AFCRL-62-911

Investigation of Speech Processing Studies

VOICE DATA PROCESSING SYSTEM

D. M. Early
H. A. Straight
O. C. King

MELPAR, INC.
3000 Arlington Boulevard
Falls Church, Virginia

Contract No. AF19(628)-214
Project No. 4610
Task 461002
Scientific Report No. 1

October 1962

Prepared for

ELECTRONIC RESEARCH DIRECTORATE
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AREOSPACE RESEARCH
LAURENCE G. HANSCOM FIELD
Bedford, Massachusetts

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FOREWORD

This report was prepared by Melpar, Inc., 3000 Arlington Blvd., Falls Church, Virginia, on Air Force Contract AF19(628)-214, under Task No. 461002 of Project No. 4610, "Investigation of Speech Processing Studies." The work was administered under the direction of Mr. Caldwell P. Smith, CRRSS, Chief of the Digital Voice Communication Branch, Electronics Research Directorate, Air Force Cambridge Research Laboratories, (OAR) Laurence G. Hanscom Field, Bedford, Massachusetts.

Efforts under this contract were initiated during September 1961 and this report covers work performed under its provisions through September 1962. The work was performed by the Communication Department of Melpar, Inc. Major contributors of the work and to the preparation of this report include D.M. Early, H.A. Straight, and O.C. King.

This report is unclassified.

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LIST OF ILLUSTRATIONS

ABSTRACT

This report contains the results of an Investigation of Speech Processing Studies covering the period from September 1961 to September 1962. This investigation has been responsible for the continued updating of the capability and flexibility of the Voice Data Processing System in an attempt to maintain optimum compatibility between the processor and the research effort for which it was intended. (The Voice Data Processing System was designed and developed for the United States Air Force under Contract AF19(604)-5579 to support research on digital voice communication and evaluation of a speech bandwidth compression technique). Changes such as automatic consolidation of "number of occurrences" and "cumulative amplitude" inputs from rank ordered tapes, use of the approximation logic for 1 and 2, as well as 3-bit spectrum pattern coding, and separation of rank ordered data into tables of voiced and unvoiced patterns have been successfully incorporated in the processor. This report also contains the results of a study to determine the optimum operating environmental for the equipment complex. The appendices include a Definition of Terms, the System Operating Instructions, and the results of a study of the Evaluation of Reliability with Respect to Thermal Environment for the Voice Data Processing System.

1. INTRODUCTION

In the design of relatively complex special purpose data processing equipments which are to be used in the laboratory in programs of research, it is often impossible to initially anticipate all facets of the impending program. This is due to the very nature of basic research -- the analyst is very often guided by the results of preceding experiments. Therefore, in the conduct of programs utilizing such data processing systems, it is not unusual that the need for modifications and additions should become apparent. It was anticipated that this would be the case with the Voice Data Processing System[1]. Therefore, a program was initiated which was to assure continued compatibility between the processor, the speech analyzer[2]; and the research effort. A substantially increased and complemented processing capability has resulted from a number of changes in the processor which have been made thus far in this program.

The Voice Data Processing System was designed, developed and fabricated by Melpar, Inc., on Air Force Contract AF19(609)-5579, under Task No. 461002 of Project No. 4610, "Design, Development and Fabrication of a Voice Data Processing System." The work was administered under the direction of Mr. Caldwell P. Smith, CRRSS, Chief of Digital Voice Communication Branch, Electronic Research Directorate, Air Force Cambridge Research Laboratories (OAR) Laurence G. Hanscom Field, Bedford, Massachusetts.

A study of the operating environment of the equipment complex was conducted and a specification of the optimum operating environs, consistent with reliability, efficiency, and protection of the equipments was established and implemented. During the installation of the equipments necessary to achieve the desired operating environment, intrinsic noise and vibration were minimized where practical and possible.

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1. Final Report, AFCRL-62-314, "Design and Development of a Digital Voice Data Processing System," Contract AF19(604)-5579, Melpar, Inc. (1962). Scientific Report No. 3, AFCRL-62-719, "Speech Data Processing in Real Time," Contract AF19(604)-5579, Melpar, Inc. (1962).

2. Final Report, AFCRL-62-67, "Analog/Digital Multiplex Equipment for Voice Signal Processing," Contract AF19(604)-8042, Epsco, Inc. (1962).

2. SYSTEM REFINEMENTS

"The contractor shall . . . study and evaluate statistics for implications with regard to speech compression techniques and logic design."

Statement of Work
Contract No. AF19(628)-214

During the course of the investigation being conducted by the Digital Voice Communication Branch of AFCRL, the statistical information gathered was carefully studied. The ultimate goal was to determine the implications of these data with regard to speech compression and processing techniques. Based on this continuing study, it became apparent that certain modifications in the processor were necessary if optimum compatibility with the research effort was to be maintained. As the need for each change became apparent, all aspects of the new function were carefully studied in order to, (1) avoid possible conflict with existing programs; and, (2) take full advantage of existing logical functions and subroutines. Once the correct approach was determined the optimum implementation considering both logic design and computer down time was established and subsequently incorporated.

During the initial planning of the Voice Data Processing System, design criteria were formulated for the various processing centers of the system. In part, these criteria established a programming method which, though fixed wired, could be readily modified to include new functions. Because of this design philosophy it was found that modifications in existing programs and the addition of new programs could be made with nominal rework and with an extremely high degree of confidence.

The changes which have been made in the system vary widely in complexity and nature and are categorized as follows:

a. Program for new modes.

1. Print and/or punch out of pattern data in order of increasing pattern address.

2. Manual accumulation of speech data from the vocoder multiplex.

b. Augment existing logical functions.

1. Automatic consolidation of "number of occurences" and recomputation of "cumulative amplitude" data items from rank ordered tapes.

2. Console preset of pattern count.

3. Separation of rank ordered data into tables of voiced and unvoiced patterns.

4. Exclusion of voicing bit comparision as a prerequisite to a valid pattern approximation.

5. Provisions for 1, and 2, as well as 3 bit spectrum pattern coding.

6. Direct transfer of input pattern to the demultiplexer.

7. Selective recording of voicing bit.

8. Parallel decimal display of voice pitch, pattern address, pattern count, and record/reproduce count.

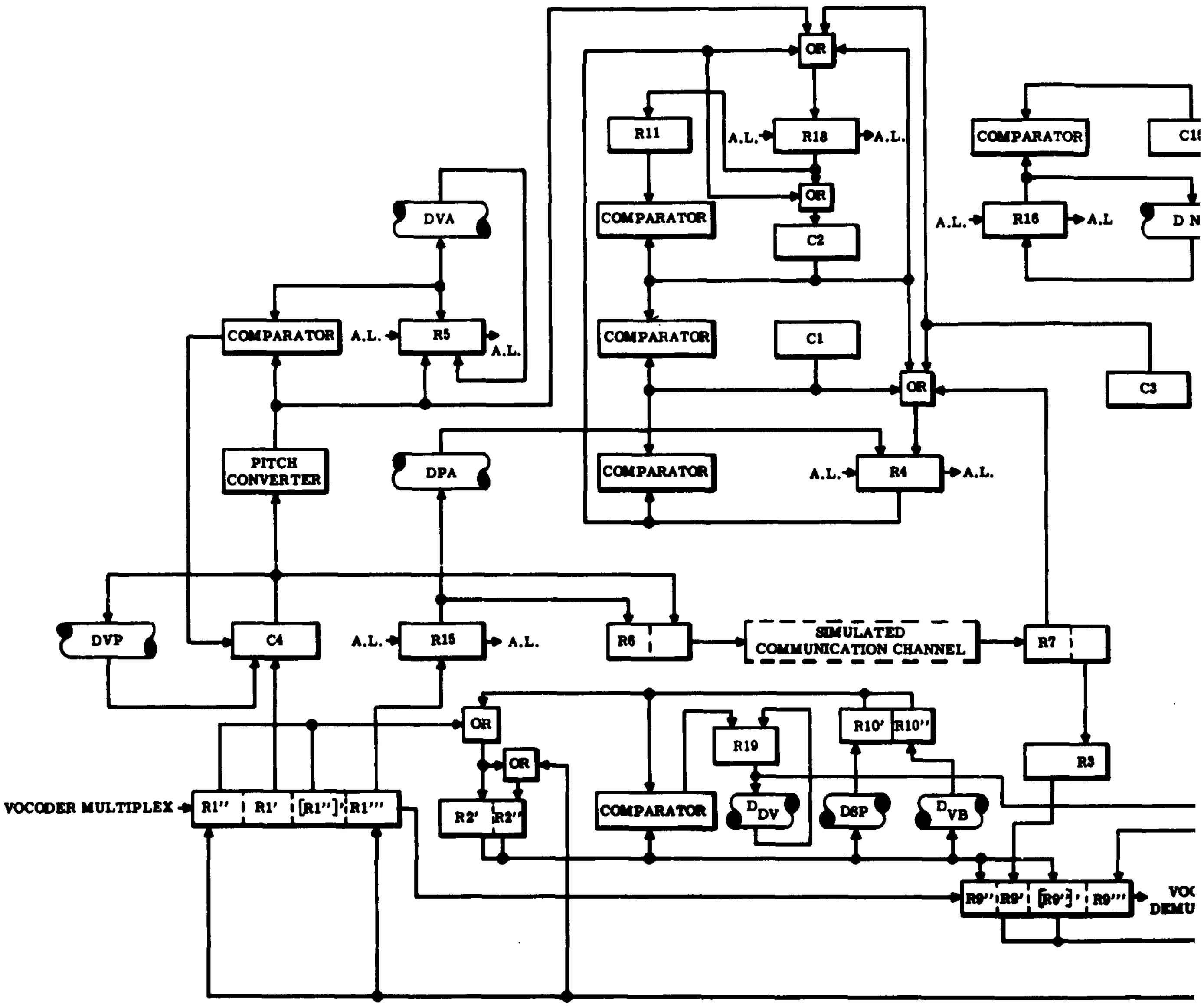
c. Processing of the pattern deviation value.

Each modification will be considered in detail in the following sections.

The detailed system block diagram and the detailed system flow charts as amended by these changes are shown in figures 1 through 5. No attempt will be made to correlate the system modifications with these figures since it would be extremely tedious and of little practical value. The figures are included only to reflect the current design of the Voice Data Processing System.

2.1 Programs for New Modes

Two new fixed wired programs have been added to the capability of the Voice Data Processing System. Although both programs are new, the information to be processed and the logical functions required in the processes existed prior to the modifications and required only that they be properly programmed.


OR
R11
A.L.
R18
A.L.
COMPARATOR
C1
OR
COMPARATOR
C2
DVA
A.L.
R16
A.L
D N
COMPARATOR
A.L.
R5
A.L.
COMPARATOR
C1
OR
C3
PITCH CONVERTER
DPA
COMPARATOR
A.L.
R4
A.L.
DVP
C4
A.L.
R15
A.L.
R6
SIMULATED COMMUNICATION CHANNEL
R7
OR
OR
R19
R10'
R10''
R3
VOCODER MULTIPLEX
R1''
R1'
[R1'']'
R1'''
R2'
R2''
COMPARATOR
D_{DV}
DSP
D_{VB}
R9''
R9'
[R9']'
R9'''
VOC
DEMU

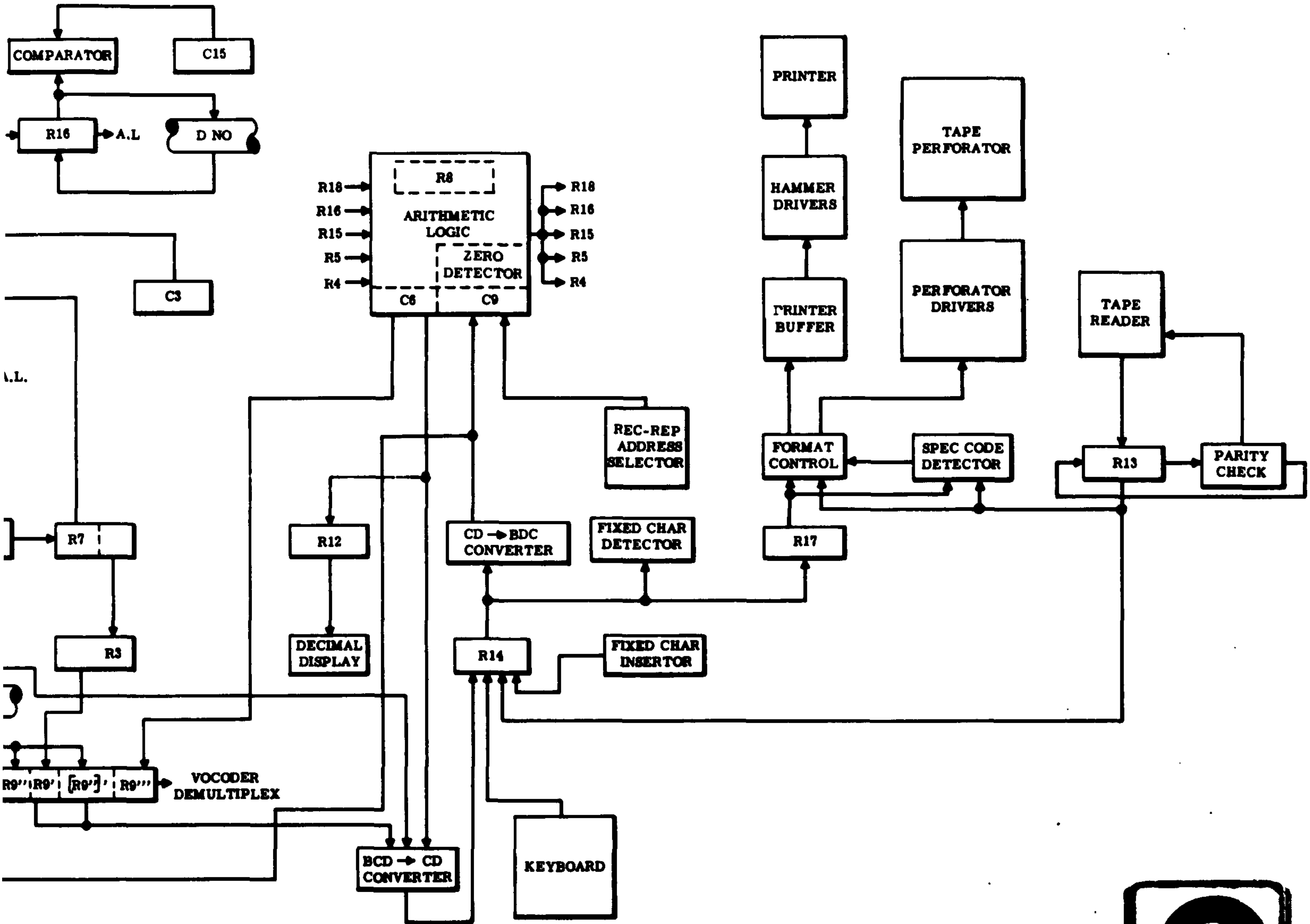
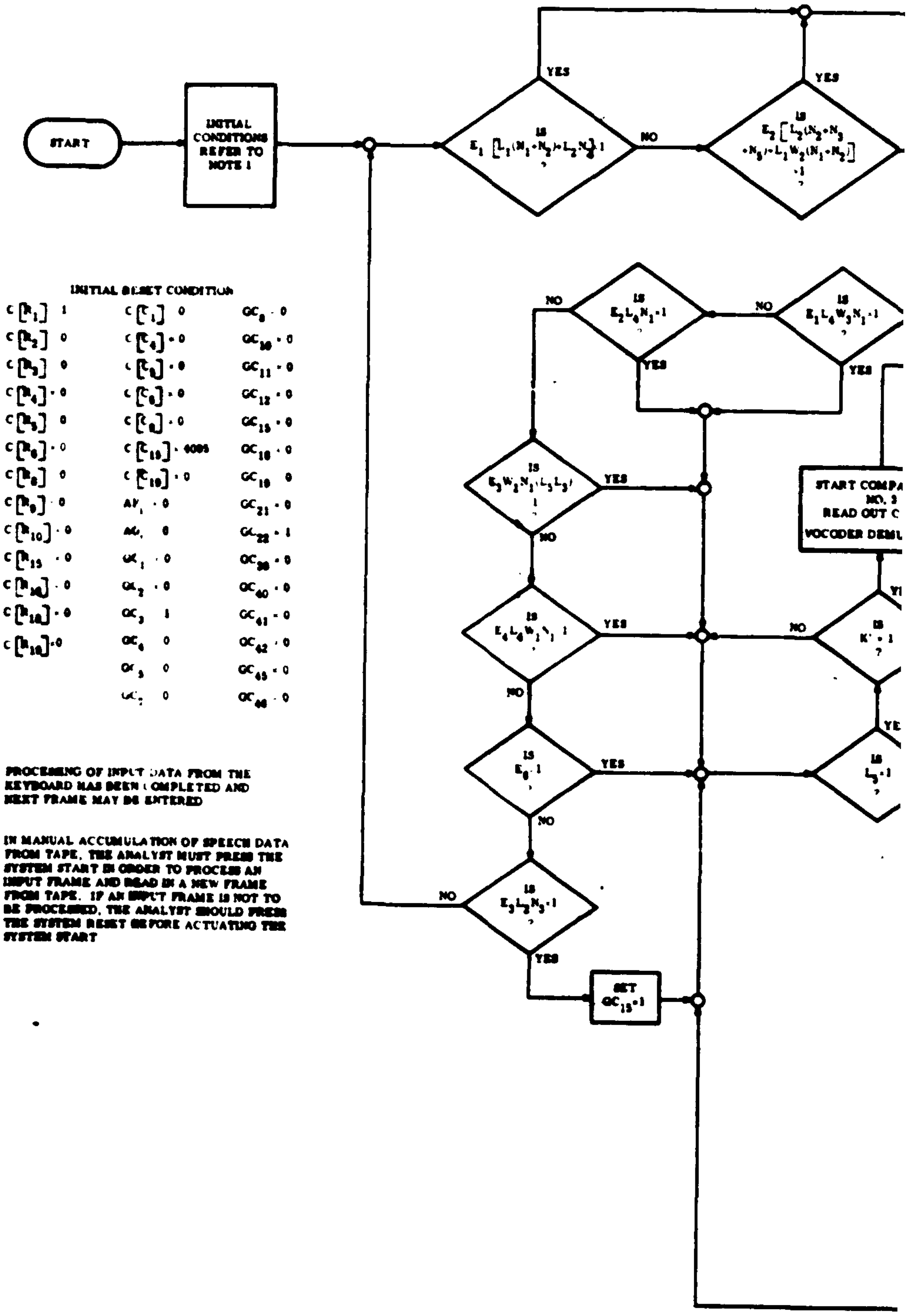


Figure 1. Detailed Block Diagram

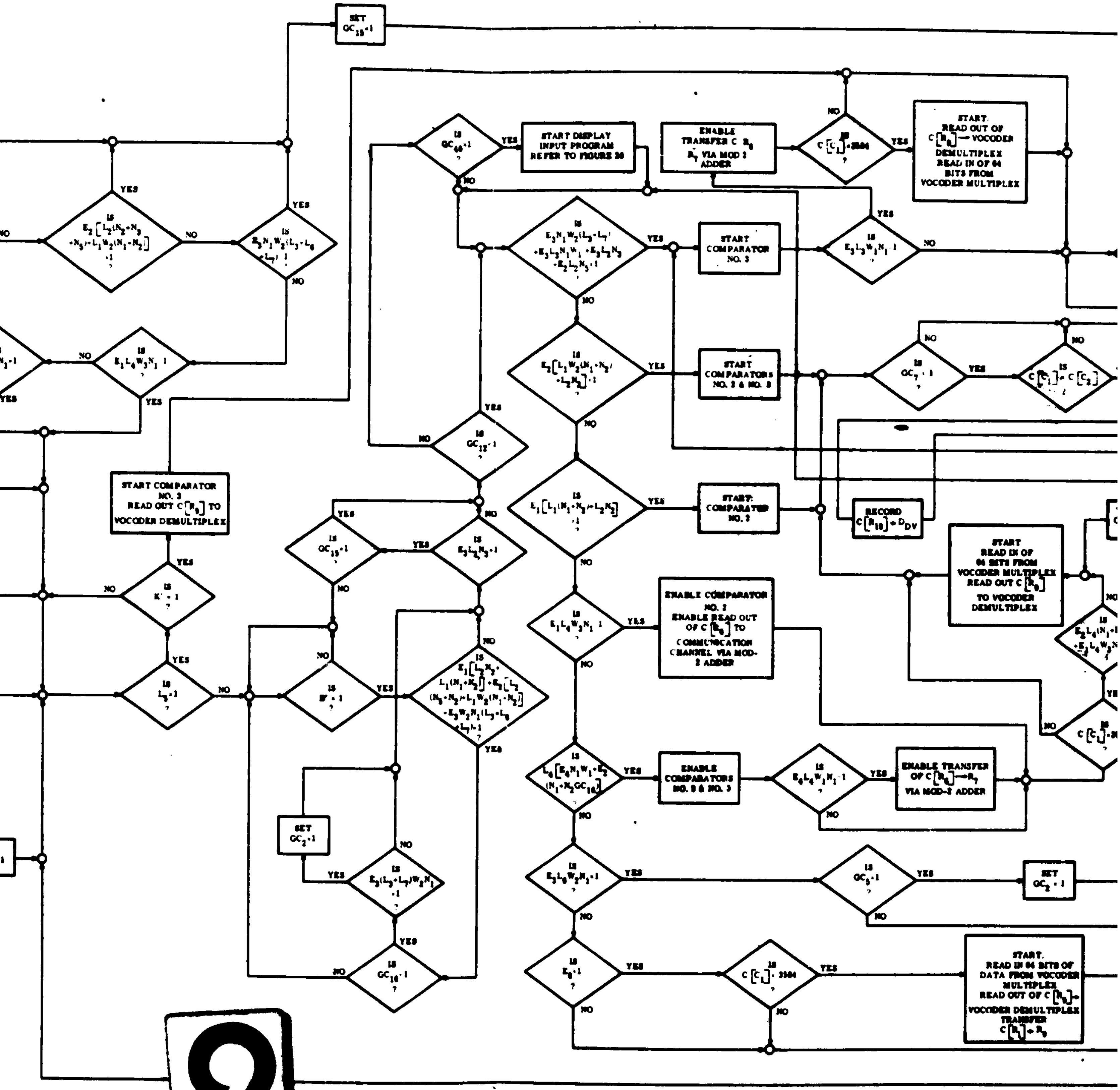


NOTE 1 INITIAL RESET CONDITION

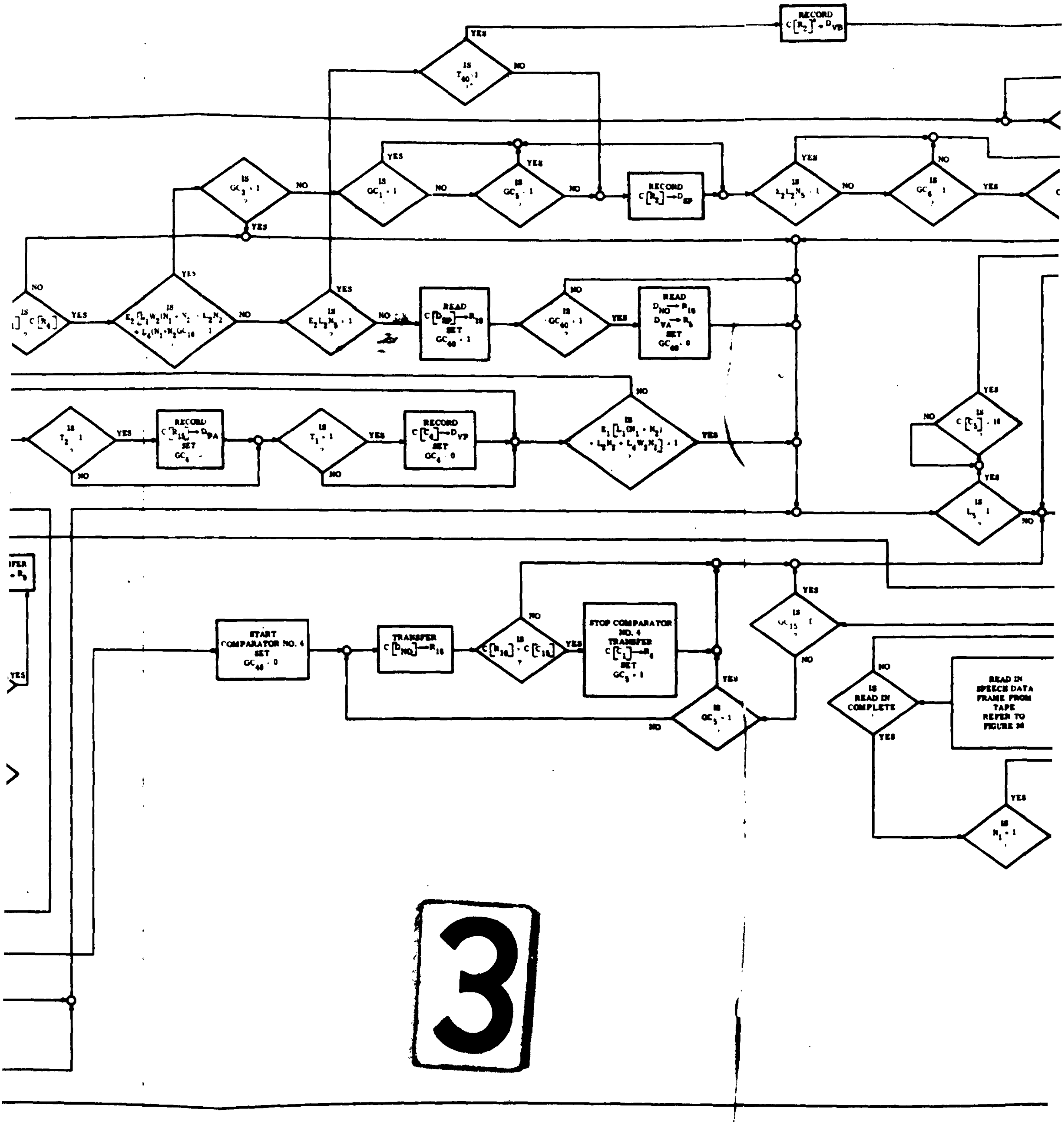
$C[R_1] = 1$	$C[C_1] = 0$	$GC_8 = 0$
$C[R_2] = 0$	$C[C_4] = 0$	$GC_{10} = 0$
$C[R_3] = 0$	$C[C_5] = 0$	$GC_{11} = 0$
$C[R_4] = 0$	$C[C_6] = 0$	$GC_{12} = 0$
$C[R_5] = 0$	$C[C_8] = 0$	$GC_{13} = 0$
$C[R_6] = 0$	$C[C_{15}] = 4095$	$GC_{18} = 0$
$C[R_8] = 0$	$C[C_{16}] = 0$	$GC_{19} = 0$
$C[R_9] = 0$	$AP_1 = 0$	$GC_{21} = 0$
$C[R_{10}] = 0$	$AG_1 = 0$	$GC_{22} = 1$
$C[R_{15}] = 0$	$GC_1 = 0$	$GC_{30} = 0$
$C[R_{16}] = 0$	$GC_2 = 0$	$GC_{40} = 0$
$C[R_{18}] = 0$	$GC_3 = 1$	$GC_{41} = 0$
$C[R_{19}] = 0$	$GC_4 = 0$	$GC_{42} = 0$
	$GC_5 = 0$	$GC_{45} = 0$
	$GC_7 = 0$	$GC_{46} = 0$

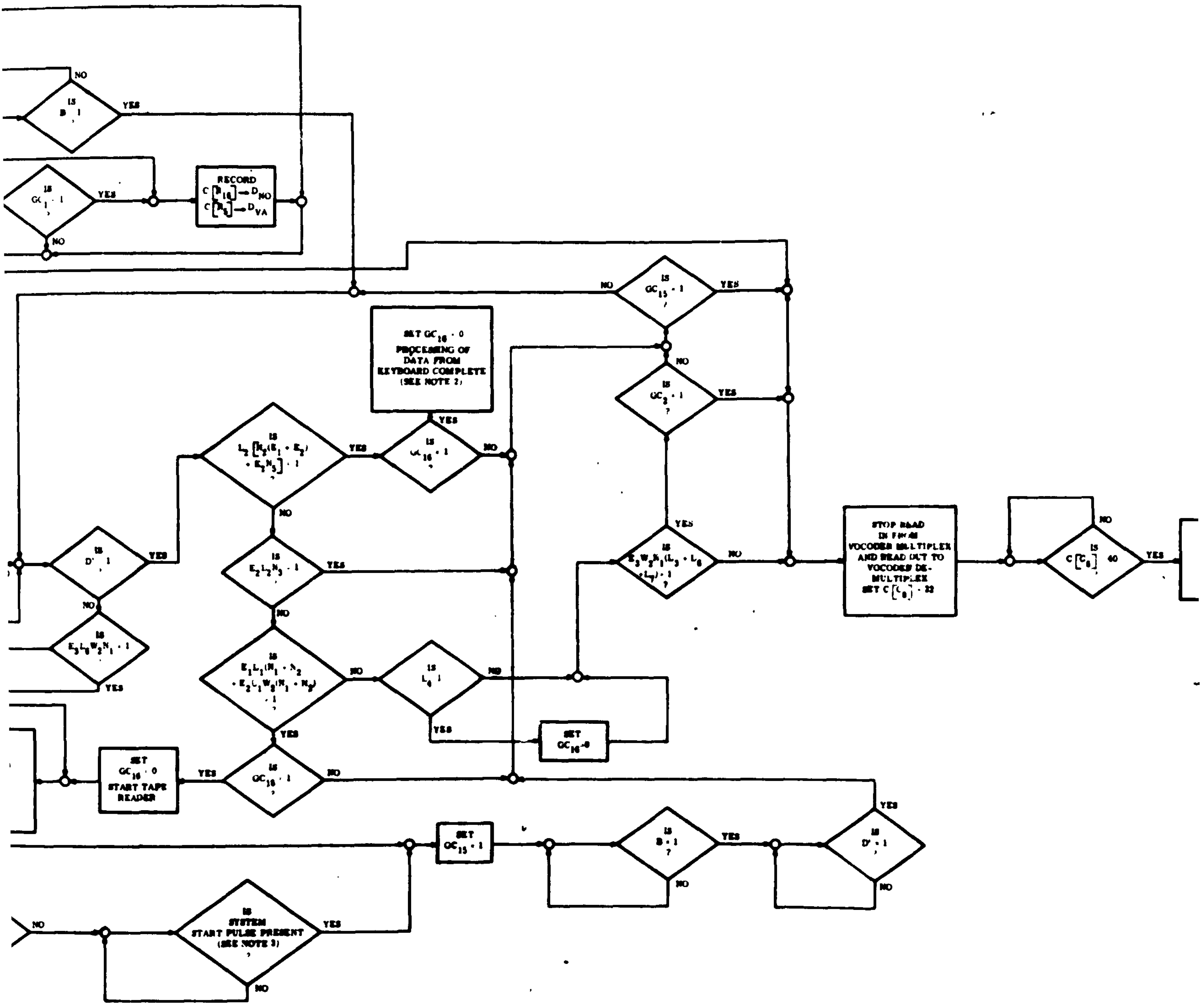
NOTE 2 PROCESSING OF INPUT DATA FROM THE KEYBOARD HAS BEEN COMPLETED AND NEXT FRAME MAY BE ENTERED

NOTE 3 IN MANUAL ACCUMULATION OF SPEECH DATA FROM TAPE, THE ANALYST MUST PRESS THE SYSTEM START IN ORDER TO PROCESS AN INPUT FRAME AND READ IN A NEW FRAME FROM TAPE. IF AN INPUT FRAME IS NOT TO BE PROCESSED, THE ANALYST SHOULD PRESS THE SYSTEM RESET BEFORE ACTUATING THE SYSTEM START


SET GC15 = 1
START DISPLAY INPUT PROGRAM REFER TO FIGURE 20
ENABLE TRANSFER C R6 R7 VIA MOD 2 ADDER
START. READ OUT OF C [R8] → VOCODER DEMULTIPLEX READ IN OF 64 BITS FROM VOCODER MULTIPLEX
START COMPARATOR NO. 3
START COMPARATORS NO. 2 & NO. 3
START COMPARATOR NO. 2
START COMPARATOR NO. 3 READ OUT C [R8] TO VOCODER DEMULTIPLEX
RECORD C [R10] → DDV
START READ IN OF 64 BITS FROM VOCODER MULTIPLEX READ OUT C [R8] TO VOCODER DEMULTIPLEX
ENABLE COMPARATOR NO. 2 ENABLE READ OUT OF C [R8] TO COMMUNICATION CHANNEL VIA MOD-2 ADDER
ENABLE COMPARATORS NO. 2 & NO. 3
ENABLE TRANSFER OF C [R8] → R7 VIA MOD-2 ADDER
SET GC2 = 1
START. READ IN 64 BITS OF DATA FROM VOCODER MULTIPLEX READ OUT OF C [R8] → VOCODER DEMULTIPLEX TRANSFER C [R8] → R9
YES
NO

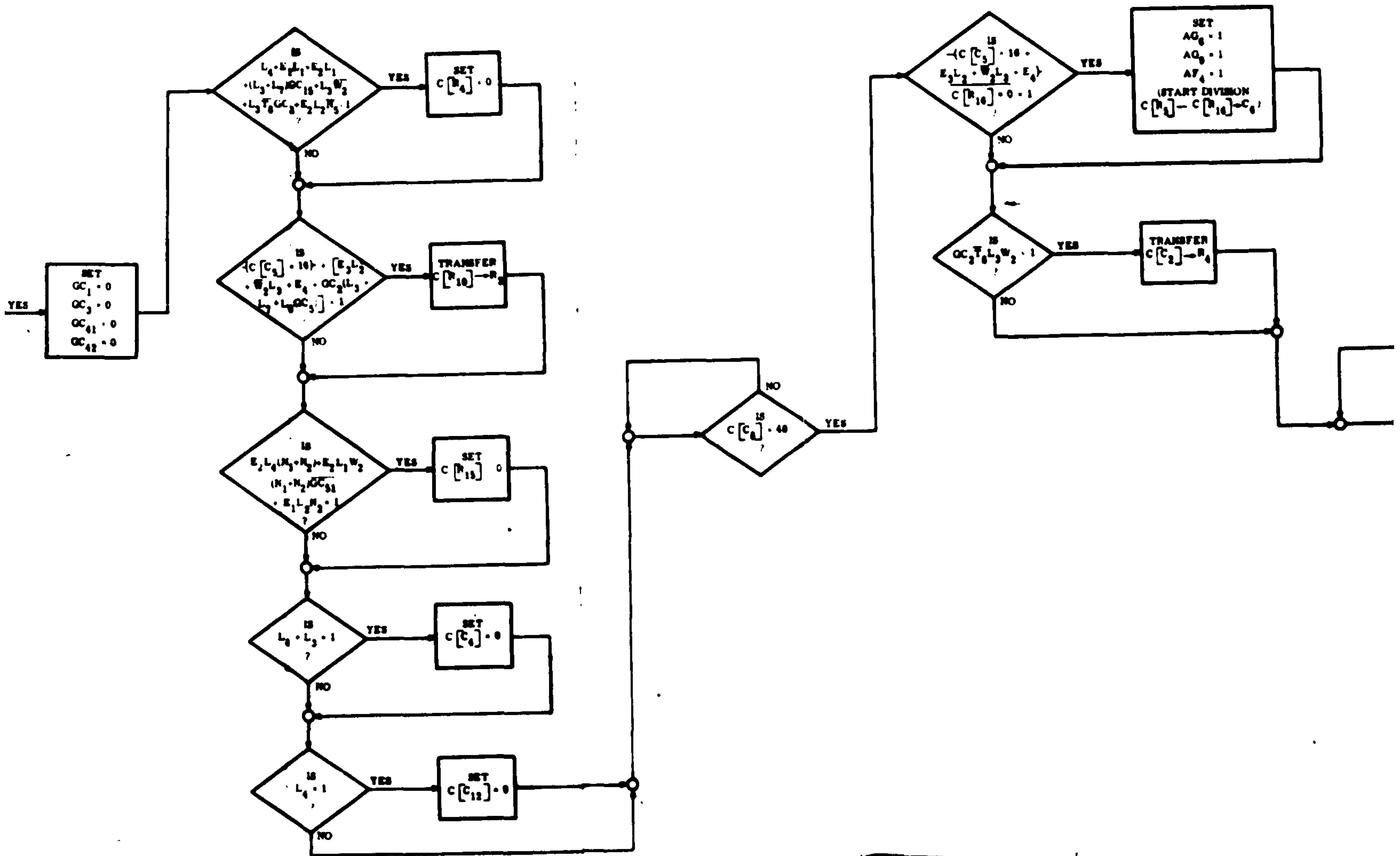
2


RECORD
YES
NO
IS GC3 = 1
IS GC1 = 1
IS GC5 = 1
RECORD
IS GC6 = 1
READ
SET
IS GC60 = 1
READ
SET
RECORD
SET
IS T1 = 1
RECORD
SET
IS L5 = 1
START COMPARATOR NO. 4 SET
TRANSFER
STOP COMPARATOR NO. 4 TRANSFER SET
IS GC15 = 1
IS GC5 = 1
IS READ IN COMPLETE
READ IN SPEECH DATA FRAME FROM TAPE REFER TO FIGURE 36
IS N1 = 1
3

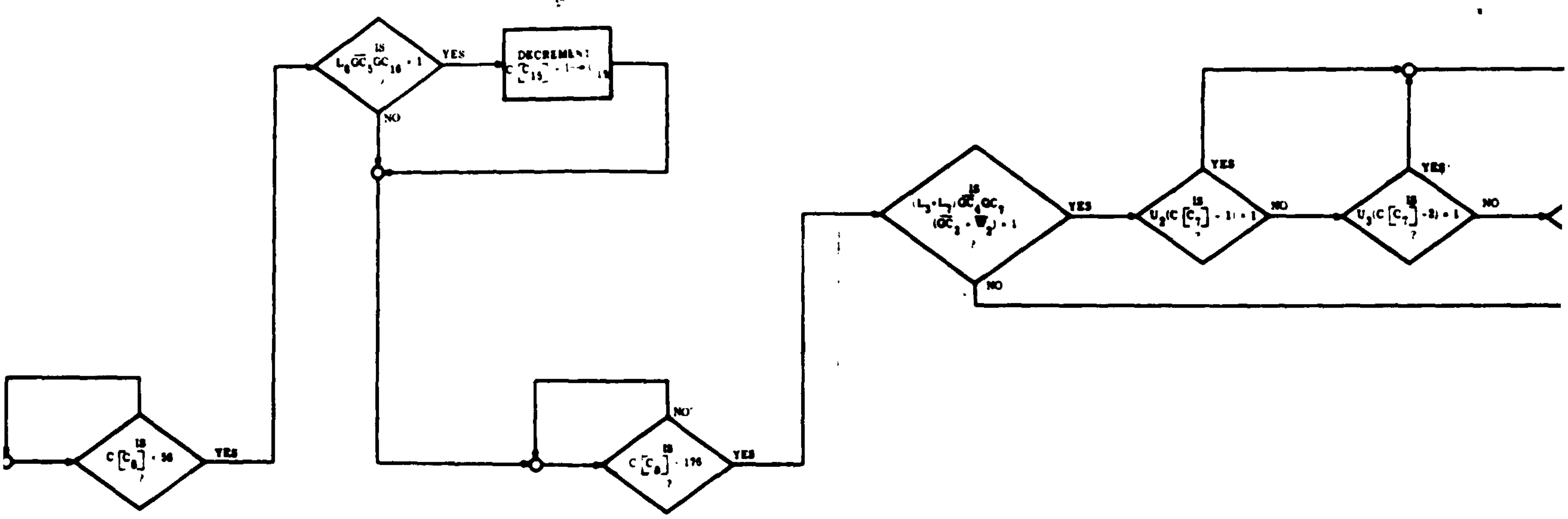


RECORD
SET GC_{16} = 0 PROCESSING OF DATA FROM KEYBOARD COMPLETE (SEE NOTE 2)
STOP READ IN FROM VOCODER MULTIPLEX AND READ OUT TO VOCODER DE-MULTIPLEX
SET GC_{16} = 0 START TAPE READER
SET GC_{15} = 1
IS SYSTEM START PULSE PRESENT (SEE NOTE 3) ?
YES
NO

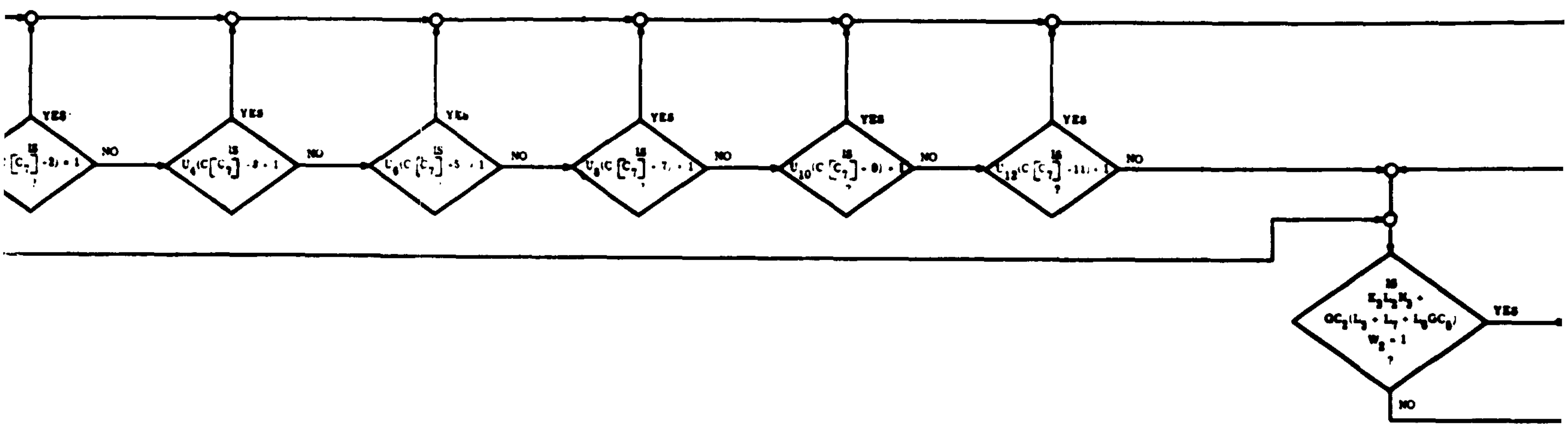
4

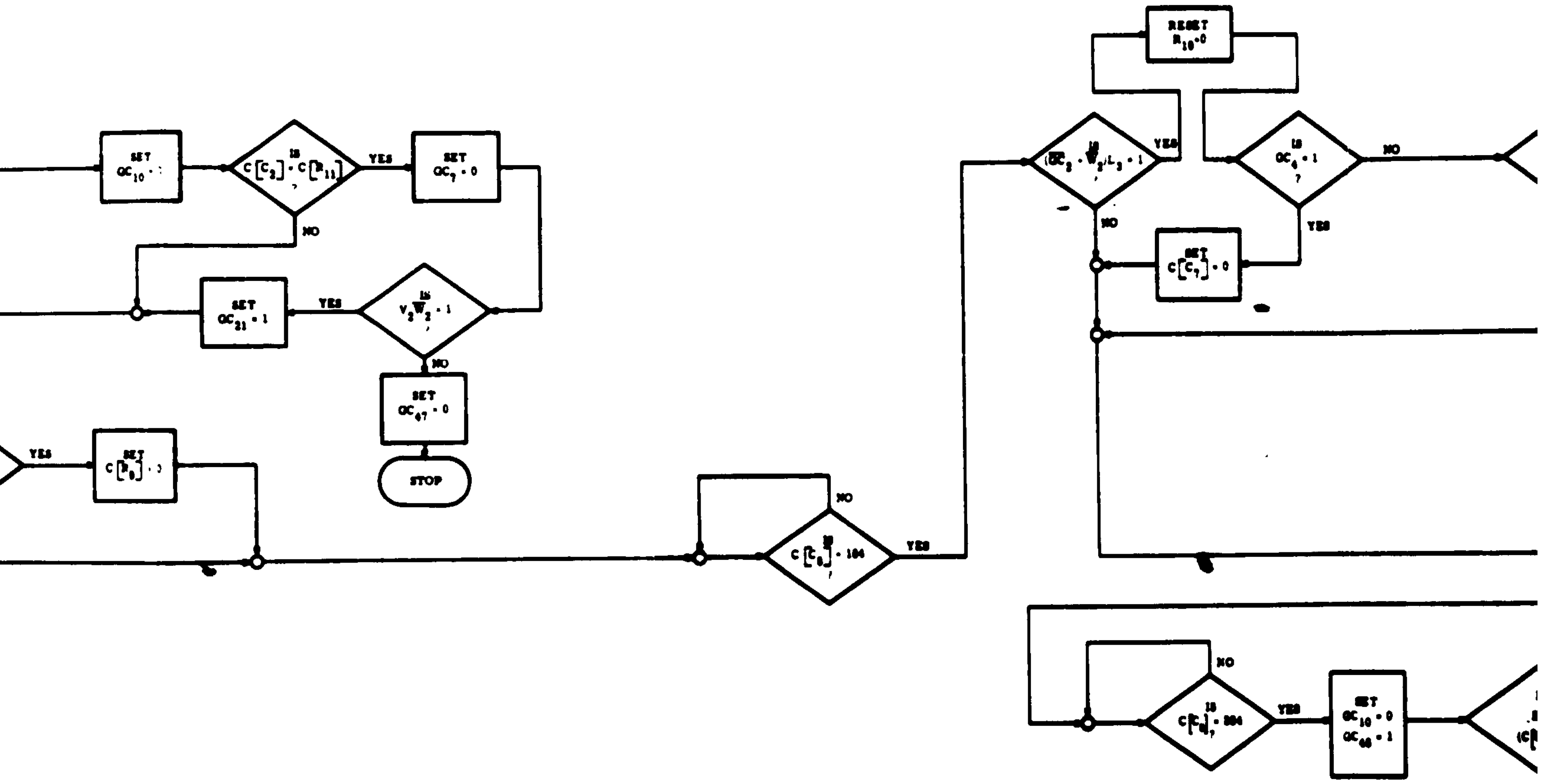


4

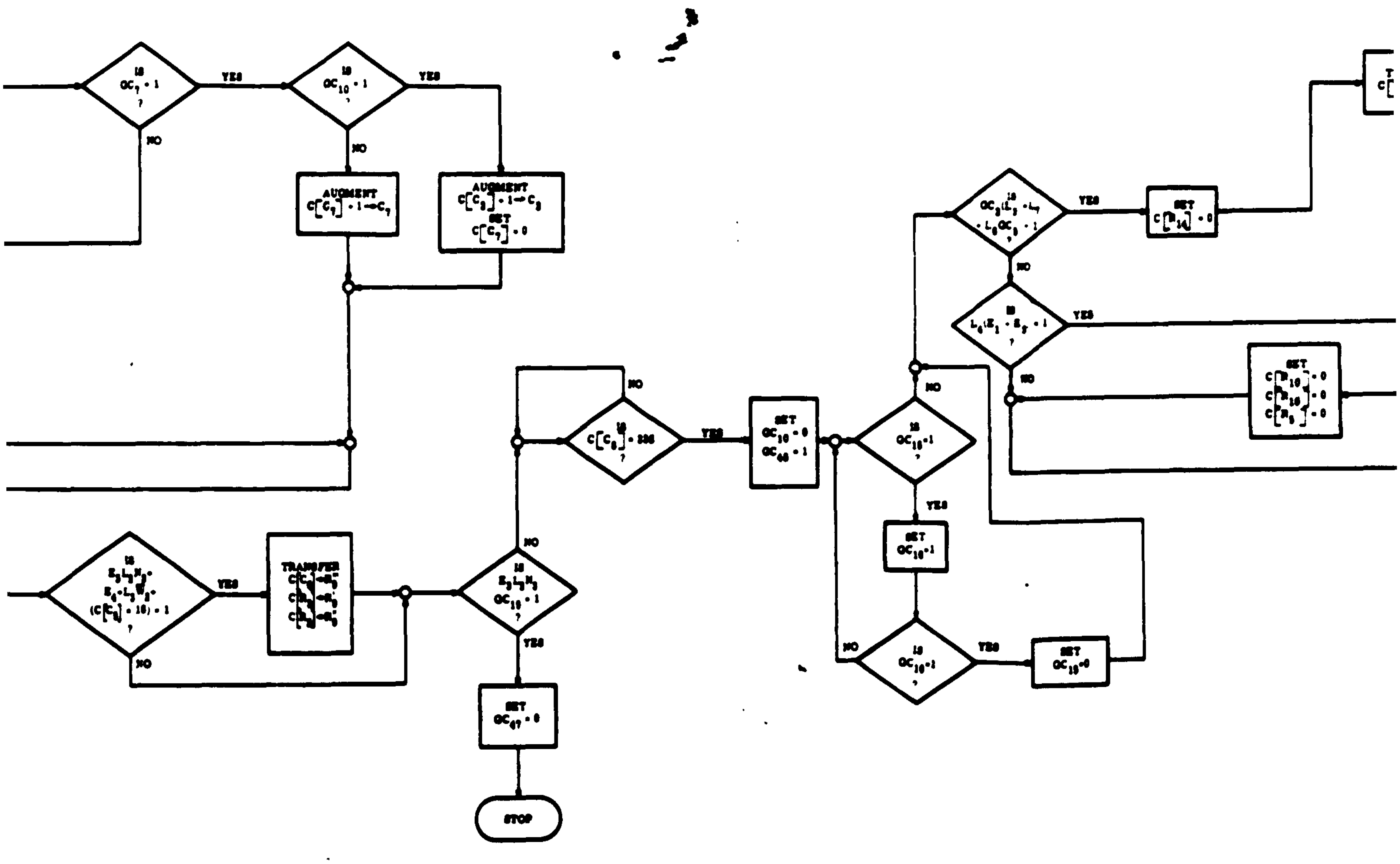


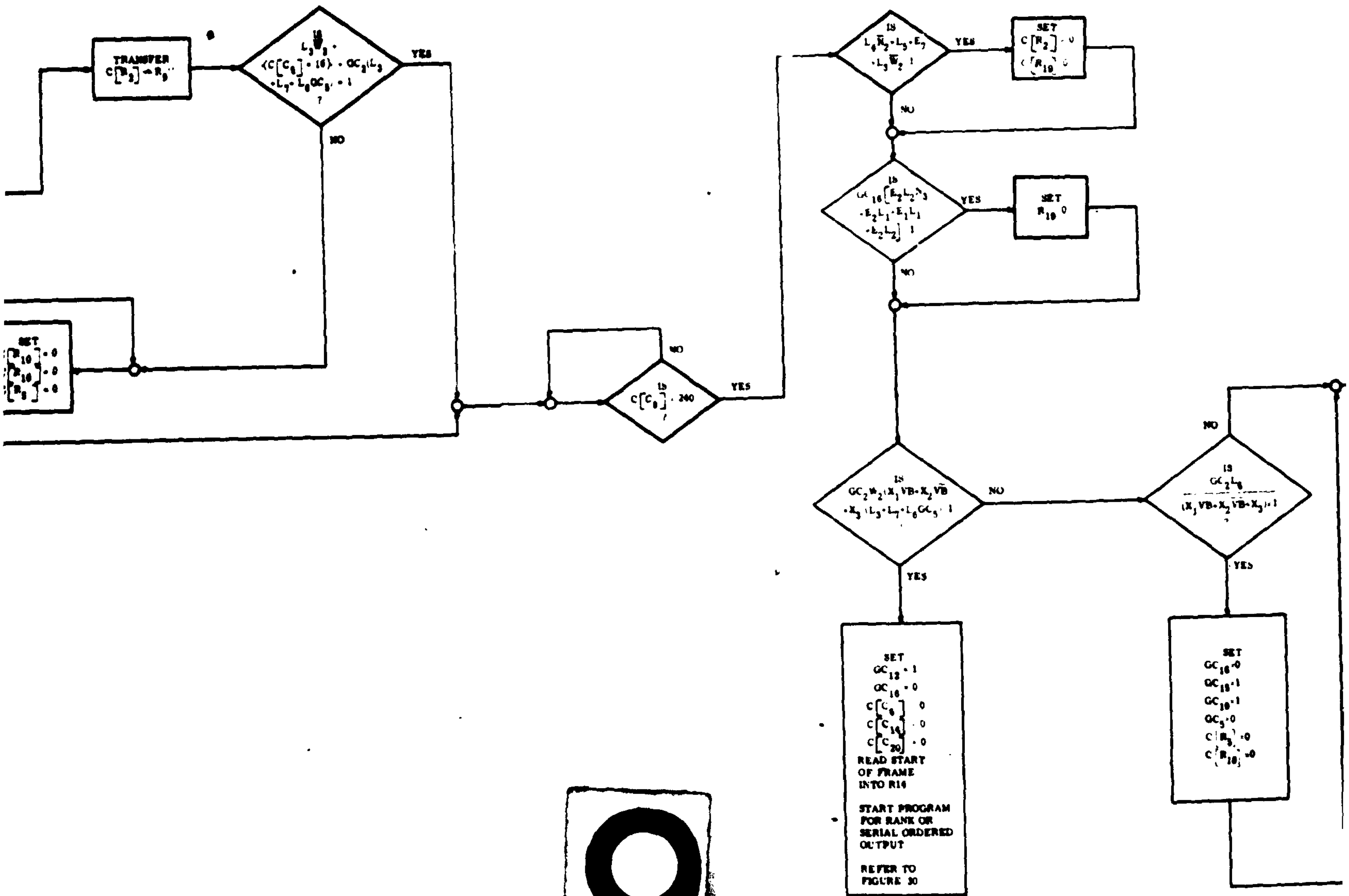
5


YES
NO
IS
YES
NO
IS
YES
NO
IS
YES
NO
IS
YES
NO
IS
YES
NO
IS
YES
NO

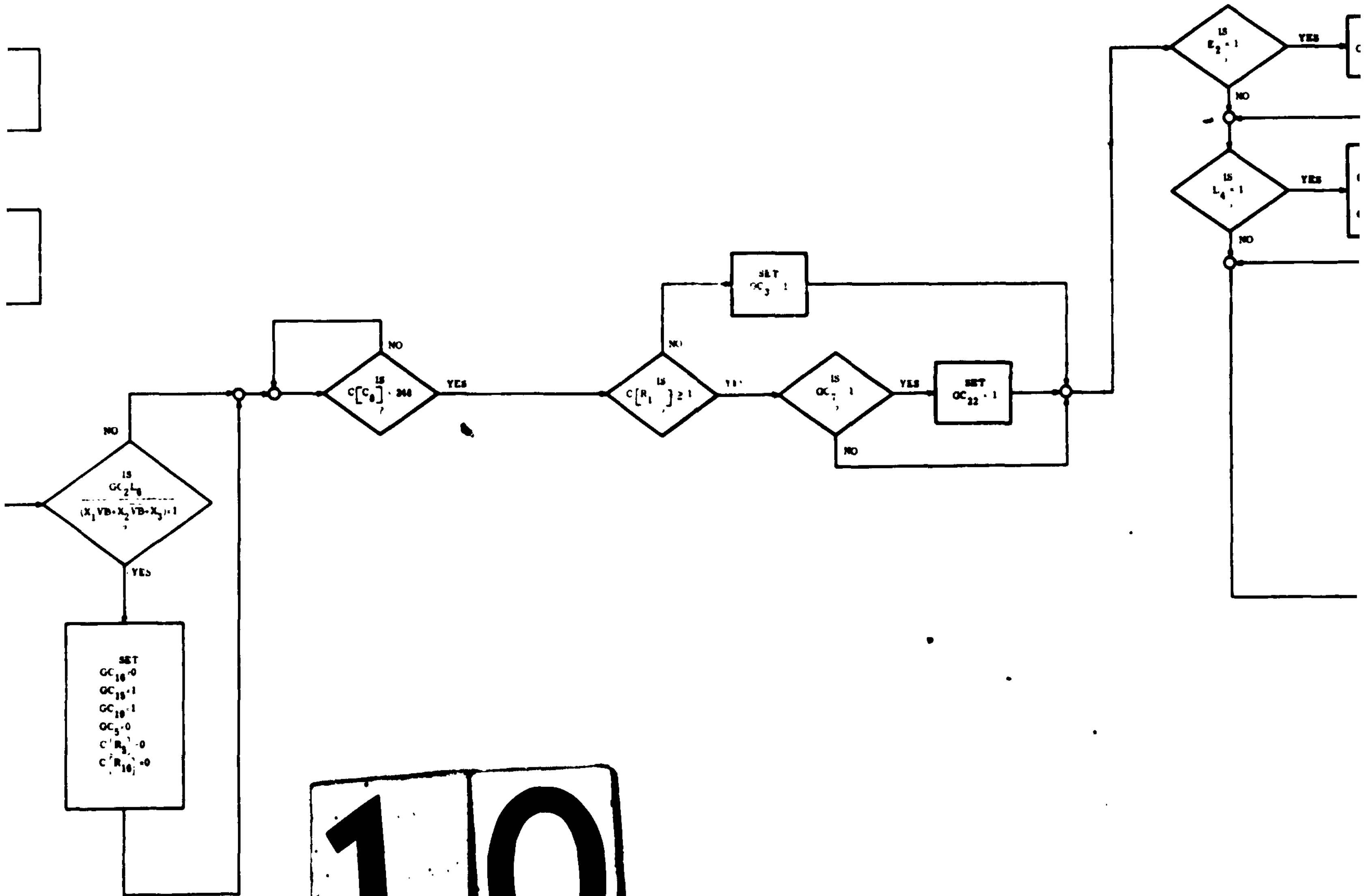


7

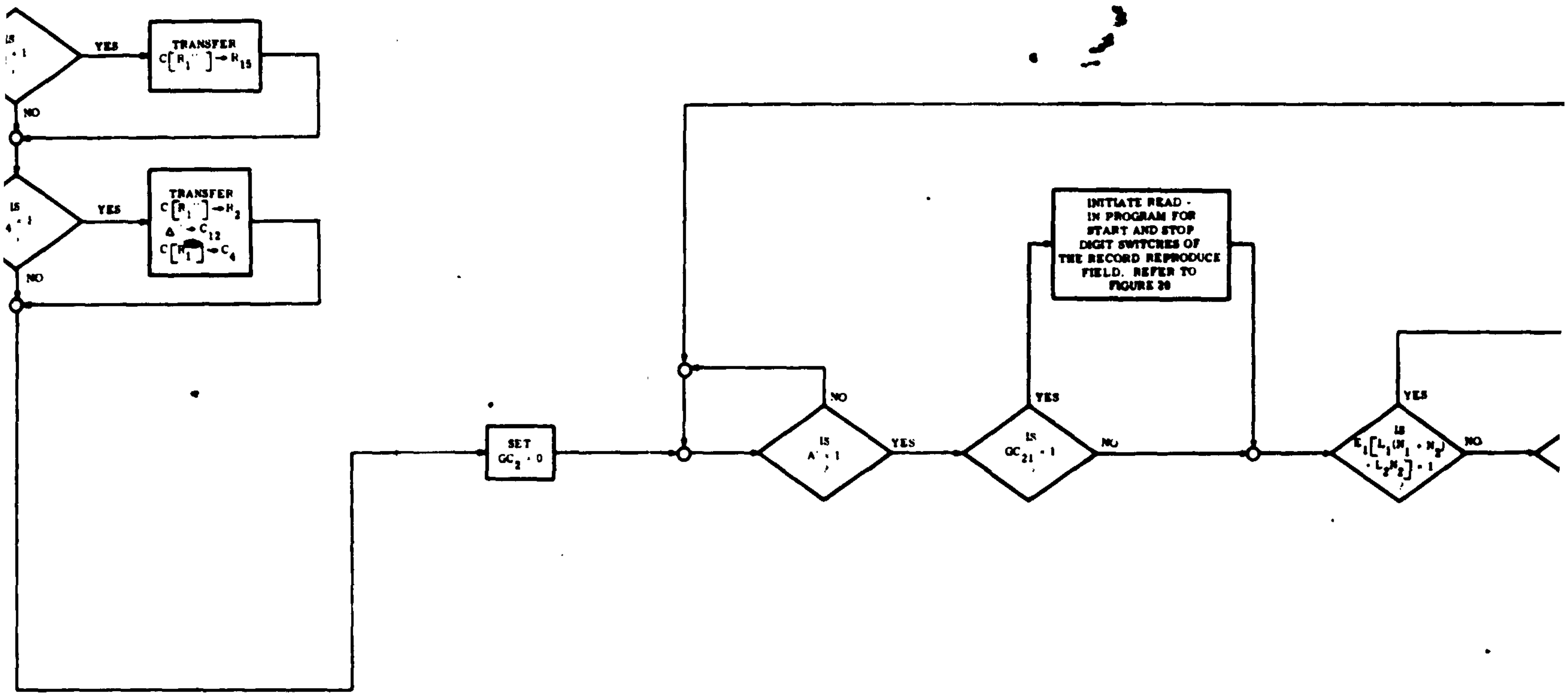

YES
NO
AUGMENT
SET
TRANSFER
STOP


TRANSFER
YES
NO
SET
IS
READ START
OF FRAME
INTO R14
START PROGRAM
FOR RANK OR
SERIAL ORDERED
OUTPUT
REFER TO
FIGURE 30

9


IS
NO
YES
SET
NO
IS
YES
IS
YES
IS
NO
SET
$GC_{22} = 1$
NO
IS
YES
NO
IS
YES
NO

10


YES
TRANSFER
NO
YES
TRANSFER
NO
SET
YES
NO
YES
INITIATE READ - IN PROGRAM FOR START AND STOP DIGIT SWITCHES OF THE RECORD REPRODUCE FIELD. REFER TO FIGURE 30
YES
NO
YES
NO

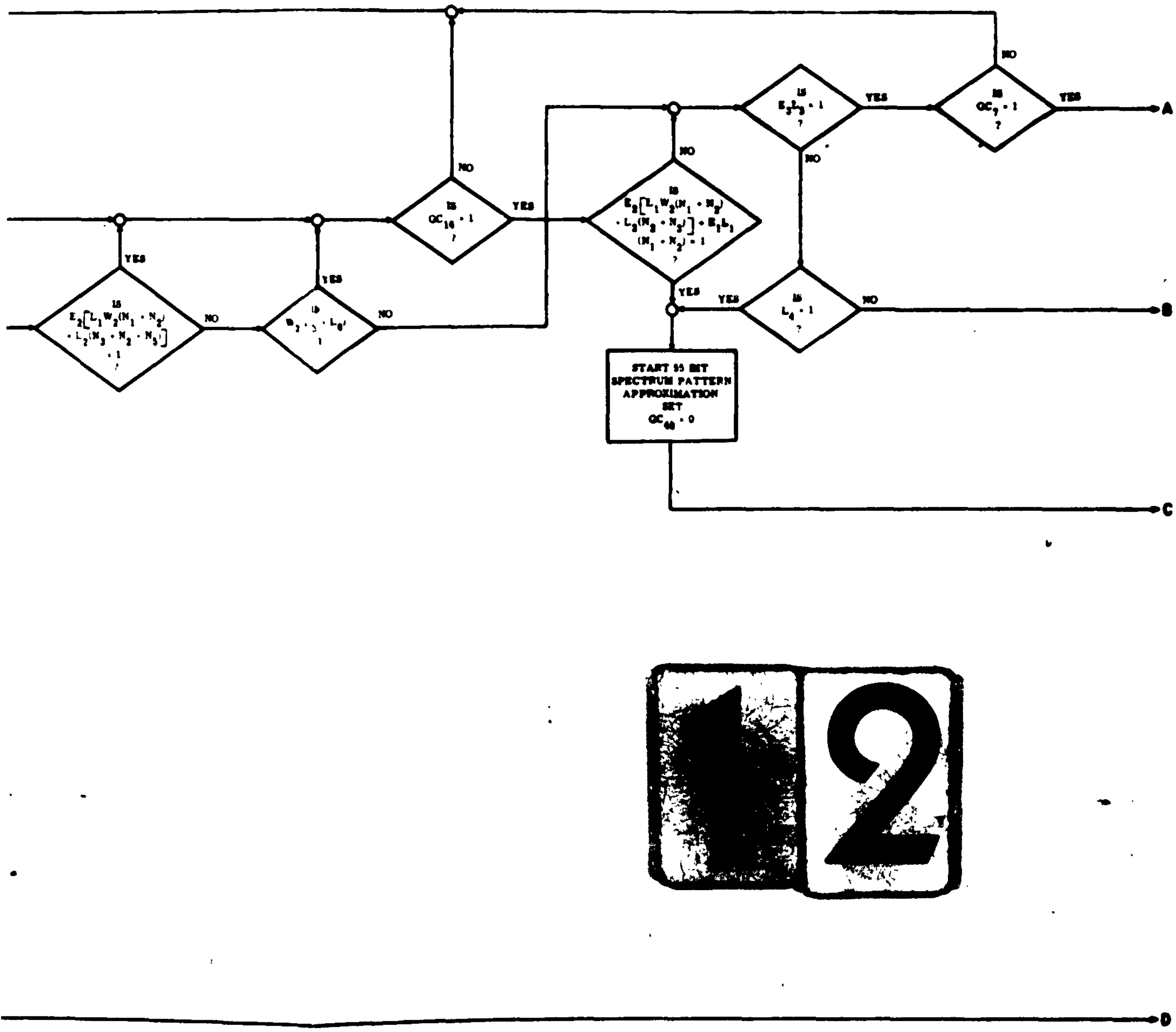
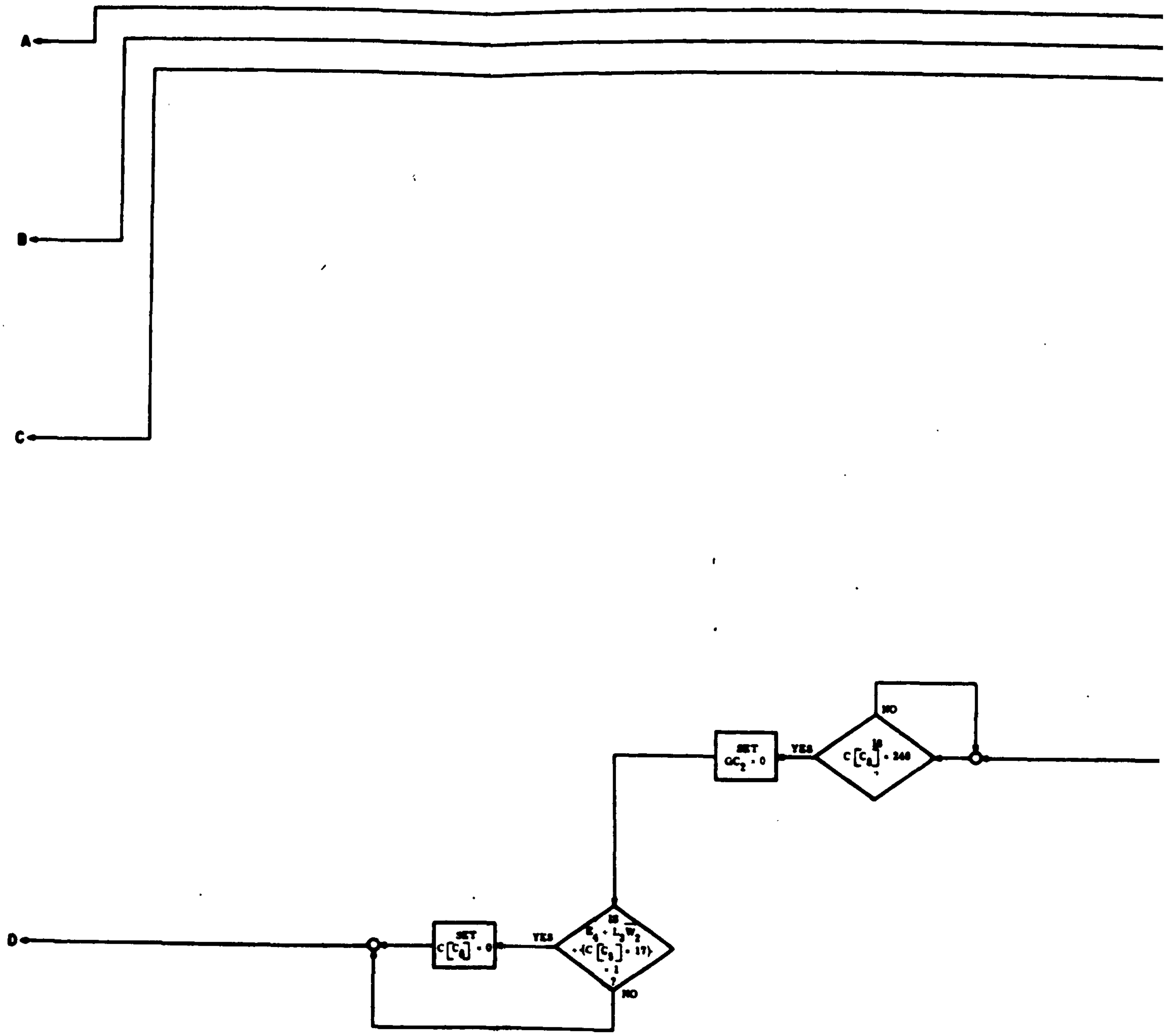
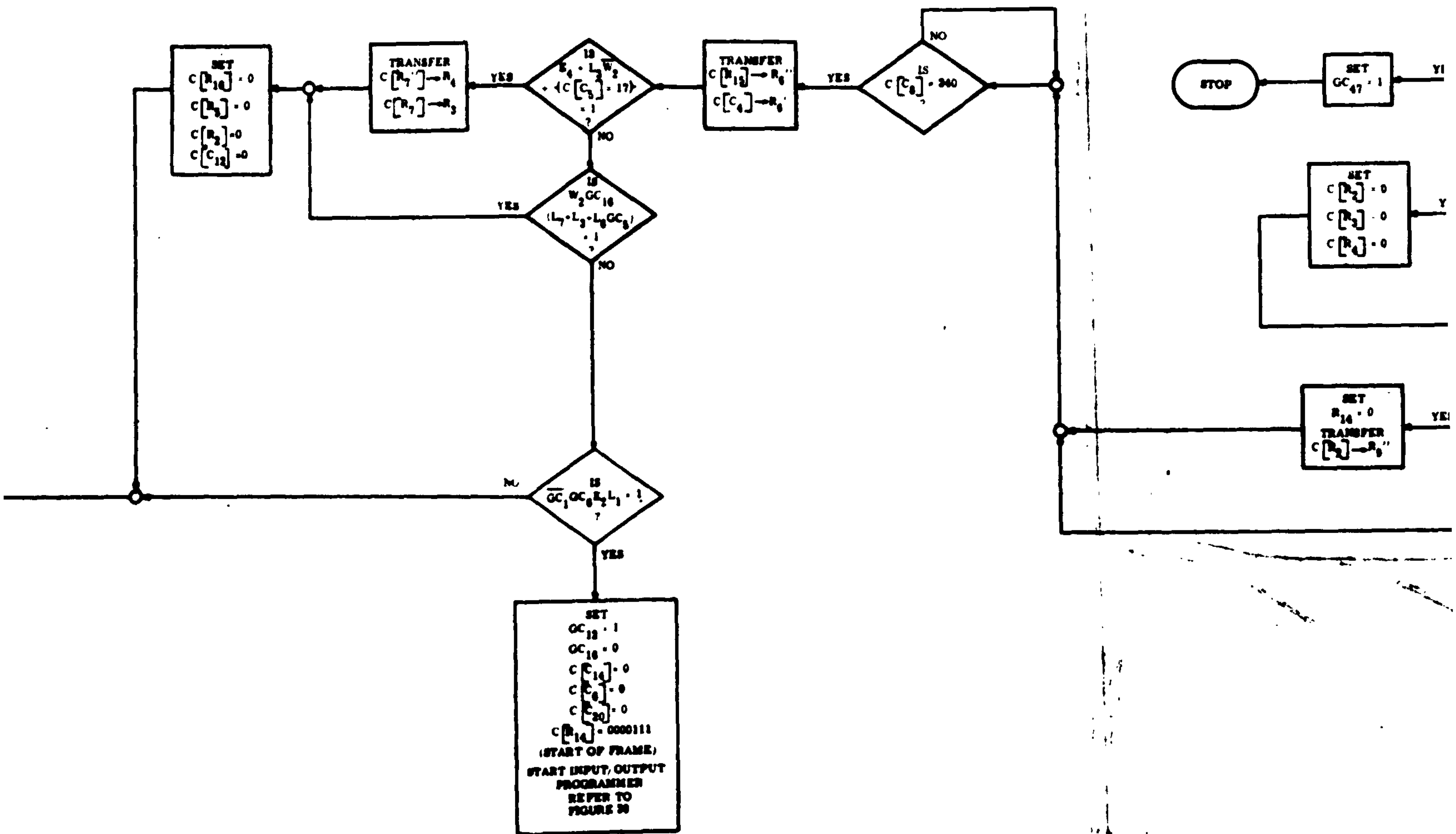
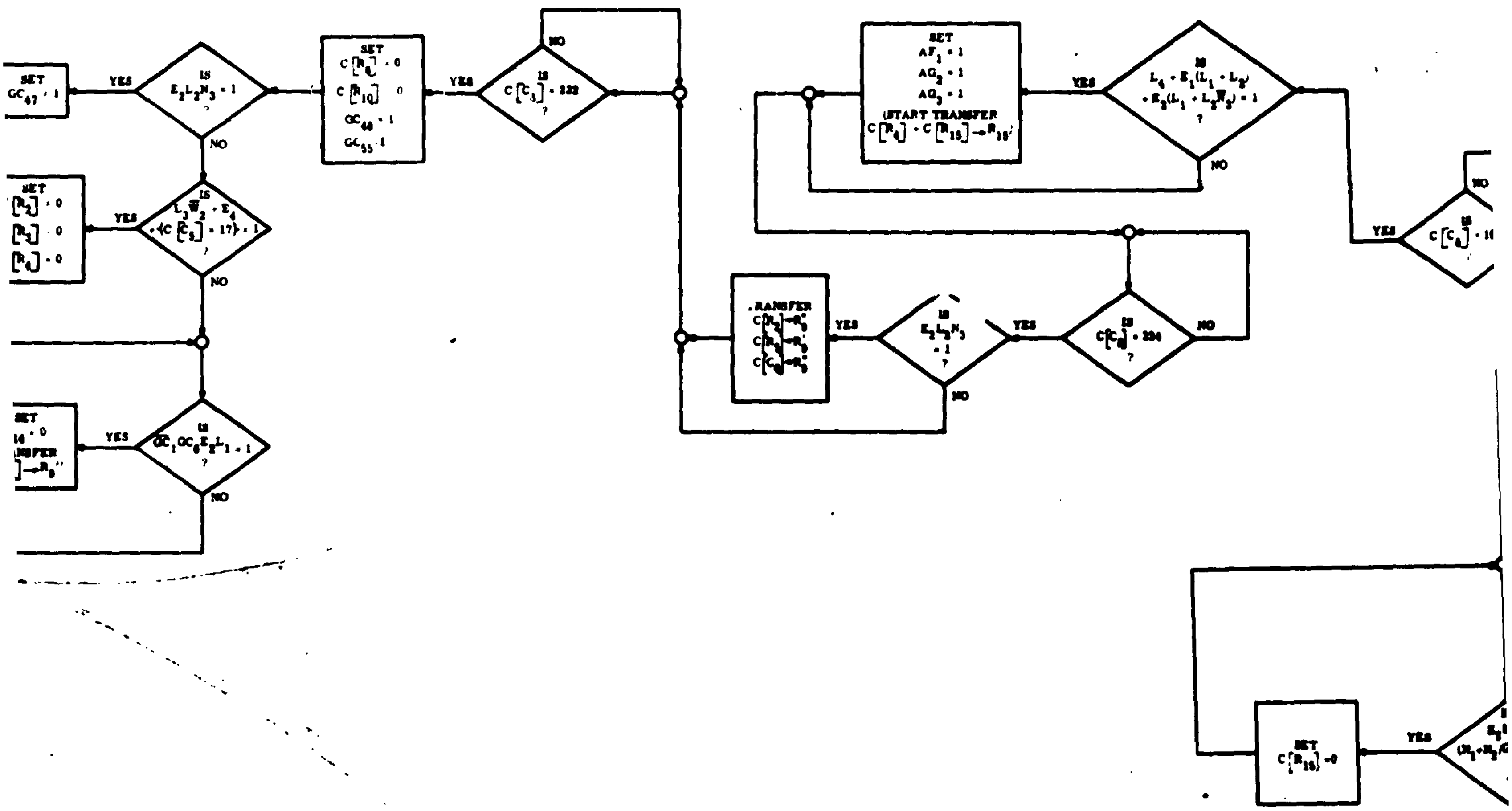


Figure 2. Detailed Flow Diagram—Central Programmer, (Sheet 1 of 2)

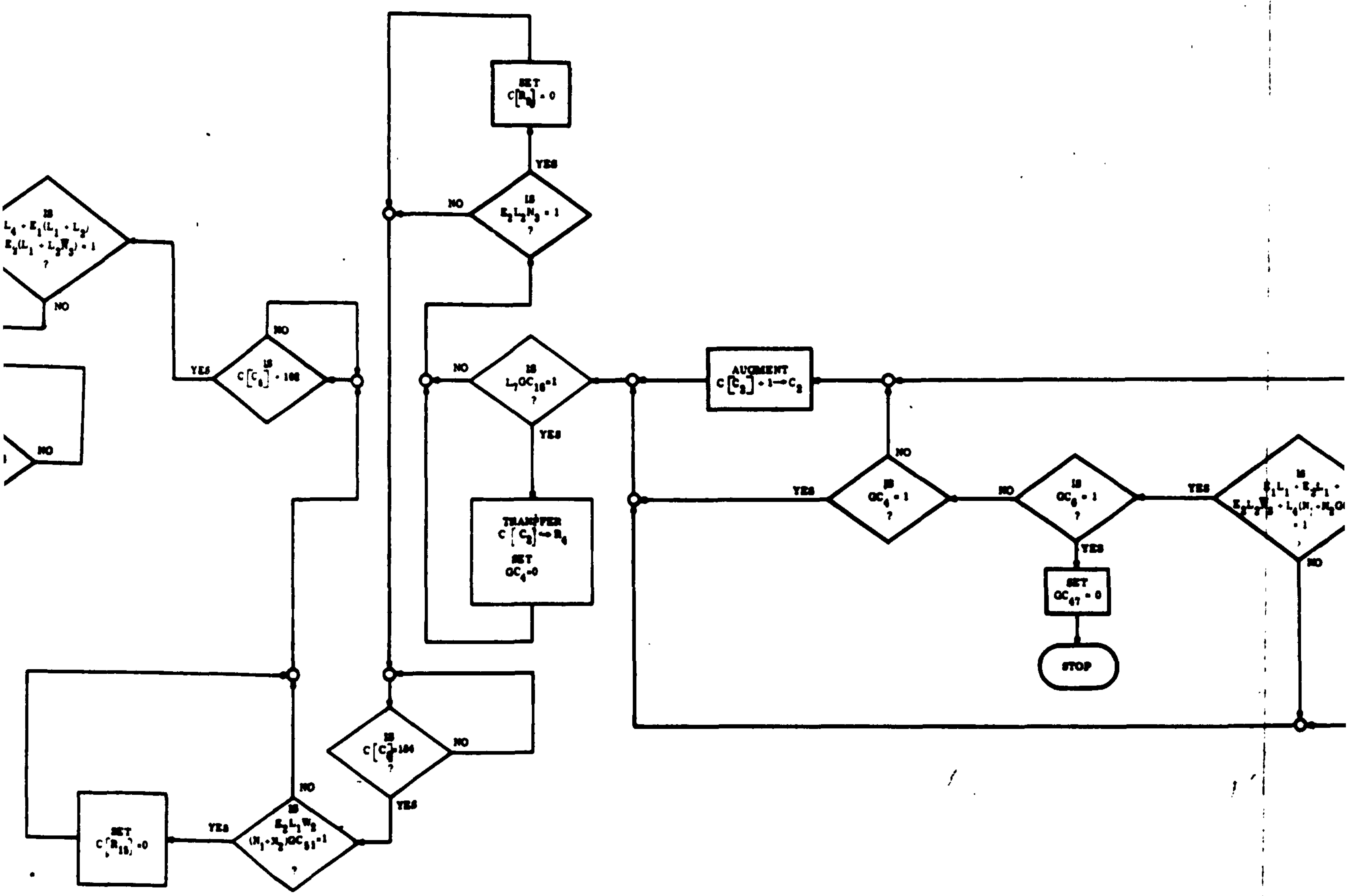

A
B
C
D
SET
YES
NO
SET
YES
NO



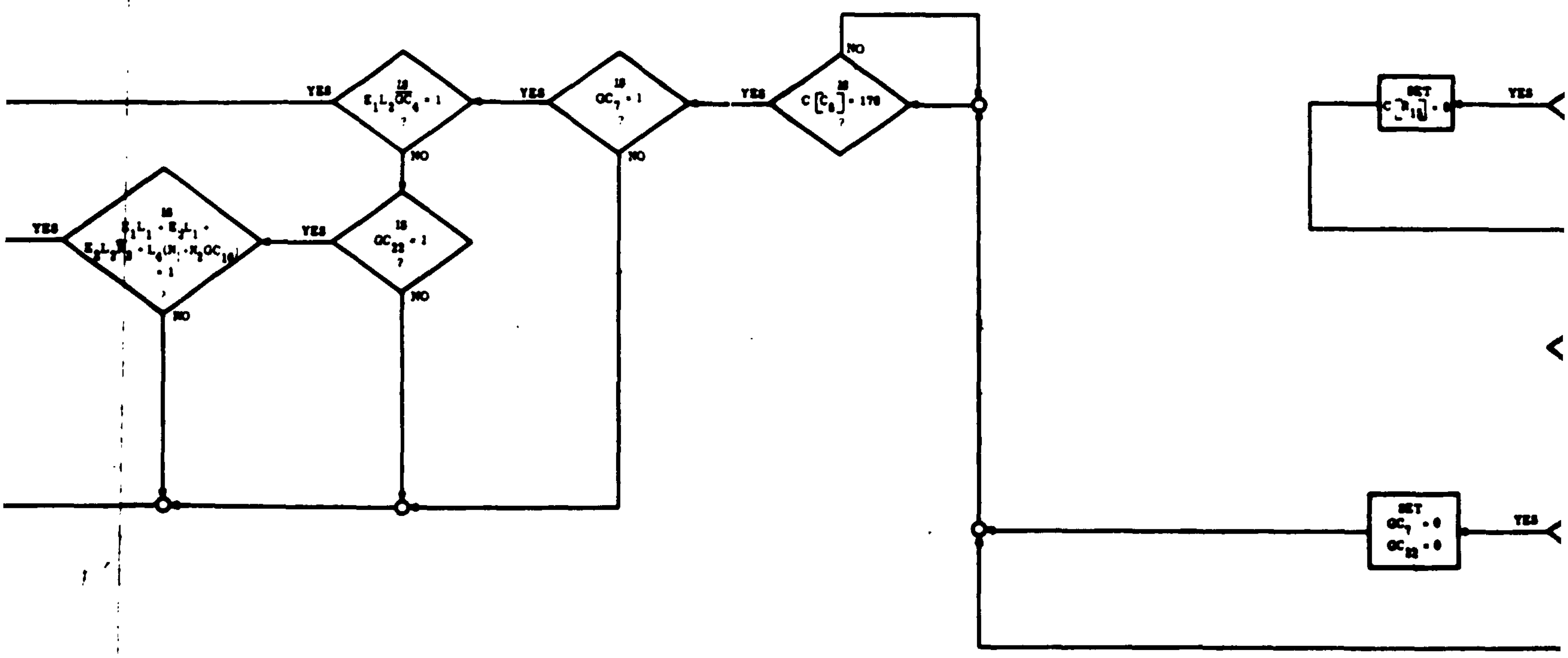
SET
C [R16] = 0
C [R5] = 0
C [R2] = 0
C [C12] = 0
TRANSFER
C [R7'] → R4
C [R7] → R3
YES
NO
IS
W2 GC16
(L7 + L3 + L8 GC5)
= 1
?
TRANSFER
C [R13] → R6''
C [C4] → R6'
IS
C [C6] = 360
?
STOP
SET
GC47 = 1
SET
C [R2] = 0
C [R3] = 0
C [R4] = 0
SET
R14 = 0
TRANSFER
C [R5] → R9''
IS
GC1 GC6 E2 L1 = 1
?
SET
GC13 = 1
GC16 = 0
C [C14] = 0
C [C6] = 0
C [C20] = 0
C [R14] = 0000111
(START OF FRAME)
START INPUT/OUTPUT
PROGRAMMER
REFER TO
FIGURE 30



3



4



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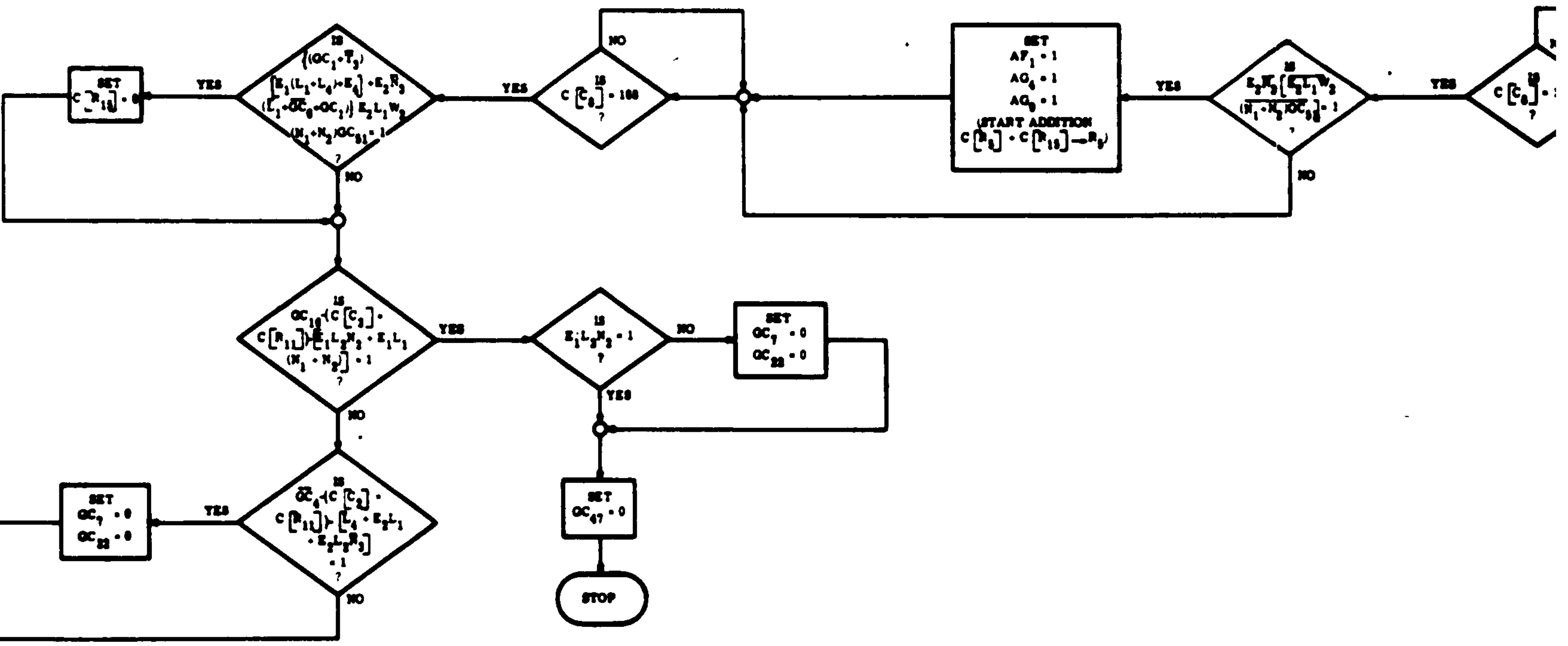
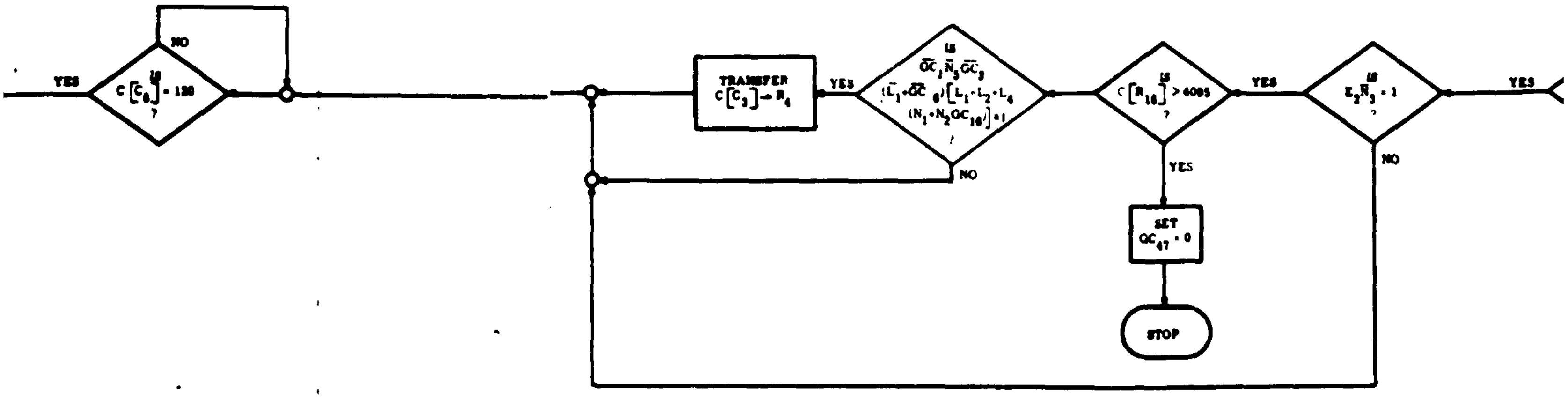
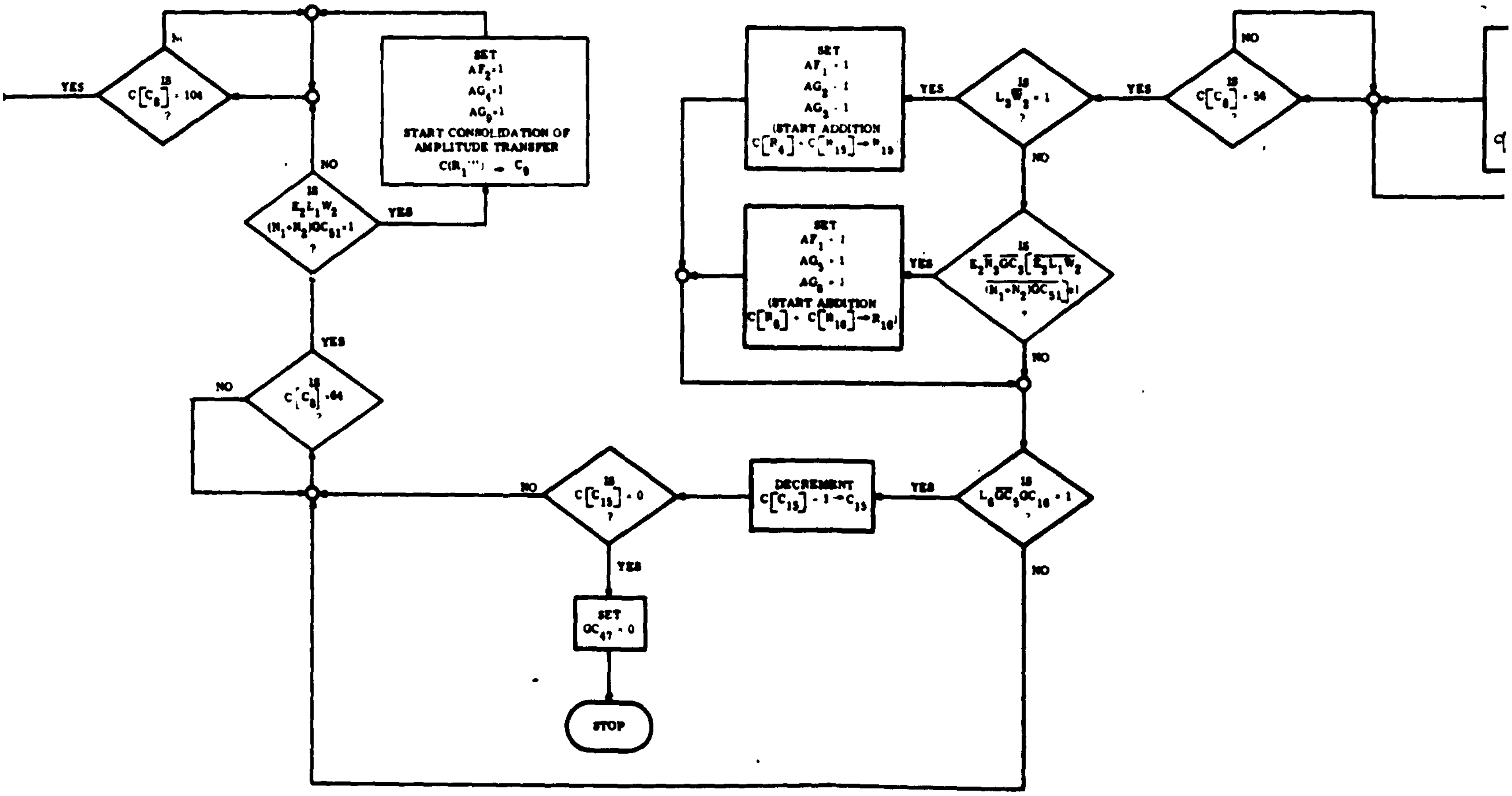

SET
YES
IS
NO
SET
$AF_1 = 1$
$AO_4 = 1$
$AO_9 = 1$
START ADDITION
SET
$OC_7 = 0$
$OC_{22} = 0$
SET
$OC_{47} = 0$
STOP

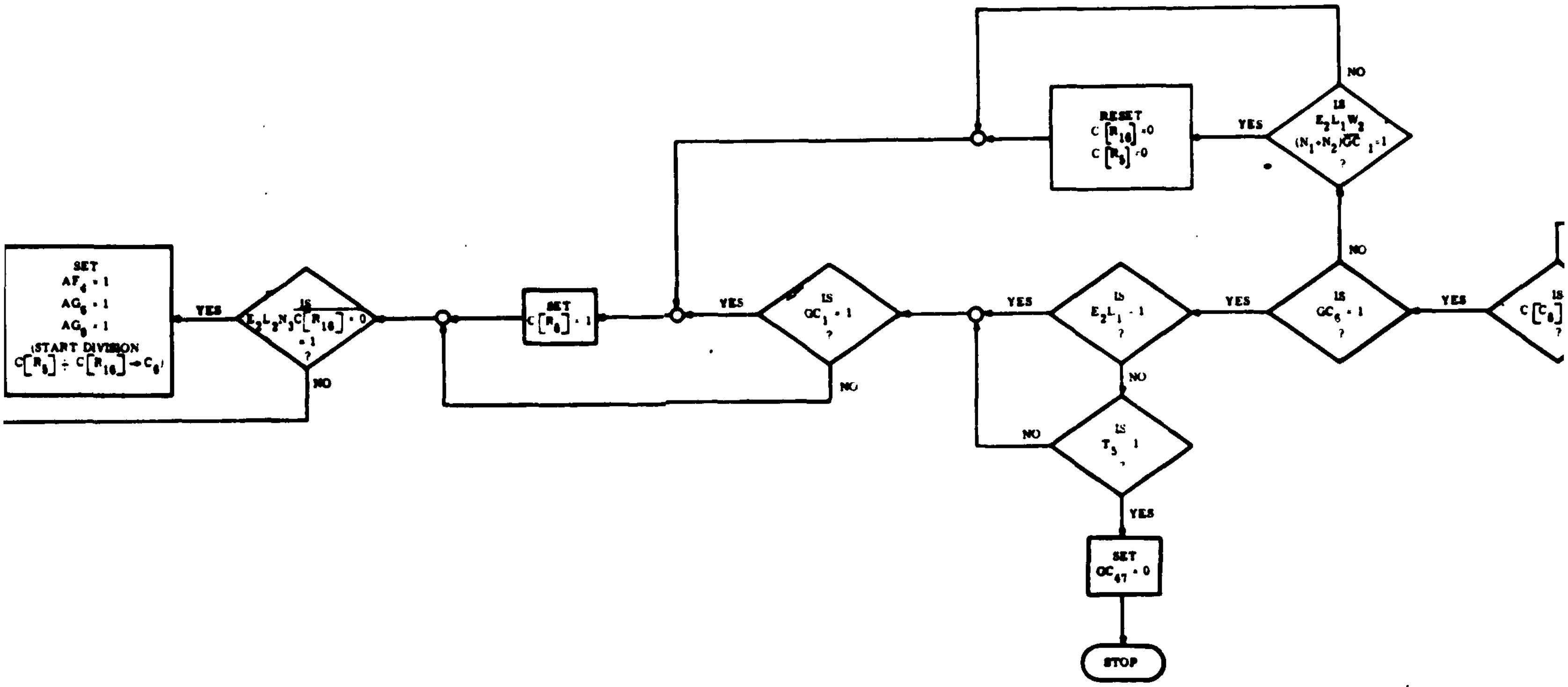
6



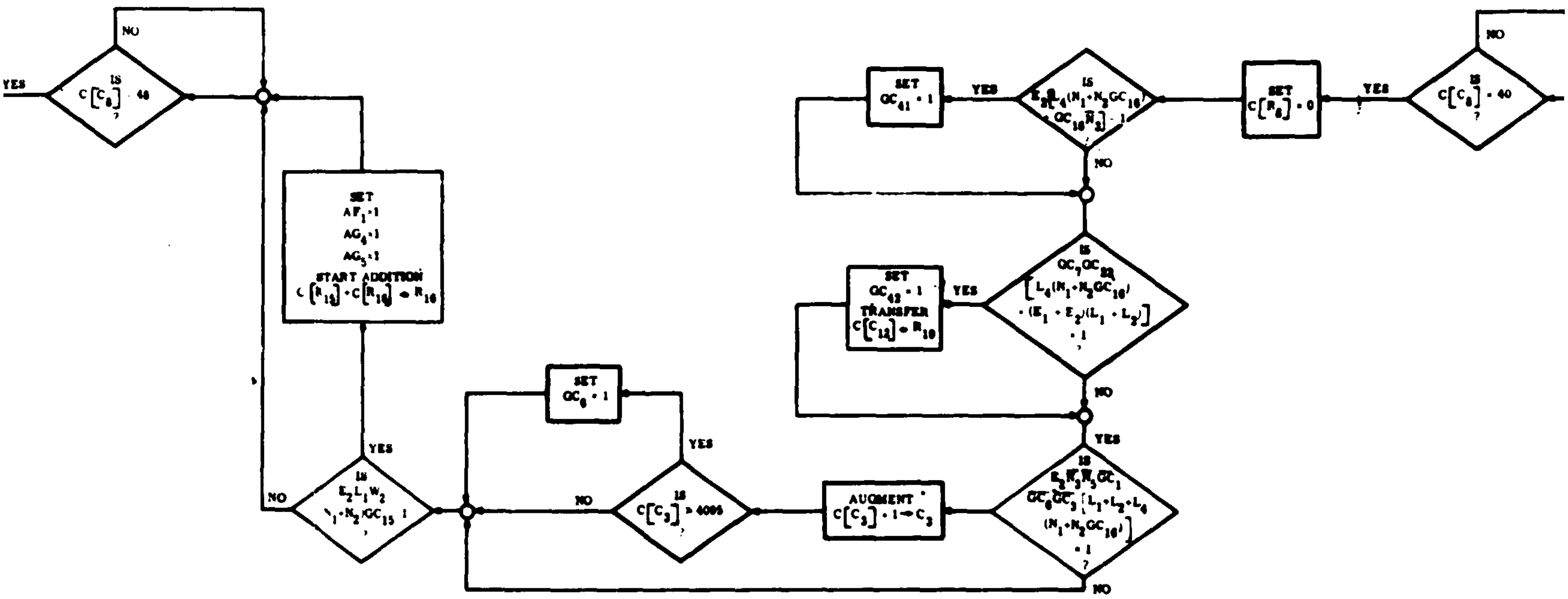
7



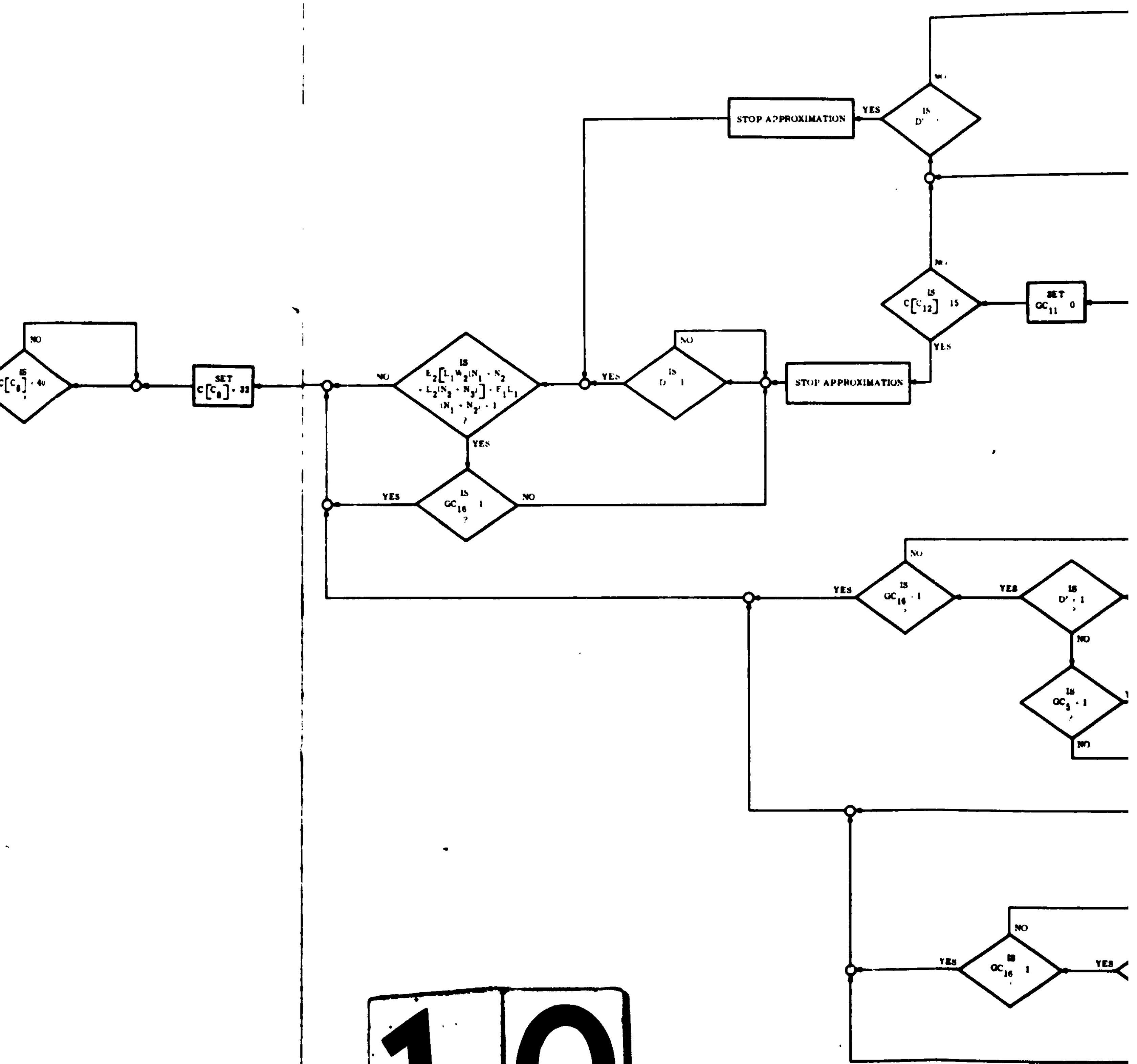
YES
IS C[C8] = 104 ?
SET
AF2 = 1
AG4 = 1
AG9 = 1
START CONSOLIDATION OF
AMPLITUDE TRANSFER
NO
YES
YES
NO
IS C[C8] = 64 ?
NO
IS C[C15] = 0 ?
YES
SET GC47 = 0
STOP
SET
AF1 = 1
AG2 = 1
AG3 = 1
(START ADDITION
YES
IS L3W2 = 1 ?
YES
IS C[C8] = 56 ?
NO
NO
SET
AF1 = 1
AG3 = 1
AG8 = 1
(START ADDITION
YES
NO
DECREMENT
C[C15] - 1 → C15
YES
NO


SET
AF4 = 1
AG6 = 1
AG9 = 1
(START DIVISION
C[R5] ÷ C[R16] → C6)
YES
IS E2L2N3C[R16] = 0 = 1 ?
NO
SET C[R6] = 1
YES
IS GC1 = 1 ?
NO
RESET
C[R16] = 0
C[R5] = 0
YES
IS E2L1W2 (N1+N2)GC1 = 1 ?
NO
YES
IS E2L1 = 1 ?
NO
NO
IS T5 = 1 ?
YES
SET GC47 = 0
STOP
YES
IS GC6 = 1 ?
NO
YES
IS C[C6] ?

8


YES
NO
IS
SET
START ADDITION
AUGMENT
TRANSFER
SET
SET
SET
SET
NO
YES
NO
YES
NO
YES
NO
YES
NO
YES
NO
YES

9


STOP APPROXIMATION
YES
NO
SET
IS
STOP APPROXIMATION
YES
NO
YES
NO
YES
YES
NO
NO
YES
YES
NO

10

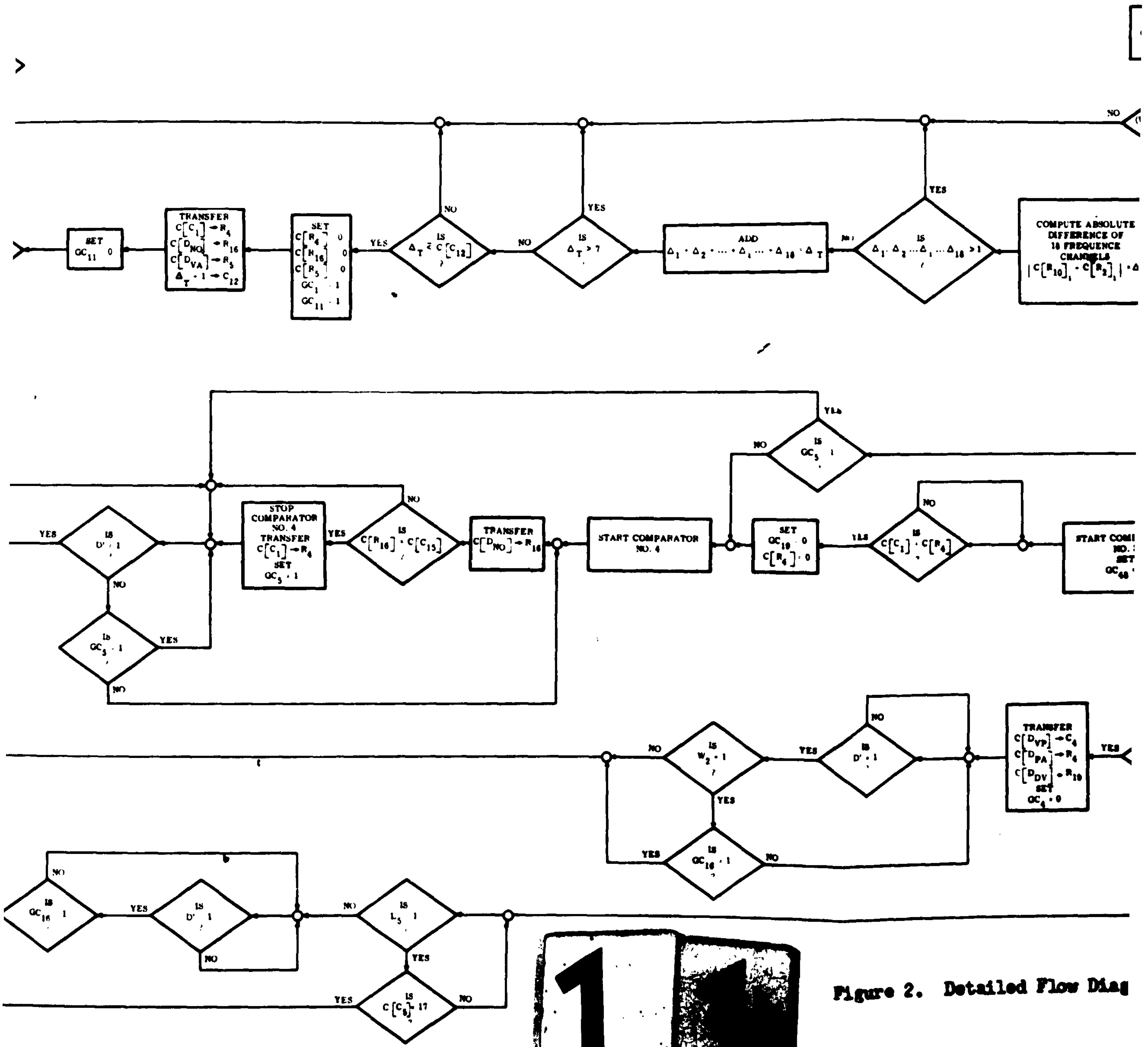


Figure 2. Detailed Flow Diag

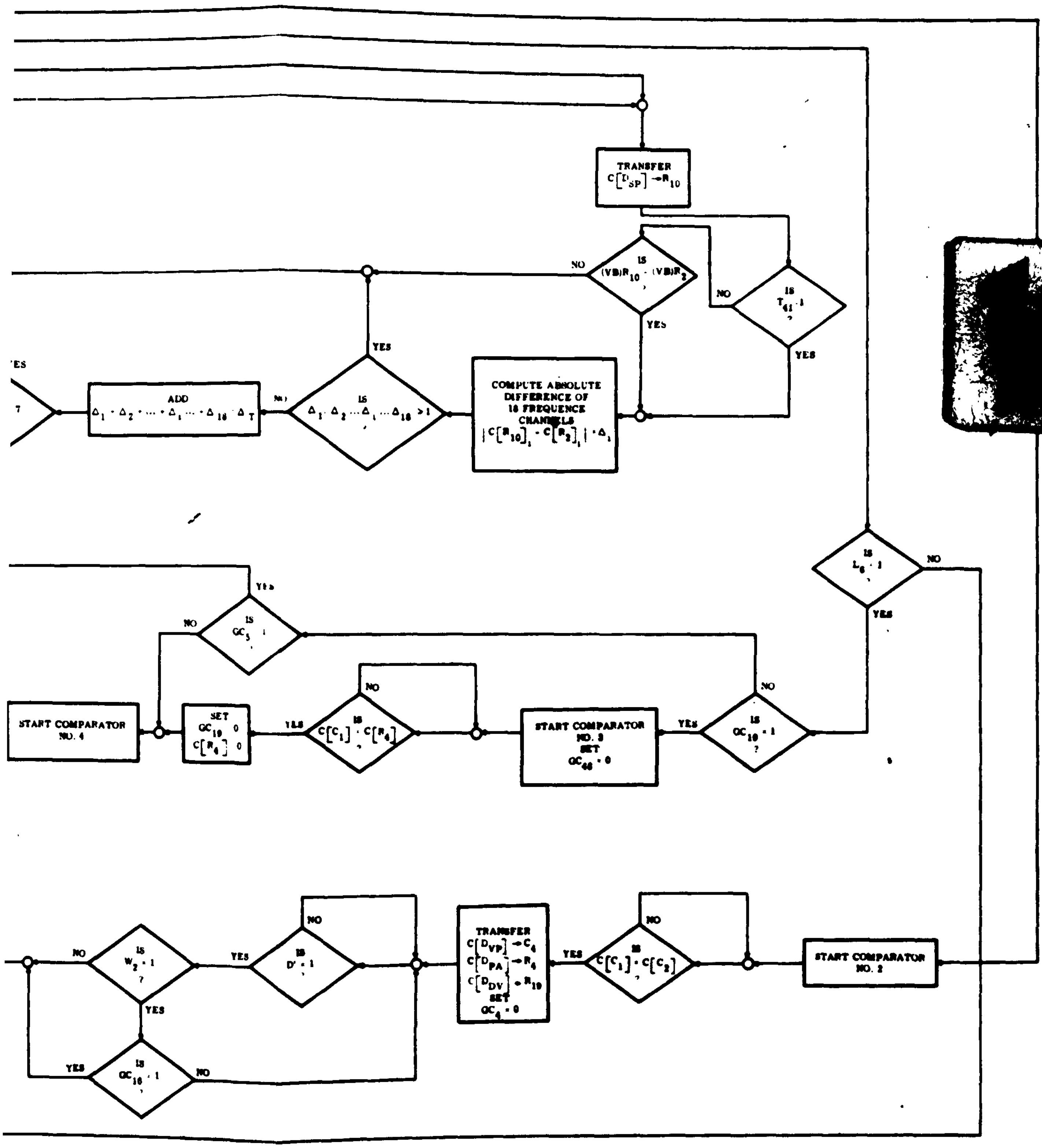
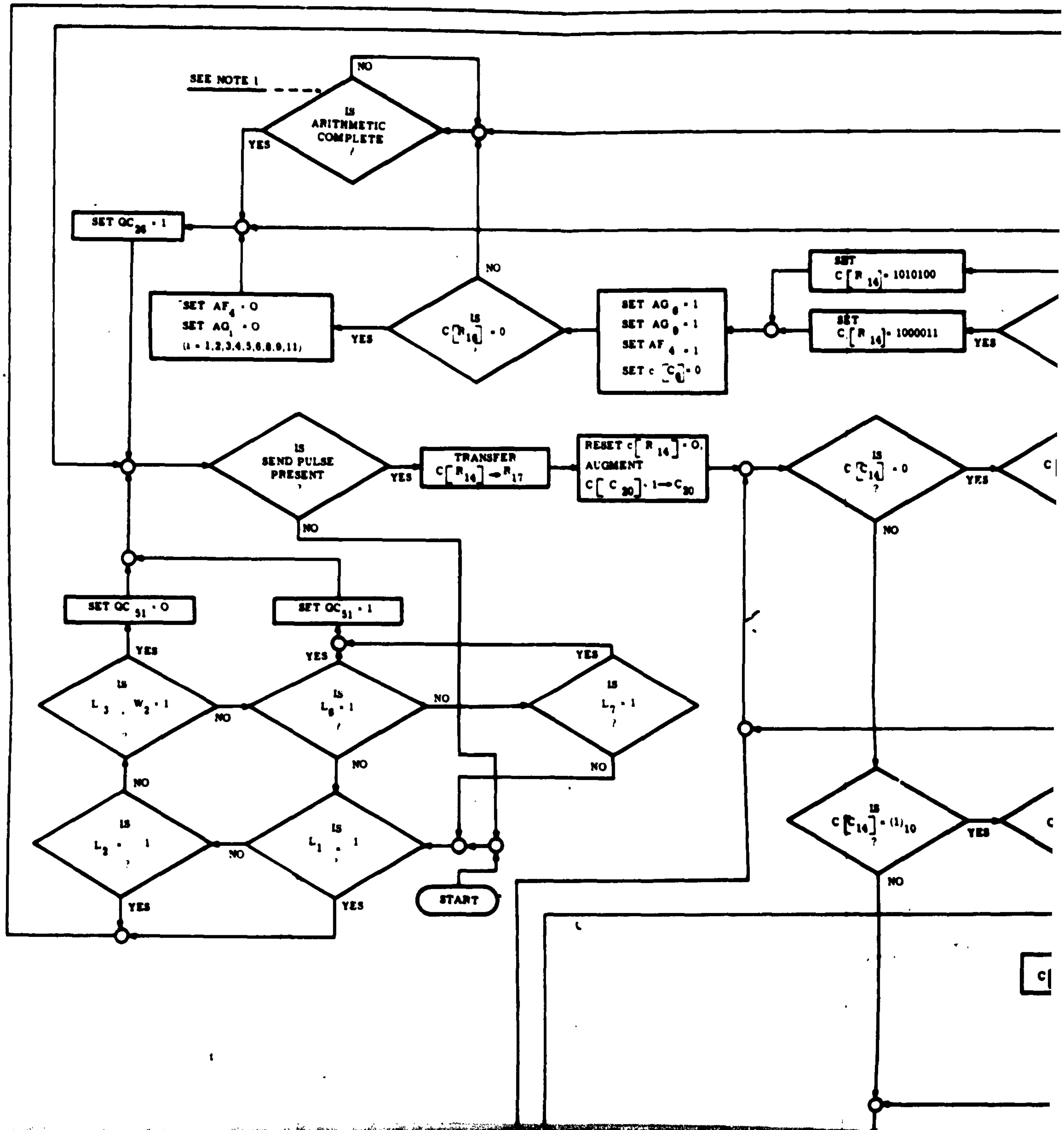
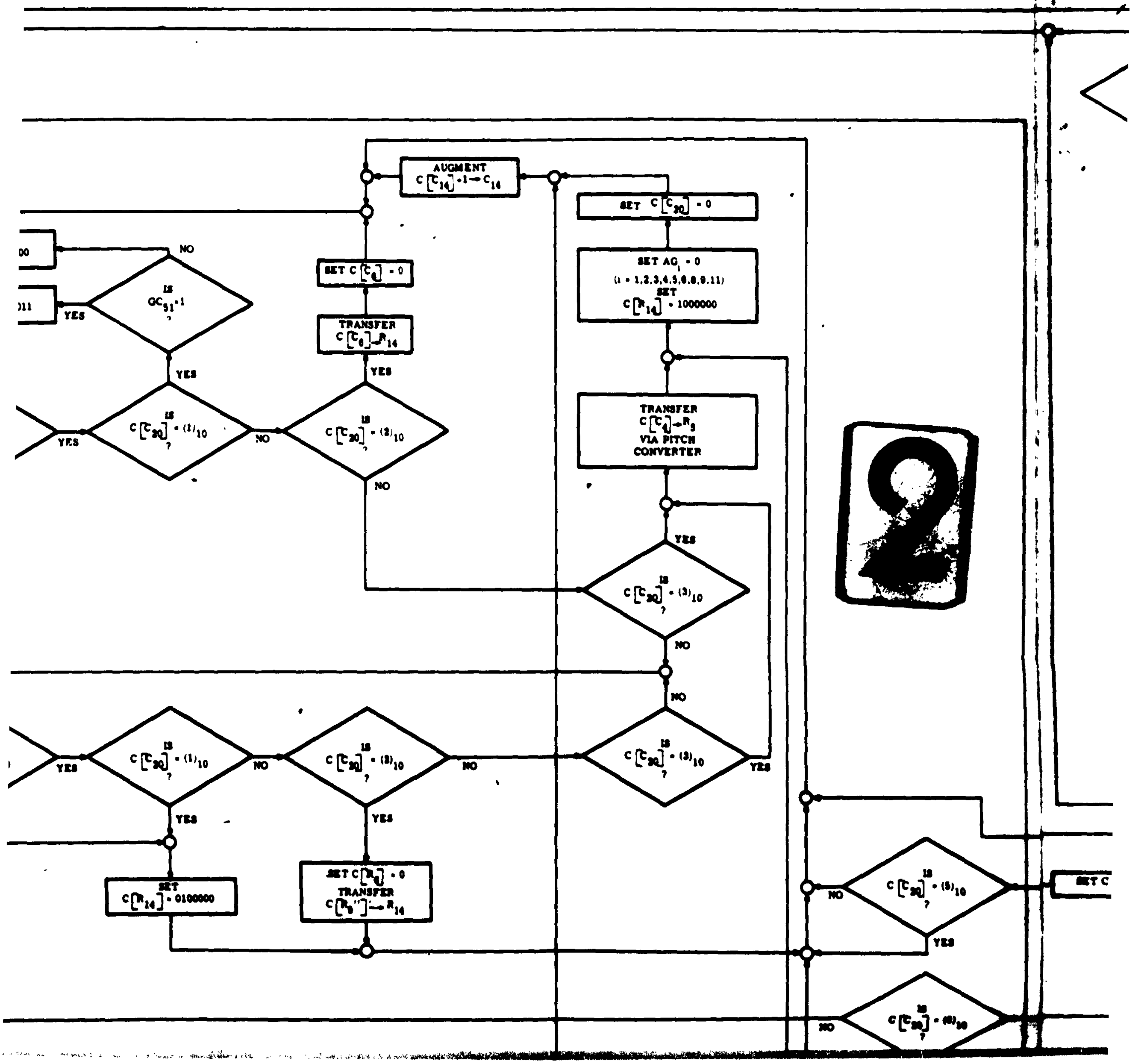


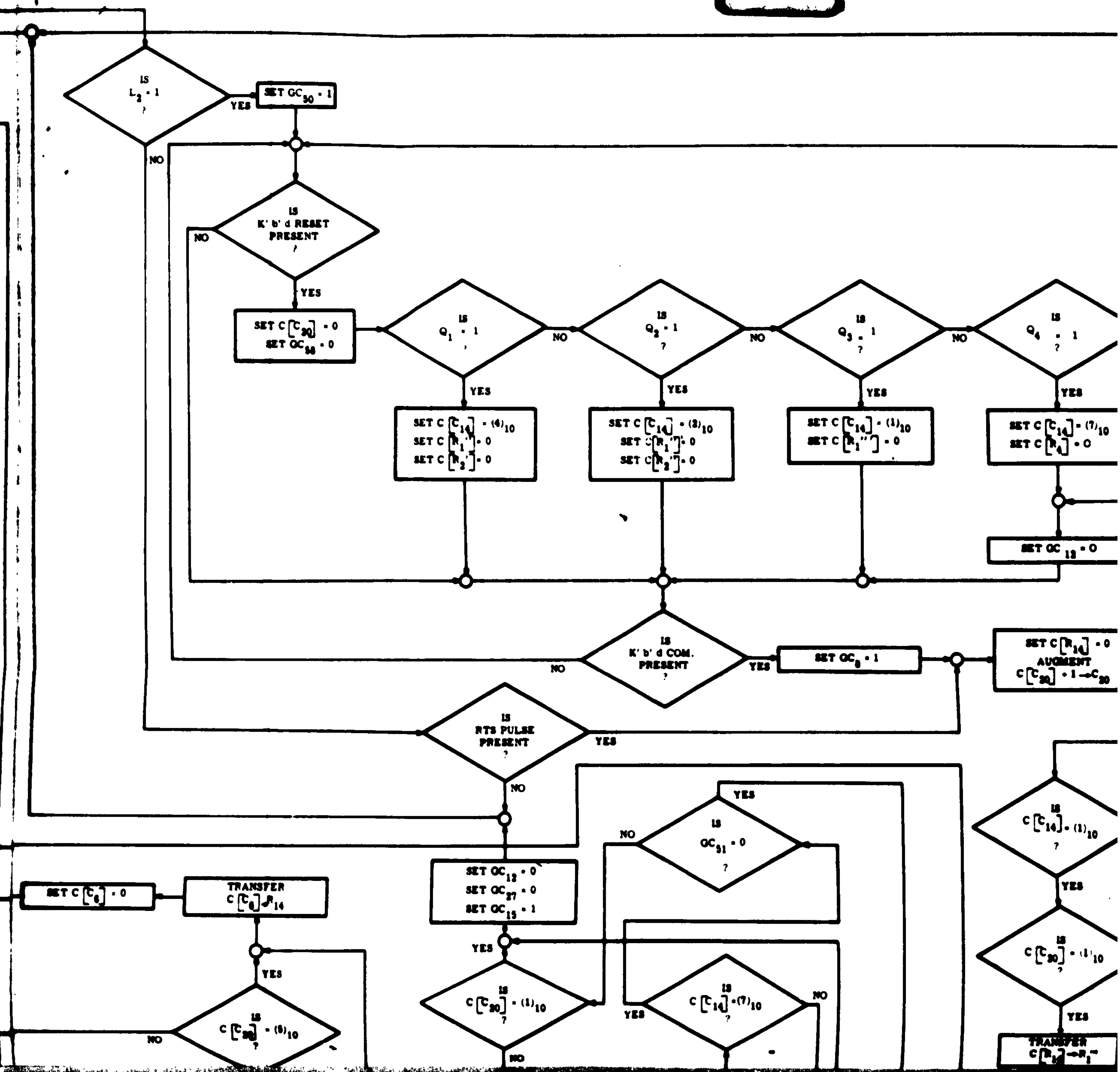
Figure 2. Detailed Flow Diagram-Central Programmer, (Sheet 2 of 2)



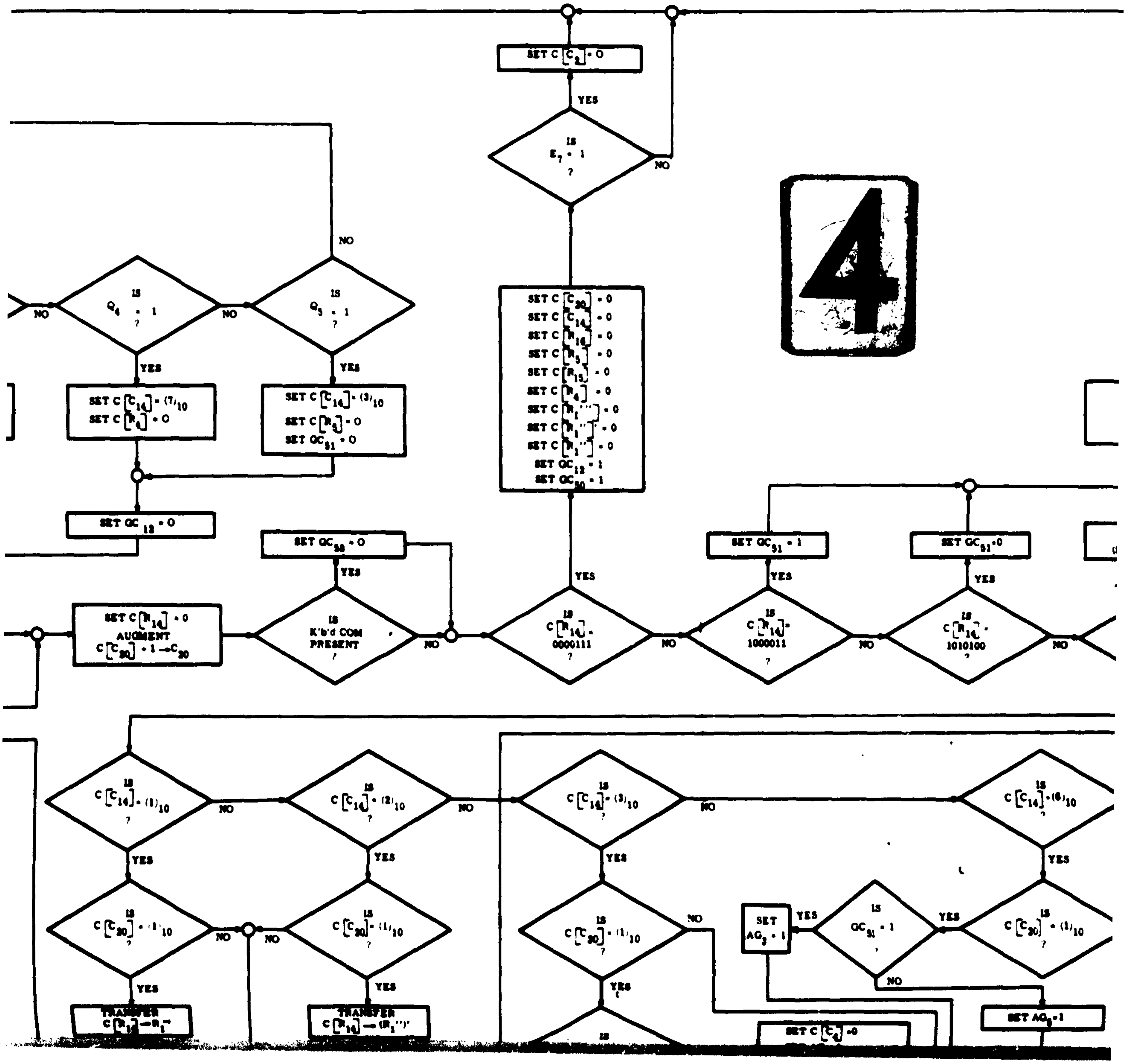
SEE NOTE 1
IS ARITHMETIC COMPLETE ?
NO
YES
SET QC36 = 1
IS C[R14] = 0 ?
NO
YES
SET AF4 = 0
SET AGi = 0
(i = 1,2,3,4,5,6,8,9,11)
SET AG6 = 1
SET AG9 = 1
SET AF4 = 1
SET c[C6] = 0
SET C[R14] = 1010100
SET C[R14] = 1000011
YES
IS SEND PULSE PRESENT ?
YES
NO
TRANSFER C[R14] → R17
RESET c[R14] = 0,
AUGMENT
C[C20] + 1 → C20
IS C[C14] = 0 ?
YES
NO
SET QC51 = 0
SET QC51 = 1
YES
YES
YES
IS L3 . W2 = 1 ?
NO
IS L8 = 1 ?
NO
IS L7 = 1 ?
NO
NO
NO
IS L2 = 1 ?
NO
IS L1 = 1 ?
YES
YES
START
IS C[C14] = (1)10 ?
YES
NO


AUGMENT C [C14] +1 → C14
SET C [C20] = 0
SET AGi = 0 (i = 1,2,3,4,5,6,8,9,11) SET C [R14] = 1000000
SET C [C6] = 0
TRANSFER C [C6] → R14
IS GC51 = 1 ?
NO
YES
IS C [C20] = (1)10 ?
IS C [C20] = (2)10 ?
TRANSFER C [C4] → R5 VIA PITCH CONVERTER
IS C [C20] = (3)10 ?
IS C [C20] = (5)10 ?
IS C [C20] = (6)10 ?
SET C [R14] = 0100000
SET C [R6] = 0 TRANSFER C [R5''] → R14
SET C
2

3

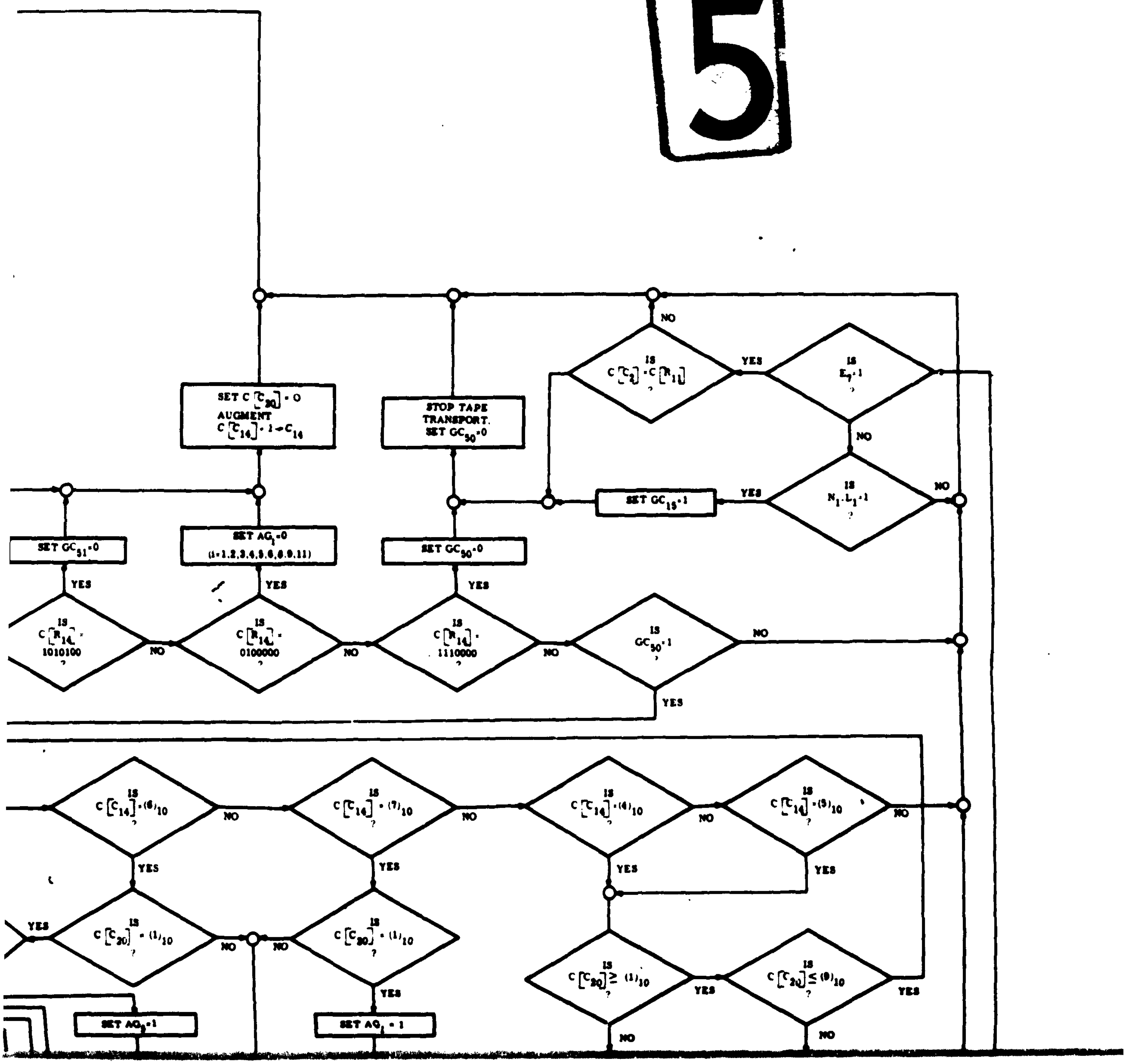


IS L2 = 1 ?
YES
NO
SET GC30 = 1
IS K' b' d RESET PRESENT ?
SET C [C30] = 0
SET GC58 = 0
IS Q1 = 1 ?
IS Q2 = 1 ?
IS Q3 = 1 ?
IS Q4 = 1 ?
SET C [C14] = (4)10
SET C [R1'] = 0
SET C [R2'] = 0
SET C [C14] = (2)10
SET C [R1''] = 0
SET C [R2''] = 0
SET C [C14] = (1)10
SET C [R1''] = 0
SET C [C14] = (7)10
SET C [R4] = 0
SET GC12 = 0
IS K' b' d COM. PRESENT ?
SET GC8 = 1
SET C [R14] = 0
AUGMENT
C [C30] + 1 → C30
IS RTS PULSE PRESENT ?
IS GC31 = 0 ?
SET GC12 = 0
SET GC27 = 0
SET GC13 = 1
IS C [C30] = (1)10 ?
IS C [C14] = (7)10 ?
IS C [C14] = (1)10 ?
IS C [C30] = (1)10 ?
SET C [C6] = 0
TRANSFER
C [C6] → R14
IS C [C30] = (8)10 ?

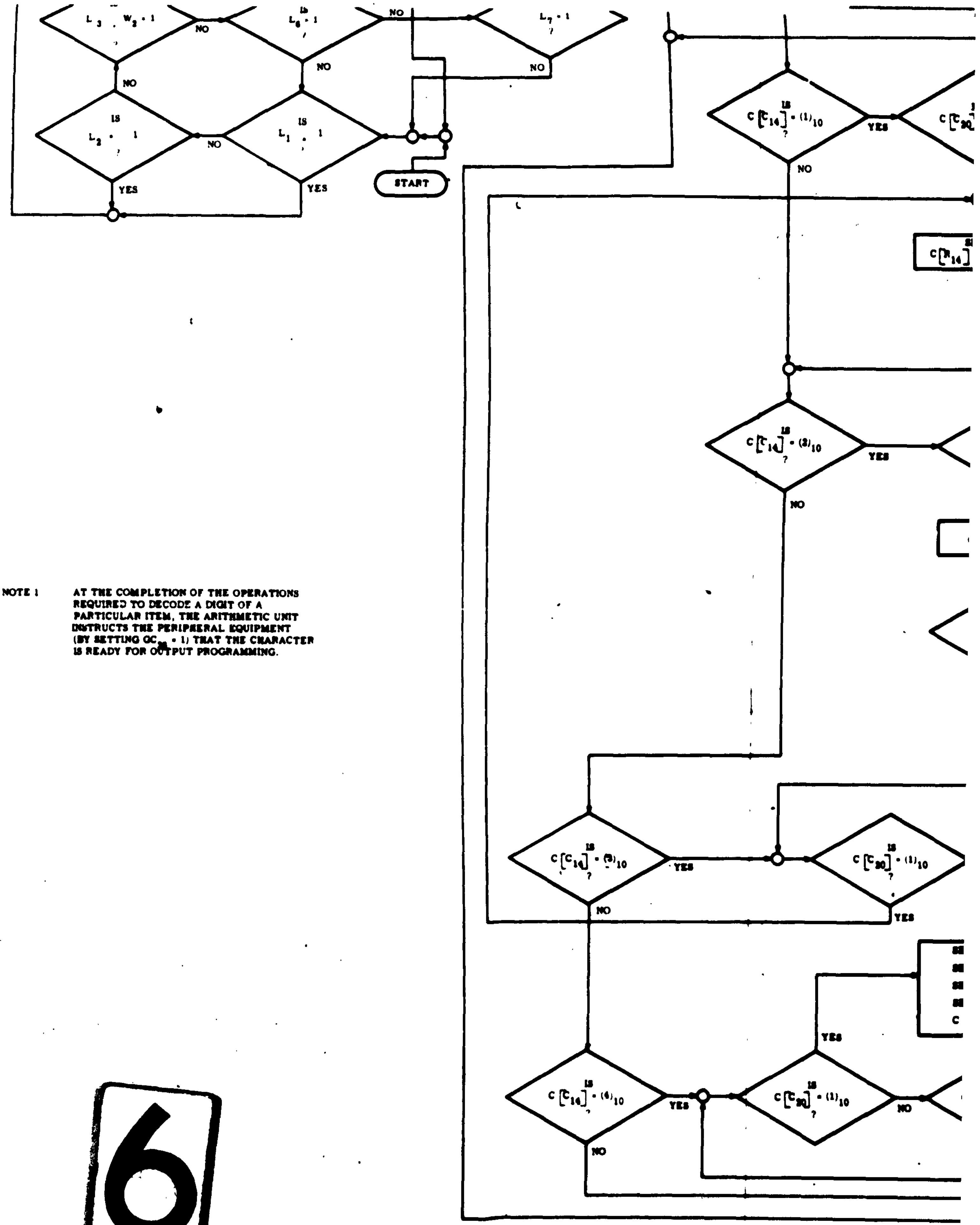


SET C [C2] = 0
YES
IS E7 = 1 ?
NO
4
IS Q4 = 1 ?
NO
IS Q5 = 1 ?
YES
SET C [C14] = (7)10
SET C [R4] = 0
SET C [C14] = (3)10
SET C [R5] = 0
SET GC31 = 0
SET GC12 = 0
SET C [C30] = 0
SET C [C14] = 0
SET C [R16] = 0
SET C [R5] = 0
SET C [R15] = 0
SET C [R4] = 0
SET C [R1'''] = 0
SET C [R1''] = 0
SET C [R1'] = 0
SET GC12 = 1
SET GC30 = 1
SET GC38 = 0
SET GC31 = 1
SET GC31 = 0
SET C [R14] = 0
AUGMENT
C [C30] + 1 → C30
IS K'b'd COM PRESENT ?
IS C [R14] = 0000111 ?
IS C [R14] = 1000011 ?
IS C [R14] = 1010100 ?
IS C [C14] = (1)10 ?
IS C [C14] = (2)10 ?
IS C [C14] = (3)10 ?
IS C [C14] = (6)10 ?
IS C [C30] = (1)10 ?
IS GC31 = 1 ?
SET AG3 = 1
SET AG3 = 1
TRANSFER C [R16] → R1'''
TRANSFER C [R16] → (R1'')'
SET C [C4] = 0
IS

5

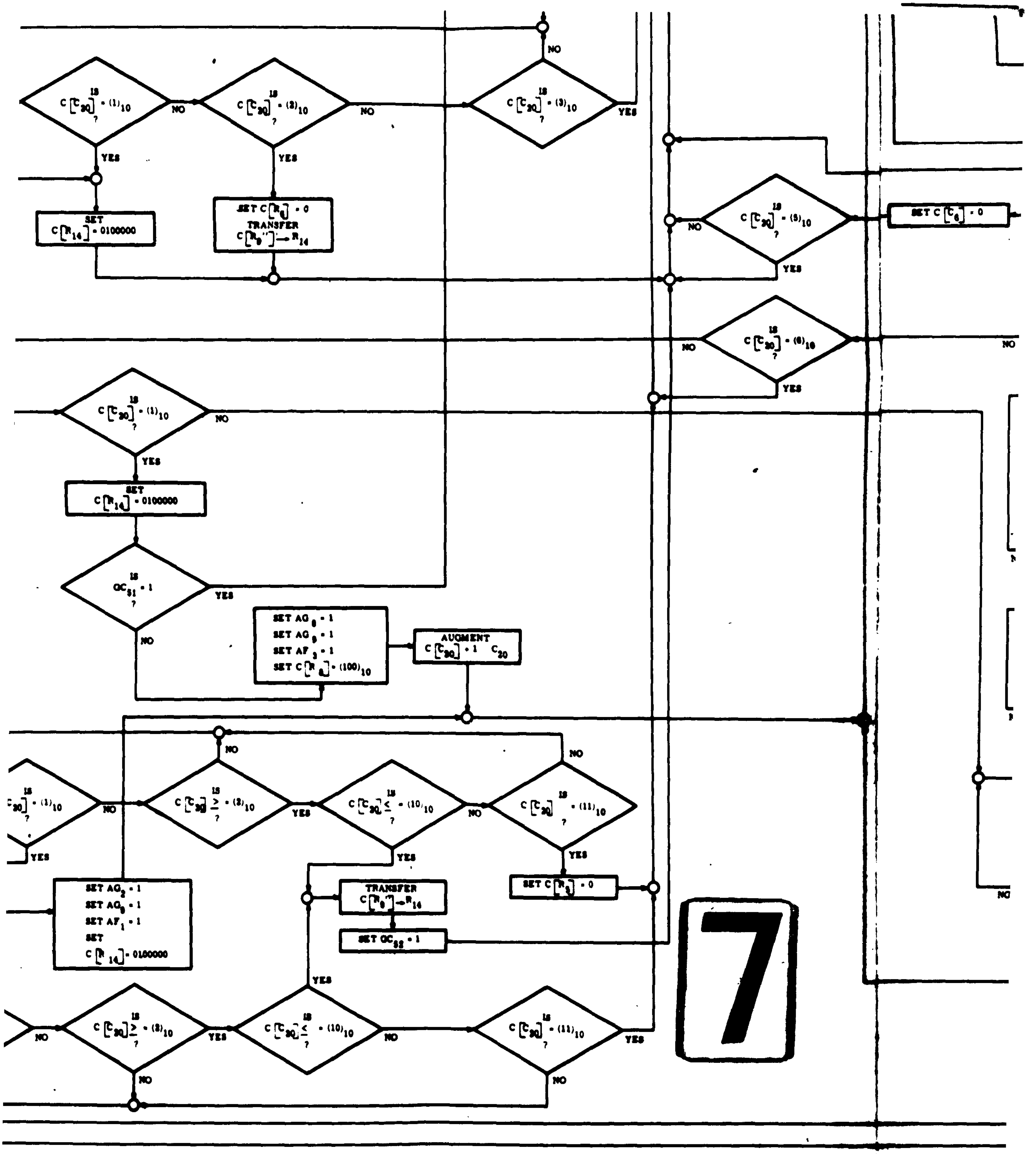


SET C [C20] = 0
AUGMENT
C [C14] + 1 → C14
STOP TAPE
TRANSPORT.
SET GC30 = 0
IS
C [C2] = C [R11]
?
IS
E7 = 1
?
IS
N1 · L1 = 1
?
SET GC15 = 1
SET GC31 = 0
SET AGi = 0
(i = 1,2,3,4,5,6,8,9,11)
SET GC30 = 0
IS
C [R14] =
1010100
?
IS
C [R14] =
0100000
?
IS
C [R14] =
1110000
?
IS
GC30 = 1
?
IS
C [C14] = (6)10
?
IS
C [C14] = (7)10
?
IS
C [C14] = (4)10
?
IS
C [C14] = (5)10
?
IS
C [C20] = (1)10
?
IS
C [C20] = (1)10
?
IS
C [C20] ≥ (1)10
?
IS
C [C20] ≤ (8)10
?
SET AG3 = 1
SET AG1 = 1
YES
NO

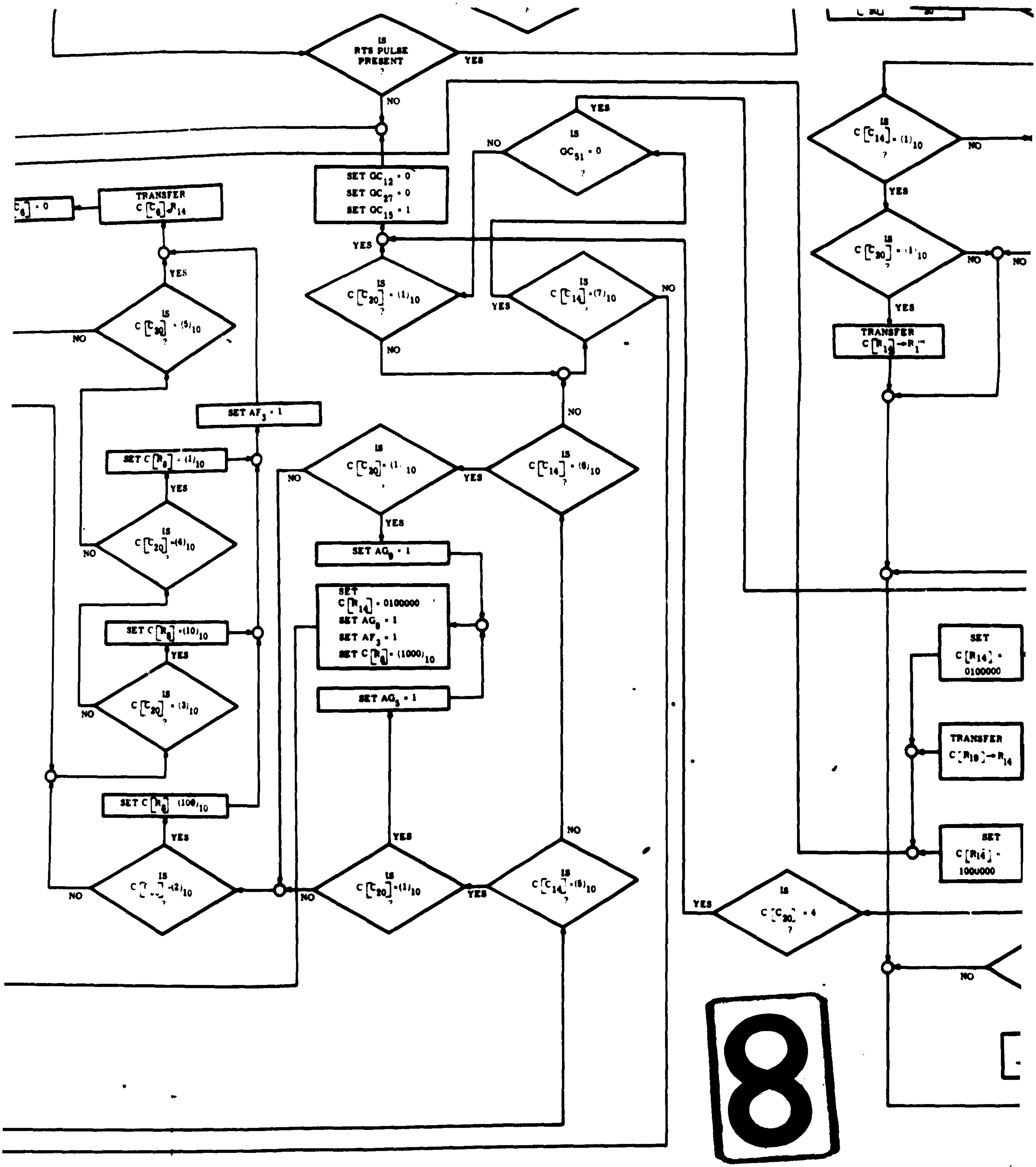


NOTE 1 AT THE COMPLETION OF THE OPERATIONS REQUIRED TO DECODE A DIGIT OF A PARTICULAR ITEM, THE ARITHMETIC UNIT INSTRUCTS THE PERIPHERAL EQUIPMENT (BY SETTING OC_{20} = 1) THAT THE CHARACTER IS READY FOR OUTPUT PROGRAMMING.

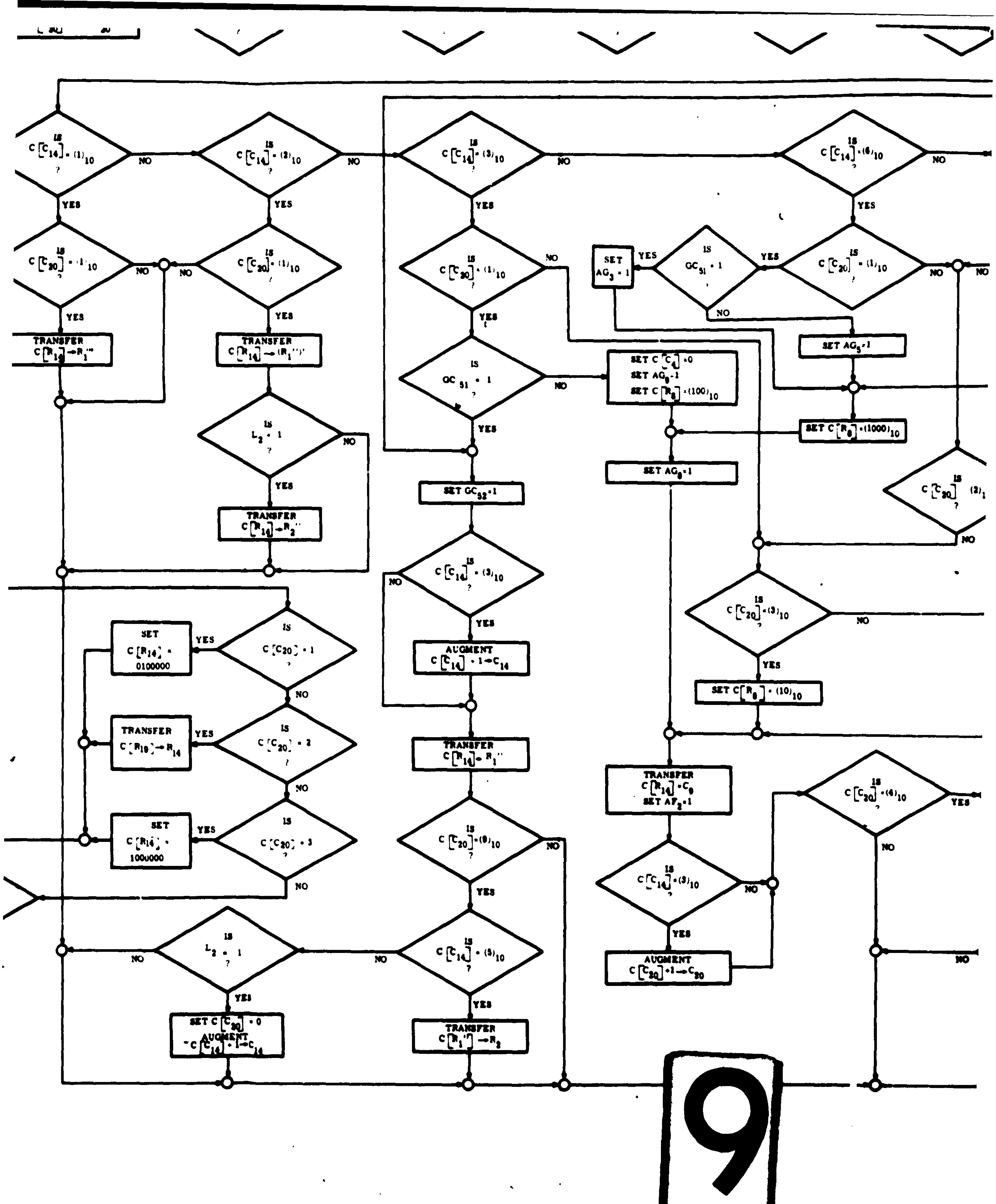
6



IS C [C20] = (1)10 ?
IS C [C20] = (2)10 ?
IS C [C20] = (3)10 ?
NO
YES
SET C [R14] = 0100000
SET C [R8] = 0
TRANSFER C [R9''] → R14
IS C [C20] = (5)10 ?
SET C [C6] = 0
IS C [C20] = (6)10 ?
IS GC31 = 1 ?
SET AG8 = 1
SET AG9 = 1
SET AF3 = 1
SET C [R8] = (100)10
AUGMENT C [C20] + 1 C20
IS C [C20] ≥ = (2)10 ?
IS C [C20] ≤ = (10)10 ?
IS C [C20] = (11)10 ?
SET C [R3] = 0
TRANSFER C [R9''] → R14
SET GC32 = 1
SET AG2 = 1
SET AG9 = 1
SET AF1 = 1
SET C [R14] = 0100000
7



IS RTS PULSE PRESENT ?
YES
NO
SET GC12 = 0
SET GC27 = 0
SET GC15 = 1
IS GC51 = 0 ?
TRANSFER C [C6] → R14
IS C [C20] = (5)10 ?
IS C [C20] = (1)10 ?
IS C [C14] = (7)10
IS C [C14] = (1)10 ?
IS C [C20] = (1)10 ?
SET AF3 = 1
SET C [R8] = (1)10
IS C [C20] = (4)10
IS C [C20] = (1)10
IS C [C14] = (6)10 ?
SET AG9 = 1
SET C [R14] = 0100000
SET AG8 = 1
SET AF3 = 1
SET C [R8] = (1000)10
SET C [R8] = (10)10
IS C [C20] = (3)10 ?
SET AG5 = 1
SET C [R8] (100)10
IS C [C20] = (2)10
IS C [C20] = (1)10 ?
IS C [C14] = (5)10 ?
SET C [R14] = 0100000
TRANSFER C [R19] → R14
SET C [R14] = 1000000
IS C [C20] = 4 ?
8


IS C[C14] = (1)10 ?
IS C[C14] = (2)10 ?
IS C[C14] = (3)10 ?
IS C[C14] = (6)10 ?
NO
YES
IS C[C20] = (1)10 ?
IS C[C20] = (1)10 ?
IS C[C20] = (1)10 ?
SET AG3 = 1
IS GC51 = 1 ?
IS C[C20] = (1)10 ?
TRANSFER C[R19] → R1'''
TRANSFER C[R14] → (R1''')'
IS GC51 = 1 ?
SET AG5 = 1
SET C[C4] = 0
SET AG9 = 1
SET C[R8] = (100)10
SET C[R8] = (1000)10
IS L2 = 1 ?
SET AG8 = 1
SET GC52 = 1
IS C[C20] (2)10 ?
TRANSFER C[R14] → R2''
IS C[C14] = (3)10 ?
IS C[C20] = (3)10 ?
SET C[R14] = 0100000
IS C[C20] = 1 ?
AUGMENT C[C14] + 1 → C14
SET C[R8] = (10)10
TRANSFER C[R19] → R14
IS C[C20] = 2 ?
TRANSFER C[R14] → R1''
TRANSFER C[R14] → C9
SET AF2 = 1
IS C[C20] = (4)10 ?
SET C[R14] = 1000000
IS C[C20] = 3 ?
IS C[C20] = (9)10 ?
IS C[C14] = (3)10 ?
IS L2 = 1 ?
IS C[C14] = (5)10 ?
AUGMENT C[C20] + 1 → C20
SET C[C20] = 0
AUGMENT C[C14] + 1 → C14
TRANSFER C[R1''] → R2
9

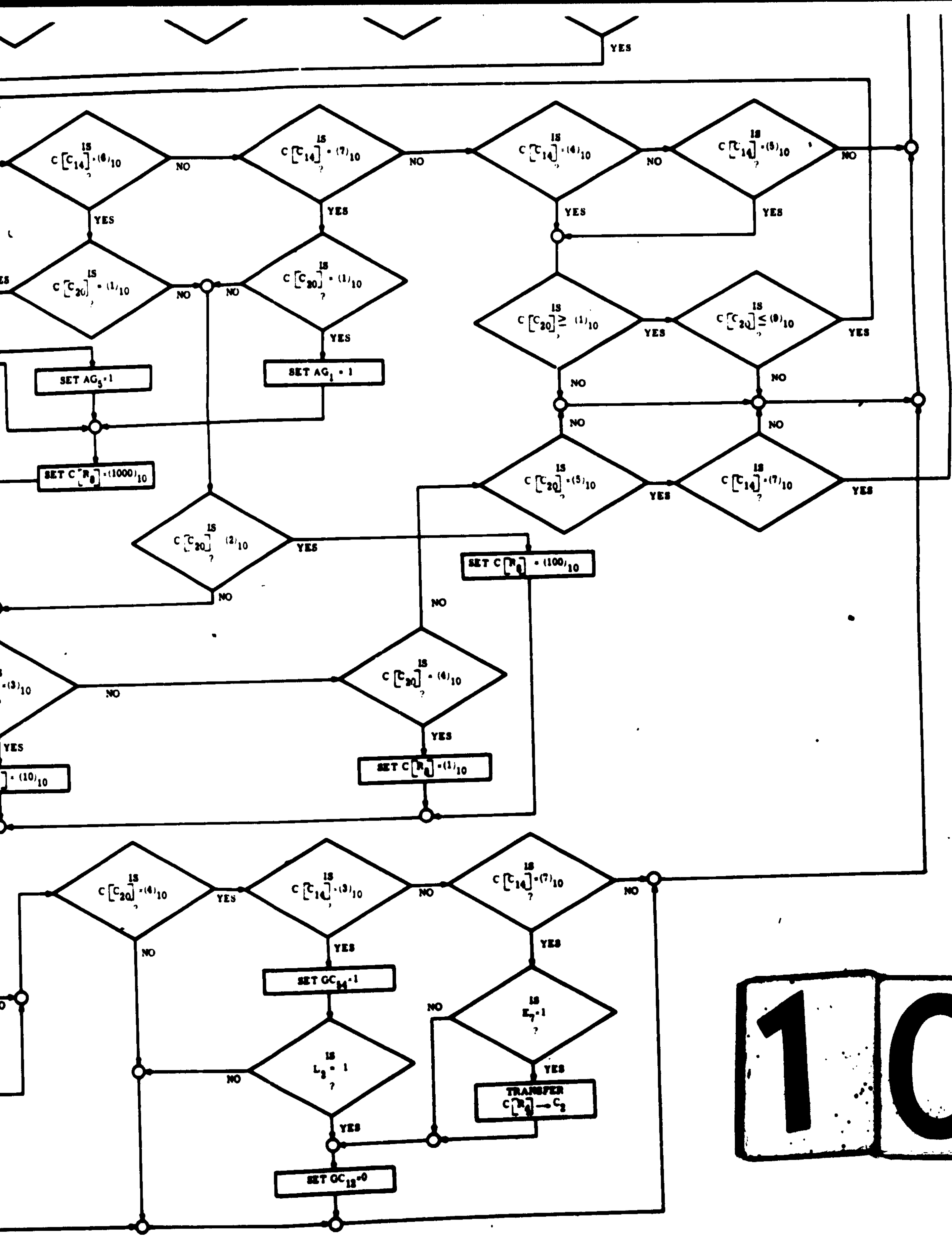
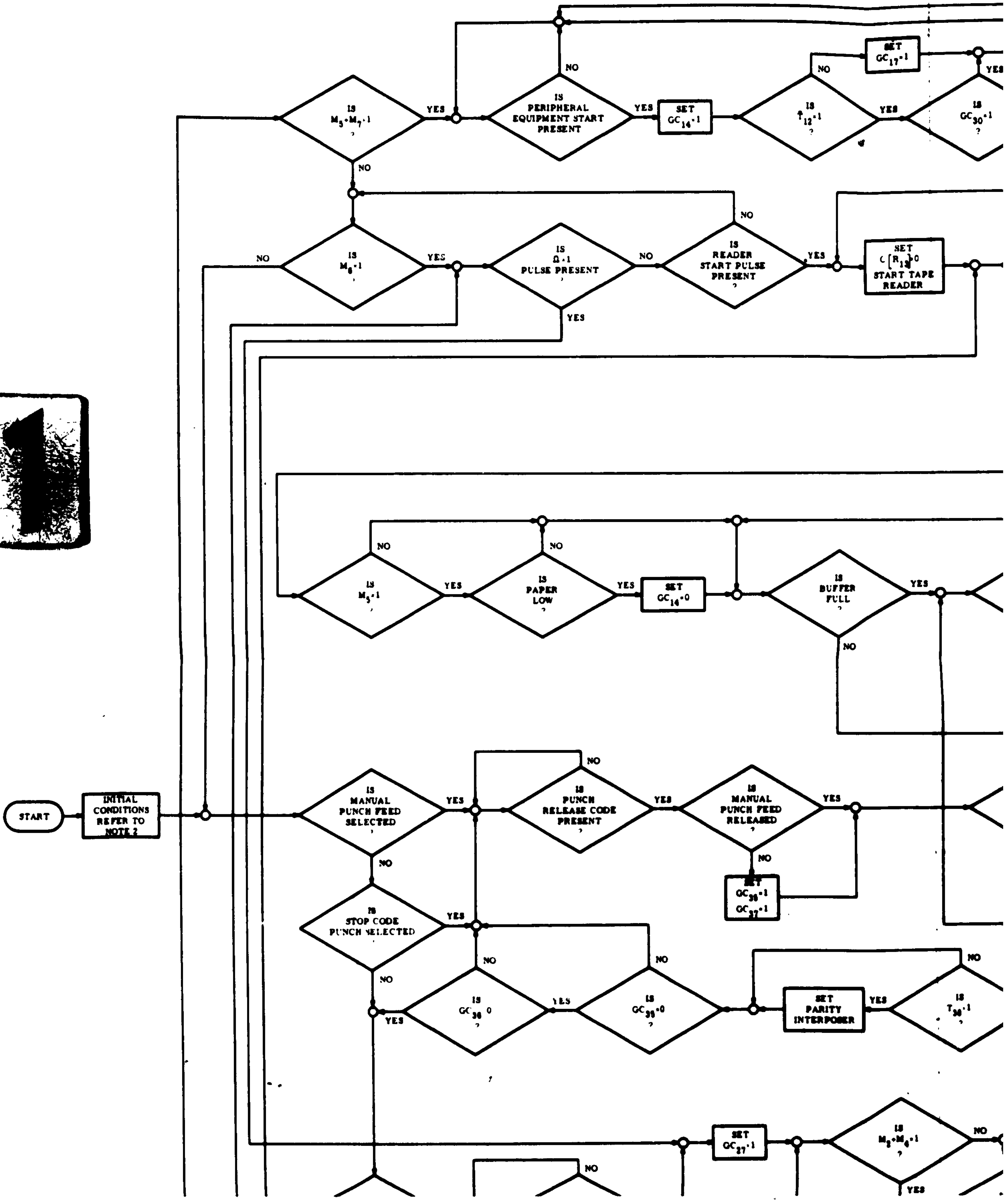
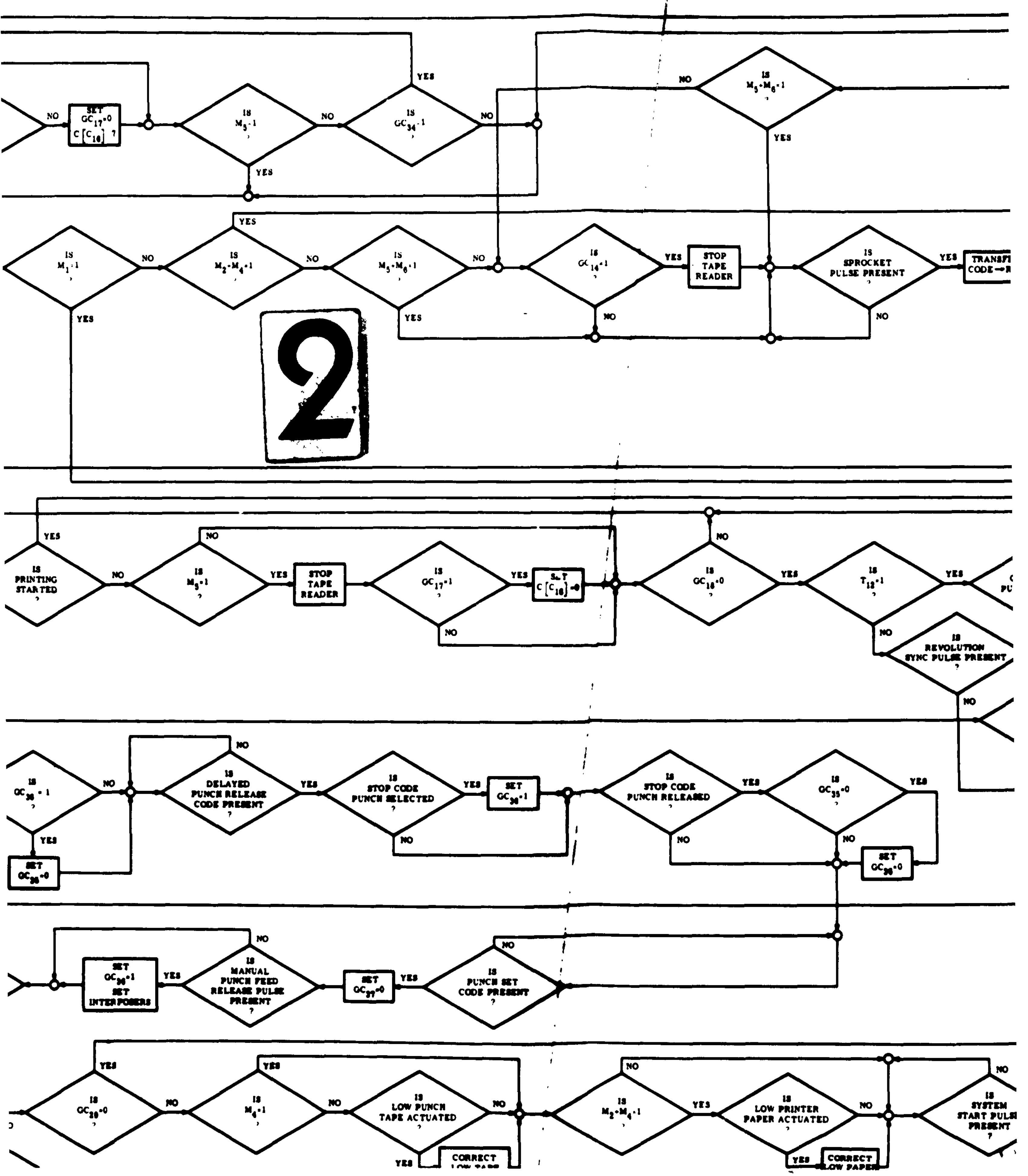


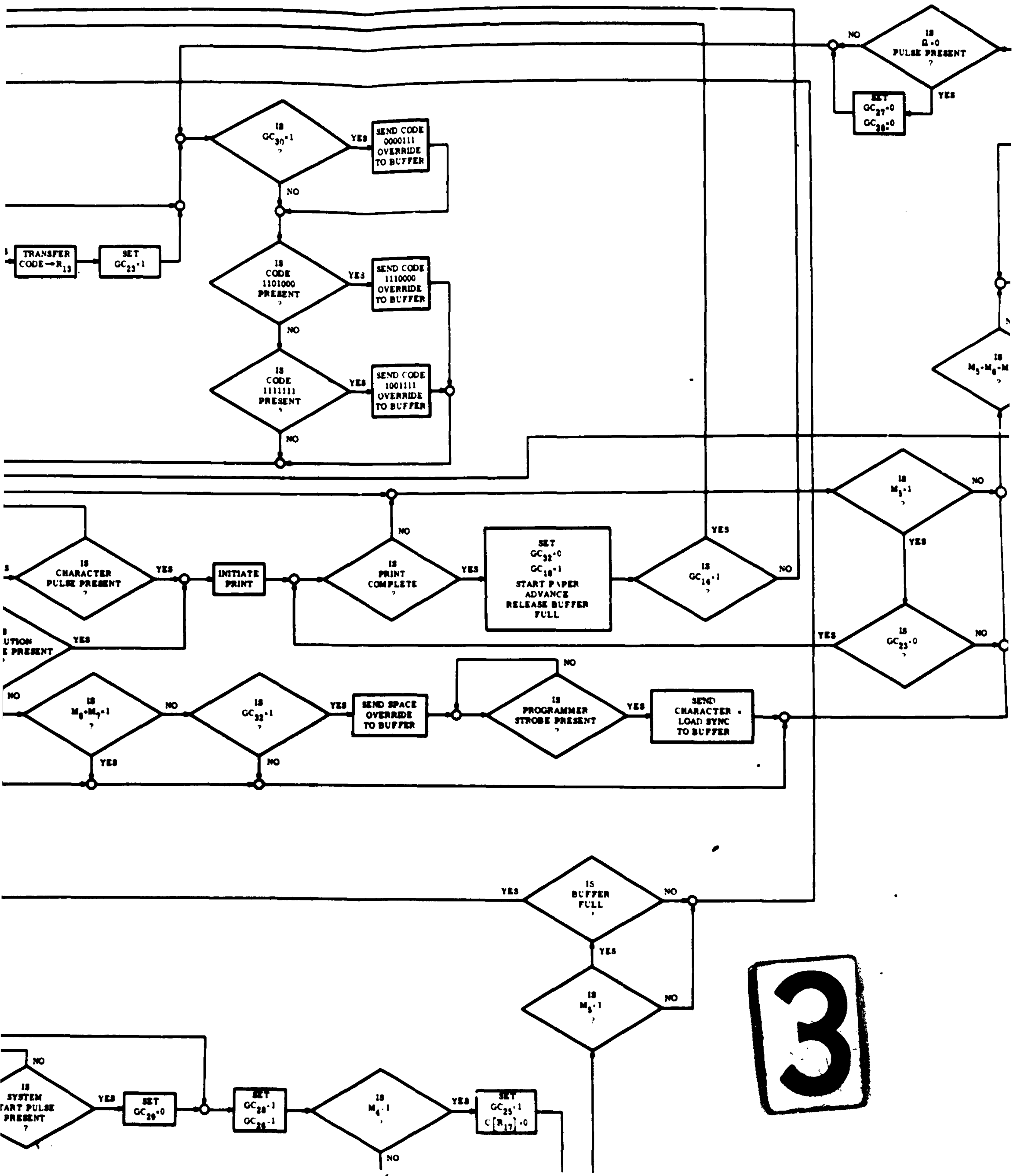
Figure 3. Detailed Flow Diagram-Input/Output Programmer

1

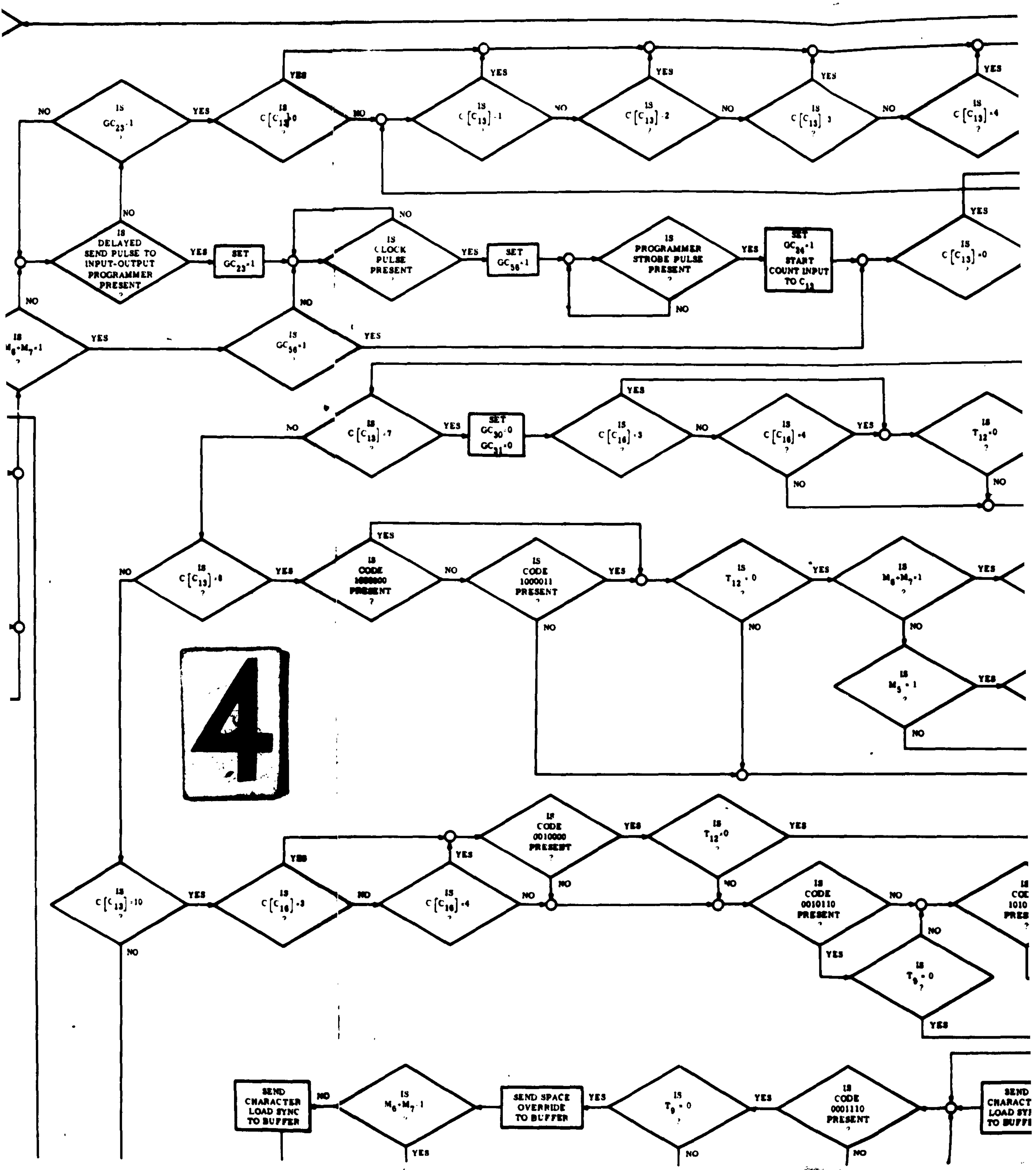

START
INITIAL CONDITIONS REFER TO NOTE 2
IS M5·M7·1 ?
YES
NO
IS PERIPHERAL EQUIPMENT START PRESENT
SET GC14·1
IS T12·1 ?
SET GC17·1
IS GC30·1 ?
IS M6·1
IS Ω·1 PULSE PRESENT
IS READER START PULSE PRESENT ?
SET C[R13]·0 START TAPE READER
IS M5·1
IS PAPER LOW ?
SET GC14·0
IS BUFFER FULL ?
IS MANUAL PUNCH FEED SELECTED
IS PUNCH RELEASE CODE PRESENT ?
IS MANUAL PUNCH FEED RELEASED ?
SET GC36·1 GC37·1
IS STOP CODE PUNCH SELECTED
IS GC36 0 ?
IS GC39·0 ?
SET PARITY INTERPOSER
IS T36·1 ?
SET GC27·1
IS M3·M4·1 ?



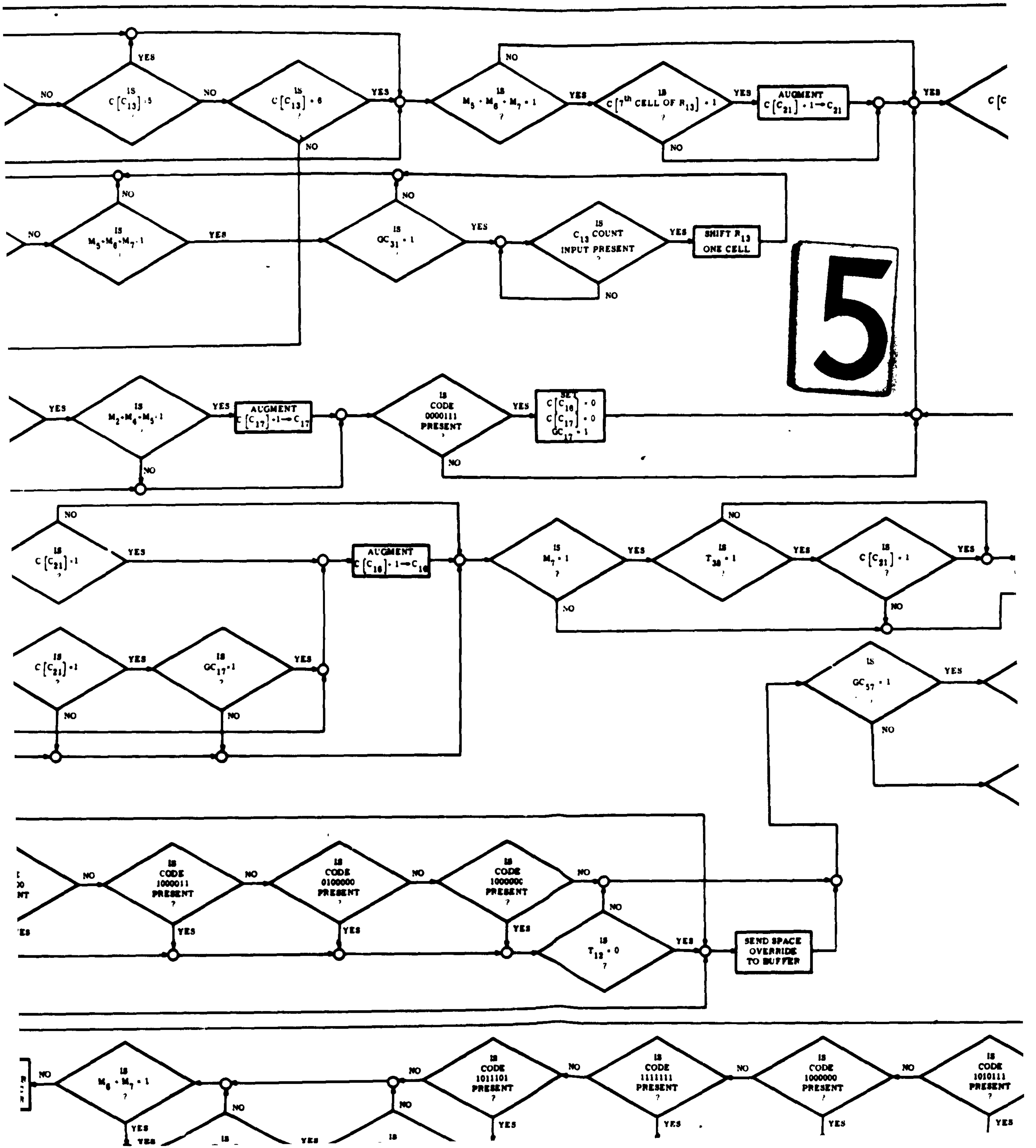
SET $GC_{17}=0$ $C[C_{16}]$?
IS $M_3=1$?
IS $GC_{34}=1$?
IS $M_5 \cdot M_6=1$?
IS $M_1=1$?
IS $M_2 \cdot M_4=1$?
IS $M_5 \cdot M_6=1$?
IS $GC_{14}=1$?
STOP TAPE READER
IS SPROCKET PULSE PRESENT ?
TRANSF CODE → R
2
IS PRINTING STARTED ?
IS $M_3=1$?
STOP TAPE READER
IS $GC_{17}=1$?
SET $C[C_{16}]=0$
IS $GC_{18}=0$?
IS $T_{12}=1$?
IS REVOLUTION SYNC PULSE PRESENT ?
IS $GC_{36}=1$?
SET $GC_{36}=0$
IS DELAYED PUNCH RELEASE CODE PRESENT ?
IS STOP CODE PUNCH SELECTED ?
SET $GC_{36}=1$
IS STOP CODE PUNCH RELEASED ?
IS $GC_{35}=0$?
SET $GC_{36}=0$
SET $GC_{36}=1$ SET INTERPOSERS
IS MANUAL PUNCH FEED RELEASE PULSE PRESENT ?
SET $GC_{37}=0$
IS PUNCH SET CODE PRESENT ?
IS $GC_{38}=0$?
IS $M_4=1$?
IS LOW PUNCH TAPE ACTUATED ?
CORRECT LOW TAPE
IS $M_2 \cdot M_4=1$?
IS LOW PRINTER PAPER ACTUATED ?
CORRECT LOW PAPER
IS SYSTEM START PULSE PRESENT ?
YES
NO


IS Ω = 0 PULSE PRESENT ?
NO
YES
SET GC27 = 0 GC28 = 0
IS GC30 = 1 ?
YES
NO
SEND CODE 0000111 OVERRIDE TO BUFFER
TRANSFER CODE → R13
SET GC23 = 1
IS CODE 1101000 PRESENT ?
SEND CODE 1110000 OVERRIDE TO BUFFER
IS CODE 1111111 PRESENT ?
SEND CODE 1001111 OVERRIDE TO BUFFER
IS CHARACTER PULSE PRESENT ?
INITIATE PRINT
IS PRINT COMPLETE ?
SET GC32 = 0 GC18 = 1 START PAPER ADVANCE RELEASE BUFFER FULL
IS GC14 = 1 ?
IS M5 = 1 ?
IS GC23 = 0 ?
IS M5 + M6 + M
IS M6 + M7 = 1 ?
IS GC32 = 1 ?
SEND SPACE OVERRIDE TO BUFFER
IS PROGRAMMER STROBE PRESENT ?
SEND CHARACTER + LOAD SYNC TO BUFFER
IS BUFFER FULL ?
IS M5 = 1 ?
IS SYSTEM START PULSE PRESENT ?
SET GC29 = 0
SET GC28 = 1 GC29 = 1
IS M4 = 1 ?
SET GC25 = 1 C[R17] = 0

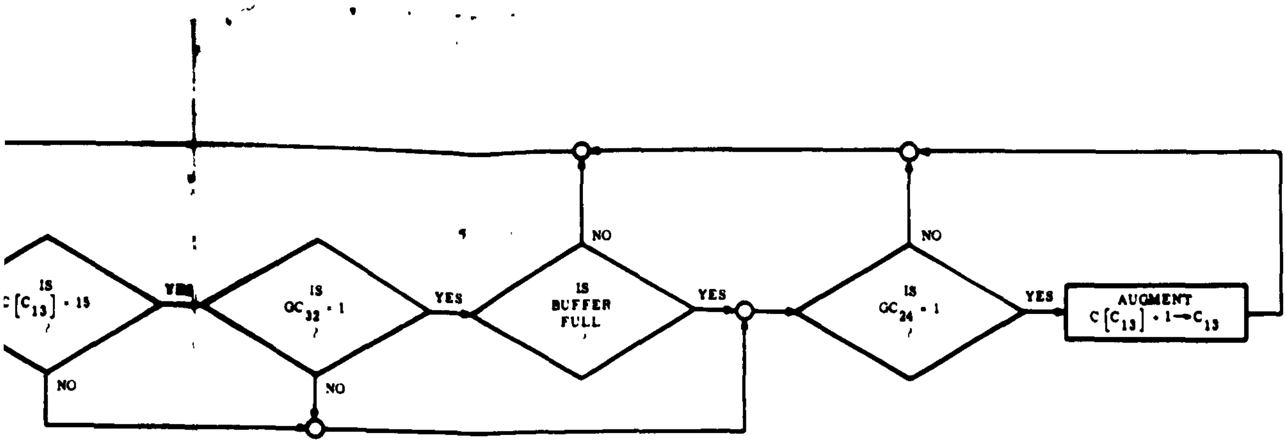
3



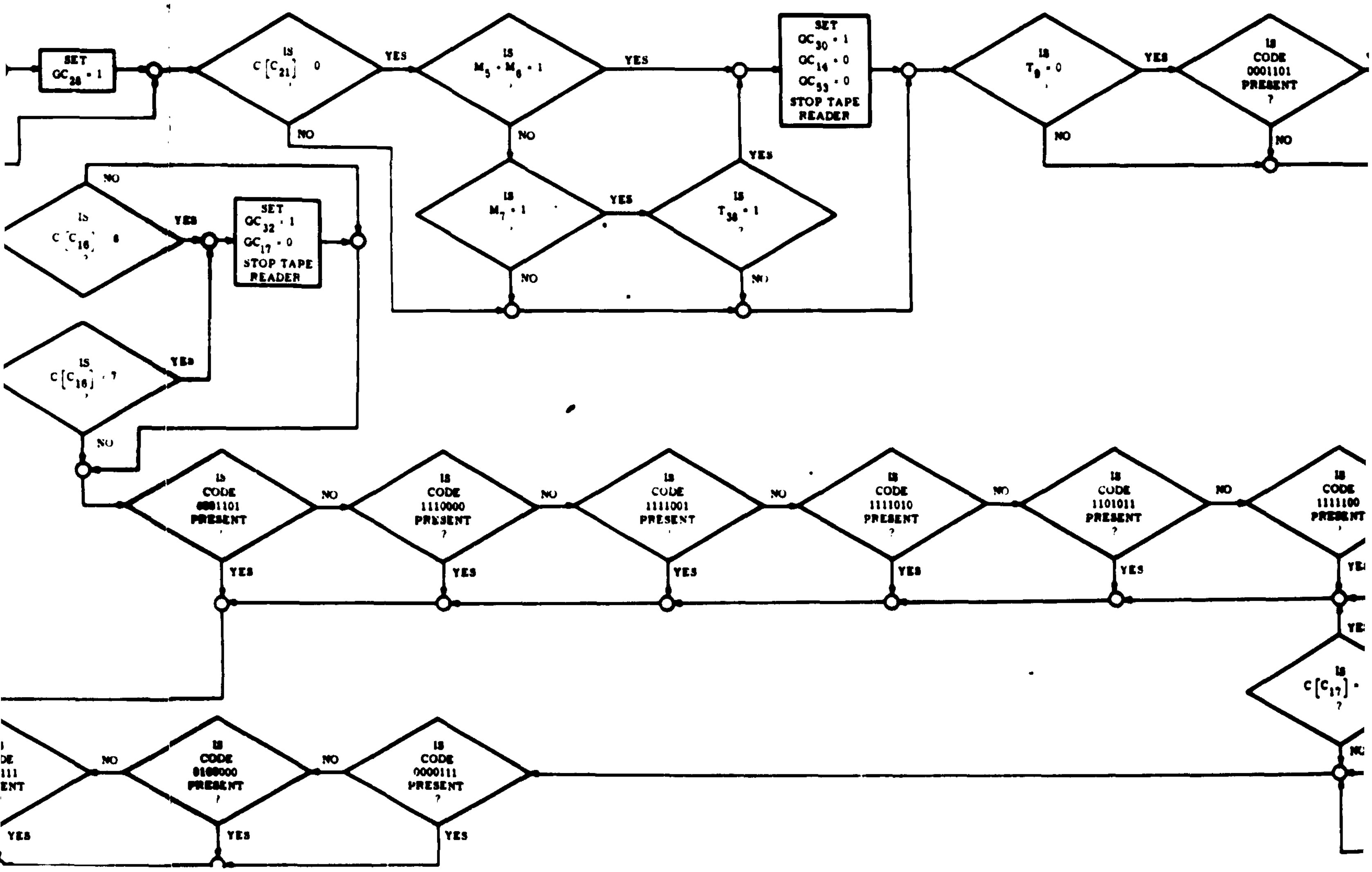
IS GC_{23} = 1 ?
IS $C[C_{13}]$ = 0 ?
IS $C[C_{13}]$ = 1 ?
IS $C[C_{13}]$ = 2 ?
IS $C[C_{13}]$ = 3 ?
IS $C[C_{13}]$ = 4 ?
IS DELAYED SEND PULSE TO INPUT-OUTPUT PROGRAMMER PRESENT ?
SET GC_{23} = 1
IS CLOCK PULSE PRESENT ?
SET GC_{56} = 1
IS PROGRAMMER STROBE PULSE PRESENT ?
SET GC_{34} = 1 START COUNT INPUT TO C_{13}
IS $C[C_{13}]$ = 0 ?
IS $M_6 \cdot M_7$ = 1 ?
IS GC_{56} = 1 ?
IS $C[C_{13}]$ = 7 ?
SET GC_{30} = 0 GC_{31} = 0
IS $C[C_{16}]$ = 3 ?
IS $C[C_{16}]$ = 4 ?
IS T_{12} = 0 ?
IS $C[C_{13}]$ = 8 ?
IS CODE 1000011 PRESENT ?
IS T_{12} = 0 ?
IS $M_6 \cdot M_7$ = 1 ?
IS M_5 = 1 ?
4
IS CODE 0010000 PRESENT ?
IS T_{12} = 0 ?
IS $C[C_{13}]$ = 10 ?
IS $C[C_{16}]$ = 3 ?
IS $C[C_{16}]$ = 4 ?
IS CODE 0010110 PRESENT ?
IS T_9 = 0 ?
SEND CHARACTER LOAD SYNC TO BUFFER
IS $M_6 \cdot M_7$ = 1 ?
SEND SPACE OVERRIDE TO BUFFER
IS T_9 = 0 ?
IS CODE 0001110 PRESENT ?
YES
NO



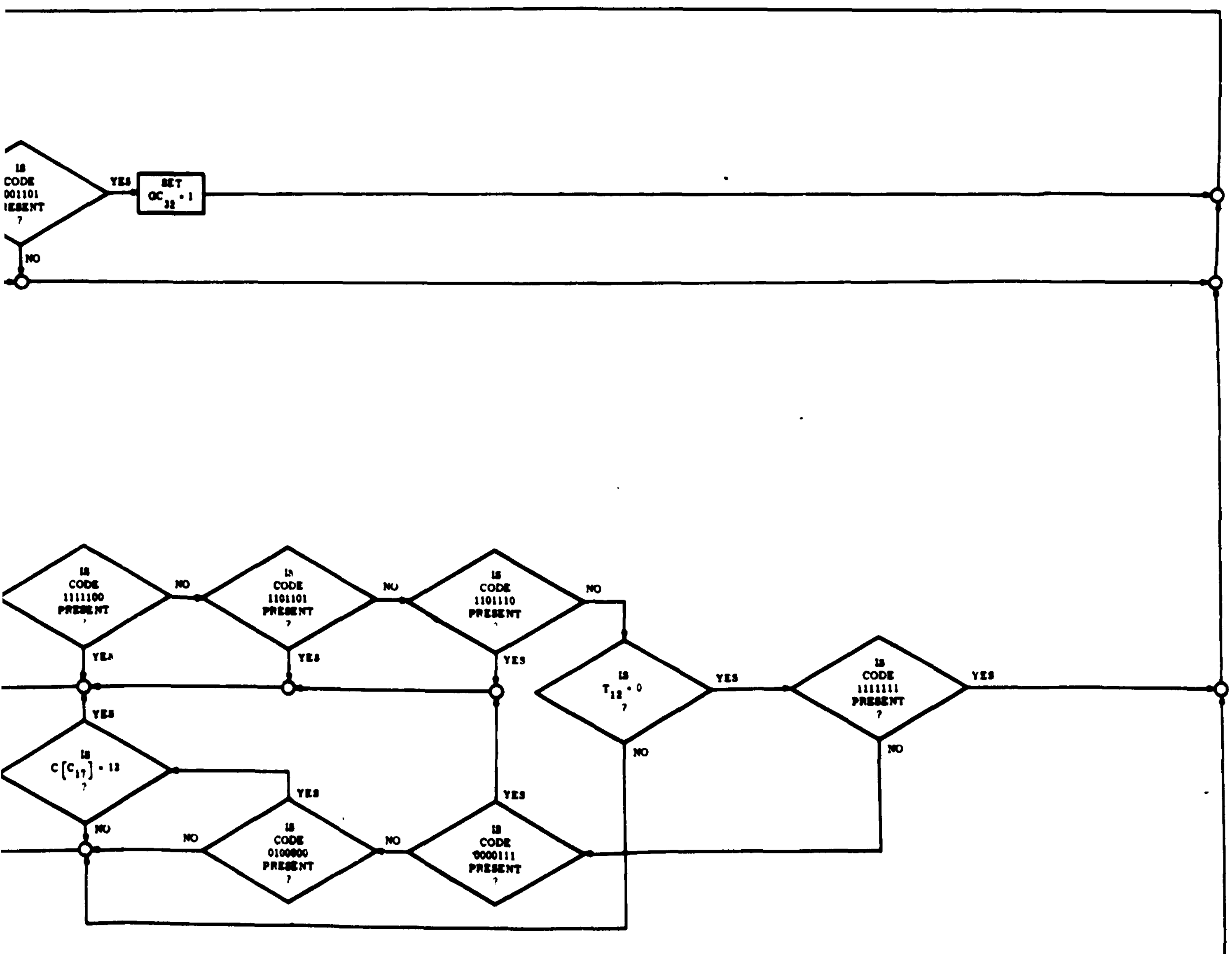
IS C[C13] = 5 ?
IS C[C13] = 6 ?
IS M5 · M6 · M7 = 1 ?
IS C[7th CELL OF R13] = 1 ?
AUGMENT C[C21] + 1 → C21
IS M5·M6·M7 = 1
IS GC31 = 1
IS C13 COUNT INPUT PRESENT ?
SHIFT R13 ONE CELL
5
IS M2·M4·M5 = 1
AUGMENT C[C17] + 1 → C17
IS CODE 0000111 PRESENT ?
SET C[C16] = 0 C[C17] = 0 GC17 = 1
IS C[C21] = 1 ?
AUGMENT C[C16] + 1 → C16
IS M7 = 1 ?
IS T38 = 1 ?
IS C[C31] = 1 ?
IS C[C21] = 1 ?
IS GC17 = 1 ?
IS GC37 = 1
IS CODE 1000011 PRESENT ?
IS CODE 0100000 PRESENT ?
IS CODE 1000000 PRESENT ?
IS T12 = 0 ?
SEND SPACE OVERRIDE TO BUFFER
IS M6 · M7 = 1 ?
IS CODE 1011101 PRESENT ?
IS CODE 1111111 PRESENT ?
IS CODE 1000000 PRESENT ?
IS CODE 1010111 PRESENT ?
YES
NO


IS C[C13] = 15 ?
YES
NO
IS GC32 = 1 ?
YES
NO
IS BUFFER FULL ?
YES
NO
IS GC24 = 1 ?
YES
NO
AUGMENT C[C13] + 1→C13

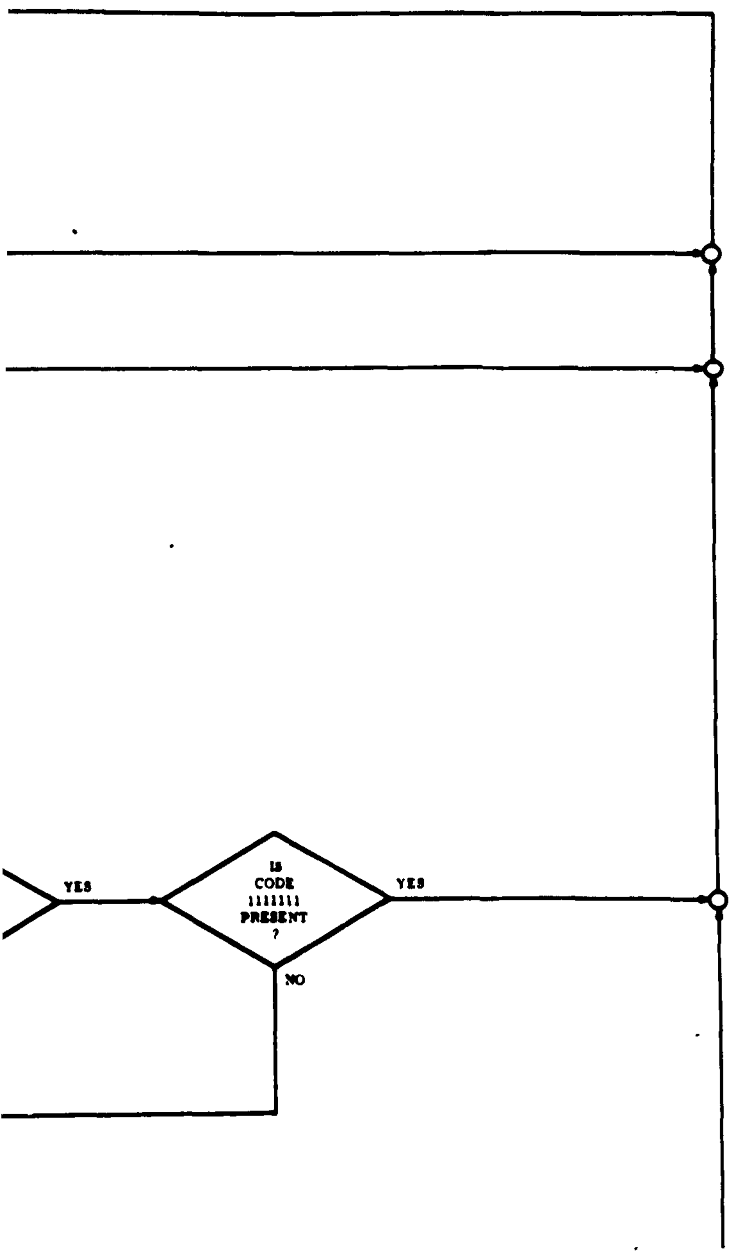
6


SET GC28 = 1
IS C[C21] 0
YES
NO
IS M5 · M6 = 1 ?
YES
NO
SET GC30 = 1 GC14 = 0 GC53 = 0 STOP TAPE READER
IS T9 = 0 ?
YES
NO
IS CODE 0001101 PRESENT ?
IS M7 = 1 ?
IS T38 = 1 ?
IS C[C16] 6
SET GC32 = 1 GC17 = 0 STOP TAPE READER
IS C[C16] = 7 ?
IS CODE 1110000 PRESENT ?
IS CODE 1111001 PRESENT
IS CODE 1111010 PRESENT ?
IS CODE 1101011 PRESENT ?
IS CODE 1111100 PRESENT
IS C[C17] ?
IS CODE 0000111 PRESENT ?

7



IS CODE 001101 ESENT ?
YES
SET OC32 = 1
NO
IS CODE 1111100 PRESENT ?
NO
IS CODE 1101101 PRESENT ?
NO
IS CODE 1101110 PRESENT
NO
YES
YES
YES
IS T12 = 0 ?
YES
IS CODE 1111111 PRESENT ?
YES
NO
NO
YES
IS C [C17] = 13 ?
YES
NO
NO
IS CODE 0100000 PRESENT ?
NO
YES
IS CODE 0000111 PRESENT ?



NOTE 1 $QC_{36} = 1$ IS SET BY EITHER THE ARITHMETIC UNIT OR THE INPUT OUTPUT PROGRAMMER DEPENDING UPON THE ITEM EITHER BEING PRINTED OR PUNCHED.

NOTE 2 INITIAL RESET CONDITIONS

A. SYSTEM INITIAL RESET

$QC_{35} = 0$

$QC_{36} = 0$

$QC_{53} = 0$

B. AUX. CONTROL PANEL RESET

$QC_{23} = 0$

$QC_{24} = 0$

$QC_{30} = 0$

$QC_{31} = 0$

$QC_{32} = 0$

$QC_{56} = 0$

$C[C_{13}] = 0$

$C[C_{21}] = 0$

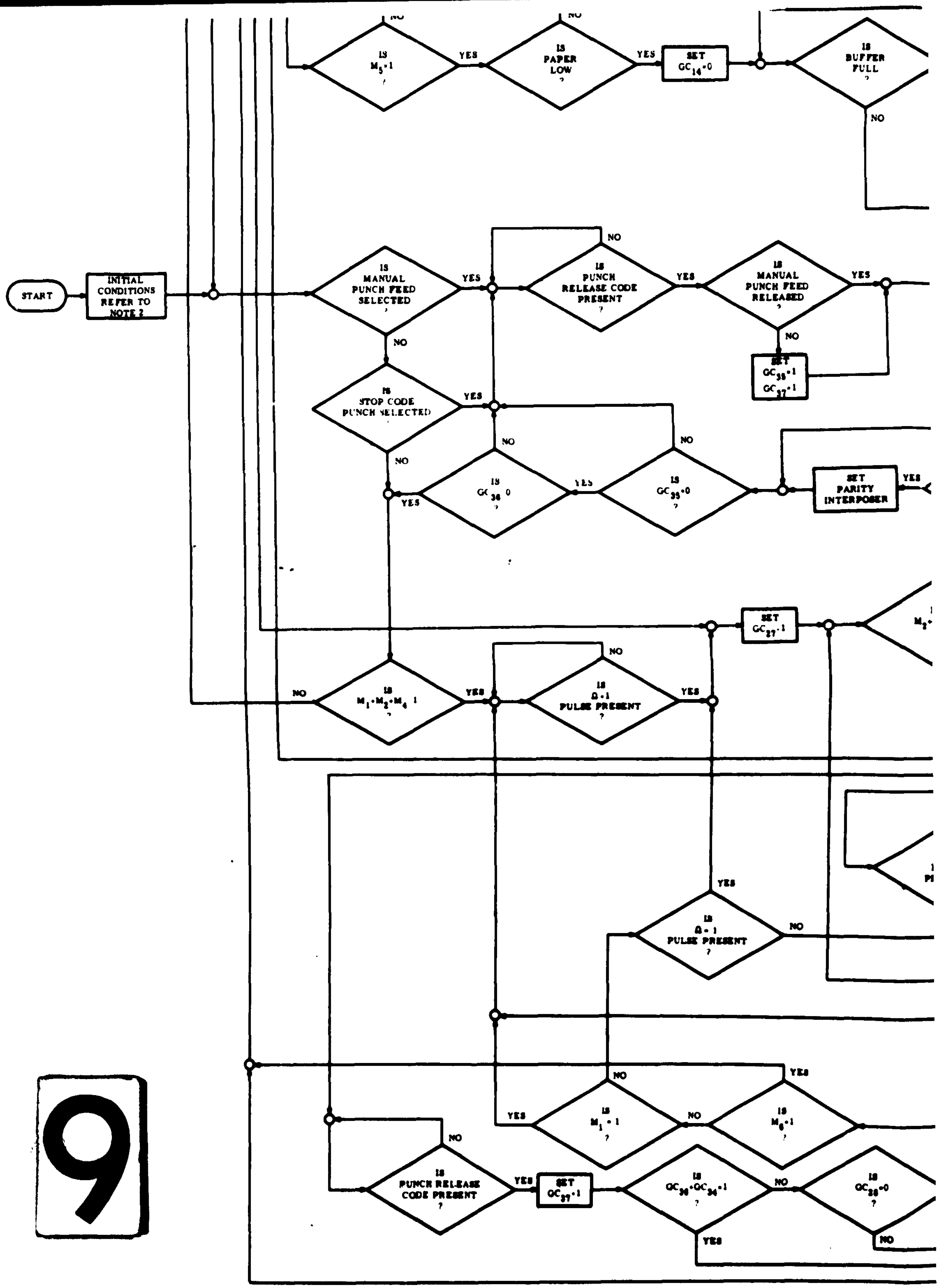
C. PUNCH RESET

$QC_{35} = 0$

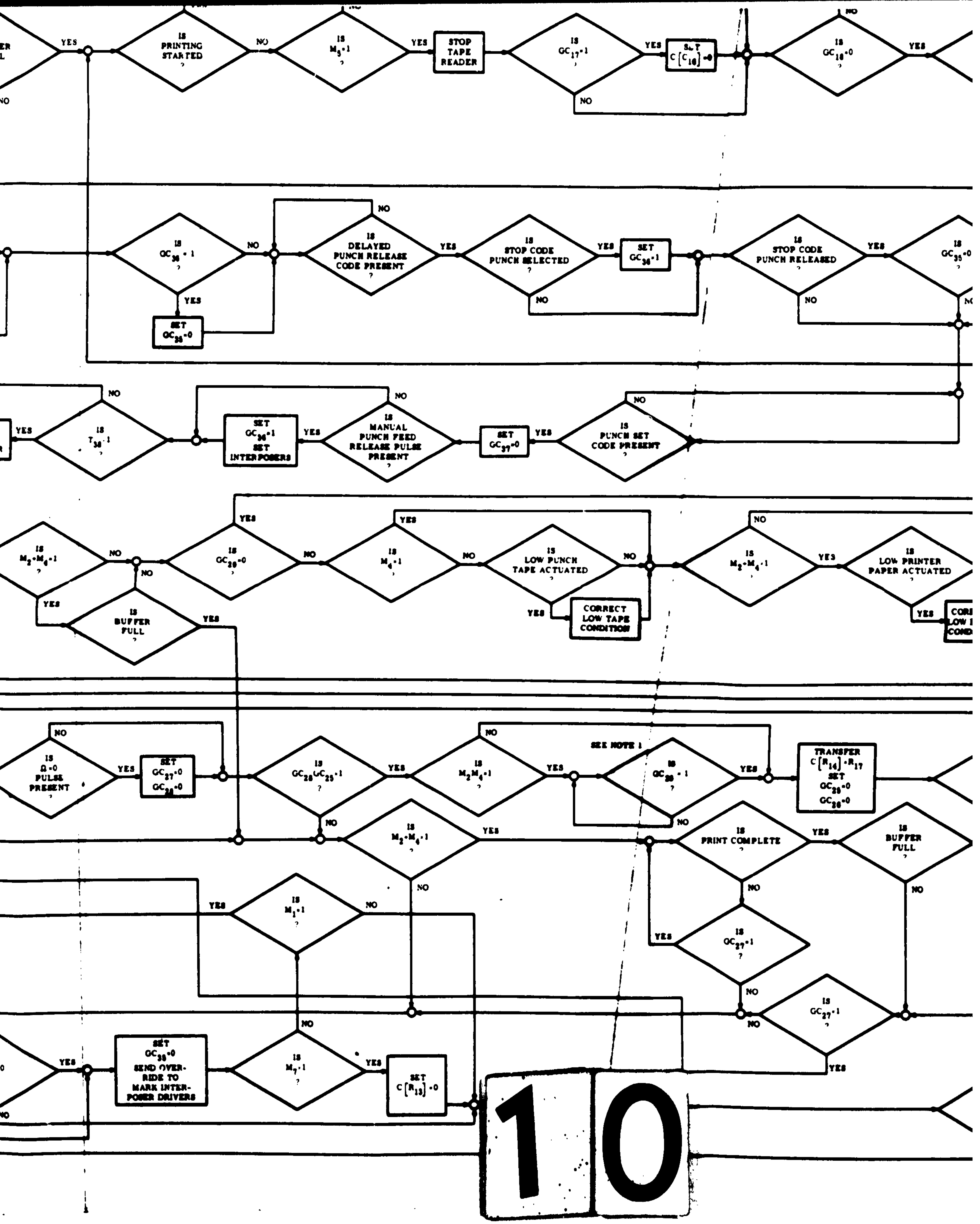
$QC_{36} = 0$

MODE	RESET
M_1	a, c
M_2	a, b, c
M.	a, b

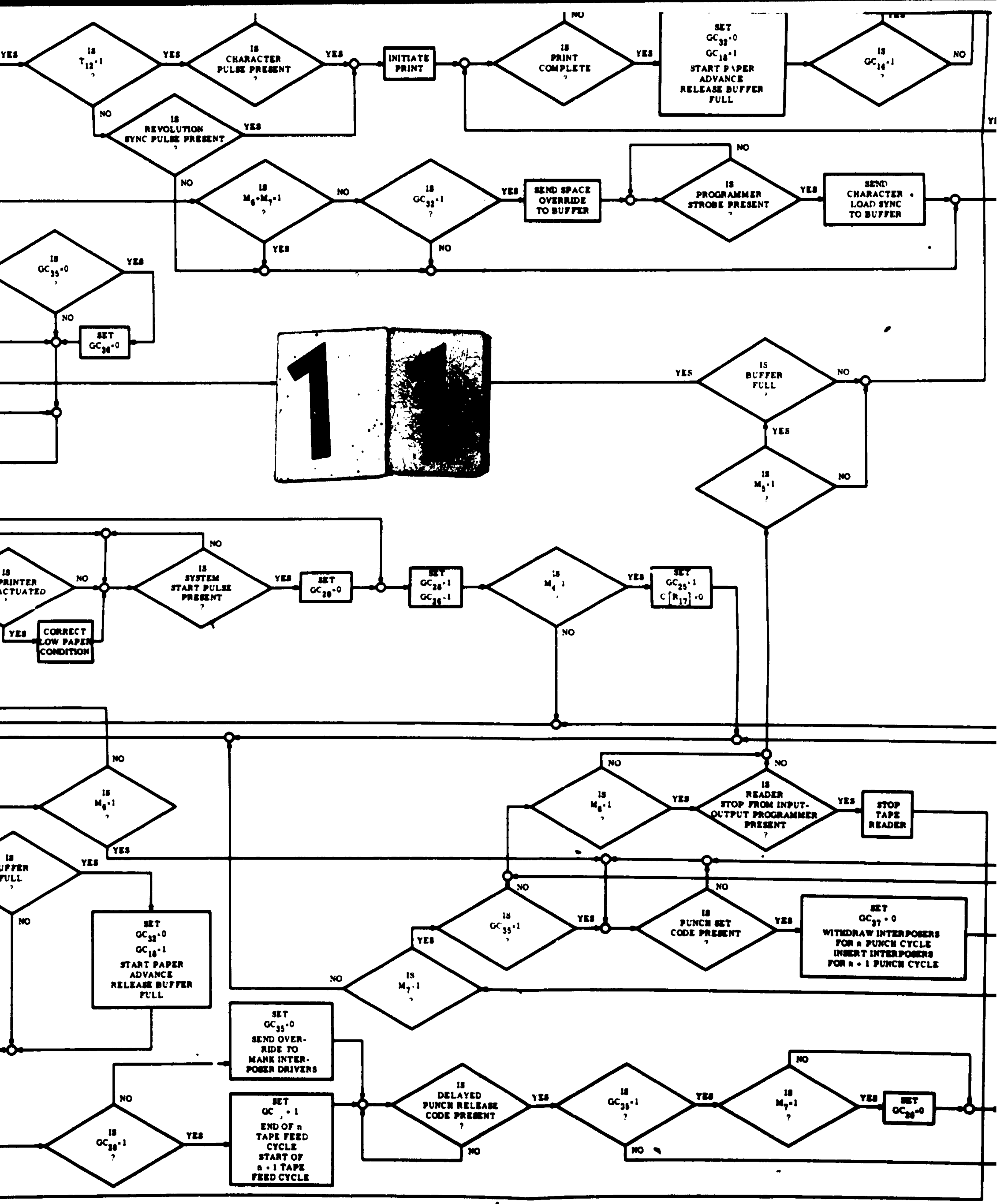
8


START
INITIAL CONDITIONS REFER TO NOTE 2
IS $M_5=1$?
IS PAPER LOW ?
SET $GC_{14}=0$
IS BUFFER FULL ?
IS MANUAL PUNCH FEED SELECTED ?
IS PUNCH RELEASE CODE PRESENT ?
IS MANUAL PUNCH FEED RELEASED ?
SET $GC_{35}=1$ $GC_{37}=1$
IS STOP CODE PUNCH SELECTED ?
IS $GC_{36}=0$?
IS $GC_{35}=0$?
SET PARITY INTERPOSER
SET $GC_{37}=1$
IS $M_1 \cdot M_2 \cdot M_4 = 1$?
IS $\Omega=1$ PULSE PRESENT ?
IS $\Omega=1$ PULSE PRESENT ?
IS $M_1=1$?
IS $M_6=1$?
IS PUNCH RELEASE CODE PRESENT ?
SET $GC_{37}=1$
IS $GC_{36} \cdot GC_{34}=1$?
IS $GC_{36}=0$?
YES
NO

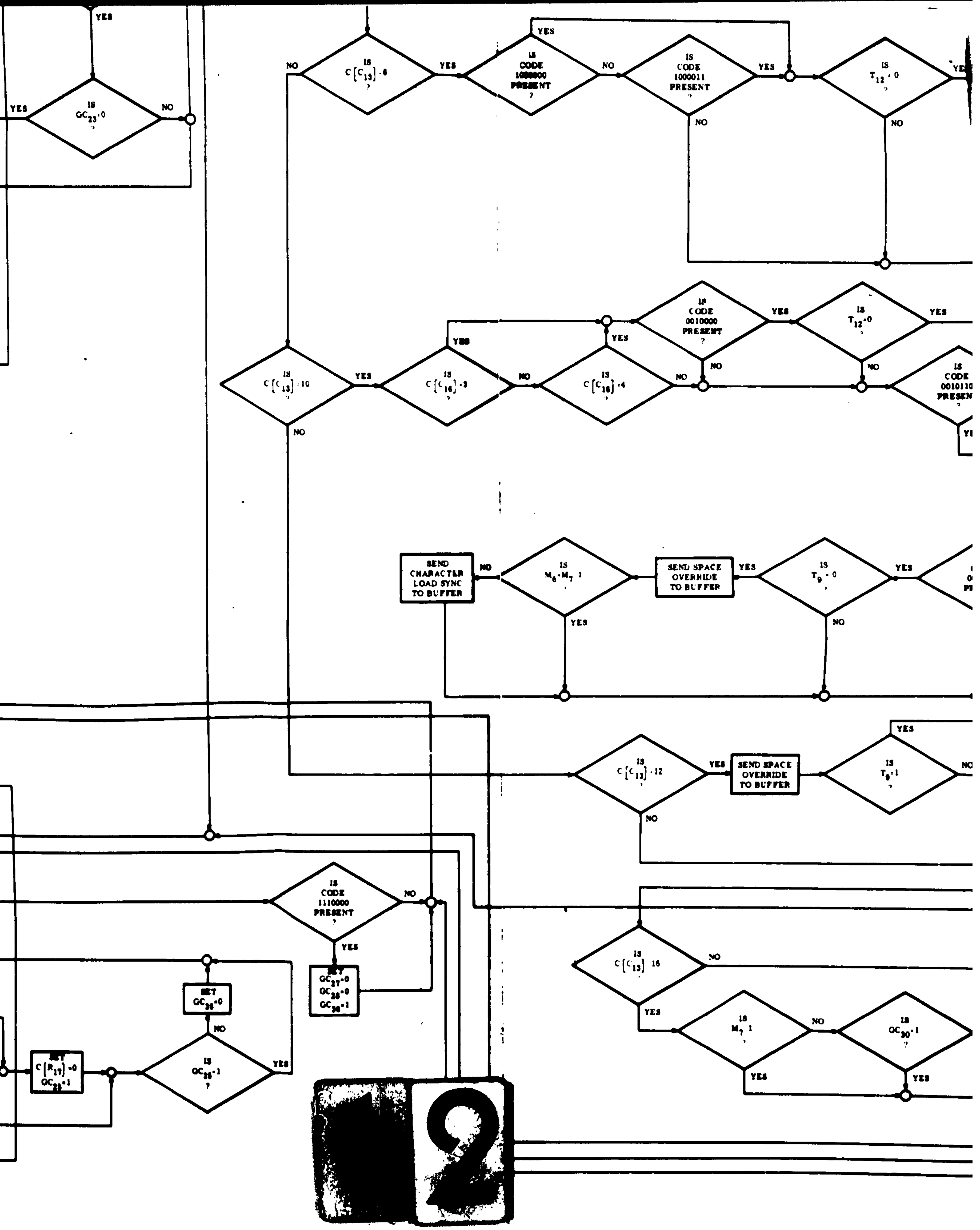
9



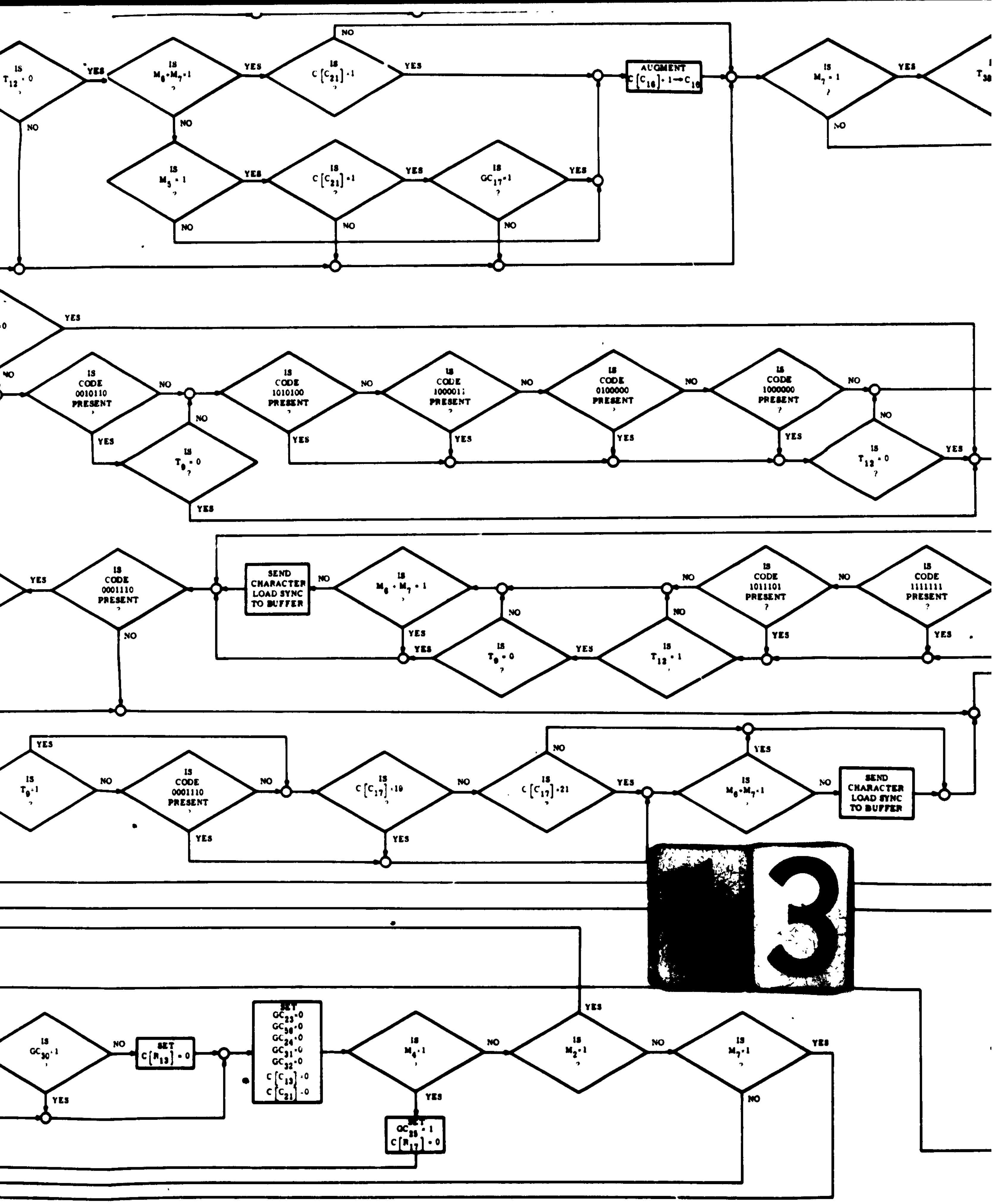
IS PRINTING STARTED ?
IS M_3=1 ?
STOP TAPE READER
IS GC_{17}=1 ?
SET C[C_{16}]=0
IS GC_{18}=0 ?
IS GC_{36}=1 ?
SET GC_{36}=0
IS DELAYED PUNCH RELEASE CODE PRESENT ?
IS STOP CODE PUNCH SELECTED ?
SET GC_{36}=1
IS STOP CODE PUNCH RELEASED ?
IS T_{38}=1 ?
SET GC_{36}=1 SET INTERPOSERS
IS MANUAL PUNCH FEED RELEASE PULSE PRESENT ?
SET GC_{37}=0
IS PUNCH SET CODE PRESENT ?
IS M_2+M_4=1 ?
IS GC_{26}=0 ?
IS M_4=1 ?
IS LOW PUNCH TAPE ACTUATED ?
CORRECT LOW TAPE CONDITION
IS LOW PRINTER PAPER ACTUATED ?
IS BUFFER FULL ?
IS Ω=0 PULSE PRESENT ?
SET GC_{27}=0 GC_{28}=0
IS $GC_{28}$$GC_{25}$=1 ?
IS $M_2$$M_4$=1 ?
SEE NOTE 1
IS GC_{28}=1 ?
TRANSFER C[R_{14}]→R_{17} SET GC_{28}=0 GC_{26}=0
IS PRINT COMPLETE ?
IS M_1=1 ?
IS GC_{27}=1 ?
SET GC_{35}=0 SEND OVER-RIDE TO MARK INTER-POSER DRIVERS
IS M_7=1 ?
SET C[R_{13}]=0
YES
NO
10



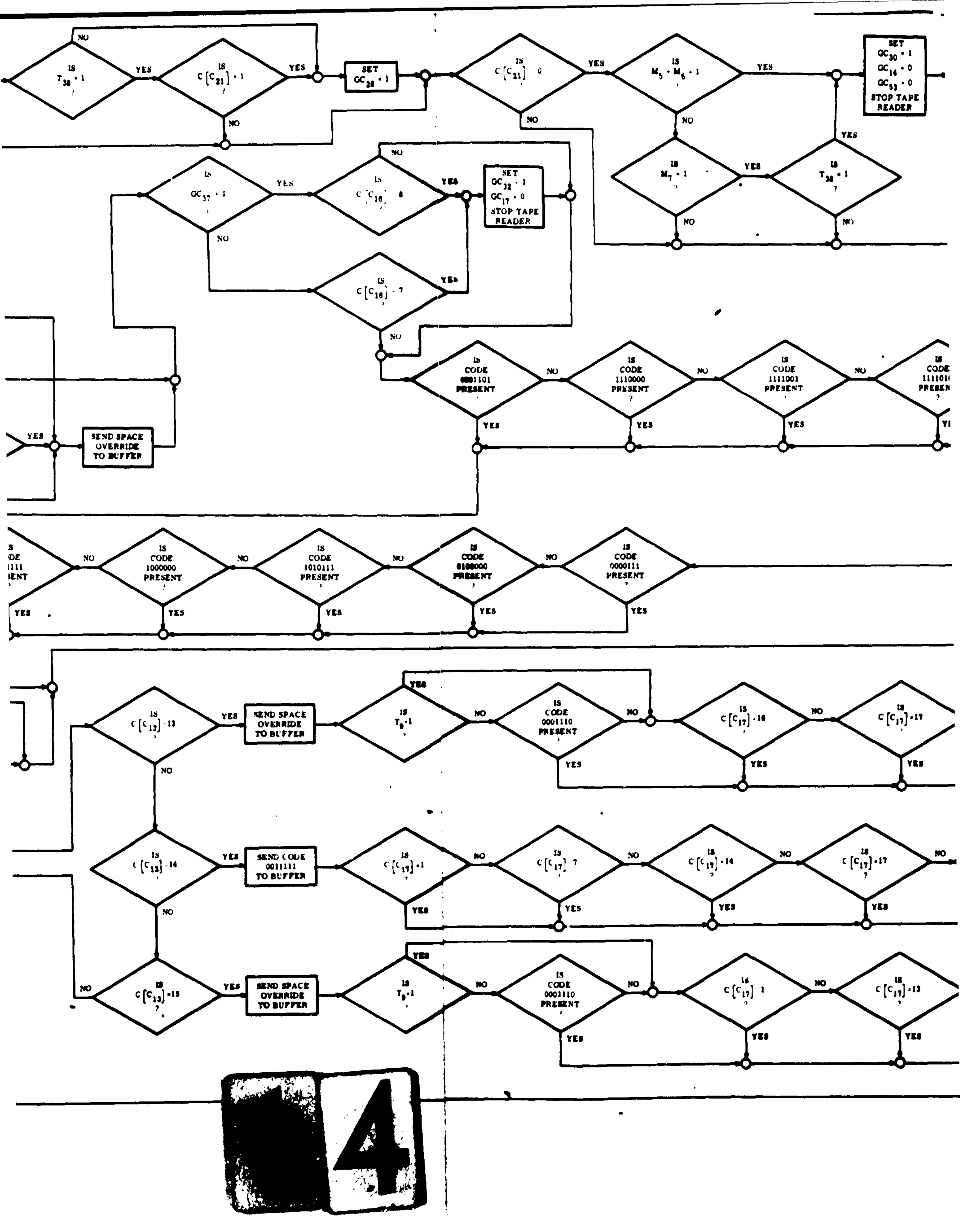
IS T12=1 ?
IS CHARACTER PULSE PRESENT ?
INITIATE PRINT
IS PRINT COMPLETE ?
SET GC32=0 GC18=1 START PAPER ADVANCE RELEASE BUFFER FULL
IS GC14=1 ?
IS REVOLUTION SYNC PULSE PRESENT ?
IS M6+M7=1 ?
IS GC32=1 ?
SEND SPACE OVERRIDE TO BUFFER
IS PROGRAMMER STROBE PRESENT ?
SEND CHARACTER + LOAD SYNC TO BUFFER
IS GC35=0 ?
SET GC36=0
IS BUFFER FULL ?
IS M5=1 ?
IS PRINTER ACTUATED ?
CORRECT LOW PAPER CONDITION
IS SYSTEM START PULSE PRESENT ?
SET GC29=0
SET GC28=1 GC26=1
IS M4=1 ?
SET GC25=1 C[R17]=0
IS M6=1 ?
IS READER STOP FROM INPUT-OUTPUT PROGRAMMER PRESENT ?
STOP TAPE READER
IS BUFFER FULL ?
SET GC32=0 GC18=1 START PAPER ADVANCE RELEASE BUFFER FULL
IS GC35=1 ?
IS PUNCH SET CODE PRESENT ?
SET GC37=0 WITHDRAW INTERPOSERS FOR n PUNCH CYCLE INSERT INTERPOSERS FOR n+1 PUNCH CYCLE
IS M7=1 ?
SET GC35=0 SEND OVER-RIDE TO MARK INTER-POSER DRIVERS
IS GC36=1 ?
SET GC =1 END OF n TAPE FEED CYCLE START OF n+1 TAPE FEED CYCLE
IS DELAYED PUNCH RELEASE CODE PRESENT ?
IS GC35=1 ?
IS M7=1 ?
SET GC36=0
YES
NO
11

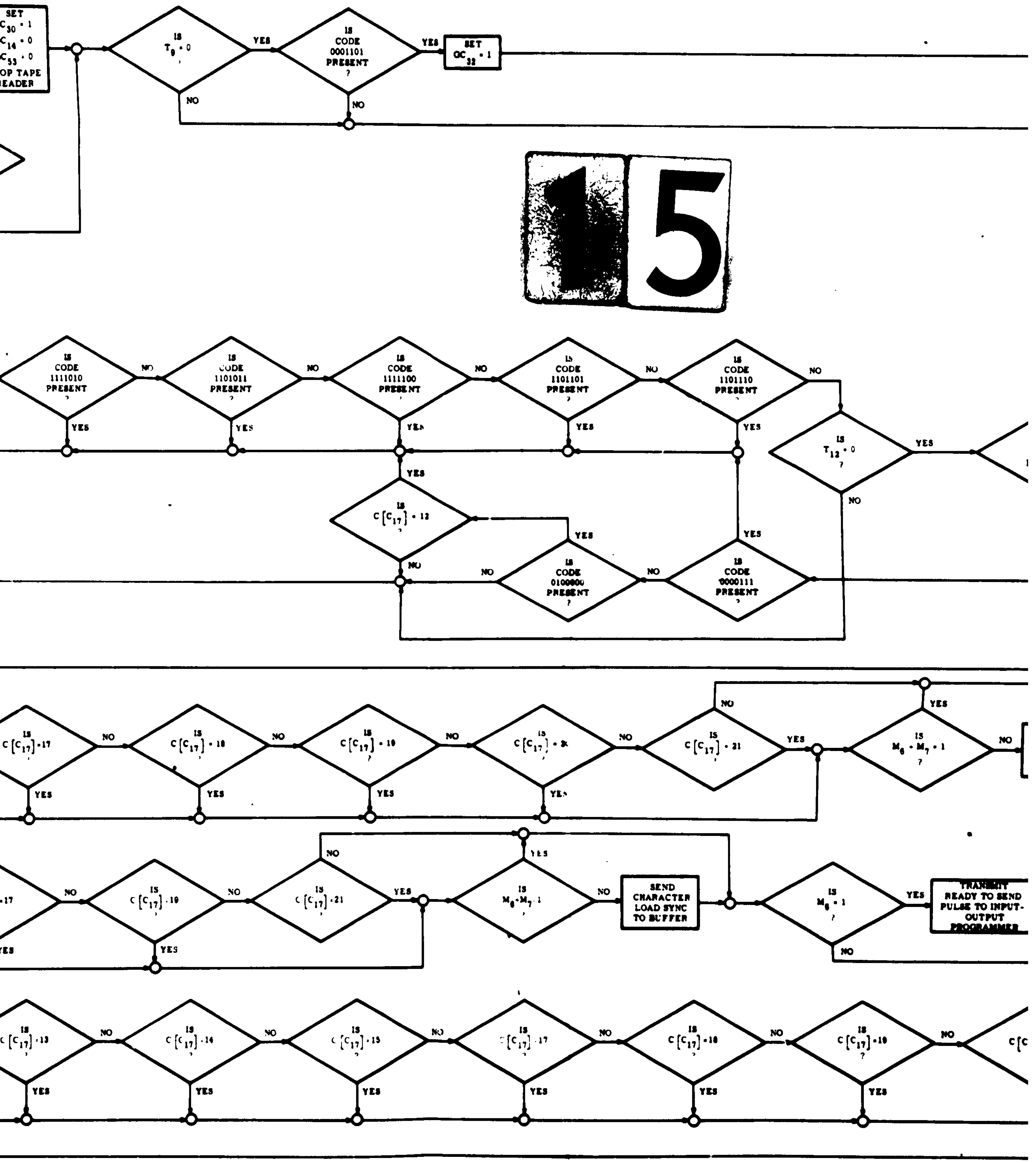


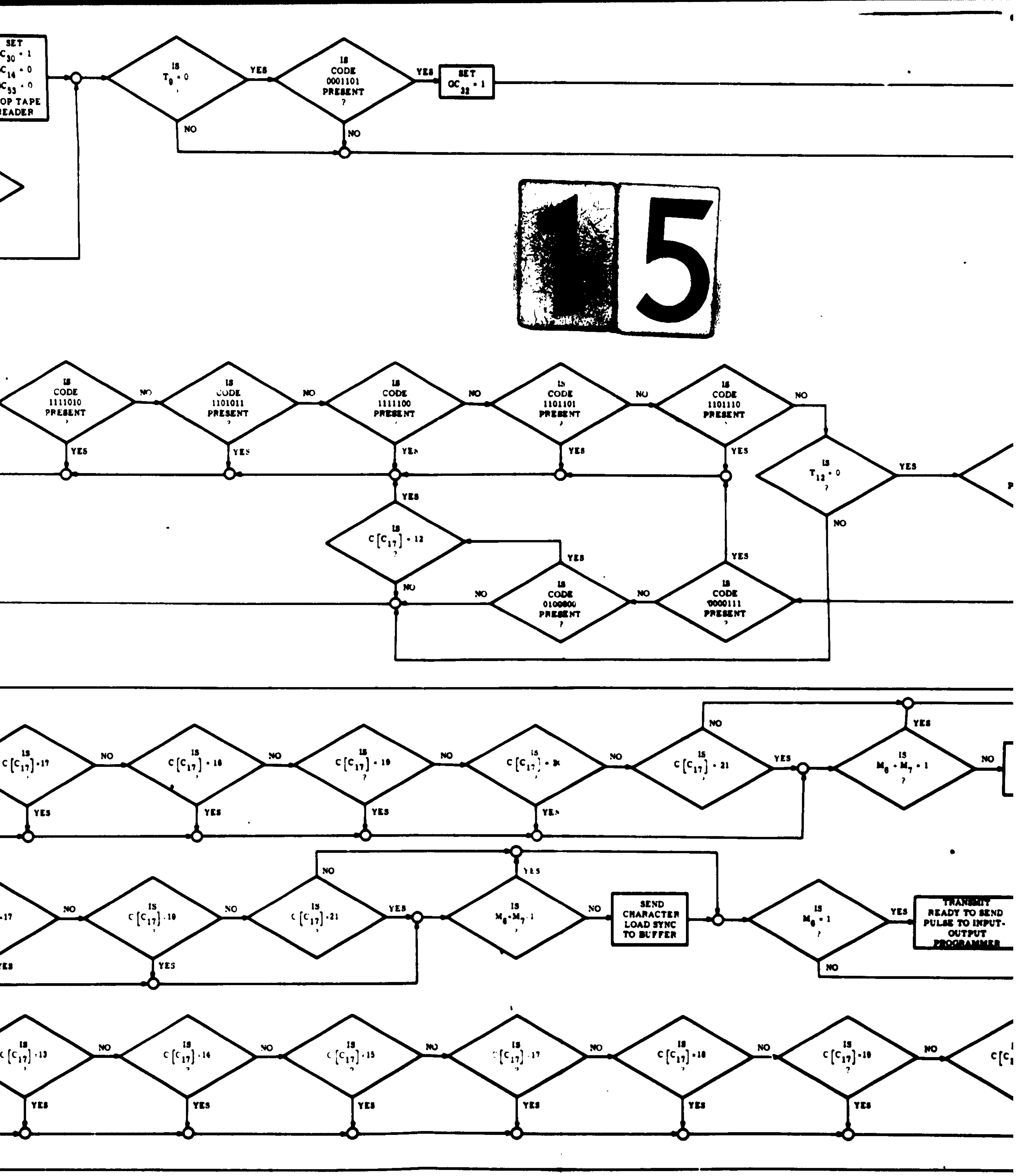
IS GC23=0 ?
IS C[C13]=6 ?
IS CODE 1000000 PRESENT ?
IS CODE 1000011 PRESENT ?
IS T12=0 ?
IS CODE 0010000 PRESENT ?
IS T12=0 ?
IS C[C13]=10 ?
IS C[C16]=3 ?
IS C[C16]=4 ?
SEND CHARACTER LOAD SYNC TO BUFFER
IS M6+M7 1 ?
SEND SPACE OVERRIDE TO BUFFER
IS T9=0 ?
IS C[C13]=12 ?
SEND SPACE OVERRIDE TO BUFFER
IS T9=1 ?
IS CODE 1110000 PRESENT ?
SET GC27=0 GC28=0 GC30=1
SET GC38=0
IS GC38=1 ?
IS C[C13] 16 ?
IS M7 1 ?
IS GC30=1 ?
YES
NO



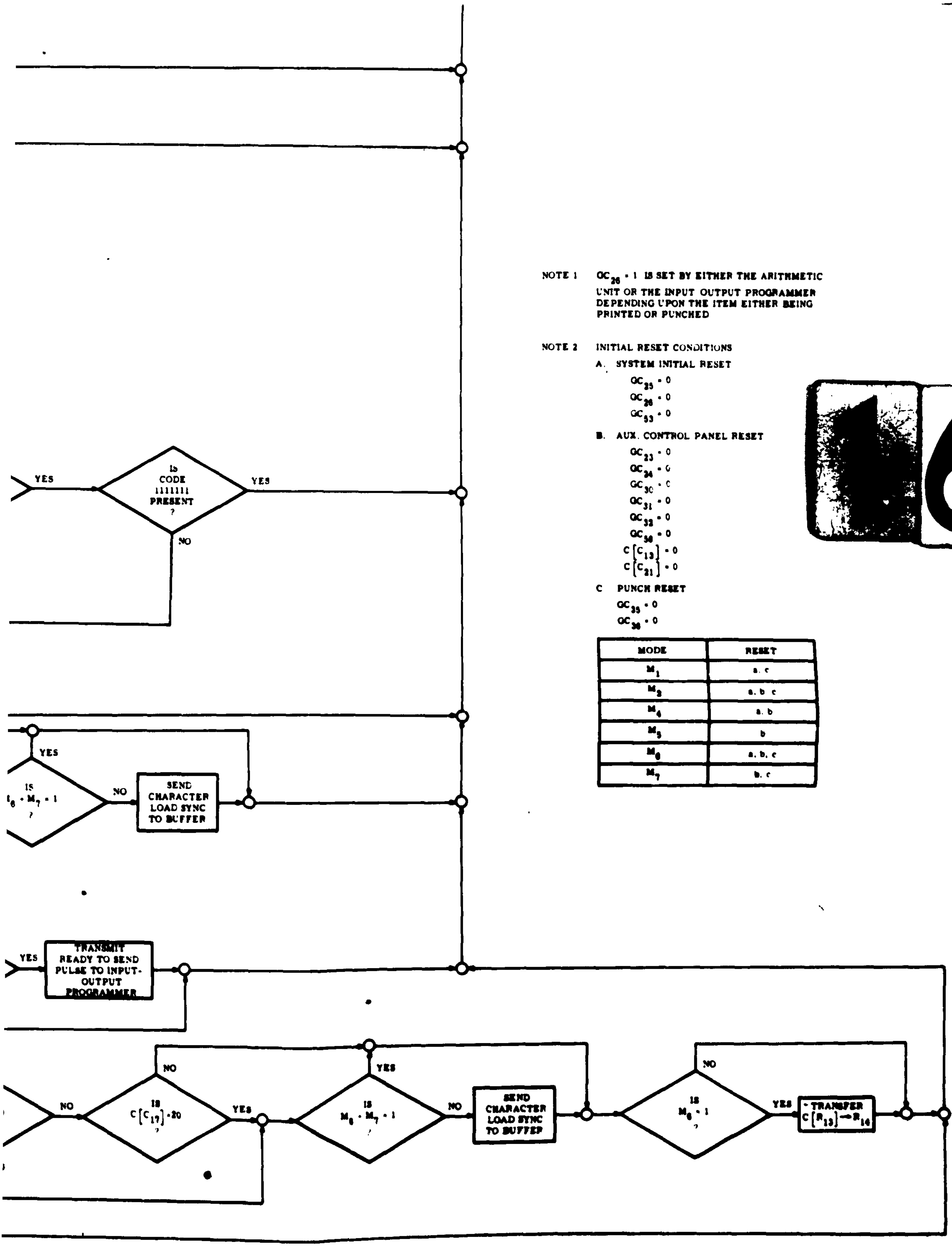
IS T12 = 0 ?
YES
NO
IS M6 • M7 = 1 ?
IS C [C21] = 1 ?
AUGMENT C [C16] + 1 → C16
IS M7 = 1 ?
IS M5 = 1 ?
IS GC17 = 1 ?
IS CODE 0010110 PRESENT ?
IS T9 = 0 ?
IS CODE 1010100 PRESENT ?
IS CODE 1000011 PRESENT ?
IS CODE 0100000 PRESENT ?
IS CODE 1000000 PRESENT ?
IS T12 = 0 ?
IS CODE 0001110 PRESENT ?
SEND CHARACTER LOAD SYNC TO BUFFER
IS M6 • M7 = 1 ?
IS T9 = 0 ?
IS T12 = 1 ?
IS CODE 1011101 PRESENT ?
IS CODE 1111111 PRESENT ?
IS T9 = 1 ?
IS CODE 0001110 PRESENT ?
IS C [C17] = 19 ?
IS C [C17] = 21 ?
IS M6 • M7 = 1 ?
SEND CHARACTER LOAD SYNC TO BUFFER
3
IS GC30 = 1 ?
SET C [R13] = 0
SET GC23 = 0 GC38 = 0 GC24 = 0 GC31 = 0 GC32 = 0 C [C13] = 0 C [C21] = 0
IS M4 = 1 ?
SET GC35 = 1 C [R17] = 0
IS M2 = 1 ?
IS M7 = 1 ?


IS T38 = 1 ?
IS C [C21] = 1 ?
SET GC28 = 1
IS C [C21] = 0 ?
IS M5 · M6 = 1
SET GC30 = 1 GC14 = 0 GC53 = 0 STOP TAPE READER
IS M7 = 1 ?
IS T38 = 1 ?
IS GC37 = 1 ?
IS C [C16] = 6 ?
SET GC32 = 1 GC17 = 0 STOP TAPE READER
IS C [C16] = 7 ?
IS CODE 0001101 PRESENT ?
IS CODE 1110000 PRESENT ?
IS CODE 1111001 PRESENT ?
SEND SPACE OVERRIDE TO BUFFER
IS CODE 1000000 PRESENT ?
IS CODE 1010111 PRESENT ?
IS CODE 0100000 PRESENT ?
IS CODE 0000111 PRESENT ?
IS C [C13] = 13 ?
SEND SPACE OVERRIDE TO BUFFER
IS T9 = 1 ?
IS CODE 0001110 PRESENT ?
IS C [C17] = 16 ?
IS C [C17] = 17 ?
IS C [C13] = 14 ?
SEND CODE 0011111 TO BUFFER
IS C [C17] = 1 ?
IS C [C17] = 7 ?
IS C [C17] = 14 ?
IS C [C17] = 17 ?
IS C [C13] = 15 ?
SEND SPACE OVERRIDE TO BUFFER
IS T9 = 1 ?
IS CODE 0001110 PRESENT ?
IS C [C17] = 1 ?
IS C [C17] = 13 ?
YES
NO
4


SET C_{30} = 1 C_{14} = 0 C_{53} = 0 STOP TAPE READER
IS T_9 = 0 ?
YES
NO
IS CODE 0001101 PRESENT ?
SET OC_{32} = 1
15
IS CODE 1111010 PRESENT ?
IS CODE 1101011 PRESENT ?
IS CODE 1111100 PRESENT ?
IS CODE 1101101 PRESENT ?
IS CODE 1101110 PRESENT ?
IS T_{12} = 0 ?
IS C[C_{17}] = 12 ?
IS CODE 0100000 PRESENT ?
IS CODE 0000111 PRESENT ?
IS C[C_{17}] = 17
IS C[C_{17}] = 18
IS C[C_{17}] = 19 ?
IS C[C_{17}] = 20
IS C[C_{17}] = 21
IS M_6 + M_7 = 1 ?
IS C[C_{17}] = 19
IS C[C_{17}] = 21
IS M_6 + M_7 = 1
SEND CHARACTER LOAD SYNC TO BUFFER
IS M_6 = 1 ?
TRANSMIT READY TO SEND PULSE TO INPUT-OUTPUT PROGRAMMER
IS C[C_{17}] = 13
IS C[C_{17}] = 14
IS C[C_{17}] = 15
IS C[C_{17}] = 17
IS C[C_{17}] = 18
IS C[C_{17}] = 19 ?



SET
C_{30} = 1
C_{14} = 0
C_{53} = 0
OP TAPE
READER
IS T_9 = 0 ?
YES
NO
IS CODE 0001101 PRESENT ?
YES
NO
SET OC_{32} = 1
15
IS CODE 1111010 PRESENT ?
NO
YES
IS CODE 1101011 PRESENT ?
IS CODE 1111100 PRESENT ?
IS CODE 1101101 PRESENT ?
IS CODE 1101110 PRESENT ?
IS T_{12} = 0 ?
IS C[C_{17}] = 12 ?
IS CODE 0100000 PRESENT ?
IS CODE 0000111 PRESENT ?
IS C[C_{17}] = 17
IS C[C_{17}] = 18
IS C[C_{17}] = 19 ?
IS C[C_{17}] = 21
IS M_6 + M_7 = 1 ?
IS C[C_{17}] = 19
IS C[C_{17}] = 21
IS M_6 + M_7 = 1
SEND CHARACTER LOAD SYNC TO BUFFER
IS M_6 = 1 ?
TRANSMIT READY TO SEND PULSE TO INPUT-OUTPUT PROGRAMMER
IS C[C_{17}] = 13
IS C[C_{17}] = 14
IS C[C_{17}] = 15 ?
IS C[C_{17}] = 17
IS C[C_{17}] = 18
IS C[C_{17}] = 19 ?



NOTE 1 $OC_{26} = 1$ IS SET BY EITHER THE ARITHMETIC UNIT OR THE INPUT OUTPUT PROGRAMMER DEPENDING UPON THE ITEM EITHER BEING PRINTED OR PUNCHED

NOTE 2 INITIAL RESET CONDITIONS

A. SYSTEM INITIAL RESET

$OC_{25} = 0$
$OC_{26} = 0$
$OC_{53} = 0$

B. AUX. CONTROL PANEL RESET

$OC_{23} = 0$
$OC_{24} = 0$
$OC_{30} = 0$
$OC_{31} = 0$
$OC_{32} = 0$
$OC_{50} = 0$
$C[C_{13}] = 0$
$C[C_{21}] = 0$

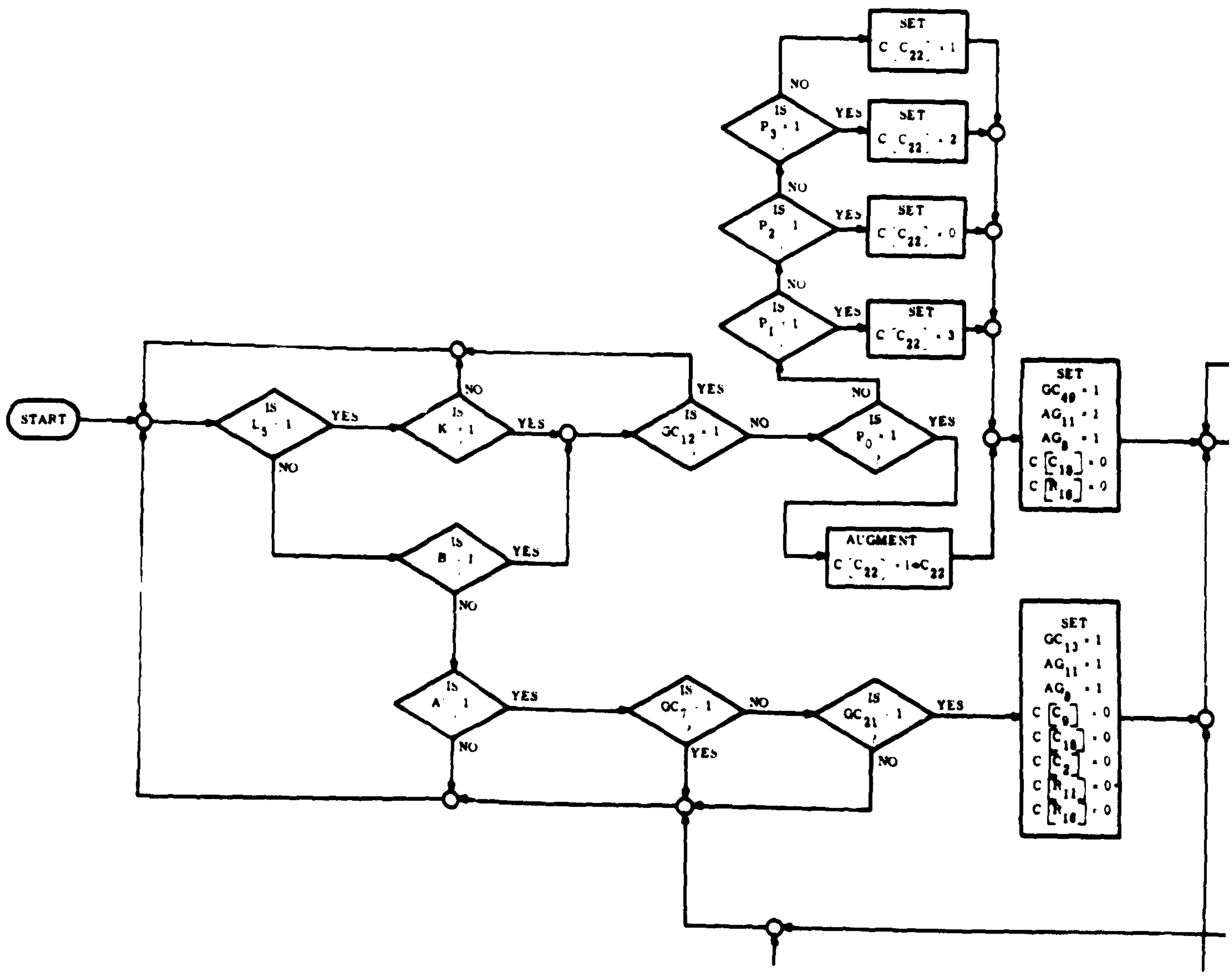
C PUNCH RESET

$OC_{35} = 0$
$OC_{36} = 0$

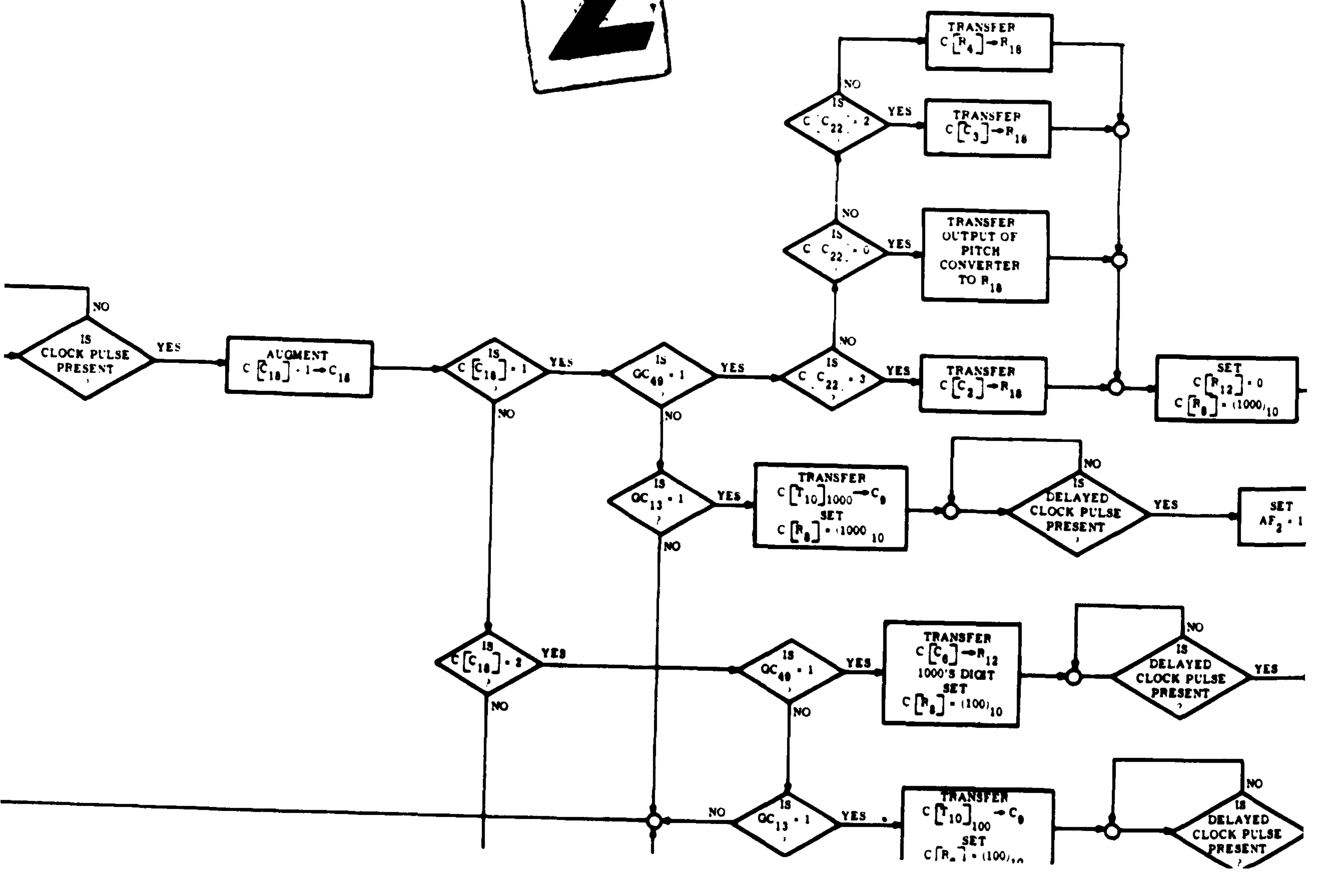
MODE	RESET
M_1	a, c
M_3	a, b, c
M_4	a, b
M_5	b
M_6	a, b, c
M_7	b, c

Figure 4. Detailed Flow Diagram-Peripheral Equipment Programmer

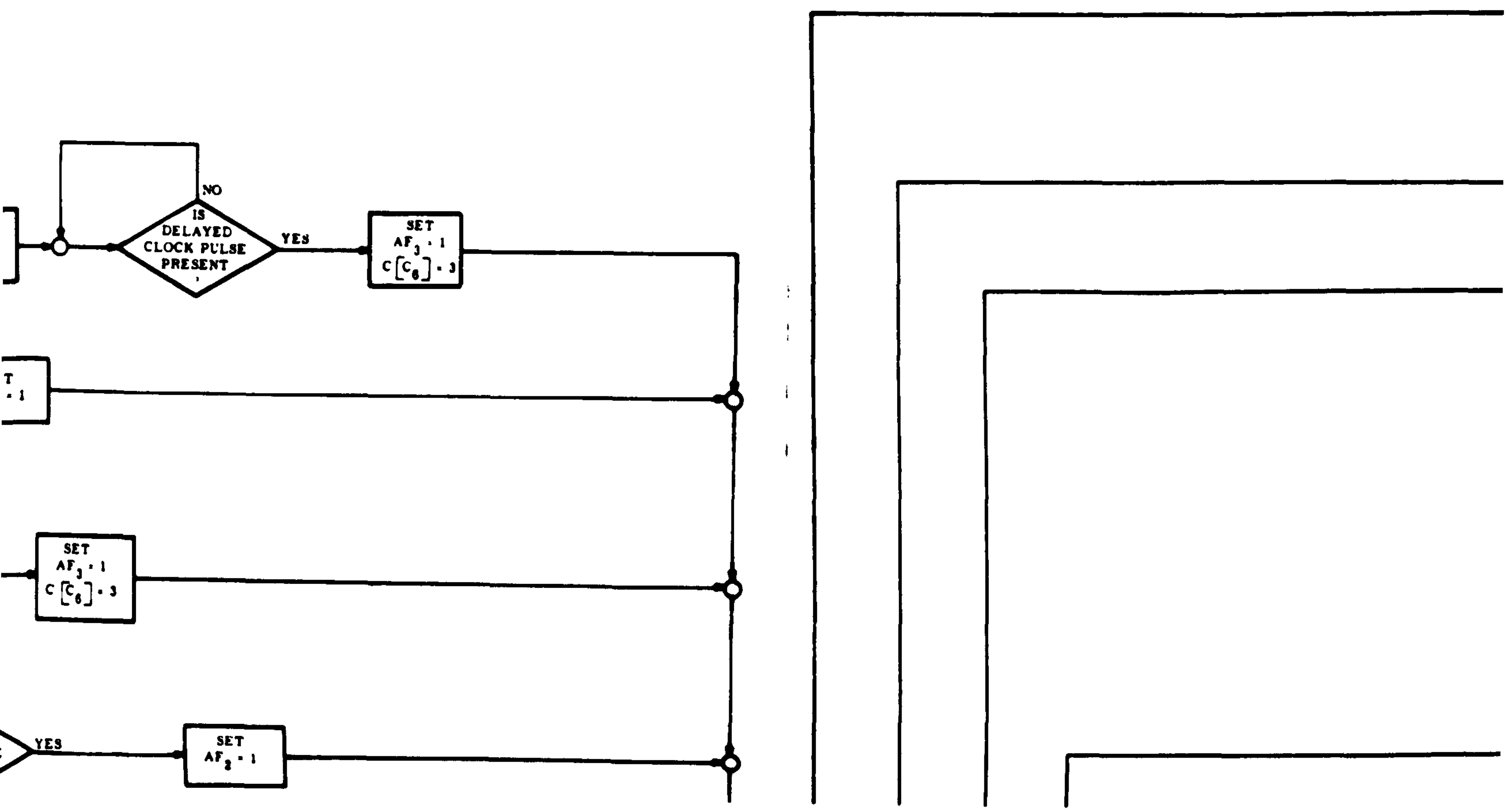
1


START
IS L_5 1
IS K 1
IS B 1
IS A 1
IS GC_{12} 1
IS GC_7 1
IS GC_{21} 1
IS P_0 1
IS P_1 1
IS P_2 1
IS P_3 1
YES
NO
SET C C_{22} 1
SET C C_{22} 2
SET C C_{22} 0
SET C C_{22} 3
AUGMENT C C_{22} 1 C_{22}
SET GC_{49} 1 AG_{11} 1 AG_8 1
SET GC_{13} 1 AG_{11} 1 AG_8 1

2

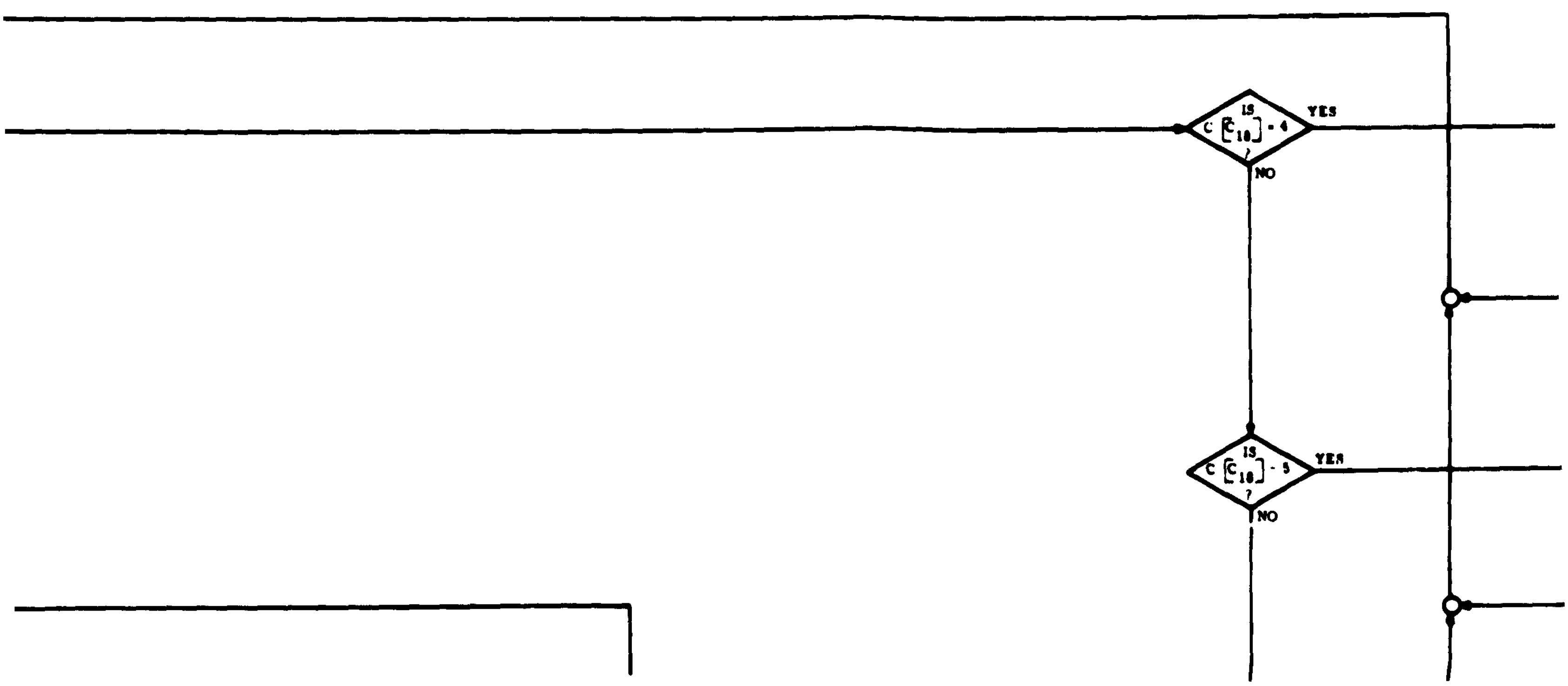

IS CLOCK PULSE PRESENT ?
NO
YES
AUGMENT C [C18] + 1 → C18
IS C [C18] = 1 ?
IS GC40 = 1 ?
IS C C22 = 3 ?
IS C C22 = 0 ?
IS C C22 = 2 ?
TRANSFER C [R4] → R18
TRANSFER C [C3] → R18
TRANSFER OUTPUT OF PITCH CONVERTER TO R18
TRANSFER C [C2] → R18
SET C [R12] = 0 C [R8] = (1000)10
IS GC13 = 1 ?
TRANSFER C [T10]1000 → C9 SET C [R8] = (1000)10
IS DELAYED CLOCK PULSE PRESENT ?
SET AF2 = 1
IS C [C18] = 2 ?
IS GC40 = 1 ?
TRANSFER C [C6] → R12 1000'S DIGIT SET C [R8] = (100)10
IS DELAYED CLOCK PULSE PRESENT ?
IS GC13 = 1 ?
TRANSFER C [T10]100 → C9 SET
IS DELAYED CLOCK PULSE PRESENT ?

3

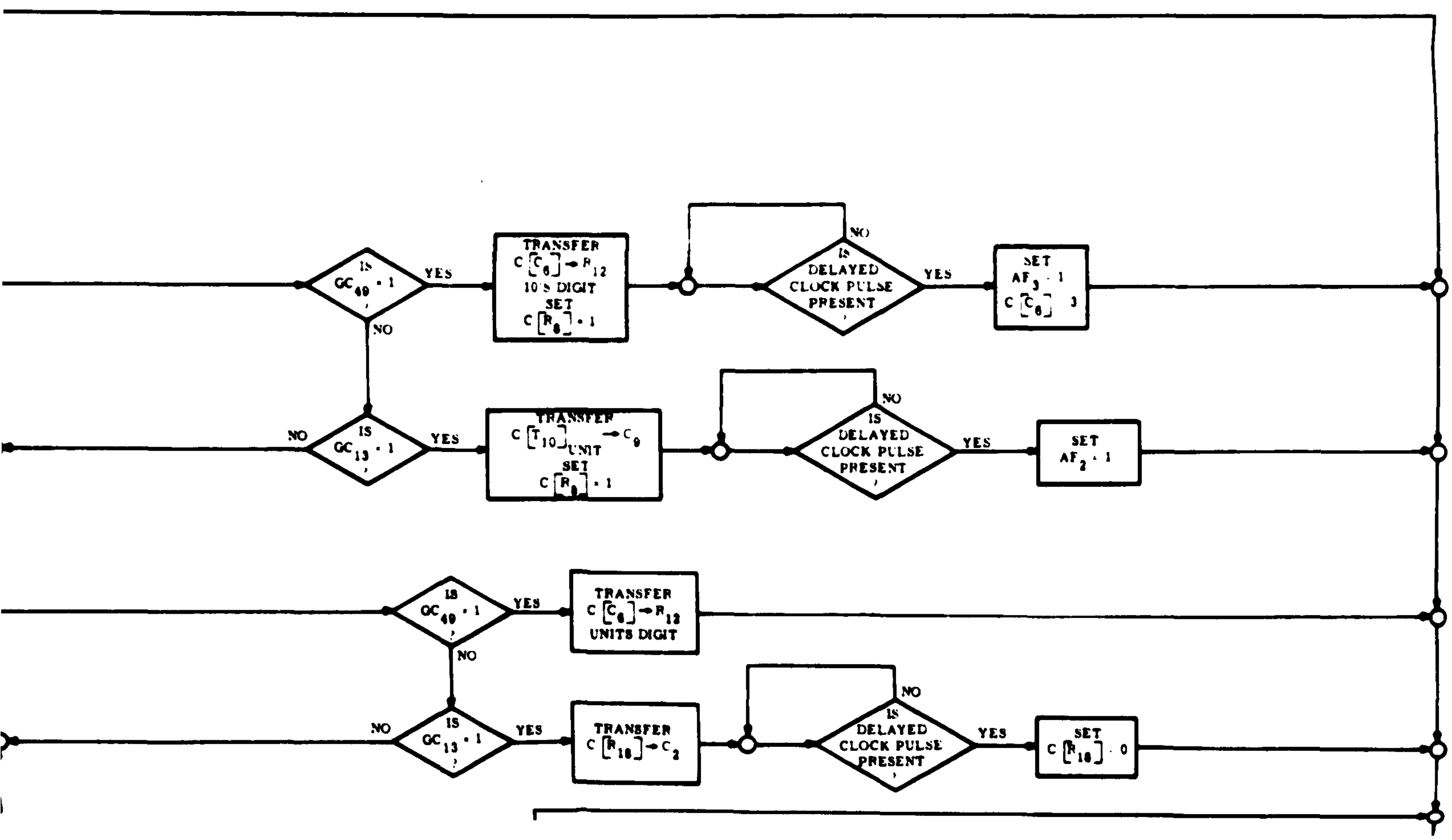


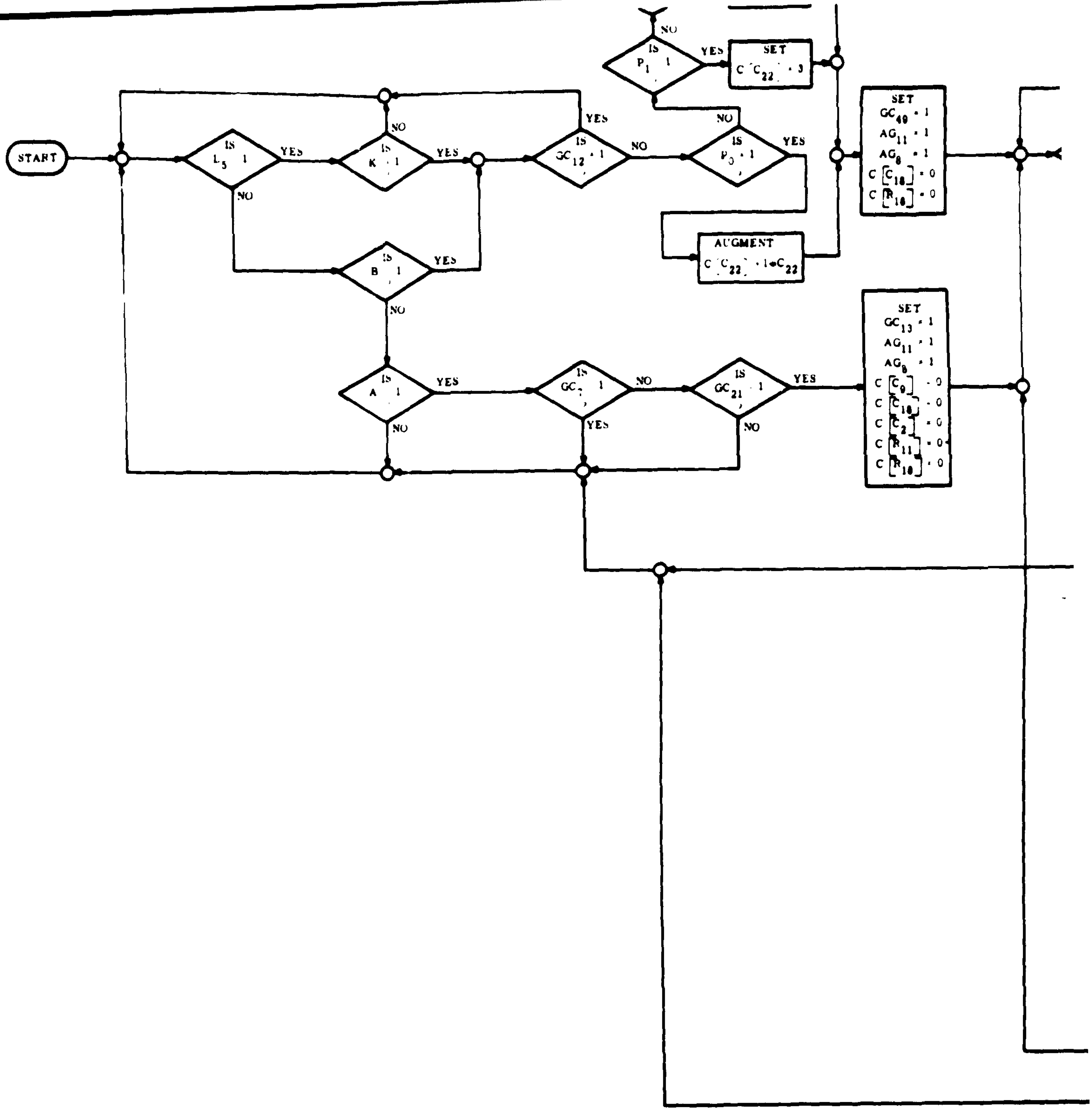
NO
IS DELAYED CLOCK PULSE PRESENT
YES
SET AF3 = 1 C[C6] = 3
T
= 1
SET AF3 = 1 C[C6] = 3
YES
SET AF2 = 1

4



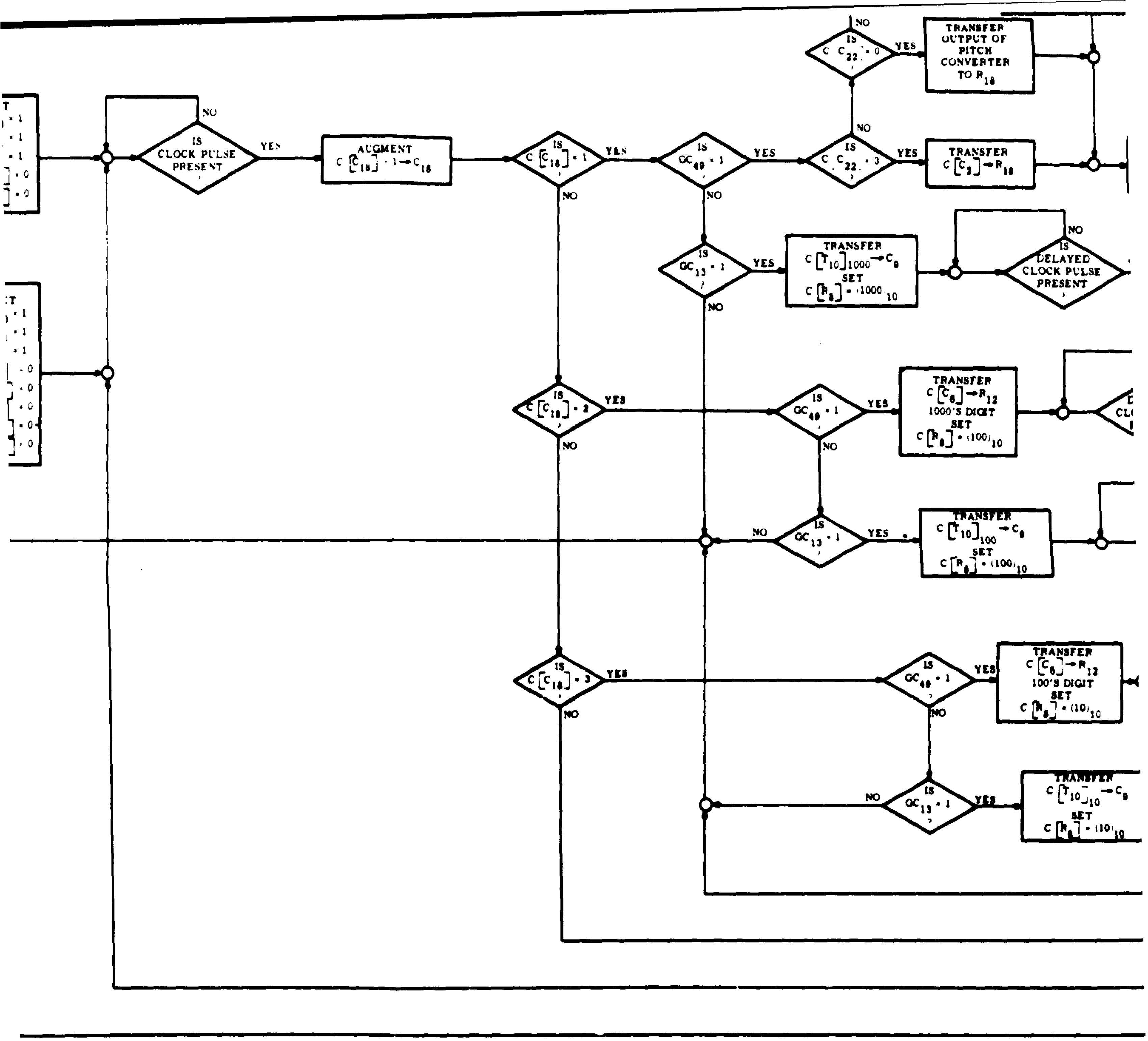
5


IS
$GC_{49} = 1$
?
YES
NO
TRANSFER
$C[C_6] \rightarrow R_{12}$
10'S DIGIT
SET
$C[R_8] = 1$
IS
DELAYED
CLOCK PULSE
PRESENT
?
SET
$AF_3 = 1$
$C[C_6] = 3$
IS
$GC_{13} = 1$
?
TRANSFER
$C[T_{10}]_{UNIT} \rightarrow C_9$
SET
$C[R_8] = 1$
SET
$AF_2 = 1$
TRANSFER
$C[C_6] \rightarrow R_{12}$
UNITS DIGIT
TRANSFER
$C[R_{18}] \rightarrow C_2$
SET
$C[R_{18}] = 0$



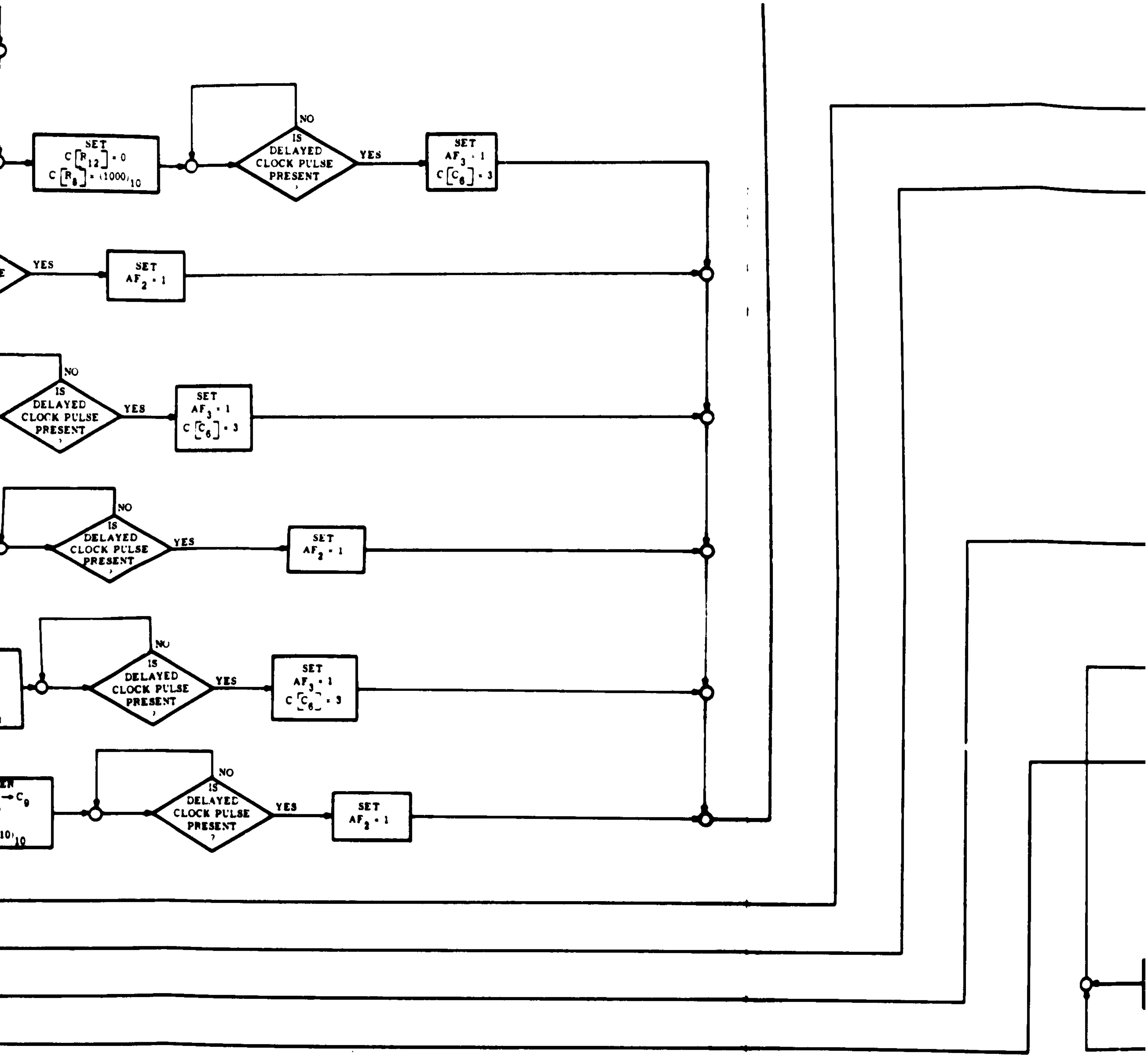
START
IS L5 1
YES
NO
IS K 1
IS B 1
IS GC12 1
IS P1 1
SET
IS P0 1
AUGMENT
SET
GC49 1
AG11 1
AG8 1
IS A 1
IS GC21 1
SET
GC13 1
AG11 1
AG8 1

6

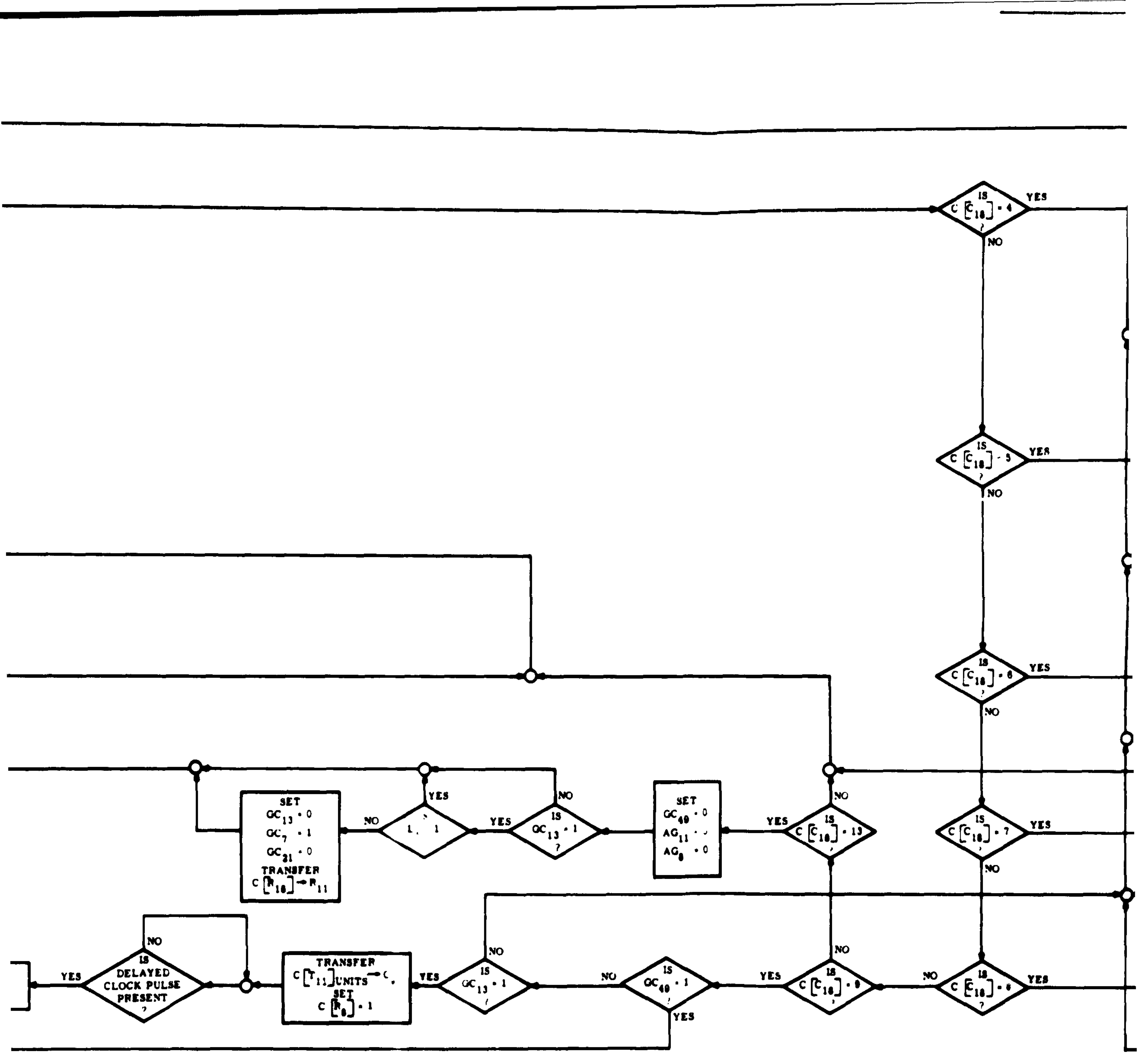


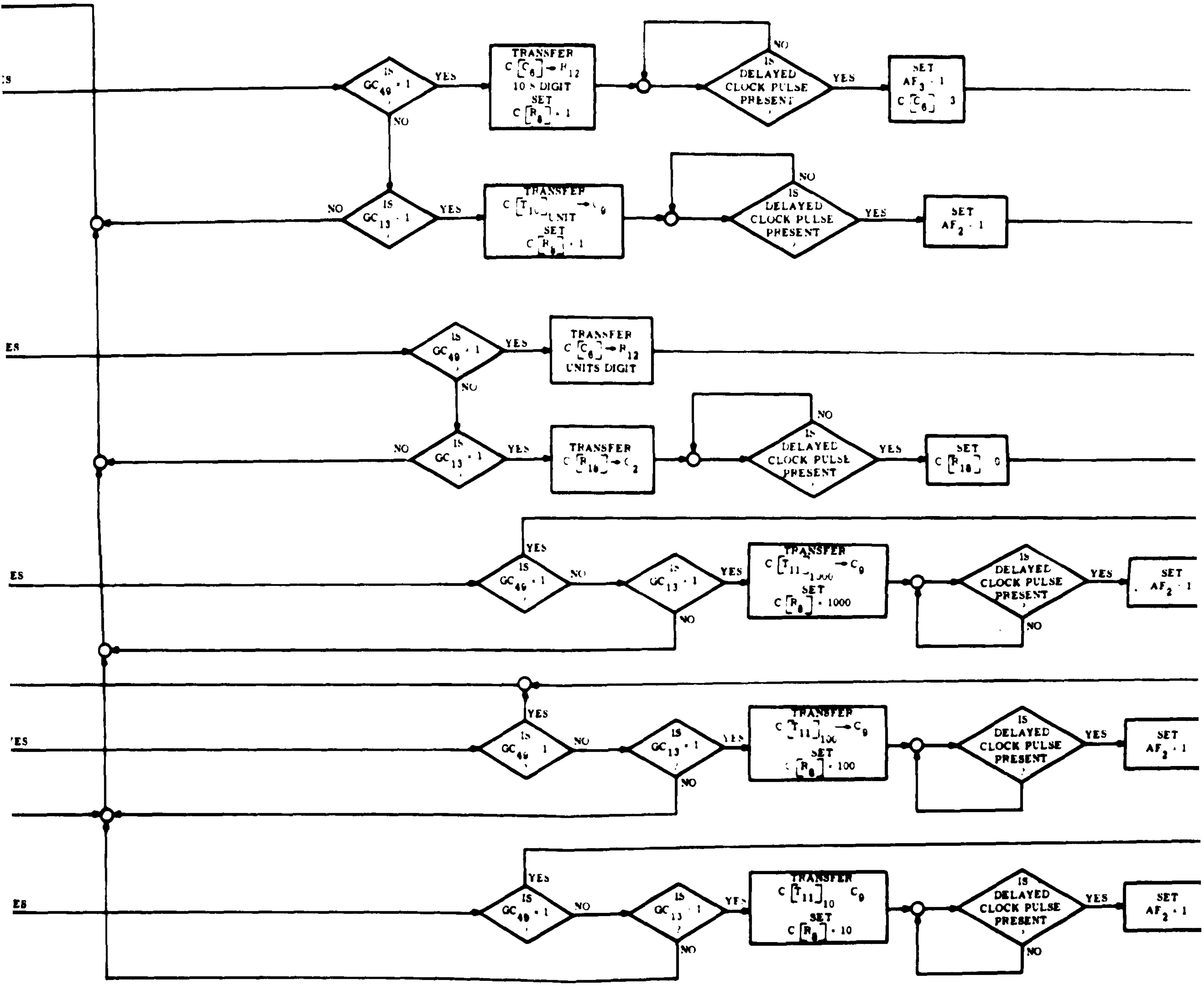
IS CLOCK PULSE PRESENT
AUGMENT
TRANSFER OUTPUT OF PITCH CONVERTER TO R_{18}
TRANSFER
IS DELAYED CLOCK PULSE PRESENT
1000'S DIGIT
SET
100'S DIGIT
YES
NO

7


SET C[R12] = 0 C[R8] = (1000)10
IS DELAYED CLOCK PULSE PRESENT?
NO
YES
SET AF3 = 1 C[C6] = 3
YES
SET AF2 = 1
IS DELAYED CLOCK PULSE PRESENT?
NO
YES
SET AF3 = 1 C[C6] = 3
IS DELAYED CLOCK PULSE PRESENT?
NO
YES
SET AF2 = 1
IS DELAYED CLOCK PULSE PRESENT?
NO
YES
SET AF3 = 1 C[C6] = 3
IS DELAYED CLOCK PULSE PRESENT?
NO
YES
SET AF2 = 1

8


IS C [C18] = 4 ?
YES
NO
IS C [C18] = 5 ?
YES
NO
IS C [C18] = 6 ?
YES
NO
IS C [C18] = 7 ?
YES
NO
IS C [C18] = 8 ?
YES
NO
IS C [C18] = 9 ?
YES
NO
IS C [C18] = 13 ?
YES
NO
SET GC40 = 0 AG11 = 0 AG8 = 0
IS GC13 = 1 ?
YES
NO
SET GC13 = 0 GC7 = 1 GC31 = 0 TRANSFER C [R18] → R11
IS GC40 = 1 ?
IS GC13 = 1 ?
TRANSFER C [T11] UNITS → C, SET C [R8] = 1
IS DELAYED CLOCK PULSE PRESENT ?



10

Figure 5. Detailed Flow Diagram-Display Calculati
and Record/Reproduce Control

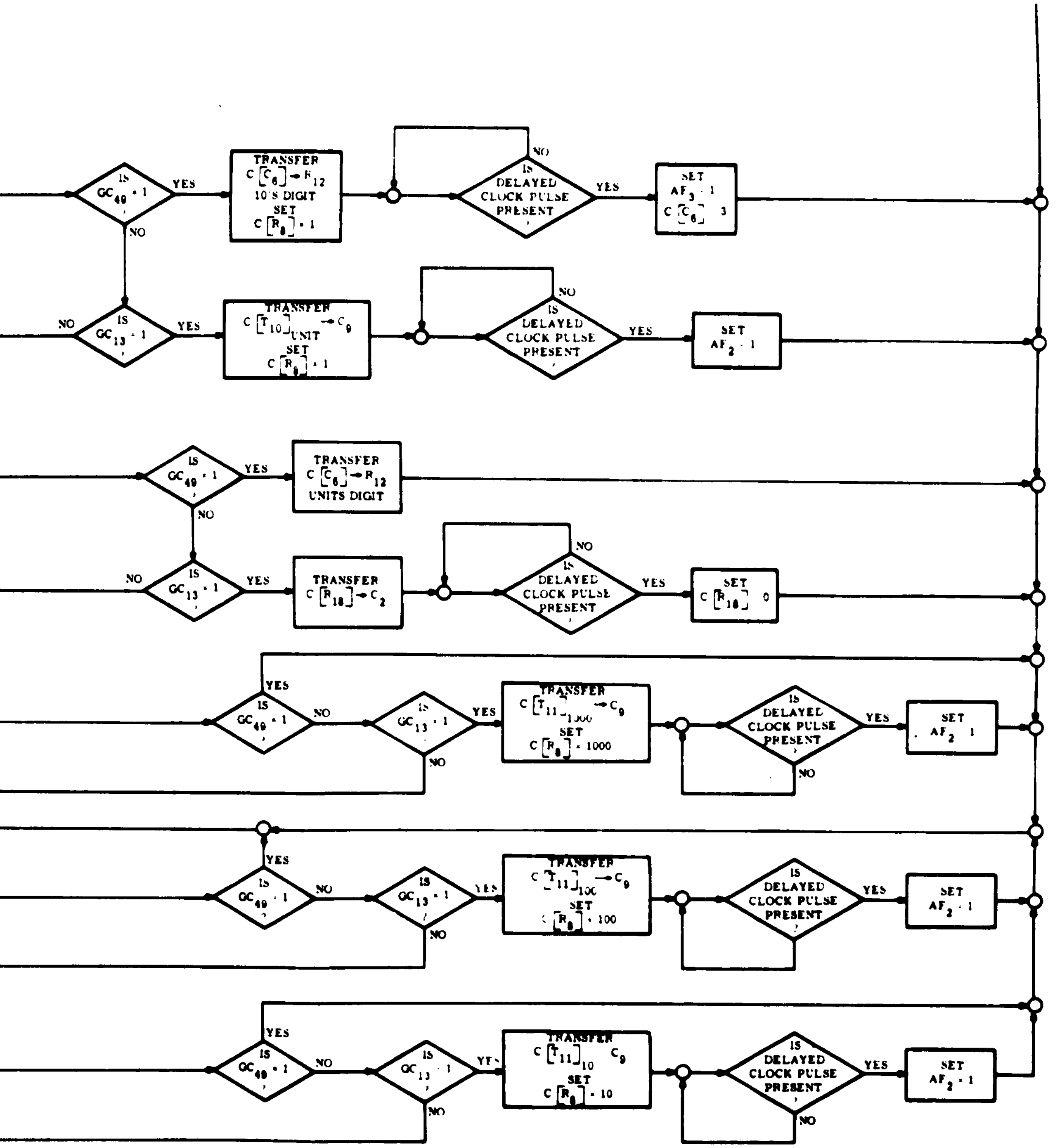


Figure 5. Detailed Flow Diagram-Display Calculation and Record/Reproduce Control

2.1.1 Address Ordered Output

The additional output mode, print and/or punch out of the voice frequency spectrum pattern data (represented by the Boolean equation $E_3L_7W_2N_1=1$), provides the system with the capability of producing "hard copy" of the contents of the spectrum pattern field of the magnetic drum, in the order in which the patterns were recorded into the memory. A segment of a pattern data table of nonsense syllables is shown in figure 6. This added capability is extremely useful in that it makes possible an extremely fast and unbiased tabulation of the contents of the pattern field, the tapes of which can be used in the automatic data consolidation discussed later in this report. The segment of the pattern field which will be contained in a particular print out is controlled by the analyst through the manual selection of a start and stop address.

2.1.2 Manual Accumulation from Multiplex

In operating the vocoder and multiplex in the manual mode, it was considered desirable that the analyst be able to continually monitor the information being transmitted to the processor and selectively process the input information a single frame at a time. This capability would make possible the complete manual control of the digital speech compression logic.

The program required in the processor for performing the manual accumulation from the vocoder ($E_2\ L_4\ N_2 = 1$) is unique in that it requires both automatic (or real-time) and manual control. This procedure is necessary so that the input spectrum pattern data can be continually displayed without being processed. From a careful consideration of this programming problem it became apparent that only the actual updating of the contents of the magnetic drum need be manually controlled. The remainder of the various sub-routine (pattern approximation, number of occurrences calculation, amplitude calculation, etc.) can continue in real time. Hence, the resulting program manually controls only the recording of data on the drum from the system START control on the console. Each time the system START is actuated, the parameters of only the first speech data frame subsequently entering the processor is accumulated. It should be noted that the "record function" is similarily controlled.

AMPLITUDE	VOICING	SPECTRUM PATTERN	PATTERN COUNT	PATTERN ADDRESS
0	0	. . . . . .	0000	0000
4	1	. 336625, ...	0001	0001
1	1	. 317655,71 3, 4 . . .	0009	0002
5	1	. 316767,612 1 3, 7 4 . . .	0003	0003
5	1	. 2 6677,421 2 2, 6 5 1 . . .	0005	0004
5	1	. 2 6677,52 2 2, 6 4 2 . . .	0007	0005
5	1	. 2 6677,52 1 2, 5 5 2 . . .	0004	0006
5	1	. 2 6677,62 1 2, 5 5 3 . . .	0017	0007
5	1	. 2 4777,63 1, 5 5 4 . . .	0001	0008
5	1	. 2 4776,74 , 4 5 4 . . .	0005	0009
5	1	. 3 4777,75 1, 3 4 2 . . .	0001	0010
4	1	. 314676,761 1 1, 2 5 . . .	0002	0011
1	1	. 312464,232 2 2, 2 4 3 . . .	0002	0012
1	1	. 1 1,222 4 5, 3 6 5 . . .	0001	0013
2	0	. . 2 2, 5 7 7 . 6 5 . 3 1 .	0012	0014
3	0	. . 1 1 4, 6 7 7 . 6 5 . 3 1 .	0006	0015
3	0	. . 2 4, 4 7 7 . 6 5 . 4 .	0003	0016
4	0	. . 1 3, 4 7 7 . 6 4 . 3 .	0001	0017
4	0	. . 1 1 3, 5 7 7 . 6 4 . 4 .	0009	0018
3	0	. 112 1 . 12 4 4, 4 7 6 . 3 5 . 2 .	0001	0019
5	1	. 326421,235 6 5, 3 3 7 . . .	0001	0020
5	1	. 2 5653,376 3 3, 3 2 4 . . .	0001	0021
5	1	. 1 3676,572 2, 1 2 4 . . .	0001	0022
5	1	. 1 2676,621 2, 1 4 4 . . .	0001	0023
5	1	. 1 2776,562 1, 2 4 4 . . .	0006	0024
5	1	. 2 2376,532 1, 2 3 4 . . .	0001	0025
5	1	. 2 2776,472 1, 3 3 4 . . .	0016	0026
5	1	. 2 3676,433 1, 3 3 4 . . .	0001	0027
5	1	. 2 3676,475 1, 2 3 4 . . .	0002	0028
5	1	. 2 2274,476 1 1, 4 2 4 . . .	0001	0029
5	1	. 3 4674,366 4 2, 3 3 2 . . .	0003	0030
3	1	. 325564,445 5 3, 2 3 1 . . .	0001	0031
3	1	. . 1 2, 3 7 6 . . .	0002	0032
4	0	. . 1, 3 7 7 . 6 5 . 4 2 .	0014	0033
4	0	. . 3, 4 7 7 . 6 5 . 4 2 .	0006	0034
5	0	. . 2, 4 7 7 . 5 5 . 5 2 .	0006	0035
4	0	. . 2, 4 7 7 . 5 5 . 4 2 .	0008	0036
4	0	. . 2, 5 7 7 . 6 5 . 3 1 .	0043	0037
4	0	. . 2, 5 7 7 . 6 5 . 3 .	0011	0038
2	0	. . 1 3, 5 7 6 . 6 5 . 3 1 .	0007	0039
4	1	. 215667,632 3 4, 4 4 2 . . .	0002	0040
5	1	. 2 5757,52 2 2, 4 4 3 . . .	0002	0041
6	1	. 1 3677,52 1 2, 4 5 4 . . .	0007	0042
6	1	. 1 2677,5 3, 4 5 3 . . .	0013	0043
6	1	. 1 2676,51 3, 4 5 3 . . .	0012	0044
6	1	. 1 1175,621 2, 4 6 3 . . .	0001	0045
6	1	. 1 1576,732 2, 3 7 4 . . .	0005	0046
6	1	. 1 476,741 1 2, 2 5 5 . . .	0012	0047
6	1	. 1 474,761 1 , 2 5 4 . . .	0005	0048
6	1	. 2 2676,611 , 3 5 3 . . .	0001	0049

Figure 6. Pattern Data Table

2.2 Refinements of Existing Logic

The refinements which have been made in the existing logical functions and fixed wired programs vary widely in complexity and nature, and have significantly increased the flexibility of the processor.

2.2.1 Automatic Consolidation

The initial design of the system provided for the accumulation of speech data tapes, but the number of occurrences of each pattern was ignored in the accumulation of data. That is, each data frame on tape was treated as a single isolated event and was counted only once in accumulation of statistics even though most of these frames on tape represented a large number of occurrences of the associated pattern. A consolidation of the data from such tapes results in accumulated amplitude specification for each pattern which ignores the relative number of occurrences of like patterns at varying average amplitudes. Thus, the number of occurrences of each pattern lost and the average amplitude is frequently disproportionately influenced by data frames on the input tapes which represent a small part of the total sample. This capability has been modified to enable the consolidation of the contents of several punched tapes into a single pattern table in which the accumulated amplitude item is properly weighted by the number of occurrences of each pattern on each of the tapes being accumulated. The number of occurrences of like patterns on the different tapes are also summed.

The changes in the programming required by this modification obviously included the multiplication of input average amplitude by number of occurrences (in order to reconstruct the cumulative amplitude) and the addition of this cumulative amplitude figure and the input number of occurrences with those previously accumulated on the magnetic drum. Programming these additional operations required only the properly sequenced selection of the arithmetic function flip-flops (AF_i) and the arithmetic gate control flip-flops (AG_j)[3].

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3. Final Report, AFCRL-62-314, "Design and Development of a Voice Data Processing System," Contract AF19(604)-5579, Melpar, Inc., 1962, p. 80.

If an overflow is detected in the consolidation routine, that is, the sum of a number of occurrences of a data word from tape and that associated with a matching pattern in memory which is greater than 4095, the accumulation routine in interrupted to permit the data frame from tape which caused the overflow to be punched out on perforated tape. It is interesting to note that due to the relative magnitudes of the computer word lengths for the number of occurrences and cumulative amplitude parameters, only the number of occurrences need ever be tested for overflow. Also, only tapes in the rank ordered format, either address ordered or rank ordered according to number of occurrences (either voiced, unvoiced, or both), will be automatically consolidated with the contents of the magnetic drum memory. Serial ordered tapes are obviously not candidates for automatic consolidation due to the nature of the data, and the frame of such tapes will continue to be accumulated as single isolated events.

2.2.2 Pattern Count Control

The number of spectrum patterns and their associated data which have been entered into the memory is stored in the processor in the spectrum pattern mode event counter. Since patterns are normally stored in consecutive memory address locations starting with address 0001 (decimal), this counter also contains the address of the last pattern recorded and is, therefore, used in determining the memory address for the next pattern to be entered into the memory.

In the process of recording (or accumulating) a set of patterns on the magnetic drum either from real-time speech input, from perforated tape, or keyboard inputs, it is often necessary to interrupt the process for preliminary test, tape search and/or changes, print outs, over night shutdown, etc. Any one of these interruptions may inadvertently destroy the contents of the pattern mode event counter and it is therefore essential that the analyst be able to reinstate its contents if the accumulation process is to correctly continue.

This capability existed in the initial design of the processor. However, it involved a complicated and time consuming process which essentially required that the analyst leave the console and manually set each of the 12 binary bits of the counter. The system has been modified so that now the analyst may use the keyboard in any of the keyboard input modes to enter a 4 decimal digit address into the temporary address storage register and subsequently transfer the content of this register into the pattern mode event counter by a manually operated gating control. This change will substantially facilitate operation of the processor.

2.2.3 Rank Ordered Output

To facilitate analysis of speech spectrum pattern statistics, the rank ordered output mode has been modified to include the capability of separating the pattern data into tables of voiced and unvoiced patterns. Short excerpts from a voiced and an unvoiced table of patterns, each generated by the same group of nonsense sylables, are shown in figures 7 and 8 respectively. A similar printed example of the same data, biased only by the number of occurrences of each pattern, is shown in figure 9. It should be interesting to note that the data shown in figure 6 is an address ordered print out of the same data.

In implementing this change, the rank ordered output mode was allowed to sequentially search for the spectrum pattern having the next highest number of occurrences as originally designed. Once the pattern is located, the associated voicing parameter is sampled to determine its state. If the state of the voicing bit is that selected, the data will be programmed out to the printer and/or punch, otherwise the detected frame will be discarded and the search continued.

2.2.4 Voicing Parameter Flexibility

In addition to the separation of the rank ordered output into tables of voiced and unvoiced patterns, further flexibility has been designed into the logical functions associated with the processing of the voicing parameter. The first to be considered is associated with the approximation logic.

Initially, the approximation logic of the processor required that the voicing bits of otherwise acceptably matched patterns be alike. From the statistics thus far collected it appears highly unlikely that a voiced pattern would ever match an unvoiced pattern, even within the maximum permissible deviation, and if this is true the logic which performs the voicing comparison is redundant. To test the validity of this assumption,

AMPLITUDE	VOICING	SPECTRUM PATTERN			PATTERN COUNT	PATTERN ADDRESS
5	1	5	1	7 4 4	0073	0258
4	1	6	2	7 7 6	0049	0318
5	1	62	2	7 7 5	0048	0284
6	1	51		6 6 5	0047	0308
4	1	71	2	6 7 5	0047	0312
5	1	61	2	6 7 5	0034	0311
5	1	721 3	2 5 5	6 2 1	0029	0492
5	1	2 2674	771 2	3 3 4	0029	0705
6	1	51	1	7 5 4	0026	0241
4	1	71	1	6 7 5	0026	0313
4	1	7	1	5 7 4	0026	0315
4	1	71	1	5 7 4	0025	0606
6	1	1 4745	64 4	5 6 4	0024	0858
5	1	2 3676	474 1	2 3 4	0023	0423
5	1	6	1	7 3 4	0023	0808
6	1	52		6 5 5	0022	0307
3	1	6	2	7 6 6	0022	0319
5	1	2 6677	52 2 2	5 4 2	0022	0403
5	1	62	1	6 7 5	0022	0605
4	1	52	2	7 7 6	0022	0825
5	1	63 2	2 4 7	6 4 2	0021	0100
5	1	6	2	7 3 4	0021	0260
4	1	7	1	6 7 5	0020	0316
6	1	5	1	7 5 5	0020	1016
5	1	62	1	6 7 6	0019	0310
5	1	1 2676	662 2	2 4 4	0019	0420
5	1	51	2	7 4 4	0019	1027
5	1	51	1	6 7 5	0019	1060
4	1	71	1	5 7 5	0018	0314
5	1	2 4774	731 1	4 5 2	0018	0455
4	1	51	3	7 5 6	0018	1028
3	1		3 5 6	6 6 6	0018	1043
5	1	2 6677	62 1 2	5 5 3	0017	0007
5	1	63 2	2 6 5	7 3 2	0017	0102
6	1	61 2		5 6 4	0017	0281
6	1	61 12	1	5 6 3	0017	0282
5	1	2 2676	473 1	3 3 4	0017	0422
5	1	2 6677	421 2 2	6 4 1	0017	0668
5	1	631 22	346 1 4	7 1 2	0017	0724
4	1		2	5 6 7	0017	0810
6	1	51	1	7 5 5	0017	1015
5	1	2 2776	472 1	3 3 4	0016	0026
6	1	51	1	6 6 5	0016	0242
6	1	2 2777	731 2 1	2 6 5	0016	0889
6	1	1 2676	5 3	4 5 3	0016	1155
5	1	63	1 5 7	6 5 2	0016	1241
5	1	72 1	4 6	7 4 2	0015	0146

Figure 7. Voiced Pattern Table

R4613

AMPLITUDE	VOICING	SPECTRUM PATTERN															PATTERN COUNT	PATTERN ADDRESS
5	0	.	.			3,	5	7	7	.	6	5	.	3		.	0048	0268
4	0	.	.			2,	5	7	7	.	6	5	.	3	1	.	0043	0037
4	0	.	.			4,	5	7	7	.	6	6	.	3		.	0041	0180
5	0	.	.			4,	4	7	7	.	6	5	.	4		.	0038	0195
4	0	.	.			,			5	.	4	6	.	7	3	.	0037	0907
5	0	.	.			,			5	.	4	6	.	7	2	.	0036	0232
2	0	.	.			4,			6	.	4	6	.	6	2	.	0036	0324
4	0	.	.			,			5	.	4	7	.	6	2	.	0035	0136
4	0	.	.			3,	3	6	7	.	7	6	.	4		.	0035	0252
5	0	.	.		1	4,	5	7	7	.	6	5	.	3	1	.	0035	0869
2	0	.	.			,				.	2	5	.	7	3	.	0029	0375
4	0	.	.		2	4,	6	7	7	.	6	4	.	3		.	0029	0589
5	0	.	.			,		3	6	.	6	7	.	5	2	.	0027	0532
4	0	.	.			,			6	.	3	6	.	7	2	.	0027	0578
4	0	.	.			3,	5	7	7	.	6	5	.	3	1	.	0027	0621
5	0	.	.			,		2	6	.	4	6	.	6	2	.	0026	0074
5	0	.	.			,		1	6	.	4	6	.	6	2	.	0026	0229
2	0	.	.			4,	6	7	7	.	5	4	.	2	1	.	0026	0636
5	0	.	.		1	4,	5	7	7	.	6	5	.	3		.	0025	0181
5	0	.	.			3,	5	7	7	.	7	5	.	4		.	0025	0266
5	0	.	.			6,	6	7	6	.	6	5	.	4	1	.	0024	0110
4	0	.	.			4,	5	7	7	.	6	5	.	4		.	0024	0179
4	0	.	.		1	4,	6	7	7	.	6	4	.	3		.	0022	0590
5	0	.	.			2,		2	5	.	4	5	.	6	3	.	0022	0779
4	0	.	.			,		2	6	.	6	7	.	5	1	.	0021	0158
5	0	.	.			2,	4	6	7	.	7	5	.	4		.	0021	0253
4	0	.	.			,			1	.	5	6	.	6	4	.	0021	0380
3	0	.	.			,		2	5	.	6	7	.	5	1	.	0021	0536
6	0	.	.			,		1	6	.	4	5	.	7	2	.	0021	0787
6	0	.	.			2,	5	6	7	.	7	5	.	4	1	.	0021	1023
3	0	.	.			5,	6	7	7	.	6	5	.	2		.	0021	1284
5	0	.	.			1,		2	6	.	4	5	.	7	2	.	0021	1312
4	0	.	.			4,	6	7	7	.	6	4	.	3	2	.	0021	1636
5	0	.	.		1	4,	6	7	7	.	6	5	.	4	1	.	0020	0112
4	0	.	.			2,	3	7	7	.	6	5	.	4	2	.	0020	0428
5	0	.	.			2,	3	7	7	.	5	5	.	5	2	.	0020	0430
5	0	.	.			,		1	6	.	4	6	.	7	2	.	0020	0577
5	0	.	.			2,			5	.	3	5	.	7	4	.	0020	0837
2	0	.	.	1	2	7,	6	7	6	.	6	4	.	3		.	0020	1034
5	0	.	.			,		2	5	.	4	6	.	6	1	.	0019	0234
4	0	.	.			2,	4	7	7	.	6	5	.	4	1	.	0019	0356
4	0	.	.			4,	5	7	7	.	6	5	.	3	1	.	0019	0633
4	0	.	.			,		1	5	.	6	6	.	6	2	.	0019	1183
4	0	.	.			2,	4	7	7	.	7	5	.	4		.	0018	0355
4	0	.	.			,		2	2	.	5	6	.	6	2	.	0018	0397
4	0	.	.			,			2	.	5	6	.	6	4	.	0018	0647
5	0	.	.			,		1	4	.	4	5	.	7	4	.	0018	1118
5	0	.	.			,		2	7	.	4	7	.	5	1	.	0018	1181
5	0	.	.			,		2	6	.	5	6	.	6	2	.	0018	1182
5	0	.	.			,		1	4	.	4	6	.	7	3	.	0017	0394
4	0	.	.		1	6,	6	7	6	.	6	5	.	4	2	.	0017	0497
	0	.	.			4,	5	6	7	.	7	5	.	4		.	0017	0561

Figure 8. Unvoiced Pattern Table

R4614

AMPLITUDE	VOICING	SPECTRUM PATTERN	PATTERN COUNT	PATTERN ADDRESS
5	1	. 5 . 1, 7 4 4 . . .	0073	0258
4	1	. 6 . 2, 7 7 6 . . .	0049	0318
5	0	. . 3, 5 7 7 . 6 5 . 3 .	0048	0268
5	1	. 62 . 2, 7 7 5 . . .	0048	0284
6	1	. 51 . , 6 6 5 . . .	0047	0308
4	1	. 71 . 2, 6 7 5 . . .	0047	0312
4	0	. . 2, 5 7 7 . 6 5 . 3 1 .	0043	0037
4	0	. . 4, 5 7 7 . 6 6 . 3 .	0041	0180
5	0	. . 4, 4 7 7 . 6 5 . 4 .	0038	0195
4	0	. . . 5 . 4 6 . 7 3 .	0037	0907
5	0	. . . 5 . 4 6 . 7 2 .	0036	0232
2	0	. . 4, 6 . 4 6 . 6 2 .	0036	0324
4	0	. . . 5 . 4 7 . 6 2 .	0035	0136
4	0	. . 3, 3 6 7 . 7 6 . 4 .	0035	0252
5	0	. . 1 4, 5 7 7 . 6 5 . 3 1 .	0035	0869
5	1	. 61 . 2, 6 7 5 . . .	0034	0311
2	0	. . . . 2 5 . 7 3 .	0029	0375
5	1	. 721 3 . 2 5 5, 6 2 1 . . .	0029	0492
4	0	. . 2 4, 6 7 7 . 6 4 . 3 .	0029	0589
5	1	. 2 2674,771 2, 3 3 4 . . .	0029	0705
5	0	. . . 3 6 . 6 7 . 5 2 .	0027	0532
4	0	. . . 6 . 3 6 . 7 2 .	0027	0578
4	0	. . 3, 5 7 7 . 6 5 . 3 1 .	0027	0621
5	0	. . . 2 6 . 4 6 . 6 2 .	0026	0074
5	0	. . . 1 6 . 4 6 . 6 2 .	0026	0229
6	1	. 51 . 1, 7 5 4 . . .	0026	0241
4	1	. 71 . 1, 6 7 5 . . .	0026	0313
4	1	. 7 . 1, 5 7 4 . . .	0026	0315
2	0	. . 4, 6 7 7 . 5 4 . 2 1 .	0026	0636
5	0	. . 1 4, 5 7 7 . 6 5 . 3 .	0025	0181
5	0	. . 3, 5 7 7 . 7 5 . 4 .	0025	0266
4	1	. 71 . 1, 5 7 4 . . .	0025	0606
5	0	. . 6, 6 7 6 . 6 5 . 4 1 .	0024	0110
4	0	. . 4, 5 7 7 . 6 5 . 4 .	0024	0179
6	1	. 1 4745,64 4 , 5 6 4 . . .	0024	0858
5	1	. 2 3676,474 1, 2 3 4 . . .	0023	0423
5	1	. 6 . 1, 7 3 4 . . .	0023	0808
6	1	. 52 . , 6 5 5 . . .	0022	0307
3	1	. 6 . 2, 7 6 6 . . .	0022	0319
5	1	. 2 6677,52 2 2, 5 4 2 . . .	0022	0403
4	0	. . 1 4, 6 7 7 . 6 4 . 3 .	0022	0590
5	1	. 62 . 1, 6 7 5 . . .	0022	0605
5	0	. . 2, 2 5 . 4 5 . 6 3 .	0022	0779
4	1	. 52 . 2, 7 7 6 . . .	0022	0825
5	1	. 63 2 . 2 4 7, 6 4 2 . . .	0021	0100
4	0	. . . 2 6 . 6 7 . 5 1 .	0021	0158
5	0	. . 2, 4 6 7 . 7 5 . 4 .	0021	0253
5	1	. 6 . 2, 7 3 4 . . .	0021	0260
4	0	. . . 1 . 5 6 . 6 4 .	0021	0380

Figure 9. Rank Ordered Table

a control has been added to the system with which the analyst can exclude the voicing comparison as a prerequisite to a valid pattern approximation.

Provisions have also been made for changing only the voicing bit of any particular spectrum pattern in the memory. Previously, in order to accomplish this it was necessary to manually enter from the keyboard the entire frame including a spectrum pattern which was exactly like that associated with the voicing bit to be changed. This was extremely undesirable when several frames were to be changed. Therefore, the system was modified to provide the analyst with the capability of altering a voicing bit by entering from the keyboard only the desired voicing parameter and the address of the frame to be changed.

2.2.5 Parallel Decimal Display

This modification provides for the continuous decimal display of four processing parameters which previously could be monitored only on a sequential operator-selected basis. Previously the selected parameter, either pitch, pattern address, the contents of the pattern mode event counter, or the contents of the record/reproduce counter, was decoded and the decimal display supporting register updated once each frame time. If the analyst wished to monitor more than one of the four parameters, which in most modes proved to be the rule rather than the exception, a decision as to which was most vital to a particular operation was required. The alternative required the analyst to continually switch between the parameters of interest. It therefore became apparent that if the processor was to operate at its maximum effectiveness, simultaneous display of these quasicontinuously varying parameters must be provided.

The implementation of this change required only that the switch which was used to select a single parameter be replaced by a two-bit counter and the addition of the logic and hardware required by the three additional displays. The decoding of each count of this counter sequentially selects each of the four parameters for the code conversions required by the displays. Unfortunately there is only enough time to decode a single parameter during each frame time thus requiring four frames or 8 revolutions of the drum to decode and update each of the displays.

With the exception of pitch, which is a special case and may vary in all three displayed digits, decoding each parameter every fourth frame can result, in the worst case, only in jumps of three digits in the least significant digit of the display. It is anticipated that this will not appreciably detract from their usefulness. However, should the perturbations in the display of a particular parameter become objectionable to the analyst, provisions have been made whereby any one of the four may be selected to be singularly decoded and displayed every frame.

2.2.6 Direct Data Transfer

In order that the analyst may monitor the output of vocoder multiplex during the real time accumulation or reduction of voice signals, the processor has been modified to permit the direct transfer of these input signals to the demultiplex. This capability, of course, allows the analyst to continually evaluate the quality of the input data to the processor and from this evaluation determine the likelihood of success for a particular data run. Since a direct data transfer mode existed prior to this modification,[4] the only programming change necessary was the "OR" of real-time accumulation ($E_2L_4N_1=1$) and reduction ($E_1L_4W_3N_1=1$) modes with the existing direct data transfer mode. The delay for the transfer of a data frame from the multiplex, through the processor's serial input and serial output registers to the demultiplex is 3 frame periods.

2.2.7 Pattern Coding Option

Initially, the voice data processing system was capable of processing only voice spectrum patterns with three bits coding per frequency channel with these bits having the conventional binary weight of 4-2-1. It is questionable, however, that this coding configuration is optimum. In order to facilitate experiments to determine a more favorable pattern contour, the processor has been modified to make possible the use of the pattern approximation logic with 1 and 2 bit as well as 3 bit coding as indicated in table 1. This option may be used to process pattern data inputs either in real time, from perforated tapes, or from keyboard.

4. Ibid, Page 34

TABLE 1

SPECTRUM CHANNEL

4	2	1	3	
X	4	2	2	Coding
X	X	4	1	

Implementing this modification required only that the 1 and 2 bit coded pattern be positioned relative to the subtractors of the approximation logic so that the least significant bit for each spectrum channel corresponds to the least significant input to the subtractors.

In the expansion of data which is coded as either 1 or 2 bits per channel, the patterns are repositioned as they are shifted out to the demultiplex so that the various weighed bit always appear in the same position in each spectrum channel.

2.3 Deviation Recording

Provisions have been made for recording into the memory and the subsequent print and/or punch-out of the pattern deviation value resulting from the processing of "expanded" speech data inputs to the system either real-time, from perforated tape, or manually entered from keyboard. The recording of the deviation value is, of course, associated only with the recording of a sequence of speech events and is therefore controlled by the record/reproduce function. It should be noted that once the record option is selected no control over the recording of the deviation value exists. Hence, if the researcher attempts to alter the contents of a previously recorded sequence by optionally recording either pitch or pattern address, the deviation will also be changed.

The deviation value is printed out in the serial ordered format as the last item in the format as shown in figure 10.

It should be noted that a pattern deviation figure will result only when a pattern in storage matches the input pattern within the specified deviation threshold. Two special cases

R4610

AMPLITUDE	VOICING	PITCH	SPECTRUM PATTERN	PATTERN COUNT	PATTERN ADDRESS	PATTERN DEVIATION
0	0	110	. . . . . .	0000	0846	0
0	0	110	. . . . . .	0000	0847	0
0	0	110	. . . . . .	0000	0848	0
0	0	110	. . . . . .	0000	0849	0
0	0	110	. . . . . .	0000	0850	0
0	0	110	. . . . . .	0000	0851	0
0	0	110	. . . . . .	0000	0852	0
0	0	110	. . . . . .	0000	0853	0
0	0	110	. . . . . .	0000	0854	4
2	0	110	. . . . 2 5 . 7 7 .	0029	0855	0
3	0	110	. . . 1 . 4 5 . 7 4 .	0010	0856	0
4	0	110	. . . 3 . 4 5 . 7 7 .	0004	0857	0
4	0	110	. . 1. 1 . 5 5 . 7 7 .	0006	0858	0
4	0	110	. . . 2 . 5 6 . 6 4 .	0018	0859	0
4	0	110	. . . 1 . 5 7 . 7 4 .	0004	0860	0
4	0	110	. . . 2 2 . 5 5 . 7 7 .	0006	0861	0
3	0	110	. . 1 2. 1 4 5 . 4 5 . 6 2 .	0002	0862	0
4	1	106	. 454222.265 2. 2 4 4 . . .	0002	0863	0
5	1	114	. 446441.374 2 2. 3 4 2 . . .	0005	0864	6
5	1	122	. 32765 .264 1 4. 3 6 2 . . .	0003	0865	0
5	1	126	. 2 774 .373 4. 4 5 2 . . .	0007	0866	0
5	1	126	. 2 6712.474 4. 4 4 3 . . .	0007	0867	0
5	1	131	. 3 6623.473 1 3. 3 5 3 . . .	0001	0868	0
4	1	135	. 326552.454 3 2. 2 4 4 . . .	0002	0869	6
3	1	131	. 324243.322 3 2. 3 4 . . .	0001	0870	0
4	1	126	. . . 1 1 4 . . .	0001	0871	0
5	0	126	. . . 1 4 . 5 5 . 7 4 .	0015	0872	0
5	0	126	. . . 5 . 4 5 . 7 7 .	0002	0873	0
5	0	126	. . . 5 . 4 6 . 7 6 .	0036	0874	0
5	0	126	. . . 1 4 . 4 6 . 6 3 .	0009	0875	0
4	0	126	. . . 1 4 . 6 6 . 6 2 .	0010	0876	0
4	0	126	. . . 2 3 . 5 6 . 7 6 .	0006	0877	0
4	0	126	. . . 2 2 . 5 6 . 6 2 .	0018	0878	0
4	0	126	. . . 2 2 . 5 6 . 6 2 .	0018	0879	1
3	0	126	. . . 1 . 6 7 . 6 2 .	0005	0880	0
1	0	126	. . . 3 . 5 7 . 5 2 .	0006	0881	0
0	0	126	. . . . . .	0000	0882	0
0	0	126	. . . . . .	0000	0883	0
0	0	126	. . . . . .	0000	0884	0
0	0	126	. . . . . .	0000	0885	0
0	0	126	. . . . . .	0000	0886	0
0	0	122	. . . . . .	0000	0887	0
0	0	122	. . . . . .	0000	0888	0
0	0	114	. . . . . .	0000	0889	0
0	0	122	. . . . . .	0000	0890	0
0	0	114	. . . . . .	0000	0891	0
0	0	122	. . . . . .	0000	0892	0
0	0	114	. . . . . .	0000	0893	0
0	0	122	. . . . . .	0000	0894	0
0	0	114	. . . . . .	0000	0895	0
0	0	122	. . . . . .	0000	0896	0
0	0	114	. . . . . .	0000	0897	0

Figure 10. Serial Ordered Table

must therefore be considered. During data accumulation modes, if an input pattern is not matched with a stored pattern then the unmatched pattern will be recorded in the next unused memory address. Under these conditions a "O" will be recorded as the deviation. Secondly, in data reduction modes when an input pattern does not find a match in the memory the address of the last matching pattern or that corresponding to the stored silence frame will be recorded in the record/reproduce field of the drum. Under these conditions a code corresponding to the printer character "$\triangle$" will be recorded as the deviation.

This modification proved to be the most difficult thus far. This was due to the changes which were required in the three main programmers, in addition to the logical circuitry necessary to record the deviation values into the memory. However, due to the initial design philosophy of the programmers, the required changes were easily determined and implemented with an extremely high degree of confidence.

3. OPERATING ENVIRONMENT

"The Contractor shall . . . investigate the operating environment of the digital voice data equipment complex, and establish and implement an optimum operating environment . . ."

Statement of Work
Contract No. AF19(628)-214

The Voice Data Processing System was implemented largely with logic modules which were designed for the Air Force FINDER program under Contract AF33(038)-21250. In the design of these modules, extensive effort was made to achieve maximum reliability, efficiency, and economy at an operating temperature near 68°F. The philosophy in this approach being that in relatively complex systems it is more economical to control the environment than to design to meet a particular specification.

Since the equipments of FINDER were to operate in a carefully controlled ambient, prior to the development of the Voice Data Processing System, no analytical or empirical data was available regarding what might be expected of these modu es at temperatures near 85°F to 90°F. Therefore, in addition to the collection of all empirical data possible during the laboratory checkout and during the first few months of operation subsequent to delivery of the Voice Data Processing System, a study was initiated to determine the effects of ambient changes upon the reliability of transistors, diodes, resistors, and capacitors as used in the various modules.

Succinctly, the results of this study indicated that an increase of 40°F (from 70°F) in the equipment complex ambient should be expected to result in a decrease of approximately 10% in the mean-time-between-failure of the system. The final report on this study is contained in this report as Appendix C.

The empirical data gathered during the first few months of operation of the system indicated that while the processor would operate in an ambient near 90°F, it was subject to a great variety of failures which often rendered data collected during these periods virtually useless. It was noted that the malfunctions which occurred at these temperatures usually corrected themselves when the ambient was sufficiently reduced.

The results of both the study and the empirical data collected clearly indicated that a substantial improvement in the reliability of the processor would be achieved by properly controlling the environment. Therefore, a specification of the optimum operating environment was established and subsequently implemented. The major equipments of the air conditioning system were a Model AV-1103 Westinghouse air cooled compressor-condenser and a DXF-113 Westinghouse air conditioner fan coil unit - nominal 10 tons capacity.

During the specification, design, and installation of the air conditioning system, every effort was made to keep the vibration and noise inherently introduced by such systems to a minimum. The results of these efforts have been gratifying. There has been virtually no vibration introduced by the installation and, due largely to acoustically lined duct work throughout, the noise level has not been appreciably increased. Also, the noise generated by the processor exhaust fans has been significantly reduced due to the addition of acoustically lined stacks.

In the first several months of operation, the air conditioning system has proven quite satisfactory. It should be noted that in arriving at the final specifications for the optimum environment, allowance was made for considerable future expansion within the laboratory.

4. SUMMARY

The Voice Data Processing System is a high-speed special-purpose digital computer designed to support research on digital voice communication, and evaluation of a technique for speech bandwidth compression. The primary objective of this investigation has been to continually adjust the capabilities of the processor to meet the dynamic requirements of these research efforts. The changes which have been made in the processor have manifested themselves largely during the course of the study and evaluation of statistics and from further study of the logic designs of the system. The results of these changes have been a significantly increased processing flexibility and capability which have assured continued optimum compatibility between the research effort and the processor.

In order to insure the continued reliability and efficiency of the Voice Data Processor, it has been necessary to specify and implement favorable operating environment for the equipment complex. The noise and vibration which are inherently introduced by such air conditioning systems were given special consideration and minimized where possible.

5. Appendices

Appendix A

DEFINITION OF TERMS

A - A=1 during every other period of revolution of the magnetic drum, i.e., during one-half frame. A = 0 during the alternate periods of revolution of the drum.

A' - A'=1 at the occurrence of the drum sync pulse which changes A from 0 to 1. A' = 0 at all other times.

B - B = 1 during every other period of revolution of the drum. If A = 1, B = 0; if B = 1, A = 0.

B' - B' = 1 at the occurrence of the drum sync pulse which changes B from 0 to 1.

c[( )] - This notation is used with a register or counter symbol enclosed by the brackets and is read, "the contents of", e.c., c[(C_1)] is read "the contents of Counter 1" or "c of C_1".

C_1 - C_1 is the 12-bit address counter which counts clock pulses to yield the address location at any time in either the spectrum pattern field or the record/reproduce field of the magnetic drum except when D = 1 (see below).

C_2 - C_2 is the 12-bit record/reproduce event counter and contains at all times the address on the drum of the position at which the pitch and/or pattern address data are to be recorded or read or have last been recorded or read, in the record/reproduce field.

C_3 - C_3 is the 12-bit pattern mode event counter and contains the sequence number and address of either the last pattern recorded or the pattern about to be recorded in the spectrum pattern field of the magnetic drum.

C_4 - C_4 is used for the input/output storage for DVP and is used in the conversion of pitch from cycles per second to the system code.

C_5 - C_5 is a MOD-18 (0-17 incl) counter used to program the operation of the Asynchronous Data Expansion Mode. The input to the counter consists of the 18 input shift pulses which coincide in time with the occurrence of each of the 18 input bits.

C_6 - C_6 is the 3-bit quotient counter.

C_7 - C_7 is a multi-moduli counter, the modulus (2, 3, 4, 6, 8, 10 or 12) being selected by a switch setting, and is used to control stretch out in the Data Reproduce Mode.

C_8 - C_8 is the 8-bit Central Programmer counter.

C_9 - C_9 is a 4-bit counter in the arithmetic unit which contains the digit to be converted in the BCD to binary conversion.

C_{10} - C_{10} is a 4-bit counter in the arithmetic unit which counts the number of clock pulses required for a given arithmetic operation.

C_{12} - C_{12} is a 4-bit counter which contains the selected deviation or one less than the deviation of the best spectrum pattern approximation found.

C_{13} - C_{13} is the 5-bit Peripheral Equipment Programmer counter.

C_{14} - C_{14} is a 3-bit item counter in the Input/Output Programmer.

C_{15} - C_{15} is a 12-bit reverse counter which is compared, in Rank Ordered Read Out, with the number of occurrences item recorded on the drum.

C_{16} - C_{16} is a 3-bit Peripheral Equipment Programmer item counter.

C_{17} - C_{17} is a 5-bit spectrum pattern character counter in the Peripheral Equipment Programmer.

C_{18} - C_{18} is a 4-bit counter which programs the read in of T_{10} and T_{11} and also programs the decoding necessary for the decimal display.

C_{19} - C_{19} is a 2-bit counter which counts the three shifts of R_1 and R_9 during input/output operations.

C_{20} - C_{20} is a 5-bit Input/Output Programmer character counter.

C_{21} - C_{21} is a 1-bit parity error counter.

C_{22} - C_{22} is a 9-bit counter which provides a 240:1 countdown for the generation of the compressed speech data clock.

R_1 - A 64-bit serial input-parallel output shift register used for the system input register for data from the Multiplex.

R_1' - The 6-bit part of R_1 which stores pitch.

R_1'' - The 55-bit part of R_1 which stores the 54 bit spectrum pattern and the voicing bit.

R_1''' - The 3-bit part of R_1 which stores input amplitude information.

R_2 - A 55-bit register which buffers the input spectrum pattern and voicing during a spectrum pattern approximation and is used as an input register for D_{SP} and D_{VB}.

R_2' - The 54-bit part of R_2 which stores the spectrum pattern.

R_2'' - The 1-bit part of R_2 which stores voicing.

R_3 - A 6-bit register used for buffer storage of pitch.

R_4 - A 15-bit shift register used as a buffer and comparator register for pattern address data and as an output register for D_{PA}.

R_5	-	A 15-bit shift register used as a buffer storage for pitch and accumulated amplitude and as an input/output register for D_{VA}.
R_6	-	An 18-bit parallel input-serial output shift register used as an output register for compressed speech data.
R_6'	-	The 6-bit part of R_6 used as an output register for pitch.
R_6''	-	The 12-bit part of R_6 which is used as an output register for pattern address.
R_7	-	An 18-bit serial input-parallel output shift register used as an input register for compressed speech.
R_7'	-	The 6-bit part of R_7 used as an input register for pitch.
R_7''	-	The 12-bit part of R_7 used as an input register for pattern address.
R_8	-	A 15-bit shift register which contains the constants for BCD to binary and binary to BCD conversions. Also used in updating number of occurrences by one.
R_9	-	A 64-bit parallel input-serial output shift register used as an output register for expanded speech.
R_9'	-	The 6-bit part of R_9 used for the storage of pitch.
R_9''	-	The 55-bit part of R_9 used to store the spectrum pattern and voicing.
R_{10}	-	A 55-bit register used for buffer storage for spectrum patterns and voicing and as an output register for D_{SP} and D_{VB}.
R_{10}'	-	The 54-bit part of R_{10} which stores the spectrum pattern.
R_{10}''	-	The 1-bit part of R_{10} which stores voicing.

R_{11} - A 12-bit register which contains the Stop address in the record/reproduce function and the Stop address during Tape Speech.

R_{12} - A 15-bit register which supports the decimal display of pattern address.

R_{13} - A 7-bit shift register used as an input register for the tape reader.

R_{14} - A 7-bit register used as an input/output register for the Input/Output Programmer.

R_{15} - A 15-bit shift register used as a buffer for input amplitude and as an input register for D_{PA}.

R_{16} - A 15-bit shift register used as an input/output register for D_{NO}.

R_{17} - A 7-bit register used as a system input register in the peripheral equipment.

R_{18} - A 15-bit shift register used as an arithmetic accumulator in decimal display calculations and for the read-in of the Start and Stop address in record/reproduce functions.

R_{19} - A 4-bit register used as an input/output register for D_{DV}.

R_{20} - An 11-bit register which supports the decimal display of pitch.

R_{21} - A 15-bit register which supports the decimal display of record/reproduce event counter.

R_{22} - A 15-bit register which supports the decimal display of the pattern mode event counter.

AG_j - Arithmetic gate control which selects the arithmetic registers used as addend and accumulator.

AG_1 - R_4 Accumulator.

AG_2 - R_4 Addend.

AG_3 - R_{15} Accumulator.

AG_4 - R_{15} Addend.

AG_5 - R_{16} Accumulator.

AG_6 - R_{16} Addend

AG_8 - R_8 Addend.

AG_9 - R_5 Accumulator.

AG_{11} - R_{18} Accumulator.

AF_i - Arithmetic function.

AF_1 - Add.

AF_2 - BCD to binary conversion.

AF_3 - Binary to BCD conversion.

AF_4 - Divide.

E_k - Function switch selection.

E_1 - Reduction.

E_2 - Accumulation.

E_3 - Expansion.

E_4 - Reduction-Expansion

E_5 - Drum Erase.

E_6 - Direct Data Transfer.

E_7 - Tape Search.

L_k = Input switch selection.

L_1 - Tape.

L_2 - Keyboard.

L_3 - Record/Reproduce.

L_4 - Multiplex.

L_5 - Compressed Speech Data.

L_6 - Number of Occurrences (D_{NO}).

L_7 - Pattern Address.

W_k - Output switch selection.

W_1 - De-Multiplex.

W_2 - Print/Punch.

W_3 - Compressed Speech Data.

N_k - Mode switch selection.

N_1 - Automatic.

N_2 - Manual.

N_3 - Interrogation.

N_5 - Speech Data Change.

P_k - Decimal Display switch selection.

P_1 - Record/Reproduce Event Counter (C_2).

P_2 - Pitch.

P_3 - Pattern Mode Event Counter (C_3).

P_4 - Spectrum Pattern address.

Q_k - Keyboard Input switch selection.

Q_1 - Spectrum Pattern.

Q_2 - Voicing.

Q_3 - Amplitude.

Q_4 - Address.

Q_5 - Pitch.

U_k - Stretch Ratio switch selection.

U_1 - 1:1.

U_2 - 2:1.

U_3 - 3:1.

U_4 - 4:1.

U_5 - 6:1.

U_6 - 8:1.

U_7 - 10:1.

U_8 - 12:1.

V_k - Record/Reproduce Mode switch selection.

V_1 - Manual.

V_2 - Automatic.

V_3 - External.

F_k - Drum Erase switch selector.

F_1 - Spectrum Pattern Field.

F_2 - Record/Reproduce Field.

F_3 - Amplitude and Number of Occurrences.

X_k - Voicing Control on Rank Ordered Print/Punch out.

X_1 - Selects Voiced Patterns.

X_2 - Selects Unvoiced Patterns.

X_3 - Selects both Voiced and Unvoiced Patterns.

T_q - Toggle or push button switch programming inputs.

T_1 - Selects the record of pitch in the Record/Reproduce field.

T_2 - Selects the record of address in the Record/Reproduce field.

T_3 - T_3 selects either the preceding address or a zero address for transmission in Reduction modes when an input pattern does not match a record pattern.

T_4 - An inhibit control on the 400 kc/s clock input from the drum.

T_5 - Selects the Stop of the system on the overflow of C_3.

T_7 - Allows the insertion of errors in compressed speech data outputs.

T_8 - In Serial Ordered Print/Punch Out selects either Spectrum Pattern Field Address.

T_9 - Selects digit formating mode in General Data printing.

T_{10} - Start address digit switch for Record/Reproduce Field.

T_{11} - Stop address switch for Record/Reproduce Field.

T_{12} - Selects either Speech Data or General Data format.

T_{13} - Console switch selecting Printer ON.

T_{14} - Console switch selecting Punch ON.

T_{15} - Console switch selecting Reader ON.

T_{16} - Peripheral equipment switch selecting Reader ON.

T_{17} - Peripheral equipment switch selecting Punch ON.

T_{18} - Peripheral equipment switch selecting Printer ON.

T_{29} - Initiates the read-in of the Start and Stop address in the Record/Reproduce functions.

T_{38} - Selects punching of parity bit when manually advancing leader through punch.

T_{40} - Manual Recording of Voicing (D_{VB}) only.

T_{41} - Voicing inhibit in spectrum pattern approximation routine.

T_{42} - Enters Spectrum Pattern Count into C_3.

Δ' - The threshold deviation figure as selected by the deviation digit switch on the console.

Δ_T - $\Delta_T = \Delta'$ or, after the occurrence of a pattern approximation, Δ_T is equal to one less than the deviation associated with the approximation. The value of Δ_T may change several times during a single approximation.

K' - K' = 1 at the occurrence of the "word sinc" pulse from the input source during the asynchronous operation of the Data Expansion Mode.

M_1 - $M_1 = T_{14}\, \overline{T}_{13}\, E_3\, (W_2 L_3 + L_6) = 1$ selects the system to punch peripheral equipment mode.

M_2 - $M_2 = T_{14}\, T_{13}\, E_3\, (W_2 L_3 + L_6) = 1$ selects the system to punch and printer peripheral equipment mode.

M_4 - $M_4 = T_{13}\, \overline{T}_{14}\, E_3\, (W_2 L_6) = 1$ selects the system to printer peripheral equipment mode.

M_5 - $M_5 = T_{16} T_{18} \bar{T}_{13} \bar{T}_{15} \bar{T}_{17} = 1$ selects the reader to printer peripheral equipment mode.

M_6 - $M_6 = L_1 T_{15} = 1$ selects the reader to system peripheral equipment mode.

M_7 - $M_7 = T_{16} T_{17} \bar{T}_{14} \bar{T}_{15} = 1$ selects the reader to punch peripheral equipment mode.

Ω - Pulses generated by the Input/Output Programmer which instructs the peripheral equipment that a frame of data is either ready to be programmed out or that the programming out of a frame has been completed.

GC_m - GC_m represents a gate control flip-flop (or equivalent) and are used to remember the occurrence of a particular event for varying lengths of time for the purpose of controlling time ordered sequences of programming functions.

GC_1 - Programs the system functions after a valid pattern approximation.

GC_2 - Programs the Expansion phase of either Rank or Serial Ordered Print/Punch out.

GC_3 - Inhibits the accumulation of silence input frames (or frames having zero amplitude).

GC_4 - Programs the first address location in the record/reproduce functions.

GC_5 - Set to one for a $c[\bar{R}_{16}] = C[\bar{C}_{15}]$ comparison and inhibit further search for output frame.

GC_6 - Detects and remembers the overflow of C_3 (Spectrum Pattern Mode Event Counter.)

GC_7 - Controls the operation of the record/reproduce function.

GC_8 - Set equal ONE for a $c[\bar{C}_1] = c[\bar{C}_2]$ comparison. Enables the reading or recording of DPA and DVP.

GC_9 - Detects a perfect match and inhibits further spectrum pattern approximations for a given input frame.

GC_{10} - Controls the programming required at the completion of the stretch out of a given frame.

GC_{11} - Programs those functions to be performed during a single clock period after a valid pattern approximation.

GC_{12} - An inhibit on the decimal display programmer controlled by the input/output programmer.

GC_{13} - Controls the program for the read in of the contents of the Start and Stop digit switches in the record/reproduce field.

GC_{14} - Programs the manually initiated reader STOP so that in speech data formats, the reader will be stopped only at the end of a frame.

GC_{15} - Controls the initiation of the processing by the Central Programmer of non-real-time data inputs.

GC_{16} - Controls the processing by the Central Programmer of non-real-time data inputs.

GC_{17} - Inhibits the printing of speech data from the reader until after the detection of a start of frame format code.

GC_{18} - Controls the paper advance level input to the printer.

GC_{19} - Inhibits the reading of D_{NO} until after the address of the last output frame has been located in the Rank Ordered Print/Punch Mode.

GC_{20} - Controls the start of printing in a general data printing format.

GC_{21} - Remembers the manual or external initiation of the record/reproduce function so that the operation may become synchronized with the drum.

GC_{22} - Inhibits the Record function until after the first non-silence frame.

GC_{23} - Controls the initiation of the Peripheral Equipment Programmer for either a code input from the system or the reader.

GC_{24} - Inhibits the count input to C_{13} until after the generation of the first programmer pulse.

GC_{25} - Indicates that the Peripheral Equipment Programmer is ready to process next code input from the system.

GC_{26} - Indicates that the Input/Output Programmer is ready to send next code to the peripheral equipment.

GC_{27} - Stores the receipt of either an $\Omega = 0$ or an $\Omega = 1$ pulse from the Input/Output Programmer.

GC_{28} - Stores $\Omega = 1$ pulse in absence of either low paper or low tape.

GC_{29} - Stores the occurrence of either a low paper or low tape until the condition has been corrected.

GC_{30} - Stores the detection of a parity error.

GC_{31} - Inhibits further shifting of R_{13} at the completion of a parity check.

GC_{32} - Controls the filling of the remainder of the printed line with spaces. Set by either the detection of a carriage return, 7th or 8th end of item, or a stop code.

GC_{34} - Stores the occurrence of either a tight tape or no tape condition of the punch.

GC_{35} - Perforator feed control flip-flop.

GC_{36} - Perforator stop control flip-flop.

GC_{37} - Perforator "Space" and "Mark" code generating flip-flop.

GC_{38} - Inhibits the count input to C_8.

GC_{39} - Controls the reading or recording of DSP, and is set by $c[C_1] = c[R_4]$ comparator.

GC_{40} - Controls the reading or recording of D_{NO} and D_{VA}, and is set by $c[C_1] = c[R_4]$ comparator.

GC_{41} - Read-Record control flip-flop for DSP, DNO, and DVA.

GC_{42} - Read-Record control flip-flop for D_{VP} and D_{PA}.

GC_{43} - Carry flip-flop of the arithmetic unit.

GC_{44} - Add-subtract flip-flop of the arithmetic unit.

GC_{45} - Arithmetic clock pulse control.

GC_{46} - Division round off flip-flop of the arithmetic unit.

GC_{47} - System start-stop flip-flop.

GC_{48} - Early or late clock control flip-flop.

GC_{49} - Decimal Display calculation control flip-flop.

GC_{50} - Stores the detection of a start of frame code in the Input/Output Programmer.

GC_{51} - Stores the occurrence of either the rank or serial ordered formating code in the Input/Output Programmer.

GC_{52} - Controls the shift of R_9 or R_1 three bits.

GC_{53} - Stores reader ON to drive the display.

GC_{54} - Enables the count input to C_4 in the pitch conversion operation.

GC_{56} - Enables the strobe clock in the Peripheral Equipment Programmer.

GC_{57} - Rank Ordered/Serial Ordered data tag in peripheral equipment programmer.

GC_{58} - Pulse shaping flip-flop for keyboard inputs.

D_{SP} - Denotes any particular address location in the Spectrum Pattern Field of the drum, containing the description of a spectrum pattern.

D_{NO} - Denotes the address location in the Spectrum Pattern Field of the drum, which contains the accumulated number of occurrences of the spectrum pattern in the same address location.

D_{VA} Denotes the address location, in the Spectrum Pattern Field of the drum, which contains the accumulated amplitude data associated with the spectrum pattern recorded at the same address.

D_{PA} - Denotes any particular address location, in the Record/Reproduce Field of the drum containing a spectrum pattern address.

D_{VP} - Denotes any particular address location, in the Record/Reproduce Field of the drum, which contains voice pitch data.

D_{VB} - Denotes any particular address location in the Spectrum Pattern Field of the drum containing the voicing bit.

D_{DV} - Denotes any particular address location in the record/reproduce field of the drum containing the deviation figure.

D - That portion of each revolution of the magnetic drum starting with the overflow of C_1 and ending with either A' or B'.

D' - A pulse occurring at the overflow of C_1 and initiates the beginning of D time.

APPENDIX B

OPERATING INSTRUCTIONS

Appendix B

OPERATING INSTRUCTIONS

1. The operating instructions for the system consist primarily of the switch settings which are necessary to select the fixed wired required required to perform the various functions of the modes and, when applicable, the sequence in which the switch closures should be made. The instructions for turning power on to the system in addition to functions which are optional variations will be given as a prefix to the operating instructions.

Prior to any operation, it is assumed that; (1) all switches are either down, zero, or in standby, (2) the Stretch Ratio selector is set to 1:1, (3) the Clock control will be turned ON prior to the initiation of any operation, (4) the magnetic drum is ON and has been allowed sufficient time to warmup, and (5) the power to the various equipments (including all power supplies) will be turned ON as necessary.

1.1 Power ON

1.1.1 Power to the drum is turned on by actuating and holding the Drum Power ON switch until the indicator lamp is lit. (The hold is necessary to allow time for the air flow detector to be energized.)

1.1.2 AC power to the remainder of the system is turned on by actuating the AC Power ON switch. Power to the logic will also be controlled by this switch if the circuit breakers on the Power Control Panel are ON. If these four breakers are open, they must be closed in the following sequence: (1) racks 5 and 10, (2) racks 3 and 4, (3) racks 1 and 2, and (4) rack 8.

1.2 Decimal Display

The parameter to be displayed by the Decimal Display may be selected at random with no prior consideration as to the mode of operation. If Decimal Display selector is in STBY, each parameter will be calculated every fourth frame time and the four parameters will be displayed in parallel. If one of four parameters is selected by Decimal Display selector (Pitch, Pattern Count, Rec/Repr. Count, or Pattern Address) only that parameter will be displayed and it will be calculated once per frame.

1.3 Binary Display

If the binary displays are to be used, they should be turned ON prior to the initiation of the process.

2. OPERATING INSTRUCTIONS

2.1 Data accumulation from the multiplex.

2.1.1 Switch Settings

2.1.1.1 Function - ACCUM

2.1.1.2 Input - VOC MUX

2.1.1.3 Mode (Optional - AUTO or MAN)

2.1.1.4 Pattern Counter Control - STOP (If the process is to stop after the detection of the 4096 spectrum pattern. If this switch is OFF, the process will continue until the detection of the 4096 occurrence of any particular spectrum pattern.)

2.1.1.5 Record (optional)

2.1.1.5.1 Select Record of PITCH and/or ADDRESS.

2.1.1.5.2 Select the Start and Stop Address as desired.

2.1.1.6 Deviation Threshold - 0-7 as desired

2.1.1.7 Aux Console Control Select Voicing Comparator - OFF if desired.

2.1.1.8 Aux Console Control Select Pattern Coding Level - 1 - 2 - 3 as desired.

2.1.2 Actuate

2.1.2.1 System - RESET

2.1.2.2 Pattern Counter Control - RESET (Refer to 2.3.2.2)

2.1.2.3 Record - START (if desired)

2.1.2.4 System - START

2.1.3 If the AUTO option was selected the operation will continue until either the 4096th spectrum pattern is detected or until the 4096th occurrence of any particular spectrum pattern has been detected depending upon previously stated option.

2.1.4 If the MAN option was selected, a single pattern will be processed each time the system - START is actuated.

2.2 Data accumulation from tape inputs

2.2.1 Switch setting

2.2.1.1 Function - ACCUM

2.2.1.2 Input - Tape

2.2.1.3 Mode (optional) - AUTO or MAN

2.2.1.4 Output - PRINT - PUNCH

2.2.1.5 Record Function (optional) refer to 2.1.1.5

2.2.1.6 Deviation Threshold - 0 - 7 as desired

2.2.1.7 Aux Console Control Select voicing comparator - OFF if desired.

2.2.1.8 Aux Console Control select Pattern Coding Level - 1 - 2 - 3 as desired.

2.2.1.9 Aux Control Panel select - SPEECH DATA

2.2.2 Peripheral Equipment Control

2.2.2.1 Reader - ON

2.2.2.2 Punch - ON

2.2.3 Load tape into reader and program for AUTO operation.

2.2.4 Actuate

2.2.4.1 Pattern Counter Control - RESET

2.2.4.2 System - RESET

2.2.4.3 Record - START (if selected)

2.2.4.4 Peripheral Equipment - Punch - RESET

2.2.4.5 System - START

2.2.5 Successive frames will be read into the system and subsequently processed until either the end of the tape is reached, the 4096 occurrence of any particular spectrum pattern is detected, or, if the record option has been selected, until the 4096 spectrum pattern has been detected. If the MAN. mode has been selected, the accumulation of each frame must be initiated by actuating the system START switch.

2.3 Data Accumulation from the Keyboard

2.3.1 Switch settings

2.3.1.1 Function - ACCUM

2.3.1.2 Input - KBD

2.3.1.3 Mode - MAN

2.3.1.4 Deviation Threshold - 0 - 7 as desired

2.3.1.5 Aux Console Control select voicing comparator - OFF if desired

2.3.1.6 Record Function (optional) Refer to 2.1.1.5

2.3.2 Actuate

2.3.2.1 System - RESET

2.3.2.2 Pattern Counter Control - RESET (The initial pattern count may be selected by selecting Keyboard Input - ADDRESS, entering 4 digit address from Keyboard, and actuating PATTERN COUNT INPUT. (Note: This procedure, (steps 2.3.1 and 2.3.2) may be used to preset the pattern counter prior to any mode of operation.)

2.3.3 Manually enter from keyboard complete speech data frome as follows: (The speech data may be entered in any sequence.)

2.3.3.1 Select Keyboard input SPECTRUM PATTERN

2.3.3.2 Press RESET on Keyboard

2.3.3.3 Select 18 characters between 0 and 7. Any sequence of characters may be entered.

2.3.3.4 Select Keyboard Input - VOICING

2.3.3.5 Press RESET on Keyboard

2.3.3.6 Enter single character, either 1 or 0

2.3.3.7 Select Keyboard Input - AM

2.3.3.8 Press RESET on Keyboard

2.3.3.9 Select single character between 1 and 7

2.3.4 Press System - START

2.3.5 Repeat 2.3.3 through 2.3.4 for successive frames to be entered.

2.4 Data reduction from the multiplex

2.4.1 Switch Settings

2.4.1.1 Function - RED

2.4.1.2 Input - VOC MUX

2.4.1.3 Output - COMM CHAN

2.4.1.4 Mode - AUTO

2.4.1.5 Deviation Threshold - 0 - 7 as desired

2.4.1.6 Record function (optional) Refer to 2.1.1.5

2.4.1.7 Address Selection - SILENCE OR PRECEDING depending upon which address is desired in case an input spectrum pattern does not match any recorded pattern.

2.4.2 Actuate

2.4.2.1 System - RESET

2.4.2.2 Record - START (if selected)

2.4.2.3 System - START

2.4.3 The process will continue until the System - STOP is actuated.

2.5 Data reduction from tape inputs

2.5.1 Switch settings

2.5.1.1 Function - RED

2.5.1.2 Input - TAPE

2.5.1.3 Mode - AUTO or MAN

2.5.1.4 Deviation Threshold - 0 - 7 as desired

2.5.1.5 Record function Start-Stop addresses as desired

2.5.1.6 Record function record PITCH and/or ADDRESS

2.5.1.7 Address selection - SILENCE or PRECEDING

2.5.2 Actuate

2.5.2.1 System - RESET

2.5.2.2 Aux. Control Panel - RESET

2.5.2.3 Record - START

2.5.3 Load the tape into the reader and program for AUTO operation.

2.5.4 Actuate System - START

The process will continue either to the end of the tape or until the STOP address is reached. If the MODE-MAN was selected, each successive input frame will be processed upon the actuation of the System START. The PRECEDING or SILENCE option determines the address to be entered in the record field if an input pattern finds no match on the drum.

2.6 Manual entry to the record field from the keyboard.

2.6.1 Switch settings

2.6.1.1 Function - RED

2.6.1.2 Input - KBD

2.6.1.3 Mode - MAN

2.6.1.4 Record - ADDRESS and/or PITCH

2.6.1.5 Record function Start - Stop address as desired

2.6.2 Actuate

2.6.2.1 System - RESET

2.6.2.2 Record - START

2.6.3 Keyboard input

2.6.3.1 Select Keyboard Input - ADDRESS

2.6.3.2 Actuate Keyboard - RESET

2.6.3.3 Enter 4 character address

2.6.3.4 Select Keyboard Input - PITCH

2.6.3.5 Actuate Keyboard - RESET

2.6.3.6 Enter 3 character pitch

2.6.4 Actuate System - START

2.6.5 Repeat 2.6.3 through 2.6.4 as desired

2.7 Data expansion from the record/reproduce field

2.7.1 Switch settings

2.7.1.1 Function - EXP

2.7.1.2 Input - REC/REPR FIELD

2.7.1.3 Output - VOC DEMUX

2.7.1.4 Mode - AUTO

2.7.1.5 Reproduce function START and STOP address as desired

2.7.1.6 Reproduce mode - AUTO, MAN, or EXTERNAL

2.7.1.7 Stretch Ratio - as desired

2.7.2 Actuate

2.7.2.1 System - RESET

2.7.2.2 Reproduce - START

2.7.2.3 System - START

2.7.3 If the AUTO reproduce mode has been chosen, when the STOP address is reached the process will be reinitiated, if MAN was chosen the process will be stopped when the STOP address if reached and, if EXTERNAL was chosen, the initiation of the process is controlled by an external pulse.

2.8 Reduction/Expansion

2.8.1 Switch Settings

2.8.1.1 Function - RED EXP

2.8.1.2 Input - VOC MUX

2.8.1.3 Output - VOC DEMUX

2.8.1.4 Mode - AUTO

2.8.1.5 Record (optional) Refer to 2.1.1.5

2.8.1.6 Deviation Threshold - 0 - 7 as desired

2.8.1.7 Address - SILENCE or PRECEDING

2.8.2 Actuate

2.8.2.1 System - RESET

2.8.2.2 Record - START (if selected)

2.8.2.3 System - START

2.8.3 The operation will continue until the system STOP is actuated. The address option selects the address that will be transmitted through the communication channel when an input pattern does not find a match on the drum.

2.9 Serial Ordered Print/Punch Out

2.9.1 Switch setting

2.9.1.1 Function - EXP

2.9.1.2 Input - REC/REPR FIELD

2.9.1.3 Output - PRINT PUNCH

2.9.1.4 Mode - AUTO

2.9.1.5 Stretch ratio as desired

2.9.2 Peripheral Equipment Control

2.9.2.1 Printer and/or Punch - ON

2.9.2.2 Select - SPECTRUM PATTERN ADDRESS or RECORD/REPRODUCE ADDRESS

2.9.3 Record/Reproduce

2.9.3.1 Start address as desired

2.9.3.2 Stop address as desired

2.9.4 Aux Control Panel

2.9.4.1 Select - SPEECH DATA

2.9.4.2 Actuate - RESET

2.9.4.3 Actuate - Punch RESET

2.9.4.4 Actuate - Reader - START

2.9.5 Actuate

2.9.5.1 System - RESET

2.9.5.2 Reproduce - START

2.9.5.3 System - START

2.9.6 A print and/or punch out of the contents of the record/reproduce field between the addresses selected will occur. The address which will be printed out will depend upon the option selected in 2.9.2.1

2.10 Rank Ordered Print/Punch Out

2.10.1 Switch Settings

2.10.1.1 Function - EXP

2.10.1.2 Input - OCCUR COUNT

2.10.1.3 Output - PRINT PUNCH

2.10.1.4 Mode - AUTO

2.10.2 Peripheral Equipment Control

2.10.2.1 Printer and/or Punch - ON

2.10.3 Aux. Control Panel

2.10.3.1 Select - SPEECH DATA

2.10.3.2 Actuate - RESET

2.10.3.3 Actuate - PUNCH - RESET

2.10.3.4 Actuate - Reader - START

2.10.4 Actuate

Aux. Console Control Panel

Select Rank Ordered Output - VOICE, UNVOICED, or VOICED and UNVOICED.

2.10.4.1 System - RESET

2.10.4.2 System - START

2.10.5 Print and/or punch out of speech data in the descending order of number of occurrences which will occur.

2.11 Print/Punch Out in Order of Increasing Spectrum Pattern Address

2.11.1 Switch Setting

2.11.1.1 Function - EXP

2.11.1.2 Input - PATTERN ADDRESS

2.11.1.3 Output - PRINT-PUNCH

2.11.1.4 Mode - AUTO

2.11.1.5 Stretch ratio as desired

2.11.2 Peripheral Equipment Control

Select Printer and/or Punch - ON

2.11.3 Record/Reproduce

2.11.3.1 Select Start address

2.11.3.2 Select Stop Address

2.11.4 Aux. Control Panel

2.11.4.1 Select - SPEECH DATA

2.11.4.2 Actuate - RESET

2.11.4.3 Actuate - Punch - RESET

2.11.4.4 Actuate - Reader - START

2.11.5 Actuate

2.11.5.1 System - RESET

2.11.5.2 Record/Reproduce - START

2.11.5.3 System - START

2.11.6 Print and/or punch out of spectrum pattern data will occur in order of increasing pattern address as selected by step 2.11.3. The data will be in the Rank Ordered Format.

2.12 Interrogation by address

2.12.1 Switch setting

2.12.1.1 Function - EXP

2.12.1.2 Input - KBD

2.12.1.3 Mode - INTERROG

2.12.1.4 Keyboard - ADDRESS

2.12.1.5 Decimal Display - STBY

2.12.2 Actuate

2.12.2.1 System - RESET

2.12.2.2 Keyboard - RESET

2.12.3 Enter address of memory location to be interrogated.

2.12.4 Actuate System - START

2.12.5 Either binary or decimal display may be used to monitor the contents of the memory location.

2.13 Interrogation by spectrum pattern

2.13.1 Switch setting

2.13.1.1 Function - ACCUM

2.13.1.2 Input - KBD

2.13.1.3 Mode - INTERROG

2.13.1.4 Deviation Threshold - 0 - 7 as desired

2.13.1.5 Keyboard input - SPECTRUM PATTERN

2.13.1.6 Decimal Display - STBY

2.13.2 Actuate

2.13.2.1 System - RESET

2.13.2.2 Keyboard - RESET

2.13.3 Enter the 18 digit spectrum pattern against which the memory is to be interrogated.

2.13.4 Select Keyboard Input - VOICING

2.13.5 Actuate Keyboard - RESET

2.13.6 Enter desired voicing bit

2.13.7 Actuate System - START

2.14 Spectrum pattern field change

2.14.1 Switch setting

2.14.1.1 Function - ACCUM

2.14.1.2 Input - KBD

2.14.1.3 Mode - SPEECH DATA CHG

2.14.1.4 Keyboard Input - SPECTRUM PATTERN

2.14.2 Actuate

2.14.2.1 System - RESET

2.14.2.2 Keyboard - RESET

2.14.3 Select 18 bit spectrum pattern

2.14.4 Select Keyboard Input - VOICING

2.14.5 Actuate Keyboard - RESET

2.14.6 Enter voicing bit

2.14.7 Select Keyboard Input - ADDRESS

2.14.8 Select 4 digit address at which spectrum pattern is to be changed.

2.14.9 Actuate system - START

2.14.10 The selected spectrum pattern will be entered at the selected address.

2.14.11 To alter voicing only

2.14.11.1 Select Aux. Console Control Record - VOICING

2.14.11.2 Repeat 2.13.1 through 2.13.10 excluding 2.13.1.4, 2.13.2.1 through 2.13.2.2 and 2.13.3.

2.15 Direct data transfer

2.15.1 Switch setting

2.15.1.1 Function - DIR DATA TRANS

2.15.2 Actuate

2.15.2.1 System - RESET

2.15.2.2 System - START

2.15.3 The input data frames from the multiplex will be transferred directly to the demultiplex.

2.16 Drum erase

2.16.1 Switch setting

2.16.1.1 Function - DRUM ERASE

2.16.1.2 Erase Selector - REC/REPR, SPECTRUM PATT, or AM & NO OCCUR as desired

2.16.2 Actuate

2.16.2.1 System - RESET

2.16.2.2 Both ERASE switches

2.16.3 Zero will be recorded in all bit positions of each address of the particular field chosen to be erased.

2.17 Reader to printer

2.17.1 Aux Control Panel switch settings

2.17.1.1 Reader - ON

2.17.1.2 Printer - ON

2.17.1.3 Select - SPEECH DATA or GENERAL DATA as desired

2.17.1.4 Select - Digit On or Off if printing general data format

2.17.2 Load tape into reader and program for automatic operation either high or low speed

2.17.3 Actuate Aux Control Panel

2.17.3.1 RESET

2.17.3.2 Reader - START

2.17.4 The data will be printed in the format selected

2.18 Perforated tape duplication

2.18.1 Aux. Control Panel switch settings

2.18.1.1 Punch - ON

2.18.1.2 Reader - ON

2.18.1.3 Parity - ON or OFF as desired

2.18.2 Load tape into reader and program for AUTO operation low speed

2.18.3 Actuate Aux. Control Panel

2.18.3.1 RESET

2.18.3.2 Punch - RESET

2.18.3.3 Reader - START

2.18.4 The input tape will be duplicated either with or without a parity check

2.19 Tape search

2.19.1 Switch settings

2.19.1.1 Function - TAPE-SRCH

2.19.1.2 Input - TAPE

2.19.2 Peripheral Equipment Control

2.19.2.1 Reader - ON

2.19.2.2 Select - GENERAL DATA

2.19.3 Set the address to be searched for into the Record/ Reproduce STOP Digit switch

2.19.4 Load tape into reader and program for AUTO operation either high or low speed

2.19.5 Actuate

2.19.5.1 Aux. Control Panel RESET

2.19.5.2 System - RESET

2.19.5.3 System - START

2.19.6 Reader will stop on the selected address

APPENDIX C

Evaluation of Reliability With Respect to Thermal Environment for the Voice Data Processing System

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FOREWORD

The purpose of this analysis was to evaluate the effect upon the reliability of the system when the temperature of the input cooling air to the racks is varied. Since this is a relative effect, the accuracy of the reliability estimate is not critical.

Mean-Time-Between-Failures (MTBF) is used as a reliability measure, but the values expressed in the analysis are not to be considered an expected value for the system in use. They are accurate only for the conditions and limitations used in the analysis, and for this reason the result is expressed as a relative value.

ABSTRACT

The results of the analysis are summarized in figure 1. An increase of 40°F in input air temperature to the cabinets results in a decrease of 10% in the reliability of the system. The decrease is linear in figure 1. While this may not appear consistent with the exponential character of other temperature effects, the temperature variation is relatively small in absolute temperature. The variation from linearity might be shown by a more refined analysis, but it would be very negligible over the short temperature range of this analysis and would not justify the increased analytical complexity required.

METHOD OF ANALYSIS

The method of analysis is based upon evaluating the MTBF of the system for five different input air temperatures ranging from 70°F to 110°F. Reliability evaluation is based upon the methods and failure rates of the "Reliability Analysis Guide" (Dec. 1961), Martin/Marietta Corporation, Electronics Systems and Products Division.

The analysis was made using the component count, operating characteristics, and other conditions furnished by the design group. (See table 1.)

To simplify the analysis the following conditions were assumed:

1. All components were required for system success. Failure of any component was a failure of the system.

2. The occurrence of failures is statistically independent and they are distributed exponentially.

3. Component density is lower below the average point, (2/3 of cabinet height), then it is above, but it is constant in both areas.

4. The temperature rise across the rack is linear from the bottom to the top of the cabinet.

5. The variation of component failure rates is linear over the 8°F spread of the cooling air temperature.

On the basis of the above assumptions, an average temperature for the entire system can be assumed for any particular input air temperature.

The following formulas then apply to the system.

$$R_s = \prod^{N} R_i \qquad (1)$$

where R_s = system reliability

R_i = the reliability of the i^{th} component.

N = number of components

TABLE 1

Component Complement

Transistors	Type	No. Used	Average Power Dissipation MW	Rated Average Power MW
2N501	Germanium	3035	2.0	25 @ 45°C
GT1449	Germanium	3597	2.3	120 @ 25°C
JX1C802 (2N1310)	Germanium	159	0.6	125 @ 25°C
GT1450	Germanium	192	0.8	120 @ 25°C
2N697	Silicon	200	24	600 @ 25°C
2N527	Germanium	104	1.4	225 @ 25°C
Diodes				
1N192	Germanium	20,437	1.0	120 @ 25°C
1N660	Silicon	54	1 ma avg	100 ma avg
PS6766	Silicon, 7V Zener	327	220	250
PS6805	Silicon, 2V Zener	4	2	250
Capacitors				
CM15	Mica, Silver	3,661	8 volts	200 volts
R332453P	Tantalum	409	8 volts	35 volts
R332454P	Paper tubular	303	8 volts	100 volts
Resistors				
RN60	Deposited Carbon	19,077	15 MW	1/8 W
RN70	Deposited Carbon	4,762	100 MW	1/4 W
MS35043	Deposited Carbon	419	200 MW	1/2 W
MS 35044	Deposited Carbon	206	560 MW	1 W

Other Conditions:

Average concentration of printed circuit cards - 2/3 of the distance from the bottom of the cabinet.

Exhaust Air Temperature equals Input temperature plus 8°F.

Input air temperature - Assume 70°, 80°, 90°, 100°, and 110°F.

$$R_i = \exp\left[-\lambda_i t \right] \qquad (2)$$

$$= \exp\left[- t/m_i \right]$$

where $_i$ = the failure rate of the i^{th} component

t = operating time

m_i = MTBF of the component

$$R_s = \prod^{N} \exp\left[- \;_i t \right] \qquad (3)$$

$$R_s = \exp\left[\sum^{N} - \lambda_i t \right] \qquad (4)$$

and if λ_i is small as it is in the present case, this can be approximated by the expression

$$R_s = 1 - \sum^{N} (-\lambda_i t) \qquad (5)$$

or for a particular period of time

$$R_s = 1 - t \left[\sum^{N} (-\lambda_i) \right] \qquad (6)$$

$$M = 1/\sum^{N} \lambda_i \qquad (7)$$

To evaluate the last term in the above expression the "Reliability Analysis Guide" provides a failure rate and three multiplying factors.

GF_R = a generic failure rate for the component based upon its use in a laboratory computer.

K_A = a multiplying factor based upon the electrical stresses of the application.

K_{op} = a multiplying factor based upon the environmental conditions under which the system is operating.

K_r = a redundancy multiplying factor.

For this analysis K_{op} and K_r were assumed to be unity.

Then $\lambda_i = (GF_R)_i (KA)_i$ (8)

$$\sum^{N} \lambda_i = \sum^{N} (GF_R)_i (KA)_i \quad (9)$$

The calculations are shown in table 2.

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TABLE 2

RELIABILITY WORK SHEET FOR DAT.

Component (Parts)	TYPE	Average Power Dissipation MW	Rated Avg. Power Dissipation MW	Power or Volt. Ratio	Duty Cycle in 100%	n (Factor)	K_{op}	GF_R $FR/10^6M$	KA 70° 21.11	KA 80° 26.67	KA 90° 32.22	(mi 10 37.
TRANSISTORS												
2N501	Germanium	2.0	25 @ 45°C	.080	1	3035	1	0.9	.030	.031	.032	.03
GT1449	Germanium	2.3	120@ 25°C	.0192	1	3597	1	0.9	.020	.021	.021	.02
(JX1C802) 2N1310	Germanium	0.6	125@ 25°C	.0048	1	159	1	0.414	.019	.019	.019	.01
GT1450	Germanium	0.8	120@25°C	.0067	1	192	1	0.9	.019	.019	.019	.01
2N697	Silicon	24	600@ 25°C	.040	1	200	1	0.7	.045	.045	.045	.04
2N527	Germanium	1.4	225@ 25°C	.0062	1	104	1	0.9	.019	.019	.019	.01
DIODES												
1N192	Germanium	1.0	120@ 25°C	.0083	1	20,437	1	0.30	.041	.041	.041	.04
1N660	Silicon	1 MA Avg.	100MA Avg.	.010	1	54	1	0.20	.057	.058	.058	.05
PS6766	Silicon-7V-Zen	220	250	.880	1	327	1	0.15	.320	.320	.330	.35
PS6805	Silicon-2V-Zen	2	250	.008	1	4	1	0.15	.056	.057	.057	.05
CAPACITORS												
CM15	Mica-Silver	8 Volts	200 Volts	.040	1	3661	1	0.083	.005	.005	.005	.00
R332453P	Tantalum	8 Volts	35 Volts	.229	1	409	1	0.60	.070	.138	.141	.16
R322454P	Paper-Tub.	8 Volts	100 Volts	.080	1	303	1	0.025	.005	.005	.005	.00
RESISTORS												
RN60	Carbon-Dep.	15 MW	125 MW	.120	1	19077	1	0.25	.180	.183	.187	.18
RN70	Carbon-Dep.	100 MW	250 MW	.400	1	4762	1	0.25	.220	.241	.247	.25
MS35043	Carbon-Dep.	200 MW	500 MW	.400	1	419	1	0.25	.220	.241	.247	.25
MS35044	Carbon-Dep.	560 MW	1000 MW	.560	1	206	1	0.25	.230	.251	.257	.26

E 2

R DATA PROCESSING SYSTEM

A (min.)			KA (2/3 level)					KA (max)						(Input Air) $\eta\ K_{\phi p} GF_R K_A$					(Average $\eta\ K_{Op}$	
°	100°	110°	75.33°	85.33°	95.33°	105.33°	115.33°	78°	88°	98°	108°	118°	←°F→	70°	80°	90°	100°	110°	75.33°	85.33°
22	37.78	43.33	24.07	29.63	35.18	40.74	46.30	25.56	31.11	36.67	42.22	47.78	CENTIGRADE°	21.11	26.67	32.22	37.78	43.33	24.07	29.63
2	.033	.034	.030	.031	.032	.033	.034	.030	.031	.032	.033	.034		81.95	84.68	87.41	90.14	92.87	81.95	84.68
1	.021	.021	.021	.021	.021	.021	.022	.021	.021	.021	.021	.022		64.75	67.98	67.98	67.98	67.98	67.98	67.98
.9	.019	.020	.019	.019	.019	.019	.020	.019	.019	.019	.020	.021		1.25	1.25	1.25	1.25	1.32	1.25	1.25
.9	.019	.020	.019	.019	.019	.020	.021	.019	.019	.019	.020	.021		3.28	3.28	3.28	3.28	3.46	3.28	3.28
5	.045	.045	.045	.045	.045	.045	.045	.045	.045	.045	.045	.045		6.30	6.30	6.30	6.30	6.30	6.30	6.30
.9	.019	.020	.019	.019	.019	.020	.021	.019	.019	.019	.020	.021		1.78	1.78	1.78	1.78	1.87	1.78	1.78
1	.041	.042	.041	.041	.041	.041	.042	.041	.041	.041	.042	.042		251.38	251.38	251.38	251.38	257.51	251.38	251.38
8	.058	.058	.057	.058	.058	.058	.058	.057	.058	.058	.058	.058		0.62	0.63	0.63	0.63	0.63	0.62	0.63
0	.350	.390	.320	.320	.350	.360	.400	.320	.330	.350	.380	.410		15.70	15.70	16.19	17.17	19.13	15.70	15.70
7	.057	.057	.056	.057	.057	.057	.057	.056	.057	.057	.057	.057		.034	.034	.034	.034	.034	.034	.034
5	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005		1.52	1.52	1.52	1.52	1.52	1.52	1.52
1	.160	.190	.130	.140	.142	.170	.220	.135	.140	.143	.180	.260		17.18	33.87	34.60	39.26	46.63	31.90	34.36
5	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005		.038	.038	.038	.038	.038	.038	.038
7	.189	.192	.180	.185	.188	.190	.193	.182	.186	.189	.191	.194		858.47	872.77	891.85	901.39	915.70	858.47	882.31
7	.250	.260	.230	.243	.249	.250	.265	.240	.245	.249	.252	.275		261.71	286.91	294.05	297.63	309.53	273.82	289.29
7	.250	.260	.230	.243	.249	.250	.265	.240	.245	.249	.252	.275		23.05	25.24	25.87	26.19	27.24	24.09	25.45
7	.260	.270	.240	.253	.259	.260	.275	.250	.255	.259	.262	.285		11.85	12.93	13.24	13.39	13.91	12.36	13.03
														1601.06	1666.29	1697.4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1601.06
1666.29
1697.40
1719.36
1765.67
1632.47
1679

2

		(Average Density Air)				(Exhaust Air)				
		$\eta K_{op} GF_R K_A$				$\eta K_{op} GF_R K_A$				
110°	75.33°	85.33°	95.33°	105.33°	115.33°	78°	88°	98°	108°	118°
43.33	24.07	29.63	35.18	40.74	46.30	25.56	31.11	36.67	42.22	47.78
92.87	81.95	84.68	87.41	90.14	92.87	81.95	84.68	87.41	90.14	92.87
67.98	67.98	67.98	67.98	67.98	71.22	67.98	67.98	67.98	67.98	71.22
1.32	1.25	1.25	1.25	1.32	1.38	1.25	1.25	1.25	1.32	1.38
3.46	3.28	3.28	3.28	3.46	3.63	3.28	3.28	3.28	3.46	3.63
6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30
1.87	1.78	1.78	1.78	1.87	1.97	1.78	1.78	1.78	1.87	1.97
257.51	251.38	251.38	251.38	251.38	257.51	251.38	251.38	251.38	257.51	257.51
0.63	0.62	0.63	0.63	0.63	0.63	0.62	0.63	0.63	0.63	0.63
19.13	15.70	15.70	17.17	17.66	19.62	15.70	16.19	17.17	18.64	20.11
.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034
1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52
46.63	31.90	34.36	34.85	41.72	53.99	33.13	34.36	35.[illegible]	44.17	63.80
.038	.038	.038	.038	.038	.038	.038	.038	.038	.038	.038
915.70	858.47	882.31	896.62	906.16	920.47	868.00	887.08	901.39	910.93	925.23
309.53	273.82	269.29	296.43	297.63	315.48	285.72	291.67	296.43	300.01	327.39
27.24	24.09	25.45	26.08	26.19	27.76	25.14	25.66	26.08	25.40	28.81
13.91	12.36	13.03	13.34	13.39	14.16	12.88	13.13	13.34	13.49	14.68
1765.67	1632.47	1679.01	1706.09	1727.42	1788.58	1656.70	1686.96	1711.10	1744.44	1817.12

.36
1765.67
1632.47
1679.01
1706.09
1727.42
1788.58
1656.70
1686.96
1711.10
1744.44
1817.12

INPUT AIR Temperature °F	λ_T Failure Rate	MTBF (Hours)	RELATIVE MTBF
70	1632.47	612.57	1.00
80	1679.01	595.59	.97
90	1706.09	586.14	.95
100	1727.42	578.90	.94
110	1788.58	559.10	.91

3

haust Air)

	$K_p GF_R K_A$		
	98°	108°	118°
1	36.67	42.22	47.78
8	87.41	90.14	92.87
3	67.98	67.98	71.22
5	1.25	1.32	1.38
3	3.28	3.46	3.63
0	6.30	6.30	6.30
8	1.78	1.87	1.97
8	251.38	257.51	257.51
3	0.63	0.63	0.63
9	17.17	18.64	20.11
4	.034	.034	.034
2	1.52	1.52	1.52
5	35.09	44.17	63.80
8	.038	.038	.038
8	901.39	910.93	925.23
7	296.43	300.01	327.39
5	26.08	26.40	28.81
3	13.34	13.49	14.68
	1711.10	1744.44	1817.12

INPUT AIR Temperature °F	λ_T Failure Rate	MTBF (Hours)	RELATIVE MTBF
70	1632.47	612.57	1.00
80	1679.01	595.59	.97
90	1706.09	586.14	.95
100	1727.42	578.90	.94
110	1788.58	559.10	.91

5.96
1711.10
1744.44
1817.12

RESULTS

The results of the calculations are shown in the graph of figure 1. The graph is a plot of relative reliability versus input air temperature, where relative reliability is defined as

$$\text{MTBF (relative)} = \frac{\text{MTBF at temperature } T^{o}}{\text{MTBF at } 70^{o}\text{F}} \qquad (10)$$

This procedure has been followed to give a clearer indication of the effect of temperature upon the expected reliability of the equipment without presenting a misleading picture of what the expected value will be.

R4609

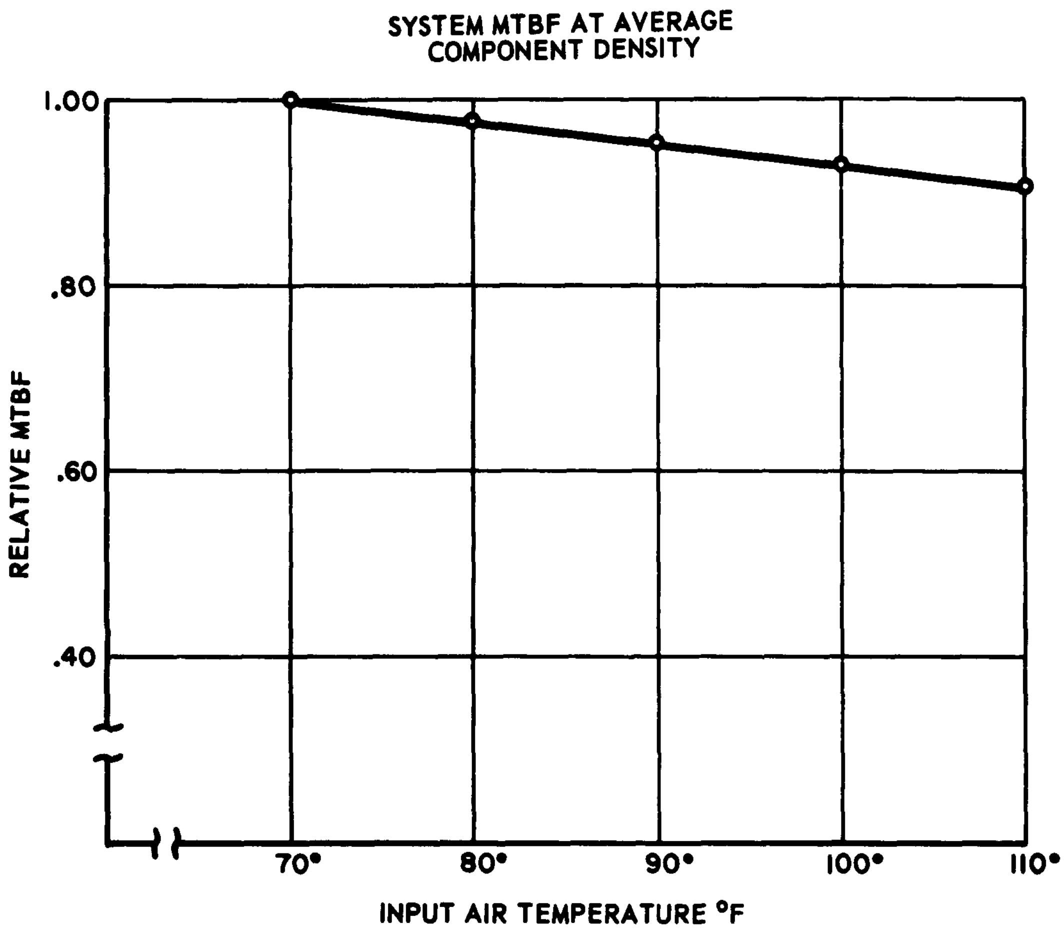

Figure C-1. Relative Reliability vs. Temperature

CONCLUSIONS AND RECOMMENDATIONS

It is obvious from figure 1 that temperature has a degenerating effect upon the reliability of the system. Every attempt should be made to keep the input air temperature as low as possible. Failure to do so will result in loss of equipment availability and an increased maintenance cost.

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