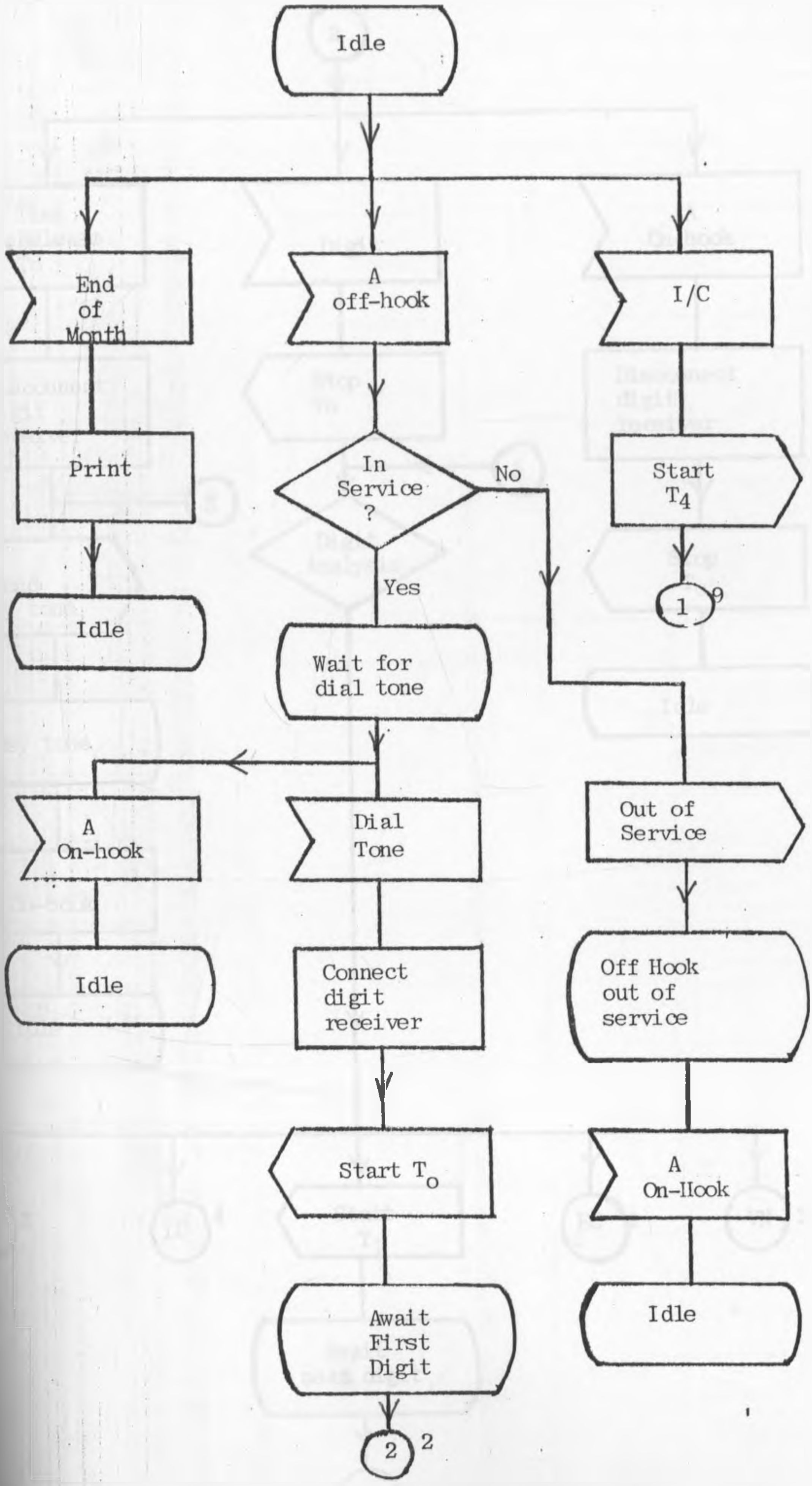


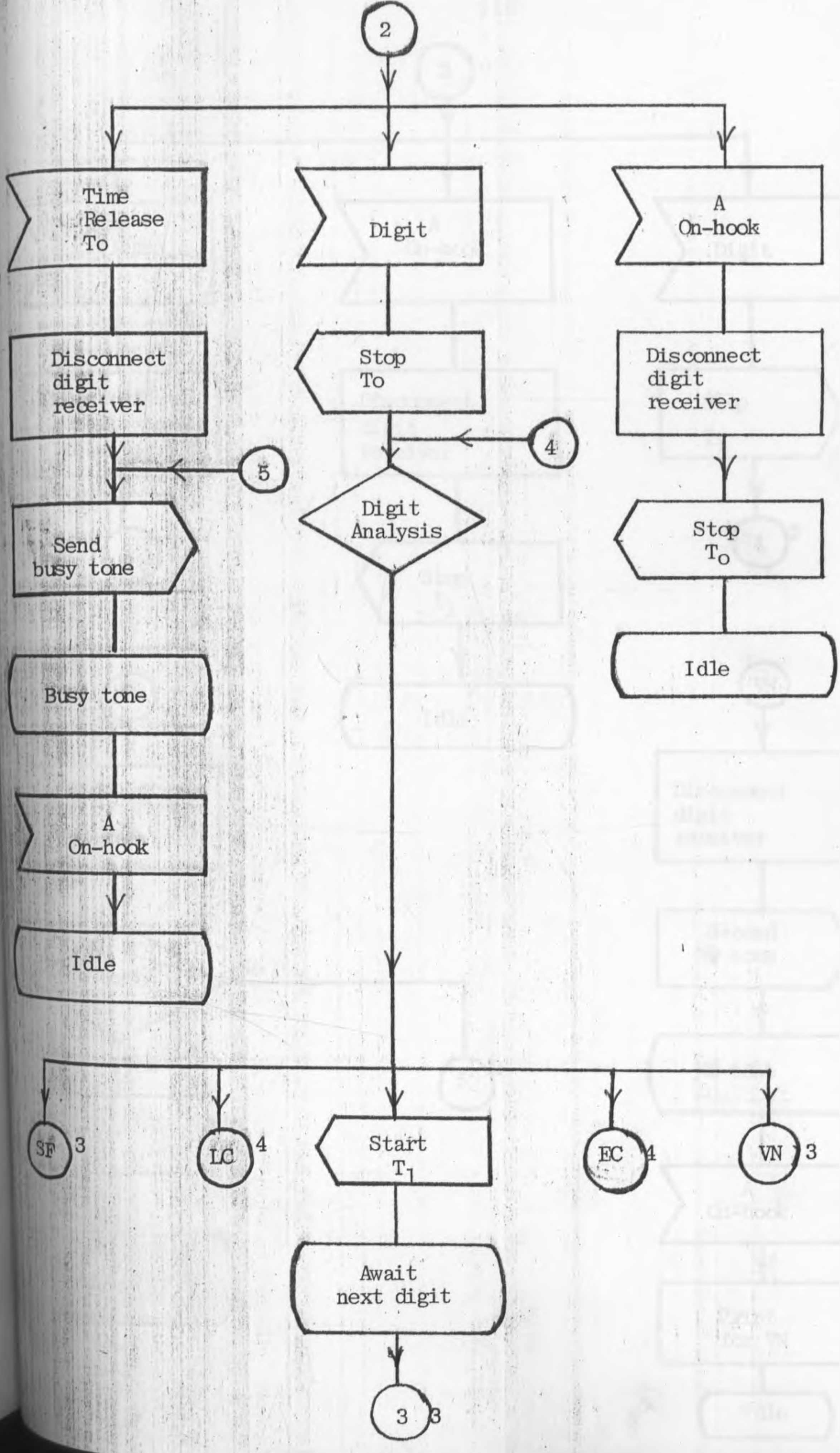
FIGURE A-2 (Page 2 of 2)

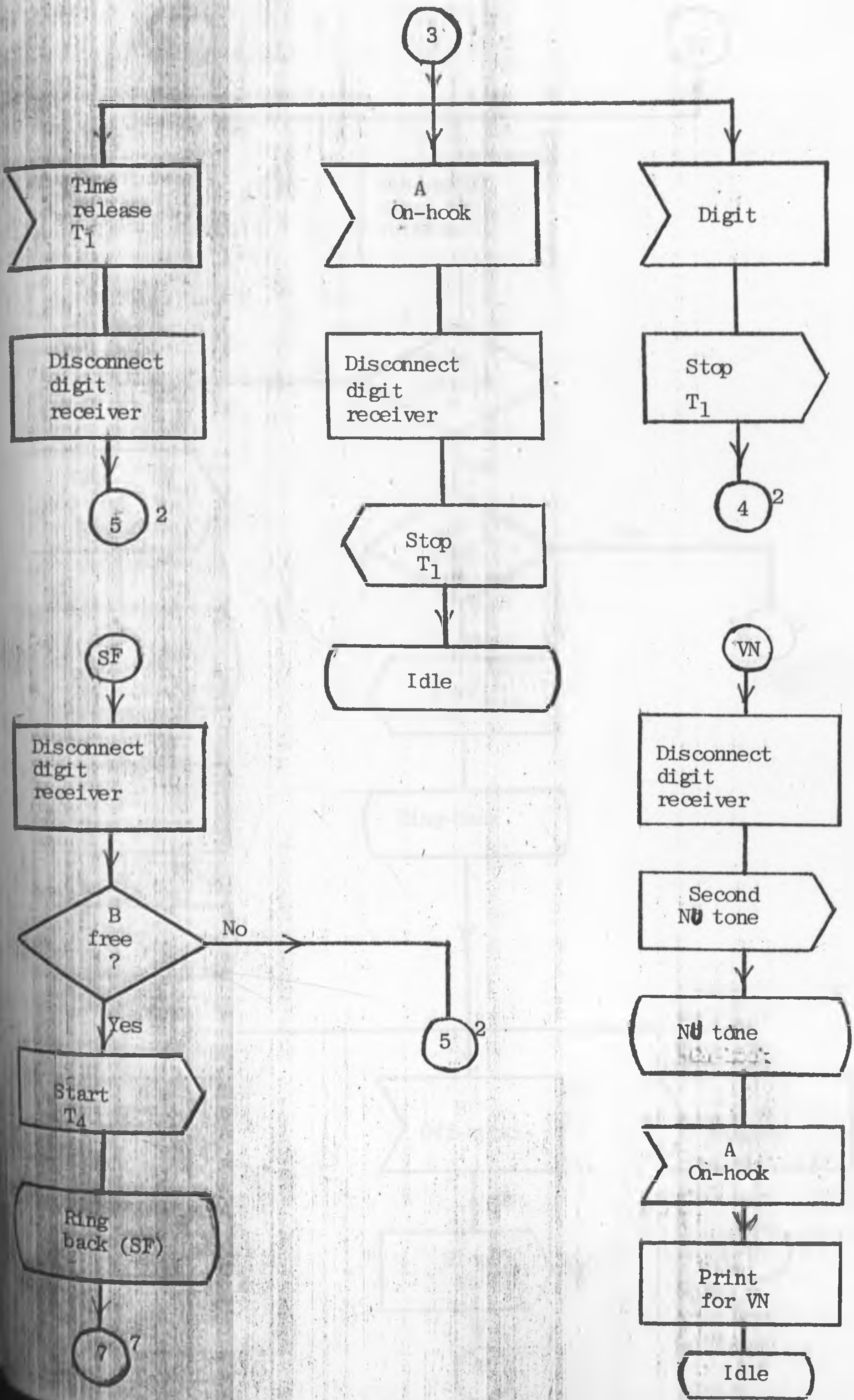
Local handling process without state pictures

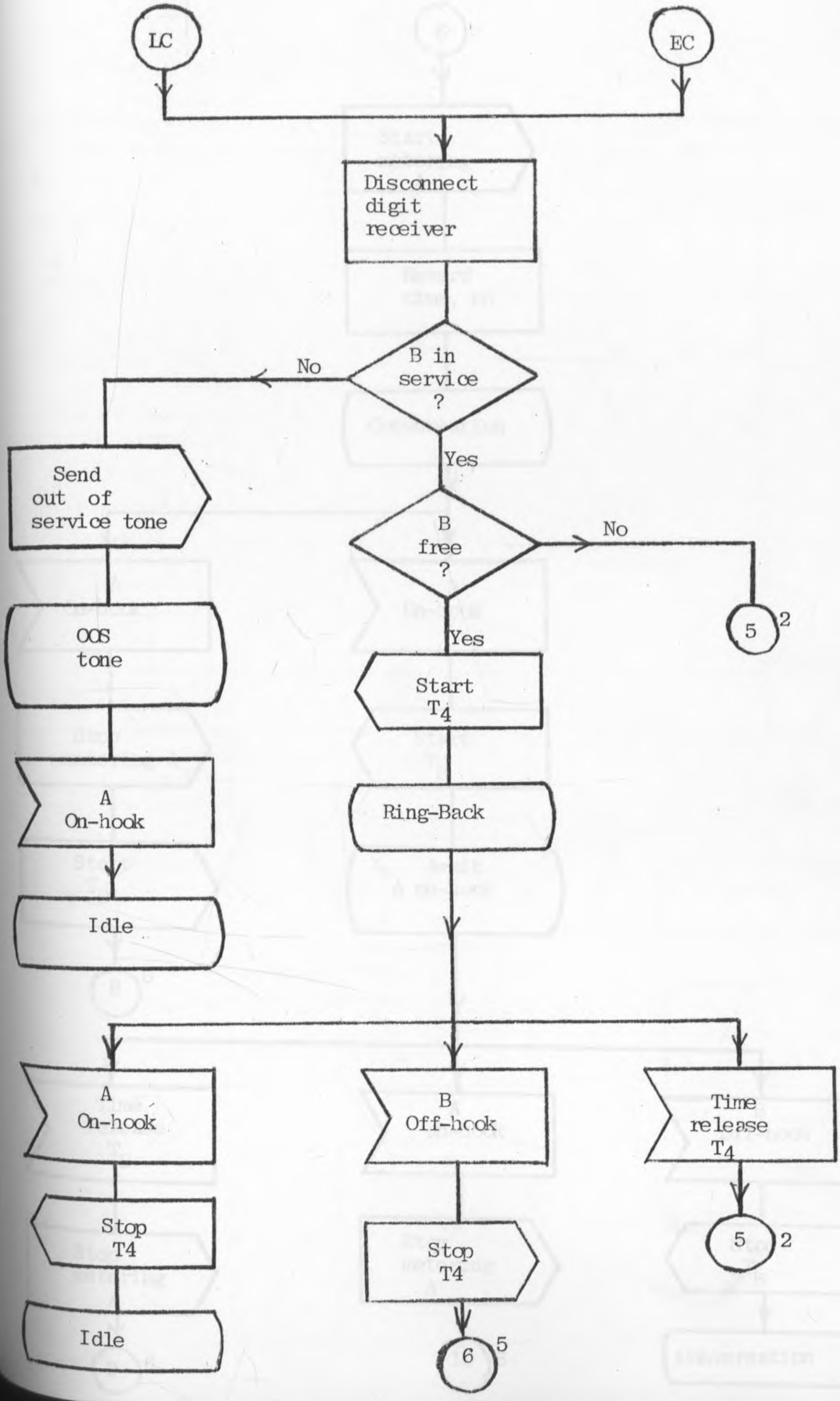
APPENDIX 4B

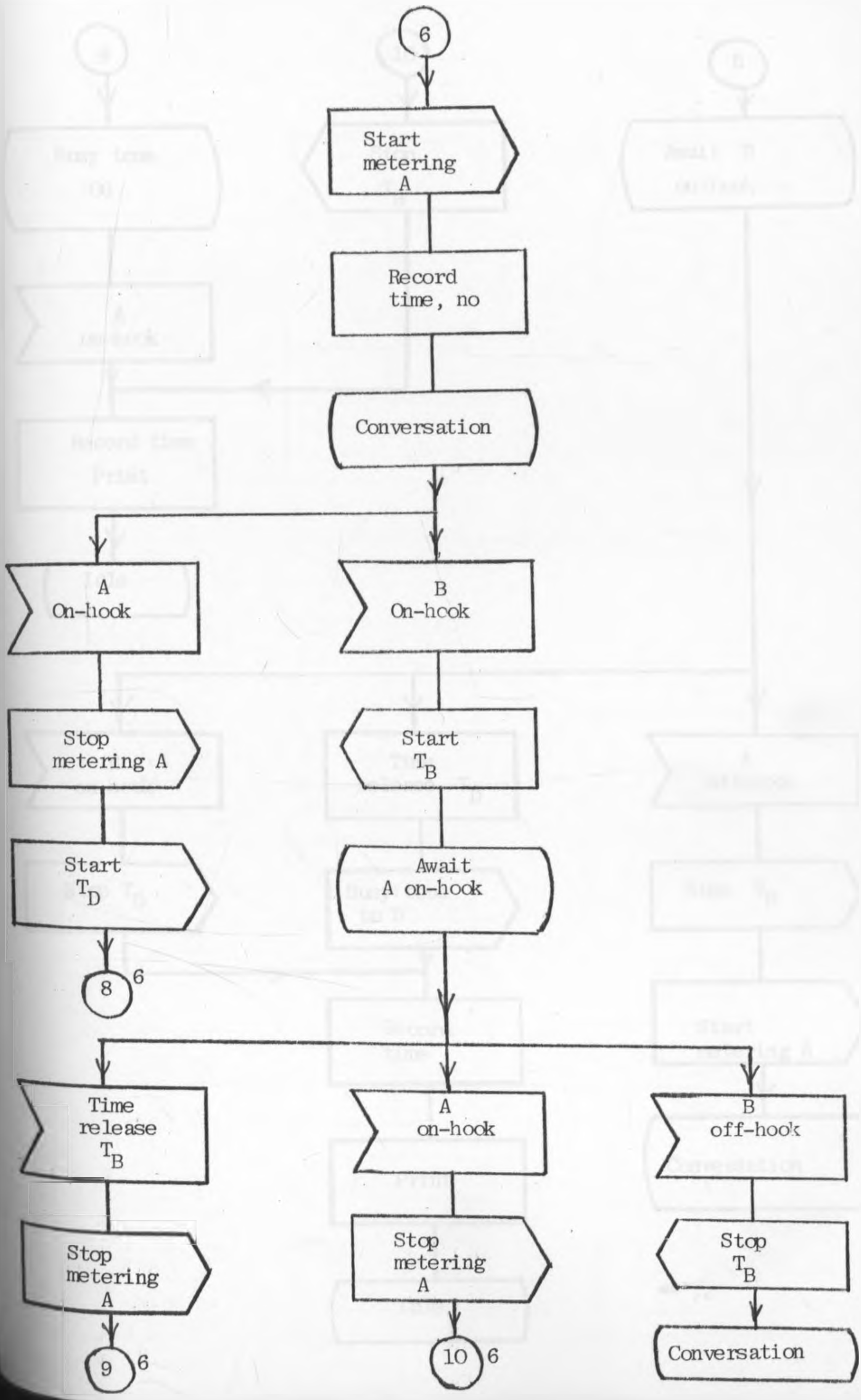
Data Processing Format for the Proposed Meter written in Specification and Description Language (SDL)

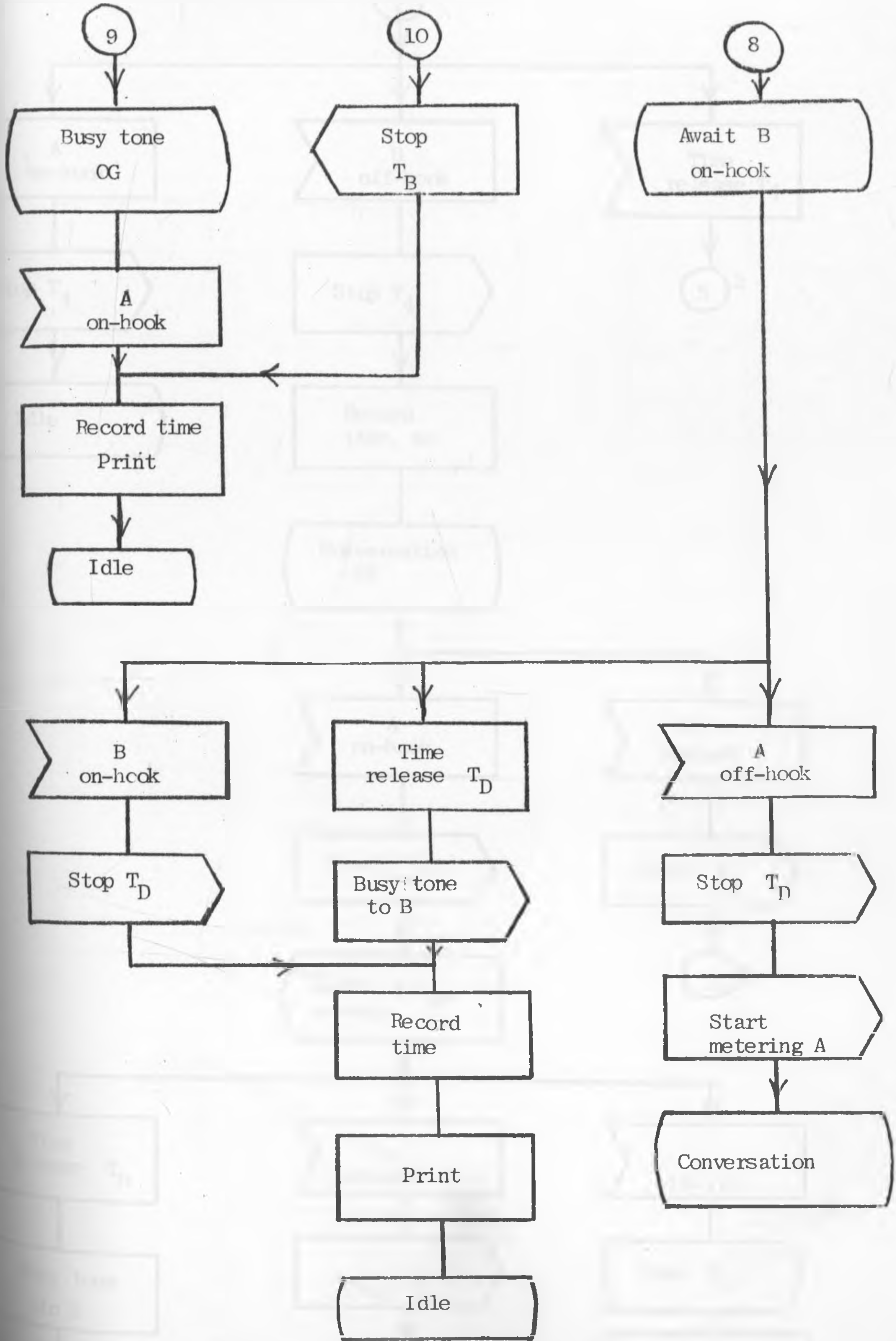

Idle
End of Month
Print
Idle
A off-hook
In Service ?
No
Yes
Wait for dial tone
A On-hook
Idle
Dial Tone
Connect digit receiver
Start T_o
Await First Digit
2
2
I/C
Start T_4
1
9
Out of Service
Off Hook out of service
A On-Hook
Idle

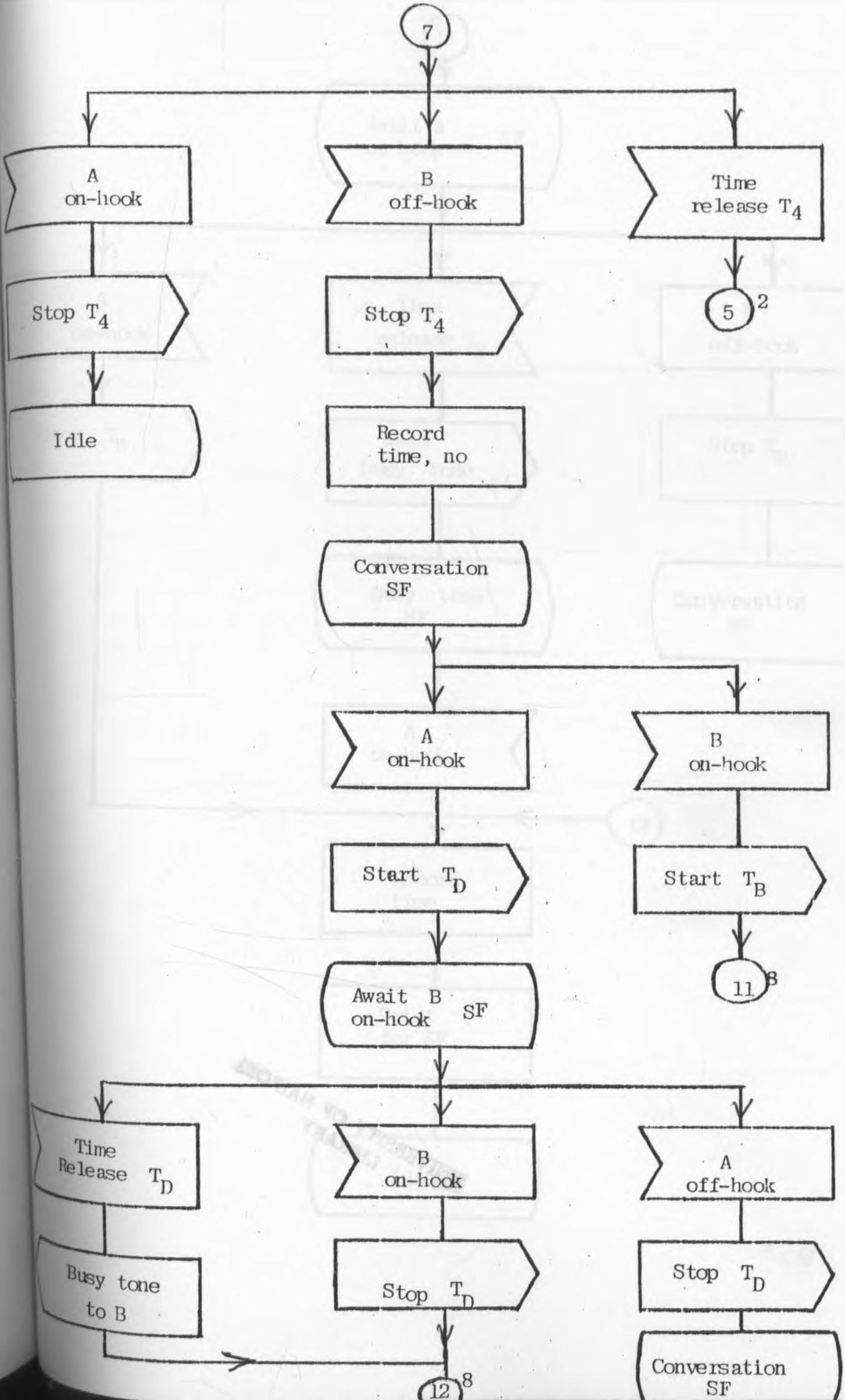

2
Time Release To
Digit
A On-hook
Disconnect digit receiver
Stop To
Disconnect digit receiver
4
5
Digit Analysis
Send busy tone
Stop T_o
Idle
Busy tone
A On-hook
Idle
SF 3
LC 4
Start T_1
EC 4
VN 3
Await next digit
3 3

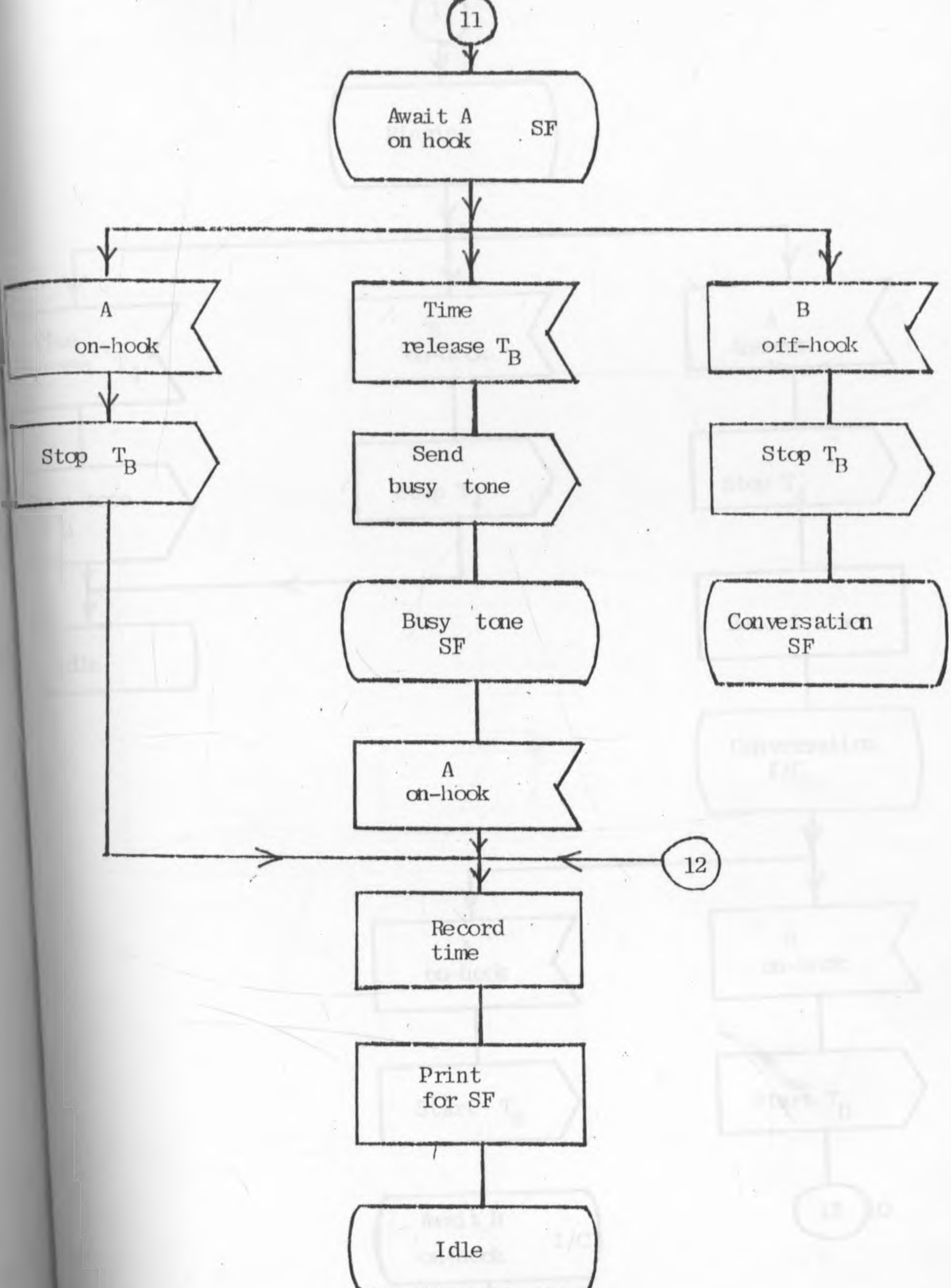

3
Time release T_1
A On-hook
Digit
Disconnect digit receiver
Disconnect digit receiver
Stop T_1
5 2
Stop T_1
4 2
Idle
SF
VN
Disconnect digit receiver
Disconnect digit receiver
B free ?
No
Yes
5 2
Second NU tone
Start T_4
NU tone
Ring back (SF)
A On-hook
Print for VN
7 7
Idle

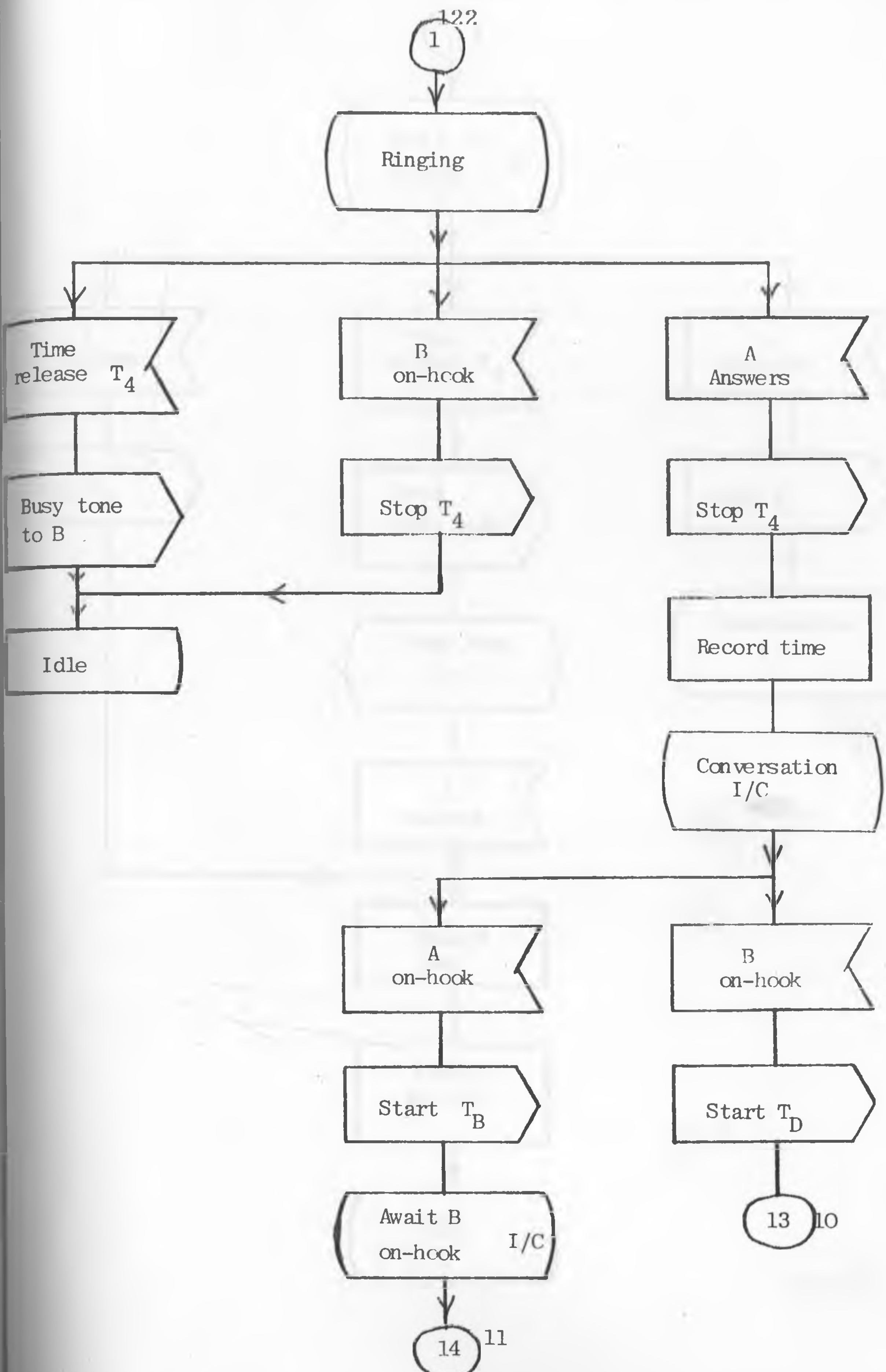

LC
EC
Disconnect digit receiver
B in service ?
No
Yes
Send out of service tone
OOS tone
A On-hook
Idle
B free ?
No
5 2
Yes
Start T_4
Ring-Back
A On-hook
Stop T4
Idle
B Off-hook
Stop T4
6 5
Time release T_4
5 2


6
Start metering A
Record time, no
Conversation
A On-hook
B On-hook
Stop metering A
Start T_B
Start T_D
Await A on-hook
8 6
Time release T_B
A on-hook
B off-hook
Stop metering A
Stop metering A
Stop T_B
9 6
10 6
Conversation

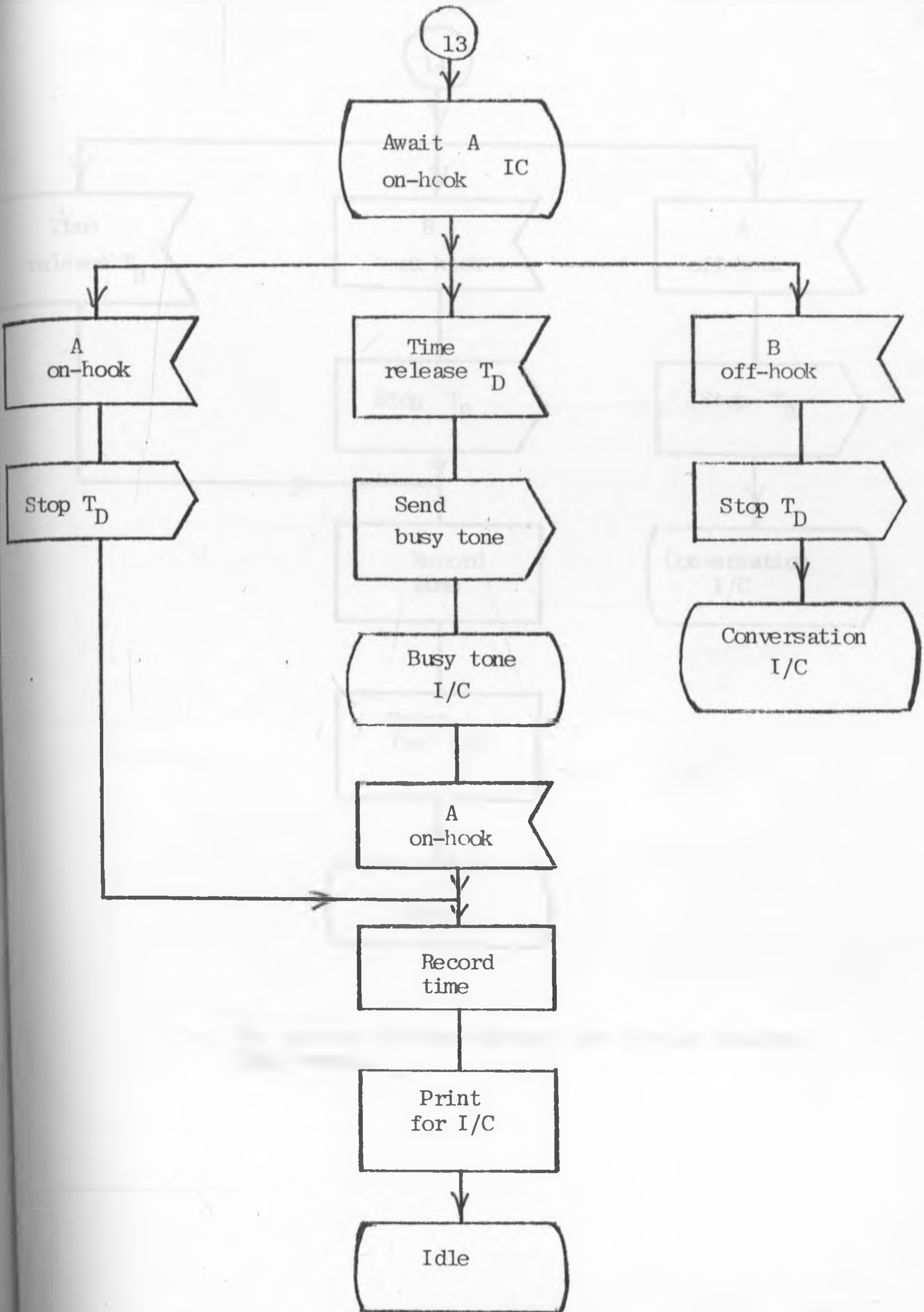

9
10
8
Busy tone OG
Stop T_B
Await B on-hook
A on-hook
Record time Print
Idle
B on-hook
Time release T_D
A off-hook
Stop T_D
Busy tone to B
Stop T_D
Record time
Start metering A
Print
Conversation
Idle

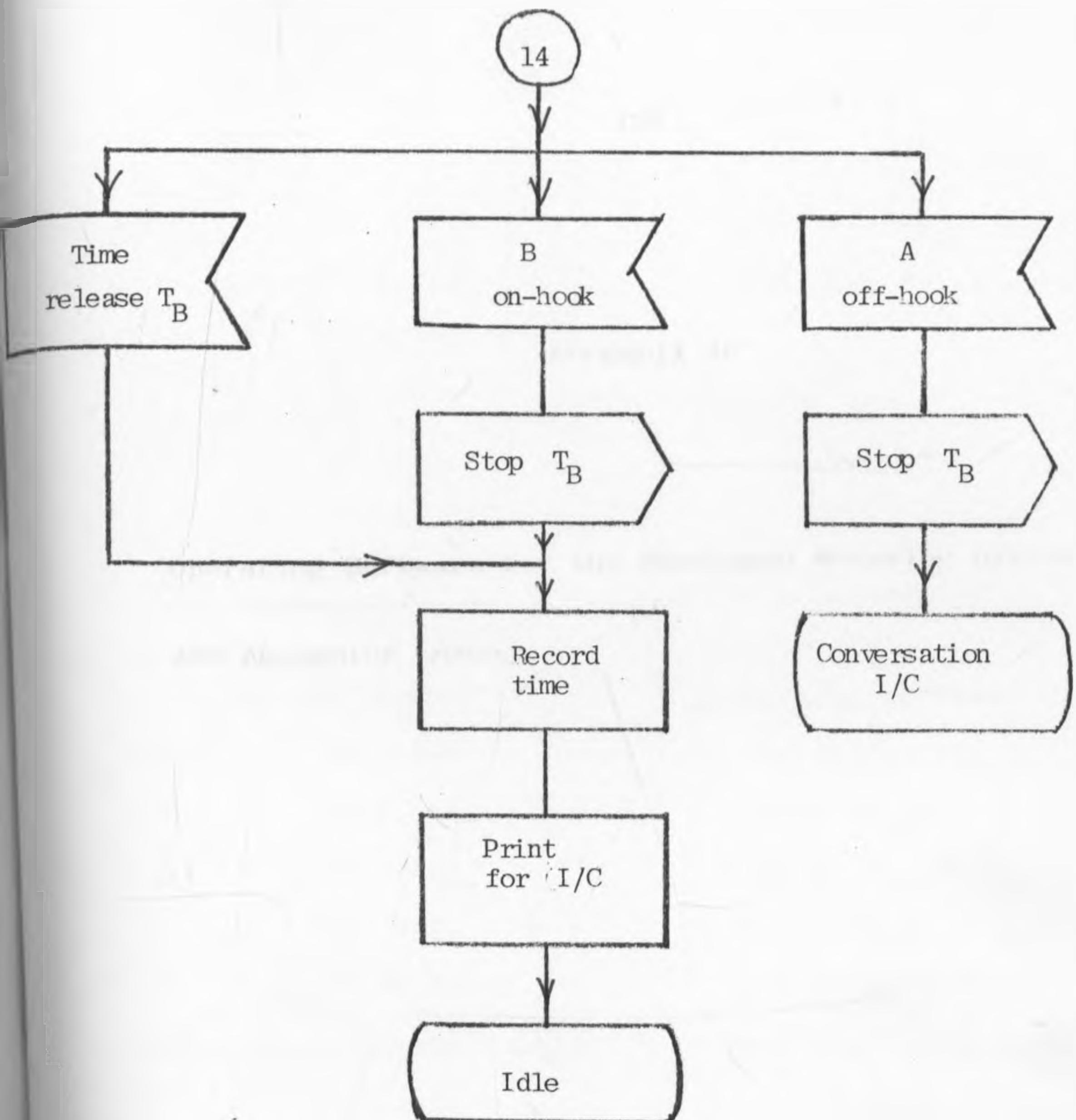

7
A
on-hook
B
off-hook
Time
release T_4
Stop T_4
Stop T_4
5
2
Idle
Record
time, no
Conversation
SF
A
on-hook
B
on-hook
Start T_D
Start T_B
11
8
Await B
on-hook SF
Time
Release T_D
B
on-hook
A
off-hook
Busy tone
to B
Stop T_D
Stop T_D
12
8
Conversation
SF


11
Await A on hook SF
A on-hook
Time release T_B
B off-hook
Stop T_B
Send busy tone
Stop T_B
Busy tone SF
Conversation SF
A on-hook
12
Record time
Print for SF
Idle



122
1
Ringing
Time release T4
B on-hook
A Answers
Busy tone to B
Stop T4
Stop T4
Idle
Record time
Conversation I/C
A on-hook
B on-hook
Start TB
Start TD
Await B on-hook I/C
13
10
14
11


13
Await A on-hook IC
A on-hook
Time release T_D
B off-hook
Stop T_D
Send busy tone
Stop T_D
Conversation I/C
Busy tone I/C
A on-hook
Record time
Print for I/C
Idle



The numbers printed against the circles indicate page number.

APPENDIX 4C

Operating Software for the Developed Metering System in Z80 Assembler Language

TELEPHONE METER

```
          ORG 4000H          ;PABX EXTENSION METERING
          LD B,0AH           ;Existing Meter Rates
          LD HL,3020H
          XOR A              ;Clear Acc.
AGAINA    LD (HL),A
          INC A
          INC HL
          DJNZ,AGAINA
          CALL PRINT         ;Background Print
NMONTH    LD C,00H           ;Initialise For New Month
START     LD B,00H           ;Clear Counter
          CALL SUBI          ;Input Line Status
          BIT 0,D            ;A Off-Hook?
          JP NZ,INCOM        ;I/C Call?
LOOP      CALL SUBI          ;1st Digit Available?
          BIT 3,D
          JP NZ,LPI
          BIT 0,D            ;A Replaced?
          JP Z,LOOP
          JP START
LPI       LD HL,300AH        ;Store 1st Digit
LPIA      CALL SUBI
          LD (HL),D
          LD E,05H           ;For Nos.Less 4 Digits
          DEC E
          INC HL
LPII      BIT 4,D            ;Next Digit Available?
```

```
            JP NZ,LPIA              ;Store Next Digit
            CALL SUBI               ;B Answered?
            BIT 2,D
            JP NZ,TIME
            BIT 0,D                 ;A Given Up?
            JP NZ,START
            JP LPII                 ;Next Digit?
TIME        CALL SUBIB              ;Record Time/Date/Month
ASCIIA      LD B,02H
            LD IX,3000H
            LD D,(IX+2)             ;1st Digit
            LD A,(IX+3)             ;2nd Digit
RPT1        BIT 0,D
            JP Z,B1
            SET 4,A
B1          BIT 1,D
            JP Z,B2
            SET 5,A
B2          BIT 2,D
            JP Z,B3
            SET 6,A
B3          BIT 3,D
            JP Z,B4
            SET 7,A
B4          DEC B
            JP Z,ANEXT
            LD (IX),A
            LD D,(IX+4)
            LD A (IX+5)
```

```
        JP RPT1
ANEXT   LD (IX+1),A
        LD A,02H            ;Special Facility?
        CP (IX+2)
        JP NZ,SUBIV         ;Emergency
        INC B               ;Count Duration
        CP (IX+3)           ;Trunk Call?
        JP NZ,MONITA
        CALL SUBIIA         ;Start Metering
        LD HL,3020H         ;Code Search
        LD A,(IX+4)
        LD IX,0814H         ;Trunk
        LD D,00H
SEARCH  CP D
        JP Z,COMM           ;Still Communicating?
        INC D
        INC HL
        JP SEARCH
COMM    CALL SUBI           ;A Replaced?
        BIT 0,D
        JP Z,AWAITB
NMETER  CALL SUBII          ;Stop Metering
        CALL SUBIA          ;Record Time/Duration/Units
        CALL SAVE           ;Print For OGL/T
        JP START
AWAITB  BIT 2,D             ;B Replaced?
        JP NZ,METER
NMET    CALL SUBII          ;Stop Meter
        CALL SUBIA          ;Read Time/Duration/Units
```

```
AWAITA    CALL SUBI          ;Printing Awaits A
          BIT 0,D
          JP Z,AWAITA
          CALL SAVE          ;Print For OGL/T
          JP START
METER     LD D,(HL)          ;Meter Rate Identified
DELAY     LD E,(HL)          ;Create Delay
LP        DEC E
          JP NZ,LP
          DEC D
          JP NZ,DELAY
          INC B              ;Step Meter
          INC C
          JP COMM
MONITA    LD IX,081BH        ;Local
MONITB    CALL SUBI          ;A Replaced?
          BIT 0,D
          JP NZ,NMETER
          BIT 2,D            ;B Replaced?
          JP Z,NMET
          JP MONITB
SUBIV     DEC E
          JP Z,D1
          XOR A
          LD (IX),A          ;Write 00 For Vacant Nos.
          INC IX
          JP SUBIV
D1        LD IX,0823H        ;Emergency
          CALL SUBI          ;A On-Hook?
```

```
            BIT 0,D
            JP Z,BWAIT
            CALL SUBIA          ;Record Time/Duration
            CALL SAVE           ;Print For SF
            JP START
BWAIT       CALL SUBI           ;B Replaced?
            BIT 2,D
            JP NZ,SUBIV
            CALL SUBIA          ;Record Time/Duration
AWAIT       CALL SUBI           ;A Replaced?
            BIT 0,D
            JP Z,AWAIT
            CALL SAVE           ;Print For SF
            JP START
INCOM       CALL SUBI           ;Incoming?
            BIT 2,D
            JP Z,EOM
            LD IX,082CH         ;I/C
INCAL       CALL SUBI
            BIT 0,D             ;A Answered?
            JP NZ,TESTB
            CALL SUBIB          ;Record Time/Date/Month
            LD B,0AH
            LD HL,3004H
            XOR A
IC          LD (HL),A           ;Zero No.Called
            INC HL
            DJNZ,IC
            CALL SUBI           ;A Replaced?
```

```
AREP      BIT 0,D
          JP Z,BREP
          CALL SUBIA        ;Record Time/Duration
          LD IY,082CH
          CALL SAVE         ;Print For I/C
          JP START
BREP      CALL SUBI         ;B Replaced?
          BIT 2,D
          JP NZ,AREP
          CALL SUBIA        ;Record Time/Duration
WAIT      CALL SUBI         ;A Replaced?
          BIT 0,D
          JP Z,WAIT
          LD IY,082CH
          CALL SAVE         ;Print For I/C
          JP START
TESTB     BIT 2,D           ;B Replaced?
          JP NZ,INCAL
          JP START
EOM       CALL SUBI         ;Month-End?
          BIT 1,D
          JP Z,START
          JP EOMI           ;Print For EOM
          RST 20H
SUBI      LD A,4FH
          OUT (06),A
          IN A,(04)
          LD D,A
          RET
```

```
SUBIA       LD A,0FH
            OUT (07),A
            LD A,02H
            OUT (05),A
            LD A,4FH
            OUT (06),A
            IN A,(04)
            LD IY,3003H
            LD (IY-1),A          ;Time Of Termination
            SUB (IY-2)
            LD (IY),A            ;Duration
            LD (IY+1),B          ;Post Units
            LD (IY+2),C          ;Accumulated Units
            RET
SUBIB       LD IY,3000H          ;Input Date
            LD B,03H
RPT2        LD A,0FH
            OUT (07),A
            LD A,02H
            OUT (05),A
            LD A,4FH
            OUT (06),A
            IN A,(04)
            LD (IY),A
            INC IY               ;Input Time
            DJNZ,RPT2
            LD (IY+11),A         ;Month
            RET
SUBIIA      LD A,0FH
```

```
        OUT (07),A
        LD A,01H
        OUT (05),A
        RET
SUBII   LD A,0FH
        OUT (07),A
        XOR A
        OUT (05),A
        RET
PRINT   LD A,54H                ;Print Background
        LD (0BD2H),A
        LD (0BF5H),A
        LD (080CH),A
        LD (084AH),A
        LD (088AH),A
        LD (090DH),A
        LD (094DH),A
        LD (09D3H),A
        LD A,52H
        LD (0BD3H),A
        LD (08CCH),A
        LD A,55H
        LD (0BD4H),A
        LD (08CBH),A
        LD (090AH),A
        LD A,4EH
        LD (0BD5H),A
        LD (0BEAH),A
        LD (0BEFH),A
```

```
LD (098AH),A
LD (090BH),A
LD (09D2H),A
LD A,4BH
LD (0BD6H),A
LD A,4CH
LD (0BD9H),A
LD (0BDDH),A
LD (0BE6H),A
LD (0BF7H),A
LD A,4FH
LD (0BDAH),A
LD (0BECH),A
LD (0BF4H),A
LD (088BH),A
LD (094BH),A
LD (098BH),A
LD (09D1H),A
LD A,43H
LD (0BDBH),A
LD (0BE3H),A
LD (0BEBH),A
LD (094AH),A
LD A,41H
LD (0BDCH),A
LD (0BE5H),A
LD (0BF6H),A
LD (080BH),A
LD A,53H
```

```
LD (0BE0H),A
LD (090EH),A
LD (094CH),A
LD A,50H
LD (0BE1H),A
LD A,45H
LD (0BE2H),A
LD (080DH),A
LD (084DH),A
LD A,49H
LD (0BE4H),A
LD (BE9H),A
LD (0BEEH),A
LD (084BH),A
LD (090CH),A
LD A,4DH
LD (0BEDH),A
LD (084CH),A
LD (09D0H),A
LD A,47H
LD (0BF0H),A
LD A,44H
LD (080AH),A
LD A,48H
LD (09D4H),A
LD A,3AH
LD (080EH),A
LD (084EH),A
LD (088CH),A
```

```
            LD (08CDH),A
            LD (098CH),A
            LD (090FH),A
            LD (094EH),A
            LD (09D5H),A
            PUSH BC
            LD BC,0190H          ;Repeat 2nd Array
            LD HL,080AH
            LD DE,0A0AH
            LDIR
            POP BC
            RET
SAVE        PUSH IX              ;CoST/Tax Calculation
            LD IX,3004H
            XOR A                ;Clear A,D,E
            LD DE,00H
            INC B                ;No. Of Units
            DEC B
            JP Z,P4
P0          ADD A,26H
            JP NC,PA
            INC E
PA          DJNZ,P0
            LD D,A
            XOR A
            BIT 7,D              ;Multiply by 15%
            JP Z,P1
            ADD A,32H
P1          BIT 6,D
```

```
            JP Z,P2
            ADD A,19H
P2          BIT 5,D
            JP Z,P3
            ADD A,0DH
P3          BIT 4,D             ;Truncated to 4 Decimal Places
            JP Z,P4
            ADD A,06H
P4          LD (IX+2),A         ;Charge/Fraction
            LD A,E
            ADC A,(IX)
            LD (IX+1),A         ;Charge
HEX         POP IX              ;Hexa/Decimal Conversion
            PUSH BC             ;Preserve Meter Reading
            PUSH IY
            PUSH IX
            LD HL,3000H         ;Source
            LD IY,0FF8H         ;Set Counter
Q0          LD DE,00H
            XOR A               ;Clear Acc.
            RLD                 ;First Digit Of (HL)
            CP 00H
            JP Z,Q2
            LD B,A
            RRD                 ;Restore A,(HL)
Q1          LD A,E
            ADD A,06H
            LD E,A
            INC D
```

```
        CALL SUBT
        DJNZ,Q1
        JP Q3
Q2      RRD              ;Restore A,(HL)
Q3      RRD              ;2nd Digit
        ADD A,E
        LD E,A
        CALL SUBT
ASCII   LD A,30H         ;ASCII Conversion
        ADC A,D
        LD D,A
        LD A,30H
        ADC A,E
        LD E,A
        LD A,30H
        ADC A,C          ;Release Meter C
        LD C,00H
        LD (IX),A        ;Screen Display
        LD (IX+1),D
        LD (IX+2),E
        LD DE,40H
        ADD IX,DE
        INC HL
        LD DE,01H
        ADD IY,DE        ;INC IY
        JP NC,Q0
        LD IY,09F4H      ;Accumulated Units
        LD DE,140H
        POP IX
```

```
        ADD IX,DE
        LD C,02H
Q9      LD B,03H
Q7      LD A,(IX)
        LD (IY),A
        INC IX
        INC IY
        DJNZ,Q7
        LD DE,3DH
        ADD IX,DE
        LD DE,140H
        POP IY               ;Charge
        PUSH IY
        ADD IY,DE
        DEC C
        JP NZ,Q9
        LD (IY+3),2EH        ;Decimal Point
        POP IY
        ADD IY,DE
        INC IY
        LD B,02H
Q10     LD A,(IX+1)
        LD (IY+3),A
        LD A,20H
        LD (IX),A            ;Erase Fractional Charge
        INC IX
        INC IY
        DJNZ,Q10
        LD (IX),A
```

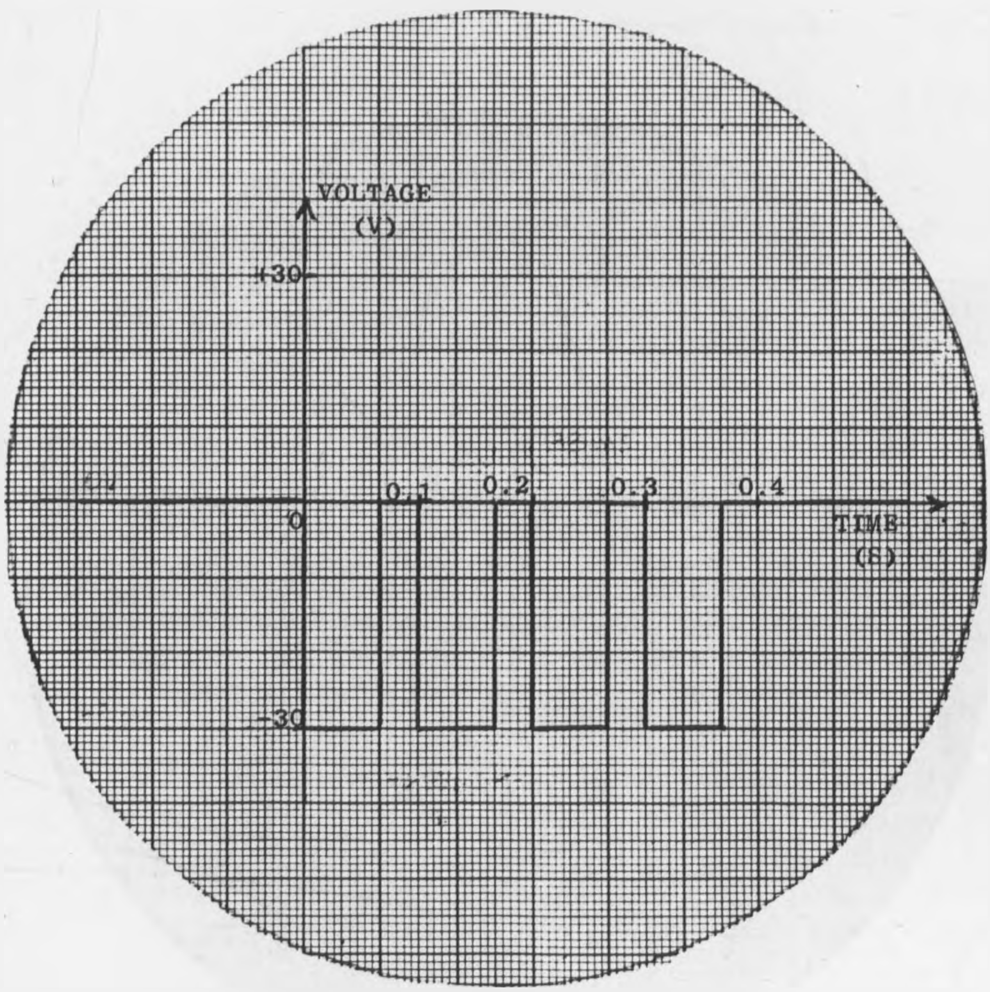
```
        LD B,02H            ;Counter
Q6      XOR A
        RLD
        ADD A,30H           ;ASCII
        LD (IX-42),A
        RRD                 ;Restore
        RRD
        LD (IX-41),A
        RLD                 ;Restore A,HL
        INC HL
        LD DE,02H
        ADD IX,DE
        DJNZ,Q6
        POP BC              ;Restore BC
        RET
SUBT    SBC A,0AH
        JP M,Q4
        INC D
        LD E,A
Q4      LD A,D
        SBC A,0AH
        JP M,Q5
        INC C
        LD D,A
Q5      XOR A
        RET
EOMI    CALL SUBI           ;Record Month
        LD (300CH),A
        LD E,A
```

```
            LD D,30H
            SBC A,0AH
            JP NC,SO
            DEC D
            LD A,E
SO          INC D
            ADD A,30H
            LD (09D7H),A
            LD A,D
            LD (09D6H),A
            JP NMONTH
```

APPENDIX 6A

Waveforms at Selected Test Points of the Constructed Unit as Seen on an Oscillograph, Superimposed against a Voltage-Time Axes Background

Fig. 6.6b: Output from Opto-isolator (Test Point (b) in Fig. 6.1a) Portraying the Dialled Digit.



Digit (4)

Fig. 6.6c: Input to Schmitt Trigger Nand (Point (c) - Fig. 6.1a) Outlining How Capacitor C2 Charges During Pulsing.

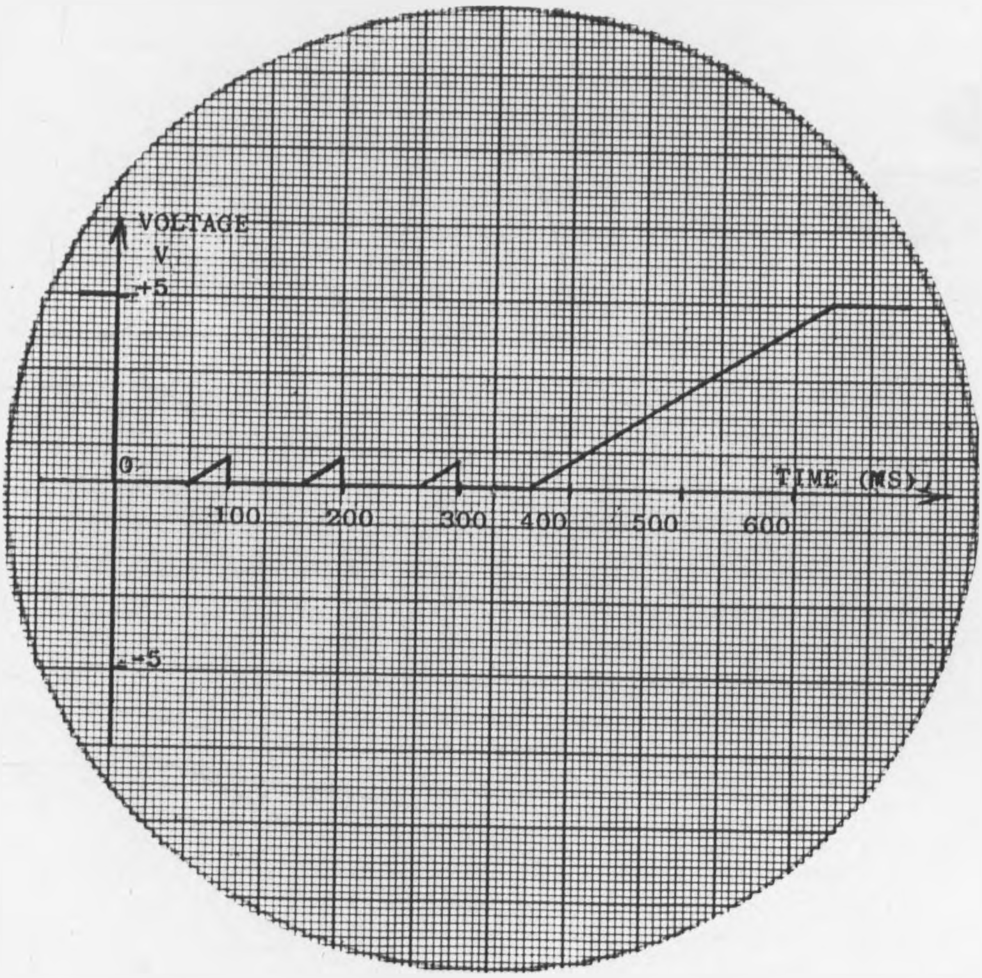


Fig. 6.6b (cont.): Succession of Two Digits Input to
"Dialled Number" Decade Counter.

<u>Fig. 6.6c: Input to Schmitt Trigger Nand (Point (c)</u>

<u>Fig. 6.1a) Outlining How Capacitor C2 Charges During Pulsing.</u>

Fig. 6.6d: Output from the Schmitt Trigger Mentioned in Fig. 6.6c.

<u>Fig. 6.6f: Negation of Signal (d) in Fig. 6.6d. Input to the "Digit Position" Decade Counter.</u>

Fig. 6.6g: "Off-Hook" Detector Output.

Fig.6.6$\bar{g}$: Negated "Off Hook" Detector Output; Reset to "Digit Position" Counter.

REFERENCES

1. Central Training School, Operations.
"Call Charging Policy".
Kenya Posts & Telecommunications Corporation.

2. Traffic Section, Central Training School.
Course: Telephone Systems : Conversation Hold Times. Section 4.2.
Kenya Posts & Telecommunications Corporation.

3. Project Engineering Deppartment, Kenya Posts & Telecommunications Corporation.
"Telephone Charging and Numbering for Kenya Telephone Exchanges (Existing & Planned)".

4. Operations Telecoms., Central Training School.
"Telephone Systems - Manual Switching". Section 7,
Kenya Posts & Telecommunications Corporation.
PP. 29-33.

5. Telephone Sales, K.P.& T.C.
The Kenya Telephone Directory - 1986.
PP.1-27.

6. Traffic Engineering, K.P.& T.C.
"Some Recording Principles Applied in Time Zone Metering". Chapter 3.

Kenya Posts & Telecommunications Corporation.

7. Project Engineering, K.P.& T.C.
"Electrical Characteristics of The Telephone Network". Sections (a) & (c).
Kenya Posts & Telecommunications.

8. Traffic Section, Central Training School, K.P.& T.C
Course 1029/1, Chapter 2.
"Telephone Systems - Types of Telephones".
Kenya Posts & Telecommunications Corporation.

9. Project Engineering, K.P. & T.C.
"Specification No. TP1-A For Decadic Pulse Push-button Telephone Sets For Use With Automatic Exchanges".
Kenya Posts & Telecommunications Corporation.

10. Jules H. Gilder.
More Telephone Accessories You Can Build .
Hayden Book Company, Inc.
PP. 3-12. PP. 23-28. PP. 34-37. PP. 75-123.

11. RS Data Sheet No. 4945 issued Nov. 1983.
Microprocessor Compatible Real Time Clock i.c 146818
Stock No. 302-003.
RS Components Ltd.

12. CCITT Yellow Book No. VI, Fascicle VI.7 Recommendation Z.101 :- General Explanation of the Specification and Description Language (SDL). International Telegraph & Telephone Consultative Committee (CCITT). PP. 15-28.

13. RS Data Sheet No. 4951 issued July 1984. Miniature Dot Matrix Impact Printer System Stock Nos. 301-959, 301-965, 301-971. RS Components Ltd.

14. RS Data Sheet No. 4787 issued July 1983. Eight digit Triplexed LCD Driver i.e 7231A Stock No. 302-514. RS Components Ltd.