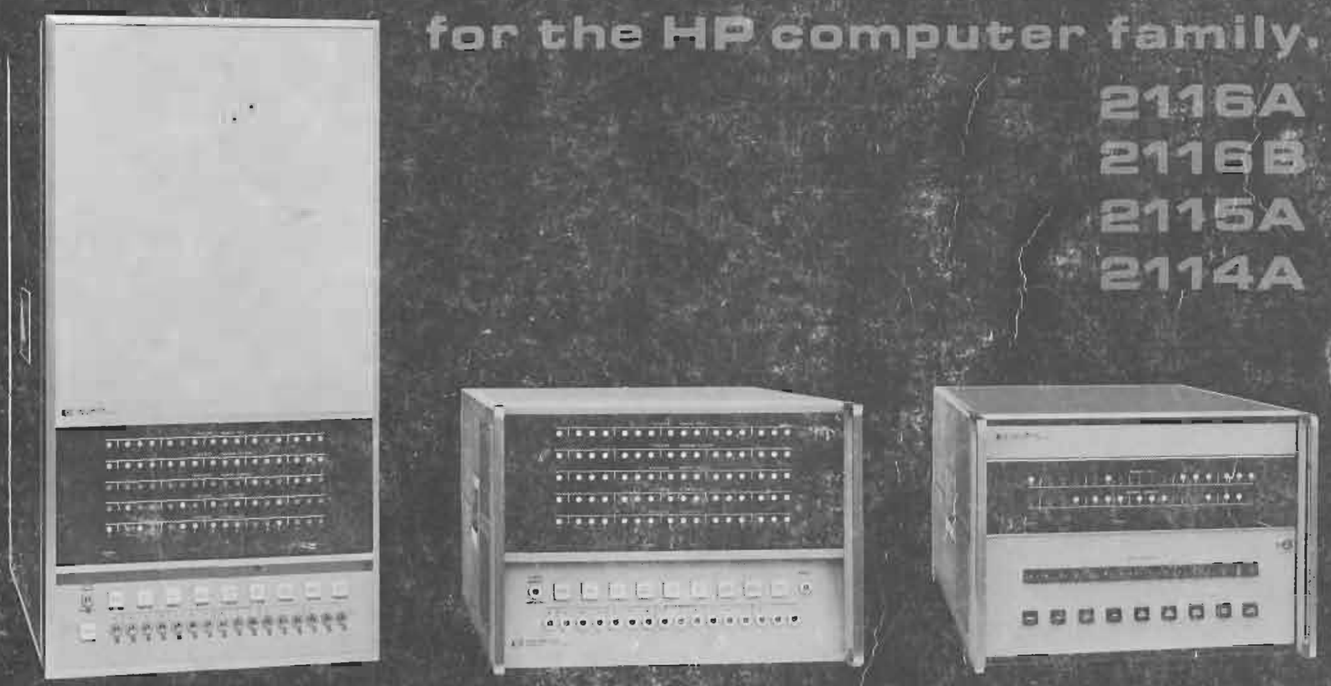
I. Johnston

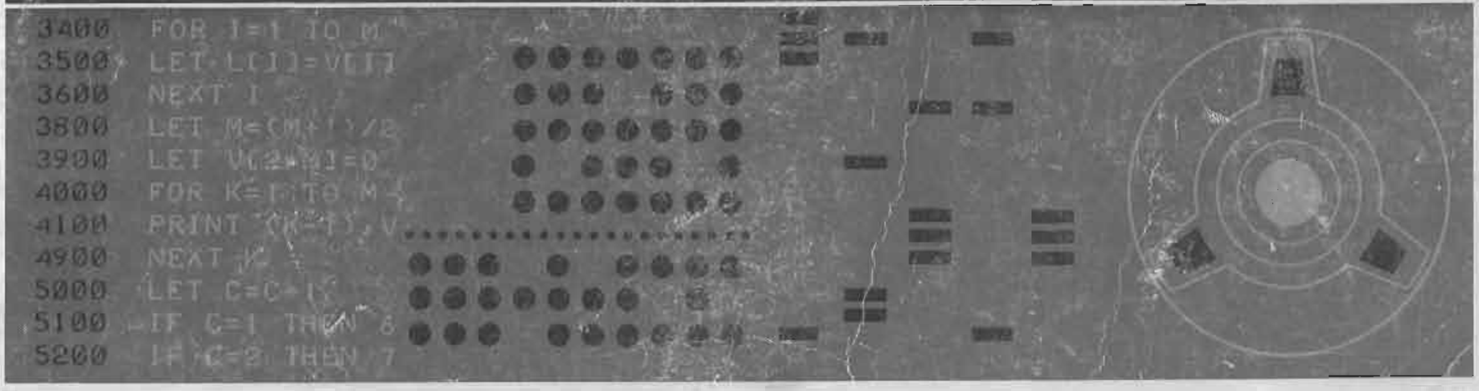
HEWLETT hp PACKARD

PROGRAMMING COURSE

for the HP computer family.

2116A
2116B
2115A
2114A





```
3400  FOR I=1 TO M
3500  LET L[I]=V[I]
3600  NEXT I
3800  LET M=(M+1)/2
3900  LET V[2*M]=0
4000  FOR K=1 TO M
4100  PRINT (K-1),V
4900  NEXT K
5000  LET C=C+1
5100  IF C=1 THEN 8
5200  IF C=2 THEN 7
```

HEWLETT-PACKARD

COMPUTER PROGRAMMING COURSE

STUDENTS MANUAL

(HP STOCK NO. 05950-8312)

- NOTICE -

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395 Page Mill Road, Palo Alto, California 94306 Area Code 415 326-1755 TWX 910-373-1296

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FOREWORD

Welcome to the Hewlett-Packard Computer Programming Course. We are very pleased to have you attend this training program and we will do our best to make your stay with us interesting and profitable.

About Hewlett-Packard

The Hewlett-Packard Company specializes in the manufacture of instruments and systems to satisfy many of the measurement and computation needs for science and industry. Today, Hewlett-Packard provides over 1500 different products for electronic, chemical and medical instrumentation applications.

Since its founding in Palo Alto almost thirty years ago, Hewlett-Packard has grown from a two-man operation into a world-wide organization of more than 12,000 people, with an annual sales volume exceeding $225 million. The company and its affiliates now have more than a dozen manufacturing plants including facilities in the United States, Western Europe and Japan. Sales and service offices are located in nearly every major city in the free world.

About the Computer Programming Course

The HP Computer Programming Course has been developed to train personnel in the use and operation of the HP computer systems. The course curriculum has evolved to its present level primarily as a result of suggestions by the many thoughtful and interested students who have preceded you. In line with Hewlett-Packard's corporate-wide policy regarding the quality of its training support, much time and effort has been expended to provide you with this planned program for learning about computers and computer programming in general, and specifically about the Hewlett-Packard equipment which you already have or are planning to purchase.

Our experience, after training in excess of 300 students, has shown that our student experience profile breaks down as follows:

1. 60% having no previous experience in computers.
2. 23% having less than one year experience.
3. 17% having more than one year experience.

Based on these figures we have attempted to orient the level of training to the 60% group while still including some degree of challenge to the students with some previous computer programming experience.

Our overall objective is to prepare each of you for the task you face in utilizing the computer system to solve your individual application problems. In order to achieve this objective the combined efforts of both student and instructor will be required.

For those of you with no previous experience the road will not be easy; however, the objective can be reached provided you make every effort possible to communicate with your instructors by your questions during and after class sessions. We believe you will find your individual instructors to be capable and interested in your desire to learn.

For those of you who have had some previous experience in programming a computer, the training program will provide answers to questions you may have and provide the "hands on" experience with the Hewlett-Packard software systems. Since your training program will be an easier one to adjust to we would like to ask your help in training those classmates of yours who may be having difficulty. By your willingness to contribute your ideas and efforts, the attainment of our objective goals to successfully prepare all of you for the tasks you face, upon leaving us, will be assured.

Training Staff
Data Products Group
Palo Alto Division
September 1968

HEWLETT-PACKARD

COMPUTER PROGRAMMING COURSE

OBJECTIVES:

1. TEACH THE STUDENT HOW TO CREATE SIMPLE FORTRAN AND ASSEMBLY LANGUAGE COMPUTER PROGRAMS.

2. PROVIDE EACH STUDENT WITH "HANDS ON" COMPUTER EXPERIENCE.

3. TEACH THE STUDENT HOW TO USE STANDARD HEWLETT-PACKARD SOFTWARE.

HEWLETT-PACKARD
COMPUTER PROGRAMMING COURSE

LESSON PLAN

LESSON I - Introduction to computers

LESSON II - Introduction to HP FORTRAN

LESSON III - The HP symbolic editor program

LESSON IV - FORTRAN control statements

LESSON V - FORTRAN programming techniques

LESSON VI - Introduction to HP computer hardware

LESSON VII - Introduction to the HP Assembler program

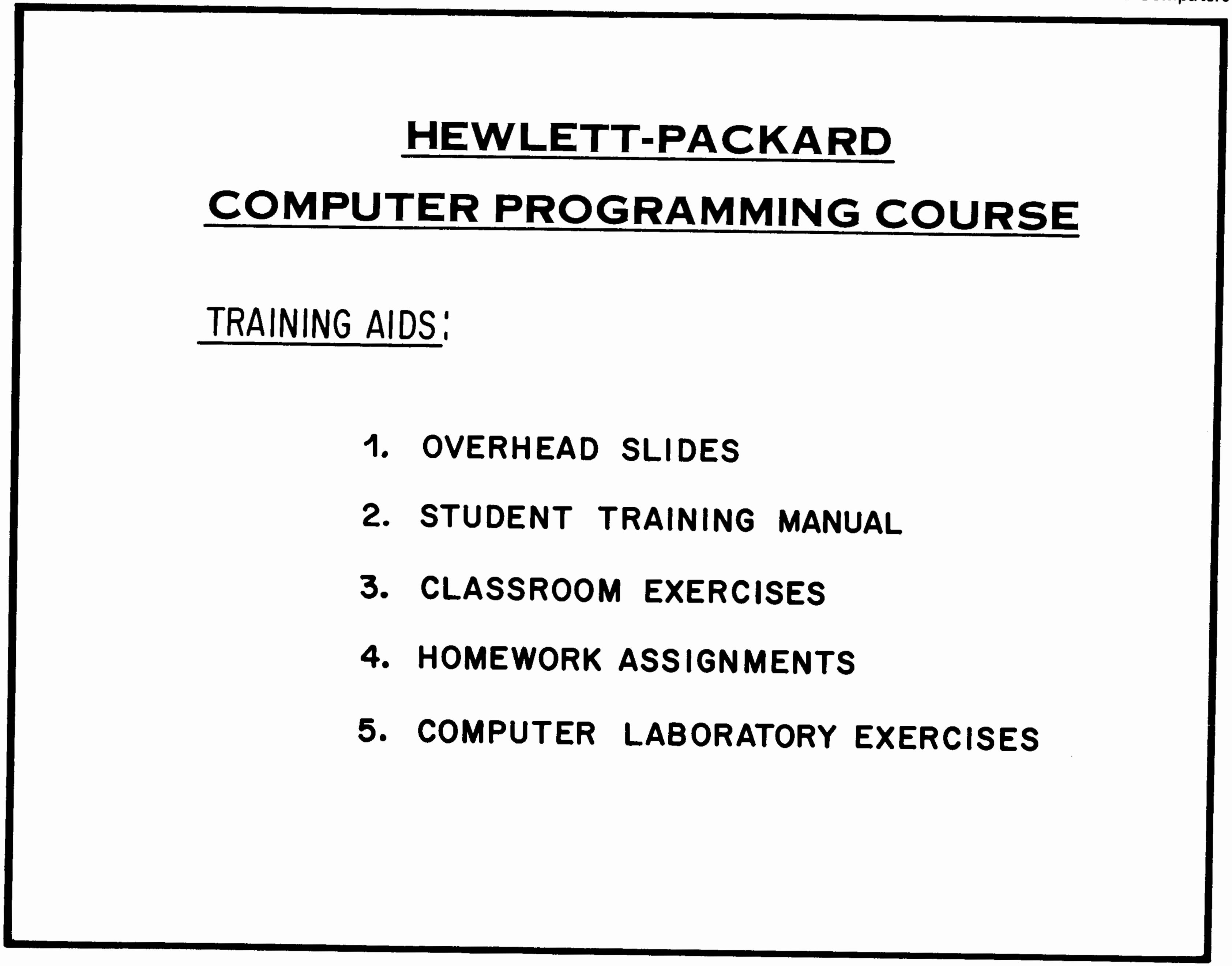
LESSON VIII - Assembler pseudo instructions

LESSON IX - Assembler programming techniques

LESSON X - HP Basic Control System, I.O.C. section

LESSON XI - HP relocating loader, configuration routines

LESSON XII - Introduction to HP BASIC



HEWLETT-PACKARD

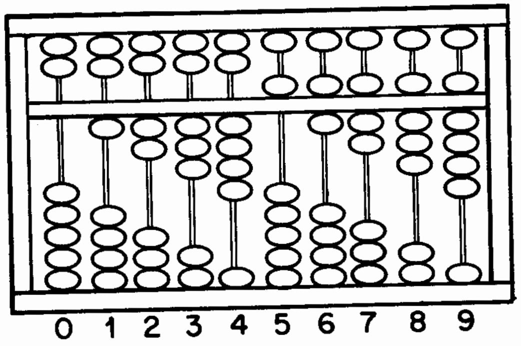
COMPUTER PROGRAMMING COURSE

TRAINING AIDS:

1. OVERHEAD SLIDES
2. STUDENT TRAINING MANUAL
3. CLASSROOM EXERCISES
4. HOMEWORK ASSIGNMENTS
5. COMPUTER LABORATORY EXERCISES

THE ABACUS

THE HISTORY OF COMPUTER DEVELOPMENT PROBABLY STARTED WITH THE INVENTION OF THE ABACUS. THIS DEVICE WAS CREATED IN CHINA APPROXIMATELY 600 BC.

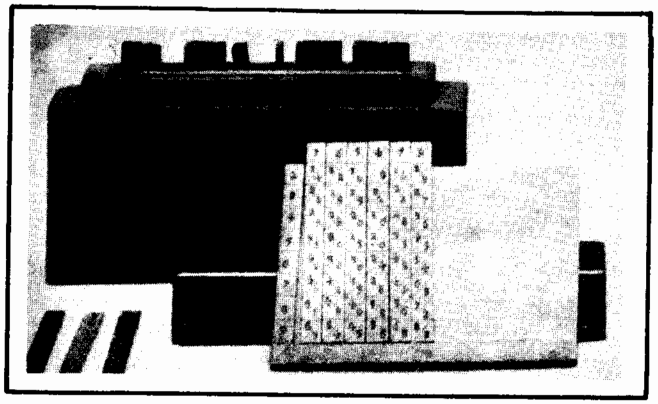


THE ABACUS

IT SHOULD BE NOTED THAT THE ABACUS IS STILL USED EXTENSIVELY IN THE ORIENT.

LOGARITHMS

IN THE EARLY 17th CENTURY JOHN NAPIER INVENTED LOGARITHMS AND ALSO A MULTIPLICATION TABLE THAT WAS REPRODUCED ON PIECES OF BONE AND SUBSEQUENTLY REFERRED TO AS "NAPIERS BONES".

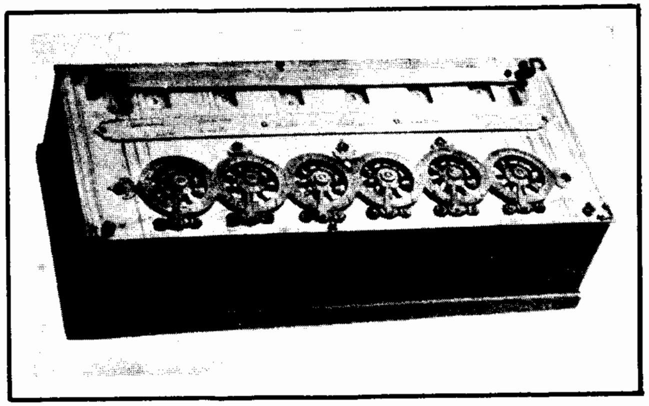


"NAPIERS BONES"

SHORTLY AFTER THE INVENTION OF LOGARITHMS WILLIAM OUGHTRED INSCRIBED LOGARITHMS ON SLIDING PIECES OF WOOD AND THE SLIDE RULE CAME INTO EXISTENCE.

PASCAL'S ADDING MACHINE

IN 1642 BLAISE PASCAL, A FRENCH MATHEMATICIAN BUILT WHAT WAS PROBABLY THE WORLDS FIRST DESK CALCULATOR.

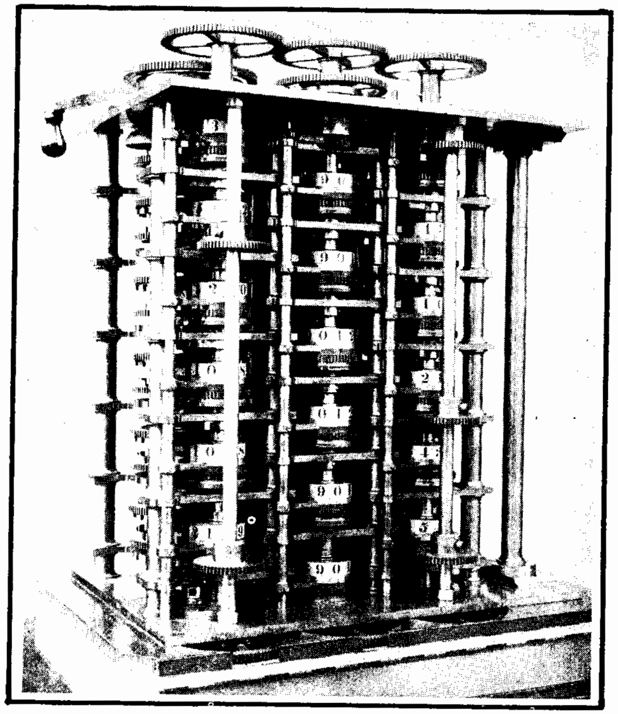


PASCAL'S ADDING MACHINE (1642)

THIS MACHINE WAS DESIGNED TO HELP PASCAL'S FATHER IN KEEPING THE BOOKS OF THE FAMILY STORE.

BABBAGE'S CONTRIBUTION

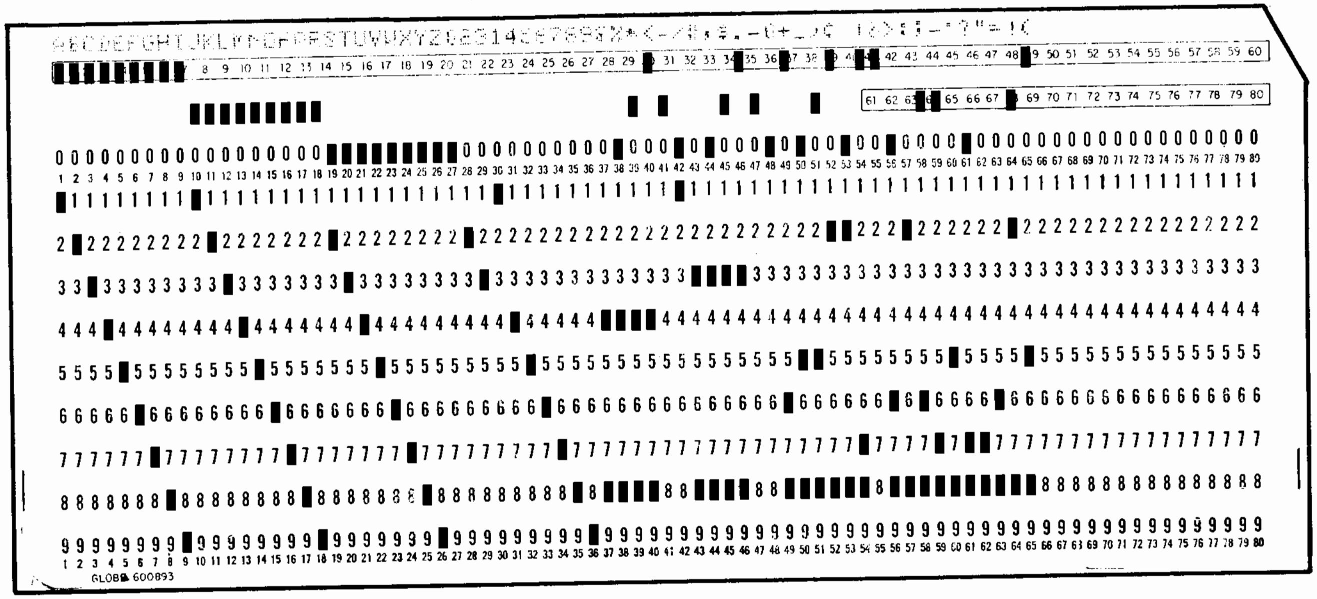
THE NEXT MAJOR MILESTONE WAS CONTRIBUTED BY CHARLES BABBAGE. IN 1822 BABBAGE DEMONSTRATED HIS "DIFFERENCE ENGINE", A MACHINE DESIGNED TO PREPARE TABLES SUCH AS COMPOUND INTEREST, LOGARITHMS AND TRIGONOMETRIC FUNCTIONS, WITHOUT THE HELP OF A HUMAN OPERATOR.



BABBAGE'S DIFFERENCE ENGINE (1822)

THE PUNCHED CARD

In 1890 Herman Hollerith invented the punched card. The original motivation for this invention was a desire to speed up the job of taking the census of the United States.



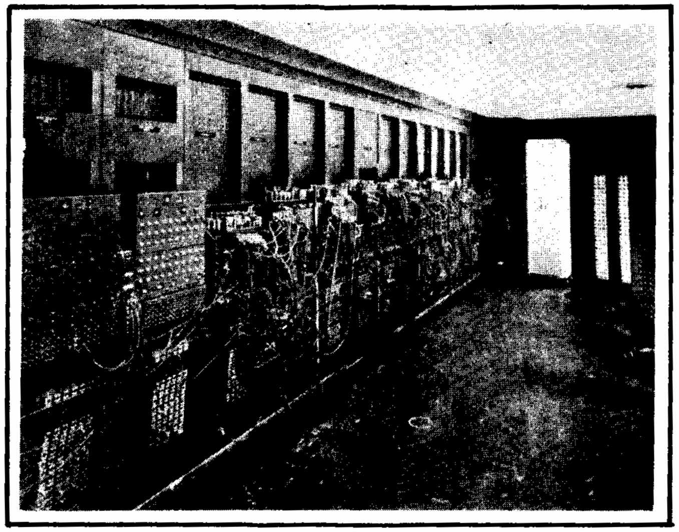
The format used to describe alphanumeric data in modern computers is called "H" or "HOLLERITH" format.

STEPS TO THE MODERN COMPUTER

IN 1939 SAMUEL WILLIAMS OF BELL LABS BUILT THE RELAY COMPUTER. THIS WAS THE FIRST ELECTRICAL DIGITAL COMPUTER AND THE FIRST BINARY MACHINE.

IN 1944 PROFESSOR HOWARD AIKEN DESIGNED THE HARVARD MARK I. THIS WAS THE FIRST OF THE LARGE SCALE GENERAL PURPOSE RELAY COMPUTERS BUILT DURING THIS PERIOD.

IN 1946 J.P. ECKERT AND DR. J.W. MAUCHLY OF THE MOORE SCHOOL OF ENGINEERING DEVELOPED THE ENIAC. THIS WAS THE FIRST ELECTRONIC DIGITAL COMPUTER AND IT CONTAINED 18,000 VACUUM TUBES.

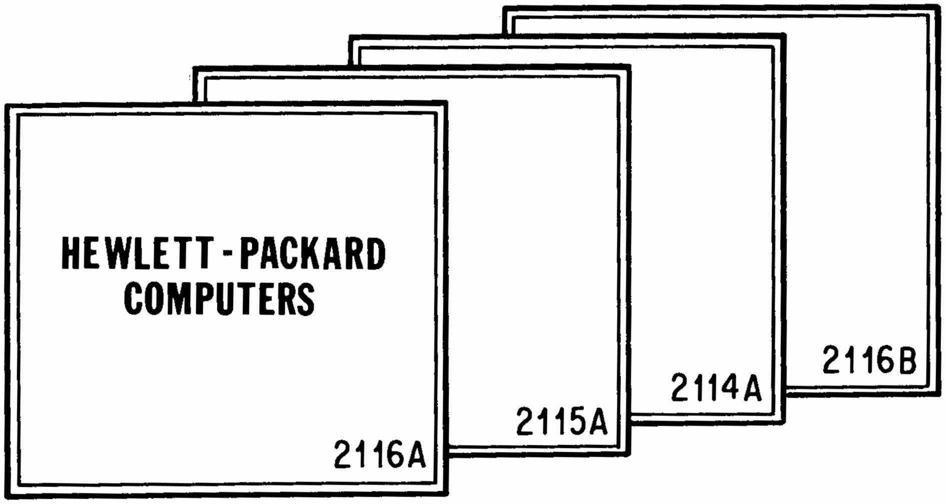


THE ENIAC

THE MODERN COMPUTER

By the 1950's IBM and others were marketing vacuum tube computers that would perform 60 operations per second.

In the late 1950's and early 1960's vacuum tubes gave way to transistors and faster memories were built.



In 1966 HEWLETT-PACKARD entered the computer market and has since contributed a family of low cost high-speed computers using integrated circuits.

COMPUTERS MUST BE PROGRAMMED

ASSUME THE FOLLOWING PROBLEM IS TO BE SOLVED BY A GIRL USING A DESK CALCULATOR –

$$X = \frac{A+B}{C+D}$$

IN MOST CASES THE GIRL WOULD HAVE TO BE PROVIDED WITH A PROCEDURE TO SOLVE THE PROBLEM.

FOR EXAMPLE:

STEP 1. **ENTER VALUE FOR C.**
STEP 2. **ADD THE VALUE OF D.**
STEP 3. **WRITE DOWN INTERMEDIATE RESULT.**
STEP 4. **ENTER VALUE FOR A.**
STEP 5. **ADD THE VALUE OF B.**
STEP 6. **DIVIDE BY THE VALUE ACHIEVED IN STEP 3.**
STEP 7. **WRITE DOWN THE FINAL RESULT.**

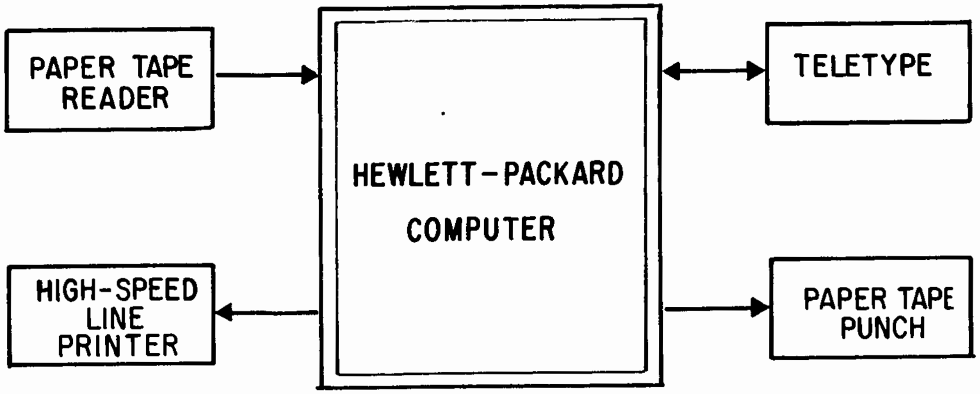
IN A SIMILAR MANNER COMPUTERS ARE "PROGRAMMED" TO SOLVE PROBLEMS.

SPEED AND INTERCOMMUNICATION

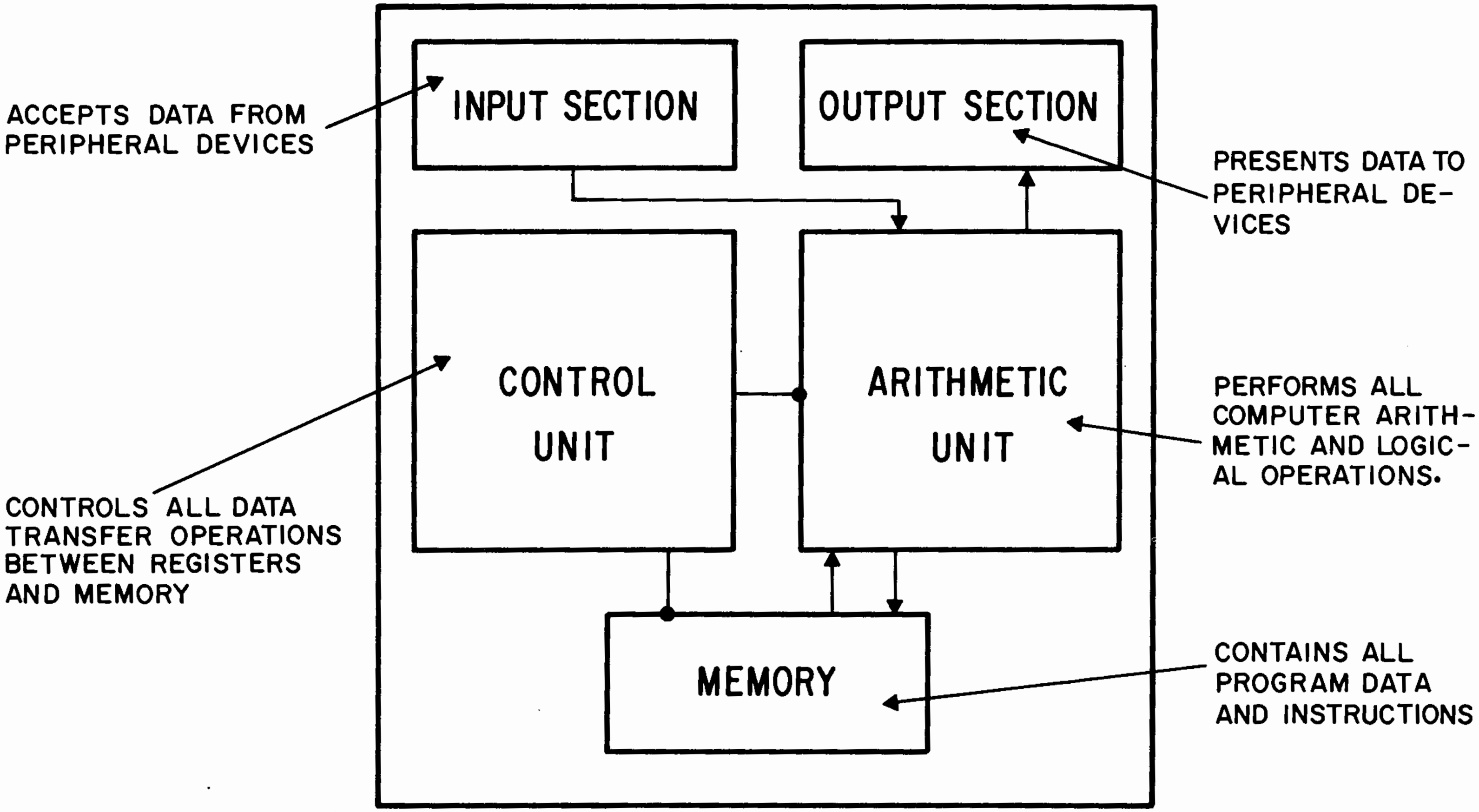
A DESK CALCULATOR IS CAPABLE OF PERFORMING COMPLICATED MATHEMATICAL PROCESSES SUCH AS DIFFERENTIATION AND INTEGRATION, HOWEVER, THE TIME REQUIRED TO SOLVE COMPLEX PROBLEMS USING THIS METHOD BECOMES PROHIBITIVELY LONG.

ADVANTAGES OF A STORED PROGRAM DIGITAL COMPUTER

1. *SPEED* – performs millions of operations in seconds.
2. *INTERCOMMUNICATIONS* – digital data can be received or transmitted by the computer.



COMPUTER BLOCK DIAGRAM



ACCEPTS DATA FROM PERIPHERAL DEVICES

CONTROLS ALL DATA TRANSFER OPERATIONS BETWEEN REGISTERS AND MEMORY

PRESENTS DATA TO PERIPHERAL DEVICES

PERFORMS ALL COMPUTER ARITHMETIC AND LOGICAL OPERATIONS.

CONTAINS ALL PROGRAM DATA AND INSTRUCTIONS

A BASIC COMPUTER

INTRODUCTION TO NUMBER SYSTEMS

HEWLETT-PACKARD computers operate on numbers in binary form; therefore, it is essential that we:

1. REVIEW THE DECIMAL NUMBER SYSTEM
2. INTRODUCE THE BINARY AND OCTAL NUMBER SYSTEMS
3. INTRODUCE BINARY ARITHMETIC
4. INTRODUCE NUMBER SYSTEM CONVERSION METHODS
5. DISCUSS THE LIMITS OF THE COMPUTER'S ABILITY TO HANDLE LARGE NUMBERS

NUMBER SYSTEMS

0,1,2,3,4,5,6,7,8,9 ARE THE TEN NUMERALS OF THE DECIMAL SYSTEM. DECIMAL VALUES LARGER THAN 9 REQUIRE MORE THAN ONE DIGIT. FOR EXAMPLE, THE DECIMAL NUMBER 109 REALLY STANDS FOR:

$$\underline{(1 \times 10^2) + (0 \times 10^1) + (9 \times 10^0)}$$

(HUNDRED'S) + (TEN'S) + (ONE'S)

$$\underline{(\ 100\ ) + (\ 0\ ) + (\ 9\ )} = 109_{10}$$

IN GENERAL:

$$\text{ANY NUMBER} = N \times b^n + N \times b^{n-1} + \cdots + N \times b^2 + N \times b^1 + N \times b^0$$

WHERE
N = DIGIT
b = BASE
$b^0 = 1$ (BY DEFINITION)

BINARY NUMBERS

Ø and 1 are the <u>TWO</u> numerals of the binary system. Binary values larger than 1 require more than one digit. For example, the BINARY number 1101101 really stands for:

$$(1 \times 2^6) + (1 \times 2^5) + (0 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$$

(SIXTY-FOUR'S) + (THIRTY-TWO'S) + (SIXTEEN'S) + (EIGHT'S) + (FOUR'S) + (TWO'S) + (ONE'S)

$$(64) + (32) + (0) + (8) + (4) + (0) + (1) = 109_{10}$$

THEREFORE:

$$1101101_2 = 109_{10}$$

OCTAL NUMBERS

0,1,2,3,4,5,6,7 ARE THE EIGHT NUMERALS OF THE OCTAL SYSTEM. OCTAL VALUES LARGER THAN 7 REQUIRE MORE THAN ONE DIGIT. FOR EXAMPLE, THE OCTAL NUMBER 155 REALLY STANDS FOR:

$$(1 \times 8^2) + (5 \times 8^1) + (5 \times 8^0)$$

(SIXTY FOUR'S) + (EIGHT'S) + (ONE'S)

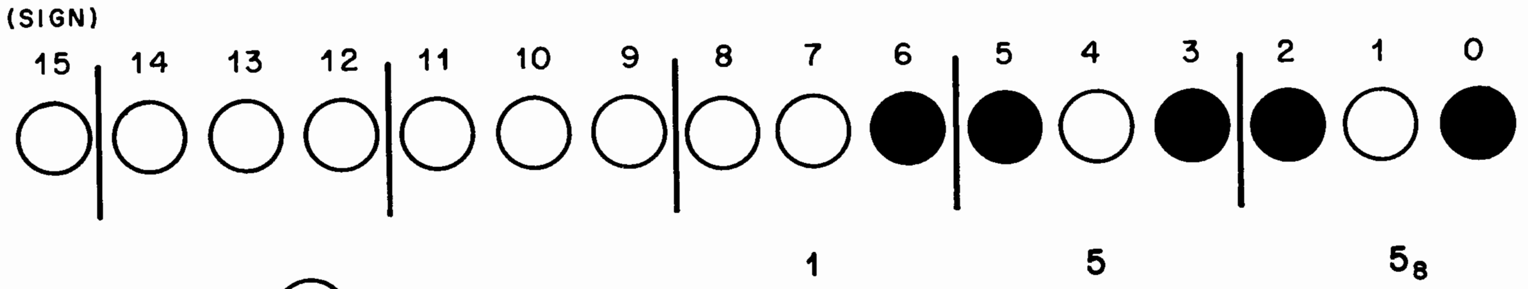
$$(\ 64\ ) + (\ 40\ ) + (\ 5\ ) = 109_{10}$$

THEREFORE —

$$1101101_2 = 155_8 = 109_{10}$$

BINARY/OCTAL RELATIONSHIP

**HEWLETT-PACKARD COMPUTERS HAVE 16 BINARY DIGITS. (BIT)
WHEN BINARY DIGITS (BITS) ARE ARRANGED IN GROUPS OF 3, OCTAL VALUES CAN BE READ DIRECTLY.**



WHERE EACH ○ = 0

AND EACH ● = 1

4	2	1	
○	○	○	= 0
○	○	●	= 1
○	●	○	= 2
○	●	●	= 3

OCTAL

	4	2	1
4 =	●	○	○
5 =	●	○	●
6 =	●	●	○
7 =	●	●	●

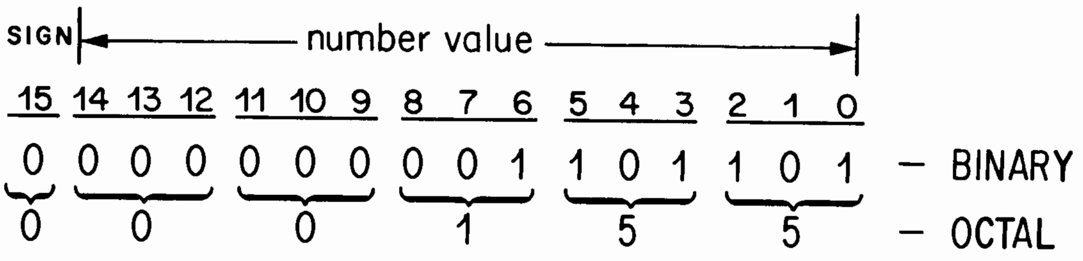
NUMBER SYSTEM CONVERSION METHODS

PROGRAMMERS MUST LEARN THE FOLLOWING NUMBER SYSTEM CONVERSION TECHNIQUES:

CONVERSION	METHOD
BINARY TO OCTAL	BY INSPECTION
OCTAL TO BINARY	BY INSPECTION
OCTAL TO DECIMAL	BY FORMULA
DECIMAL TO OCTAL	BY FORMULA

REMEMBER:

OCTAL IS USED TO REPRESENT BINARY NUMBERS MORE EFFICIENTLY



SIGN	number value					
15	14 13 12	11 10 9	8 7 6	5 4 3	2 1 0	
0	0 0 0	0 0 0	0 0 1	1 0 1	1 0 1	– BINARY
0	0	0	1	5	5	– OCTAL

- TO CONVERT THE OCTAL NUMBER 155 TO DECIMAL, PROCEED IN THE FOLLOWING WAY.

1. Multiply the most significant octal digit by 8

2. Add the next least significant octal digit, then multiply the result by 8

3. Continue using step 2 above until the least significant digit is reached

4. The least significant digit is added to the total but the result is NOT multiplied by 8.

EXAMPLE:

CONVERT 155_8 TO DECIMAL

```
  155
 x8
  8
 +5
 13
 x8
104
 +5
109₁₀   DECIMAL RESULT
```

OCTAL TO DECIMAL CONVERSION

● TO CONVERT THE DECIMAL NUMBER 109 TO OCTAL PROCEED IN THE FOLLOWING WAY.

1. **Divide the decimal number by 8 and write down the remainder.** $8\,\frac{\angle 109}{13} + 5$ REMAINDER

2. **Divide the quotient of the previous step by 8 and write down the remainder.** $8\,\frac{\angle 13}{1} + 5$ REMAINDER

3. **Repeat step 2 until the "new" quotient becomes zero.** $8\,\frac{\angle 1}{0} + 1$ REMAINDER

↑ READ OCTAL VALUE

4. **The octal value is read as follows:**

   THE LAST REMAINDER IS THE <u>MOST</u> SIGNIFICANT OCTAL DIGIT.

   THE FIRST REMAINDER IS THE <u>LEAST</u> SIGNIFICANT OCTAL DIGIT.

   $109_{10} = 155_8$

DECIMAL TO OCTAL CONVERSION

BINARY ARITHMETIC

- *In the computer a special logic circuit performs addition using binary arithmetic. Actual computer numbers are 16"BITS" long, however, for simplicity the following example uses only 6 "BITS."*

EXAMPLE

```
                 GENERATED
                  CARRIES
           1 1
X     0 0 1 1 1 0
Y     0 0 1 1 0 1
     -------------
sum   0 1 1 0 1 1
```

RULES OF BINARY ADDITION

CARRY (IN)	X	Y
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

SUM	CARRY (OUT)
0	0
1	0
1	0
0	1
1	0
0	1
0	1
1	1

TWO'S COMPLEMENT NUMBERS

HEWLETT-PACKARD COMPUTERS USE THE TWO'S COMPLEMENT ARITHMETIC TECHNIQUE. THE PROCESS OF "TWO'S COMPLEMENTATION" CHANGES A POSITIVE INTEGER VALUE TO NEGATIVE AND VICE-VERSA.

FOR EXAMPLE:

NOTE: IF SIGN = 0, NORMAL FORM (POSITIVE)
IF SIGN = 1, TWO'S COMPLEMENT FORM (NEGATIVE)

SIGN	VALUE					
0	1	1	0	1	1	A NORMAL NUMBER (POSITIVE)
1	0	0	1	0	0	THE ONE'S COMPLEMENT { ALL 1's BECOME 0's ALL 0's BECOME 1's
0	0	0	0	0	1	ADD ONE
1	0	0	1	0	1	THE TWO'S COMPLEMENT (NEGATIVE)

COMPLEMENTATION TECHNIQUES

The decimal number 109_{10} when converted to octal appears as 155_8. The example shows the two's complement operation performed on this value.

EXAMPLE:

SIGN	BINARY		OCTAL	
0	000 000 001 101 101	(POSITIVE)	0	00155
1	111 111 110 010 010	(ONE'S COMPLEMENT)	1	77622
0	000 000 000 000 001	(ADD ONE)	0	00001
1	111 111 110 010 011	(NEGATIVE TWO'S COMPLEMENT)	1	77623

NOTE THE MOST SIGNIFICANT OCTAL DIGIT REPRESENTS A SINGLE BIT. TO COMPLEMENT WITH OCTAL NUMBERS REMEMBER —

1 — COMPLEMENT THE SIGN DIGIT. (1 or Ø)

2 — TAKE THE EIGHTS COMPLEMENT ON THE REMAINING DIGITS.

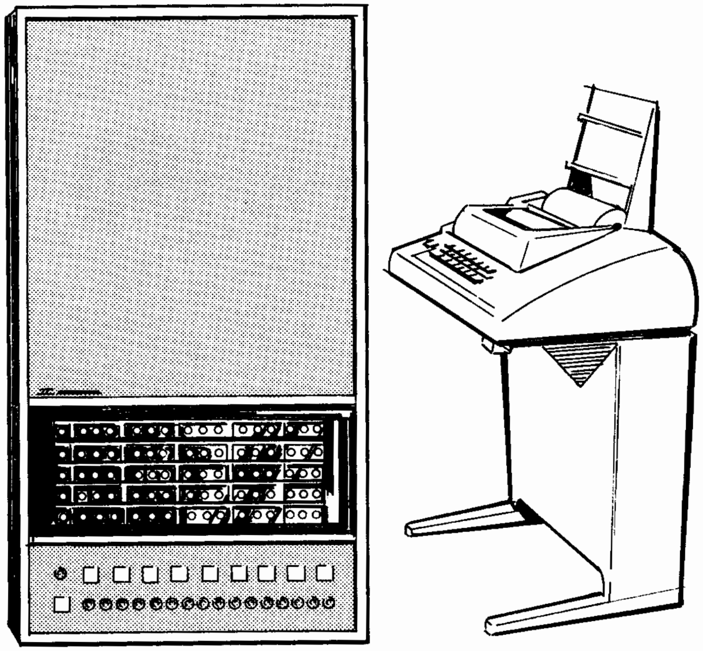
NEGATIVE NUMBER CONVERSIONS

TO CONVERT A NEGATIVE DECIMAL NUMBER TO 16 BIT MACHINE FORM.

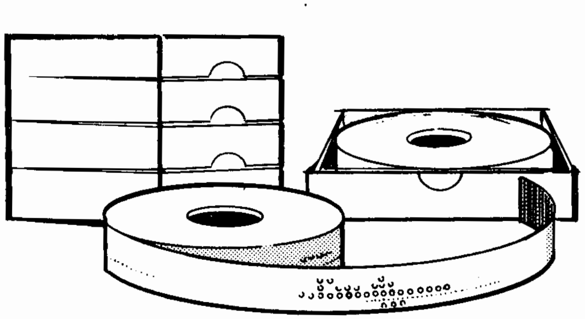
1. ASSUME THE DECIMAL VALUE IS POSITIVE
2. CONVERT TO OCTAL FORM
3. TAKE THE TWO'S COMPLEMENT. (OR EIGHT'S COMPLEMENT)

TO CONVERT TWO'S COMPLEMENT NUMBERS TO DECIMAL FORM.

1. TAKE THE TWO'S COMPLEMENT.
2. CONVERT TO DECIMAL
3. AFFIX A MINUS SIGN TO THE DECIMAL RESULT

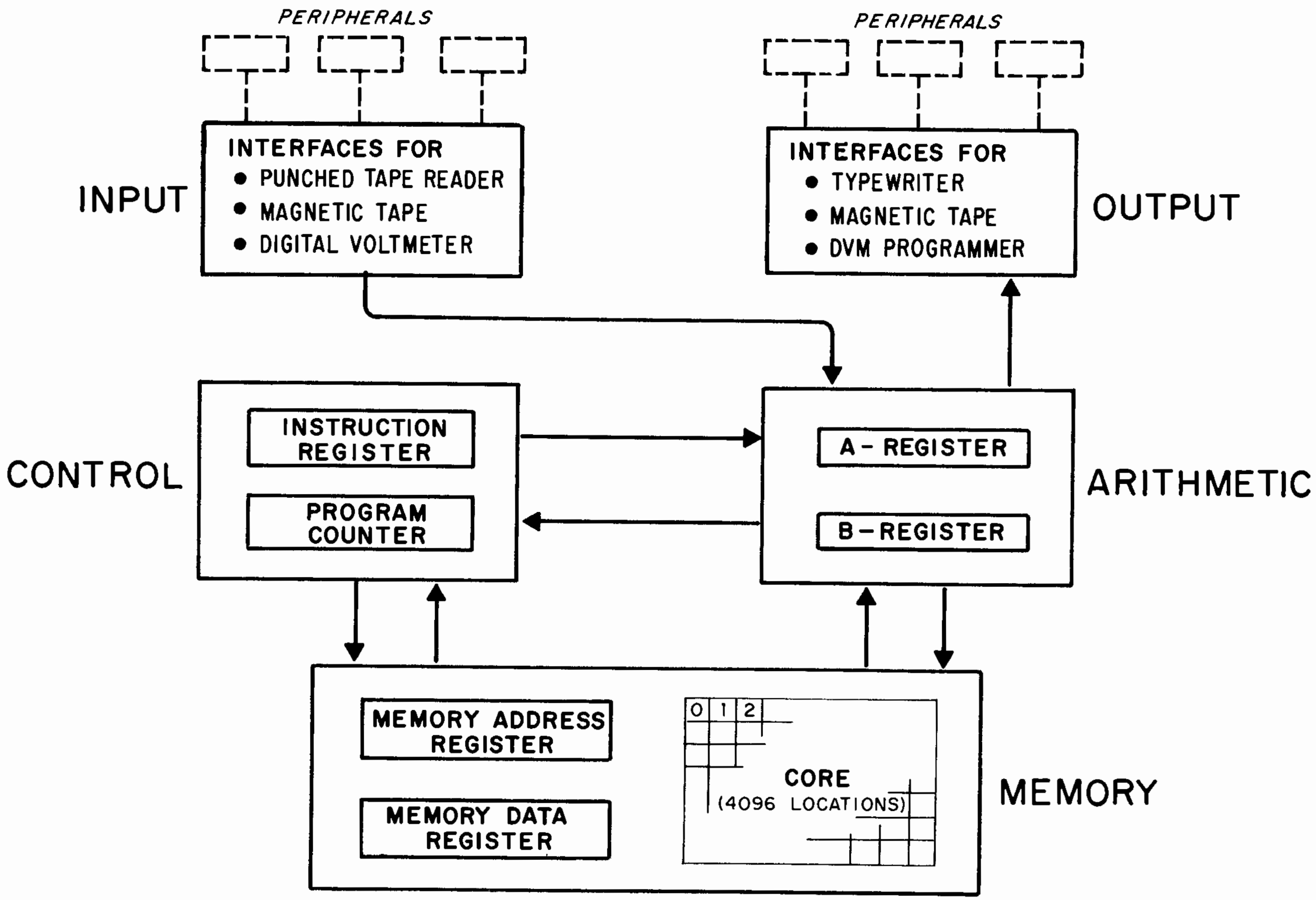


HARDWARE



SOFTWARE

A COMPUTER SYSTEM IS COMPOSED
OF HARDWARE AND SOFTWARE



BASIC ELEMENTS OF COMPUTER HARDWARE

COMPUTER WORD FORMAT

DATA FORMAT (INTEGER)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SIGN	INTEGER														

0	0	0	1	0	1	0	0	1	1	1	0	1	1	1	1

EXAMPLE: $+12357_8$

INSTRUCTION FORMAT (MEMORY REFERENCE INSTRUCTION)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	INSTRUCTION				Z/C	MEMORY WORD ADDRESS									

0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0

EXAMPLE: "LOAD REGISTER "A" WITH THE CONTENTS OF LOCATION 200_8"

FULL ADDRESS FORMAT

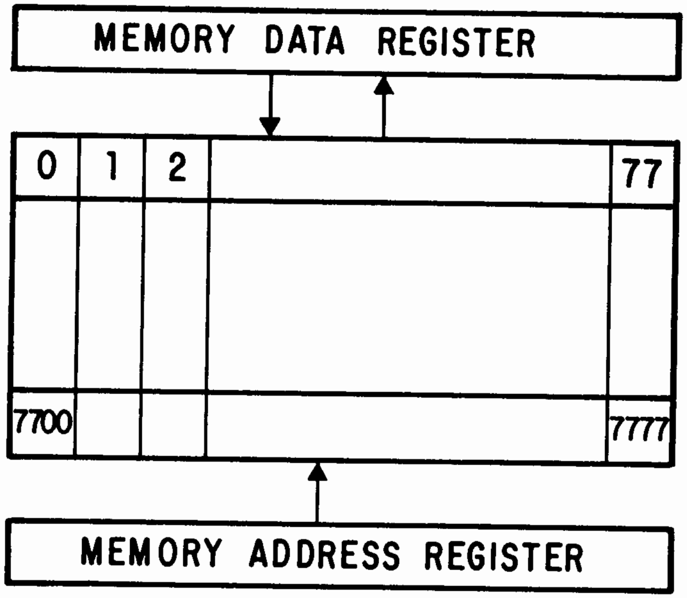
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	PAGE ADDRESS					MEMORY WORD ADDRESS									

0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0

EXAMPLE: MEMORY ADDRESS 17700_8

MEMORY

ADDRESSING & DATA TRANSFER CONCEPTS

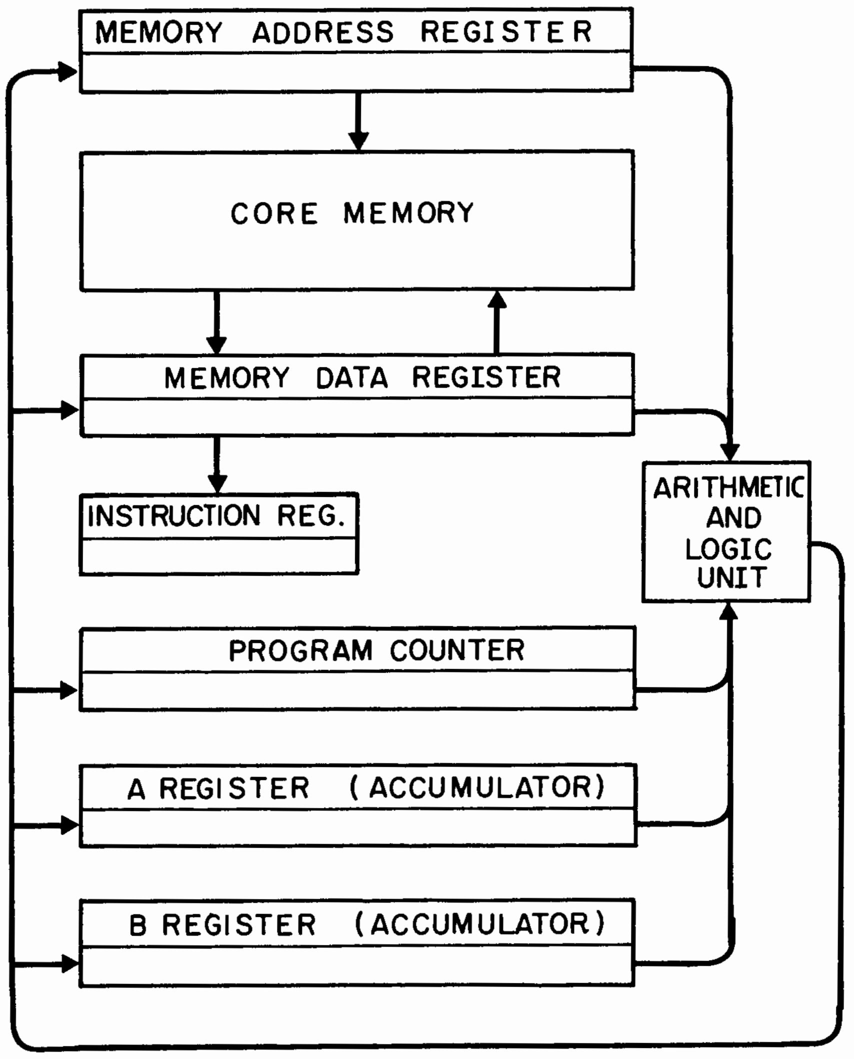


1.) ASSUME MEMORY ADDRESS 7700_8 CONTAINS 1001110000111100
←16 BITS→

2.) ALL DATA TO AND FROM THE MEMORY PASSES THROUGH THE MEMORY DATA REGISTER – READING WORD 7700_8 PUTS 1001110000111100 IN THE MEMORY DATA REGISTER.

3) MEMORY ADDRESS REGISTER – HOLDS THE NUMBER OF THE WORD ADDRESSED IN MEMORY – TO READ THE CONTENTS OF MEMORY ADDRESS 7700_8 THE NUMBER 7700_8 IS PLACED IN THE MEMORY ADDRESS REGISTER.

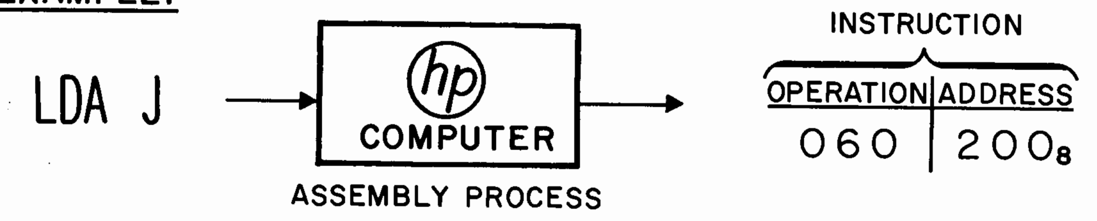
COMPUTER REGISTERS



COMPUTER INSTRUCTIONS

COMPUTER INSTRUCTIONS TAKE TWO BASIC FORMS. ONE FORM IS HUMAN ORIENTED, WHILE THE OTHER IS MACHINE ORIENTED. THE COMPUTER TRANSLATES FROM "MAN" TO "MACHINE" LANGUAGE.

FOR EXAMPLE:

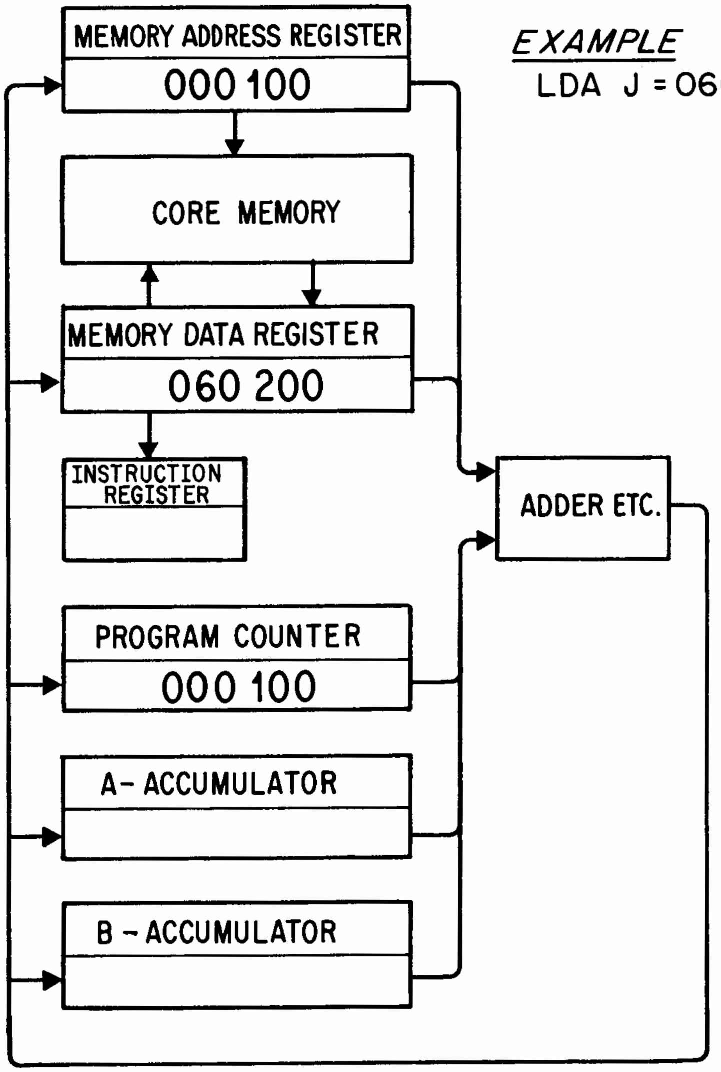


THE ABOVE INSTRUCTION MEANS; "LOAD REGISTER A WITH THE CONTENTS OF MEMORY LOCATION J". THE ASSEMBLY PROCESS CONVERTS "LDA J" TO THE MACHINE INSTRUCTION 060200_8.

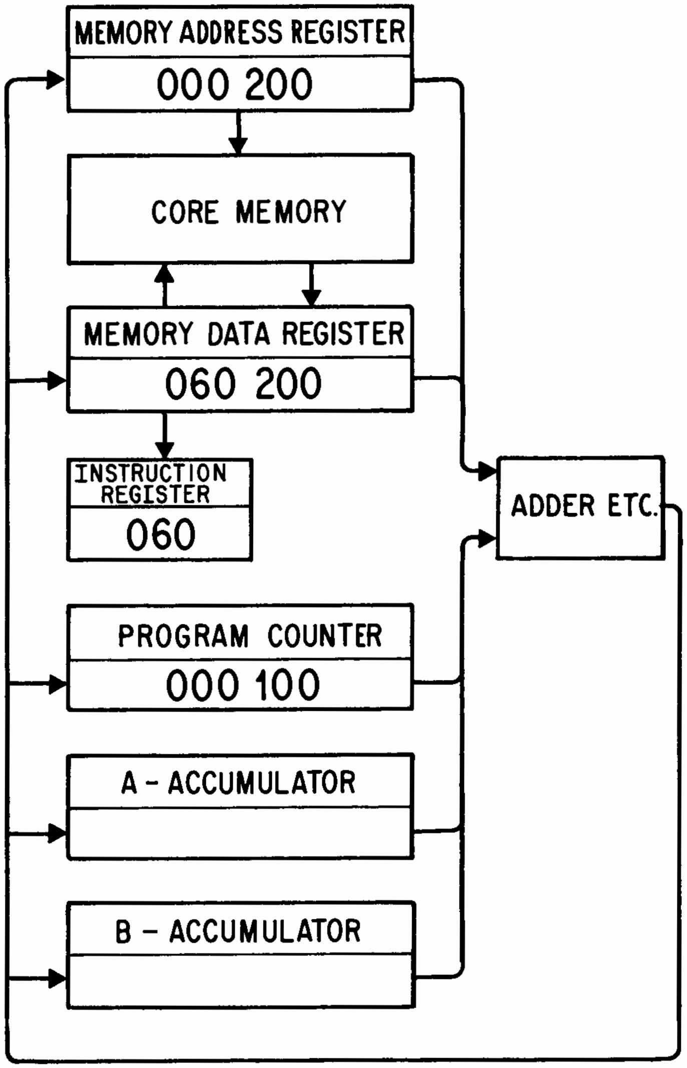
NOTE: IN THIS EXAMPLE "J" IS ARBITRARILY REPRESENTING MEMORY LOCATION 200_8.

INSTRUCTION EXECUTION SEQUENCE

EXAMPLE
LDA J = 060 200



a. Instruction is Read from Memory

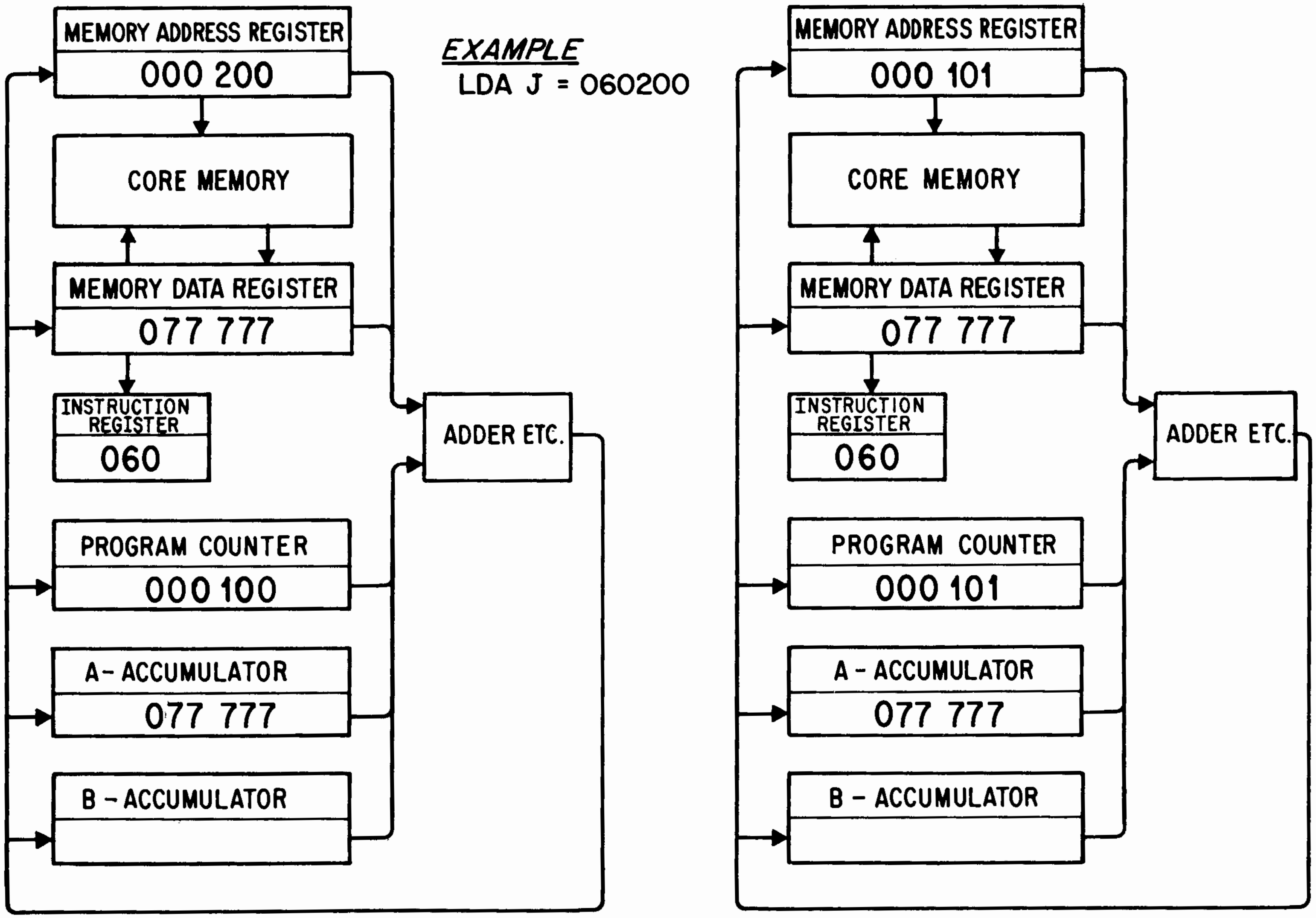


b. End of Fetch Phase

INSTRUCTION IN LOCATION 100 - FETCH PHASE

INSTRUCTION EXECUTION cont'd

EXAMPLE
LDA J = 060200

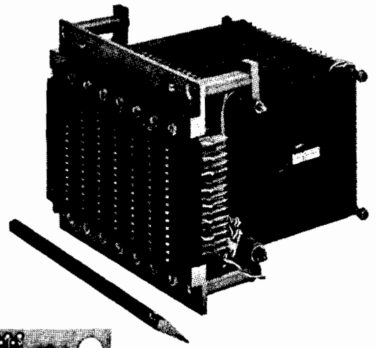


c. Instruction is Executed

d. End of Execute Phase

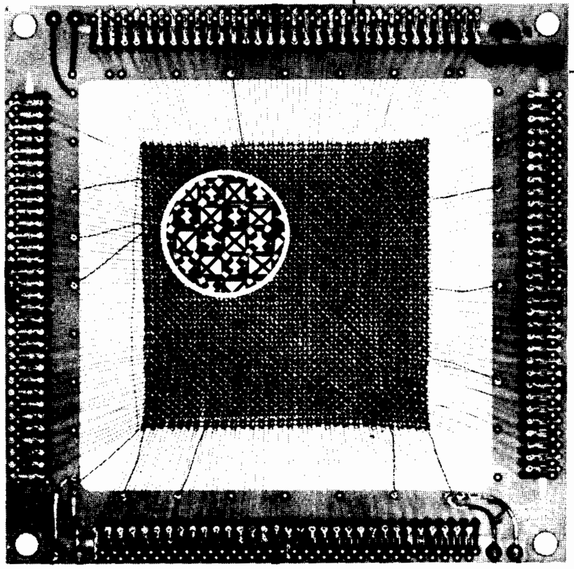
INSTRUCTION IN LOCATION 100 -EXECUTE PHASE

CORE MEMORY



4096 – Word
Core Module

17 CORE PLANES PER MODULE. EACH CORE PLANE SUPPLIES ONE BIT OF THE COMPUTER WORD. (16 DATA BITS + PARITY BIT).



Memory Plane

4096 CORES PER MEMORY PLANE. ONLY ONE CORE ON EACH PLANE IS INTERROGATED WHEN A MEMORY LOCATION IS ADDRESSED.

TYPES OF COMPUTER INSTRUCTIONS

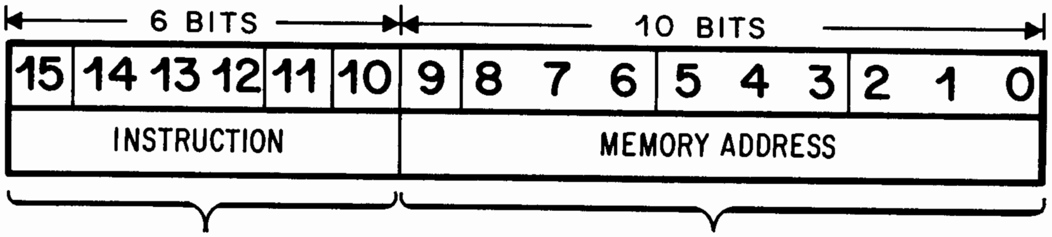
THERE ARE THREE TYPES OF COMPUTER INSTRUCTIONS —

- ✓ *Memory Reference*
- ✓ *Register Reference*
- ✓ *Input/output*

MEMORY REFERENCE INSTRUCTION

— USED FOR —

READING DATA FROM MEMORY
STORING DATA IN MEMORY
ARITHMETIC OPERATIONS
LOGIC OPERATIONS
ALTERATION OF PROGRAM COUNTER
CONTROLLING PROGRAM LOOPS



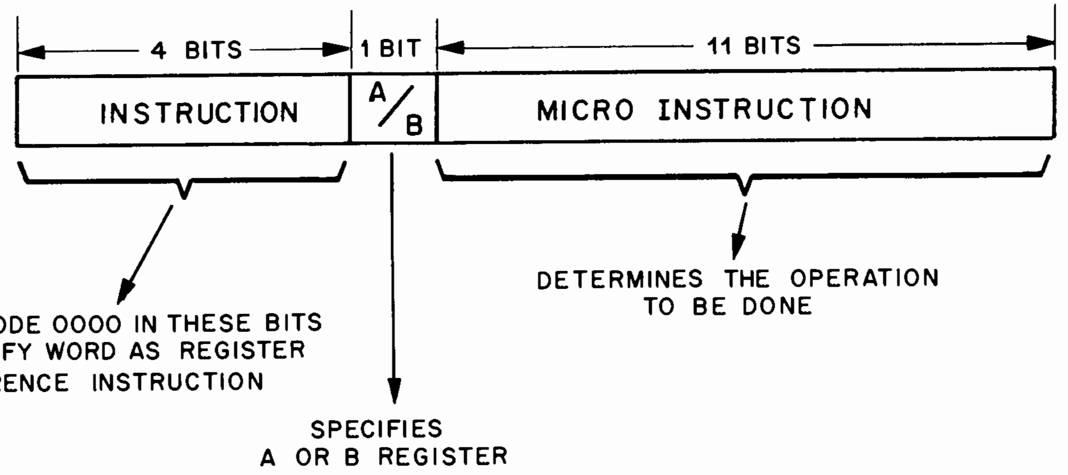
SELECTS 1 OF 14 INSTRUCTIONS
AND DETERMINES ADDRESSING MODE

SPECIFIES THE MEMORY WORD ADDRESS

REGISTER REFERENCE INSTRUCTIONS

- MOVE DATA WITHIN AND BETWEEN ACCUMULATORS
- CLEAR OR COMPLEMENT ACCUMULATORS
- TEST BITS IN ACCUMULATORS

INSTRUCTION FORMAT



4 BITS

1 BIT

11 BITS

INSTRUCTION

A/B

MICRO INSTRUCTION

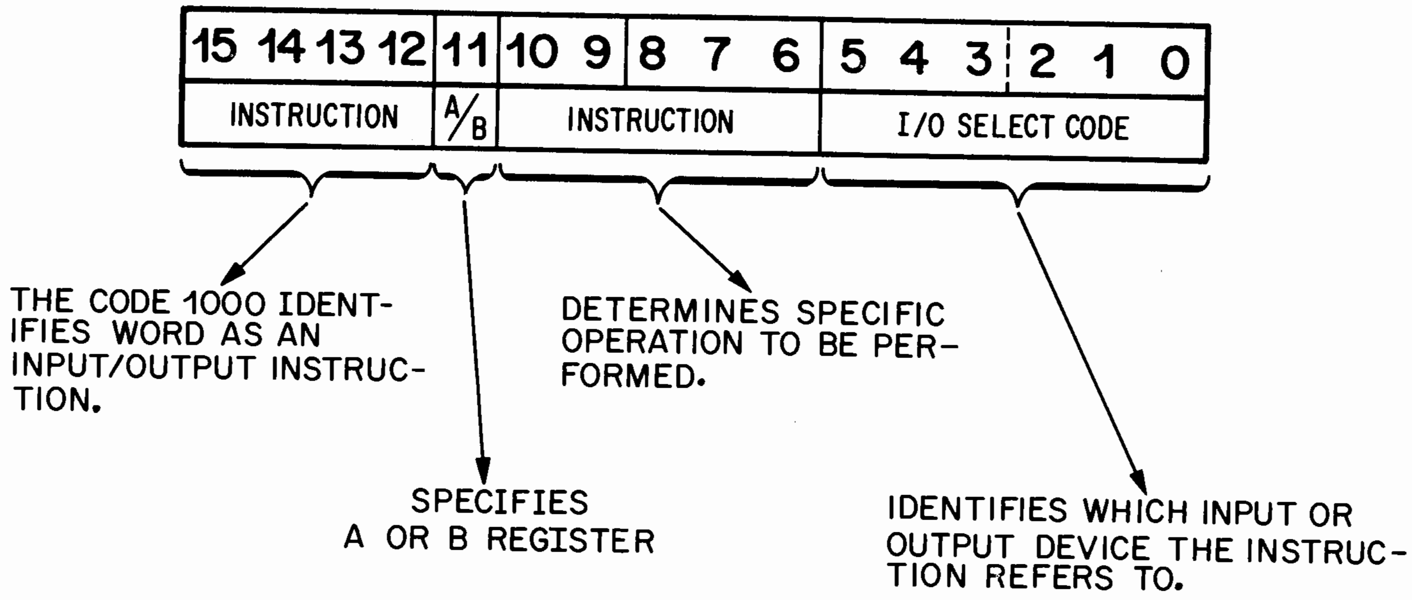
THE CODE 0000 IN THESE BITS IDENTIFY WORD AS REGISTER REFERENCE INSTRUCTION

SPECIFIES A OR B REGISTER

DETERMINES THE OPERATION TO BE DONE

INPUT/OUTPUT INSTRUCTIONS

READ DATA FROM DEVICES
OUTPUT DATA TO DEVICES
CHECK STATUS OF DEVICES

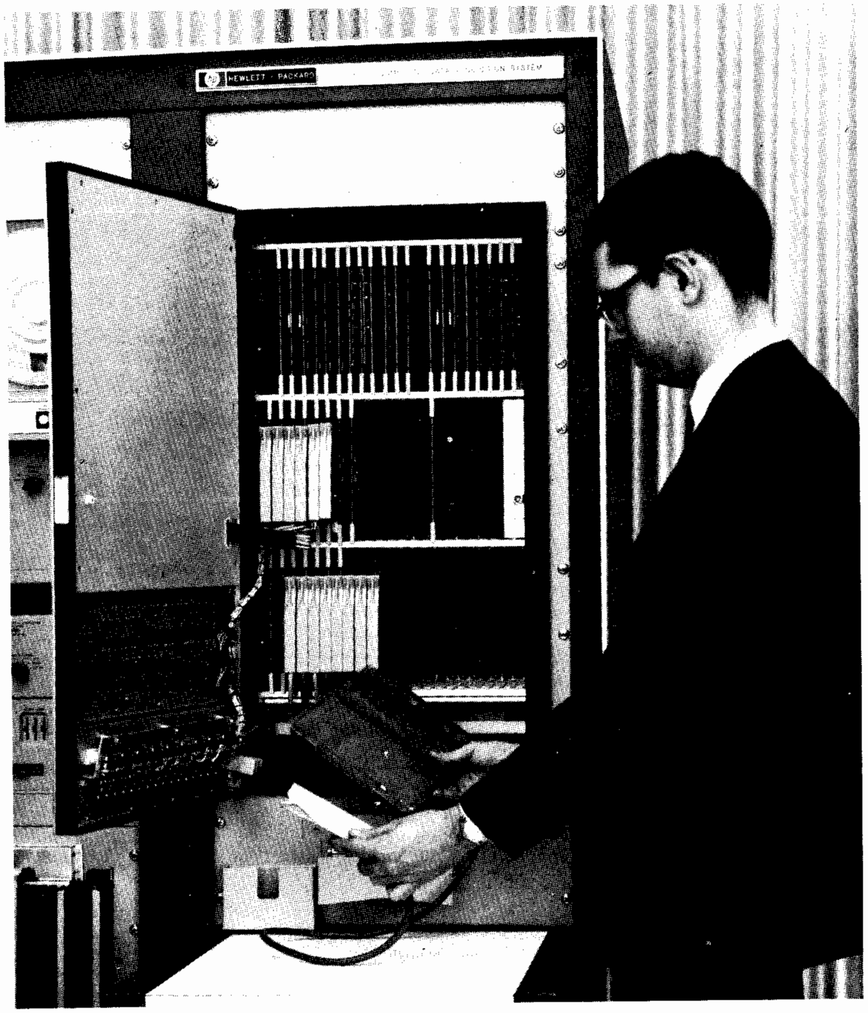


THE CODE 1000 IDENTIFIES WORD AS AN INPUT/OUTPUT INSTRUCTION.

SPECIFIES A OR B REGISTER

DETERMINES SPECIFIC OPERATION TO BE PERFORMED.

IDENTIFIES WHICH INPUT OR OUTPUT DEVICE THE INSTRUCTION REFERS TO.



HP-INTERFACE CARD

I/O Interface cards are simple to install or rearrange

PRIORITY INTERRUPT SYSTEM

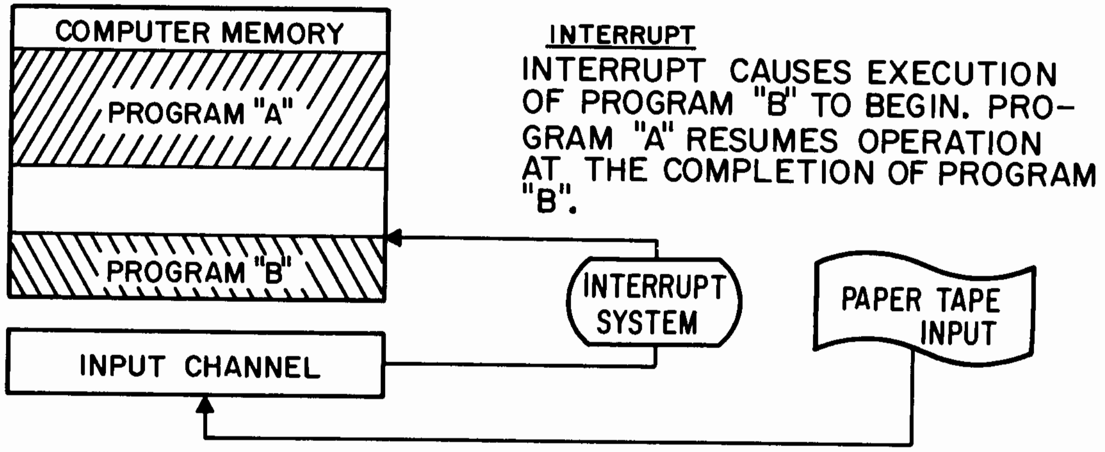
THE INTERRUPT SYSTEM ALLOWS THE COMPUTER TO PERFORM USEFUL WORK WHILE A PERIPHERAL DEVICE IS COMPLETING A CYCLE. EACH INTERRUPTING DEVICE IS UNIQUELY IDENTIFIED AND ASSIGNED A PRIORITY TO PREVENT SIMULTANEOUS INTERRUPT REQUESTS FROM MORE THAN ONE DEVICE.

FOR EXAMPLE:

ASSUME PROGRAM "A" IS A LARGE INTEGRATION ROUTINE, AND PROGRAM "B" IS A ROUTINE THAT HANDLES PAPER TAPE INPUT DATA.

NORMAL OPERATION

PROGRAM "A" HAS CONTROL AND IS IN EXECUTION.



INTERRUPT

INTERRUPT CAUSES EXECUTION OF PROGRAM "B" TO BEGIN. PROGRAM "A" RESUMES OPERATION AT THE COMPLETION OF PROGRAM "B".

INPUT/OUTPUT DATA TRANSFERS

Data transfers that do not use the interrupt system are made under program control. The controlling program must cause the computer to "WAIT" for the slower peripheral device. The steps in a non-interrupt data <u>input</u> program are:

```
1 - TURN THE INTERRUPT SYSTEM OFF.
2 - START THE DEVICE AND TURN THE READY FLAG OFF.
3 - WAIT FOR THE DEVICE READY FLAG TO COME ON.(WAIT LOOP)
4 - WHEN THE FLAG COMES ON, TRANSFER DATA TO COMPUTER.
5 - HAS ALL THE DATA BEEN TRANSFERRED?
        NO, GO TO STEP 2
        YES, GO TO STEP 6
6 - HALT THE COMPUTER
```

NOTE: *THE COMPUTER WILL SPEND THE MOST TIME ON STEP 3*

COMPUTER SOFTWARE

SOFTWARE IS THE GENERAL TERM GIVEN TO ALL PROGRAMS AND ROUTINES THAT EXTEND THE CAPABILITY OF THE COMPUTER. SOFTWARE CAN BE DIVIDED LOOSELY INTO FOUR CLASSES:

1. <u>TRANSLATORS</u> — PROGRAMS WHICH TRANSLATE HUMAN-ORIENTED LANGUAGES INTO MACHINE LANGUAGES.
2. <u>CONTROL SYSTEMS</u> — PROGRAMS WHICH TAKE CARE OF ALL FUNCTIONS ESSENTIAL TO OPERATION OF THE COMPUTER SYSTEM.
3. <u>UTILITY ROUTINES</u> — PROGRAM EDITORS, PROGRAM DEBUGGING ROUTINES, HARDWARE DIAGNOSTICS.

THE ABOVE SOFTWARE IS NORMALLY SUPPLIED BY THE COMPUTER MANUFACTURER.

4. <u>APPLICATIONS PROGRAMS</u> — THESE ENABLE THE COMPUTER TO BE EFFECTIVE IN A SPECIFIC APPLICATION.

APPLICATIONS PROGRAMS ARE NORMALLY CREATED BY THE USER.

HEWLETT-PACKARD SOFTWARE

TRANSLATION PROGRAMS

FORTRAN, ALGOL and "BASIC" COMPILERS
HP SYMBOLIC ASSEMBLER

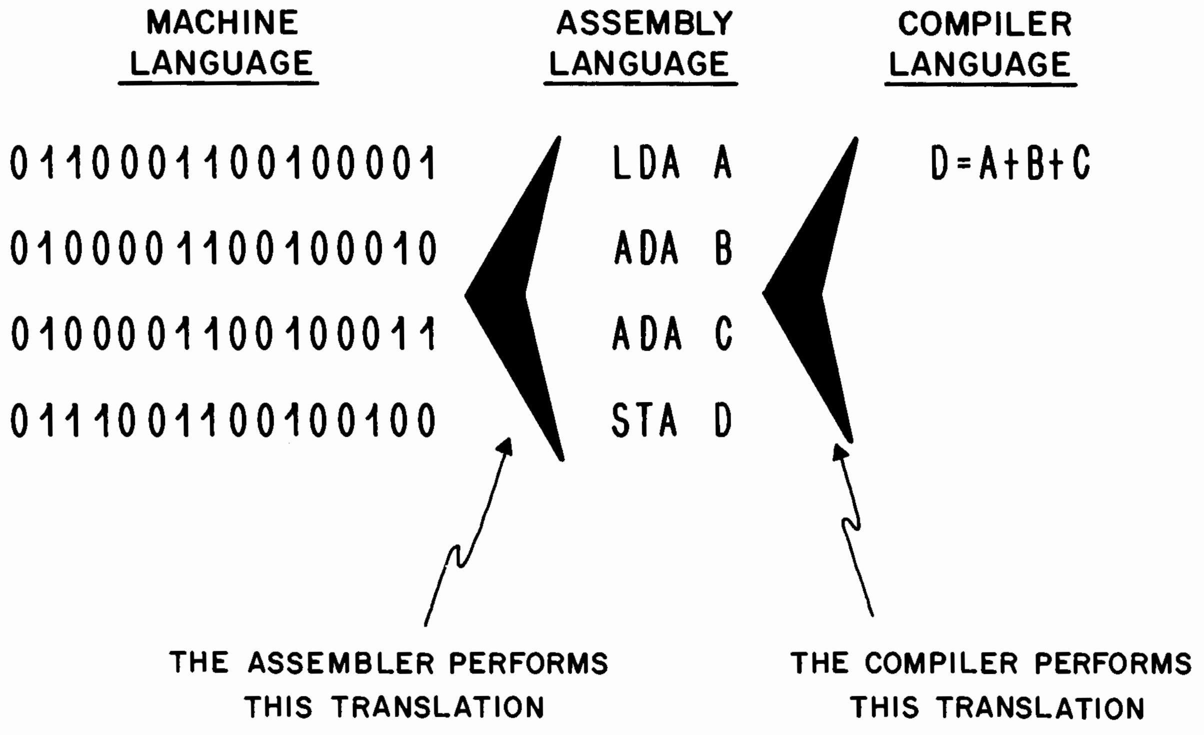
CONTROL SYSTEM

BASIC CONTROL SYSTEM

UTILITY ROUTINES

SYMBOLIC EDITOR
LIBRARY ROUTINES
DEBUGGING ROUTINE
PREPARE CONTROL SYSTEM
HARDWARE DIAGNOSTICS
PREPARE TAPE SYSTEM
SYSTEM INPUT OUTPUT DUMP

PROGRAMMING LANGUAGES



MACHINE LANGUAGE

```
0110001100100001
0100001100100010
0100001100100011
0111001100100100
```

ASSEMBLY LANGUAGE

```
LDA  A
ADA  B
ADA  C
STA  D
```

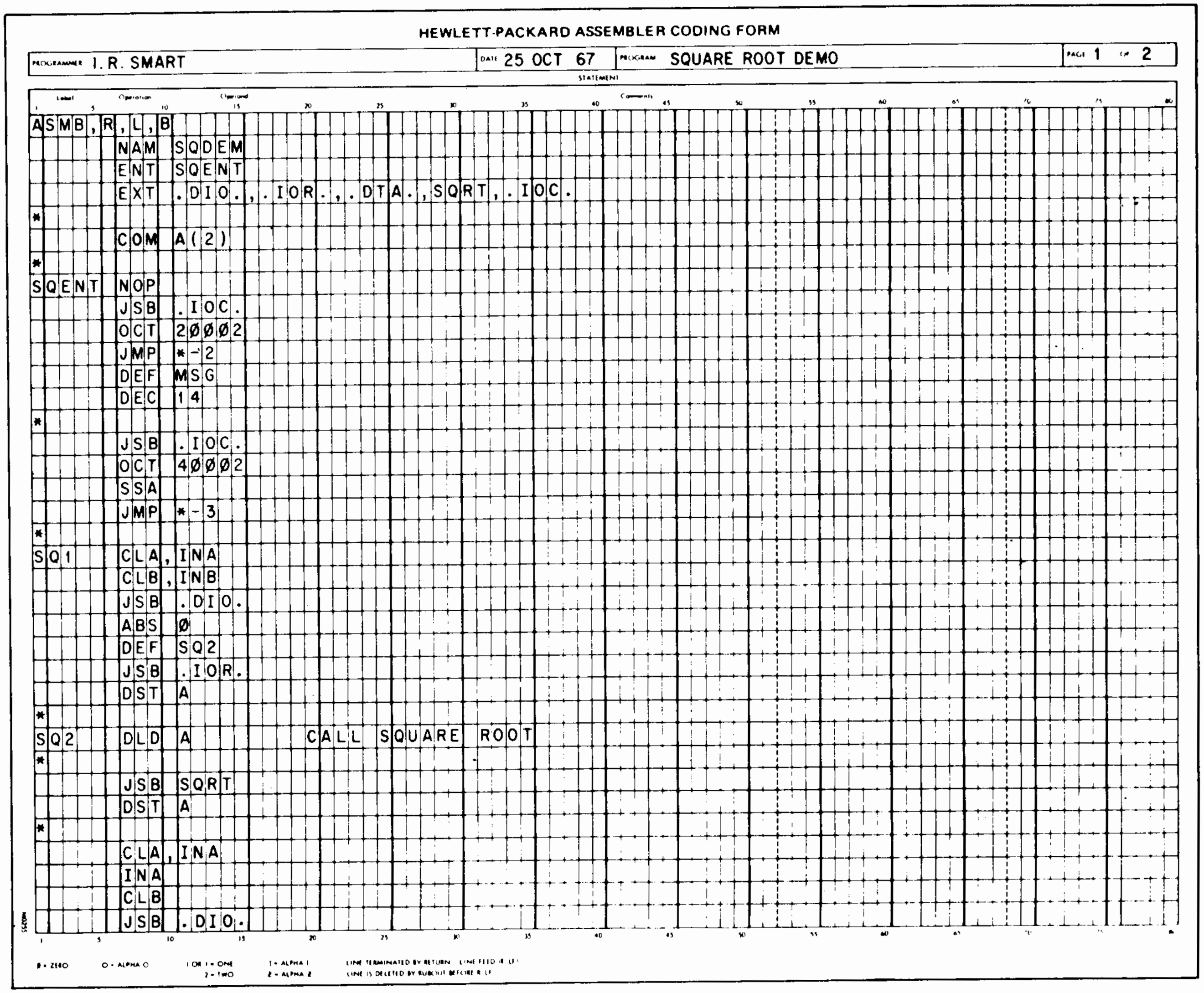
COMPILER LANGUAGE

```
D=A+B+C
```

THE ASSEMBLER PERFORMS THIS TRANSLATION

THE COMPILER PERFORMS THIS TRANSLATION

SOURCE PROGRAM IN ASSEMBLY LANGUAGE



HEWLETT-PACKARD ASSEMBLER CODING FORM

PROGRAMMER I. R. SMART | DATE 25 OCT 67 | PROGRAM SQUARE ROOT DEMO | PAGE 1 OF 2

STATEMENT

Label | Operation | Operand | Comments

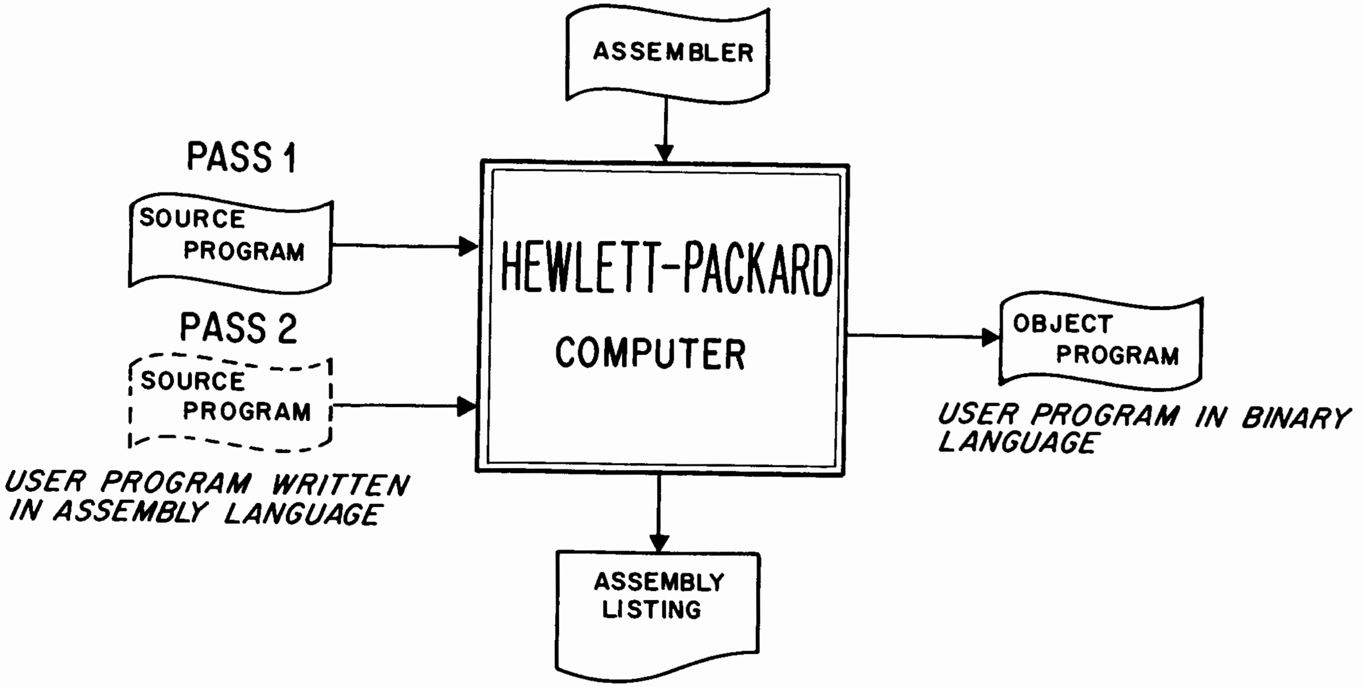
```
ASMB,R,L,B
      NAM SQDEM
      ENT SQENT
      EXT .DIO.,.IOR.,.DTA.,SQRT,.IOC.
*
      COM A(2)
*
SQENT NOP
      JSB .IOC.
      OCT 2ØØØ2
      JMP *-2
      DEF MSG
      DEC 14
*
      JSB .IOC.
      OCT 4ØØØ2
      SSA
      JMP *-3
*
SQ1   CLA,INA
      CLB,INB
      JSB .DIO.
      ABS Ø
      DEF SQ2
      JSB .IOR.
      DST A
*
SQ2   DLD A         CALL SQUARE ROOT
*
      JSB SQRT
      DST A
*
      CLA,INA
      INA
      CLB
      JSB .DIO.
```

Ø = ZERO O = ALPHA O 1 OR I = ONE I = ALPHA I 2 = TWO Z = ALPHA Z

LINE TERMINATED BY RETURN - LINE FEED (R LF)
LINE IS DELETED BY RUBOUT BEFORE R LF

M0255

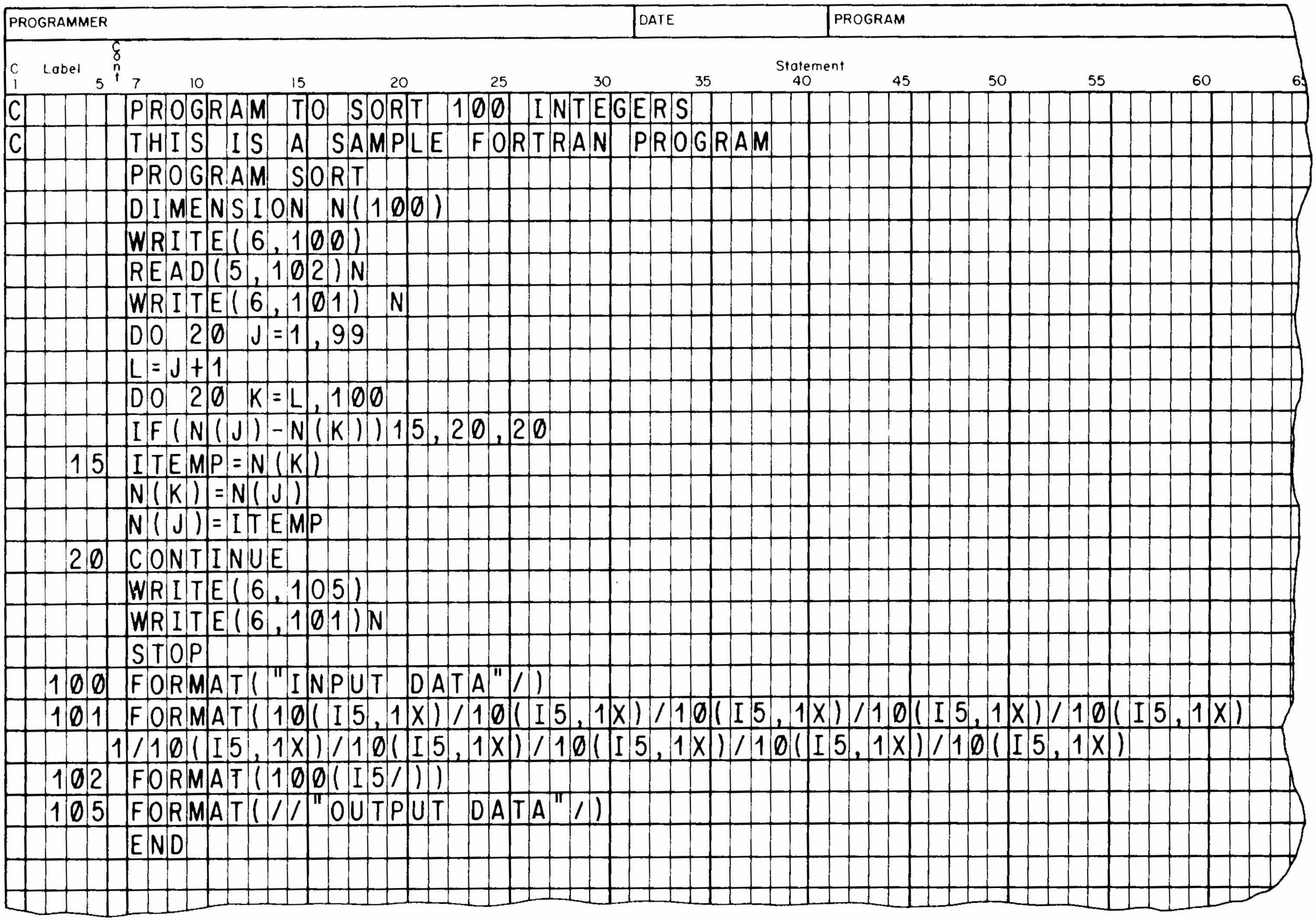
ASSEMBLY PROCESS



1. ASSEMBLER PROGRAM IS LOADED INTO THE COMPUTER.
2. SOURCE PROGRAM IS PROCESSED BY THE ASSEMBLER, PRODUCING THE OBJECT PROGRAM TAPE AND THE ASSEMBLY LISTING IN A <u>TWO PASS</u> OPERATION.

ASSEMBLY LISTING

```
 A     B     C                         D
0001                    ASMB,R,L,B
0002  00000                       NAM SQDEM
0003                              ENT SQFNT
0004                              EXT .DIO.,.IOR.,.DTA.,SQRT,.IOC.
0005*
0006                              COM A(2)
0007*
0008  00000 000000  SQENT NOP
0009  00001 016005X               JSB .IOC.
0010  00002 020002                OCT 20002
0011  00003 026001R               JMP *-2
0012  00004 000045R               DEF MSG
0013  00005 000016                DEC 14
0014*
0015  00006 016005X               JSB .IOC.
0016  00007 040002                OCT 40002
0017  00010 002020                SSA
0018  00011 026006R               JMP *-3
0019*
0020  00012 002404  SQ1           CLA,INA
0021  00013 006404                CLB,INB
0022  00014 016001X               JSB .DIO.
0023  00015 000000                ABS 0
0024  00016 000022R               DEF SQ2
0025  00017 016002X               JSB .IOR.
0026  00020 016006X               DST A
      00021 000000C
0027*
0028  00022 016007X SQ2           DLD A         CALL SQUARE ROOT
      00023 000000C
0029  00024 016004X               JSB SQRT
0030  00025 016006X               DST A
      00026 000000C
0031  00027 002404                CLA,INA
0032  00030 002004                INA
0033  00031 006400                CLB
0034  00032 016001X               JSB .DIO.
```

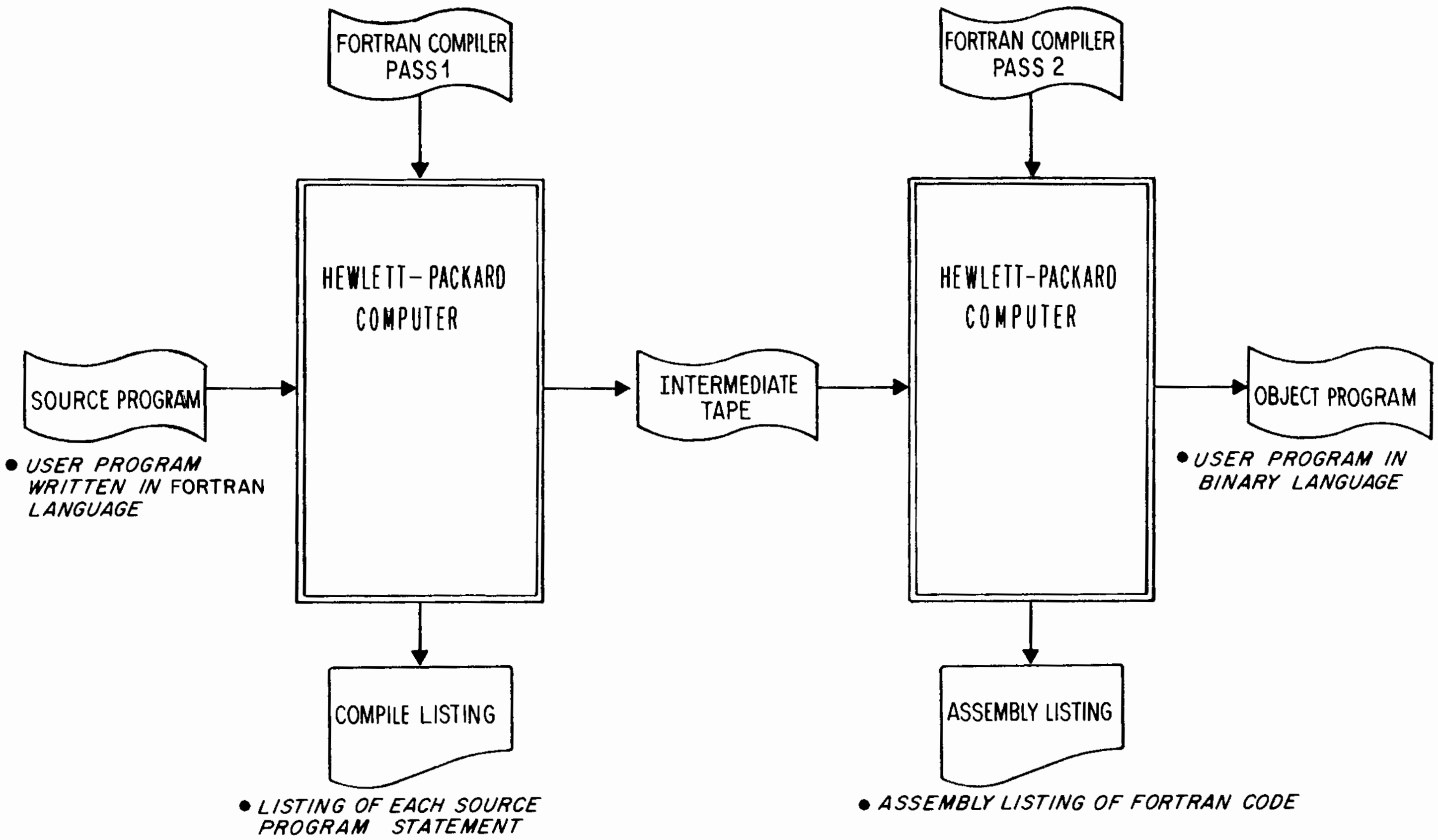


PROGRAMMER
DATE
PROGRAM
C
Label
Cont
Statement
1
5
7
10
15
20
25
30
35
40
45
50
55
60
65

```
C     PROGRAM TO SORT 1ØØ INTEGERS
C     THIS IS A SAMPLE FORTRAN PROGRAM
      PROGRAM SORT
      DIMENSION N(1ØØ)
      WRITE(6,1ØØ)
      READ(5,1Ø2)N
      WRITE(6,1Ø1) N
      DO 2Ø J=1,99
      L=J+1
      DO 2Ø K=L,1ØØ
      IF(N(J)-N(K))15,2Ø,2Ø
   15 ITEMP=N(K)
      N(K)=N(J)
      N(J)=ITEMP
   2Ø CONTINUE
      WRITE(6,105)
      WRITE(6,1Ø1)N
      STOP
  1ØØ FORMAT("INPUT DATA"/)
  1Ø1 FORMAT(1Ø(I5,1X)/1Ø(I5,1X)/1Ø(I5,1X)/1Ø(I5,1X)/1Ø(I5,1X)
     1/1Ø(I5,1X)/1Ø(I5,1X)/1Ø(I5,1X)/1Ø(I5,1X)/1Ø(I5,1X))
  1Ø2 FORMAT(1ØØ(I5/))
  1Ø5 FORMAT(//"OUTPUT DATA"/)
      END
```

SOURCE PROGRAM IN FORTRAN

FORTRAN COMPILATION PROCESS



- *USER PROGRAM WRITTEN IN* FORTRAN *LANGUAGE*
- *LISTING OF EACH SOURCE PROGRAM STATEMENT*
- *ASSEMBLY LISTING OF FORTRAN CODE*
- *USER PROGRAM IN BINARY LANGUAGE*

1 – FORTRAN COMPILER PASS 1 IS LOADED INTO THE COMPUTER

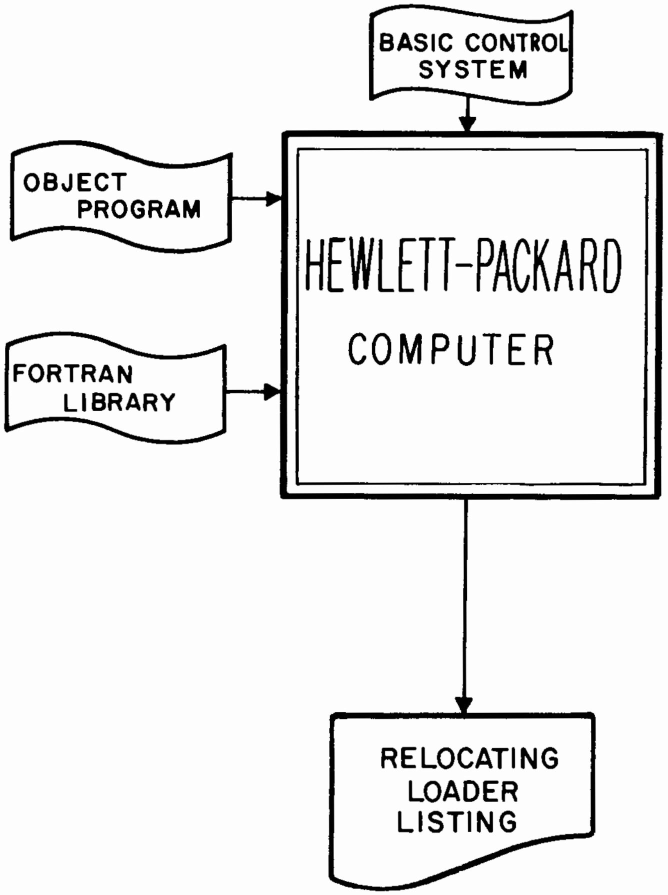
2 – SOURCE PROGRAM TAPE IS PROCESSED, BY THE COMPILER, PRODUCING THE INTERMEDIATE TAPE AND THE COMPILE LISTING.

3 – FORTRAN COMPILER PASS 2 IS LOADED INTO THE COMPUTER

4 – INTERMEDIATE TAPE IS PROCESSED, PRODUCING THE OBJECT PROGRAM TAPE & THE ASSEMBLY LISTING

USING THE BASIC CONTROL SYSTEM

THE B.C.S. IS USED TO LOAD OBJECT PROGRAMS PRODUCED BY THE FORTRAN COMPILER AND THE SYMBOLIC ASSEMBLER.



① LOAD THE B.C.S. TAPE INTO THE COMPUTER.

② PROCESS (LOAD) THE OBJECT PROGRAM TAPE.

③ PROCESS (LOAD) THE REQUIRED LIBRARY ROUTINES.

NOTE: THE BASIC CONTROL SYSTEM ALSO CONTAINS SUBROUTINES THAT ARE USED TO CONTROL THE INPUT/OUTPUT EQUIPMENT.

UTILITY PROGRAMS

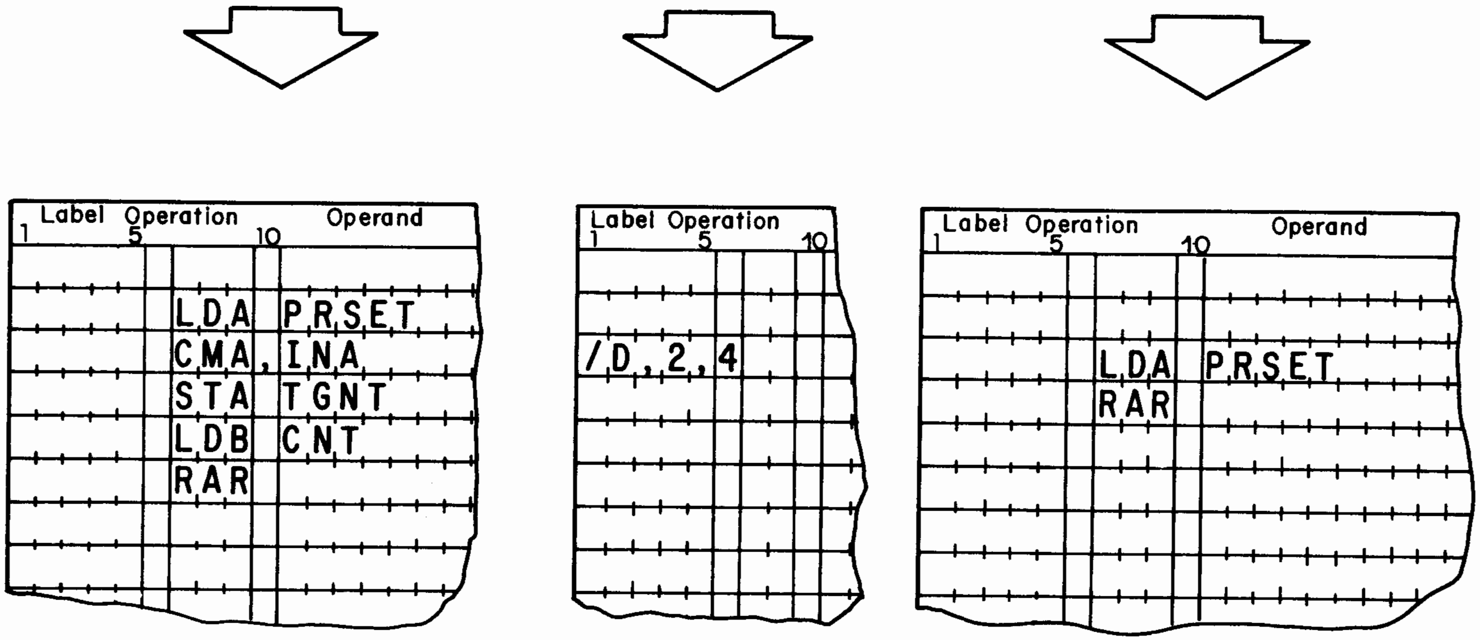
NAME		FUNCTION
FORTRAN-LIBRARY	—	Used primarily with compiler object programs. Standard mathematical subroutines for evaluating SIN, COSINE, SQUARE ROOT and other functions are found in the library.
PREPARE CONTROL SYSTEM	–	Used to create a BASIC CONTROL SYSTEM tailored to a specific hardware configuration.
HARDWARE DIAGNOSTICS	–	Used primarily in hardware maintenance to check the operation of the computer or peripheral equipment.
SYSTEM INPUT OUTPUT DUMP	–	Used to provide input-output flexibility for all HEWLETT-PACKARD standard software systems.
PREPARE TAPE SYSTEM	–	Used to create a magnetic tape operating system.
SYMBOLIC EDITOR	_	Used to make insertions, deletions, or replacements in source language program tapes.

EXAMPLE OF PROGRAM EDITING

ORIGINAL SOURCE PROGRAM

EDIT FILE, SHOWING CODING NEEDED TO DELETE STATEMENTS 2 THROUGH 4 FROM SOURCE PROGRAM

NEW SYMBOLIC FILE (SOURCE PROGRAM) PRODUCED BY EDITOR

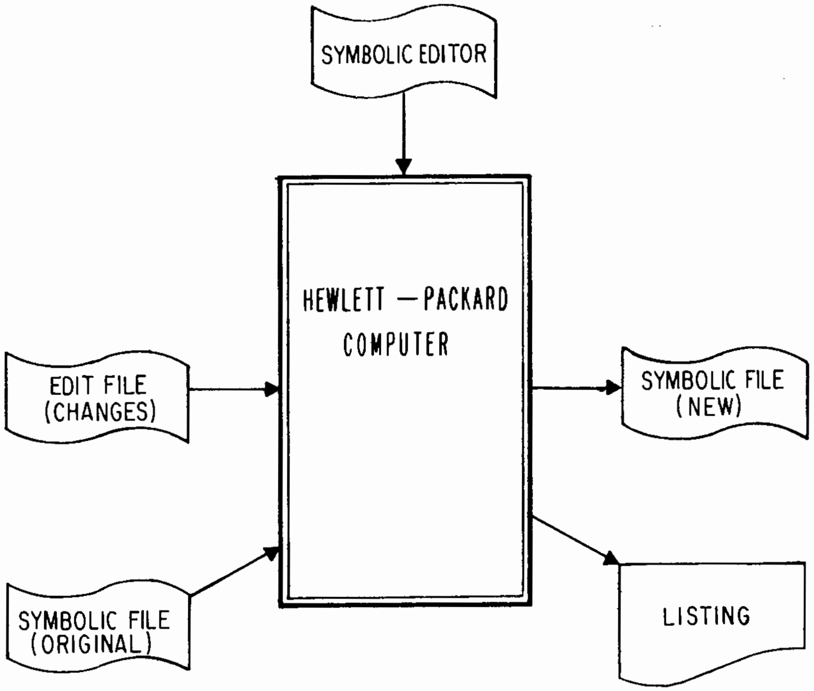


```
    LDA PRSET
    CMA,INA
    STA TGNT
    LDB CNT
    RAR
```

```
/D,2,4
```

```
    LDA PRSET
    RAR
```

EDITING PROCESS



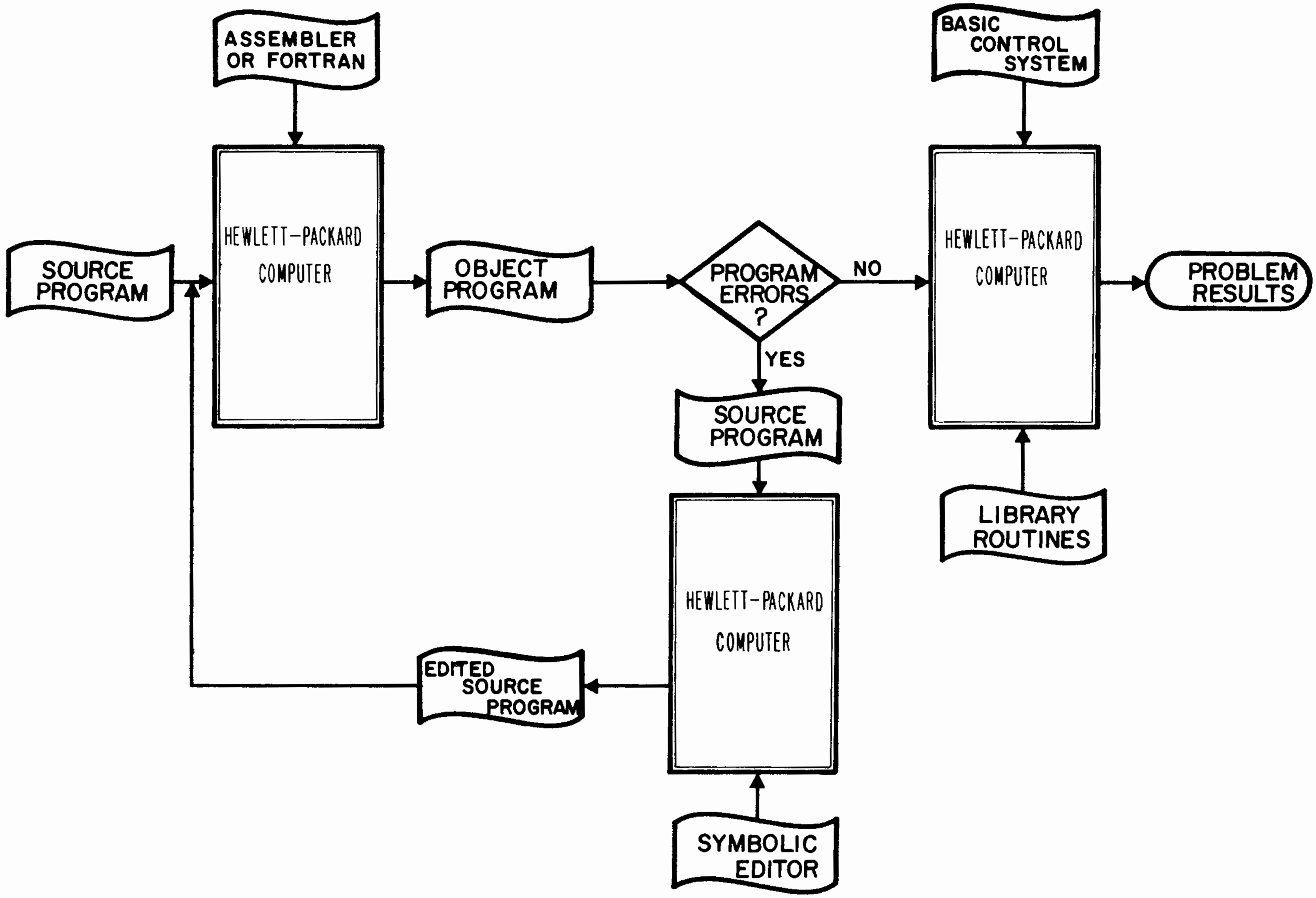
1 - SYMBOLIC EDITOR PROGRAM IS LOADED INTO THE COMPUTER

2 - THE EDIT FILE IS LOADED INTO THE COMPUTER

3 - THE ORIGINAL SYMBOLIC FILE IS PROCESSED, PRODUCING A NEW SYMBOLIC FILE

NOTE: LISTING A SYMBOLIC FILE REQUIRES A SECOND PASS

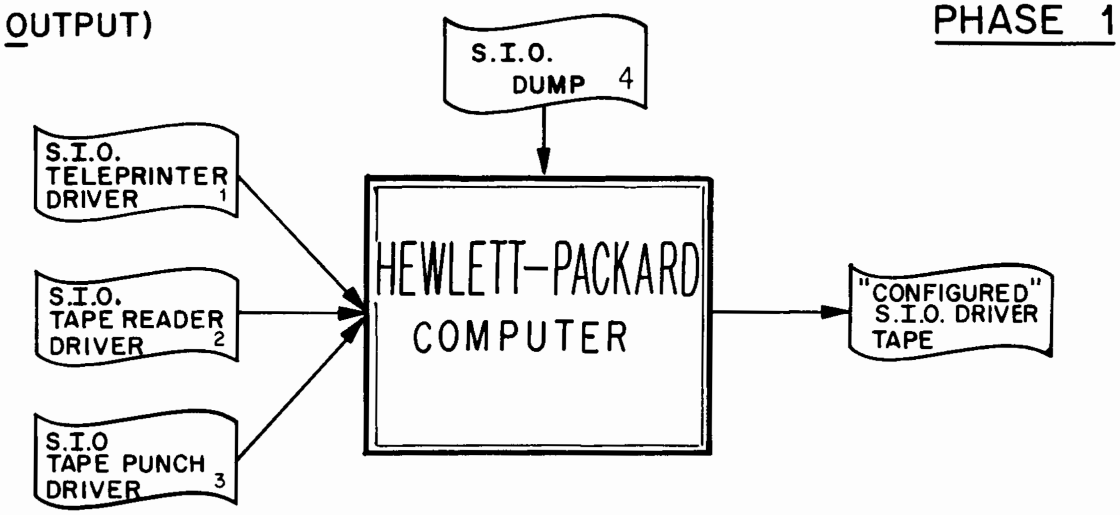
FORTRAN/ASSEMBLER PROGRAMMING ENVIRONMENT



S.I.O. CONFIGURATION PROCESS

(SYSTEM INPUT OUTPUT)

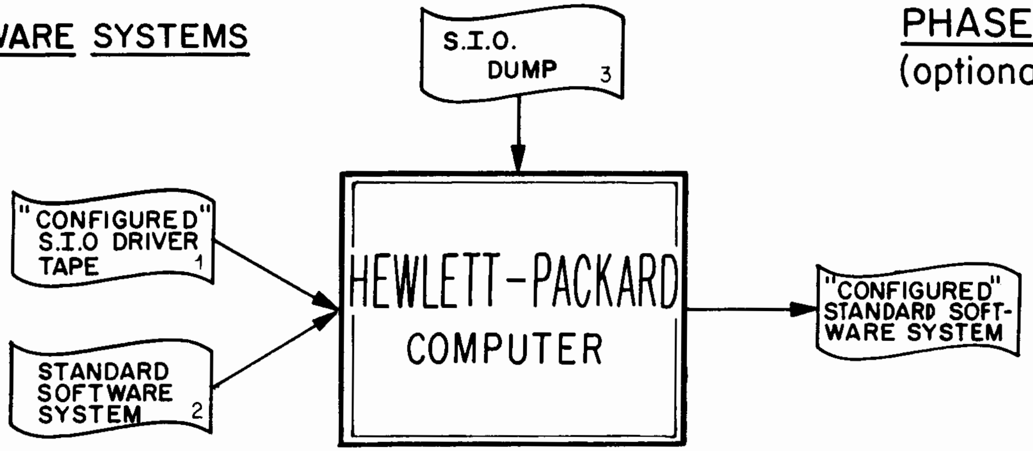
PHASE 1



STANDARD SOFTWARE SYSTEMS

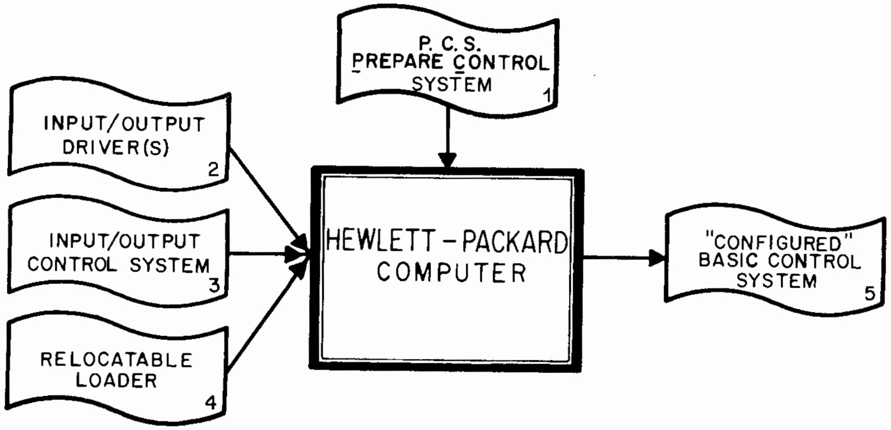
FORTRAN
ALGOL
ASSEMBLER
SYMBOLIC EDITOR

PHASE 2
(optional)



B.C. S. CONFIGURATION PROCESS

(BASIC CONTROL SYSTEM)

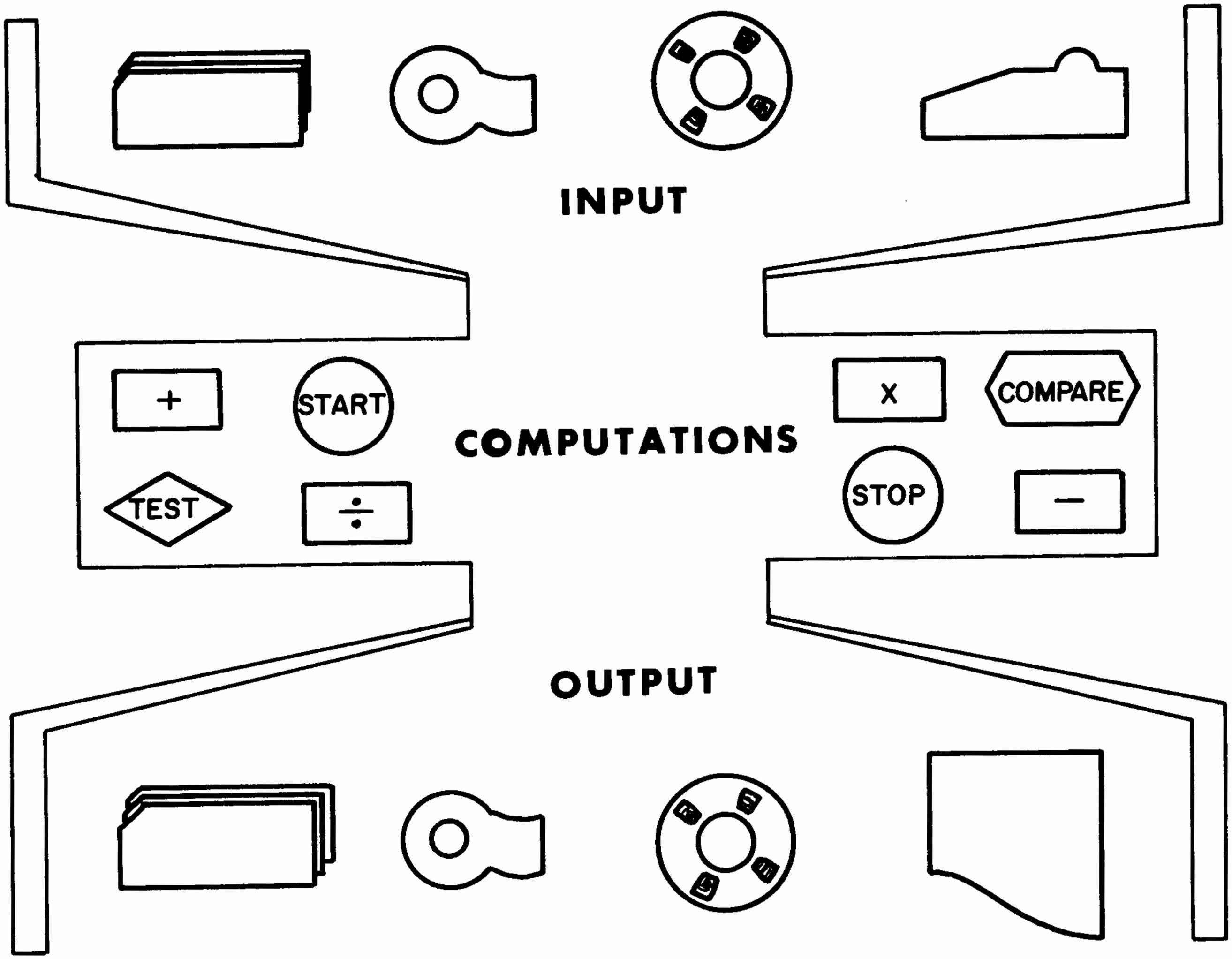


A BASIC CONTROL SYSTEM IS "TAILORED" TO THE HARDWARE CONFIGURATION OF THE SYSTEM.

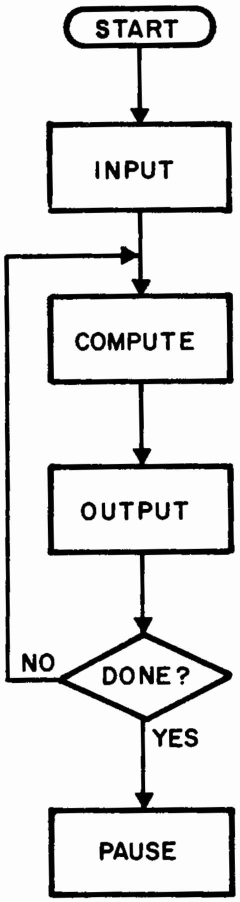
1. THE P.C.S CONTROL PROGRAM IS LOADED
2. THE INPUT/OUTPUT DRIVER (S) MODULE IS PROCESSED.
3. THE INPUT/OUTPUT CONTROL SYSTEM MODULE IS PROCESSED
4. THE RELOCATABLE LOADER MODULE IS PROCESSED
5. THE "CONFIGURED" B.C.S. TAPE IS PRODUCED.

THE COMPONENTS OF A COMPUTER PROGRAM

MOST COMPUTER PROGRAMS CONSIST OF THREE PARTS



EXAMPLE- DEFINING THE PROBLEM

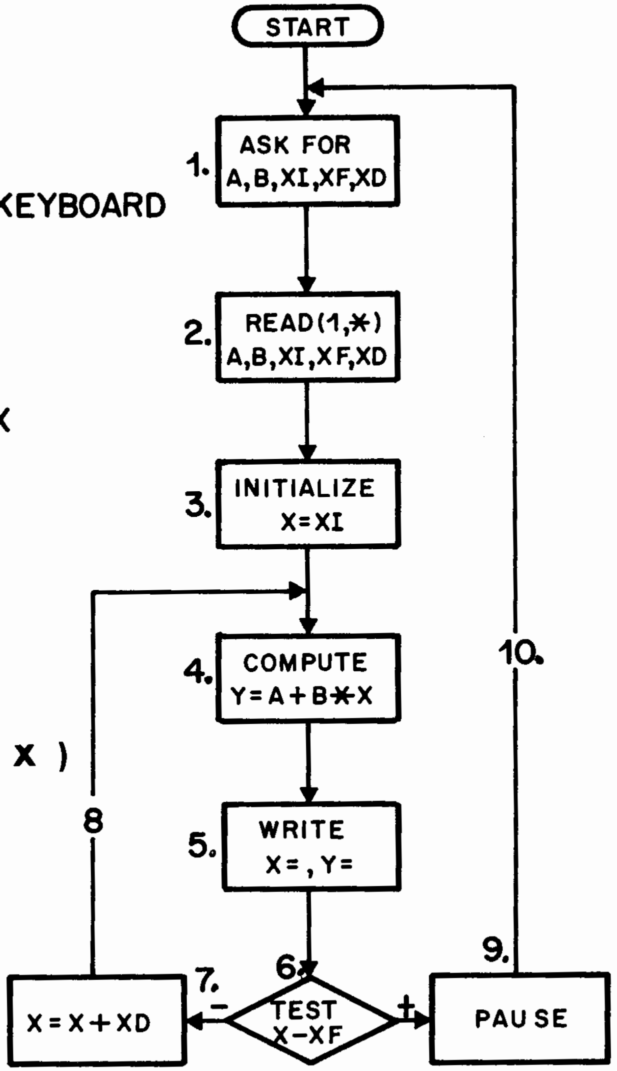


PROBLEM : SOLVE Y=A+B∗X
WHERE: A&B ARE ENTERED ON THE KEYBOARD

X TAKES ON THE VALUES:
XI - INITIAL VALUE OF X
XF - FINAL VALUE OF X
XD - INCREMENTAL VALUE FOR X

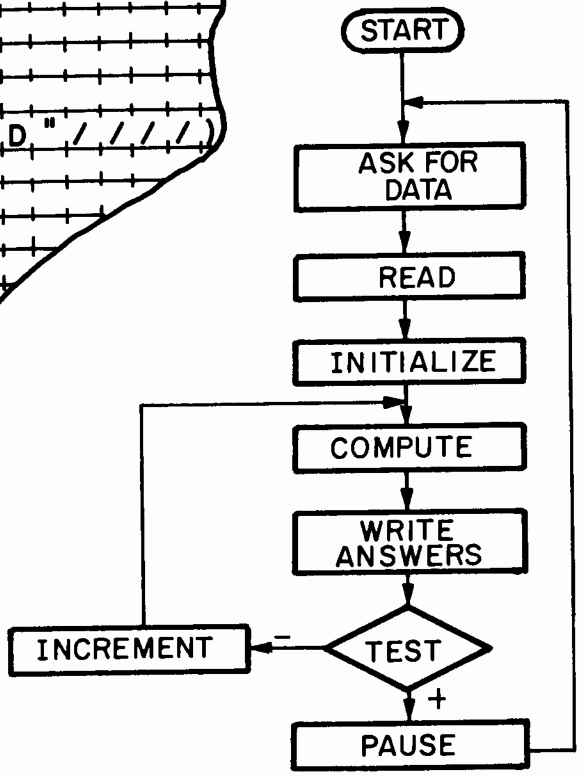
SOLUTION STEPS

1. ASK FOR A, B, XI, XF, XD
2. READ A, B, XI, XF, XD
3. INITIALIZE (X = XI)
4. CALCULATE (Y = A + B ∗ X)
5. WRITE X AND Y
6. IF X<XF, GO TO STEP 7.
   IF X≥XF, GO TO STEP 9.
7. ADD XD TO X
8. GO TO STEP 4
9. PAUSE
10. WHEN RUN IS PUSHED,
    GO TO STEP 1.

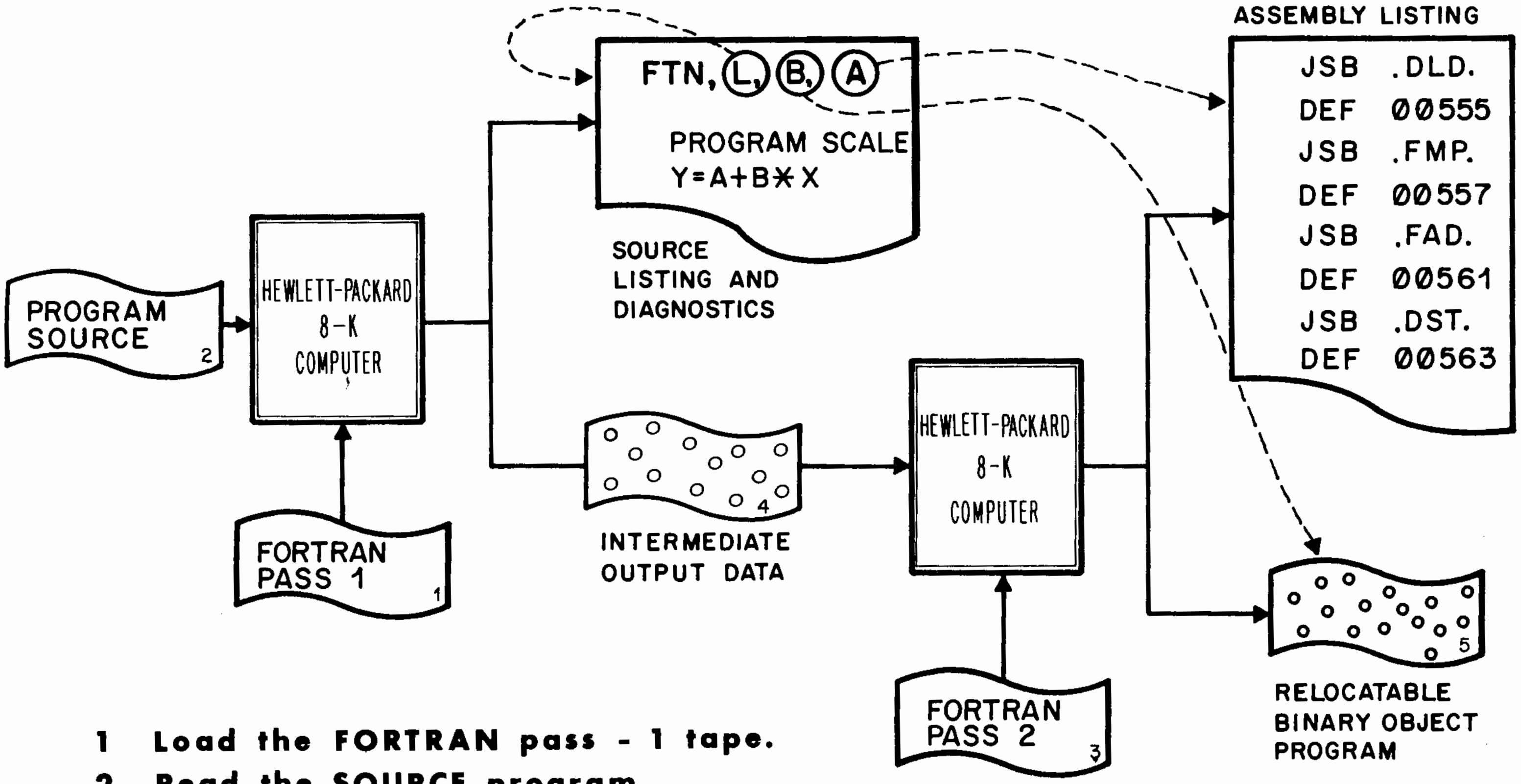


EXAMPLE- CODING THE PROGRAM

```
LABEL  C              STATEMENT
1    5 6 7
FTN,L,B,A
        PROGRAM SCALE

    1   WRITE(2,2Ø)
   2Ø   FORMAT("ENTER A,B,XI,XF,XD"////)

        READ(1,*)A,B,XI,XF,XD

        X=XI

    4   Y=A+B*X

        WRITE(2,3Ø)X,Y
   3Ø   FORMAT("(X,Y) = "2F12.4)

        IF (X-XF)7,9

    7   X=X+XD

        GO TO 4

    9   PAUSE

        GO TO 1

        END
        ENDS
```



COMPILING THE PROGRAM



1 Load the FORTRAN pass - 1 tape.

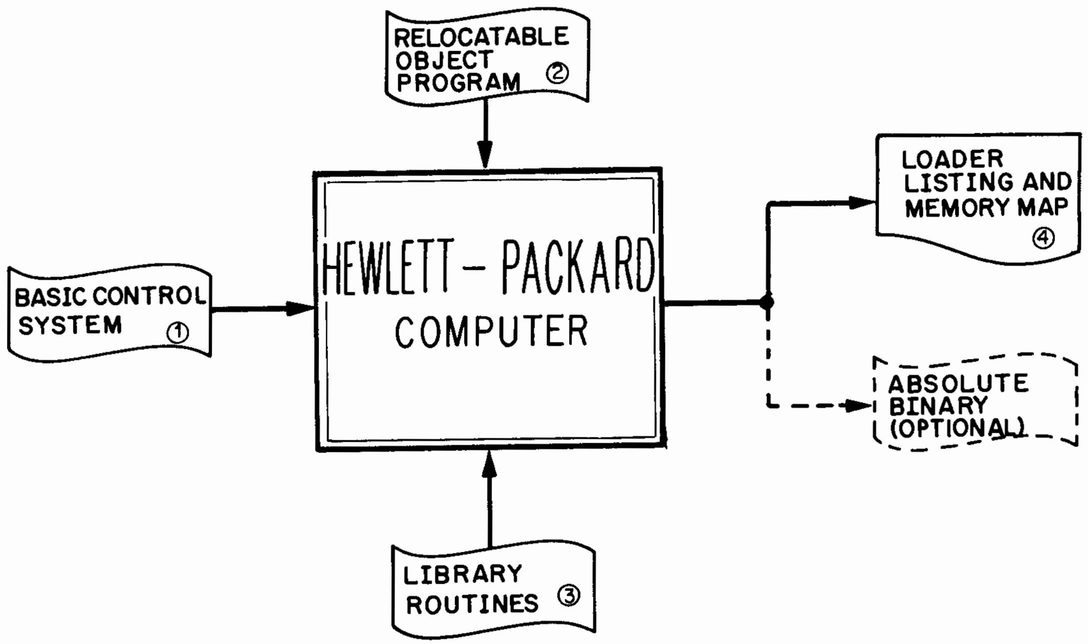
2 Read the SOURCE program.

3 Load the FORTRAN pass - 2 tape.

4 Read the INTERMEDIATE tape.

5 At this point compilation is complete.

LOADING THE OBJECT PROGRAM


RELOCATABLE OBJECT PROGRAM ②
BASIC CONTROL SYSTEM ①
HEWLETT-PACKARD COMPUTER
LOADER LISTING AND MEMORY MAP ④
ABSOLUTE BINARY (OPTIONAL)
LIBRARY ROUTINES ③

1 - LOAD THE BASIC CONTROL SYSTEM TAPE.

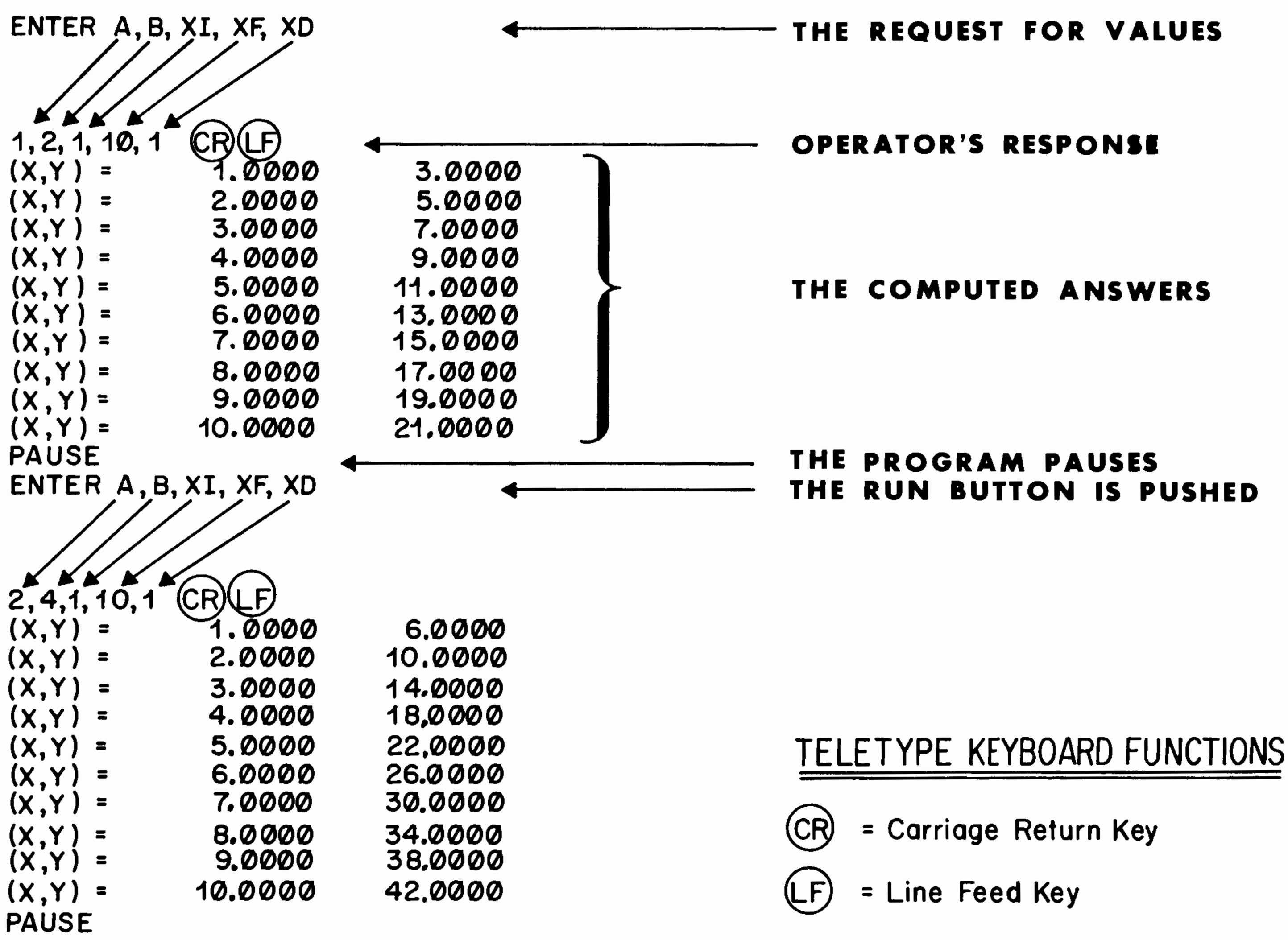
2 - PROCESS THE OBJECT PROGRAM TAPE.

3 - PROCESS THE LIBRARY TAPE.

4 - THE LOADER LISTING ENDS WITH THE MESSAGE "*RUN".

5 - DEPRESSING THE "RUN" PUSHBUTTON ALLOWS PROGRAM EXECUTION TO BEGIN.

EXAMPLE – THE PROGRAM IN EXECUTION



```
ENTER  A,B, XI, XF, XD

1,2,1,10,1 (CR)(LF)
(X,Y) =        1.0000      3.0000
(X,Y) =        2.0000      5.0000
(X,Y) =        3.0000      7.0000
(X,Y) =        4.0000      9.0000
(X,Y) =        5.0000     11.0000
(X,Y) =        6.0000     13.0000
(X,Y) =        7.0000     15.0000
(X,Y) =        8.0000     17.0000
(X,Y) =        9.0000     19.0000
(X,Y) =       10.0000     21.0000
PAUSE
ENTER  A,B, XI, XF, XD

2,4,1,10,1 (CR)(LF)
(X,Y) =        1.0000      6.0000
(X,Y) =        2.0000     10.0000
(X,Y) =        3.0000     14.0000
(X,Y) =        4.0000     18.0000
(X,Y) =        5.0000     22.0000
(X,Y) =        6.0000     26.0000
(X,Y) =        7.0000     30.0000
(X,Y) =        8.0000     34.0000
(X,Y) =        9.0000     38.0000
(X,Y) =       10.0000     42.0000
PAUSE
```

THE REQUEST FOR VALUES

OPERATOR'S RESPONSE

THE COMPUTED ANSWERS

THE PROGRAM PAUSES

THE RUN BUTTON IS PUSHED

TELETYPE KEYBOARD FUNCTIONS

(CR) = Carriage Return Key

(LF) = Line Feed Key

LESSON II OBJECTIVES

THE PRIMARY OBJECTIVE OF LESSON II IS:

EXPLAIN JUST ENOUGH OF FORTRANS DO'S AND DONT'S TO ENABLE THE STUDENT TO:

1 - WRITE A SIMPLE FORTRAN PROGRAM

2 - KEYPUNCH THE PROGRAM

3 - COMPILE THE PROGRAM

4 - LOAD AND EXECUTE THE PROGRAM

THE METHOD OF "LEARNING BY DOING" WILL BE USED WHENEVER POSSIBLE IN THIS COURSE.

AN INTRODUCTION TO

FORMULA TRANSLATION

FORMULATED STATEMENT

```
X=B*B-4.*A*C
```

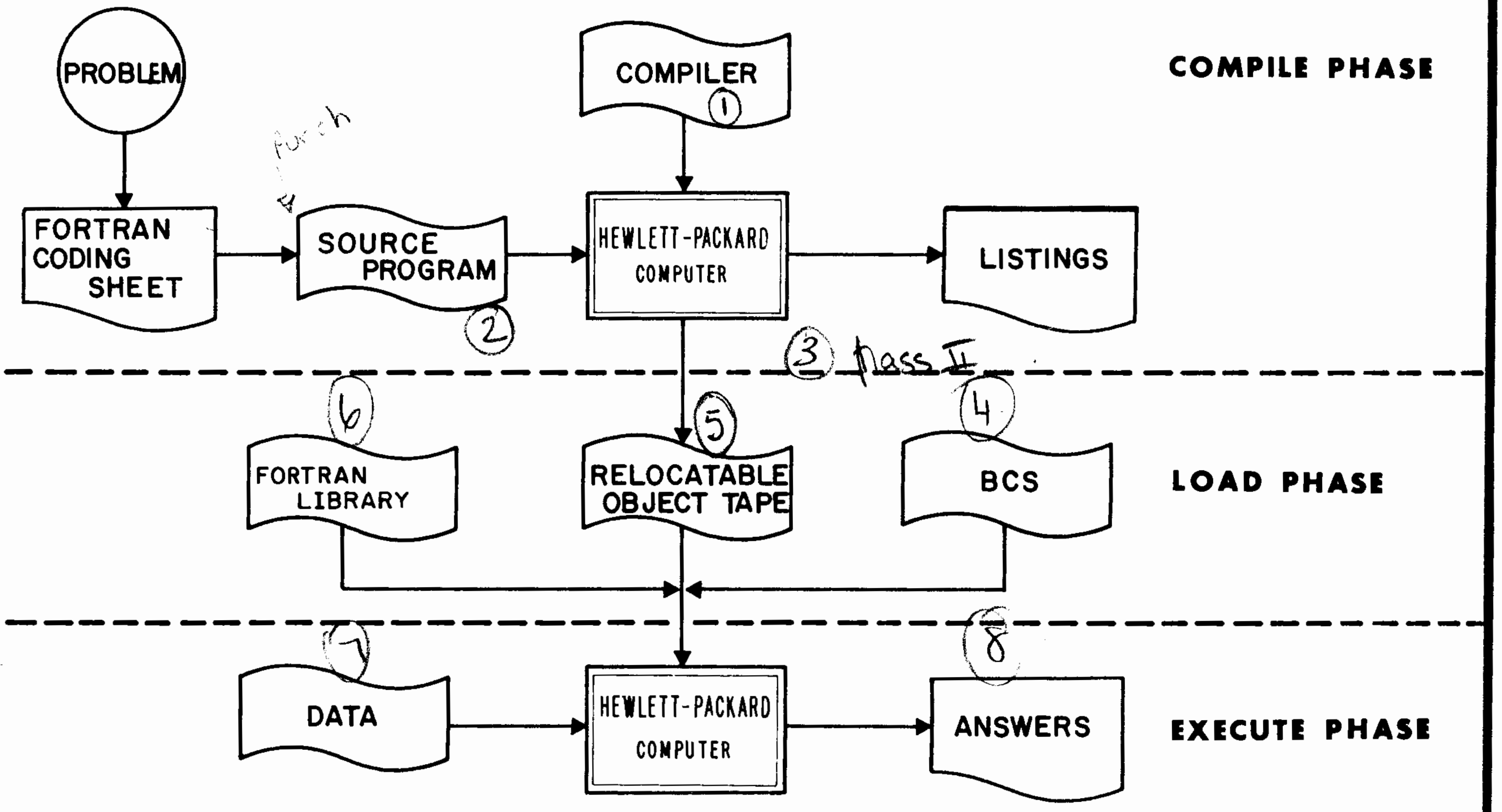
YOU WILL:

1.) GET ACQUAINTED WITH FORTRAN

2.) WRITE FORTRAN PROGRAMS

3.) OPERATE THE COMPUTER

FORTRAN OPERATING ENVIRONMENT



A	THROUGH Z
Ø	THROUGH 9
	SPACE
=	EQUALS means replace
+	PLUS
-	MINUS
*	ASTERISK
/	SLASH
( )	PARENTHESES
,	COMMA
$	DOLLAR SIGN
.	DECIMAL POINT
"	QUOTATION MARK

THE FORTRAN CHARACTER SET

2116A FORTRAN CODING FORM

PROGRAMMER | DATE | PROGRAM | PAGE OF

STATEMENT

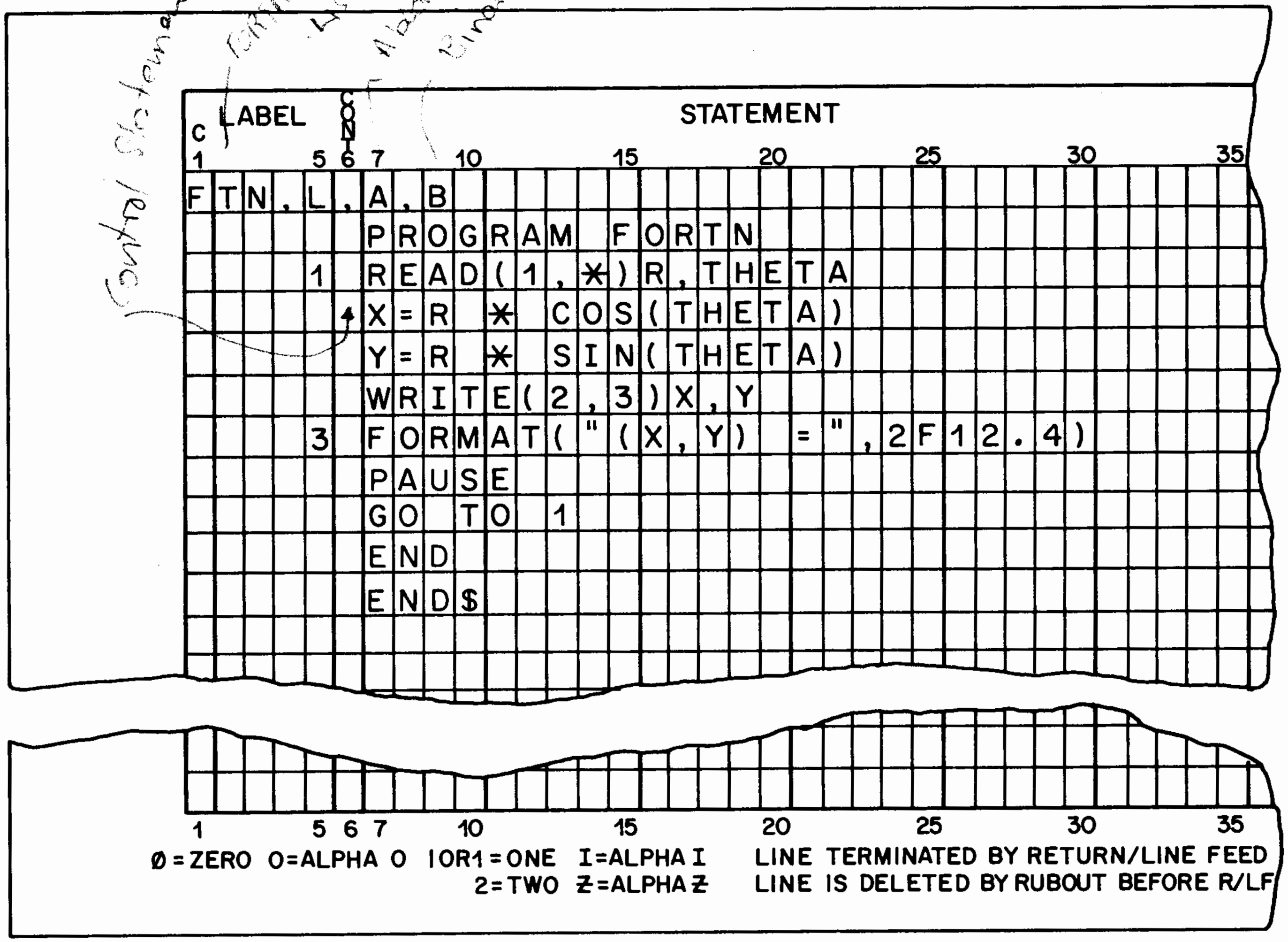
C 1 | Label 5 | CONT 6 | 7 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

LABEL FREE FIELD

1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

M0251

Ø = ZERO O = ALPHA O I OR 1 = ONE 2 = TWO I = ALPHA I Z = ALPHA Z LINE TERMINATED BY RETURN / LINE FEED (R/LF) LINE IS DELETED BY RUBOUT BEFORE R/LF



Control Statement

FORTRAN Listing Absolute Binary tape

```
C LABEL    C                 STATEMENT
           O
           N
           T
1       5  6 7   10       15        20       25       30      35
FTN,L,A,B
      PROGRAM FORTN
    1 READ(1,*)R,THETA
      X=R * COS(THETA)
      Y=R * SIN(THETA)
      WRITE(2,3)X,Y
    3 FORMAT("(X,Y) =",2F12.4)
      PAUSE
      GO TO 1
      END
      END$
1       5  6 7   10       15        20       25       30      35
```

∅=ZERO O=ALPHA O 1OR1=ONE I=ALPHA I LINE TERMINATED BY RETURN/LINE FEED
2=TWO Ƶ=ALPHA Ƶ LINE IS DELETED BY RUBOUT BEFORE R/LF

USING THE FORTRAN CODING FORM

FORTRAN STATEMENT LABEL RULES

1. LABELS ARE USED FOR REFERENCE BETWEEN PROGRAM STATEMENTS.

2. THE LABEL MAY CONSIST OF 1-4 NUMERIC DIGITS PLACED IN ANY OF THE FIRST FIVE POSITIONS OF A STATEMENT LINE. NO DUPLICATE LABELS ARE PERMITTED.

3. THE NUMBER IS UNSIGNED AND IN THE RANGE 1 TO 9999. THE LABELS DO NOT HAVE TO BE IN NUMERICAL SEQUENCE.

4. IMBEDDED SPACES AND LEADING ZEROS ARE IGNORED.

5. IF NO LABEL IS USED THE FIRST FIVE POSITIONS OF THE STATEMENT LINE MUST BE BLANK.

EXAMPLES

1	2	3	4	5	
				1	VALID LABELS
			1		
9	9	9	9		
9		9	9	9	
Ø	Ø	5	1	2	
A	B	C	D		INVALID LABELS
2	3	.	5		
3	4	5	6	7	

COMMENTS AND CONTINUATION STATEMENTS

COMMENTS ARE IDENTIFIED BY THE CHARACTER "C" IN COLUMN 1. POSITIONS 2-72 MAY CONTAIN THE COMMENT.

CONTINUATION STATEMENTS ARE IDENTIFIED BY ANY CHARACTER OTHER THAN "SPACE OR ZERO" IN COLUMN 6 AND DO NOT CONTAIN A "C" IN COLUMN 1.

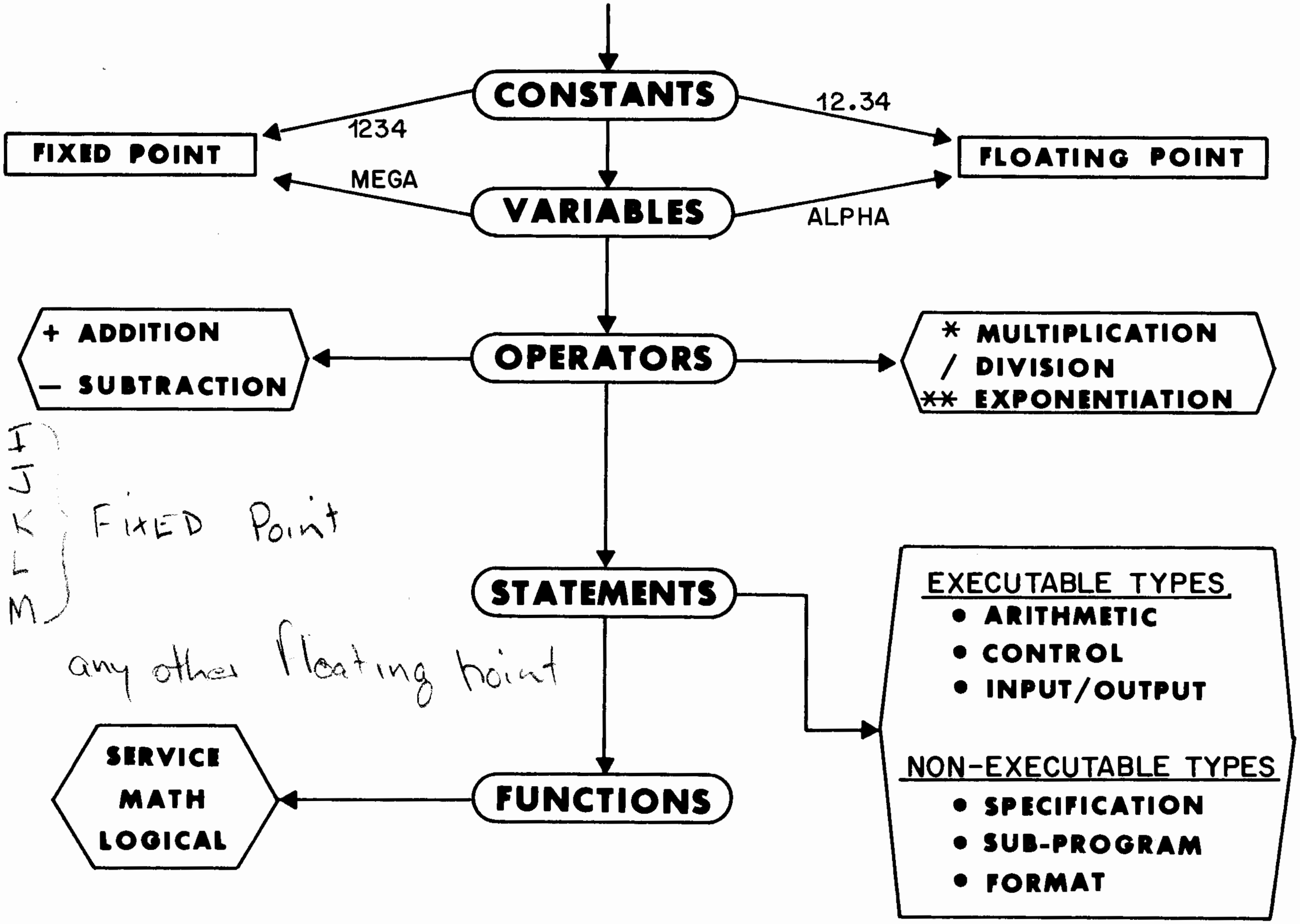
UP TO FIVE CONTINUATION LINES PER STATEMENT ARE PERMITTED.

COLUMNS 7-72 MAY BE USED FOR THE CONTINUATION STATEMENT.

EXAMPLES:

```
C LABEL CONT
1     5 6 7  10   15   20      65   70   75   80
CTHIS IS AN EXAMPLE OF A COMMENT
C
C***A CONTINUATION EXAMPLE******
      WRITE(2,1Ø)
   1Ø FORMAT(/"FORTRAN PROGRAMMI
     1NG EXAMPLE OF A CONTINUATI
     2ON STATEMENT")
```

THE FORTRAN LANGUAGE COMPONENTS



CONSTANTS

VARIABLES

OPERATORS

STATEMENTS

FUNCTIONS

FIXED POINT

FLOATING POINT

1234

MEGA

12.34

ALPHA

- + ADDITION
- — SUBTRACTION

- * MULTIPLICATION
- / DIVISION
- ** EXPONENTIATION

EXECUTABLE TYPES
- ARITHMETIC
- CONTROL
- INPUT/OUTPUT

NON-EXECUTABLE TYPES
- SPECIFICATION
- SUB-PROGRAM
- FORMAT

SERVICE
MATH
LOGICAL

I
J
K } FIXED Point
L
M

any other floating point

STATEMENTS

1.) **EXECUTABLE TYPES**

A - ARITHMETIC

B - CONTROL

1. **GO TO**
2. **IF**
3. **DO**
4. **CALL**
5. **PAUSE**
6. **CONTINUE**
7. **RETURN**
8. **END**

C - INPUT/OUTPUT

1. **READ**
   FREE-FIELD
   FORMATTED
2. **WRITE**
3. *REWIND*
4. *BACKSPACE*
5. *END FILE*

2.) **NON-EXECUTABLE TYPES**

A - SPECIFICATION

1. **DIMENSION**
2. *COMMON*
3. *EQUIVALENCE*

B - SUB-PROGRAM

1. **FUNCTION**
2. **PROGRAM**
3. **SUBROUTINE**

C - FORMATS

1. **QUOTE**
2. **I**
3. **F**
4. **SLASH**
5. **H**
6. **X**
7. **E**
8. **A**

FUNCTIONS

GROUP	TYPE	SYMBOL
SERVICE	TRANSFER SIGN	SIGN
	FLOAT	FLOAT
	FIX	IFIX
MATH	ABSOLUTE VALUE	ABS
	EXPONENTIAL	EXP
	NATURAL LOGARITHM	ALOG
	TRIGONOMETRIC SINE	SIN
	TRIGONOMETRIC COSINE	COS
	TRIGONOMETRIC TANGENT	TAN
	HYPERBOLIC TANGENT	TANH
	SQUARE ROOT	SQRT
	ARCTANGENT	ATAN
LOGICAL	BOOLEAN AND	IAND
	BOOLEAN OR	IOR
	BOOLEAN NOT	NOT

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= ANY QUANTITY REPRESENTED BY A NUMERIC VALUE

FIXED POINT CONSTANTS

REPRESENT INTEGER NUMBERS. THERE IS NO DECIMAL POINT. THE NUMBER MUST BE IN THE RANGE -32768 TO +32767. THE VALUE IS REPRESENTED BY ONE COMPUTER WORD.

EXAMPLES— 7, -5, +132, 697, 1234, 32715

FLOATING POINT CONSTANTS

REPRESENT REAL NUMBERS. THERE MUST BE A DECIMAL POINT. THE NUMBER MUST BE IN THE RANGE -10^{38} TO $+10^{38}$. THE NUMBER YIELDS A PRECISION OF SEVEN DECIMAL DIGITS AND IS REPRESENTED BY TWO COMPUTER WORDS:

THE FRACTION PLUS SIGN UTILIZES 24 BITS.
THE EXPONENT PLUS SIGN UTILIZES 8 BITS.

EXAMPLES— 7.,7.Ø, -7.,52.3, 4.12,.17, 75.

NOTE: IN FORTRAN .... 3 IS NOT THE SAME AS 3.

THEREFORE	3.+5 3 +5.	ARE NOT PERMITTED	BUT	3.+5. 5 +3	ARE PERMITTED

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= ANY QUANTITY REPRESENTED BY AN ALPHANUMERIC SYMBOL

FIXED POINT VARIABLES   **THEY REPRESENT INTEGER NUMBERS. THERE IS NO DECIMAL POINT. THEY RANGE FROM -32768 TO +32767**

EXAMPLES: I, J, K, L, M, N, IKE, JOHN, KEN,

FLOATING POINT VARIABLES   **THEY REPRESENT REAL NUMBERS. THEY ARE IN FLOATING POINT REPRESENTATION. THEY RANGE FROM -10^{38} TO $+10^{38}$.**

EXAMPLES: A, B, ·· H, O, P, ··· Ƶ, ALPHA, BETA, SIGMA,

NOTE: A VARIABLE NAME IS COMPOSED OF 5 OR LESS ALPHANUMERIC CHARACTERS.

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= SPECIAL CHARACTERS USED TO REPRESENT ARITHMETIC OPERATIONS + - * / **

WHEN OPERATORS ARE USED IN A STATEMENT TO FORM AN EXPRESSION, THE COMPILER EVALUATES THE EXPRESSION FROM LEFT TO RIGHT AND PERFORMS THE ARITHMETIC OPERATIONS IN THE FOLLOWING SEQUENCE:

CLASS 1 - ** EXPONENTIATION

CLASS 2 - * MULTIPLICATION
/ DIVISION

CLASS 3 - + ADDITION
— SUBTRACTION

EXCEPTION: OPERATIONS MAY BE GROUPED BY THE USE OF PARENTHESES. WHEN USED; EXPRESSIONS WITHIN PARENTHESES ARE EVALUATED FIRST, THEN**, THEN * AND /, THEN + AND– .

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= EXECUTABLE TYPES

ARITHMETIC

GENERAL FORM: $\alpha = \beta$

MUST BE A VARIABLE → α

$=$ **STANDS FOR "REPLACE"**

β → **MUST BE AN EXPRESSION**

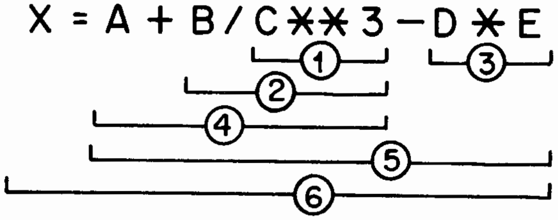
DEFINITION

AN EXPRESSION IS A COMBINATION OF CONSTANTS AND/OR VARIABLES SEPARATED BY OPERATORS.

EXAMPLE

LABEL 1 5	C 6	STATEMENT 7
17		X = A+B/C**3-D*E

WOULD BE SOLVED IN THIS ORDER



X = A + B / C ** 3 − D * E

FORTRAN ARITHMETIC

FORTRAN ARITHMETIC IS VERY SIMILAR TO CONVENTIONAL MATHEMATICAL NOTATION. ONE IMPORTANT DIFFERENCE CONCERNS THE LEFT SIDE OF THE EQUAL SIGN. IN FORTRAN, THE TERM ON THE LEFT SIDE OF THE EQUAL SIGN MUST BE SINGLE VALUED.

FOR EXAMPLE: ONE MIGHT SOLVE FOR X/5:

$$X/5=C^2+Y^2$$

IN FORTRAN, THIS IS NOT PERMITTED, THE ABOVE MUST BE WRITTEN:

```
X = 5. *(C**2+Y**2)
```

— ADDITIONAL EXAMPLES —

CONVENTIONAL NOTATION	FORTRAN NOTATION
$X=3Y$	`X=3*Y`
$N=6(K-2)$	`N=6*(K-2)`
$X+4=2Y$	`Y=(X+4.)/2.`
$\frac{Y}{2}=\frac{Z}{3}+\frac{X}{3}$	`Y=2.*((X+Z)/3.)`
$A^{(X+Y)}=Z$	`Z=A**(X+Y)`

ALGEBRAIC OPERATIONS IN FORTRAN

ALGEBRA	OPERATION	FORTRAN STATEMENT
$X = Y + Z$	Addition	X = Y + Z
$X = Y - Z$	Subtraction	X = Y - Z
$X = Y \cdot Z$	Multiplication	X = Y * Z
$X = Y/Z$	Division	X = Y/Z
$X = Y^Z$	Raise to a power	X = Y ** Z
$X = \sqrt{Y}$	Square Root	X = SQRT(Y)
$X = e^Y$	Natural Anti-Log	X = EXP(Y)
$X = SIN(Y)$	Sine	X = SIN(Y)
$X = COS(Y)$	Cosine	X = COS(Y)
$X = TAN^{-1}(Y)$	Arc Tangent	X = ATAN(Y)
$X = TANH(Y)$	Hyperbolic Tangent	X = TANH(Y)
$X = LN(Y)$	Natural Log	X = ALOG(Y)

A WORD OF CAUTION! ! !

THE USE OF REAL AND INTEGER VALUES WITHIN AN EXPRESSION MUST NOT BE MIXED.

INTEGER VALUES SHOULD BE USED IN INTEGER EXPRESSIONS

AND

REAL VALUES SHOULD BE USED IN REAL EXPRESSIONS

VALID EXAMPLES

```
I = 5
X = 5.Ø
J = I+3
Y = X+3.Ø
K = I+J*K-3
Z = X+Y*Z-3.Ø
```

INVALID EXAMPLES

```
I = 5+X*J       -   X IS A REAL VARIABLE
X = 5.+I*Y      -   I IS AN INTEGER VARIABLE
J = K/2.5       -   2.5 IS A REAL CONSTANT
Y = Z*A/5       -   5 IS AN INTEGER CONSTANT
```

LEGAL INTERMIXING OF INTEGER AND REAL VALUES

EXPONENTIATION:

A REAL NUMBER MAY BE RAISED TO AN INTEGER POWER:

```
X = B**I
```

AN INTEGER NUMBER MAY NOT BE RAISED TO A REAL POWER:

J=I ~~**~~ R

ACROSS THE EQUAL SIGN

AN INTEGER MAY BE SET EQUAL TO A REAL EXPRESSION:

```
I = X
```

A REAL NUMBER MAY BE SET EQUAL TO AN INTEGER:

```
X= I
```

EXPONENTIAL AND CONVERSION LIBRARY ROUTINES

.RTOI	REAL NUMBER TO INTEGER POWER
.RTOR	REAL NUMBER TO REAL POWER
.ITOI	INTEGER TO INTEGER POWER
FLOAT	INTEGER TO FLOATING POINT CONVERSION
IFIX	FLOATING POINT TO INTEGER CONVERSION

EVALUATION PROBLEM

GIVEN:

THE FORTRAN STATEMENT: X=A*B**C/D $X = A*B^{C/D}$

PROBLEM:

WHICH OF THE FOLLOWING IS A CORRECT INTERPRETATION OF THE STATEMENT GIVEN?

a.) $X=[A*B]^{(C/D)})$ c.) $X=\frac{[A*B]^{C}}{D}$

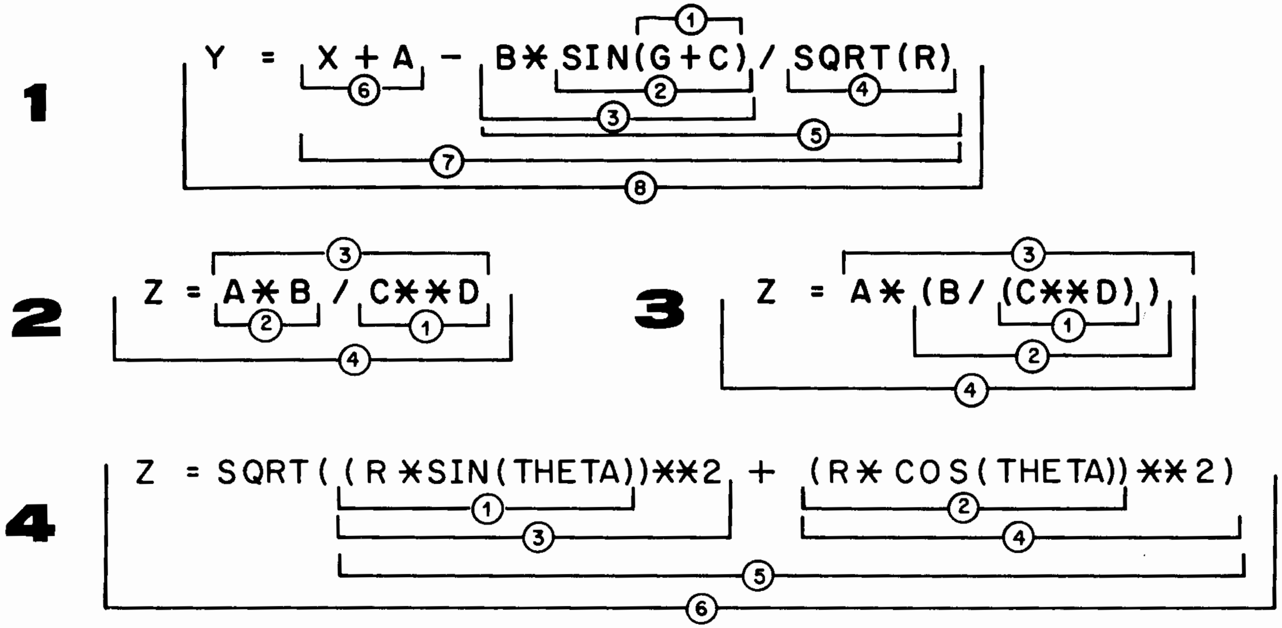
b.) $X=A*[B^{(C/D)}]$ d.) $X=\frac{A*(B)^{C}}{D}$

RULES:

- **EXPRESSIONS IN PARENTHESES ARE EVALUATED FIRST**
- **THEN **, THEN * AND /, THEN + AND –.**
- **STATEMENT SCANNING IS FROM LEFT TO RIGHT**

SUMMARY

EVALUATION OF STATEMENTS



```
1   Y = X + A - B* SIN(G+C)/ SQRT(R)

2   Z = A*B / C**D

3   Z = A* (B/ (C**D) )

4   Z = SQRT( (R *SIN(THETA))**2 + (R* COS( THETA)) **2 )
```

VARIABLE NAMES

- INteger names start with I,J,K,L,M,N
- REAL names start with A through H and O through Z
- Names have FIVE or LESS alphanumeric characters, the first being a letter

FORTRAN LIBRARY FUNCTIONS INCLUDE:

Y = SQRT (X)
Y = EXP (X)
Y = ALOG (X)
Y = SIN (X)

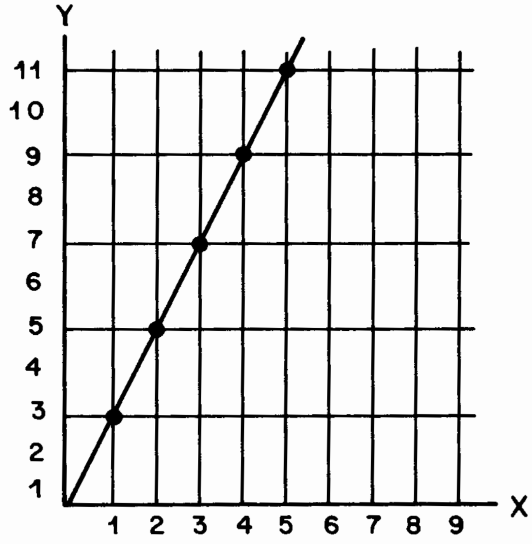
Y = COS (X)
Y = TAN (X)
Y= ATAN (X)
Y = TANH (X)

SAMPLE PROBLEM - IN-LINE CODING

PROBLEM

SOLVE Y=A+B·X
Where A=1, B=2 AND X=1,2,3,4,5....

SOLUTION



LABEL 1 5	C 6	STATEMENT 7
		A = 1. Ø
		B = 2. Ø
		X = 1. Ø
23		Y = A + B ✱ X
		X = 2. Ø
45		Y = A + B ✱ X
		X = 3. Ø
35		Y = A + B ✱ X
		X = 4. Ø
32		Y = A + B ✱ X

ETC

NOTE:
Y TAKES THE VALUES 3,5,7,9,11,13, ...

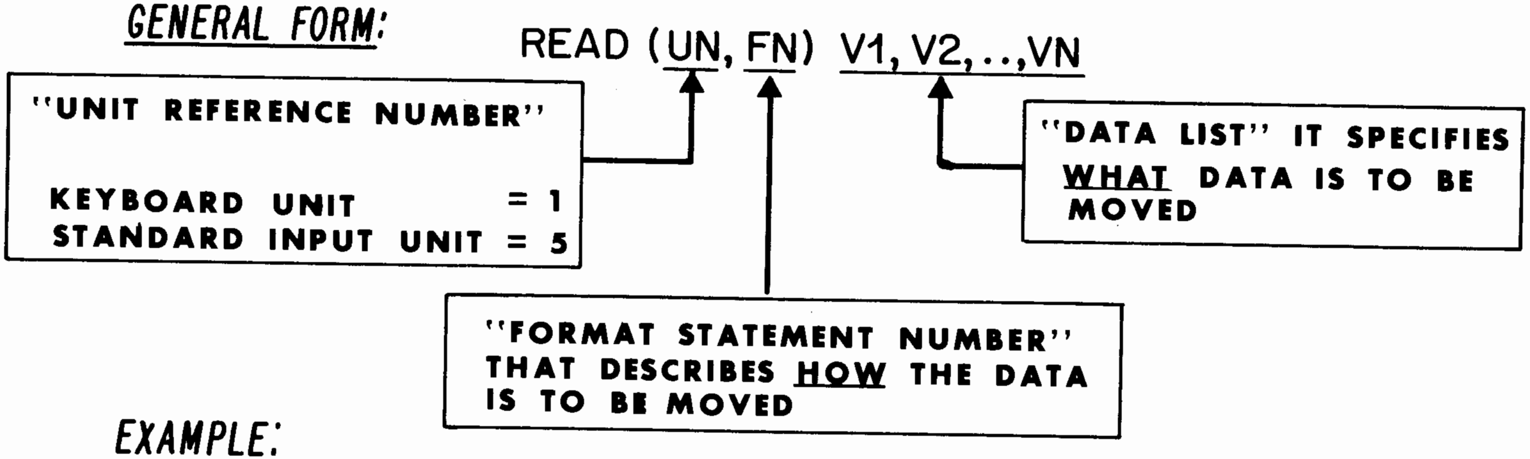
CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= EXECUTABLE TYPES

INPUT/OUTPUT — THE **READ** STATEMENT

THE READ STATEMENT READS DATA FROM AN INPUT DEVICE

GENERAL FORM:



READ (UN, FN) V1, V2,..,VN

"UNIT REFERENCE NUMBER"

KEYBOARD UNIT = 1
STANDARD INPUT UNIT = 5

"FORMAT STATEMENT NUMBER" THAT DESCRIBES HOW THE DATA IS TO BE MOVED

"DATA LIST" IT SPECIFIES WHAT DATA IS TO BE MOVED

EXAMPLE:

```
 LABEL  C          STATEMENT
1     5 6 7
          READ(1,7)IX,Y
```

MEANS READ THE VALUES FOR IX AND Y FROM THE KEYBOARD AS PER FORMAT STATEMENT #7

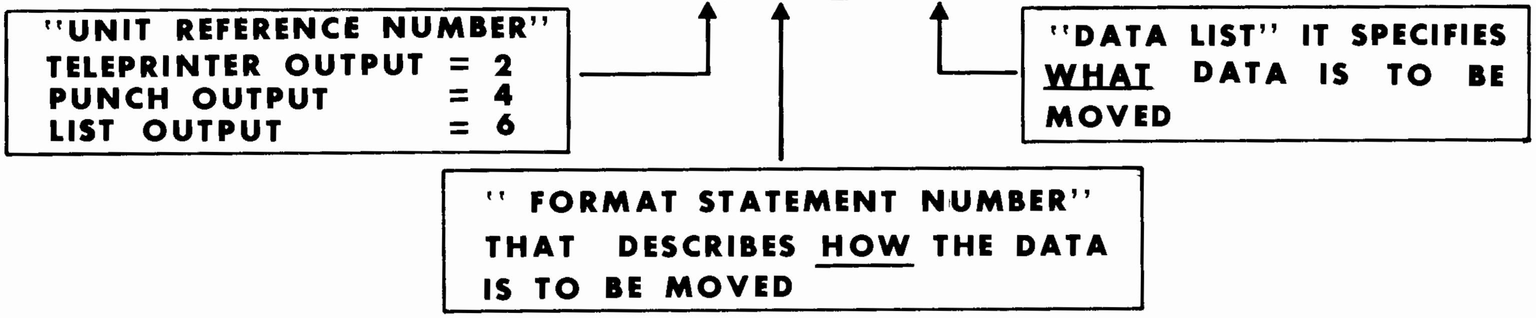
CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= <u>EXECUTABLE TYPES</u>

INPUT/OUTPUT — THE **WRITE** STATEMENT

THE WRITE STATEMENT WRITES INFORMATION ON AN OUTPUT DEVICE

GENERAL FORM: WRITE (UN, FN) V1, V2, . . , VN



"UNIT REFERENCE NUMBER"

TELEPRINTER OUTPUT	= 2
PUNCH OUTPUT	= 4
LIST OUTPUT	= 6

" FORMAT STATEMENT NUMBER" THAT DESCRIBES **HOW** THE DATA IS TO BE MOVED

"DATA LIST" IT SPECIFIES **WHAT** DATA IS TO BE MOVED

EXAMPLE:

```
LABEL    |C| STATEMENT
1       5|6|7
         | |WRITE(2,17)I2,PHI
```

MEANS

WRITE THE VALUES OF I2 AND PHI ON THE TELETYPE AS PER FORMAT STATEMENT #17

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= NON-EXECUTABLE TYPES

FORMATS – THE GENERAL SPECIFICATIONS

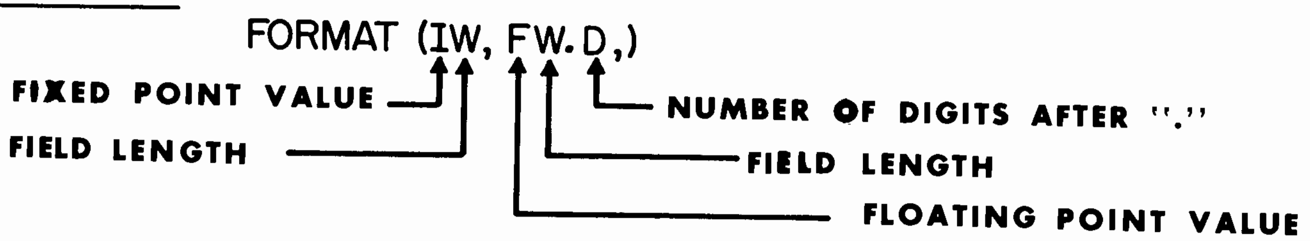
A FORTRAN FORMAT STATEMENT TELLS

1- The length of the fields - I.E. the number of characters allocated to each variable in the data list

2- The mode of the values - I.E. fixed or floating point

3- Position of the decimal point- only for floating point

GENERAL FORM:



FORMAT (IW, FW.D,)

FIXED POINT VALUE

FIELD LENGTH

NUMBER OF DIGITS AFTER "."

FIELD LENGTH

FLOATING POINT VALUE

EXAMPLE:

LABEL 1 5	C 6	STATEMENT 7
59		FORMAT(I4,F10.4)

MEANS

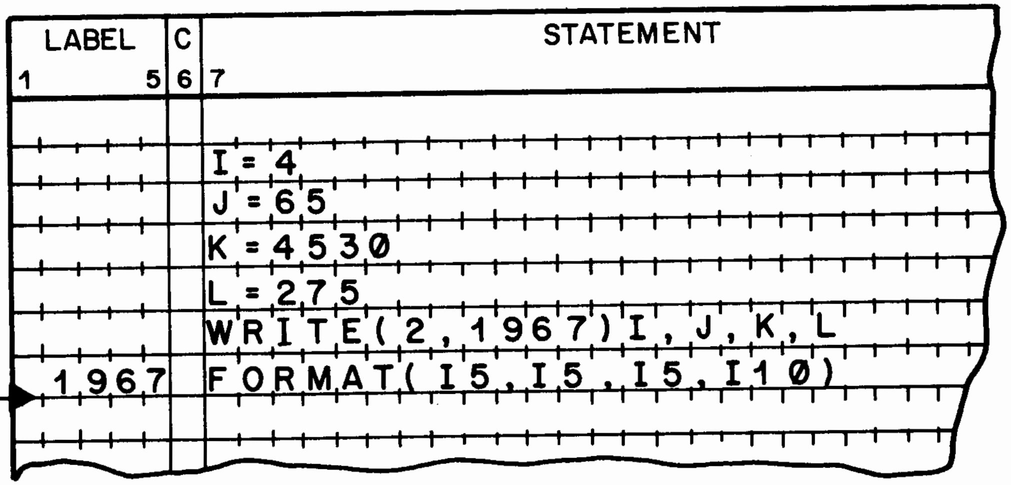
THE FIRST VALUE IS FIXED POINT (INTEGER) 4 CHARACTERS LONG
THE SECOND VALUE IS FLOATING POINT 10 DIGITS LONG WITH 4 DIGITS AFTER "."

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= NON-EXECUTBLE TYPES

FORMATS – THE I FORMAT

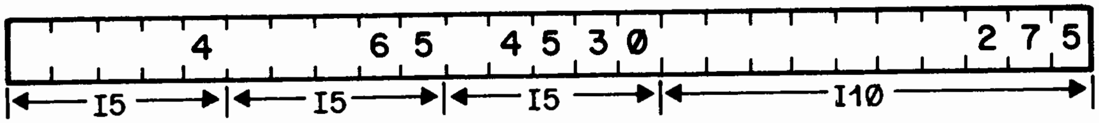
THE I FORMAT IS USED TO DEFINE THE SPECIFICATIONS OF **INTEGER** VALUES.



```
      I=4
      J=65
      K=4530
      L=275
      WRITE(2,1967)I,J,K,L
 1967 FORMAT(I5,I5,I5,I10)
```

THIS FORMAT

DEFINES → INTEGER DATA SPECIFICATIONS



CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

= NON-EXECUTABLE TYPES

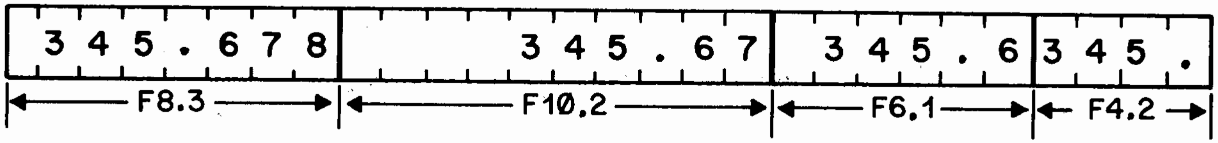
FORMATS — THE F FORMAT

THE F FORMAT IS USED TO DEFINE THE SPECIFICATIONS OF FLOATING POINT VALUES.

```
LABEL  |C| STATEMENT
1     5|6|7
       | |
       | |A=345.678
       | |WRITE(2,1Ø)A,A,A,A
   1Ø  | |FORMAT(F8.3,F1Ø.2,F6.1,F4.2)
```

THIS FORMAT

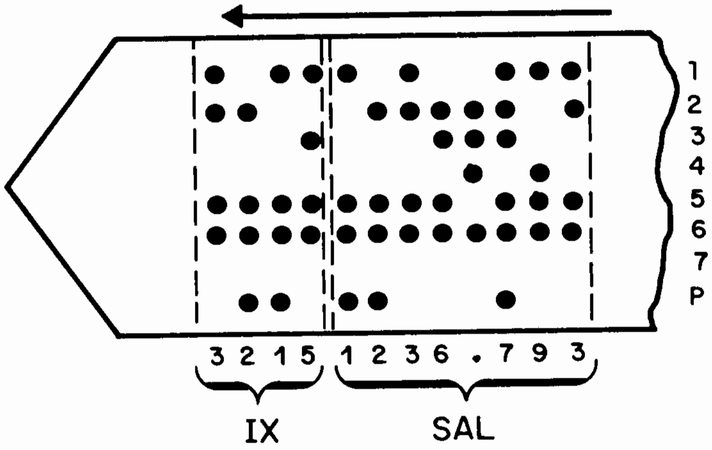
DEFINES **FLOATING POINT DATA SPECIFICATIONS**



EXAMPLE: **USING THE I AND F FORMAT WITH A READ STATEMENT**

READ FROM THE PHOTOREADER IX AND SAL
IX IS 4 CHARACTERS LONG
SAL IS 8 CHARACTERS LONG, 3 OF WHICH ARE AFTER THE DECIMAL POINT

ASCII CODE

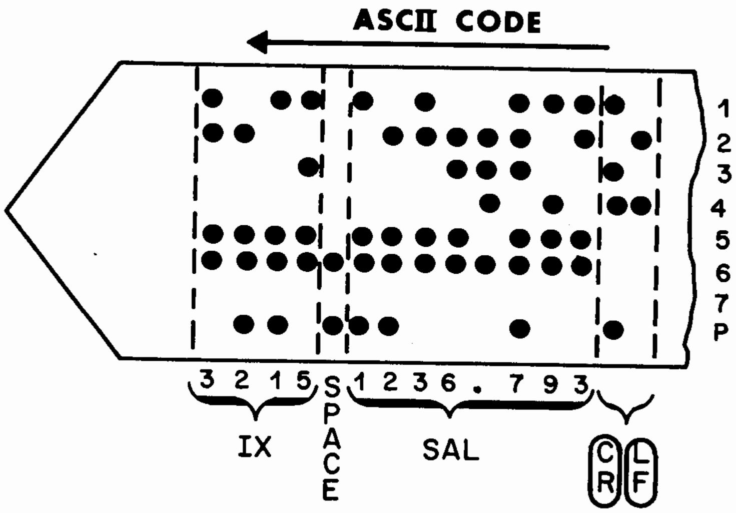


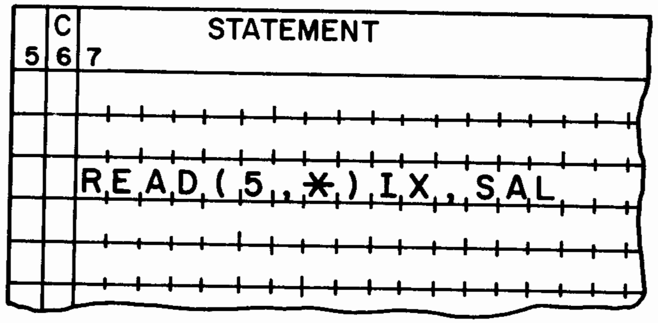
LABEL 1 5	C 6	STATEMENT 7
		READ(5,62)IX,SAL
62		FORMAT(I4,F8.3)

FREE FIELD INPUT

FREE FIELD INPUT PERMITS THE READING OF NUMERIC DATA WITHOUT A DEFINITIVE FORMAT STATEMENT. DATA ITEMS ARE SEPARATED BY SPACES OR A COMMA. THE ASTERISK (*) CHARACTER IS USED IN PLACE OF THE FORMAT NUMBER IN THE READ STATEMENT TO DEFINE THE FREE FIELD MODE OF INPUT.

EXAMPLE: USING FREE FIELD INPUT, READ VALUES FOR IX AND SAL



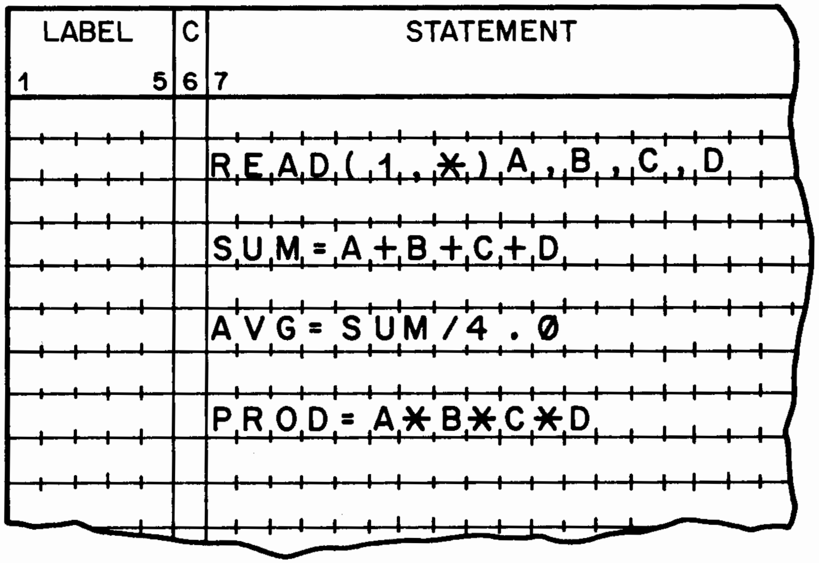


```
READ(5,*)IX,SAL
```

SAMPLE PROBLEM - FREE-FIELD DATA INPUT

PROBLEM: READ FOUR NUMBERS FROM THE KEYBOARD AND CALCULATE THE SUM, AVERAGE AND PRODUCT.

SOLUTION



LABEL 1 5	C 6	STATEMENT 7
		READ(1,*)A,B,C,D
		SUM=A+B+C+D
		AVG=SUM/4.Ø
		PROD=A*B*C*D

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

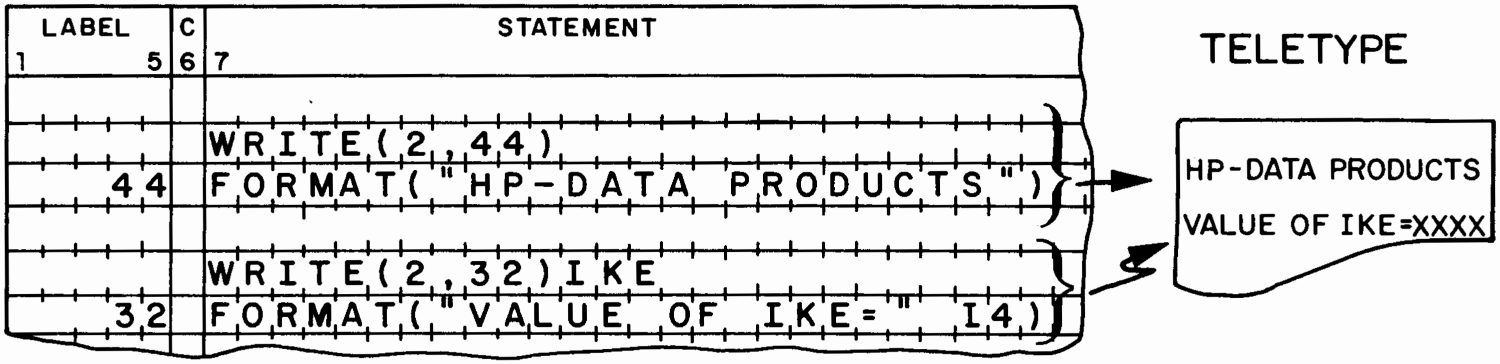
– NON-EXECUTABLE TYPES

FORMATS – THE QUOTE FORMAT

THE QUOTE FORMAT IS USEFUL FOR WRITING MESSAGES AND HEADINGS ON AN OUTPUT DEVICE. TO ACCOMPLISH THIS YOU ENCLOSE THE MESSAGE IN QUOTATION MARKS.

EXAMPLE:

THE FOLLOWING STATEMENTS WILL GENERATE CODING TO PRODUCE MESSAGES ON THE TELETYPE:



```
LABEL  C  STATEMENT
1    5 6 7

          WRITE(2,44)
   44     FORMAT("HP-DATA PRODUCTS")

          WRITE(2,32)IKE
   32     FORMAT("VALUE OF IKE=" I4)
```

TELETYPE

```
HP-DATA PRODUCTS
VALUE OF IKE=XXXX
```

SAMPLE PROBLEM–DATA OUTPUT

EXAMPLE: USING THE I,F AND QUOTE FORMATS WITH A WRITE STATEMENT.

WRITE ON THE TELETYPE THE HEADING "J K". THEN WRITE THE VALUES OF J AND K WHERE J IS 3 CHARACTERS LONG AND K IS 2 CHARACTERS LONG.

SAY J=354
K=62

```
  J  K
35462
```

TTY OUTPUT

NOW, WRITE THE HEADING "VALUE" AND THE VALUE OF V, WHERE V IS XX.XX (SAY 1.75)

```
  J  K
35462
VALUE
 1.75
```

TTY OUTPUT

```
LABEL C  STATEMENT
1   5 6  7
      WRITE(2,3)
      WRITE(2,7)J,K
    7 FORMAT(I3,I2)
    3 FORMAT("  J  K")

      WRITE(2,6)
      WRITE(2,37)V
    6 FORMAT("VALUE")
   37 FORMAT(F5.2)
```

LESSON III OBJECTIVES

TO INSTRUCT THE STUDENT IN THE USE OF THE HEWLETT - PACKARD SYMBOLIC EDITOR PROGRAM. MASTERING THE USE OF THE SYMBOLIC EDITOR WILL ALLOW THE STUDENT TO CORRECT ERRORS IN SOURCE LANGUAGE PROGRAMS BY REPLACING, DELETING OR INSERTING THE APPROPRIATE STATEMENT (S).

THE SYMBOLIC EDITOR SYSTEM

DEFINITION ------A software program for maintenance functions associated with development of computer programs.

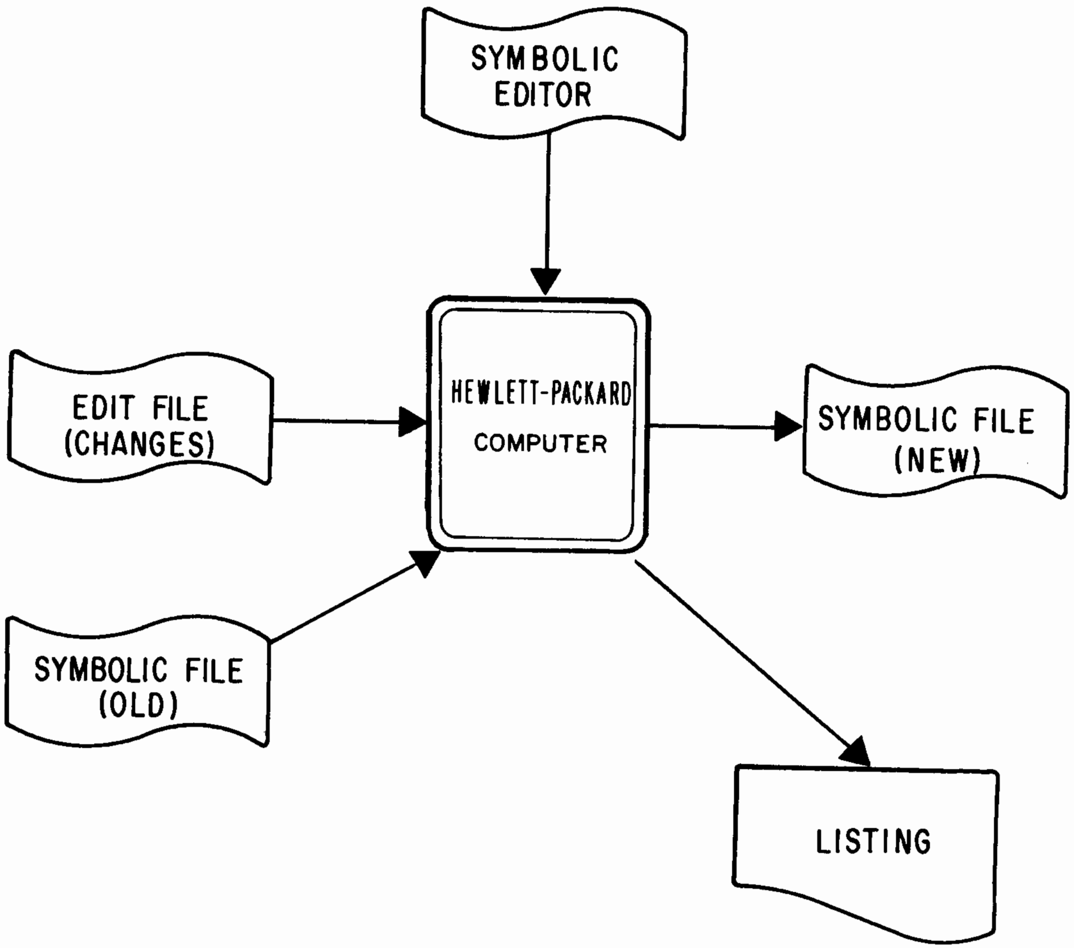
PURPOSE -------Provides a method for editing and updating symbolic source language programs or files.

MAJOR PROGRAM CAPABILITIES

1) Provides for the insertion, deletion and replacement of:
   - Entire source statements
   - Characters within a source statement

2) Provides a listing of a source program

3) Produces an updated source tape



EDIT PROCESS

EDITOR RULES AND FORMATS

- ▶ ALL CONTROL STATEMENTS BEGIN WITH THE CHARACTER SLASH (/).
- ▶ ALL STATEMENTS ARE TERMINATED BY A CARRIAGE RETURN, LINE FEED CODE. (CR, LF)
- ▶ THE EDIT FILE IS TERMINATED BY A (/E) CONTROL STATEMENT.
- ▶ ALL STATEMENTS ARE REFERRED TO BY THEIR SEQUENCE IN THE SOURCE FILE.

STATEMENT EDITING

$/e, r_1$ $[, r_2]$ where:

e = An editing code: I, D or R

r's = Sequence numbers in the range 1 through 9999. r_2, if specified, must be greater than r_1.

CHARACTER EDITING

$/ee, r, c_1$ $[, c_2]$ where:

ee = An editing code: CI, CD, or CR

r = Sequence number in the range 1 through 9999.

c's = Character positions within the record that are to be edited. Blank positions must be included in the character count. An edited statement MAY NOT exceed 72 characters.

STATEMENT INSERTIONS

EXAMPLE: If we wanted to insert four statements into the original source program following statement number 3

(symbolic file)

PROGRAMMER

	Label (1–5)	Operation (10)	Operand (15)
1	READ	LDA	PRSET
2		CMA,INA	
3		STA	TGNT
4		JMP	WAIT

PROGRAMMER

Label (1–5)	Operation (10)	Operand (15)
/I,3		
	CLA	
NEXT	RAR	
	STC	13B,C
WAIT	SFS	13B
/E		

PROGRAMMER

Label (1–5)	Operation (10)	Operand (15)
READ	LDA	PRSET
	CMA,INA	
	STA	TGNT
	CLA	
NEXT	RAR	
	STC	13B,C
WAIT	SFS	13B
	JMP	WAIT

This coding would be necessary to create an updated file (edit file)

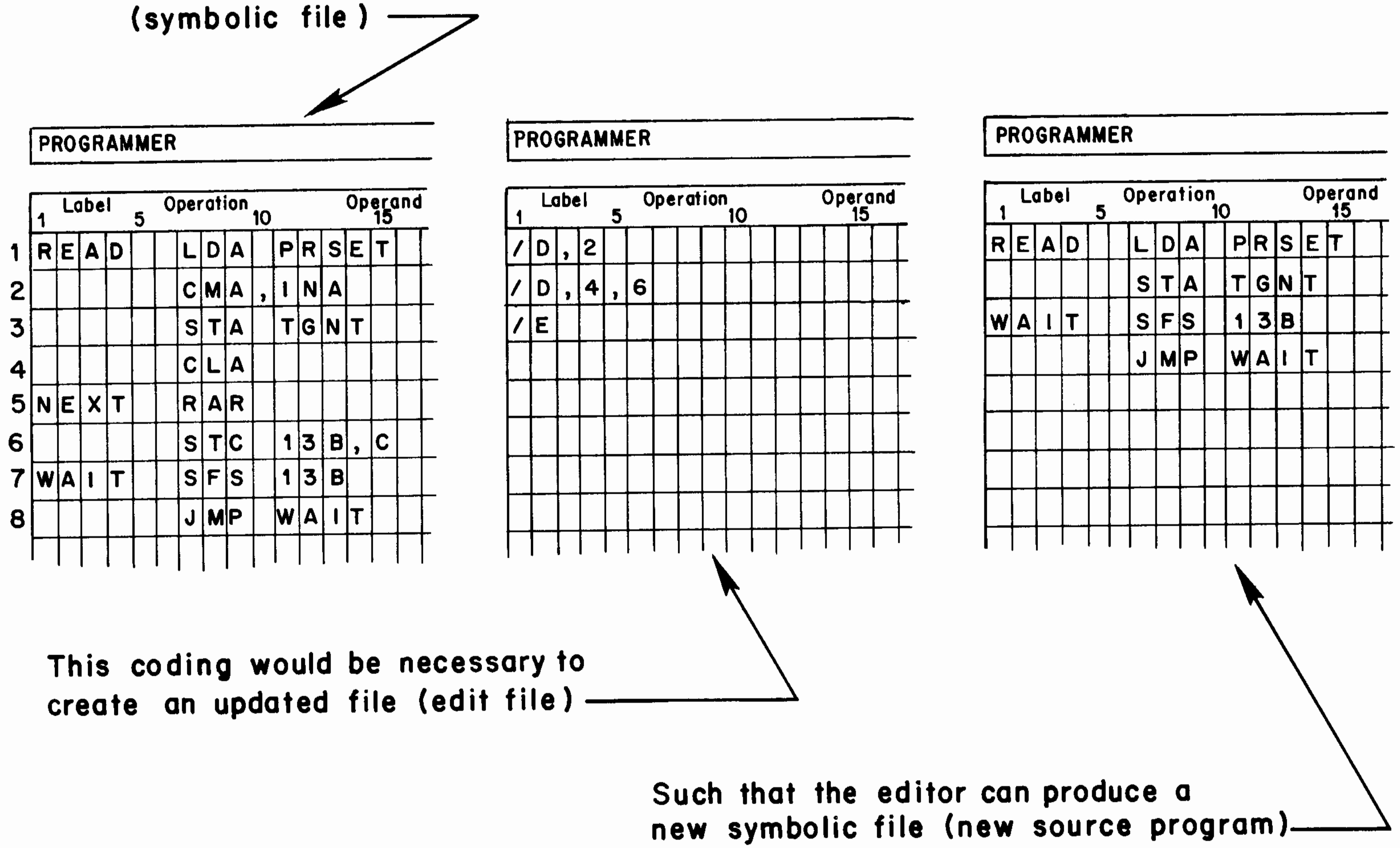
NOTE: REFERENCES TO LINE NUMBERS MUST BE SEQUENTIAL AND UNIQUE.

Such that the editor can produce a new symbolic file (new source program)

STATEMENT DELETIONS

EXAMPLE: If we wanted to delete statement numbers 2, 4, 5 and 6 from the original source program

(symbolic file)



```
PROGRAMMER

  Label      Operation       Operand
 1       5             10        15
1 READ      LDA  PRSET
2           CMA,INA
3           STA  TGNT
4           CLA
5 NEXT      RAR
6           STC  13B,C
7 WAIT      SFS  13B
8           JMP  WAIT
```

```
PROGRAMMER

  Label      Operation       Operand
 1       5             10        15
/D,2
/D,4,6
/E
```

```
PROGRAMMER

  Label      Operation       Operand
 1       5             10        15
READ      LDA  PRSET
          STA  TGNT
WAIT      SFS  13B
          JMP  WAIT
```

This coding would be necessary to create an updated file (edit file)

Such that the editor can produce a new symbolic file (new source program)

STATEMENT REPLACEMENTS

EXAMPLE: If we wanted to replace statement numbers 1 through 3 and 6 and 7 from the original source program

(symbolic file)

PROGRAMMER

```
 Label  Operation   Operand
1     5     10     15
1 READ  LDA PRSET
2       CMA,INA
3       STA TGNT
4       CLA
5 NEXT  RAR
6       STC 13B,C
7 WAIT  SFS 13B
8       JMP WAIT
```

PROGRAMMER

```
 Label  Operation   Operand
1     5     10     15
/R,1,3
READ  LDB PRSET
/R,6,7
      STC 15B,C
WAIT  SFS 15B
/E
```

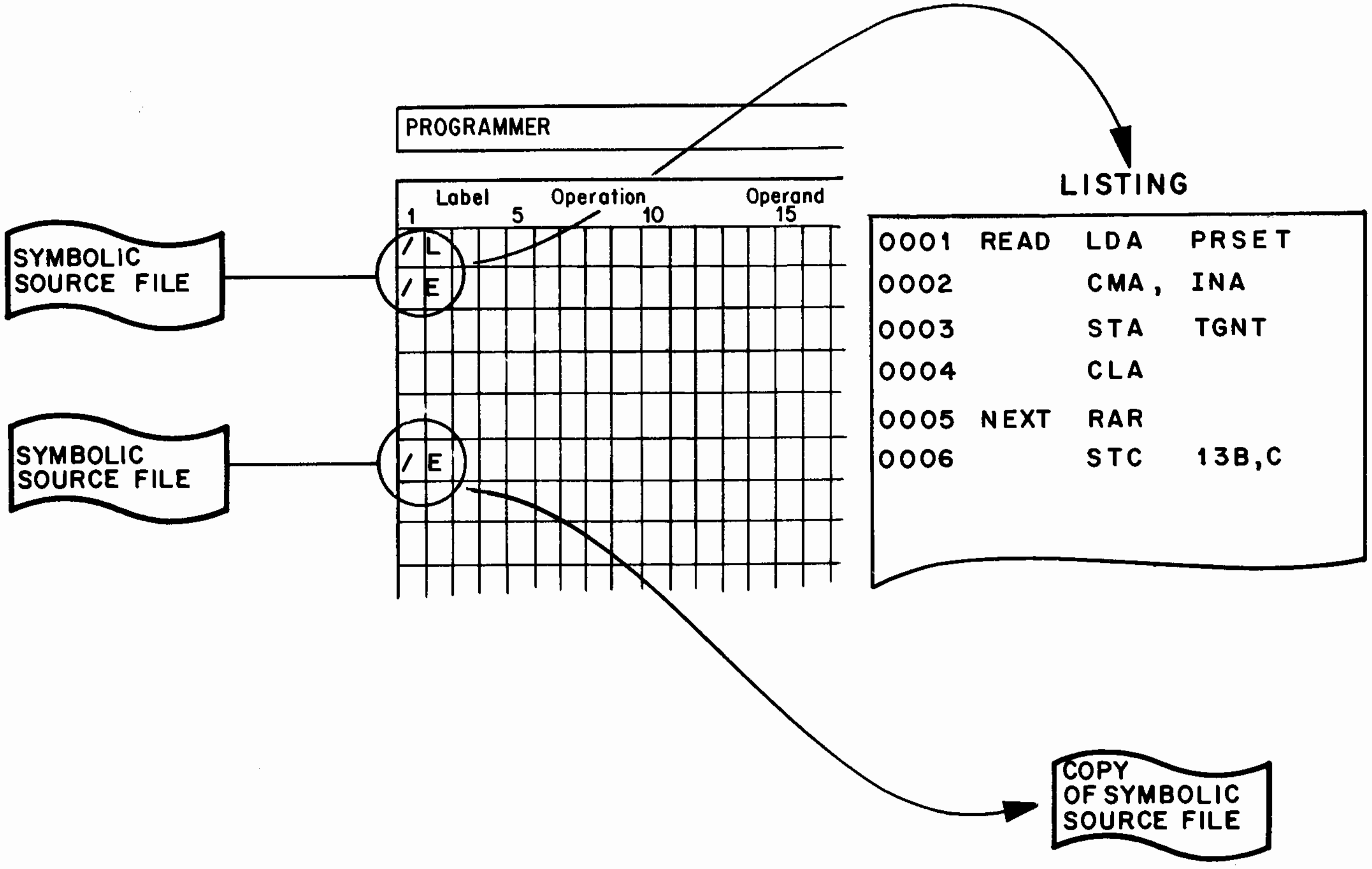
PROGRAMMER

```
 Label  Operation   Operand
1     5     10     15
READ  LDB PRSET
      CLA
NEXT  RAR
      STC 15B,C
WAIT  SFS 15B
      JMP WAIT
```

This coding would be necessary to create an updated file (edit file)

Such that the editor can produce a new symbolic file (new source program)

SYMBOLIC FILE LIST/COPY FUNCTIONS



```
0001  READ  LDA   PRSET
0002        CMA,  INA
0003        STA   TGNT
0004        CLA
0005  NEXT  RAR
0006        STC   13B,C
```

LESSON IV OBJECTIVES

TO INTRODUCE SOME ADDITIONAL CAPABILITIES OF FORTRAN.

1 - TRANSFER OF PROGRAM CONTROL FROM ONE FORTRAN STATEMENT TO ANOTHER.

2 - MAKING LOGICAL DECISIONS BASED ON THE RESULTS OF AN EVALUATED EXPRESSION.

3 - EXECUTING A GROUP OF FORTRAN STATEMENTS A SPECIFIED NUMBER OF TIMES.

4 - CREATING AND OPERATING ON ARRAYS OF DATA USING VARIABLES WITH SUBSCRIPTS.

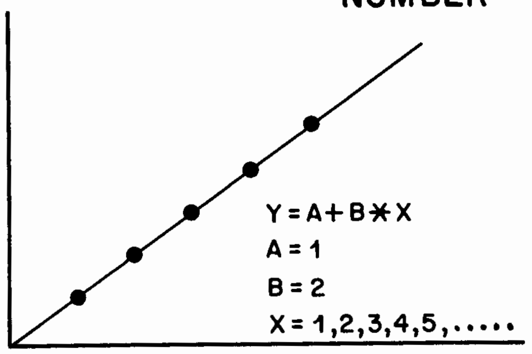
CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

– EXECUTABLE TYPES

CONTROL – THE GO TO STATEMENT

GENERAL FORM

GO TO N ← STATEMENT NUMBER



LABEL 1 5	C 6	STATEMENT 7
		A = 1 . Ø
		B = 2 . Ø
		X = 1 . Ø
45		Y = A + B ∗ X
		X = X + 1 . Ø
		GO TO 45

NOTE: THE "GO TO" STATEMENT IN THIS EXAMPLE ALLOWS THE PROGRAMMER TO REPEAT THE CALCULATION INDEFINITELY. Y TAKES THE VALUES: 3,5,7,9,11,13,15. . . . .

CONSTANTS
VARIABLES
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FUNCTIONS

– EXECUTABLE TYPES

CONTROL — THE IF STATEMENT

GENERAL FORM

$$\text{IF }\underbrace{(E)}_{\text{AN EXPRESSION}}\underbrace{N_1,N_2,N_3}$$

STATEMENT TO "GO TO"
DEPENDING UPON THE
EVALUATION OF E
IF E<Ø.∴ GO TO N_1
IF E=Ø.∴ GO TO N_2
IF E>Ø.∴ GO TO N_3

EXAMPLE

LABEL 1 5	C 6	STATEMENT 7
		IF(X-1Ø.)11,83,35

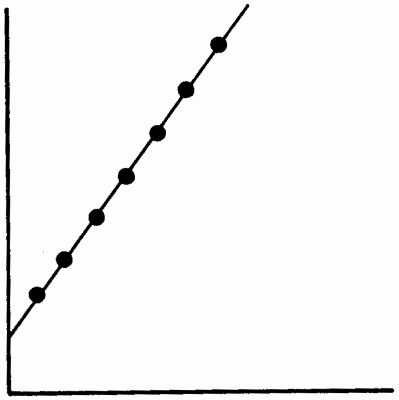
IT SAYS:

IF X - 1Ø.< Ø THEN GO TO STATEMENT 11
IF X - 1Ø.= Ø THEN GO TO STATEMENT 83
IF X - 1Ø.> Ø THEN GO TO STATEMENT 35

SAMPLE PROBLEM - USING THE "IF" STATEMENT

PROBLEM

SOLVE: Y=A+B*X
WHERE: A=1, B=2
AND X=1, 2,3,4,5,6,
7,8,9 &1Ø



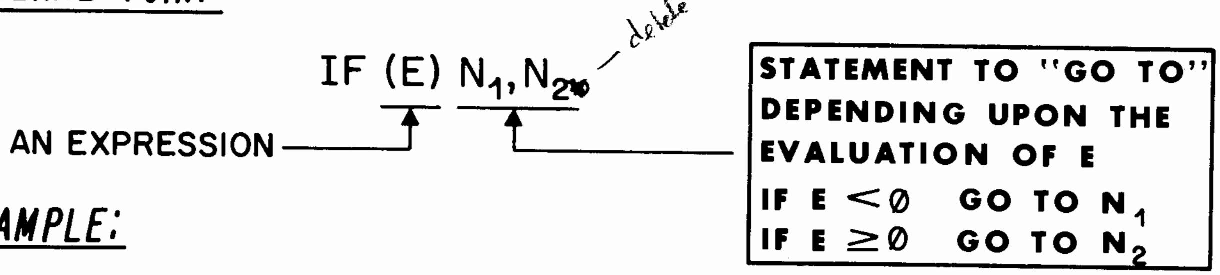
SOLUTION

LABEL 1 5	C 6	STATEMENT 7
		A=1.Ø
		B=2.Ø
		X=1.Ø
5		Y=A+B*X
		X=X+1.Ø
		IF(X-1Ø.)5,5,3
3		CONTINUE

NOTE: Y TAKES THE VALUES 3,5,7,9,11,13,15,17,19 & 21 ONLY!!

THE TWO BRANCH IF STATEMENT

GENERAL FORM:



IF (E) N_1, N_2 — delete

AN EXPRESSION

STATEMENT TO "GO TO" DEPENDING UPON THE EVALUATION OF E
IF E $<\emptyset$ GO TO N_1
IF E $\geq\emptyset$ GO TO N_2

EXAMPLE:

LABEL 1 5	C 6	STATEMENT 7
		IF(X-1Ø.)11,83

IT SAYS:

IF X - 1Ø. < Ø THEN GO TO STATEMENT 11
IF X - 1Ø. ≥ Ø THEN GO TO STATEMENT 83

NOTE:
IF (E) N_1, N_2
HAS THE SAME EFFECT AS
IF (E) N_1, N_2, N_2

SUMMARY

SAMPLE PROBLEM

WRITE A SET OF STATEMENTS TO PERFORM THE FOLLOWING:
READ TWO VALUES FROM THE KEYBOARD AND CALCULATE THE SUM.
IF THE SUM IS POSITIVE; TYPE OUT THE SUM.
IF THE SUM IS NEGATIVE; TYPE OUT THE WORD "REJECT".
PROGRAM A LOOP FOR CONTINUOUS PROBLEM SOLUTIONS.

SAMPLE SOLUTION

LABEL 1 5	C 6	STATEMENT 7
5		READ(1,*)A,B
		SUM=A+B
		IF(SUM)1Ø,2Ø
2Ø		WRITE(2,1ØØ)SUM
1ØØ		FORMAT("SUM="F1Ø.4)
		GO TO 5
1Ø		WRITE(2,2ØØ)
2ØØ		FORMAT("REJECT")
		GO TO 5

RULES:

READ/WRITE statements: indicate the **UNIT NO., FORMAT NO.** and the **DATA LIST** elements. Using an (*) for the format no. of a **READ** statement indicates the **FREE-FIELD INPUT** mode.

IF statements: TRANSFER CONTROL to one of **TWO** or **THREE** branches. The **TWO** branch **IF** represents **NEGATIVE** and **NON-NEGATIVE**. The **THREE** branch **IF** represents **NEGATIVE, ZERO** and **POSITIVE NON-ZERO**.

These two statements are equivalent:

IF (N) 1 Ø, 2 Ø **IF (N) 1 Ø, 2 Ø, 2 Ø**

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

– EXECUTABLE TYPES

CONTROL – THE PAUSE STATEMENT

GENERAL FORM PAUSE

WHEN THIS STATEMENT IS EXECUTED THE COMPUTER WILL WRITE "PAUSE" ON THE TELEPRINTER AND THEN HALT. WHEN THE RUN BUTTON IS PUSHED THE COMPUTER WILL RESUME EXECUTION AT THE NEXT FORTRAN STATEMENT.

EXAMPLE

CONSIDER A PROGRAM WHICH MUST PROCESS DATA READ FROM A TAPE PLACED IN THE PHOTOREADER. AT SOME TIME THE FORTRAN PROGRAM MAY:

1. WRITE A MESSAGE ON THE TELEPRINTER REQUESTING THE DATA TAPE.
2. PAUSE THE OPERATOR WOULD NOW PUT THE DATA TAPE IN THE PHOTOREADER, AND PRESS RUN.

```
 LABEL      STATEMENT
1    5 6 7
           WRITE(2,1ØØ)
  1ØØ      FORMAT("LOAD DATA TAPE")
           PAUSE
```

SUBSCRIPT NOTATION

ANALYSIS:

IN ALGEBRA, SUBSCRIPTS ARE WRITTEN:

$a_1 X + a_2 X^2 + a_3 X^3 \ldots .$

IN FORTRAN, THE EQUIVALENT EXPRESSION WOULD BE:

```
A (1) *X+A (2) * X ** 2 + A (3) *X ** 3 . . . .
```

GENERAL FORM:

$\alpha \quad (I) \quad = \quad \beta$

FIXED OR FLOATING POINT VARIABLE NAME

SUBSCRIPT

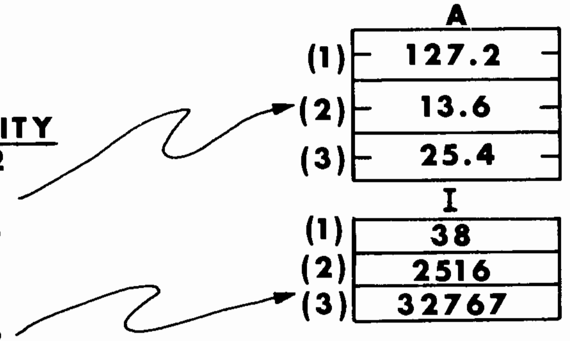
ANY EXPRESSION

INTEGER CONSTANT, VARIABLE,OR CERTAIN EXPRESSIONS

- A SET OF SUBSCRIPTED VARIABLE QUANTITIES IS CALLED AN ARRAY
- THE INDIVIDUAL QUANTITIES OF THE ARRAY ARE CALLED ELEMENTS

EXAMPLE:

ARRAY NAME	ELEMENT NAME	QUANTITY
	A (1)	127.2
A	A (2)	13.6
	A (3)	25.4
	I (1)	38
I	I (2)	2516
	I (3)	32767



A

(1)	127.2
(2)	13.6
(3)	25.4

I

(1)	38
(2)	2516
(3)	32767

CONSTANTS
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FUNCTIONS

– NON - EXECUTABLE

Computer Museum

SPECIFICATION – THE **DIMENSION** STATEMENT

GENERAL FORM:

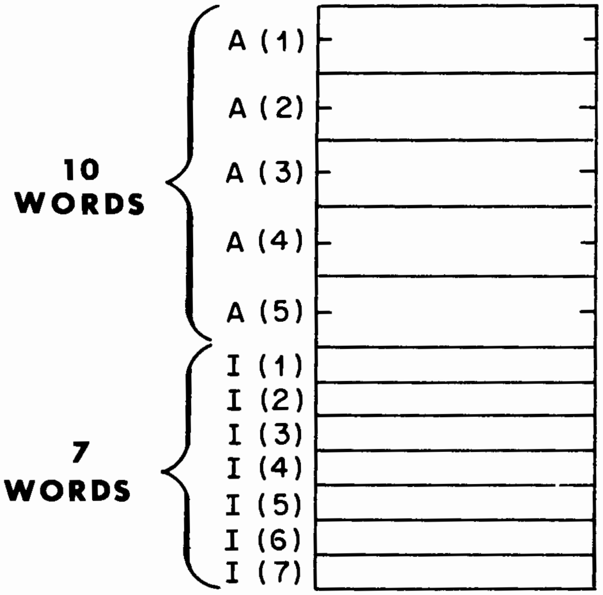
DIMENSION A(5), I(7), B(5)

VARIABLE NAME ↑ ↑ NUMBER OF ELEMENTS

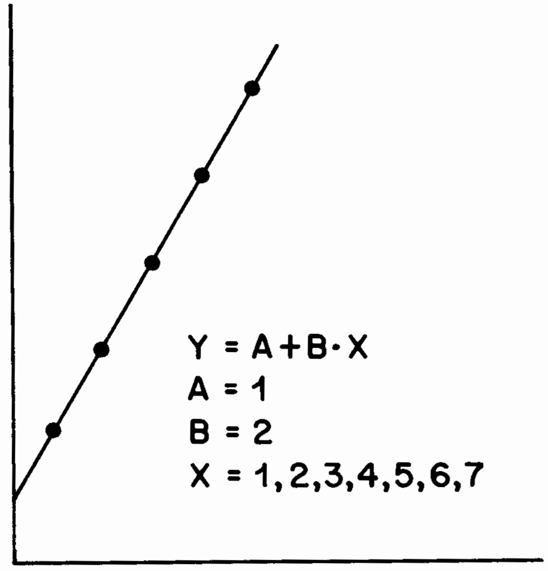
A DIMENSION STATEMENT MUST APPEAR BEFORE THE FIRST EXECUTABLE STATEMENT OF THE PROGRAM.

EXAMPLE:

```
LABEL    STATEMENT
1   5 6 7
        PROGRAM SAM
        DIMENSION A(5), I(7), B(5)
        A(1)=1.5
        A(2)=4.3
        A(3)=234.56
        A(4)=1Ø.Ø.
        A(5)=32.676
        B(1)=A(1)*A(2)
        A(6)=45.1
          ↑
        ERROR
```



SUBSCRIPTED VARIABLES IN FORTRAN ARITHMETIC STATEMENTS



Y = A+B·X
A = 1
B = 2
X = 1,2,3,4,5,6,7

Y(1) = 3
Y(2) = 5
Y(3) = 7
Y(4) = 9
Y(5) = 11
Y(6) = 13
Y(7) = 15

```
LABEL   C  STATEMENT
1    5  6  7
           PROGRAM DEMO4
           DIMENSION Y(7)
           A=1.Ø
           B=2.Ø
           X=1.Ø
           I=1
   1Ø      Y(I)=A+B*X
           IF(I-7)2Ø,3Ø
   2Ø      I=I+1
           X=X+1.Ø
           GO TO 1Ø
   3Ø      PAUSE
```

A SAMPLE PROBLEM — COMPUTE THE SINE FOR 36Ø ANGLES

PROBLEM: FILL AN ARRAY WHICH HAS 36Ø ELEMENTS WITH THE TRIGONOMETRIC SINE OF THE NUMBER OF DEGREES CORRESPONDING TO THAT ELEMENT.

SOLUTION:

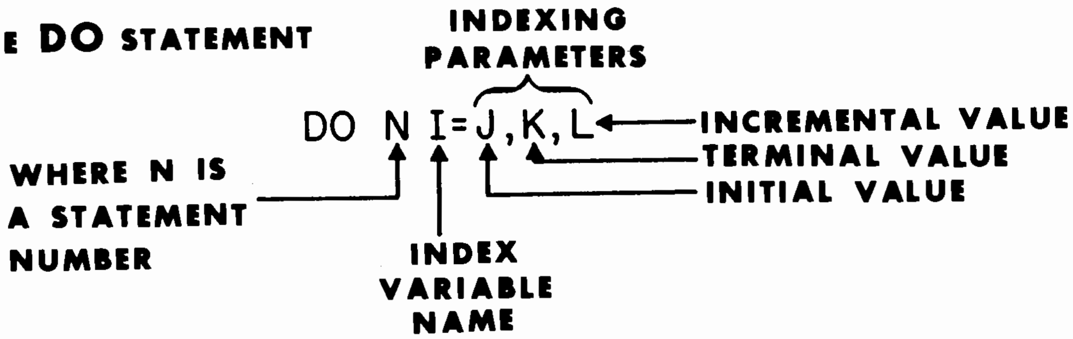
```
LABEL  C  STATEMENT
1    5 6  7
          DIMENSION SINE(36Ø)
          I=1
   1Ø     RAD=FLOAT(I)*Ø.Ø1745
          SINE(I)=SIN(RAD)
          IF (I-36Ø)2Ø,3Ø
   2Ø     I=I+1
          GO TO 1Ø
   3Ø     PAUSE
```

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

- EXECUTABLE

CONTROL — THE **DO** STATEMENT

GENERAL FORM



EXAMPLE:

```
      SUM=0.0
      DO 5  J=1,10,1
    5 SUM=SUM+X
```

- SET J = 1, (INITIAL VALUE). DO ALL STATEMENTS DOWN TO AND INCLUDING STATEMENT 5 (THE RANGE OF THE "DO").
- ADD 1 (INCREMENTAL VALUE) TO J.
- IF J ≤ 10, (TERMINAL VALUE) RE-EXECUTE THE STATEMENTS IN THE RANGE.
- IF J > 10, THE "DO" IS SATISFIED AND CONTROL PASSES TO THE NEXT STATEMENT IN SEQUENCE.

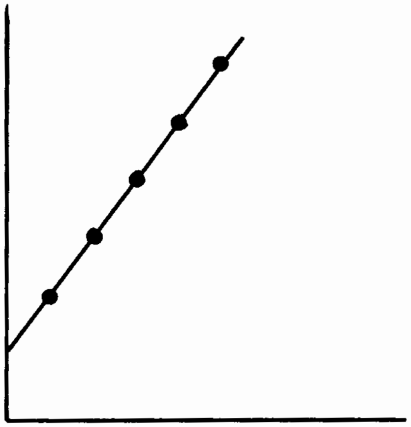
USING THE DO PROBLEM #1

PROBLEM: SOLVE : Y = A + B · X

Where A = 1 B = 2
And X = 1,2,3,4,5,6,7,8,9,10

SOLUTION:

```
LABEL            STATEMENT
1   5 6 7
      A = 1.Ø
      B = 2.Ø
      X = 1.Ø
      DO 5 I = 1,1Ø
      Y = A+B*X
    5 X = X+1.Ø
```



NOTE: IF THE INCREMENTAL VALUE OF THE "DO" IS 1, IT NEED NOT BE SPECIFIED.

USING THE DO — PROBLEM #2

PROBLEM:

ASSUME THAT ARRAY X CONTAINS 1ØØ VALUES. FIND THE SUM.

SOLUTION:

```
LABEL    C          STATEMENT
1       5 6 7
            DIMENSION X(1ØØ)
            SUM=Ø.Ø
            DO 1Ø I=1,1ØØ
     1Ø     SUM=SUM+X(I)
            PAUSE
```

RULES:

- THE LABEL WHICH TERMINATES THE DO LOOP IS ON A STATEMENT WHICH IS PART OF THE LOOP
- THE LABEL WHICH TERMINATES THE DO LOOP MAY NOT BE ON A "GO TO" , "IF","RETURN", "STOP", "PAUSE", OR "DO" STATEMENT.

CONSTANTS
VARIABLES
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- EXECUTABLE

CONTROL—THE CONTINUE STATEMENT

GENERAL FORM: *CONTINUE*

THE CONTINUE STATEMENT IS A DUMMY FORTRAN STATEMENT WHICH IS USED TO PROVIDE A LEGAL TERMINATION FOR A "DO" LOOP WHEN THE LAST STATEMENT WOULD OTHERWISE BE A :

GO TO, IF, RETURN, PAUSE, STOP OR ANOTHER "DO" STATEMENT.

EXAMPLE:

INVALID "DO" LOOP

```
      SUM=Ø.Ø
      DO 1Ø I=1,1ØØ
      SUM=SUM+DELTA
1Ø    IF(SUM-5ØØ.)1Ø,2Ø,2Ø
2Ø    J=J+1
```

VALID "DO" LOOP

```
      SUM=Ø.Ø
      DO 1Ø I=1,1ØØ
      SUM=SUM+DELTA
      IF(SUM-5ØØ.)1Ø,2Ø,2Ø
1Ø    CONTINUE
2Ø    J=J+1
```

USING THE DO PROBLEM #3

PROBLEM: WRITE a FORTRAN program which reads 1ØØ numbers from the photoreader and calculates the sum, average, and RMS value.

GIVEN: The RMS value = the square root of the sum of the squares of the difference between the mean value and the individual data points:

$$RMS = \sqrt{\frac{\sum_{i=1}^{100} (Xi-\overline{X})^2}{100}}$$

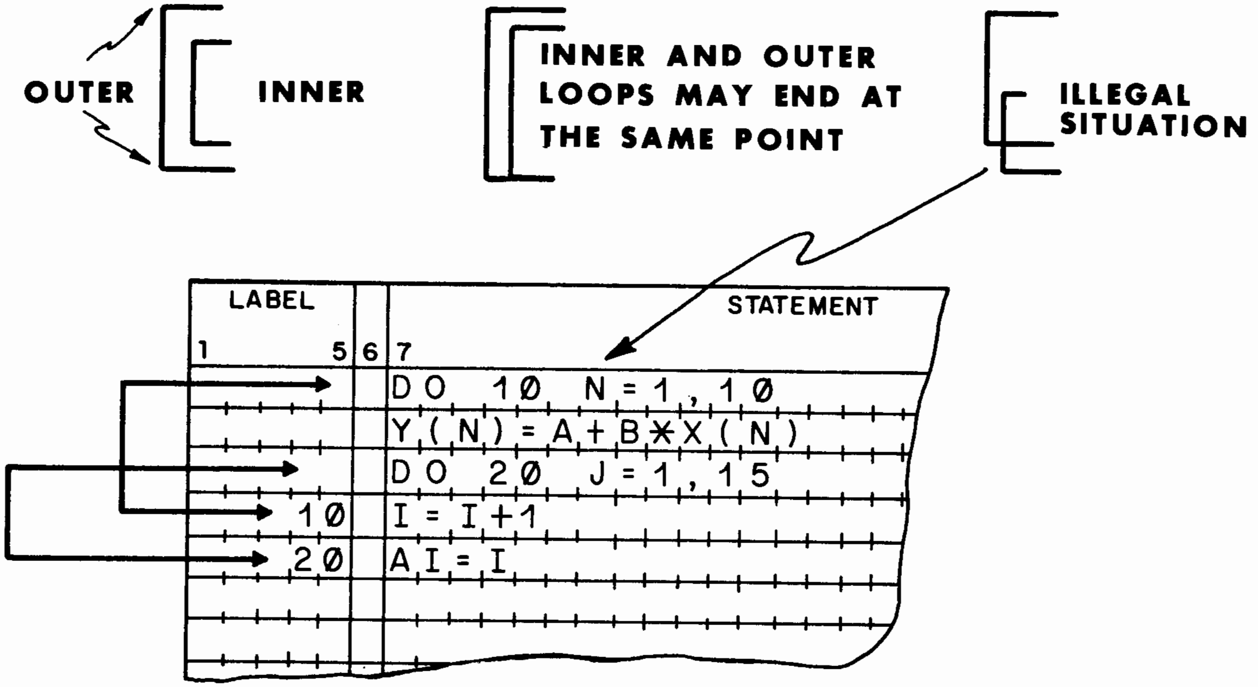
SOLUTION:

```
      PROGRAM DEMO6
      DIMENSION X(1ØØ)
    5 WRITE(2,1)
    1 FORMAT("INSERT DATA TAPE IN P.R., PUSH RUN")
      PAUSE
      SUM=Ø.Ø
      DO 2 I=1,1ØØ
         READ(5,*)X(I)
         SUM=SUM+X(I)
    2 CONTINUE
      AVG=SUM/1ØØ.
      SUMSQ=Ø.Ø
      DO 3 I=1,1ØØ
    3    SUMSQ=SUMSQ+(X(I)-AVG)**2
      RMS=SQRT(SUMSQ/1ØØ.)
      WRITE(2,4)SUM,AVG,RMS
    4 FORMAT("SUM="F1Ø.3/"AVG="F1Ø.3/"RMS="F1Ø.3///)
      PAUSE
      GO TO 5
      END
```

4 carriage returns.

NESTED DO LOOPS

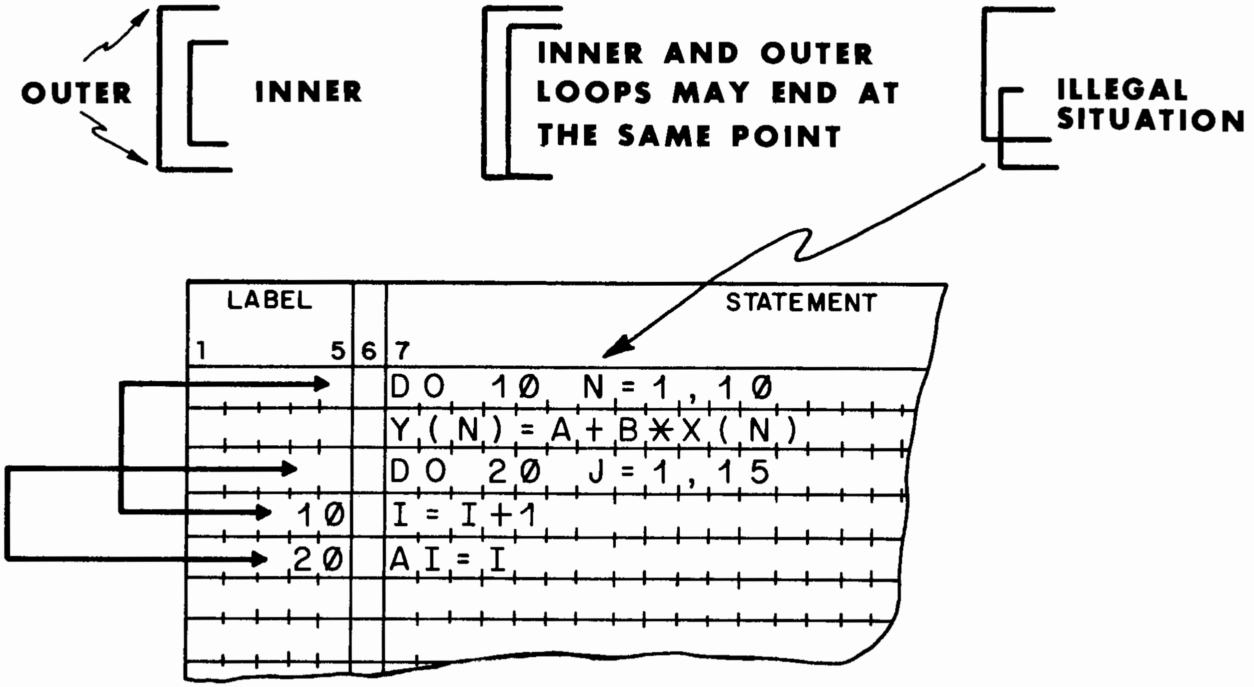
RULE: It is permissible for one "DO" loop to contain another "DO" loop within its range; however, care must be given to avoid illegal transfers. Generally, it is required that all statements in the range of the inner "DO" also be within the range of the outer "DO".



```
      DO 10 N=1,10
      Y(N)=A+B*X(N)
      DO 20 J=1,15
   10 I=I+1
   20 AI=I
```

NESTED DO LOOPS

RULE: It is permissible for one "DO" loop to contain another "DO" loop within its range; however, care must be given to avoid illegal transfers. Generally, it is required that all statements in the range of the inner "DO" also be within the range of the outer "DO".



```
      DO 10 N=1,10
      Y(N)=A+B*X(N)
      DO 20 J=1,15
   10 I=I+1
   20 AI=I
```

LESSON V OBJECTIVES

TO INTRODUCE SOME ADDITIONAL CAPABILITIES OF FORTRAN.

THESE INCLUDE:

1 - SOME ADDITIONAL FORMAT SPECIFICATIONS FOR MORE INPUT/OUTPUT FLEXIBILITY.

2 - MORE "FREE FIELD" INPUT CAPABILITIES.

3 - TWO DIMENSIONAL ARRAYS

4 - ARRAY INPUT/OUTPUT TECHNIQUES

5 - SUBROUTINES AND FUNCTION SUBPROGRAMS.

CONSTANTS
VARIABLES
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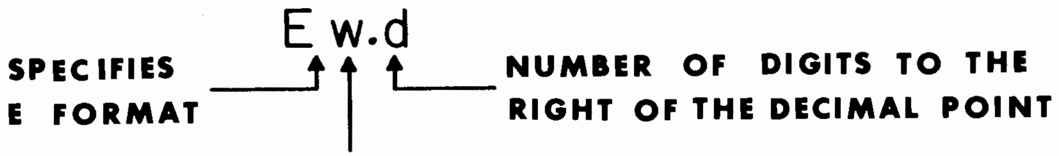
STATEMENTS
FUNCTIONS

– NON EXECUTABLE

FORMATS — THE E FORMAT

GENERAL FORM



E w.d

SPECIFIES E FORMAT

NUMBER OF DIGITS TO THE RIGHT OF THE DECIMAL POINT

FIELD WIDTH INCLUDING SIGNS, DECIMAL POINT, AND EXPONENT.

NOTE: PROPER OUTPUT WILL **ALWAYS** RESULT IF w≥d+7

OUTPUT EXAMPLES

NUMBER	FORMAT	PRINTED AS	REMARKS
+10.4365	E1Ø.3	^^.1Ø4E+Ø2	
−12.34	E12.3	^^^−.123E+Ø2	
−1Ø.4365	E7.5	$$$$$$$	w<d+7

INPUT EXAMPLES

NUMBER	FORMAT	CONVERTED VALUE	REMARKS
+1.2345E2	E9.3	123.45	Decimal point overides format
1234	E4.2	12.34	Format inserts decimal point

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

– NON-EXECUTABLE

FORMATS — THE FORMAT REPEAT FACTOR

A FORMAT SPECIFICATION CAN BE USED "n" TIMES BY USING THE REPEAT FACTOR IN FRONT OF THE SPECIFICATION, AND PROVIDING THE PROPER PARENTHESES TO EFFECT THE DESIRED REPEAT COUNT.

EXAMPLE 1

```
  1ØØ  FORMAT(F1Ø.2,I5,F1Ø.2,I5,F1Ø.2,I5)
  2ØØ  FORMAT(3(F1Ø.2,I5))
```

THE TWO FORMATS SHOWN ABOVE ARE EQUIVALENT.

EXAMPLE 2

WRITE ON THE TELEPRINTER:
THE TIME IS XX:XX:XX.

```
       WRITE(2,1Ø)IHH,IMM,ISS
   1Ø  FORMAT("THE TIME IS",I2,2(":",I2))
```

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VARIABLES
OPERATORS
STATEMENTS — NON-EXECUTABLE
FUNCTIONS

FORMATS THE SLASH (/) IN A FORMAT

THE **SLASH (/)** CHARACTER IS USED TO INDICATE THE END OF ONE RECORD AND THE BEGINNING OF ANOTHER. THE CLOSING PARENTHESIS OF THE FORMAT STATEMENT INDICATES THE END OF THE INPUT/OUTPUT OPERATION.

EXAMPLE

```
12345 CR LF 789653.123 CR LF 56789 1.954 CR LF
```

THESE STATEMENTS

```
LABEL  C  STATEMENT
1    5 6  7
          READ(5,102)I,A,B
  1Ø2     FORMAT(I5/F1Ø.3/F1Ø.3)

          WRITE(2,1Ø24)I
 1Ø24     FORMAT("THE VALUE OF I IS"
        1  I6/"INPUT TEST OVER")
```

PRODUCE THIS RESULT

```
THE VALUE OF I IS 12345
INPUT TEST OVER
```

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS
FUNCTIONS

– NON EXECUTABLE

FORMATS – THE X FORMAT

THE **X** FORMAT IS USED TO INSERT SPACES IN OUTPUT DATA AND CAN BE USED TO IGNORE ALPHA CHARACTERS AND PUNCTUATION MARKS ON INPUT.

GENERAL FORM:

REPEAT COUNT   X IDENTIFIER

```
  1ØØ FORMAT(F1Ø.2,5X,I2,3X,I5/)
```

EXAMPLE

AN INPUT DATA TAPE HAS THE FOLLOWING FORM:

WEIGHT∧∧1Ø∧∧PRICE∧∧$1.98∧∧TOTAL∧∧$19.8Ø

THE FORTRAN STATEMENTS SHOWN WILL CAUSE THE PUNCTUATION MARKS TO BE IGNORED.

```
LABEL        STATEMENT
1    5 6 7
           READ(5,1Ø4)I,A,B
  1Ø4      FORMAT(8X,I2,1ØX,F4.2,1ØX,F5.2)
```

RESULT: I CONTAINS 1Ø, A CONTAINS 1.98, B CONTAINS 19.8Ø

CONSTANTS
VARIABLES
OPERATORS
STATEMENTS — NON-EXECUTABLE
FUNCTIONS

FORMATS - THE A FORMAT

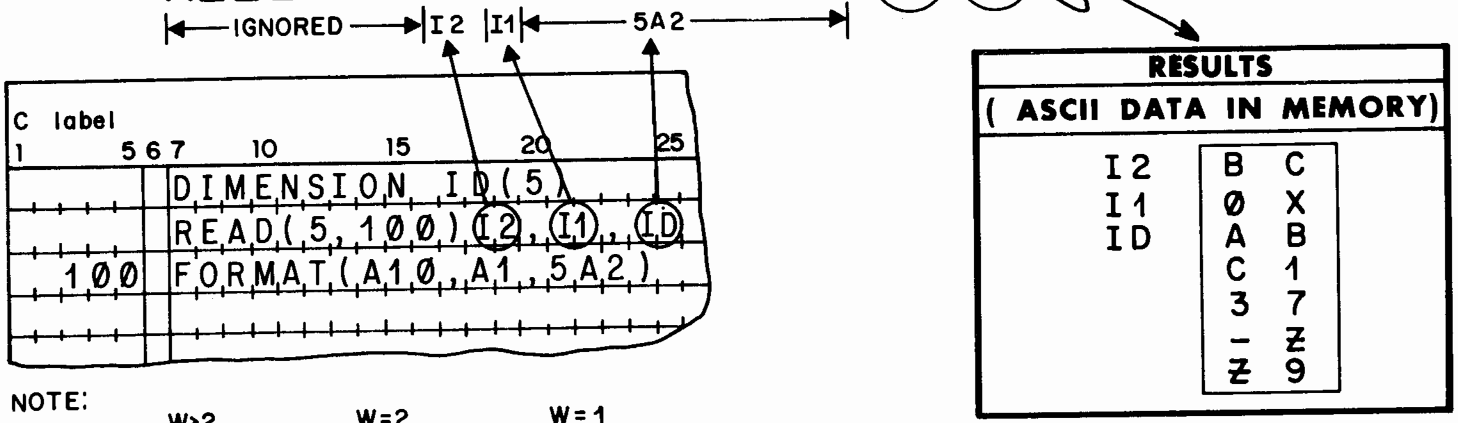
THE A FORMAT CAUSES ALPHANUMERIC DATA ON AN EXTERNAL MEDIUM TO BE TRANSLATED TO OR FROM ASC II FORM IN MEMORY.

GENERAL FORM: r A w

REPEAT COUNT — r; IDENTIFIER — A; FIELD — w

FOR EXAMPLE: ASSUME AN INPUT DATA TAPE CONTAINS:

AƵƵ213-ABCXABC137-ƵƵ9 (CR) (LF)

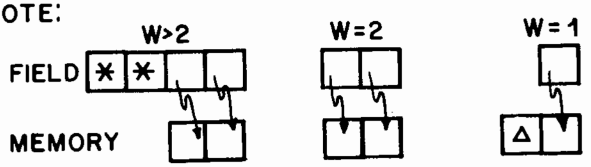


```
     DIMENSION ID(5)
     READ(5,100)I2,I1,ID
100  FORMAT(A1Ø,A1,5A2)
```

RESULTS
(ASCII DATA IN MEMORY)

I2	B	C
I1	Ø	X
ID	A	B
	C	1
	3	7
	-	Ƶ
	Ƶ	9

NOTE:



* IGNORED ON INPUT
SPACES ON OUTPUT

△ IGNORED ON OUTPUT
ZERO ON INPUT

ADDITIONAL FREE-FIELD INPUT CAPABILITY

FREE-FIELD INPUT permits the reading of ASCII numeric data items without a definitive format statement. Special symbols included with the data items direct the formatting.

SPECIAL SYMBOLS:

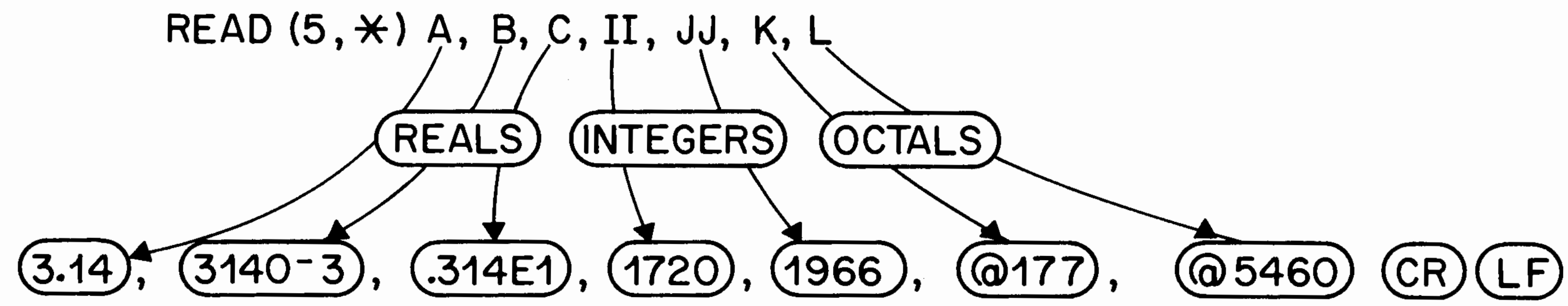
(SPACE) (,)	=	DATA ITEM DELIMITERS
(/)	=	RECORD TERMINATOR
(+)(–)	=	SIGN OF ITEM
(.)(E)(+)(–)	=	FLOATING POINT NUMBER
(@)	=	OCTAL INTEGER
("...")	=	COMMENTS

RULES:

- FREE-FIELD is indicated when an ASTERISK is used instead of a format statement number in the READ statement.
- A DATA ITEM is any continuous string of numeric and special symbols occurring between two commas, a comma and a space or two spaces. The data value corresponds to a list element.
- Two consecutive commas indicate that no data item is supplied for the corresponding list element. The current value of the list element in memory is unchanged.
- An initial comma indicates the first list element is to be skipped.
- A Ⓒⓡ Ⓛⓕ terminates each input data line record.

EXAMPLES : FREE-FIELD INPUT

#1 - DATA TYPES



```
READ (5,*) A, B, C, II, JJ, K, L
```

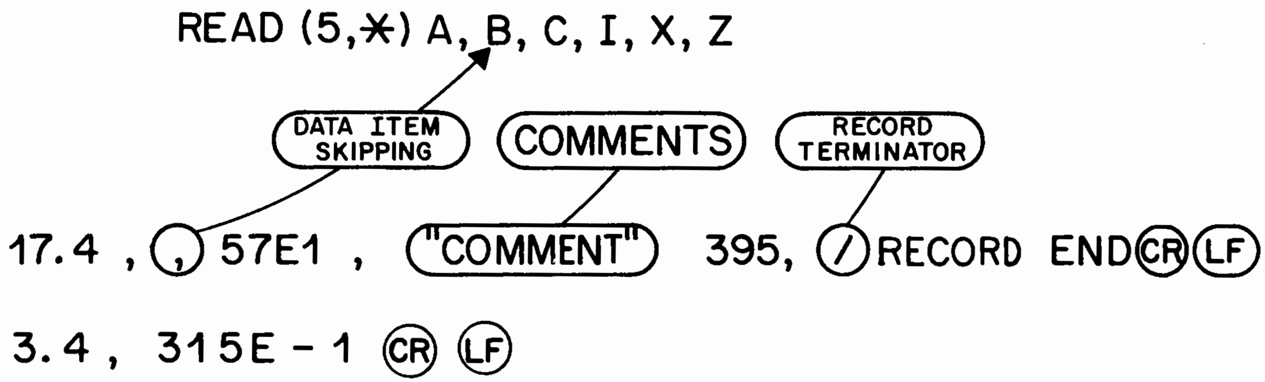
REALS

INTEGERS

OCTALS

```
3.14, 3140-3, .314E1, 1720, 1966, @177, @5460 CR LF
```

#2 - SPECIAL SYMBOL USAGE



```
READ (5,*) A, B, C, I, X, Z
```

DATA ITEM SKIPPING

COMMENTS

RECORD TERMINATOR

```
17.4 , , 57E1 , "COMMENT" 395, / RECORD END CR LF
3.4 , 315E - 1 CR LF
```

	MEMORY RESULTS
A	17.4
B	UNCHANGED
C	570.
I	395
X	3.4
Z	31.5

MORE INFORMATION ON SUBSCRIPTS

- IN HP FORTRAN A VARIABLE MAY HAVE ONE OR TWO SUBSCRIPTS.

  FOR EXAMPLE: Y (I) = A + B – C OR X (I,J) = A + B – C

- THE SECOND SUBSCRIPT IMPLIES THAT THE ARRAY HAS TWO DIMENSIONS.
- A TWO DIMENSIONAL ARRAY CAN BE VISUALIZED USING ROWS AND COLUMNS.
- THE LEFT SUBSCRIPT YIELDS THE ROW NUMBER.
- THE RIGHT SUBSCRIPT YIELDS THE COLUMN NUMBER.
- THE SIZE OF A TWO DIMENSIONAL ARRAY IS EQUAL TO THE PRODUCT OF THE SUBSCRIPTS

EXAMPLE

LABEL 1 5	C 6	STATEMENT 7
		DIMENSION X(3,3)
		I = 3
		J = 2
		X(I,J) = SQRT(ALPHA+GAMMA)

2 DIMENSIONAL ARRAY "X"

ROW	COLUMN 1	COLUMN 2	COLUMN 3	"J"
1				
2				
3		✱		
"I"				

SAMPLE PROBLEM: USING A TWO DIMENSIONAL ARRAY

PROBLEM: Assume the existence of a two dimensional array SCORE (6,3) which is filled out to contain the scores of 6 students for each of 3 quizzes. Write a series of statements which finds the average score of student 4.

SOLUTION:

```
LABEL        STATEMENT
1    5 6 7
           DIMENSION SCORE(6,3)
           SUM=0.0
           DO 10 I=1,3
   10      SUM=SUM+SCORE(4,I)
           AVG=SUM/3.0
```

ARRAY SCORE

ROW	CO 1	LU 2	MN 3
1			
2			
3			
4	X	X	X
5			
6			

STUDENT NUMBER

QUIZ NUMBER

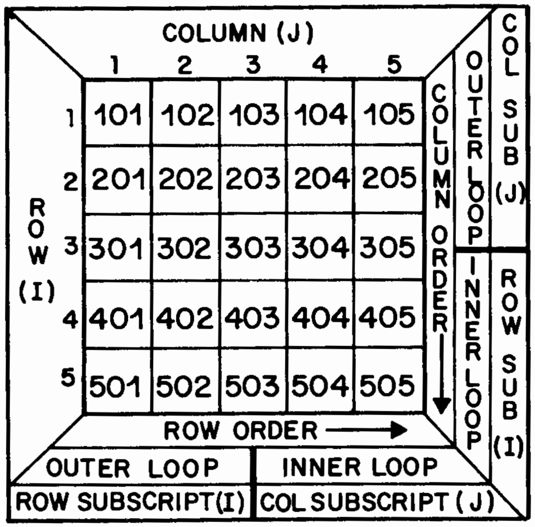
SAMPLE PROBLEM – USING "NESTED DO LOOPS"

Assume the existence of a two dimensional array SCORE (6, 3) which is filled out with the scores of 6 students for each of three quizzes. Find the composite average.

```
LABEL  C   STATEMENT
1    5 6 7
             DIMENSION SCORE(6,3)
C            SUM THE ELEMENTS

             SUM=Ø.Ø

             DO 1Ø ISTU=1,6

             DO 1Ø IQZ=1,3

   1Ø        SUM=SUM+SCORE(ISTU,IQZ)

             AVG=SUM/18.
```

2 DIMENSIONAL ARRAY CONVENTIONS

ARRAY IA



	1	2	3	4	5
1	101	102	103	104	105
2	201	202	203	204	205
3	301	302	303	304	305
4	401	402	403	404	405
5	501	502	503	504	505

RULE:

TO FILL A TWO DIMENSIONAL ARRAY IN COLUMN ORDER THE ROW SUBSCRIPT VARIES MOST RAPIDLY.

RULE:

TO FILL A TWO DIMENSIONAL ARRAY IN ROW ORDER THE COLUMN SUBSCRIPT VARIES MOST RAPIDLY.

PROBLEM:

FILL ARRAY "IA" IN COLUMN ORDER.

SOLUTION:

```
      PROGRAM ARRAY
      DIMENSION IA(5,5)
       DO 1ØØ J=1,5
       DO 1ØØ I=1,5
1ØØ    IA(I,J)=1ØØ*I+J
```

ARRAY IA
IN MEMORY

101
201
301
401
501
102
202
302
402
502
103
203
303
403
503
104
204
304
404
504
105
205
305
405
505

SUMMARY:

TRANSMIT ARRAY	OUTER LOOP CONTROLS	INNER LOOP CONTROLS
BY COLUMN	COLUMN SUBSCRIPT (J)	ROW SUBSCRIPT (I)
BY ROW	ROW SUBSCRIPT (I)	COLUMN SUBSCRIPT (J)

INPUT/OUTPUT OF ENTIRE ARRAYS IN NATURAL ORDER

- **When a Dimensioned variable name is used in an input-output list without subscripts, the entire array is transmitted.**

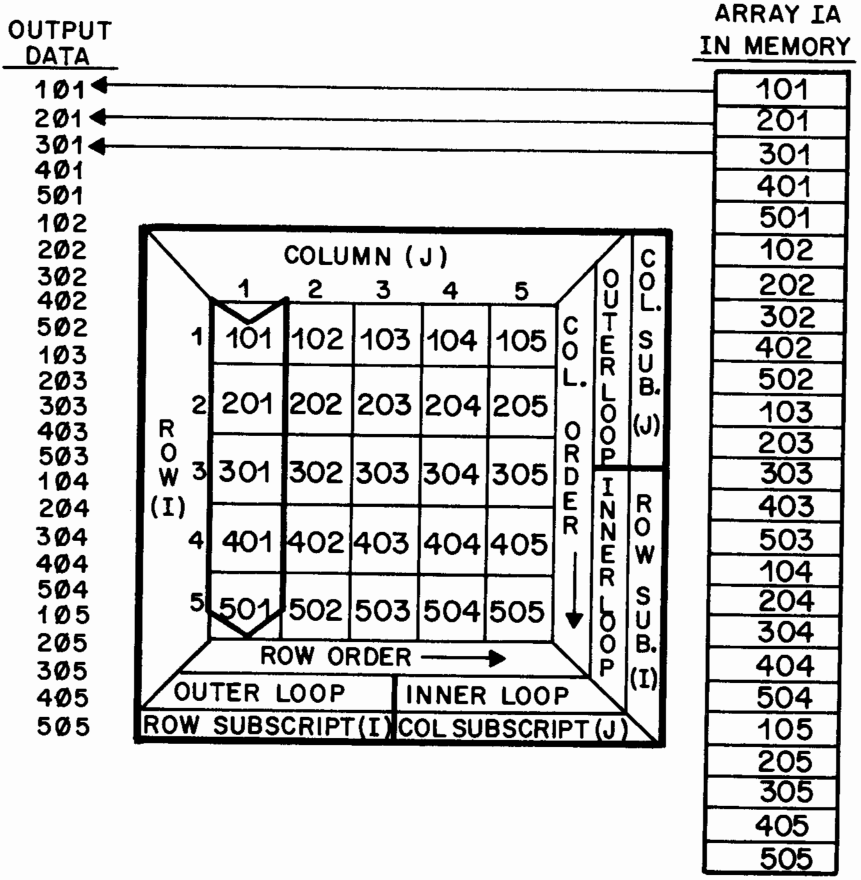
Example: **write the contents of array IA in natural order.**

PROGRAM

```
      PROGRAM DEMO1
      DIMENSION IA(5,5)
      WRITE(2,100)IA
100   FORMAT(I6)
```

- **The array is output in column order from sequential memory locations-THIS IS NATURAL ORDER**

- **The single format specification is used repeatedly until all elements of the array are transmitted**



OUTPUT DATA

```
101
201
301
401
501
102
202
302
402
502
103
203
303
403
503
104
204
304
404
504
105
205
305
405
505
```

COLUMN (J)

ROW (I)	1	2	3	4	5
1	101	102	103	104	105
2	201	202	203	204	205
3	301	302	303	304	305
4	401	402	403	404	405
5	501	502	503	504	505

ARRAY IA IN MEMORY

101
201
301
401
501
102
202
302
402
502
103
203
303
403
503
104
204
304
404
504
105
205
305
405
505

INPUT/OUTPUT OF ENTIRE ARRAYS IN ROW ORDER

- If natural order (column) is not to be used, subscripting information must be provided.

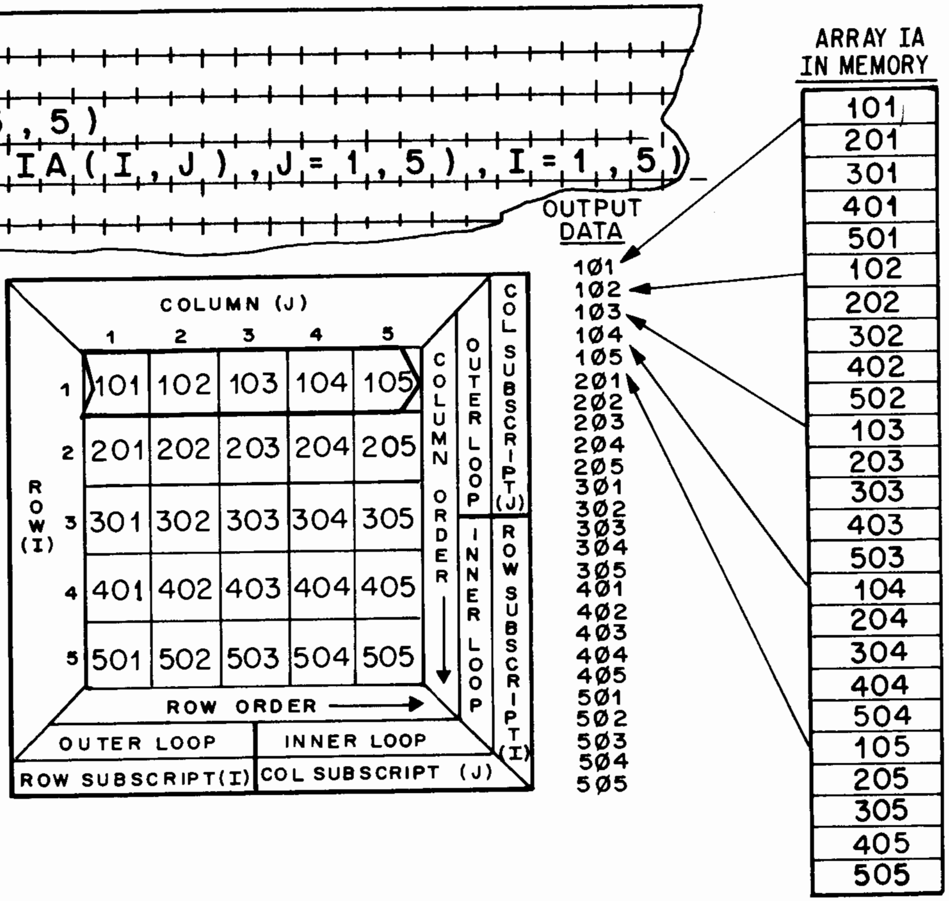
  Example: write the contents of array IA in row order.

PROGRAM:

```
      PROGRAM DEMO2
      DIMENSION IA(5,5)
      WRITE(2,101)((IA(I,J),J=1,5),I=1,5)
  1Ø1 FORMAT(I6)
```

- The array is output in row order from non-sequential memory locations.

- The single format specification is used repeatedly until all elements of the array are transmitted.



		COLUMN (J)				
		1	2	3	4	5
ROW (I)	1	101	102	103	104	105
	2	201	202	203	204	205
	3	301	302	303	304	305
	4	401	402	403	404	405
	5	501	502	503	504	505

OUTPUT DATA

```
1Ø1
1Ø2
1Ø3
1Ø4
1Ø5
2Ø1
2Ø2
2Ø3
2Ø4
2Ø5
3Ø1
3Ø2
3Ø3
3Ø4
3Ø5
4Ø1
4Ø2
4Ø3
4Ø4
4Ø5
5Ø1
5Ø2
5Ø3
5Ø4
5Ø5
```

ARRAY IA IN MEMORY

101
201
301
401
501
102
202
302
402
502
103
203
303
403
503
104
204
304
404
504
105
205
305
405
505

SAMPLE PROBLEM : FINDING THE LARGEST ELEMENT IN AN ARRAY

CASE 1 A ONE DIMENSIONAL ARRAY X(232) FIND THE LARGEST VALUE IN ARRAY X

SOLUTION: ASSUME THAT THE FIRST IS THE LARGEST ELEMENT. COMPARE THE SECOND NUMBER WITH THE FIRST. IF THE SECOND IS LARGER THAN THE FIRST, EXCHANGE VALUES. IF THE FIRST WAS LARGER, COMPARE THE THIRD VALUE WITH THE FIRST, ETC.

```
        BIG=X(1)
        DO 1Ø I=2,232
        IF(BIG-X(I))5,1Ø
    5   BIG=X(I)
   1Ø   CONTINUE
```

CASE 2 A TWO DIMENSIONAL ARRAY Y (25,34) FIND THE LARGEST VALUE IN ARRAY Y

SOLUTION: SAME TECHNIQUE AS ABOVE

```
        BIG=Y(1,1)
        DO 1Ø I=1,25
        DO 1Ø J=1,34
        IF(BIG-Y(I,J))5,1Ø
    5   BIG=Y(I,J)
   1Ø   CONTINUE
```

SUBSCRIPT EXPRESSIONS

ALLOWABLE FORMS:

A SUBSCRIPTED EXPRESSION IS RESTRICTED TO THE FOLLOWING ALLOWABLE FORMS.

n
i
m*i
i+n
i−n
m*i+n
m*i−n

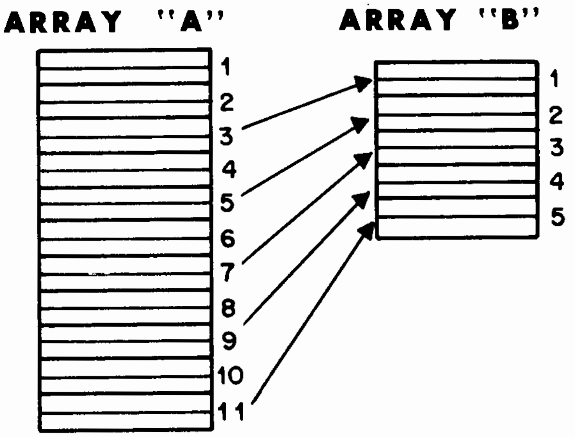
THE VALUE OF THE SUBSCRIPT EXPRESSION, EVEN WITHOUT THE ADDED OR SUBTRACTED CONSTANTS, MUST NEVER BE LESS THAN 1, OR GREATER THAN THE VALUE SPECIFIED WITHIN THE DIMENSION STATEMENT.

where m and n → REPRESENT INTEGER CONSTANTS
and i → REPRESENTS AN INTEGER VARIABLE

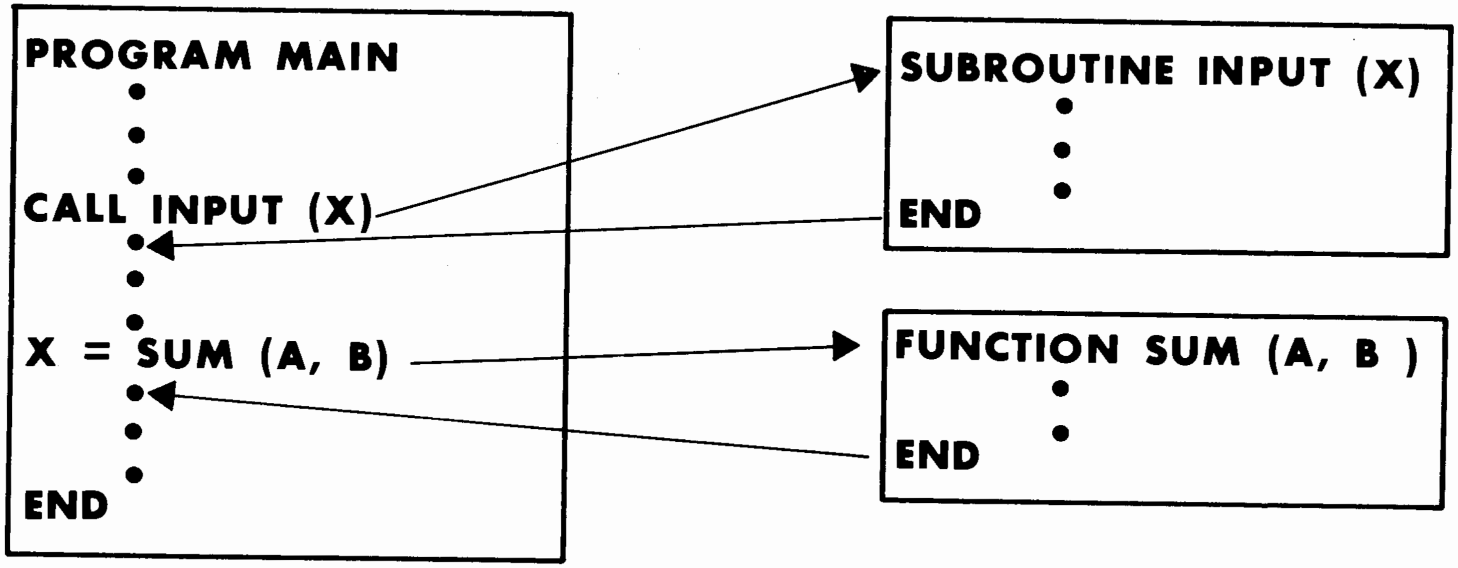
EXAMPLE: ASSUME THAT WE WANT TO TAKE THE 3, 5, 7, 9, 11, ... elements out of array A and put them into the 1, 2, 3, 4, 5 elements of array B.

SOLUTION:

```
LABEL  C STATEMENT
1    5 6 7
         I = 1
   2Ø    B(I) = A(2*I+1)
         I = I+1
         IF(I-5)2Ø,2Ø,1Ø
   1Ø    PAUSE
```



INTRODUCTION TO SUBROUTINE AND FUNCTION SUBPROGRAMS



```
PROGRAM MAIN
      •
      •
      •
CALL INPUT (X)
      •
      •
      •
X = SUM (A, B)
      •
      •
      •
END
```

```
SUBROUTINE INPUT (X)
      •
      •
      •
END
```

```
FUNCTION SUM (A, B )
      •
      •
END
```

- SUBROUTINES and FUNCTIONS are subprograms that are EXTERNAL to the main program and perform a specific operation.

- SUBROUTINES may or may not require parameter (argument) data.

- FUNCTIONS must have at least one parameter and produce a single value that is returned in the function name.

SUBROUTINE SUBPROGRAMS

SUBROUTINE DECLARATION

GENERAL FORM: SUBROUTINE B λλλλ (a_1, a_2, a_3, ... , a_n)

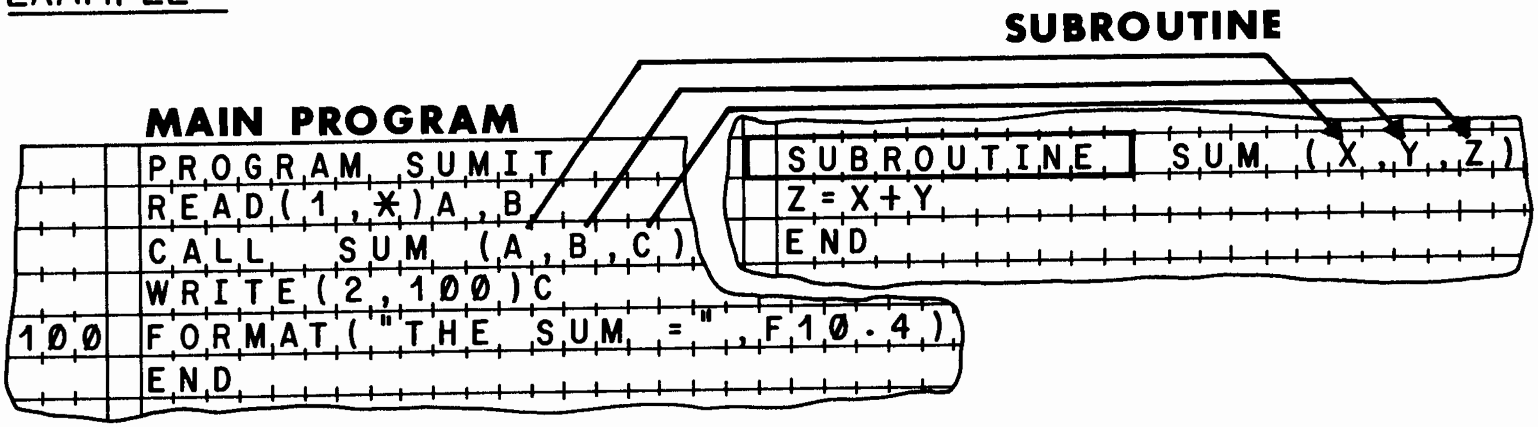
SUBROUTINE NAME ↕ DUMMY PARAMETERS (OPTIONAL)

SUBROUTINE CALL

GENERAL FORM: CALL B λλλλ (A_1, A_2, A_3, ... , A_n)

ACTUAL PARAMETERS (OPTIONAL)

EXAMPLE:



MAIN PROGRAM

```
     PROGRAM SUMIT
     READ(1,*)A,B
     CALL  SUM  (A,B,C)
     WRITE(2,100)C
100  FORMAT("THE SUM =",F10.4)
     END
```

SUBROUTINE

```
SUBROUTINE SUM (X,Y,Z)
Z=X+Y
END
```

THE "CALL SUM" TRANSFERS CONTROL FROM THE MAIN PROGRAM TO THE SUBROUTINE.

THE ADDRESSES OF THE ACTUAL ARGUMENTS IN THE MAIN PROGRAM REPLACE THE DUMMY ARGUMENTS OF THE SUBROUTINE.

THE SUBROUTINE OBTAINS ARGUMENT VALUES (A, B) FROM THE MAIN PROGRAM, COMPUTES A + B AND STORES (C) IN THE MAIN PROGRAM.

SUBROUTINE EXAMPLES

THE PROGRAMS SHOWN WILL PRODUCE IDENTICAL RESULTS

EXAMPLE 1

IN LINE

```
      PROGRAM SUM1
      READ(1,*)A,B
      C=A+B
      WRITE(2,1ØØ)C
1ØØ   FORMAT(' THE SUM=',F1Ø.4)
      END
```

EXAMPLE 2

EXTERNAL

```
      PROGRAM SUMIT
      READ(1,*)A,B
      CALL SUM(A,B,C)
      WRITE(2,1ØØ)C
1ØØ   FORMAT(' THE SUM=',F1Ø.4)
      END
```

```
      SUBROUTINE SUM(X,Y,Z)
      Z=X+Y
      END
```

ACTUAL ARGUMENTS (A,B,C) "REPLACE" DUMMY ARGUMENTS (X,Y,Z) WHICH ARE USED TO WRITE THE SUBROUTINE

A SAMPLE SUBROUTINE PROBLEM

PROBLEM: Write a program which reads two numbers from the Teletype and considers them R and THETA. It calls **SUBROUTINE CONVT (R, THETA, X,Y)** which returns X and Y as rectangular components of the polar vector R, THETA. Assume that THETA is in radians. The program should write the value of X and Y on the Teleprinter. Write the subroutine.

SOLUTION:

```
      PROGRAM DEMOS
    1 READ(1,*)R,THETA
      CALL CONVT(R,THETA,X,Y)
      WRITE(2,2)X,Y
    2 FORMAT("(X,Y) = ",2F1Ø.3)
      END

      SUBROUTINE CONVT(RAD,ANGLE,XCORD,YCORD)
      XCORD=RAD*COS(ANGLE)
      YCORD=RAD*SIN(ANGLE)
      END
```

- **R, THETA ARE INPUT PARAMETERS**
- **X,Y ARE OUTPUT PARAMETERS**

FUNCTION SUBPROGRAMS

FUNCTION DECLARATION

GENERAL FORM: **FUNCTION B ∧∧∧∧ $(a_1, a_2, a_3, \ldots, a_n) = e$**

NAME OF THE FUNCTION **DUMMY PARAMETERS** **ARITHMETIC EXPRESSION**

FUNCTION CALL

GENERAL FORM: **Y = B ∧∧∧∧ $(A_1, A_2, A_3, \ldots, A_n)$**

(ACTUAL PARAMETERS)

MAIN PROGRAM

```
      PROGRAM ADDIT
      READ(1,*)A,B
      C=ADDF(A,B)
      WRITE(2,100)C
100   FORMAT("THE SUM =",F9.2)
      END
```

FUNCTION SUBPROGRAM

```
      FUNCTION ADDF(A,B)
      ADDF=A+B
      END
```

THE FUNCTION DECLARATION ESTABLISHES (A, B) TO BE DUMMY PARAMETERS.

THE PROGRAM CALLS THE FUNCTION AND PROVIDES ACTUAL PARAMETERS (A, B) THE (A, B) IN THE PROGRAM AND THE (A, B) IN THE FUNCTION ARE NOT THE SAME. THE MODE OF THE DUMMY PARAMETERS (REAL AND/OR INTEGER) USED IN THE FUNCTION DECLARATION MUST CORRESPOND TO THE MODE OF THE ACTUAL PARAMETERS USED IN THE FUNCTION CALL.

INTEGER AND REAL FUNCTIONS

- INTEGER FUNCTIONS START WITH THE LETTERS I,J,K,L,M,N
- REAL FUNCTIONS START WITH THE LETTERS A-H AND O-Z

EXAMPLE 1 A FUNCTION TO FIND THE LARGEST OF TWO INTEGERS.

```
      FUNCTION IBIG(J,K)
      IF(J-K)1Ø,2Ø
   1Ø IBIG=K
      RETURN
   2Ø IBIG=J
      END
```

CAUSES A RETURN TO THE CALLING PROGRAM.

EXAMPLE 2 A FUNCTION THAT COMPARES AN INTEGER AGAINST A HIGH AND LOW LIMIT, AND:

SETS I = + 1 IF DATA ≥ HIGH LIMIT
I = - 1 IF DATA ≤ LOW LIMIT
I = Ø IF DATA IS WITHIN LIMITS

```
      FUNCTION ICMPR(XHI,XLO,DATA)
      I=1
      IF(DATA-XHI)1Ø,1ØØ,1ØØ
   1Ø I=Ø
      IF(DATA-XLO)2Ø,2Ø,1ØØ
   2Ø I=-1
  1ØØ ICMPR=I
      END
```

EXAMPLE 3 A "REAL" FUNCTION TO COMPUTE THE HYPOTENUSE OF A RIGHT TRIANGLE.

```
      FUNCTION HYPOT(X,Y)
      HYPOT=SQRT(X*X+Y*Y)
      END
```

A SAMPLE FUNCTION PROBLEM

THE PROGRAM SHOWN BELOW WILL EVALUATE A QUADRATIC EQUATION AND PRINT ONE ROOT IF THE DISCRIMINANT IS POSITIVE. THE FUNCTION DISC (A,B,C,I) EVALUATES SQRT (ABS(B*B—4.*A*C)) AND RETURNS:

I = 1 FOR A POSITIVE DISCRIMINANT
I = -1 FOR A NEGATIVE DISCRIMINANT

THE PROGRAM

```
      PROGRAM QUAD
    1 READ(5,*)A,B,C
      ROOT1=(-B+DISC(A,B,C,I))/(2.*A)
      IF(I)3,2
    2 WRITE(2,1ØØ)ROOT1
  1ØØ FORMAT("ROOT ONE =",E13.7)
    3 PAUSE
      GO TO 1
      END
```

THE FUNCTION

```
      FUNCTION DISC(A,B,C,I)
      X=B*B-4.*A*C
      I=1
      IF(X)1Ø,2Ø
   1Ø I=-1
      X=-X
   2Ø DISC=SQRT(X)
      END
```

NOTE: FUNCTIONS CAN RETURN MORE THAN ONE VALUE.

THE RESULTS OF FUNCTION "DISC" ARE RETURNED TO THE MAIN PROGRAM USING THE A & B REGISTERS WHILE "I" IS STORED IN THE MAIN PROGRAM USING THE PARAMETER LIST.

LESSON VI OBJECTIVES

THIS LESSON IS A DISCUSSION OF THE HARDWARE CAPABILITIES OF HEWLETT PACKARD COMPUTERS, AND IS A PREREQUISITE TO ANY DISCUSSION OF THE HEWLETT PACKARD ASSEMBLER PROGRAM. LESSON VI WILL PROVIDE A KNOWLEDGE OF THE HARDWARE CAPABILITIES OF THE COMPUTER THAT IS ESSENTIAL TO THE ASSEMBLY LANGUAGE PROGRAMMER.

COMPUTER WORDS

COMPUTER WORDS ARE USED TO REPRESENT:

- DATA WORDS – STORE DATA USED IN COMPUTATION SUCH AS: 5, 10, +32767, −32767.
- INSTRUCTION WORDS-ARE ORDERS THAT TELL THE MACHINE WHAT TO DO –SUCH AS ADD, SHIFT OR STORE DATA.
- ADDRESS WORDS - ARE USED TO SPECIFY A 15 BIT MEMORY ADDRESS VALUE IN THE RANGE 0–32767_{10}.

FIVE BASIC WORD FORMATS -

ARE USED IN HP COMPUTERS TO REPRESENT INSTRUCTIONS, ADDRESSES AND DATA.

1. Memory Reference Instruction

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	OP				Z/C	WORD ADDRESS									

2. Register Reference Instruction

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OP						MICRO OP									

3. Input-Output Instruction

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OP						SUB OP				SELECT CODE					

4. Full Address

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	PAGE ADDRESS					WORD ADDRESS									

5. Data (single-precision integer)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SIGN	INTEGER														

COMPUTING OPERATIONS

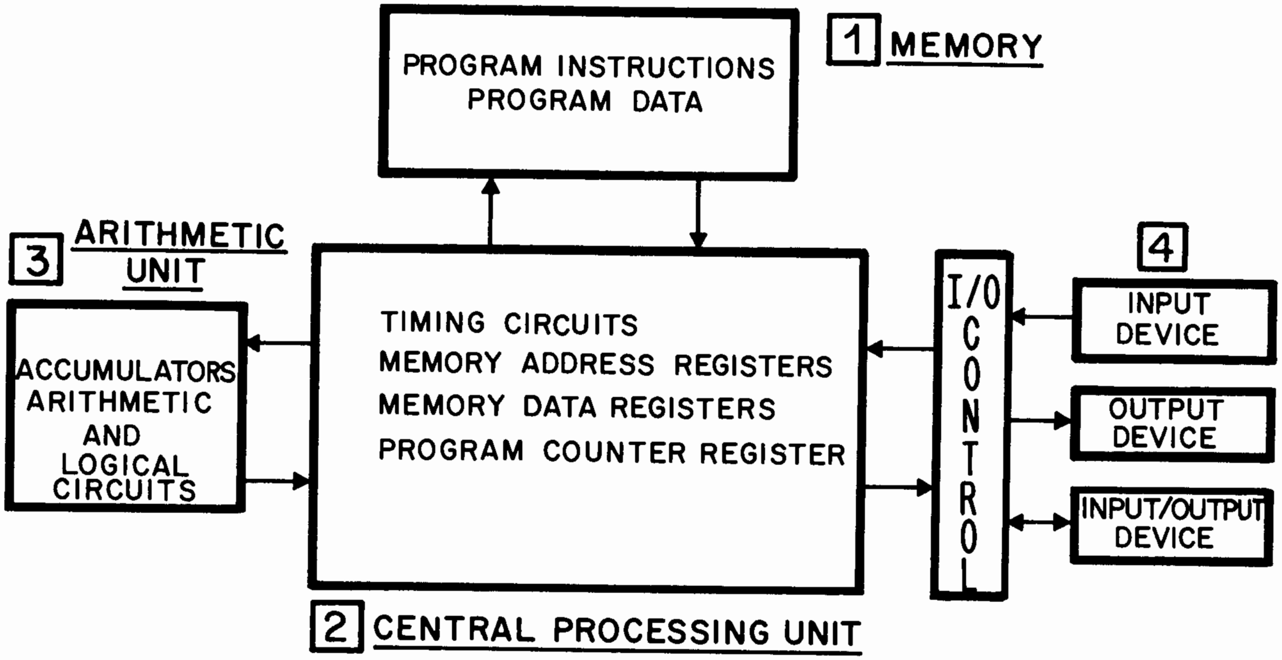
ASSUME THE FOLLOWING INITIAL CONDITIONS:

1. A PROBLEM CONSISTING OF n COMPUTER INSTRUCTIONS IS STORED IN SEQUENTIAL MEMORY LOCATIONS.
2. THE MEMORY ADDRESS OF THE FIRST INSTRUCTION IS PLACED IN THE COMPUTER" PROGRAM COUNTER" REGISTER.

PROGRAM EXECUTION FOLLOWS THIS SIMPLE PATTERN:

1. READ (FETCH) AN INSTRUCTION FROM MEMORY.
2. DECODE THE INSTRUCTION. IF THE INSTRUCTION IS NOT A MEMORY REFERENCE TYPE, GO TO 4.
3. READ THE OPERAND FROM MEMORY.
4. EXECUTE THE INSTRUCTION.
5. INCREMENT THE "PROGRAM COUNTER" REGISTER.
6. GO TO STEP 1.

A BASIC COMPUTER



1 MEMORY CONTAINS ALL PROGRAM INSTRUCTIONS AND PROGRAM CONSTANTS (NUMBERS)

2 THE C.P.U. CONTROLS AND DIRECTS ALL COMPUTER OPERATIONS.

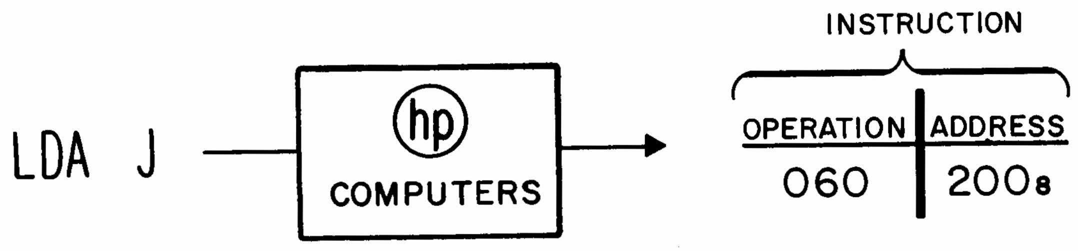
3 THE ARITHMETIC UNIT PERFORMS ALL LOGICAL AND ARITHMETIC OPERATIONS, AS DIRECTED BY THE C.P.U.

4 THE I/O DEVICES, DIRECTED BY THE C.P.U., TRANSFER DATA OR INSTRUCTIONS TO OR FROM MEMORY.

COMPUTER INSTRUCTIONS

ON THE NEXT FEW SLIDES THE COMPUTER'S INSTRUCTION EXECUTION SEQUENCE WILL BE DISCUSSED. A BRIEF REVIEW OF COMPUTER INSTRUCTIONS IS SHOWN.

FOR EXAMPLE



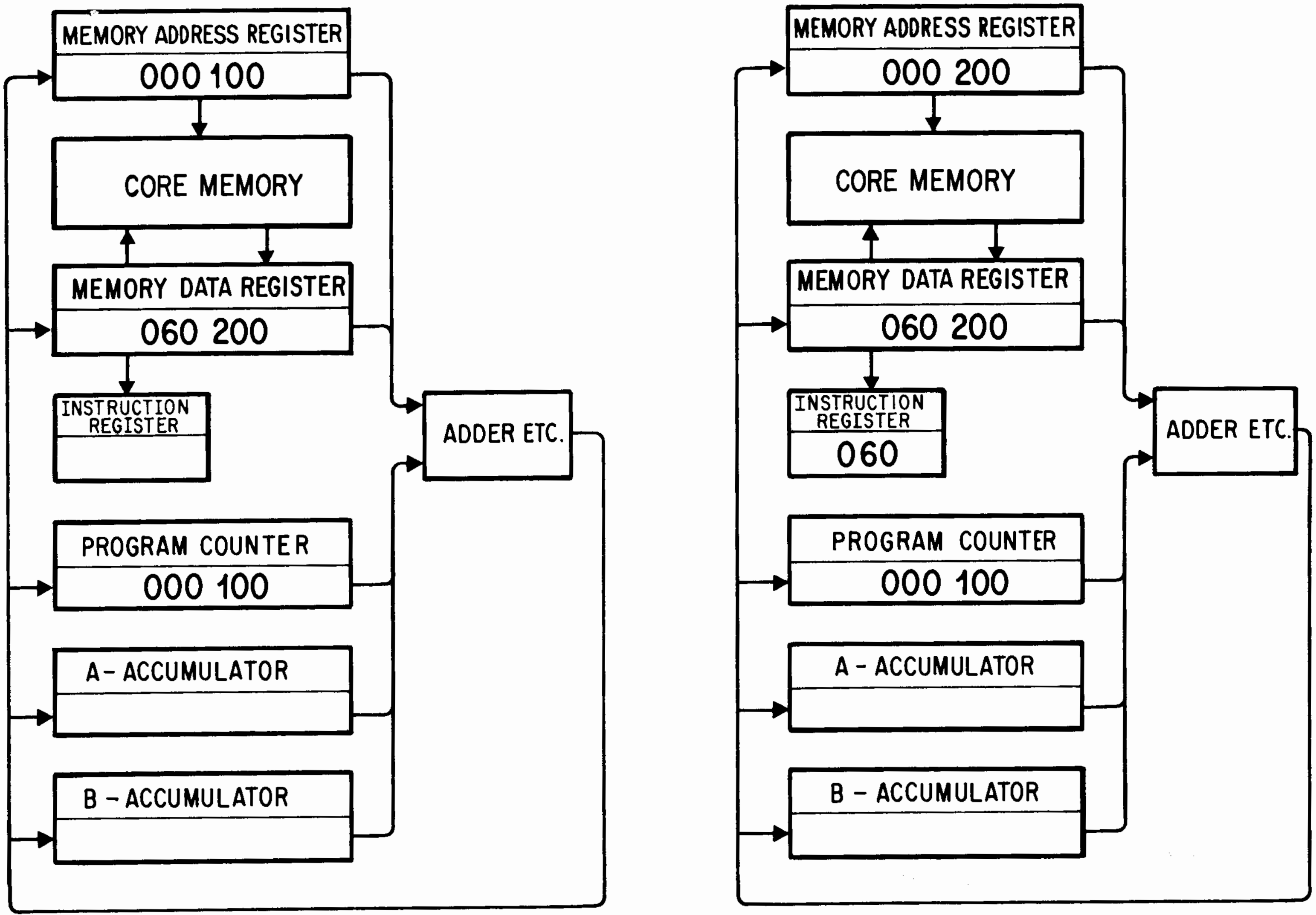
TRANSLATION:

LOAD REGISTER "A" WITH THE CONTENTS OF MEMORY LOCATION "J". REMEMBER, THE COMPUTER ONLY UNDERSTANDS 060200. LDA J IS STRICTLY FOR OUR BENEFIT.

NOTE: IN THIS EXAMPLE "J" IS ARBITRARILY REPRESENTING MEMORY LOCATION 200_8.

INSTRUCTION EXECUTION

EXAMPLE
(LDA J = 060200)



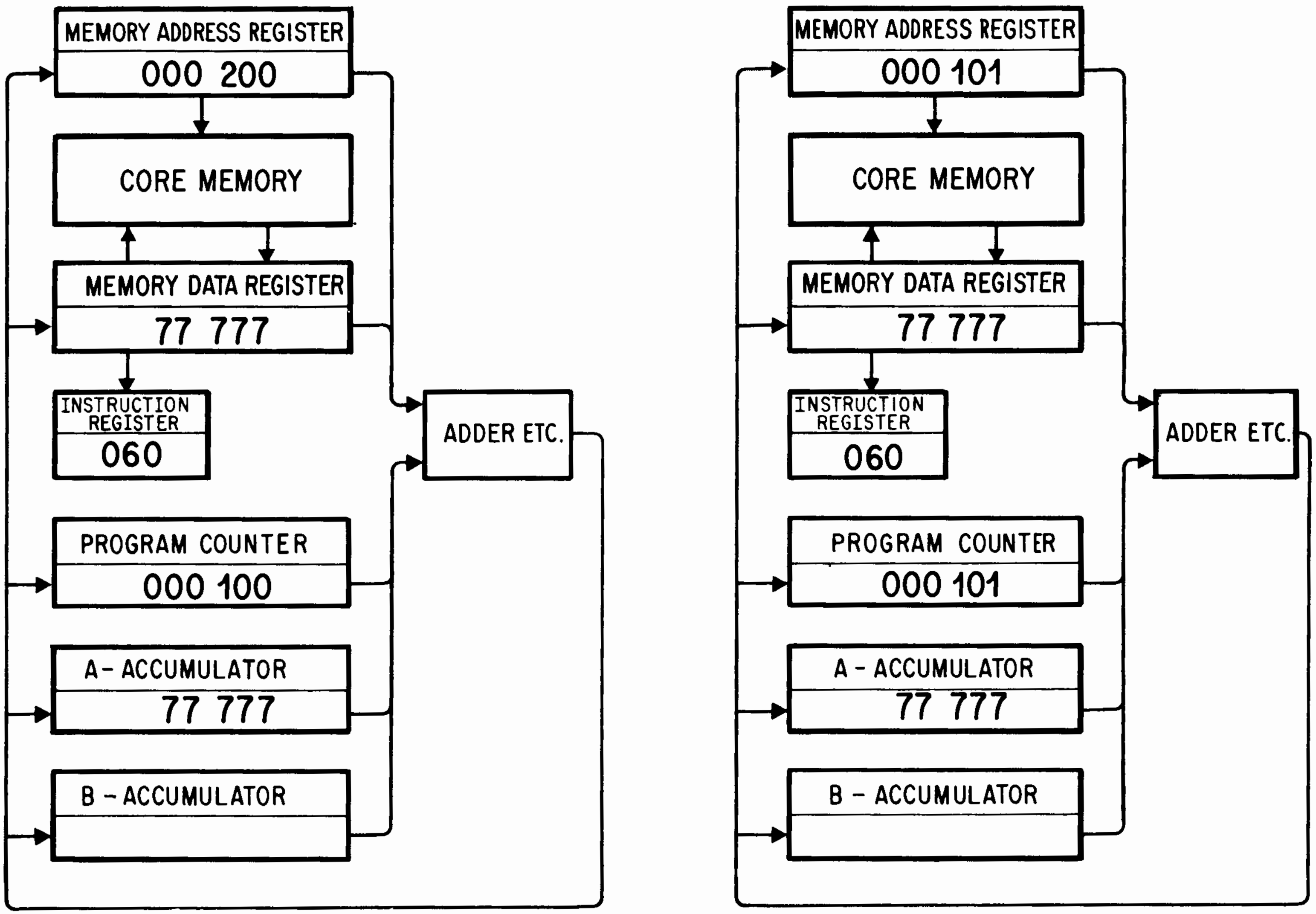
a. Instruction is Read from Memory

b. End of Fetch Phase

INSTRUCTION IN LOCATION 100 - FETCH PHASE

INSTRUCTION EXECUTION cont'd

EXAMPLE
(LDA J=060200)



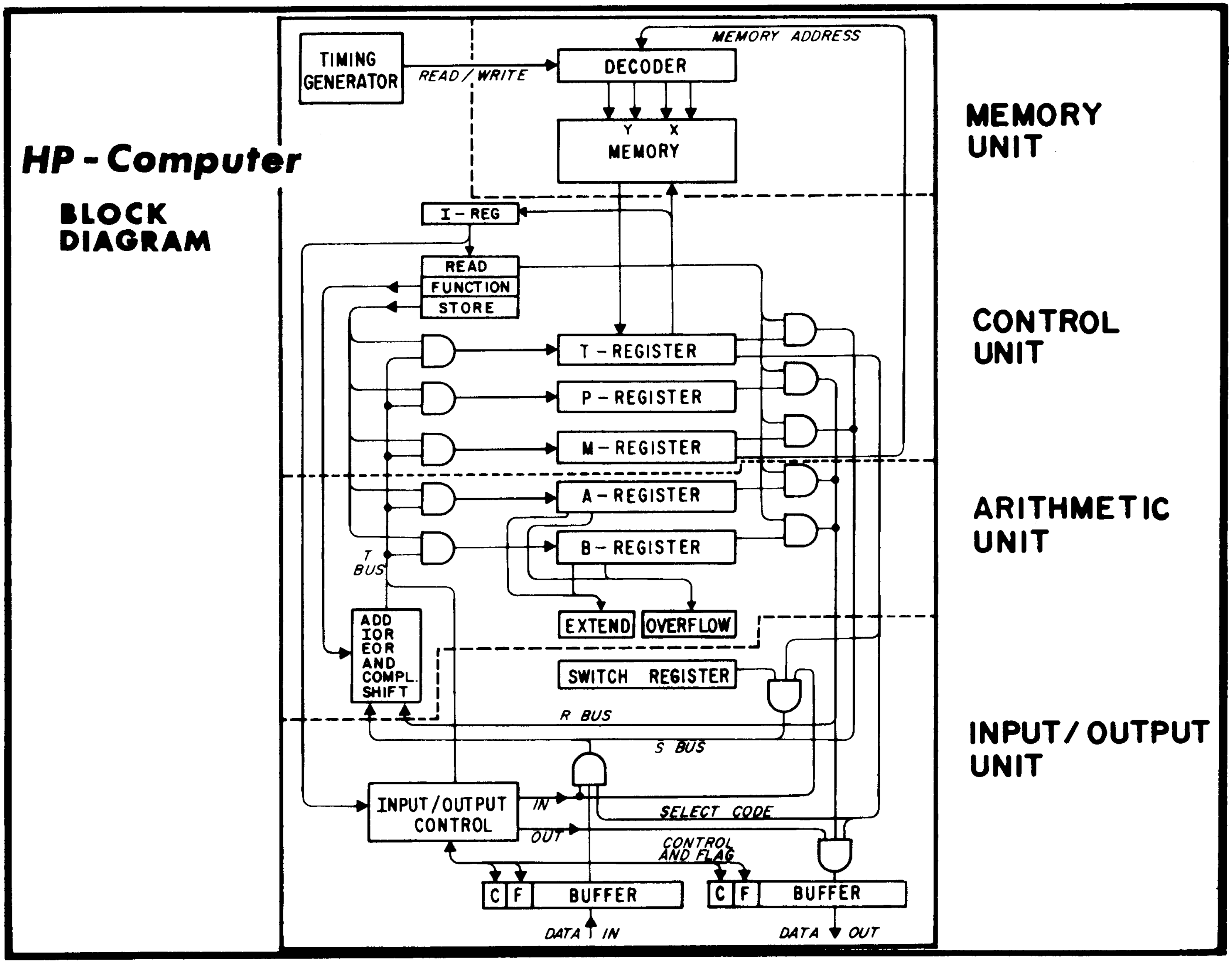
c. Instruction Executed

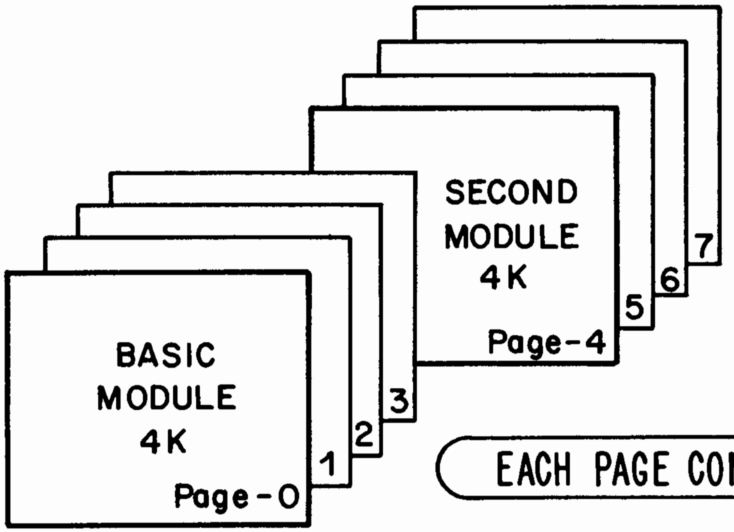
d. End of Execute Phase

INSTRUCTION IN LOCATION 100 - EXECUTE PHASE

HP - Computer

BLOCK DIAGRAM





EACH PAGE CONTAINS 1024_{10} LOCATIONS

MODULE	PAGE	OCTAL	
		FROM	TO
BASIC	0	0	01777
"	1	02000	03777
"	2	04000	05777
"	3	06000	07777
SECOND	4	10000	11777
"	5	12000	13777
"	6	14000	15777
"	7	16000	17777

MEMORY ADDRESSING (8K)

MEMORY
6000 — 7777
4000 — 5777
2000 — 3777
0000 — 1777

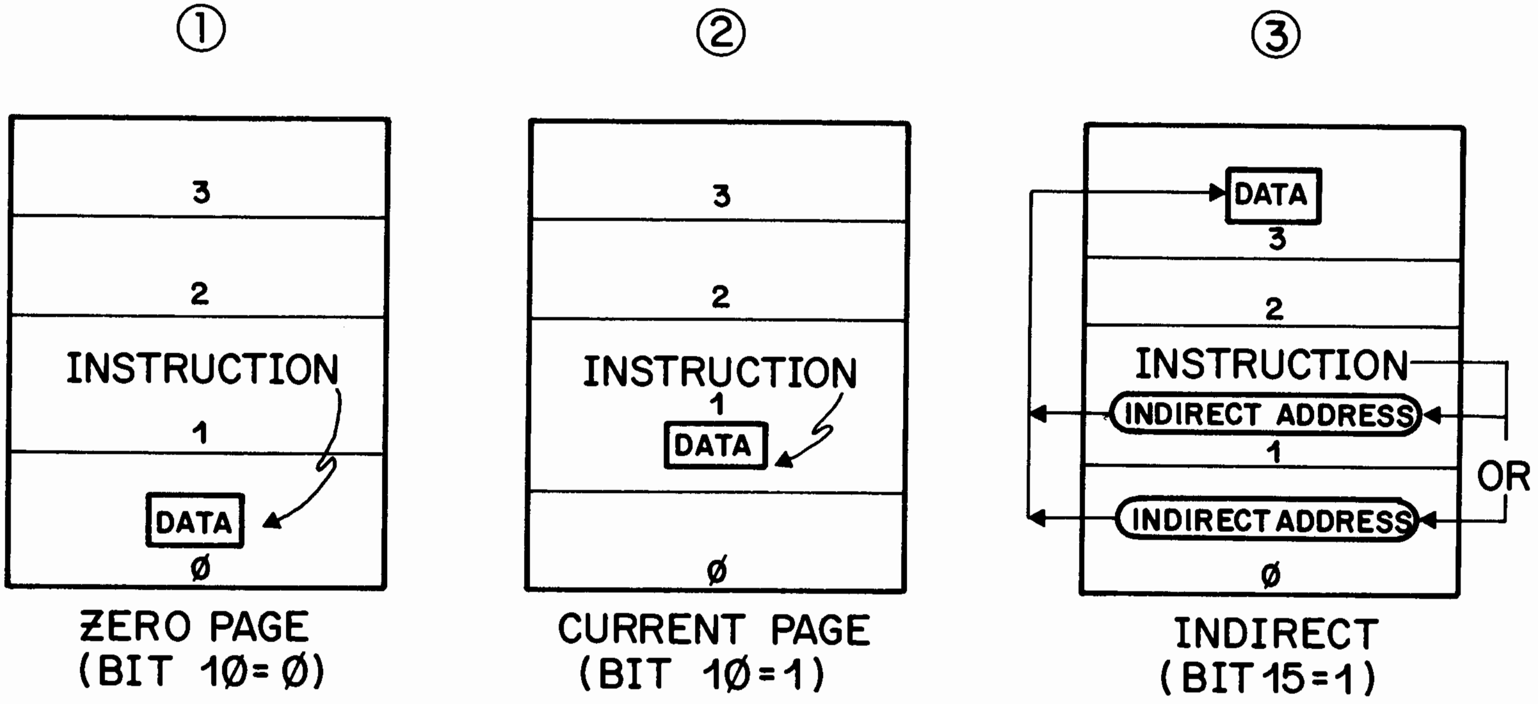
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	PAGE ADDRESS					WORD ADDRESS									

3	0000 — 1777
2	0000 — 1777
1	0000 — 1777
0	0000 — 1777

MEMORY ADDRESS REGISTER

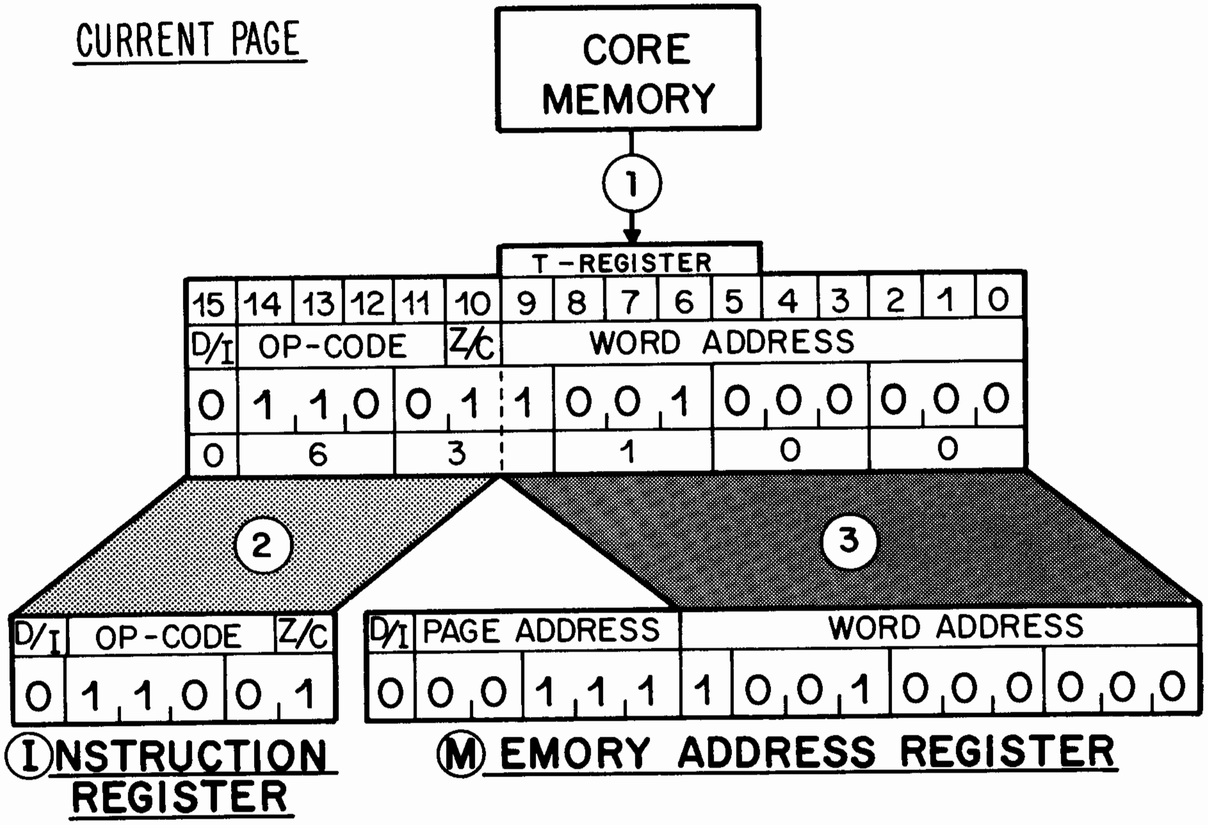
MEMORY REFERENCE INSTRUCTION

15	14 —— 11	10	9 —— 0
D/I	OP CODE	Z/C	MEMORY ADDRESS



MEMORY ADDRESSING MODES

CURRENT PAGE



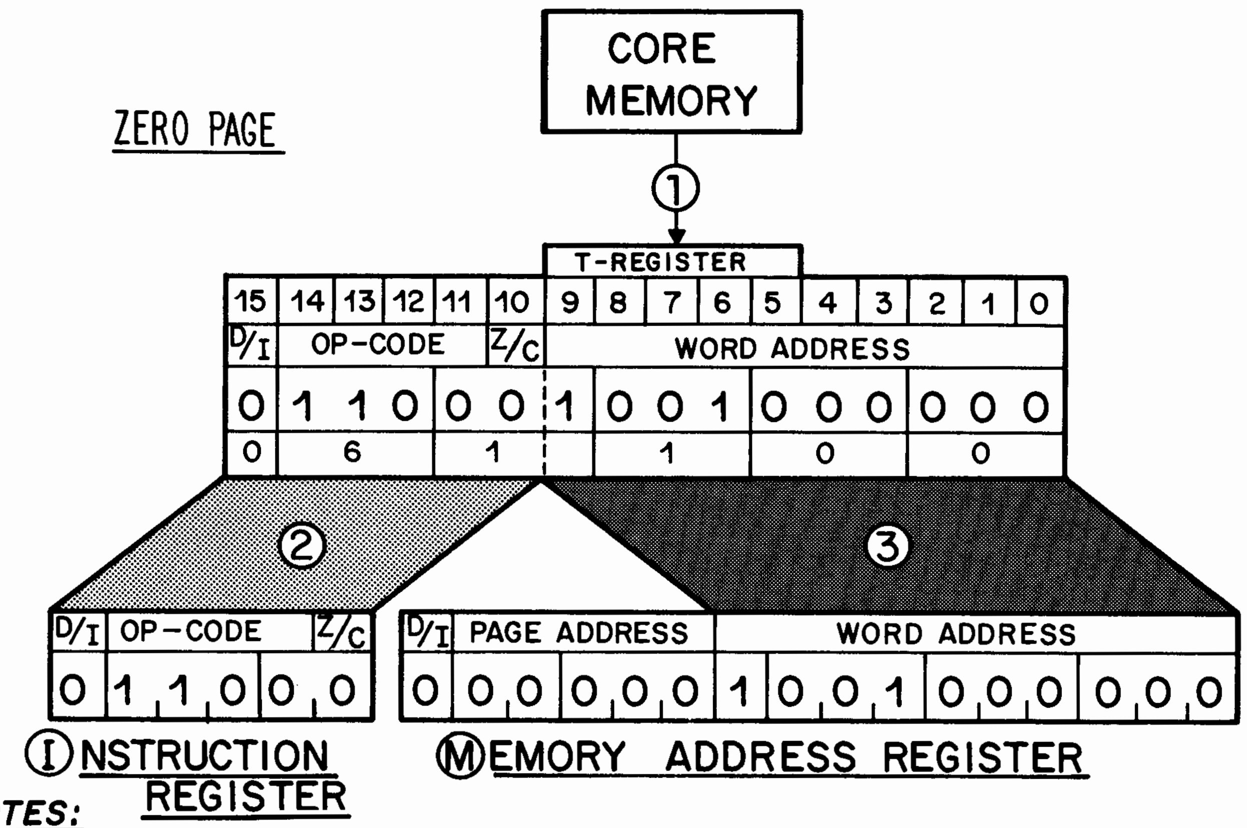
NOTES:

1. INSTRUCTION TRANSFERRED FROM MEMORY TO THE T-REGISTER.

2. BITS 10-15 TRANSFERRED FROM T-REG. TO THE I-REG.

3. BITS 0-9 FROM T-REG. ARE MERGED WITH BITS 10-15 OF THE M-REG.

MEMORY REFERENCE INSTRUCTION DECODING



NOTES:

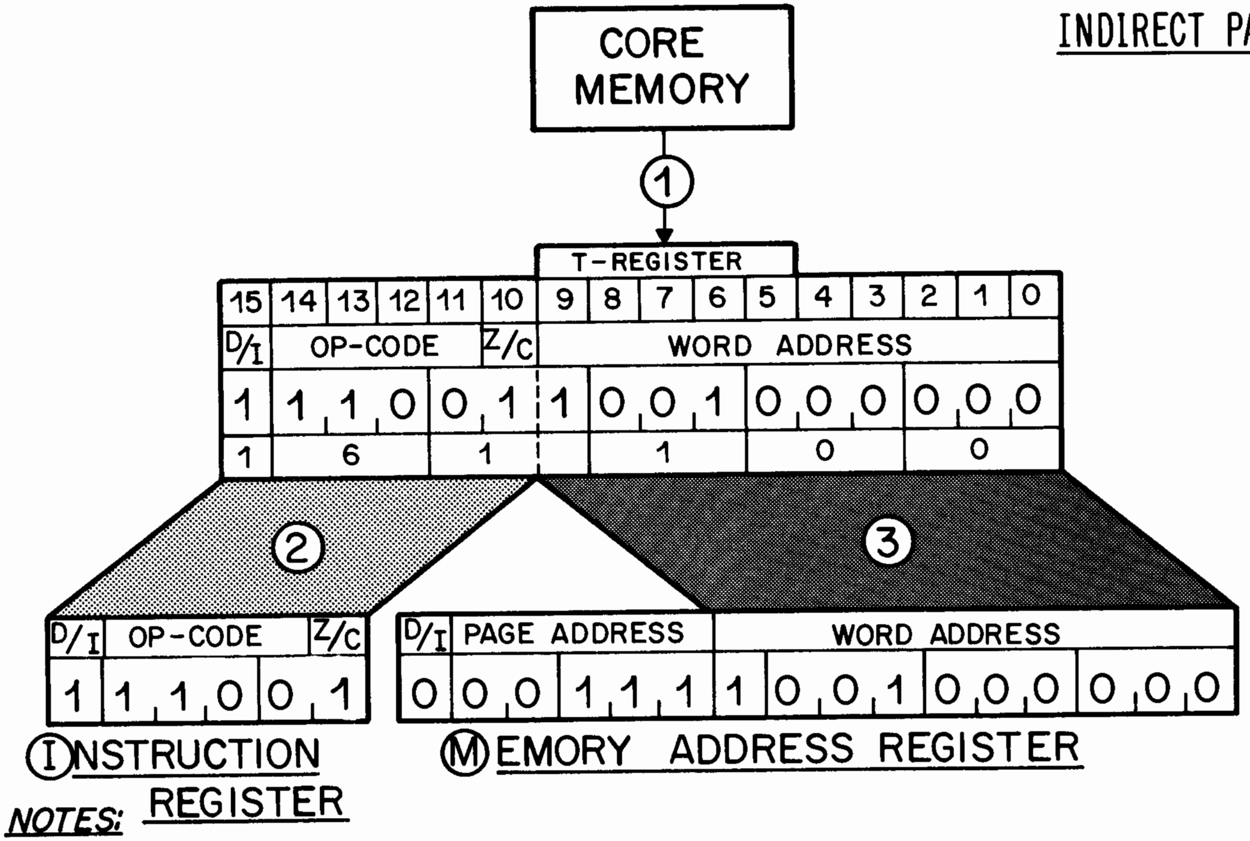
1. INSTRUCTION TRANSFERRED FROM MEMORY TO THE T-REGISTER.

2. BITS 10-15 TRANSFERRED FROM T-REG. TO THE I-REG.

3. BITS 0-9 TRANSFERRED FROM T-REG TO THE M-REG AND BITS 10-15 OF M-REG ARE CLEARED TO ZERO.

MEMORY REFERENCE INSTRUCTION DECODING

INDIRECT PART I



NOTES:

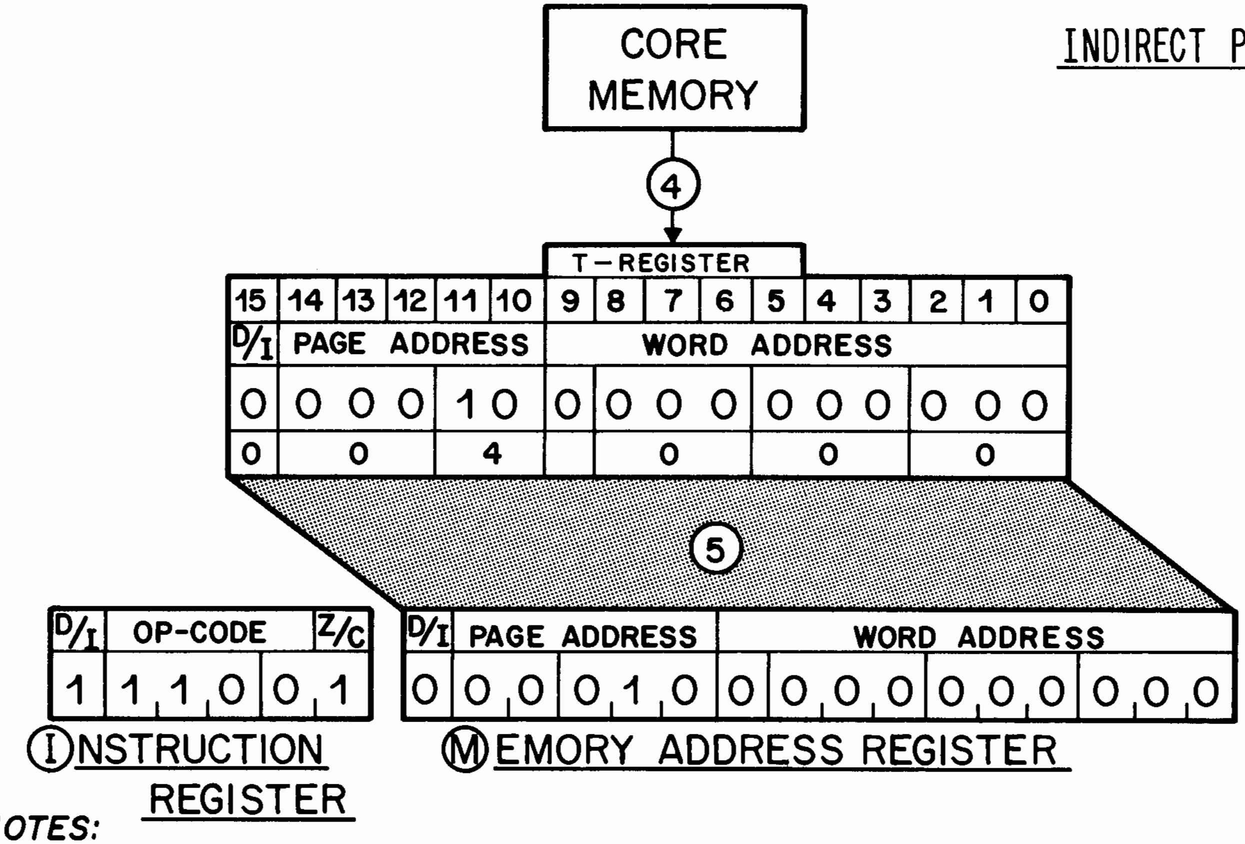
① INSTRUCTION TRANSFERRED FROM MEMORY TO THE T-REGISTER.

② BITS 10–15 TRANSFERRED FROM T-REG. TO THE I-REG.

③ BITS 0–9 FROM T-REG. ARE MERGED WITH BITS 10–15 OF THE M-REG. BIT 15 OF I-REG. = 1 CAUSES ANOTHER CYCLE TO BEGIN.

MEMORY REFERENCE INSTRUCTION DECODING

INDIRECT PART II



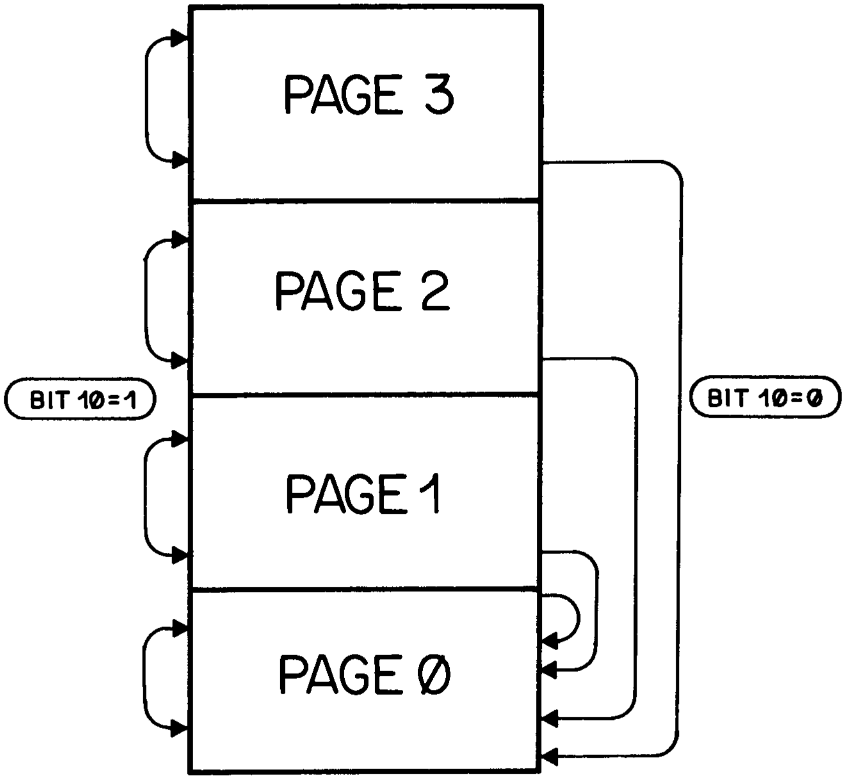
NOTES:

(4) THE 15 BIT ADDRESS IS TRANSFERRED FROM MEMORY TO THE "T"-REGISTER

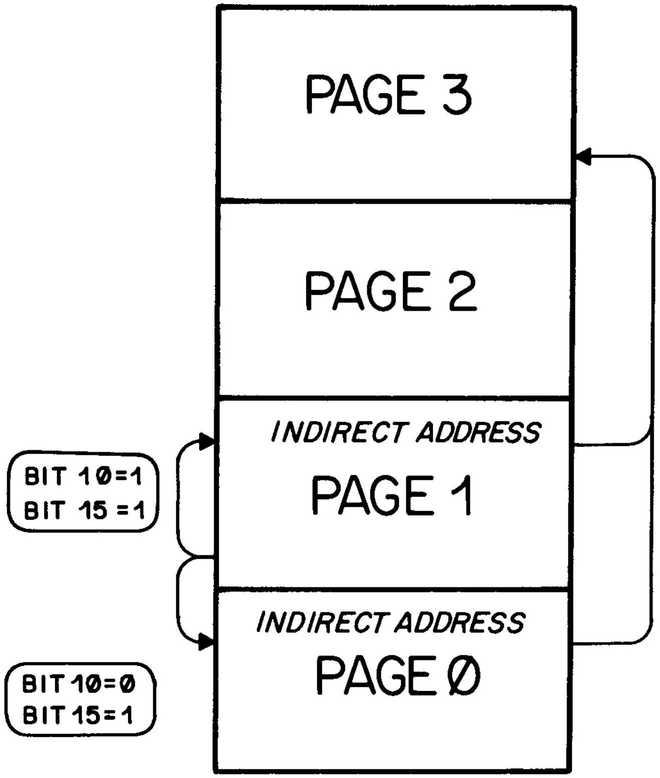
(5) BITS 0-15 TRANSFERRED FROM T-REGISTER TO THE M-REGISTER.

I-REG IS NOT CHANGED

MEMORY REFERENCE INSTRUCTION DECODING



MEMORY ADDRESSING
(DIRECT)



MEMORY ADDRESSING
(INDIRECT)

MEMORY ADDRESSING REVIEW

A UNIQUE FEATURE OF H-P COMPUTERS IS THE ABILITY TO ADDRESS THE "A" OR "B" REGISTERS DIRECTLY. THE METHOD USED TO PROVIDE THIS FEATURE WAS TO MAKE REGISTER "A" SYNONYMOUS WITH MEMORY ADDRESS Ø AND REGISTER "B" SYNONYMOUS WITH MEMORY ADDRESS 1.

THEREFORE

MEMORY ADDRESS Ø IS THE "A" REGISTER.
MEMORY ADDRESS 1 IS THE "B" REGISTER.

EXAMPLE

LOAD THE "A" REGISTER WITH THE CONTENTS OF THE "B" REGISTER.

MNEMONIC	MACHINE CODE
LDA 1	060001

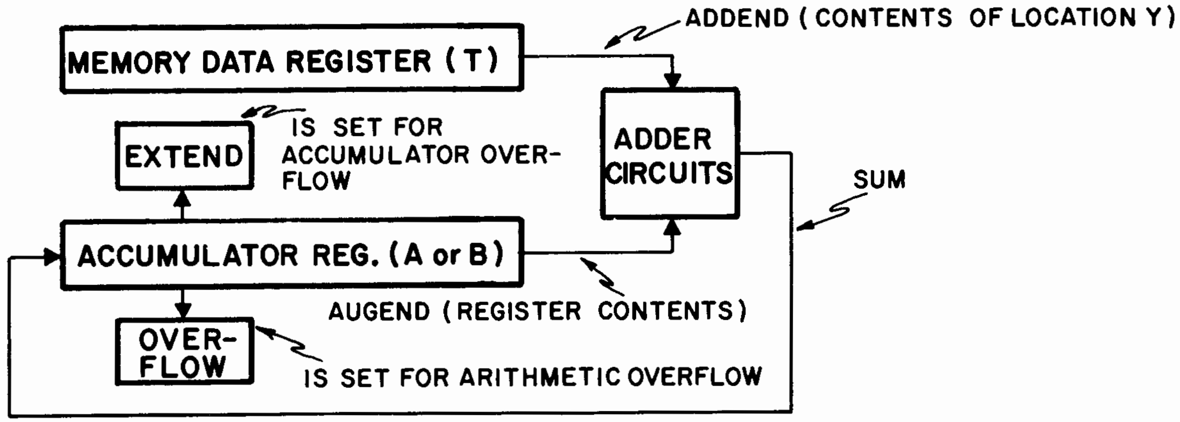
ADDRESSABLE REGISTERS

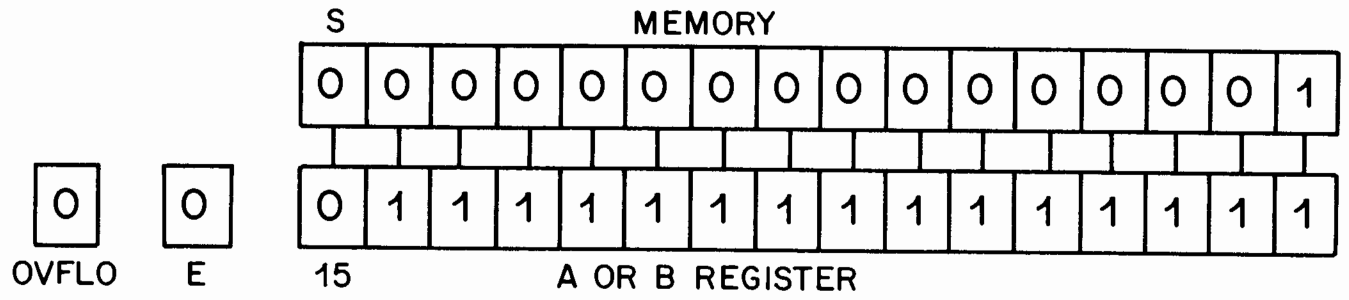
● COMPUTER ARITHMETIC OPERATIONS

THE BASIC ARITHMETIC OPERATION OF THE COMPUTER IS THE INTEGER ADD. IT IS IMPORTANT THAT THE PROGRAMMER UNDERSTAND HOW THE MACHINE PERFORMS THIS BASIC OPERATION.

FOR EXAMPLE, ADA Y MEANS:

> TO THE CONTENTS OF REGISTER "A" ADD THE CONTENTS OF MEMORY LOCATION Y. THE SUM REPLACES THE PREVIOUS CONTENTS OF REGISTER "A".

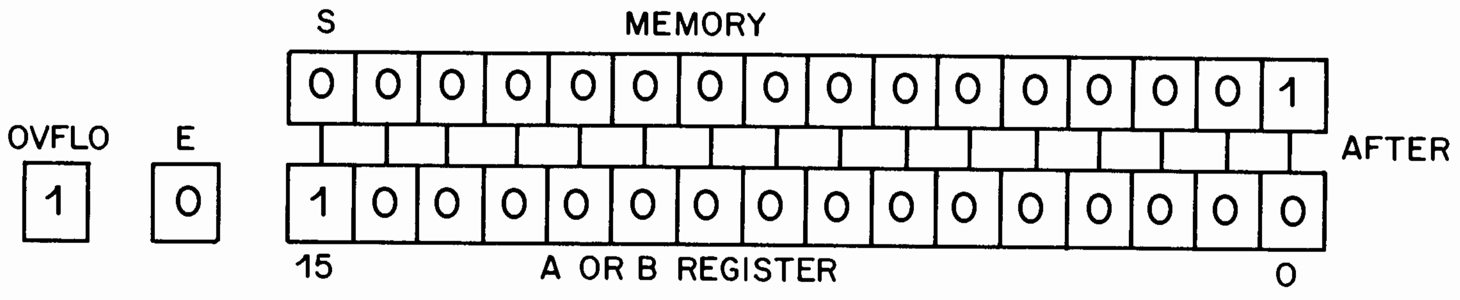

ADDEND (CONTENTS OF LOCATION Y)
MEMORY DATA REGISTER (T)
ADDER CIRCUITS
EXTEND
IS SET FOR ACCUMULATOR OVERFLOW
SUM
ACCUMULATOR REG. (A or B)
AUGEND (REGISTER CONTENTS)
OVERFLOW
IS SET FOR ARITHMETIC OVERFLOW



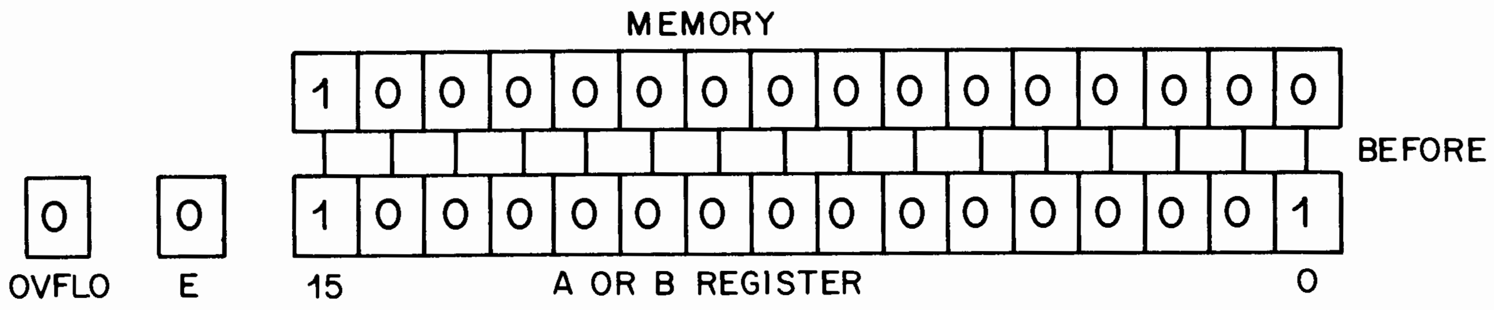
INSTRUCTION

[ADD]

POSITIVE OVERFLOW CASE. THE CARRY IN TO BIT 15 CHANGES THE SIGN. THE ADDITION OF TWO POSITIVE NUMBERS CANNOT CORRECTLY PRODUCE A NEGATIVE RESULT. THE OVERFLOW LAMP IS ON.



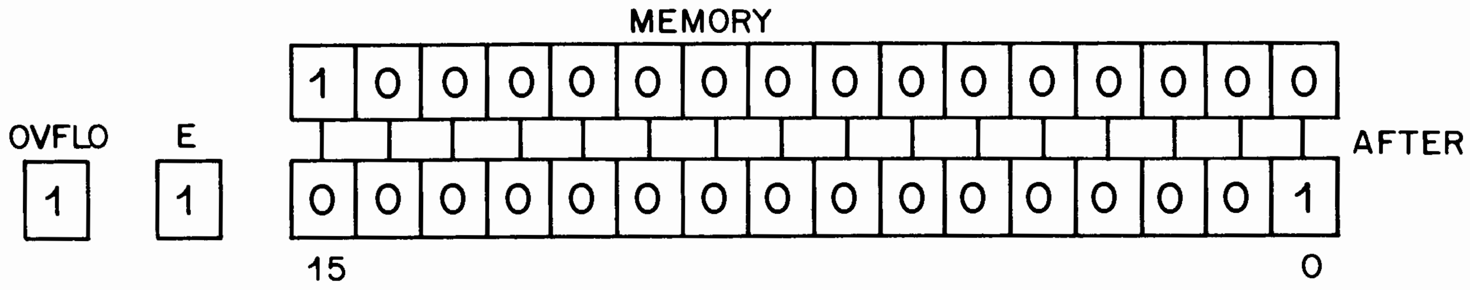
POSITIVE OVERFLOW



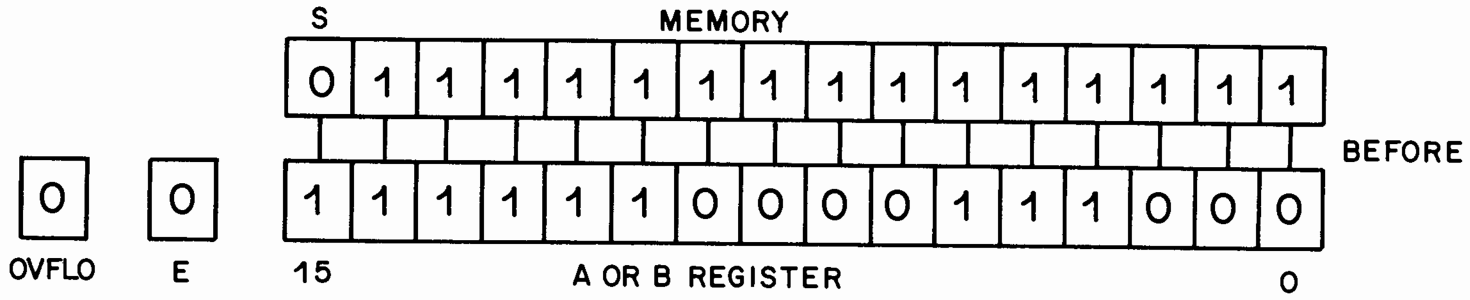
INSTRUCTION

[ADD]

NEGATIVE OVERFLOW. NO CARRY IN TO BIT 15 CHANGES THE SIGN. THE ADDITION OF TWO NEGATIVE NUMBERS CANNOT CORRECTLY PRODUCE A POSITIVE RESULT. THE OVERFLOW LAMP IS ON AND THE CARRY FROM BIT 15 WILL SET E TO 1.



NEGATIVE OVERFLOW

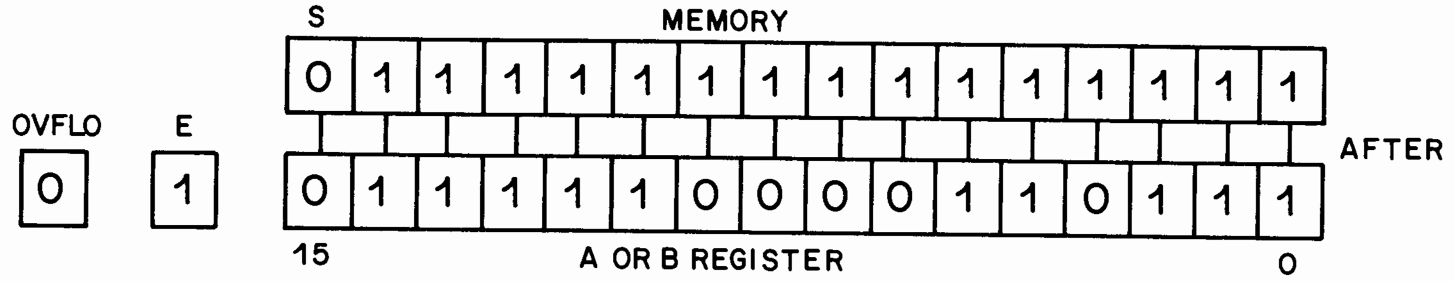


		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	0

INSTRUCTION

[ADD]

A POSITIVE NUMBER ADDED TO A NEGATIVE NUMBER (OR THE CONVERSE) WILL NEVER SET THE OVERFLOW CONDITION. IT IS POSSIBLE HOWEVER TO SET "E" TO 1 WITHOUT THE OVERFLOW CONDITION.



		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1	0	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1

ADDITION OF POSITIVE AND NEGATIVE NUMBERS

MEMORY	A/B REGISTER	RESULT	"OVFLO"	"E" REGISTER
+	+	+	NO	Ø
+	+	−	YES	Ø
+	−	±	NO	1 OR Ø
−	+	±	NO	1 OR Ø
−	−	−	NO	1
−	−	+	YES	1

* OVFLO, E REGISTERS CAN BE SET BY ADD OR INCREMENT INSTRUCTIONS.

TABLE OF CONDITIONS

(STATUS OF "OVF" & "E" REGISTERS)

6-22

LESSON VII OBJECTIVES

THIS LESSON PROVIDES A BRIEF OVER VIEW OF ASSEMBLY LANGUAGE PROGRAMMING AND INTRODUCES THE INDIVIDUAL ASSEMBLER INSTRUCTIONS. THE ASSEMBLER INSTRUCTIONS ARE LIKE TOOLS IN A TOOLBOX. LEARNING HOW TO USE EACH "TOOL" IN THE TOOLBOX IS THE JOB OF THE ASSEMBLY LANGUAGE PROGRAMMER.

THE PRIMARY OBJECTIVE OF LESSON VII IS TO PROVIDE ENOUGH ASSEMBLER "TOOLS" TO ENABLE THE STUDENT TO WRITE A SIMPLE ASSEMBLY LANGUAGE PROGRAM.

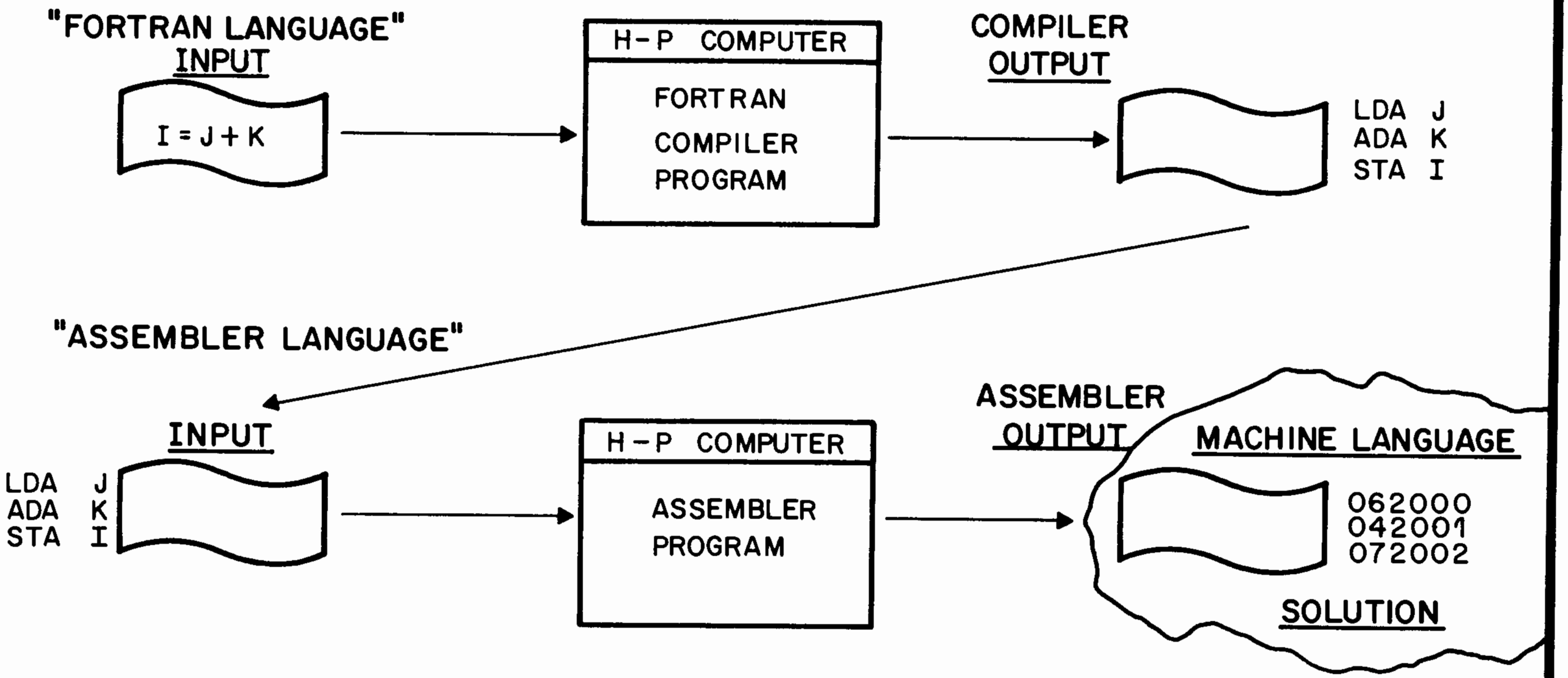
INTRODUCTION TO HP ASSEMBLY LANGUAGE

THE FORTRAN, STATEMENT, X=B*B-4.*A*C PRODUCED THE FOLLOWING ASSEMBLY LANGUAGE CODE:

	SYMBOLIC CODE		EXPLANATION
	opcode ↓	operands	— Remarks
double load into both accumulater.	DLD	B	LOAD B (INTO ACCUMULATORS)
Floating point multiply of B.	FMP	B	MULTIPLY B (B^2)
double store in X B(2)	DST	X	STORE RESULT TO X
double load real -4.	DLD	RM4	LOAD MINUS 4. (-4.)
Floating multiply by A.	FMP	A	MULTIPLY A (-4.A)
" " by C	FMP	C	MULTIPLY C (-4.AC)
Floating ADD from X.	FAD	X	ADD X (B^2-4.AC)
double store in X.	DST	X	STORE RESULT TO X

First character must be ALPHA or decimal point
A Comment be longer than 5

COMPILERS AND ASSEMBLERS



NOTES: OUTPUT OF THE COMPILER BECOMES THE ASSEMBLER INPUT
OUTPUT OF THE ASSEMBLER IS IN MACHINE LANGUAGE

THE HP FORTRAN COMPILER (PASS 2 SECTION) CONTAINS A VERSION OF THE HP ASSEMBLER PROGRAM.

THE ASSEMBLY LANGUAGE VS FORTRAN

WHY TEACH ASSEMBLY LANGUAGE WHEN FORTRAN IS AVAILABLE ?

ANSWER

1. ASSEMBLY LANGUAGE IS USED FOR ALL HP SOFTWARE DEVELOPMENT.
2. CERTAIN PROGRAMMING APPLICATION PROBLEMS ARE DIFFICULT OR IMPOSSIBLE TO SOLVE USING FORTRAN.
3. USER DEVELOPED ASSEMBLER LANGUAGE SUBROUTINES CALLED BY FORTRAN MAIN PROGRAMS, ENHANCE THE TOTAL CAPABILITY OF THE COMPUTING SYSTEM.

THE HEWLETT-PACKARD SYMBOLIC ASSEMBLER PROVIDES "MEMORY PAGE FREE" PROGRAMMING AND IS A VERY EFFICIENT METHOD OF CREATING MACHINE LANGUAGE COMPUTER PROGRAMS.

THE TEN STEPS FROM PROBLEM TO PROGRAM

ALL Compilers takes
SA. 100_8;
BCS SA. 2_8
Assembled Program 2_8

STEP 1 - DEFINE THE PROBLEM.

STEP 2 - PREPARE A FLOWCHART SOLUTION.

STEP 3 - WRITE AN ASSEMBLY LANGUAGE PROGRAM.

STEP 4 - KEYPUNCH THE SOURCE LANGUAGE TAPE USING A TELEPRINTER.

STEP 5 - LOAD THE ASSEMBLER PROGRAM INTO THE HP COMPUTER.

STEP 6 - ASSEMBLE THE SOURCE PROGRAM. SA. 100.

STEP 7 - LOAD THE BASIC CONTROL SYSTEM INTO THE HP COMPUTER.

STEP 8 - LOAD THE ASSEMBLER PRODUCED BINARY OBJECT TAPE.

STEP 9 - (OPTIONAL) LOAD LIBRARY ROUTINES.

STEP 10 EXECUTE THE OBJECT PROGRAM. SA. 2_8

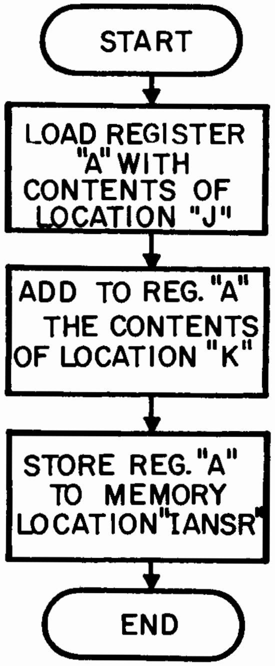
2_8 = forced to execute.

PROBLEM DEFINITION

1. USING ASSEMBLY LANGUAGE TECHNIQUES WRITE A PROGRAM TO COMPUTE IANSR = J + K

   Where $J = 15726_{10}$
   $K = 9279_{10}$

2. FLOWCHART SOLUTION


START
LOAD REGISTER "A" WITH CONTENTS OF LOCATION "J"
ADD TO REG. "A" THE CONTENTS OF LOCATION "K"
STORE REG. "A" TO MEMORY LOCATION "IANSR"
END

Relocatable
Absolute.
Binary tape.
Listing
Symbol table.

ASSEMBLER CODING FORM

HP ASSEMBLER CODING FORM

Programmer I.R. SMART	Date 5-27-68	Program SAMPLE PROG.

```
Label  Operation  Operand                    Statement
1   5     10   15   20   25   30   35   40   45   50   55
ASMB,R,B,L,T
*THIS IS A SAMPLE ASSEMBLY LANGUAGE PROGRAM
*ASTERISK IN COL 1 INDICATES "COMMENT" STATEMENT
*PROGRAM TO COMPUTE IANSR=J+K, WHERE J=15726,K=9279
*                                   REMARKS FIELD
      NAM SAMPL     PROGRAM NAME IS SAMPL
      ENT START     THIS DEFINES THE "ENTRY POINT"
K     DEC 9279      K IS DEFINED AS A DEC CONSTANT
J     DEC 15726     J IS DEFINED AS A DEC CONSTANT
IANSR OCT Ø         RESERVES A MEMORY CELL FOR IANSR
START NOP           THIS IS THE ENTRY POINT
      LDA J         LOAD J INTO REGISTER "A"
      ADA K         ADD CONTENTS OF K TO REG "A"
      STA IANSR     STORE J+K TO MEMORY CELL IANSR
      HLT 77B       HALT THE COMPUTER
      JMP START+1   TRANSFER CONTROL TO START+1
      END START     END OF PROGRAM,CONTROL TO ENT PT
```

Must have NAM

must define entry

Variable. Integ.

Comments

Remarks are not translated.

Must have end Statement

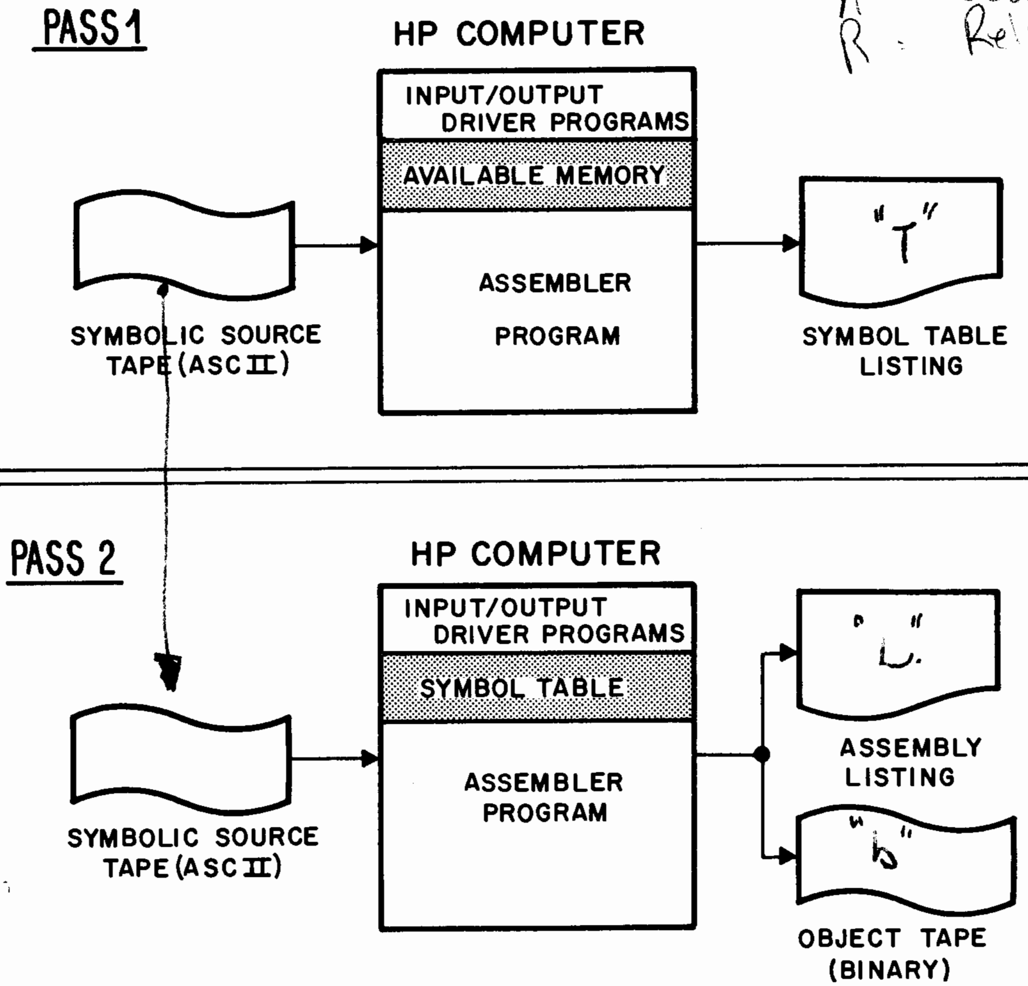
All labels as Symbolic addresses.

B designates octal max 77.B

Symbol table arranges the label in ALPA order & assignes the address (Relocatable)

ASSEMBLER PROGRAM OPERATIONS

A = absolute
R = Relocatable



PASS 1 OPERATIONS CREATE A "SYMBOL TABLE" IN THE AVAILABLE MEMORY AREA.

PASS 2 OPERATIONS RELATE THE SOURCE DATA TO THE SYMBOL TABLE, AND PRODUCE THE BINARY OBJECT TAPE AND THE ASSEMBLY LISTING.

NOTE: ASSEMBLER PRODUCED OUTPUT IS OPTIONAL.

ASSEMBLER PROCESSING

PASS 1

PROGRAM LOCATION COUNTER =	PLC$_8$	LABEL	OP CODE	OPERAND
		ASMB,R,B,L,T		
NAM SETS P.L.C. TO Ø	Ø		NAM	SAMPL
ASSEMBLER SYMBOL TABLE	Ø	Relative address	ENT	START
"K" IS ASSIGNED THE VALUE Ø	Ø	K	DEC	9279
"J" " " 1	1	J	DEC	15726
"IANSR" " " 2	2	IANSR	OCT	Ø
"START" " " 3	3	START	NOP	
	4		LDA	J
this point can be placed at any available location	5		ADA	K
	6		STA	IANSR
	7		HLT	77B
	10		JMP	START+1
			END	START

NOTE: ONLY STATEMENTS WITH LABELS CREATE SYMBOL TABLE ENTRIES. THE SYMBOL VALUE IS ASSIGNED BY THE PROGRAM LOCATION COUNTER.

Note has nothing to do with P Register.

ASSEMBLER PROCESSING

PASS 2

LOCATION8	CONTENTS8	LABEL	OP CODE	OPERAND
ØØØØØ			NAM	SAMPL
Relative location	Contents of Relative address		ENT	START
ØØØØØ	Ø22Ø77	K	DEC	9279
ØØØØ1	Ø36556	J	DEC	15726
ØØØØ2	ØØØØØØ	IANSR	OCT	Ø
ØØØØ3	ØØØØØØ	START	NOP	
ØØØØ4	Ø62ØØ1R		LDA	J
ØØØØ5	Ø42ØØØR		ADA	K
ØØØØ6	Ø72ØØ2R Relocatable Value.		STA	IANSR
ØØØØ7	1Ø2Ø77		HLT	77B
ØØØ1Ø	Ø26ØØ4R		JMP	START+1
			END	START

NOTE: MEMORY REFERENCE INSTRUCTIONS SEARCH THE SYMBOL TABLE TO FIND THE PROPER OPERAND VALUE.

MNEMONIC CODES ARE CONVERTED TO THEIR BINARY EQUIVALENT.

ASSEMBLY LISTING

Relocatable

```
PAGE ØØØ1

ØØØ1                    ASMB,R,B,L,T
K       R ØØØØØØ
J       R ØØØØØ1
IANSR   R ØØØØØ2
START   R ØØØØØ3
**  NO ERRORS*
```

Syntax error here.

assigned decimal numbers for edit

ERROR APPEAR before the statement

```
PAGE ØØØ2

ØØØ1                    ASMB,R,B,L,T
ØØØ2*THIS IS A SAMPLE ASSEMBLY LANGUAGE PROGRAM
ØØØ3*ASTERISK IN COL 1 INDICATES "COMMENT" STATEMENT
ØØØ4*PROGRAM TO COMPUTE IANSR=J+K, WHERE J =15726,K=9279
ØØØ5*                                   REMARKS FIELD
ØØØ6  ØØØØØ               NAM SAMPL     PROGRAM NAME IS SAMPL
ØØØ7                      ENT START     THIS DEFINES THE "ENTRY POINT "
ØØØ8  ØØØØØ Ø22Ø77  K     DEC 9279      K IS DEFINED AS A DEC CONSTANT
ØØØ9  ØØØØ1 Ø36556  J     DEC 15726     J IS DEFINED AS A DEC CONSTANT
ØØ1Ø  ØØØØ2 ØØØØØØ  IANSR OCT Ø         RESERVES A MEMORY CELL FOR IANSR
ØØ11  ØØØØ3 ØØØØØØ  START NOP           THIS IS THE ENTRY POINT
ØØ12  ØØØØ4 Ø62ØØ1R       LDA J         LOAD J INTO REGISTER "A"
ØØ13  ØØØØ5 Ø42ØØØR       ADA K         ADD CONTENTS OF K TO REG. "A"
ØØ14  ØØØØ6 Ø72ØØ2R       STA IANSR     STORE J+K TO MEMORY CELL IANSR
ØØ15  ØØØØ7 1Ø2Ø77        HLT 77B       HALT THE COMPUTER
ØØ16  ØØØ1Ø Ø26ØØ4R       JMP START+1   TRANSFER CONTROL TO START+1
ØØ17                      END START     END OF PROGRAM, CONTROL TO ENT PT
** NO ERRORS*
```

no memory loc

no memory loc

A	THROUGH	Ƶ
Ø	THROUGH	9
.	PERIOD	
*	ASTERISK	
+	PLUS	
–	MINUS	
,	COMMA	
( )	PARENTHESES	
	SPACE	

ALL CHARACTERS ARE ASCII CODE

THE ASSEMBLER CHARACTER SET

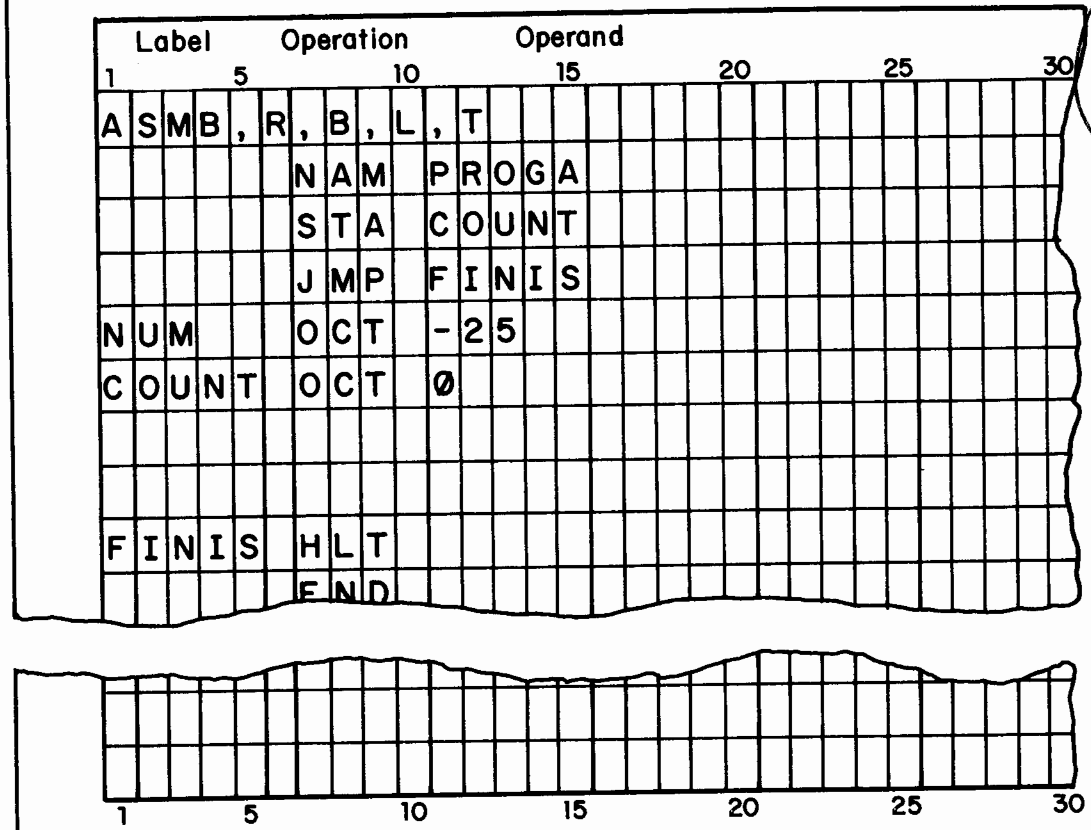
```
 LABEL       OP CODE    OPERAND    REMARKS
ASMB,R,B,L,T
              NAM        TEST 1
BEGIN         NOP
              LDA        COUNT
              JMP        GO
NUM           OCT        -12
COUNT         OCT        Ø
GO          PROGRAM      CONTINUATION
              END        BEGIN
```

THE CONTROL STATEMENT MUST BEGIN IN COLUMN 1, AND IT MUST BE THE FIRST PHYSICAL STATEMENT OF A SOURCE PROGRAM.

ASMB	IDENTIFIES ASSEMBLY INPUT
A/R	ABSOLUTE OR RELOCATABLE PROGRAM.
B	BINARY OBJECT TAPE REQUESTED
L	ASSEMBLY LISTING REQUESTED
T	LISTING OF SYMBOL TABLE REQUESTED
END	MUST BE THE LAST PHYSICAL STATEMENT OF A PROGRAM

All Entry Points must be NOP.

THE CONTROL STATEMENTS



```
ASMB,R,B,L,T
      NAM PROGA
      STA COUNT
      JMP FINIS
NUM   OCT -25
COUNT OCT Ø


FINIS HLT
      END
```

LABEL FIELD

ONE TO FIVE CHARACTERS, THE FIRST OF WHICH MUST BE ALPHABETIC OR THE PERIOD.

OPERATION FIELD

ALWAYS A THREE LETTER MNEMONIC CODE. COMMA IN COL. 1Ø EXTENDS OPERATION FIELD FOR COMBINABLE INSTRUCTIONS.

OPERAND FIELD

ALPHANUMERIC CHARACTERS, MAY EXTEND TO COL 52. not beyond.

Ø=ZERO O=ALPHA O 1 OR 1= ONE I=ALPHA I LINE TERMINATED BY RETURN/LINE FEED (R/LF)
2=TWO Ƶ=ALPHA Ƶ LINE IS DELETED BY RUBOUT BEFORE R/LF

USING THE ASSEMBLER CODING SHEET

LABEL   OP CODE   OPERAND

must begin with ALPHA or Period
1 to Five characters

	1	2	3	4	5		
VALID LABELS	A						
	.	A	B	C	D		
	.	1	2	3	4		
	A	.	1	2	3		
	.						
INVALID LABELS	1	.	A	B			FIRST CHARACTER NUMERIC
	A	B	C	1	2	3	6 CHARS.,TRUNCATED TO ABC 12
	A	B	*	C			ASTERISK ILLEGAL
		A	B	C			NO LABEL, FIRST BLANK TERMINATES LABEL FIELD.

EXAMPLES OF LABELS

SPECIAL USE OF THE ASTERISK IN THE LABEL FIELD

- Asterisk in column 1 identifies a comment statement.
- Positions 2 –80 are available for comments.
- Comments appear in the assembly listing exactly as they appear in the source program.
- Comments are not processed by the assembler and use no storage.

  NOTE: POSITIONS 1 – 68 ONLY WILL BE PRINTED ON
  THE 2752A TELEPRINTER.

EXAMPLE:

```
              LABEL        OP CODE    OPERAND

COLUMN        |1|2|3|4|5|
              ---------------------------------------
              |*|T|H|I|S| IS AN EXAMPLE OF WRITING A COMMENT
              |*|S|T|A|T|EMENT
```

```
 Label  Operation  Operand    Remarks
1   5    10   15   20   25   30   35   40
ASMB,R,L
      NAM SAMB     THE REMARKS FIELD IS
      CLA          SEPARATED FROM THE
      CMA          OPERAND FIELD BY AT
      INA          LEAST ONE SPACE
```

THE REMARKS FIELD EXTENDS FROM THE OPERAND FIELD TO THE 80th CHARACTER. THE ENTIRE STATEMENT LENGTH SHOULD NOT EXCEED 52 CHARACTERS. REMARKS SHOULD BE OMITTED IF THE FOLLOWING STATEMENTS ARE USED WITHOUT OPERANDS: NAM, END, HLT, SOC, SOS.

REMARKS FIELD

PROGRAM LOCATION COUNTER	LABEL	OP CODE	OPERAND	REMARKS
2001		LDA	COUNT	
2002		STA	COUNT-1	
2003		JMP	*+3	
2004		OCT	Ø	
2005	COUNT	DEC	-25	
2006		HLT		

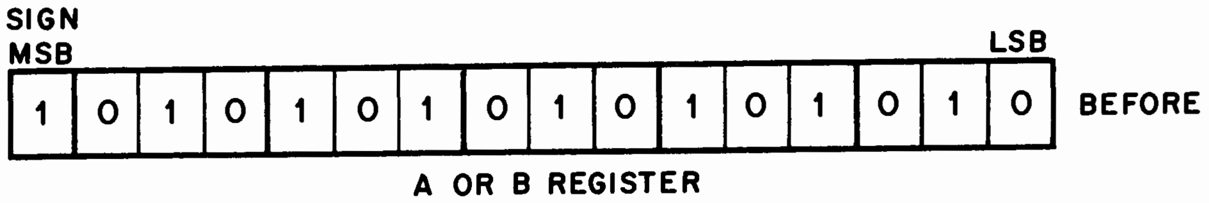
IN THIS EXAMPLE THE * HAS A VALUE OF 2003 THEREFORE * + 3 = 2006. * EQUALS THE VALUE OF THE P.L.C. WHEN IT IS ENCOUNTERED IN THE ASSEMBLY.

RELATIVE ADDRESSING

A SYMBOL USED IN THE OPERAND FIELD MUST BE DEFINED ELSEWHERE IN THE PROGRAM IN ONE OF THE FOLLOWING WAYS:

	LABEL	OP CODE	OPERAND
		LDA	*ALPHA*
AS A LABEL IN A MACHINE OPERATION	*ALPHA*	NOP	——
OR, AS A LABEL OF A PSEUDO	*ALPHA*	DEC	100
OR, IN THE OPERAND FIELD OF A COM OR EXT		COM EXT	*ALPHA* (10) *ALPHA*
OR, AS A LABEL OF AN ARITHMETIC PSEUDO.	*ALPHA*	MPY	——

SYMBOL DEFINITION



SIGN
MSB

LSB

1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

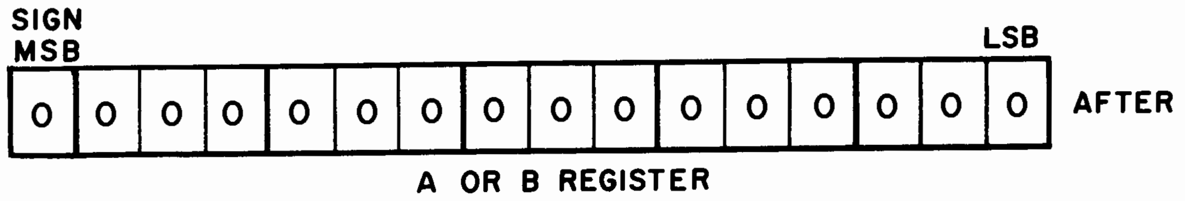
BEFORE

A OR B REGISTER

INSTRUCTION

[CLA / CLB]

CLEAR THE INDICATED REGISTER. ALL 16 BITS ARE SET TO Ø. OVFLO, 'E' ARE NOT AFFECTED.



SIGN
MSB

LSB

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AFTER

A OR B REGISTER

CLEAR ACCUMULATOR

SIGN MSB															LSB	
1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	BEFORE

A OR B REGISTER

INSTRUCTION

[CMA/CMB]

COMPLEMENT THE CONTENTS OF THE INDICATED REGISTER. THIS IS A 1's COMPLEMENT. ALL Ø's BECOME 1's. ALL 1's BECOME Ø's. OVFLO, 'E' ARE NOT AFFECTED.

SIGN MSB															LSB	
0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	AFTER

A OR B REGISTER

COMPLEMENT ACCUMULATOR

SIGN
MSB   LSB

1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	BEFORE

A OR B REGISTER

INSTRUCTION

[CCA/CCB]

CLEAR AND THEN COMPLEMENT THE INDICATED REGISTER.

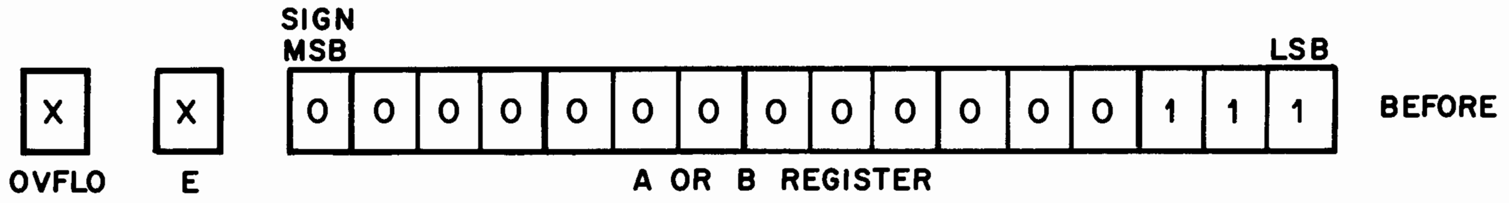
ALL 16 BITS ARE SET TO 1. OVFLO, 'E' ARE NOT AFFECTED.

SIGN
MSB   LSB

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	AFTER

A OR B REGISTER

CLEAR, COMPLEMENT THE ACCUMULATOR



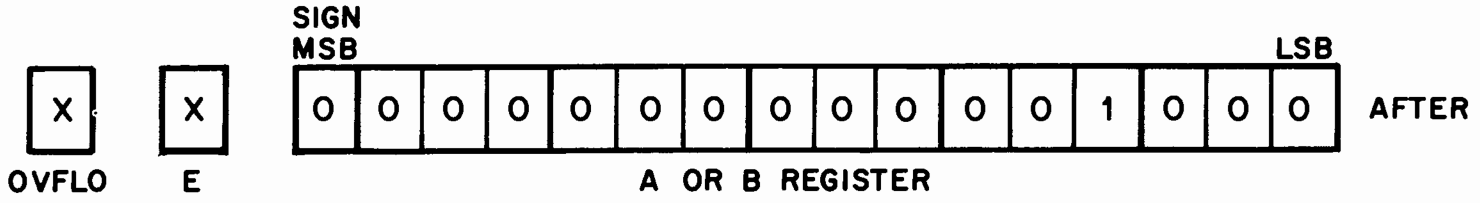
0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1

INSTRUCTION

[INA/INB]

X = 1 OR Ø

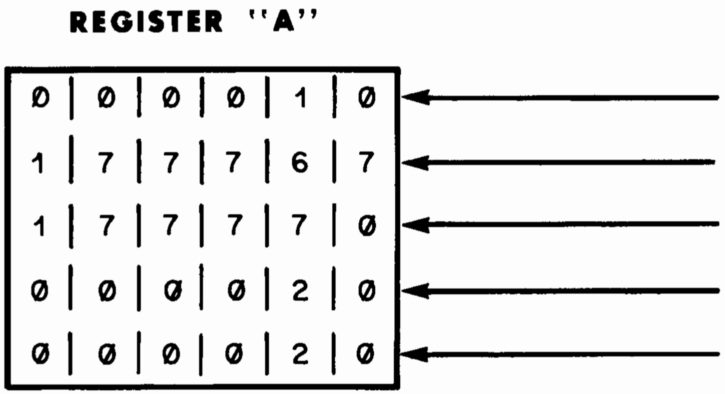
INCREMENT THE CONTENTS OF THE INDICATED REGISTER BY 1. OVERFLOW CAN BE SET AS A RESULT OF THIS OPERATION. IF A CARRY IS GENERATED FROM BIT 15, THE E REGISTER WILL BE SET TO 1 ALSO.



0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0

INCREMENT THE ACCUMULATOR

PROBLEM: compute Z = X−Y



REGISTER "A"

Ø	Ø	Ø	Ø	1	Ø
1	7	7	7	6	7
1	7	7	7	7	Ø
Ø	Ø	Ø	Ø	2	Ø
Ø	Ø	Ø	Ø	2	Ø

```
LABEL   OP CODE   OPERAND      REMARKS
          •
          •
        LDA       Y            LOAD Y
        CMA                    1'S COMPLEMENT
        INA                    2'S COMPLEMENT
        ADA       X            SUBTRACT
        STA       Ƶ            Ƶ=X-Y
        JMP       STOP         JUMP AROUND
                                    CONSTANTS
Y       OCT       1Ø
X       OCT       3Ø
Ƶ       OCT       Ø(2Ø)
STOP    CLA
          •
          •
          •
```

SUBTRACT EXAMPLE

INSTRUCTION

[CLE]

E $\boxed{1}$ OR $\boxed{0}$ BEFORE

CLEAR THE CONTENTS OF E, E IS RESET TO Ø, THE CONTENTS OF THE OTHER REGISTERS ARE NOT ALTERED BY ANY 'E' REGISTER INSTRUCTIONS.

E $\boxed{0}$ $\boxed{0}$ AFTER

INSTRUCTION

[CME]

E $\boxed{0}$ OR $\boxed{1}$ BEFORE

COMPLEMENT E,Ø BECOMES 1,1 BECOMES 0

E $\boxed{1}$ $\boxed{0}$ AFTER

INSTRUCTION

[CCE]

E $\boxed{0}$ OR $\boxed{1}$ BEFORE

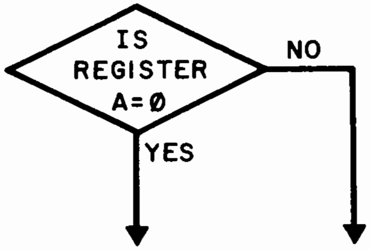
CLEAR AND THEN COMPLEMENT E

E $\boxed{1}$ $\boxed{1}$ AFTER

'E' REGISTER INSTRUCTIONS

THE ABILITY TO MAKE LIMITED DECISIONS BASED ON PRE-DEFINED CONDITIONS IS VERY IMPORTANT IN COMPUTER PROGRAMS.

FOR EXAMPLE



IN ORDER TO IMPLEMENT THE DECISION SYMBOL ONE OR MORE MACHINE INSTRUCTIONS ARE REQUIRED.

THE INSTRUCTION CODE TO IMPLEMENT THIS DECISION WOULD BE:

SZA (SKIP IF REG."A" IS ZERO)

```
LABEL  OPCODE  OPERAND  REMARKS
         :
         :
       SZA               IS REG A=Ø?
       JMP     N ZERO    NO
       JMP       ZERO    YES
```

NOTE: ALL HP COMPUTER "SKIP-TYPE INSTRUCTIONS WORK IN THIS MANNER.

DECISION MAKING INSTRUCTIONS

SIGN
MSB

LSB

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SKIP CONDITION

A OR B REGISTER

INSTRUCTION

[SZA/SZB]

THIS INSTRUCTION TESTS THE CONTENTS OF THE INDICATED REGISTER. IF THE TEST CONDITION IS PRESENT (16 Ø'S) THE NEXT SEQUENTIAL INSTRUCTION IS SKIPPED. ANY CONDITION OF THE REGISTER OTHER THAN 16 Ø'S CAUSES THE NEXT SEQUENTIAL INSTRUCTION TO BE EXECUTED. THE CONTENTS OF THE A, B, E, OR OVFLO REGISTERS ARE NOT AFFECTED BY THIS INSTRUCTION.

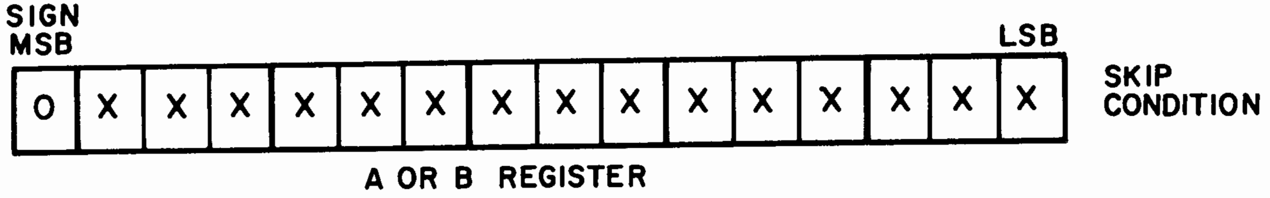
SIGN
MSB

LSB

1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	NO SKIP CONDITION

A OR B REGISTER

SKIP ON ZERO

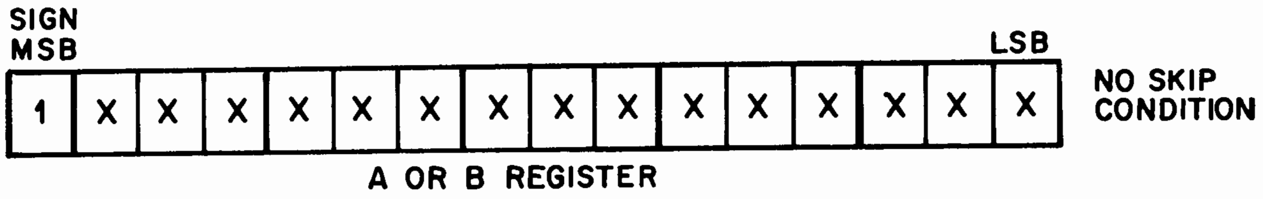


INSTRUCTION

[SSA/SSB]

X = 1 OR Ø

THIS INSTRUCTION TESTS THE CONTENTS OF BIT POSITION 15. IF BIT 15=Ø (POSITIVE) THE NEXT SEQUENTIAL INSTRUCTION IS SKIPPED. IF BIT POSITION 15=1 (NEGATIVE) THE NEXT SEQUENTIAL INSTRUCTION IS EXECUTED. THE CONTENTS OF A,B,E, OR OVFLO ARE NOT AFFECTED BY THIS INSTRUCTION.



SKIP SIGN POSITIVE

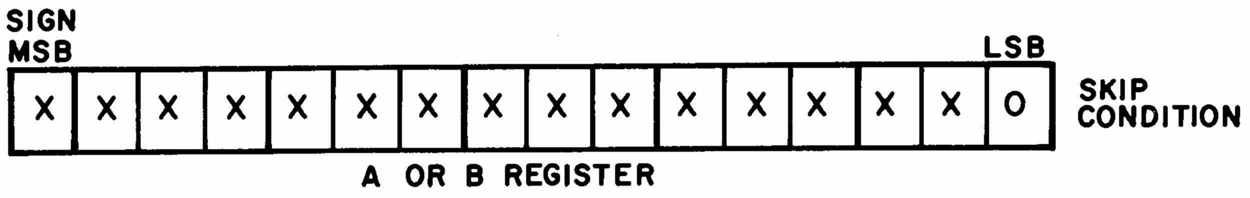
EXAMPLE

PROBLEM:

READ A 16 BIT VALUE FROM THE CONSOLE SWITCH REGISTER. IF THE VALUE IS POSITIVE TAKE THE 2's COMPLEMENT. IF THE VALUE IS NEGATIVE, CONTINUE THE PROGRAM.

SOLUTION:

```
 Label    Operation      Operand         Remarks
1        5 6 7    10        15         20       25        30
     LIA 1    READ SWITCH REGISTER
     SSA      IS VALUE POSITIVE?
     JMP CONT NO
     CMA      YES, TAKE COMPLEMENT
     INA      ADD ONE
CONT ---      CONTINUE PROGRAM
```



SIGN
MSB

LSB

X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0

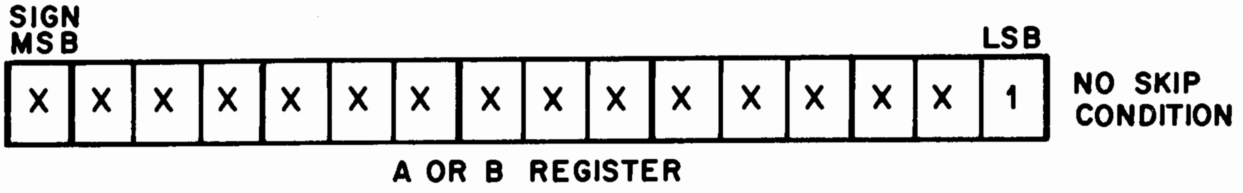
SKIP
CONDITION

A OR B REGISTER

INSTRUCTION

[SLA/SLB]

THIS INSTRUCTION TESTS THE CONTENTS OF BIT POSITION Ø. IF THIS BIT IS Ø THE NEXT SEQUENTIAL INSTRUCTION IS SKIPPED. IF BIT POSITION Ø CONTAINS A 1 THE NEXT SEQUENTIAL INSTRUCTION IS EXECUTED. THE CONTENTS OF A, B, E, OR OVFLO ARE NOT AFFECTED BY THIS INSTRUCTION.



SIGN
MSB

LSB

X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1

NO SKIP
CONDITION

A OR B REGISTER

SKIP ON L.S.B. ZERO

INSTRUCTION

[SEZ]

SKIP THE NEXT SEQUENTIAL INSTRUCTION IF THE 'E' REGISTER IS Ø

Ø E	**SKIP CONDITION**	1 E	**NO SKIP CONDITION**

SEZ INSTRUCTION

INSTRUCTION

[RSS]

REVERSE THE SKIP 'SENSE' FOR ALL SKIP INSTRUCTIONS. AN RSS USED WITH A SKIP INSTRUCTION COMPLEMENTS THE SKIP CONDITION.

EXAMPLES:

RSS	**=**	**UNCONDITIONAL SKIP**
SEZ , RSS	**=**	**SKIP IF E ≠ Ø**
SZA , RSS	**=**	**SKIP IF A ≠ Ø**
SLB , RSS	**=**	**SKIP IF LSB OF B ≠ Ø**
SSA , RSS	**=**	**SKIP IF MSB OF A ≠ Ø**
SSA , SLA , RSS	**=**	**SKIP IF MSB AND LSB OF A = 1**

RSS INSTRUCTION

OP CODE

$$\left\{\begin{matrix}\text{CLA}\\ \text{CMA}\\ \text{CCA}\end{matrix}\right\},[\text{SEZ}],\left\{\begin{matrix}\text{CLE}\\ \text{CME}\\ \text{CCE}\end{matrix}\right\},[\text{SSA}],[\text{SLA}],[\text{INA}],[\text{SZA}],[\text{RSS}]$$

$$\left\{\begin{matrix}\text{CLB}\\ \text{CMB}\\ \text{CCB}\end{matrix}\right\},[\text{SEZ}],\left\{\begin{matrix}\text{CLE}\\ \text{CME}\\ \text{CCE}\end{matrix}\right\},[\text{SSB}],[\text{SLB}],[\text{INB}],[\text{SZB}],[\text{RSS}]$$

1. INSTRUCTIONS ARE COMBINED FROM LEFT TO RIGHT IN THE ORDER SHOWN
2. IF TWO OR MORE SKIP CONDITIONS ARE INCLUDED, A SKIP OCCURS IF EITHER OR BOTH CONDITIONS ARE PRESENT: EXCEPTION, SSA/B, SLA/B, RSS; BOTH CONDITIONS MUST BE MET.

COMBINING GUIDE
ALTER - SKIP INSTRUCTIONS

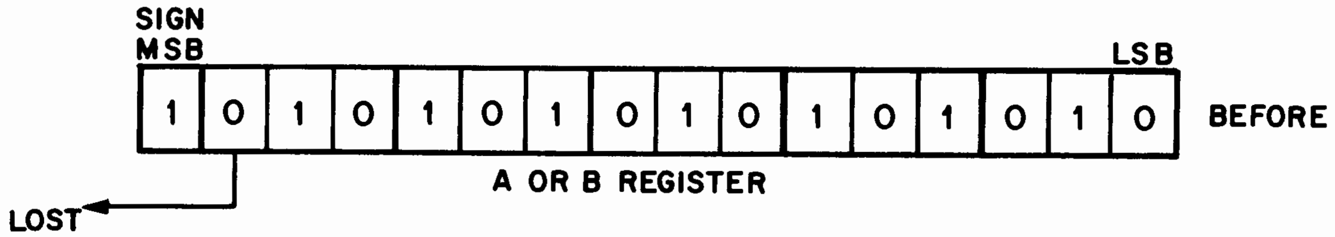
EXAMPLE

PROBLEM:

TEST A VALUE IN REGISTER "B".
IF ODD AND NEGATIVE JMP XYZ
IF EVEN OR POSITIVE JMP ABC

SOLUTION:

```
  Label     Operation      Operand     Remarks
1   5         10             15          20     25     30
      SSB,SLB,RSS
      JMP ABC
      JMP XYZ
```

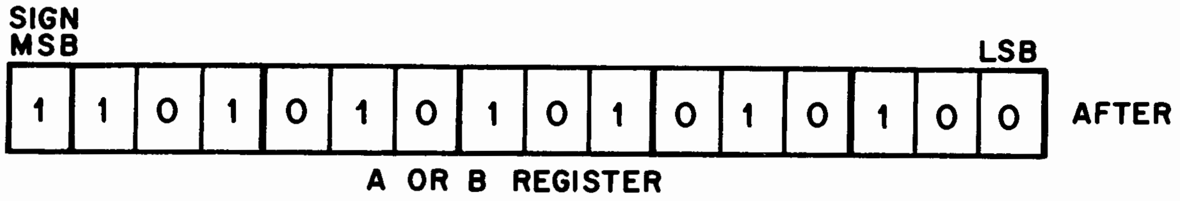


INSTRUCTION

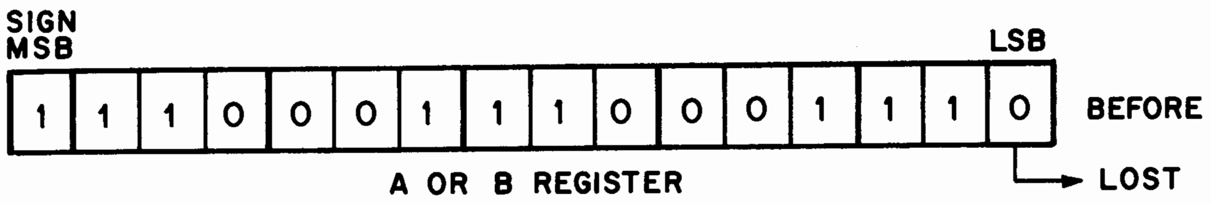
[ALS/BLS]

←

SHIFT THE INDICATED REGISTER LEFT 1 BIT ARITHMETICALLY, THAT IS, BITS Ø THRU 14 SHIFT LEFT. SIGN, BIT 15, IS NOT AFFECTED. BITS SHIFTED OUT OF BIT POSITION 14 ARE LOST. OVFLO, 'E' REGISTER ARE NOT AFFECTED.



ACCUMULATOR LEFT SHIFT



SIGN MSB | LSB

1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	BEFORE

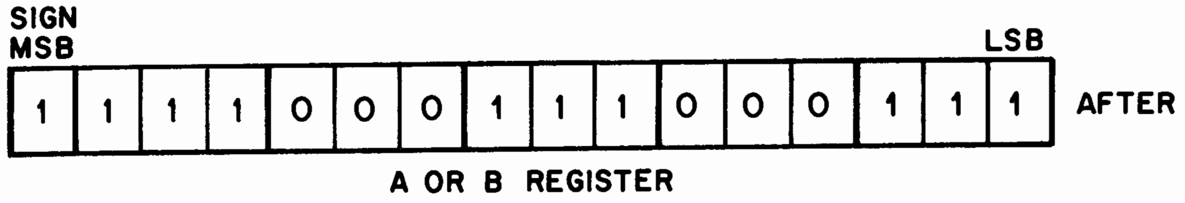
A OR B REGISTER

LOST

INSTRUCTION

ARS/BRS

SHIFT THE INDICATED REGISTER RIGHT 1 BIT ARITHMETICALLY, THAT IS, BITS 14 THRU Ø SHIFT RIGHT. SIGN, BIT 15, IS NOT AFFECTED. BITS SHIFTED OUT OF BIT Ø ARE LOST. A COPY OF BIT 15 (SIGN) IS SHIFTED INTO BIT 14. OVFLO, 'E' REGISTER ARE NOT AFFECTED.

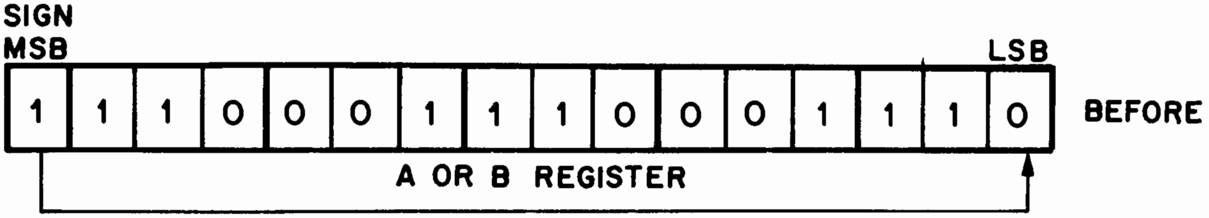


SIGN MSB | LSB

1	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	AFTER

A OR B REGISTER

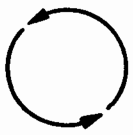
ACCUMULATOR RIGHT SHIFT



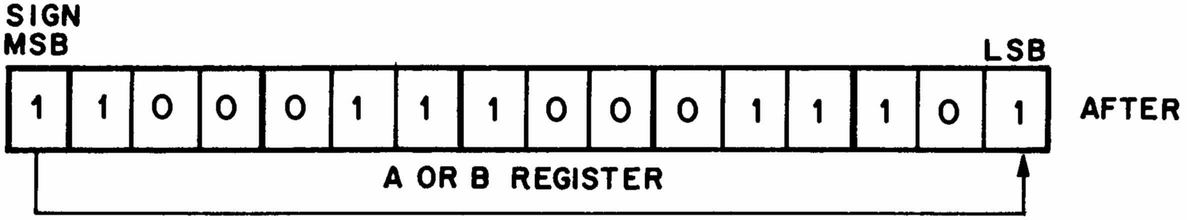
1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0

INSTRUCTION

[RAL/RBL]

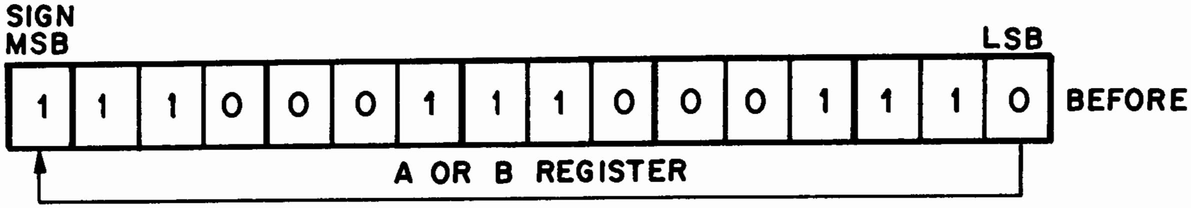


ROTATE THE INDICATED REGISTER LEFT 1 BIT. BIT 15 IS ROTATED AROUND TO BIT POSITION Ø. NO BITS ARE LOST. OVFLO, 'E' NOT AFFECTED.



1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	1

ROTATE ACCUMULATOR LEFT



SIGN MSB — LSB

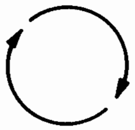
1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0

BEFORE

A OR B REGISTER

INSTRUCTION

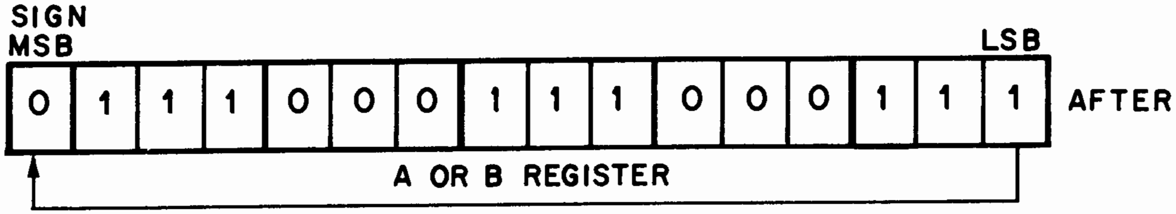
[RAR/RBR]



ROTATE THE INDICATED REGISTER RIGHT 1 BIT.

BIT Ø IS ROTATED AROUND TO BIT POSITION 15.

NO BITS ARE LOST. OVFLO, 'E' NOT AFFECTED.



SIGN MSB — LSB

0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1

AFTER

A OR B REGISTER

ROTATE ACCUMULATOR RIGHT

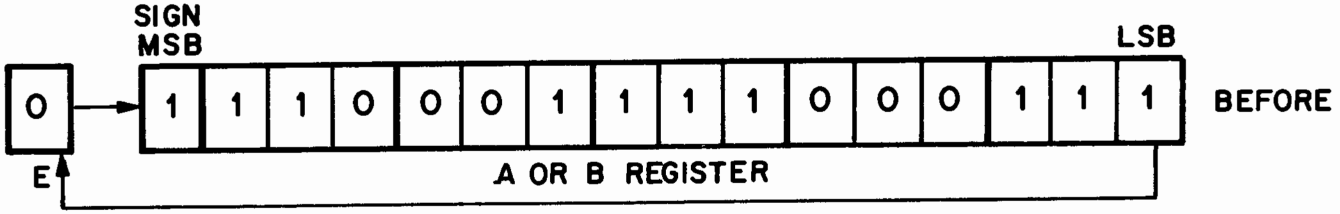
EXAMPLE

PROBLEM:

TEST BIT 15 OF THE "A" REGISTER.
IF BIT 15 =1 , JMP TO LOCATION BUSY
IF BIT 15 =0 , TEST BIT 14
IF BIT 14 =1 , JMP TO LOCATION ERROR
IF BIT 14 = 0, (PROGRAM CONTINUATION)

SOLUTION:

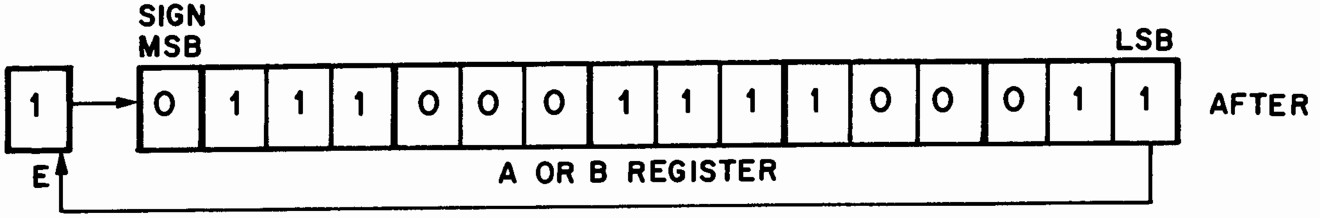
```
 Label   Operation    Operand    Remarks
1   5    10   15   20   25   30
      SSA          BIT 15=1
      JMP BUSY     YES
      RAL          NO
      SSA          BIT 14=1
      JMP ERROR    YES
      PROGRAM CONTINUATION
```



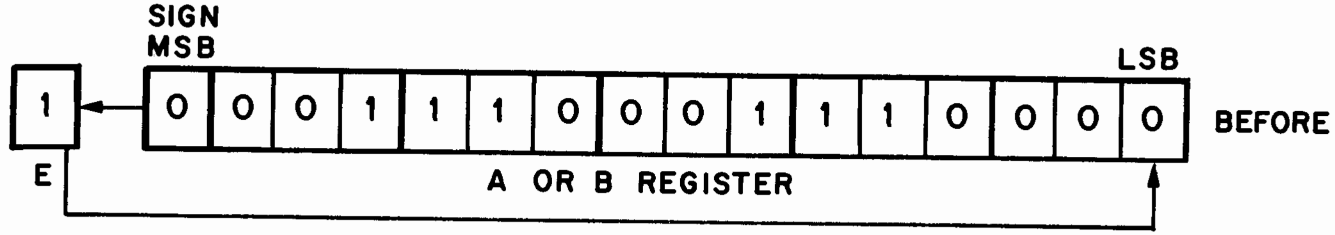
INSTRUCTION

[ERA/ERB]

ROTATE THE INDICATED REGISTER RIGHT, 1 BIT, WITH THE EXTEND REGISTER ('E'). BIT Ø IS ROTATED INTO 'E' AND CONTENTS OF 'E' ARE ROTATED INTO BIT POSITION 15. NO BITS ARE LOST. OVFLO IS NOT AFFECTED.

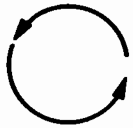


'E' RIGHT WITH ACCUMULATOR

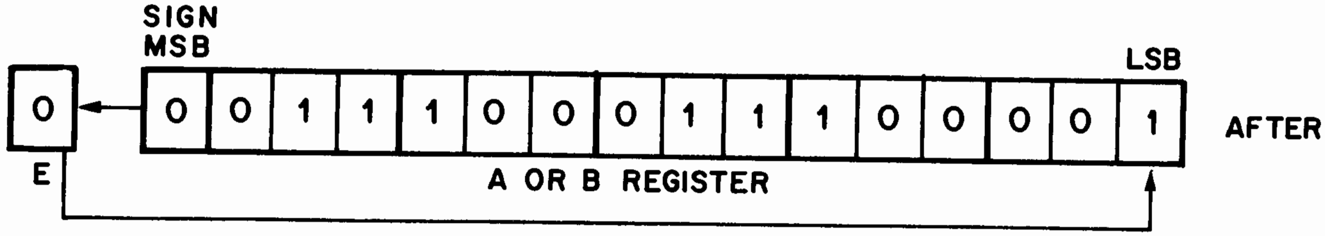


INSTRUCTION

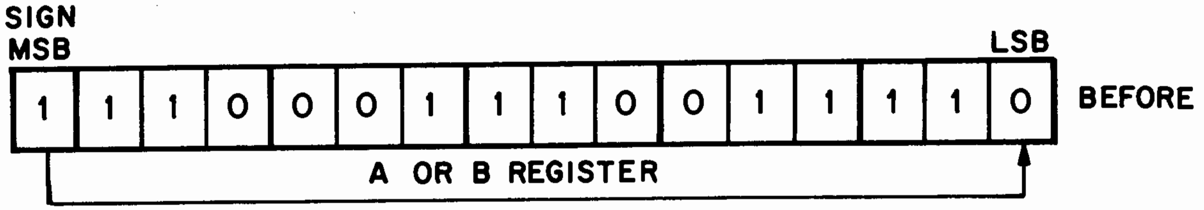
[ELA/ELB]



ROTATE THE INDICATED REGISTER LEFT, 1 BIT, WITH THE EXTEND REGISTER ('E'). BIT 15 IS ROTATED INTO 'E' AND CONTENTS OF 'E' ARE ROTATED AROUND TO BIT POSITION Ø. NO BITS ARE LOST. OVFLO IS NOT AFFECTED.

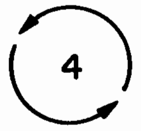


'E' LEFT WITH ACCUMULATOR

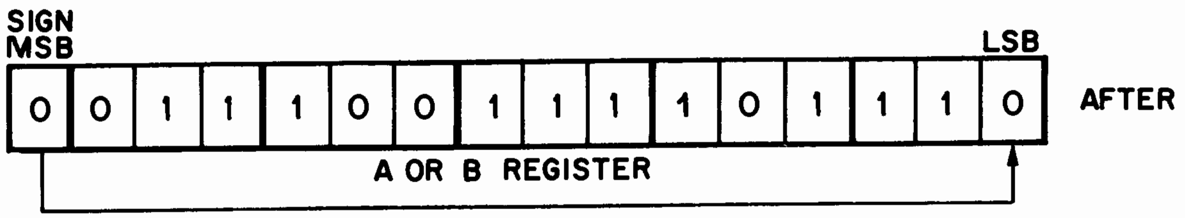


INSTRUCTION

[ALF/BLF]



ROTATE THE INDICATED REGISTER LEFT 4 PLACES. NO BITS ARE LOST. BIT 15, 14, 13, 12 ARE ROTATED AROUND TO BIT POSITIONS 3, 2, 1, 0 RESPECTIVELY. OVFLO, 'E' ARE NOT AFFECTED.



ACCUMULATOR LEFT ROTATE FOUR

$$\left\{\begin{matrix}\mathbf{ALS}\\\mathbf{ARS}\\\mathbf{RAL}\\\mathbf{RAR}\\\mathbf{ALR}\\\mathbf{ALF}\\\mathbf{ERA}\\\mathbf{ELA}\end{matrix}\right\},\left[\mathbf{CLE}\right],\left[\mathbf{SLA}\right],\left\{\begin{matrix}\mathbf{ALS}\\\mathbf{ARS}\\\mathbf{RAL}\\\mathbf{RAR}\\\mathbf{ALR}\\\mathbf{ALF}\\\mathbf{ERA}\\\mathbf{ELA}\end{matrix}\right\}$$

$$\left\{\begin{matrix}\mathbf{BLS}\\\mathbf{BRS}\\\mathbf{RBL}\\\mathbf{RBR}\\\mathbf{BLR}\\\mathbf{BLF}\\\mathbf{ERB}\\\mathbf{ELB}\end{matrix}\right\},\left[\mathbf{CLE}\right],\left[\mathbf{SLB}\right],\left\{\begin{matrix}\mathbf{BLS}\\\mathbf{BRS}\\\mathbf{RBL}\\\mathbf{RBR}\\\mathbf{BLR}\\\mathbf{BLF}\\\mathbf{ERB}\\\mathbf{ELB}\end{matrix}\right\}$$

COMBINING GUIDE
SHIFT-ROTATE INSTRUCTIONS

EXAMPLE

PROBLEM:

CLEAR BIT Ø. TEST BIT 1 AND JUMP TO LOCATION "SAM" IF BIT 1 IS A ONE. RESTORE ALL BITS TO THEIR ORIGINAL POSITIONS IN THE REGISTER.

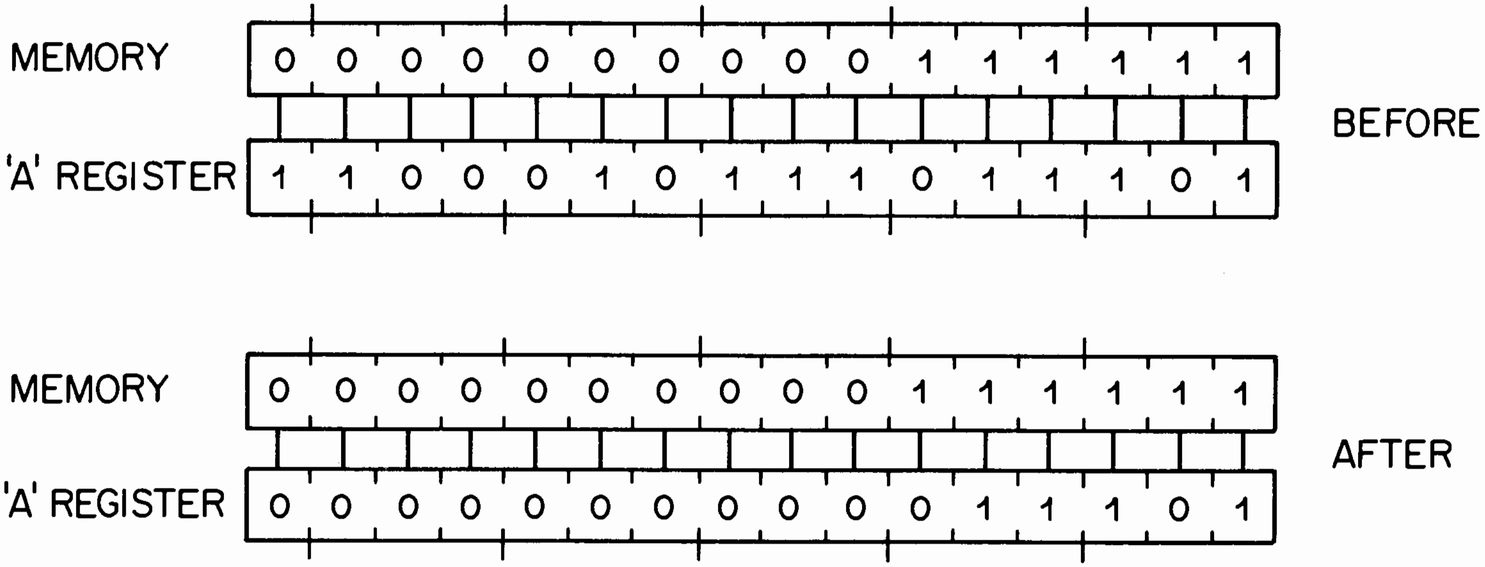
SOLUTION:

```
  Label    Operation    Operand     Remarks
1   5          10   15   20   25   30
      ERA,CLE,SLA,ELA
      JMP SAM
      PROGRAM CONTINUATION
```

"A" REGISTER	MEMORY LOCATION	AND	IOR	XOR
0	0	0	0	0
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0

LOGICAL TRUTH TABLE

LABEL	OP CODE	OPERAND
	AND	MASK
	•	
	•	
MASK	OCT	77



MEMORY 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1

'A' REGISTER 1 1 0 0 0 1 0 1 1 1 0 1 1 1 0 1

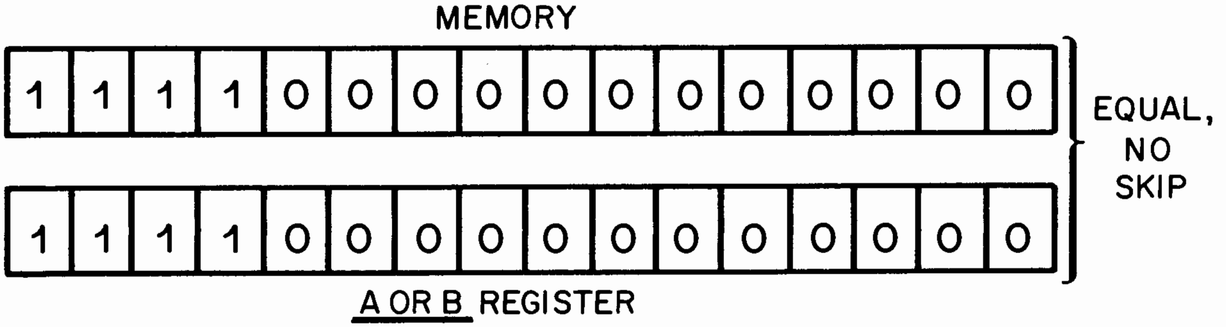
BEFORE

MEMORY 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1

'A' REGISTER 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1

AFTER

THE AND INSTRUCTION



MEMORY

1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0

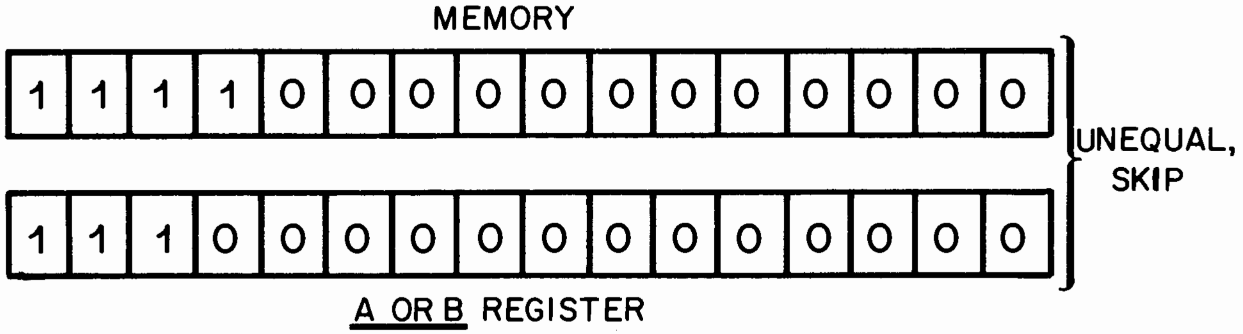
A OR B REGISTER

EQUAL,
NO
SKIP

INSTRUCTION

[CPA/B Y]

COMPARE THE CONTENTS OF THE SPECIFIED REGISTER AGAINST THE CONTENTS OF MEMORY LOCATION Y. IF ALL 16 BITS COMPARE (EQUAL) THE NEXT SEQUENTIAL INSTRUCTION IS EXECUTED. IF THE COMPARE FAILS, (UNEQUAL) THE NEXT SEQUENTIAL INSTRUCTION IS SKIPPED.



MEMORY

1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0

A OR B REGISTER

UNEQUAL,
SKIP

THE COMPARE INSTRUCTION

A COMPARE INSTRUCTION EXAMPLE

THE CONTENTS OF REGISTER "A" ARE UNKNOWN. DEVISE A PROGRAM SEGMENT THAT WILL TEST THE STATUS OF BITS 3 THROUGH 6. IF THIS FIELD CONTAINS THE OCTAL VALUE 12, TRANSFER TO A LABEL CALLED TRUE. IF THIS FIELD CONTAINS ANY OTHER VALUE THE PROGRAM SHOULD CONTINUE.

REGISTER "A" CONTENTS

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
X	X	X	X	X	X	X	X	X	?	?	?	?	X	X	X

```
1   5 6 7  10   15   20   25   30   35   40   45   50
      AND M170      ISOLATE BITS 3 THROUGH6
      CPA M120      DOES"A"COMPARE TO TEST VALUE?
      JMP TRUE      YES, JUMP TO TRUE ROUTINE
      JMP FALSE     NO, CONTINUE PROGRAM
M170  OCT 170       OCTAL MASK
M120  OCT 120       OCTAL TEST VALUE
FALSE ———
```

LESSON VIII OBJECTIVES

THE OBJECTIVES OF LESSON VIII ARE:

1 - INTRODUCE THE STUDENT TO BASIC I/O OPERATIONS.

2 - PROVIDE THE STUDENT WITH MORE ASSEMBLY LANGUAGE PROGRAMMING "TOOLS' IN THE FORM OF ASSEMBLY DIRECTING PSEUDO INSTRUCTIONS.

3 - INTRODUCE THE TECHNIQUES OF LOOPING AND INDIRECT ADDRESSING.

15			12	11 ——— 6	5 ——— 0
1	0	0	0	INSTRUCTION	SELECT CODE

I/O INSTRUCTION FORMAT

INPUT/OUTPUT DEVICE – A PHYSICAL DEVICE CAPABLE OF TRANSMITTING AND/OR RECEIVING COMPUTER DATA.

I/O INTERFACE CARD – A COMPUTER ELECTRONICS CARD THAT PROVIDES THE PHYSICAL AND ELECTRICAL CONNECTION BETWEEN THE DEVICE AND THE COMPUTER.

I/O CHANNEL – THE RECEPTACLE IN THE I/O CARD CAGE THAT HOLDS THE I/O INTERFACE CARD.

SELECT CODE – IDENTIFIES A PARTICULAR I/O CHANNEL.

INTERRUPT LOCATION – A MEMORY LOCATION IN THE RANGE 4-77_8, EACH SELECT CODE IDENTIFIES AN INTERRUPT LOCATION.

INTERRUPT – A PHASE OF COMPUTER OPERATION.

INTRODUCTION TO INPUT/OUTPUT

INPUT/ OUTPUT STRUCTURE

THE STRUCTURE OF THE *HEWLETT-PACKARD* COMPUTER PROVIDES 2 DISTINCT METHODS OF INPUT-OUTPUT DATA TRANSFER OPERATIONS.

1 – NON-INTERRUPT METHOD

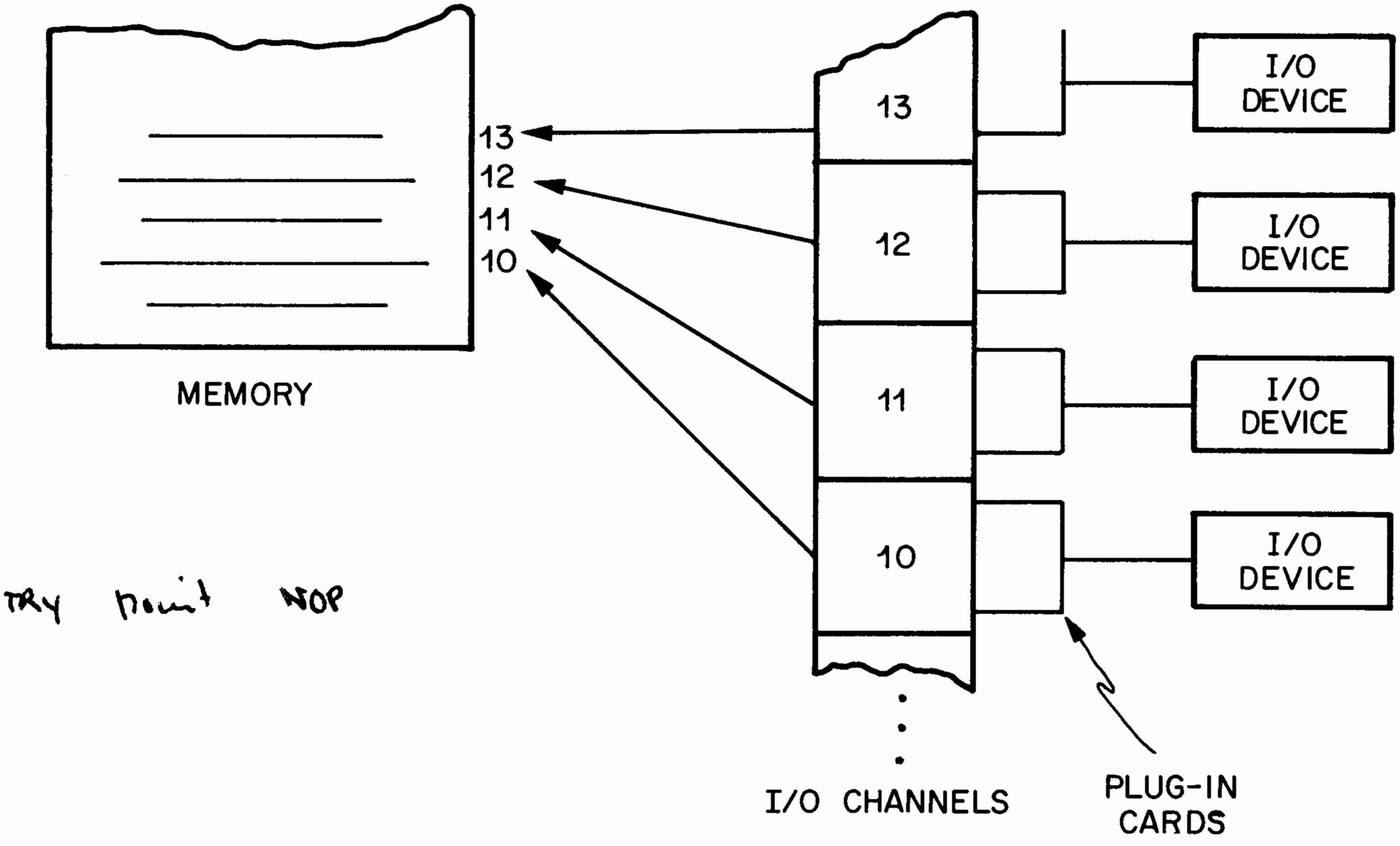
The user commands the I/O device to cycle and then programs a loop that "waits" for the device cycle to complete.

ADVANTAGE – easy to use
DISADVANTAGE – inefficient

2 – INTERRUPT METHOD

The user commands the I/O device to cycle and continues execution of the "main" program. The completion of the device cycle will interrupt the main program and transfer control to a subroutine that will handle the actual data transfer.

ADVANTAGE – efficient
DISADVANTAGE – requires more programming effort.



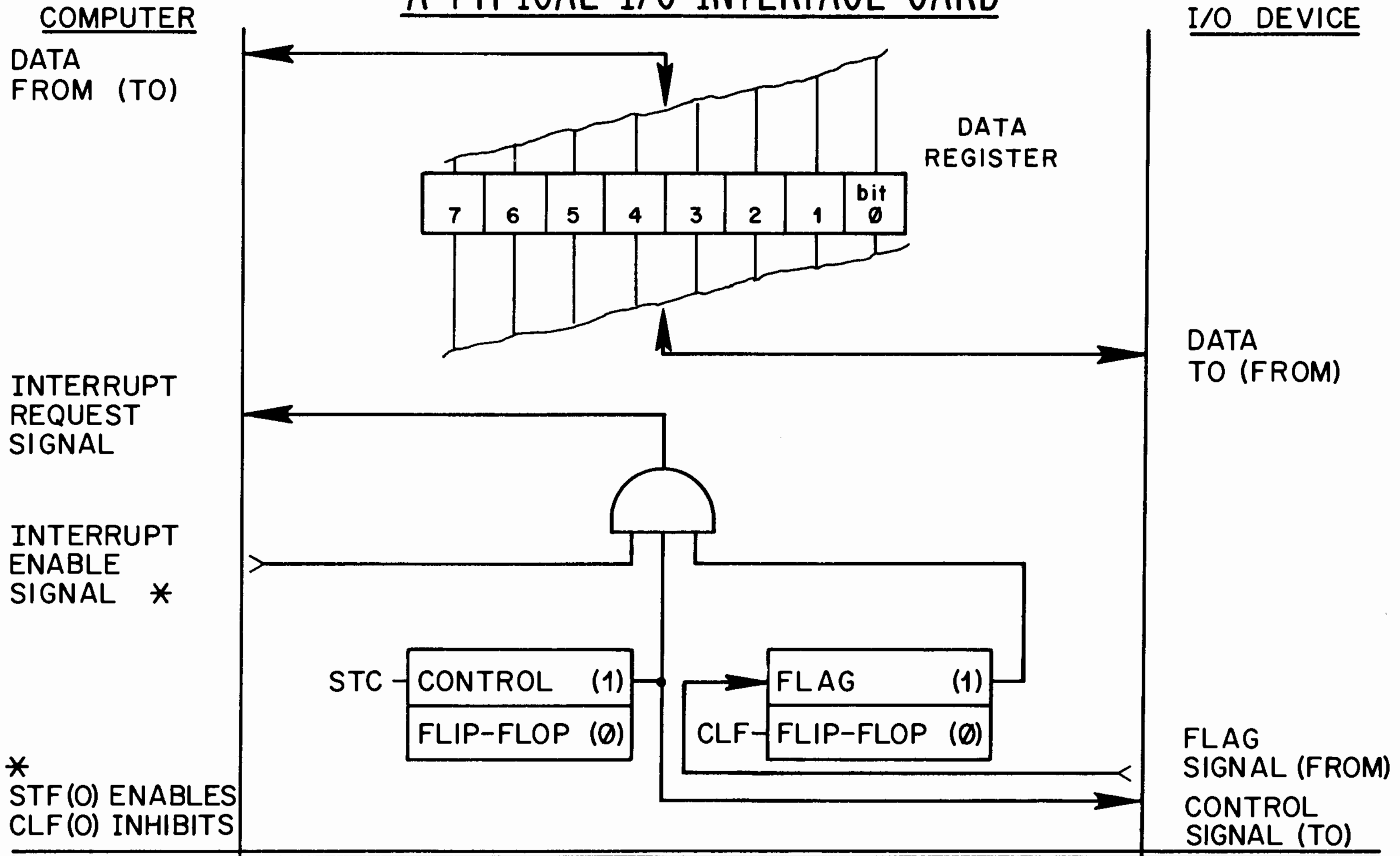
ENTRY point NOP

SELECT CODES AND INTERRUPT ADDRESSES

SELECT CODE	INTERRUPT LOCATION	FUNCTIONAL ASSIGNMENTS
0	NONE NOP	ENABLE/DISABLE I/O AND INT. SYST.
1	NONE HLT 77	SWITCH REGISTER
2	NONE JSB. I, S.	DMA CH 1 } auto start wh
3	NONE SA.	DMA CH 2 } for Dma.
4	4 –	POWER FAIL 200 machine cycles. before hlt.
5	5 –	MEMORY PROTECT
6	6 –	DMA CH1
7	7 –	DMA CH2
10	10 –	I/O DEVICE HIGHEST PRIORITY
.	.	. .
.	.	. .
.	.	. .
.	.	. .
77	77	I/O DEVICE LOWEST PRIORITY

SELECT CODE ASSIGNMENTS

A TYPICAL I/O INTERFACE CARD



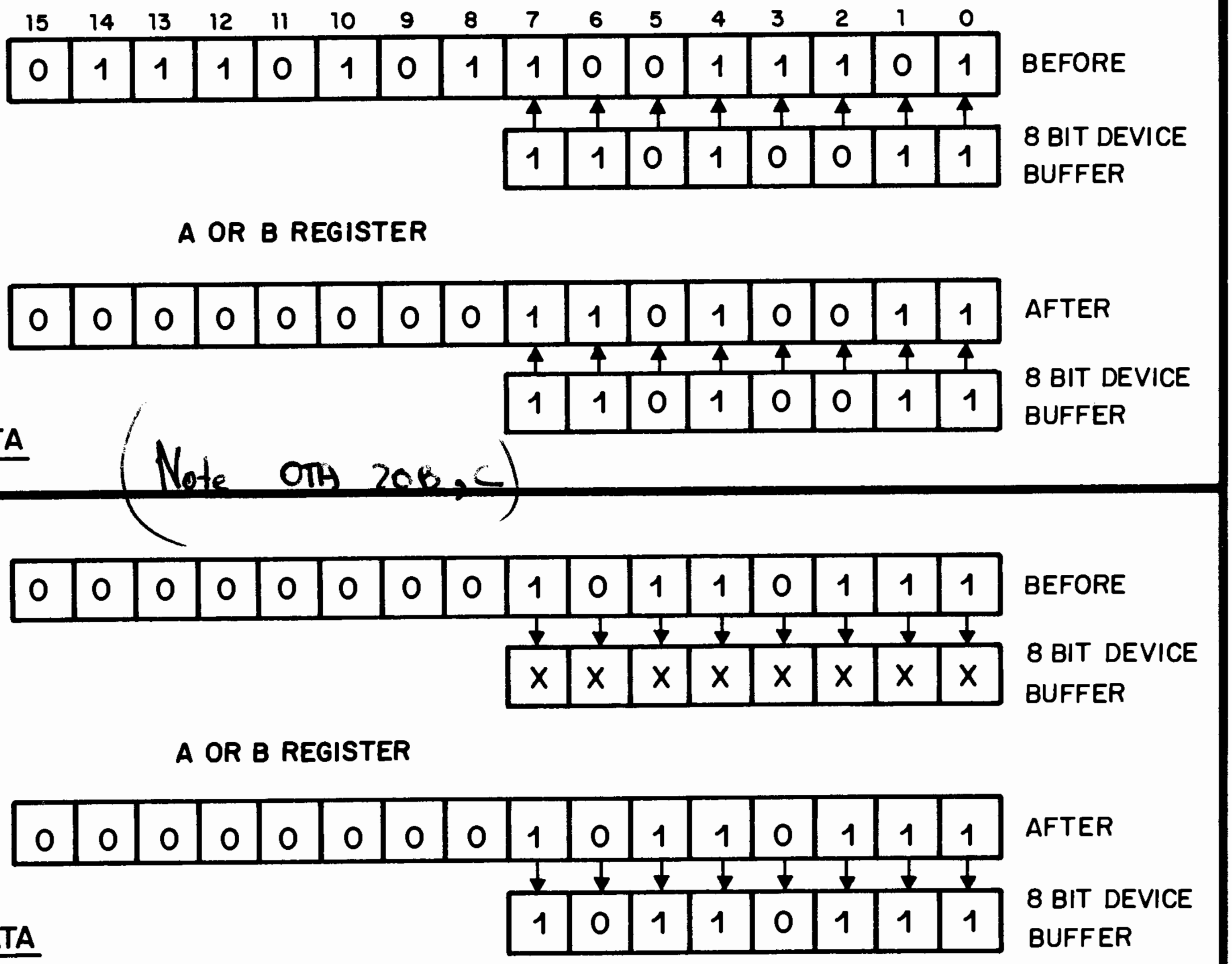
mnemonic	instruction	function
STC (sc)	SET CONTROL FLIP-FLOP	START DEVICE
CLC (sc)	CLEAR CONTROL " "	CLEAR DEVICE
STF (sc)	SET FLAG " "	SET FLAG, "READY"
CLF (sc)	CLEAR FLAG " "	CLEAR FLAG, "BUSY"

STF 00 TURN ON Interrupt

DATA TRANSFERS (8 BIT DEVICE)

~~[illegible]~~
STC ~~A~~ (SC), C
SFS ~~[illegible]~~ 20B
JMP *-1
LIA (SC)
STC ~~A~~ (SC), C
SFS (SC)
~~JMP *-1~~

INSTRUCTION
[LIA/B(sc)]
MIA



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0	1	1	1	0	1	0	1	1	0	0	1	1	1	0	1	BEFORE
								1	1	0	1	0	0	1	1	8 BIT DEVICE BUFFER

A OR B REGISTER

0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	AFTER
								1	1	0	1	0	0	1	1	8 BIT DEVICE BUFFER

INPUT DATA

(Note OTA 20B, C)

OTA (20)B
STC 20B, C
SFS 20
JMP *-1
INSTRUCTION
[OTA/B(sc)]
OTA (20

0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	BEFORE
								X	X	X	X	X	X	X	X	8 BIT DEVICE BUFFER

A OR B REGISTER

0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	AFTER
								1	0	1	1	0	1	1	1	8 BIT DEVICE BUFFER

OUTPUT DATA

1		0			2			0			7			7		
1	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	①

"T" REGISTER

INSTRUCTION

[HLT(sc),C]

THIS INSTRUCTION WILL HALT THE COMPUTER. THE INSTRUCTION WILL BE DISPLAYED IN THE "T" REGISTER. THE (SC) OPTION ALLOWS THE SELECTION OF I/O ADDRESSES 0-77. THE, C OPTION ALLOWS THE FLAG BIT OF THE SELECTED DEVICE TO BE CLEARED.

① SHOWS HALT INSTRUCTION DISPLAY; SC=77_8, NO (C) OPTION.

② SHOWS HALT INSTRUCTION DISPLAY; WITH (C) OPTION TO CLEAR FLAG ON DEVICE ØØ (TURN OFF INT. SYST.)

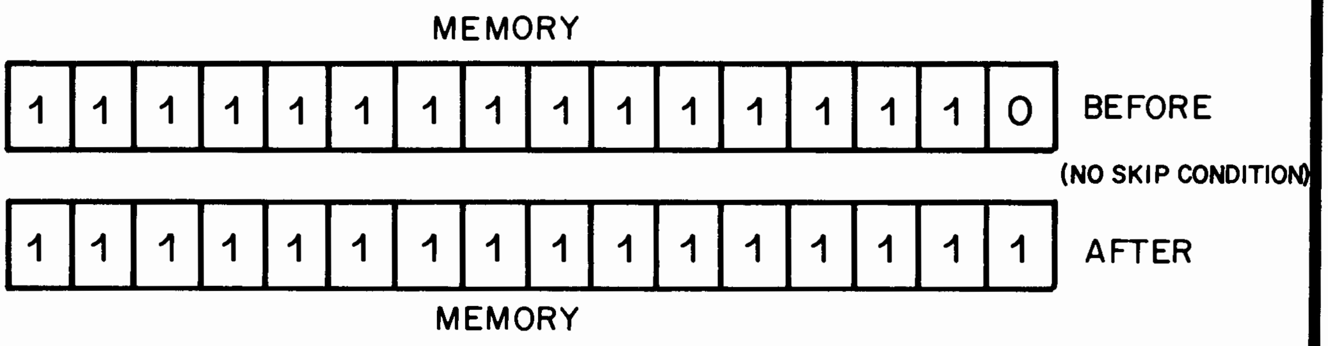
1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	②

"T" REGISTER

THE HALT INSTRUCTION

```
LABEL     OP CODE    OPERAND    REMARKS
          CLF         Ø         INHIBIT THE INTERRUPT  SYSTEM
          STC         1ØB, C    START READER
WAIT1     SFS         1ØB       FLAG = 1 ?
          JMP         WAIT1     NO
          LIA         1ØB       YES, LOAD DATA IN "A"
          ALF, ALF              POSITION IN HIGH "A"
          STC         1ØB, C    START READER
WAIT2     SFS         1ØB       FLAG = 1?
          JMP         WAIT2     NO
          MIA         1ØB       YES, MAKE 16 BIT WORD IoR operation
```

I/O DATA TRANSFER EXAMPLE



MEMORY

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 BEFORE

(NO SKIP CONDITION)

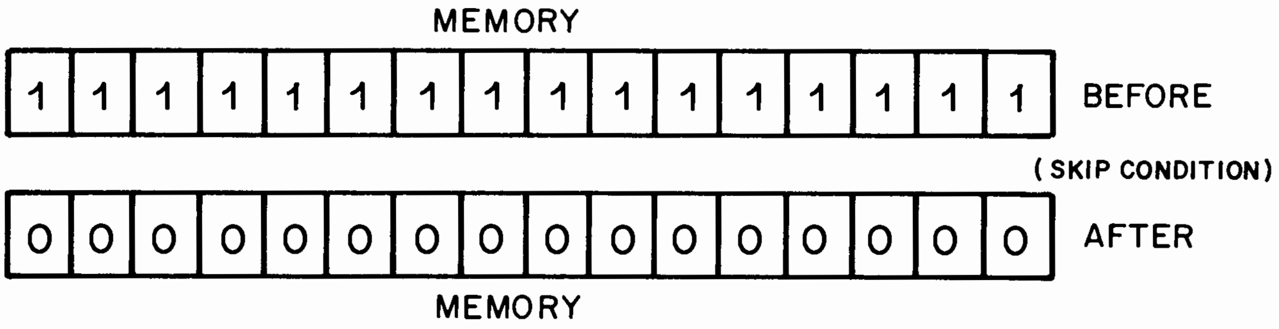
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 AFTER

MEMORY

INSTRUCTION

[ISZ Y]

INCREMENT THE CONTENTS OF MEMORY LOCATION Y AND TEST FOR ZERO. IF Y IS EQUAL TO ZERO THE NEXT SEQUENTIAL INSTRUCTION IS SKIPPED. IF Y IS NOT EQUAL TO ZERO, THE NEXT SEQUENTIAL INSTRUCTION IS EXECUTED.



MEMORY

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 BEFORE

(SKIP CONDITION)

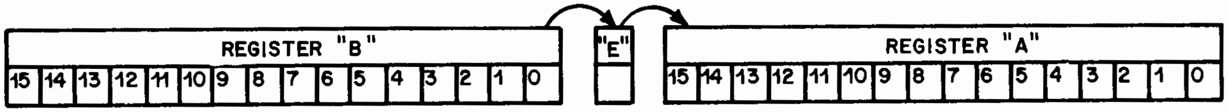
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 AFTER

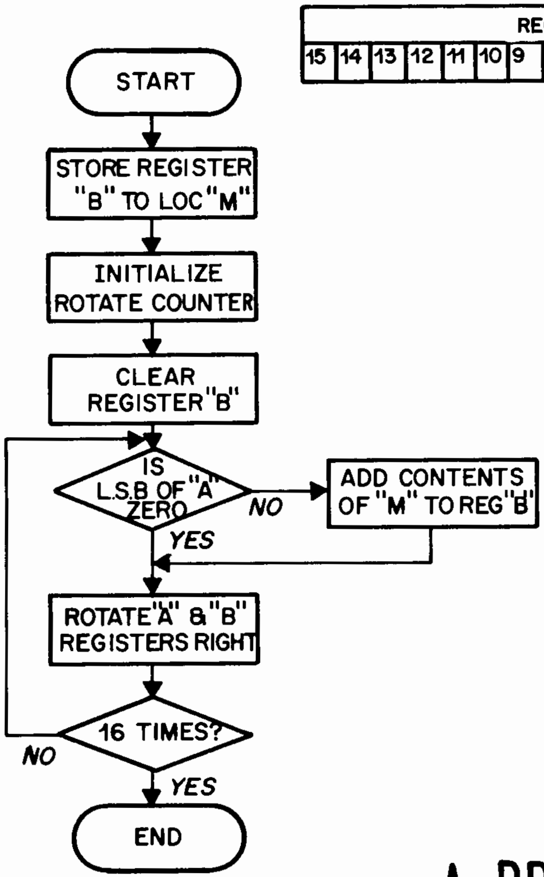
MEMORY

THE INCREMENT-SKIP ZERO INSTRUCTION

MULTIPLY THE CONTENTS OF REGISTER "B" BY THE CONTENTS OF REGISTER "A".

NOTE: Register "A" can be linked to Register "B" through Register "E".




START
STORE REGISTER "B" TO LOC "M"
INITIALIZE ROTATE COUNTER
CLEAR REGISTER "B"
IS L.S.B OF "A" ZERO
NO
YES
ADD CONTENTS OF "M" TO REG "B"
ROTATE "A" & "B" REGISTERS RIGHT
16 TIMES?
NO
YES
END

LABEL	OP CODE	OPERAND
START	STB	M
	LDB	M2Ø
	STB	CNTR
	CLB	
LOOP	CLE	
	SLA	
	ADB	M
	ERB	
	ERA	
	ISZ	CNTR
	JMP	LOOP
	HLT	
	JMP	START
M	OCT	Ø
M2Ø	OCT	177760
CNTR	OCT	Ø

REMARKS

SAVE B
SET COUNTER
TO MINUS 20_8
CLEAR B

ADD 1 TO CNTR, ZERO?
NO, STAY IN LOOP
YES, HALT COMPUTER

MINUS 20_8
WORKING COUNTER

A PROGRAM LOOP EXAMPLE

THE B S S PSEUDO INSTRUCTION

BLOCK STARTING SYMBOL

THIS PSEUDO WILL CAUSE THE ASSEMBLER TO ALLOCATE A BLOCK OF MEMORY LOCATIONS TO A PROGRAM. THE CONTENTS OF THE MEMORY BLOCK CAN NOT BE DETERMINED WHEN THE OBJECT PROGRAM IS LOADED FOR EXECUTION AND MUST BE TAKEN INTO CONSIDERATION BY THE PROGRAMMER.

FOR EXAMPLE:

THESE belong to decimal buffer

LOCATION	CONTENTS	LABEL	OP CODE	OPERAND	REMARKS
00000			NAM	BLOCK	
			ENT	START	
00000	000000	BUFFR	BSS	512	SET ASIDE 512 MEMORY LOCATIONS
01000	000000	START	NOP		
01001	002400		CLA		
01002	006400		CLB		
			•		
			•		
			•		

buffer = 0 } 512 locations.
" = 511. }

INDIRECT ADDRESSING

THE ASSEMBLER PROGRAM WILL SET THE INDIRECT ADDRESSING BIT (15) FOR ALL MEMORY REFERENCE OPERANDS TAGGED WITH THE ",I" DESIGNATOR.

FOR EXAMPLE:

```
LOCATION    CONTENTS   LABEL   OPCODE   OPERAND    REMARKS
                                 •
2ØØØ        ØØ2Ø21     ADRES    OCT      2Ø21       OCTAL CONSTANT
 •                               •
 •                               •
 •                               •
2Ø1Ø        Ø62ØØØ              LDA      ADRES      PICK UP OCTAL CONSTANT

2Ø11        166ØØØ              LDB      ADRES,I    PICK UP DECIMAL CONSTANT
 •                               •
 •                               •
 •                               •
2Ø21        Ø77777              DEC      32767      DECIMAL CONSTANT
                                 •
                                 •
                                END
```

NOTE: AFTER EXECUTION OF CODING
REGISTER "A" = 002021
REGISTER "B" = 077777

THE DEF PSEUDO INSTRUCTION

THE DEF PSEUDO DEFINES THE MEMORY ADDRESS OF A PROPERLY DEFINED SYMBOL. THE ASSEMBLER GENERATES A 15 BIT MEMORY ADDRESS IN THE OBJECT PROGRAM WHEREVER THE DEF APPEARS.

FOR EXAMPLE:

15 bit address word.

```
LOCATION   CONTENTS   LABEL   OPCODE   OPERAND   REMARKS

00000                         NAM      SAMPL
00000      000114R    ADRES   DEF      TABLE     DEF ADDRESS OF TABLE
                              ENT      START
00001      000000     START   NOP
00002      066000R            LDB      ADRES     GET ADDRESS OF TABLE
00003      160001             LDA      1,I       LOAD "A" THRU "B"
  .          .                 .        .        (GET FIRST TABLE VALUE)
  .          .                 .        .
  .          .                 .        .
  .          .                 .        .
00114      000000     TABLE   BSS      100
                              END      START
```

PSEUDO INSTRUCTIONS ENT AND EXT

ENTRY POINT AND EXTERNAL PSEUDO INSTRUCTIONS PROVIDE OBJECT PROGRAM LINKAGE CAPABILITY.

FOR EXAMPLE:

PROGRAM "A" IS TO BE EXECUTED FIRST WITH CONTROL THEN PASSING TO PROGRAM "B".

SEGMENT 1

```
LABEL    OPCODE    OPERAND

         NAM       PROGA
         ENT       START
         EXT       SAM
START    NOP
           •
           •
           •
         JMP       SAM
         END       START
```

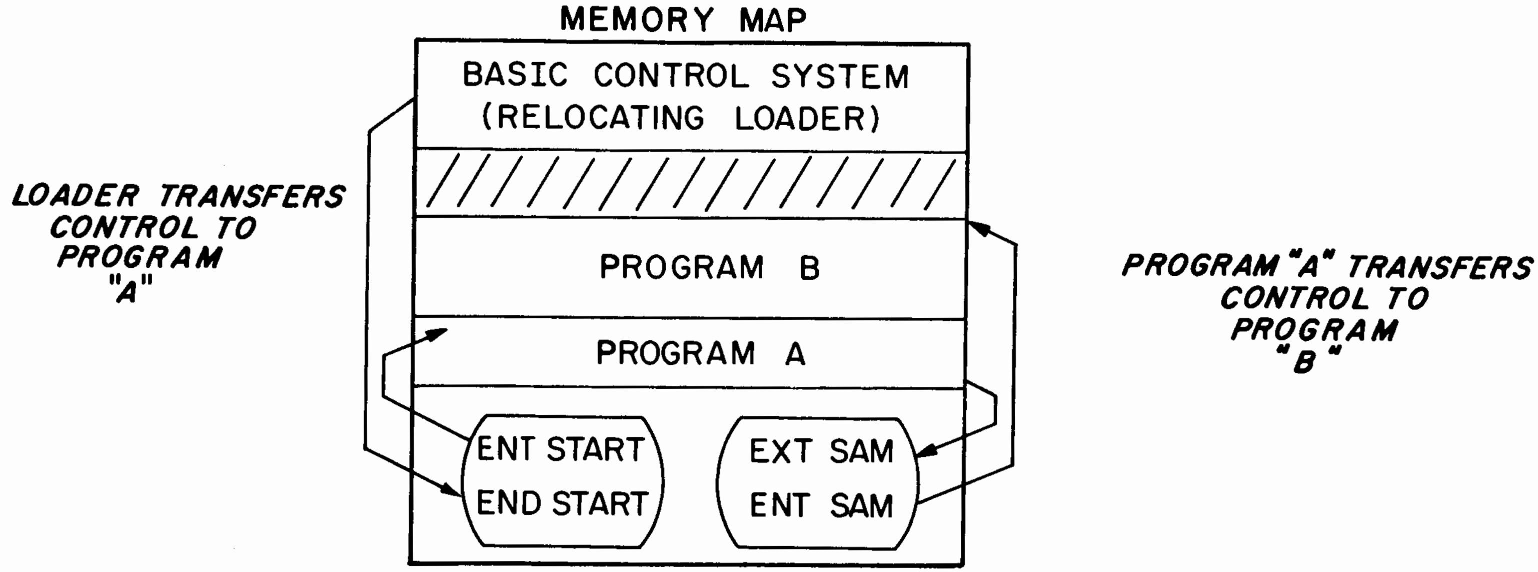
SEGMENT 2

```
LABEL    OPCODE    OPERAND

         NAM       PROGB
         ENT       SAM
SAM      CLA
           •
           •
           •
         END
```

OBJECT PROGRAM LINKAGE

OBJECT PROGRAM LINKAGE IS ACCOMPLISHED BY THE RELOCATING LOADER. THE LOADER CREATES LINKAGES ON THE BASE PAGE BY MATCHING "ENT" POINTS WITH "EXT" SYMBOLS. THE LOADER TRANSFERS TO THE LAST PROGRAM LOADED THAT HAS A VALID "END" RECORD.

FOR EXAMPLE:


MEMORY MAP
BASIC CONTROL SYSTEM (RELOCATING LOADER)
PROGRAM B
PROGRAM A
ENT START
END START
EXT SAM
ENT SAM
LOADER TRANSFERS CONTROL TO PROGRAM "A"
PROGRAM "A" TRANSFERS CONTROL TO PROGRAM "B"

THE JUMP SUBROUTINE INSTRUCTION (JSB)

THE JUMP SUBROUTINE INSTRUCTION (JSB) PROVIDES A METHOD TO EXECUTE A "SUBROUTINE" AND RETURN TO THE PROPER POINT IN THE "MAIN PROGRAM". TO PERFORM THIS FUNCTION 3 DISTINCT OPERATIONS ARE REQUIRED.

① - PRESERVE THE RETURN ADDRESS.

② - TRANSFER CONTROL TO THE SUBROUTINE.

③ - RETURN TO THE "MAIN PROGRAM".

EXAMPLE:

MAIN PROGRAM

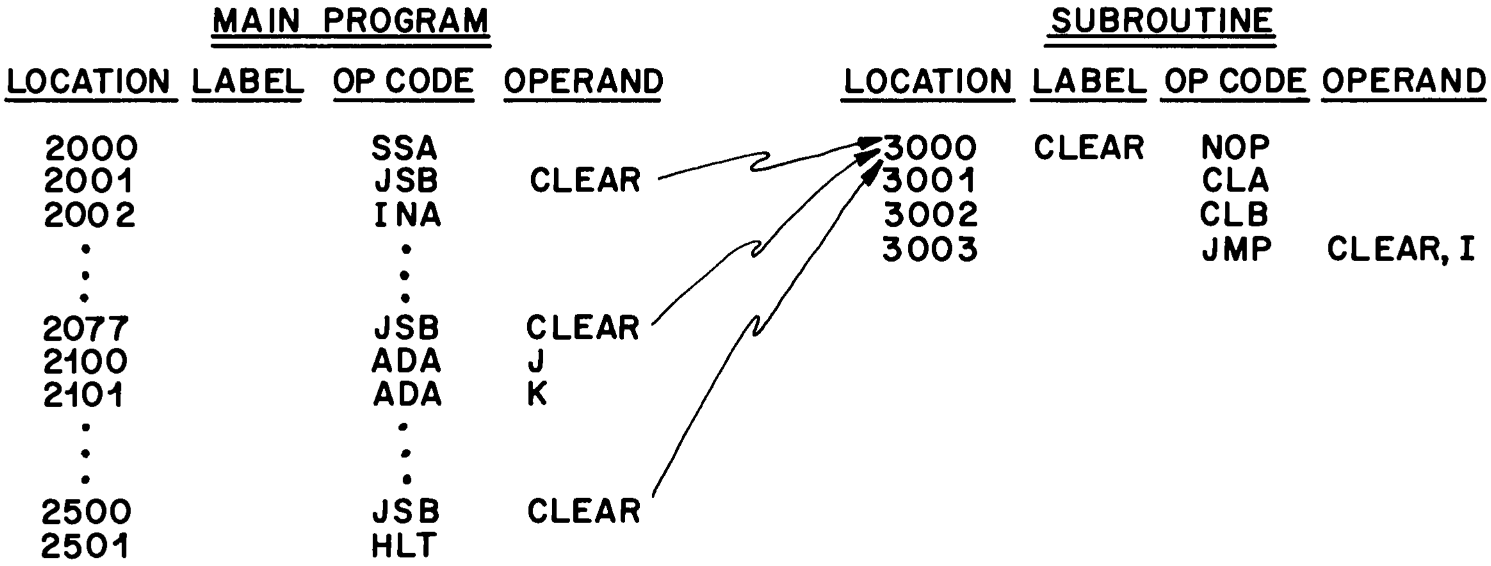
LOCATION	LABEL	OP CODE	OPERAND
100		LDA	I
101		JSB	CMP
102		ADA	J
103		HLT	
104	I	OCT	1
105	J	OCT	7

SUBROUTINE

LOCATION	LABEL	OP CODE	OPERAND
200	CMP	102 ~~NOP~~	
201		CMA	
202		INA	
203		JMP	CMP,I

A JSB EXAMPLE

A SUBROUTINE TO CLEAR THE "A" AND "B" REGISTERS IS SHOWN AS AN EXAMPLE. THE SUBROUTINE IS "ENTERED" FROM 3 DIFFERENT POINTS IN THE "MAIN PROGRAM."



MAIN PROGRAM

```
LOCATION  LABEL  OP CODE  OPERAND

  2000             SSA
  2001             JSB     CLEAR
  2002             INA
   .                .
   .                .
   .                .
  2077             JSB     CLEAR
  2100             ADA     J
  2101             ADA     K
   .                .
   .                .
   .                .
  2500             JSB     CLEAR
  2501             HLT
```

SUBROUTINE

```
LOCATION  LABEL  OP CODE  OPERAND

  3000    CLEAR    NOP
  3001             CLA
  3002             CLB
  3003             JMP     CLEAR, I
```

THE EQU PSEUDO INSTRUCTION

THE EQU PSEUDO INSTRUCTION EQUATES THE OPERAND SYMBOL TO THE LABEL FIELD.

FOR EXAMPLE:

```
LOCATION   CONTENTS   LABEL   OPCODE   OPERAND    REMARKS

00000                         NAM      CHAR
00017                 READR   EQU      17B        READR "EQUALS" 17B
                              ENT      START
00000      000000     START   NOP
00001      103717             STC      READR,C
00002      102317             SFS      READR
00003      026002R            JMP      *-1
00004      102517             LIA      READR
00005      126000R            JMP      START,I
```

NOTE:

THE VALUE OF THE LABEL "READR" DEPENDS ENTIRELY ON THE OPERAND OF THE EQU PSEUDO INSTRUCTION. ALL OPERAND REFERENCES TO THE "READR" SYMBOL ARE ASSIGNED THE VALUE 17_8.

THE COM PSEUDO INSTRUCTION

- THE COM PSEUDO RESERVES A BLOCK OF STORAGE LOCATIONS THAT MAY BE USED IN COMMON BY SEVERAL SUBPROGRAMS.

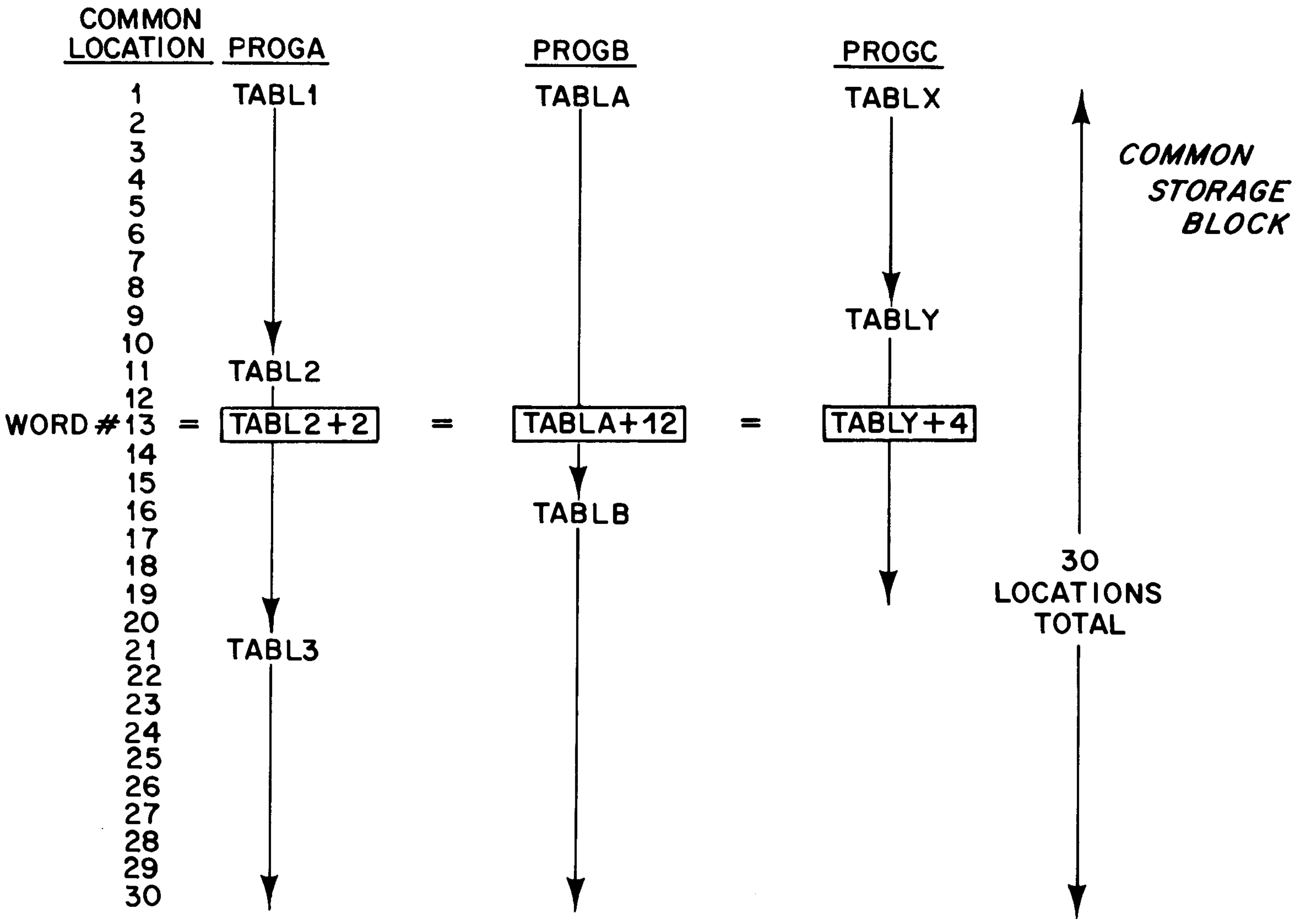
GENERAL FORM: symbolic name for first address.

COM	name_1 (size_1), name_2 (size_2), . . . , name_n (size_n)	REMARKS

- EACH NAME IDENTIFIES A SEGMENT OF THE BLOCK FOR THE SUBPROGRAM IN WHICH THE COM STATEMENT APPEARS.
- STORAGE LOCATIONS ARE ASSIGNED CONTIGUOUSLY
- THE LENGTH OF THE BLOCK IS EQUAL TO THE SUM OF THE LENGTHS OF ALL SEGMENTS NAMED IN ALL COM STATEMENTS IN THE SUBPROGRAM.
- TO REFER TO THE COMMON BLOCK, OTHER SUBPROGRAMS MUST ALSO INCLUDE A COM STATEMENT. with similar dimensions
- AT LOAD TIME; THE SUBPROGRAM WITH THE GREATEST COMMON DECLARATION MUST BE LOADED FIRST. or a diagnostic will occur.

```
        LABEL      OP CODE      OPERAND

                   NAM          PROGA
 S      START      NOP
 E                 LDA          TABL1
 G                  :
 M                  :
 E                 COM          TABL1 (1Ø) ,TABL2 (1Ø), TABL3(1Ø)
 N                  :
 T                  :
"A"                END          START
-----------------------------------------------------------------
 S
 E                 NAM          PROGB
 G
 M                 COM          TABLA (15),  TABLB (15)
 E                  :
 N                  :
 T
"B"                END
-----------------------------------------------------------------
 S                 NAM          PROGC
 E                 STA          TABLX
 G                  :
 M                  :
 E
 N                 COM          TABLX (8), TABLY (11)
 T                  :
"C"                 :
                   END
```

USING THE COM PSEUDO



COMMON STORAGE

ASCII CHARACTER CODES

TAPE CHANNELS 87 654 * 321
OCTAL CODE

	0	1	2	3	4	5	6	7
00	NULL	SOM	EOA	EOM	EOT	WRU	RU	BELL
01	FE	H.TAB	LF	V. TAB	FORM	CR	SO	SI
02	DC	X-ON	TAPE ON	X-OFF	TAPE OFF	ERROR	SYNC	LEM
03	SØ	S1	S2	S3	S4	S5	S6	S7
04	SPACE	!	"	#	$	%	&	'
05	(	)	*	+	,	–	.	/
06	Ø	1	2	3	4	5	6	7
07	8	9	:	;	<	=	>	?
10	@	A	B	C	D	E	F	G
11	H	I	J	K	L	M	N	O
12	P	Q	R	S	T	U	V	W
13	X	Y	Z	[	\	]	↑	←
14								
15								
16								
17					ACK	ALT MODE	ESC	RO

Example: Character 'S'

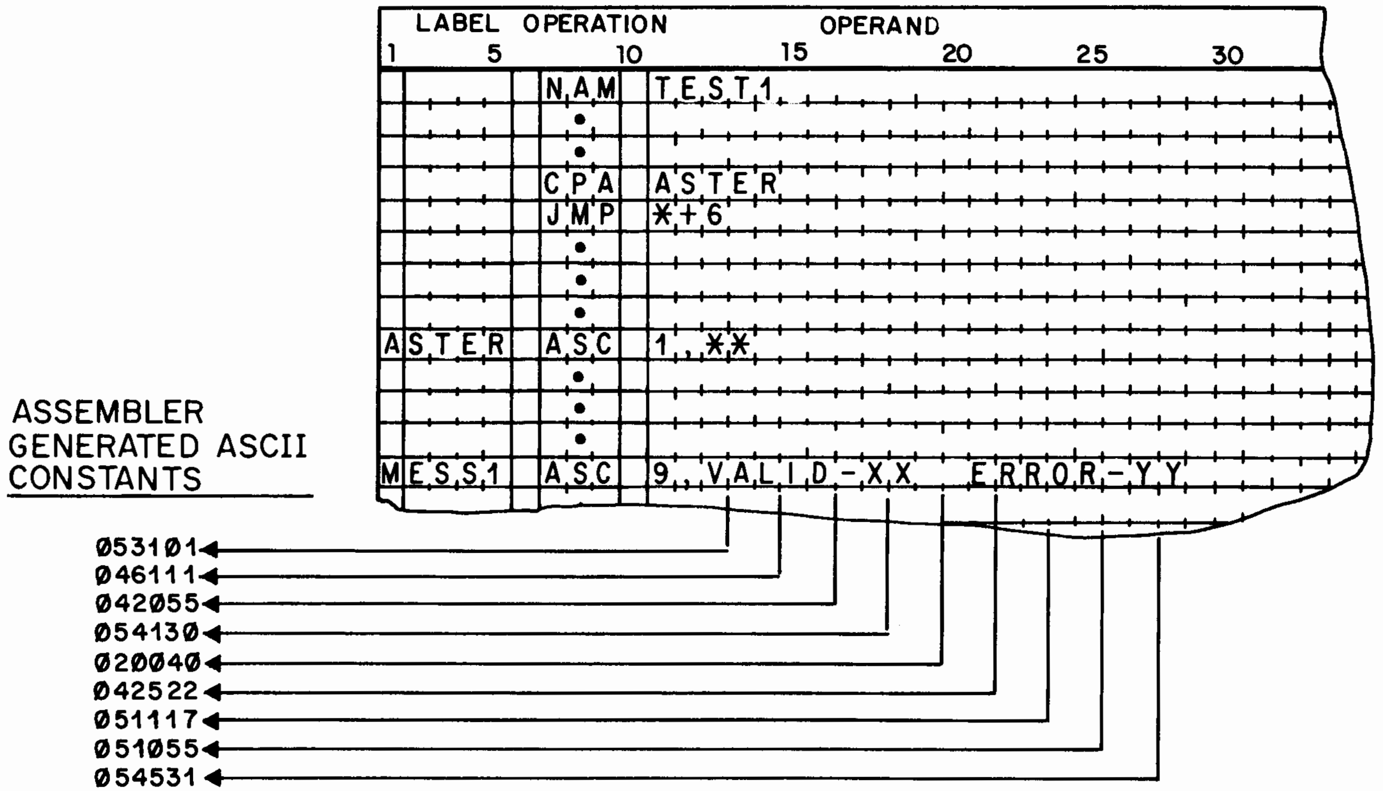
Octal	1	2		3
Binary	01	010		011
Tape Channels	87	654	*	321

(*Feed hole)

THE ASC PSEUDO INSTRUCTION

THE ASC PSEUDO IS USED TO DEFINE ALPHANUMERIC CONSTANTS.

FOR EXAMPLE:



```
LABEL OPERATION       OPERAND
1    5    10     15      20      25      30
       NAM  TEST1
        •
        •
       CPA  ASTER
       JMP  *+6
        •
        •
        •
ASTER  ASC  1,**
        •
        •
        •
MESS1  ASC  9,VALID-XX  ERROR-YY
```

ASSEMBLER GENERATED ASCII CONSTANTS

```
Ø531Ø1
Ø46111
Ø42Ø55
Ø5413Ø
Ø2ØØ4Ø
Ø42522
Ø51117
Ø51Ø55
Ø54531
```

LESSON IX OBJECTIVES

THE OBJECTIVES OF LESSON IX ARE TO TEACH THE STUDENT SOME BASIC PROGRAMMING TECHNIQUES.

THESE INCLUDE:

- ADDRESS MODIFICATION
- SUBROUTINES
- ARITHMETIC PSEUDO INSTRUCTIONS
- INPUT/OUTPUT TECHNIQUES (FORTRAN I/O)

ADDRESS MODIFICATION

ADDRESS MODIFICATION IS AN IMPORTANT PROGRAMMING TECHNIQUE.

FOR EXAMPLE: A PROGRAM TO SUM THE CONTENTS OF 1Ø SEQUENTIAL MEMORY LOCATIONS.

```
LABEL  OPCODE OPERAND         REMARKS
1    5        10   15     20    25    30
       NAM  MOD1
B      EQU  1
       ENT  START     ENTRY POINT
START  NOP
       LDA  CNT       INITIALIZE
       STA  CNTR      COUNTER
       CLA            CLEAR A
       LDB  PNTR      LOAD ADDRESS OF TABLE
LOOP   ADA  B,I       ADD INDIRECTLY THRU "B"
       INB            ADD 1 TO ADDRESS
       ISZ  CNTR      IS COUNTER ZERO?
       JMP  LOOP      NO, CONTINUE
       HLT  77B       YES, HALT COMPUTER
       JMP  START+1   PROGRAM RESTART
CNT    DEC  -1Ø       COUNT VALUE
CNTR   BSS  1         WORKING COUNTER
PNTR   DEF  TABLE     ADDRESS OF TABLE
TABLE  DEC  1Ø,5,15,23,752,8272,33,84,9,28
       END  START
```

15 bit address [illegible] [illegible] TABLE

SUBROUTINES

SUBROUTINES ARE WRITTEN TO DO A SPECIFIC JOB. MOST SUBROUTINES REQUIRE DATA (PARAMETERS) FROM THE MAIN PROGRAM.

FOR EXAMPLE:

A SUBROUTINE TO COMPUTE THE ABSOLUTE VALUE OF THE CONTENTS OF REGISTER "A."

main [illegible] ENT IABS

[illegible] IABS

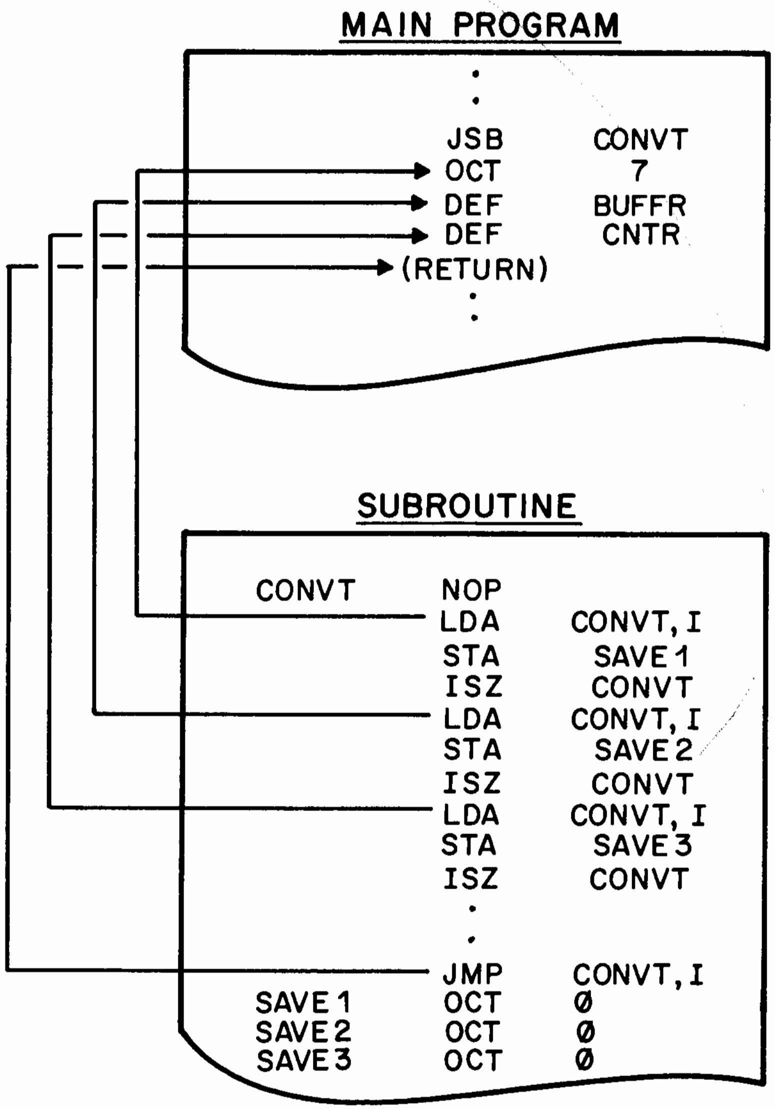
function

LABEL	OP CODE	OPERAND	REMARKS
IABS	NOP		
	SSA, RSS		A < Ø
	JMP	IABS,I	NO, A = ANSWER
	CMA, INA		YES, COMPLEMENT VALUE
	SSA		DID A = 100000
	CMA		YES, SET A=077777
	JMP	IABS,I	NO, A=ANSWER

LABEL	OP CODE	OPERAND	REMARKS
ONE PARAMETER CALLING SEQUENCE	LDA	NUMBR	CONVERT (NUMBR)
	JSB	IABS	TO ITS ABSOLUTE VALUE
	(RETURN)		
TWO PARAMETER CALLING SEQUENCE	LDA	ADDRS	BUFFER ADDRESS IN "A" REGISTER
	LDB	COUNT	COUNT IN "B" REGISTER
	JSB	READ	TRANSFER TO READ ROUTINE
	(RETURN)		
THREE OR MORE PARAMETER CALLING SEQUENCE	JSB	CONVT	TRANSFER TO CONVERT ROUTINE
	OCT	7	CODE WORD
	DEF	BUFFR	BUFFER ADDRESS
	DEF	CNTR	COUNTER
	(RETURN)		

CALLING SEQUENCE

(TECHNIQUES FOR TRANSFER OF PARAMETER DATA TO SUBROUTINES)



MAIN PROGRAM

```
        .
        .
        JSB     CONVT
        OCT     7
        DEF     BUFFR
        DEF     CNTR
      (RETURN)
        .
        .
```

SUBROUTINE

```
CONVT   NOP
        LDA     CONVT,I
        STA     SAVE1
        ISZ     CONVT
        LDA     CONVT,I
        STA     SAVE2
        ISZ     CONVT
        LDA     CONVT,I
        STA     SAVE3
        ISZ     CONVT
        .
        .
        JMP     CONVT,I
SAVE1   OCT     Ø
SAVE2   OCT     Ø
SAVE3   OCT     Ø
```

DIRECT TRANSFER OF PARAMETERS

FORTRAN COMPATIBLE ASSEMBLER SUBROUTINES

PART 1 - THE FORTRAN CALL

FORTRAN MAIN PROGRAMS MAY COMMUNICATE WITH ASSEMBLY LANGUAGE SUBROUTINES. THIS FEATURE IS POSSIBLE ONLY IF THE SUBROUTINE IS COMPATIBLE WITH THE STANDARD FORTRAN CALLING SEQUENCE.

FOR EXAMPLE:

```
  FORTRAN          GENERATED ASSEMBLY LANGUAGE CODING

                                 REMARKS

                   JSB  SAM   TRANSFER TO "SAM"
                   DEF  *+4   DEFINE RETURN ADDRESS
CALL SAM(J,K,L)    DEF  J     DEFINE ADDRESS OF J
                   DEF  K     DEFINE ADDRESS OF K
                   DEF  L     DEFINE ADDRESS OF L
                   (RETURN)
                   DEF  *+1 + N (where N is the number of Parameter
                                 in call Statement)
```

THE ACTUAL TRANSFER OF DATA ITEMS IS THE RESPONSIBILITY OF THE SUBROUTINE

FORTRAN COMPATIBLE ASSEMBLER SUBROUTINES

PART 2 - THE ASSEMBLY LANGUAGE SUBROUTINE

A FORTRAN LIBRARY ROUTINE CALLED .ENTR MAY BE USED TO TRANSFER THE ADDRESSES OF THE PARAMETERS FROM THE MAIN PROGRAM TO THE SUBROUTINE.

[illegible]

FOR EXAMPLE:

```
LABEL     OPCODE  OPERAND               REMARKS

          NAM     SAM
          ENT     SAM
          EXT     .ENTR
J         BSS     1         LOCATION FOR ADDRESS OF PARAMETER   J
K         BSS     1            "      "     "     "    "        K
L         BSS     1            "      "     "     "    "        L
SAM       NOP               ENTRY POINT THIS ICR bit is [illegible],I
          JSB     .ENTR     TRANSFER TO .ENTR
          DEF     J         DEFINE ADDRESS OF FIRST PARAMETER
          LDA     J,I       TRANS ADDRESS Parameters.
          ADA     K,I
          STA     L,I
          JMP     SAM,I     RETURN TO MAIN PROGRAM
```

Reseved for addresses

ENTRY No Parameter

JSB .ENTR
DEF SAM

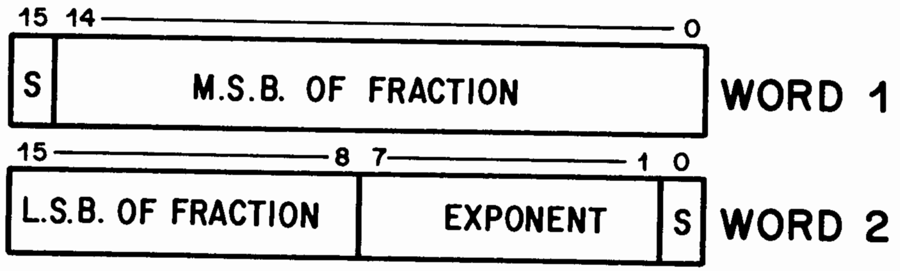
NOTE: MAIN PROGRAM AND SUBROUTINE PARAMETERS MUST AGREE AS TO TYPE:

REAL OR INTEGER

$6\frac{1}{3}$ digits resolution.

FLOATING POINT NUMBERS

FLOATING POINT NUMBERS USE TWO MEMORY LOCATIONS IN THE FOLLOWING FORM:



FLOATING POINT NUMBERS HAVE A RANGE IN MAGNITUDE OF APPROXIMATELY -10^{38} TO 10^{38}

FOR EXAMPLE: THE GREATEST POSITIVE FLOATING POINT NUMBER WOULD BE:

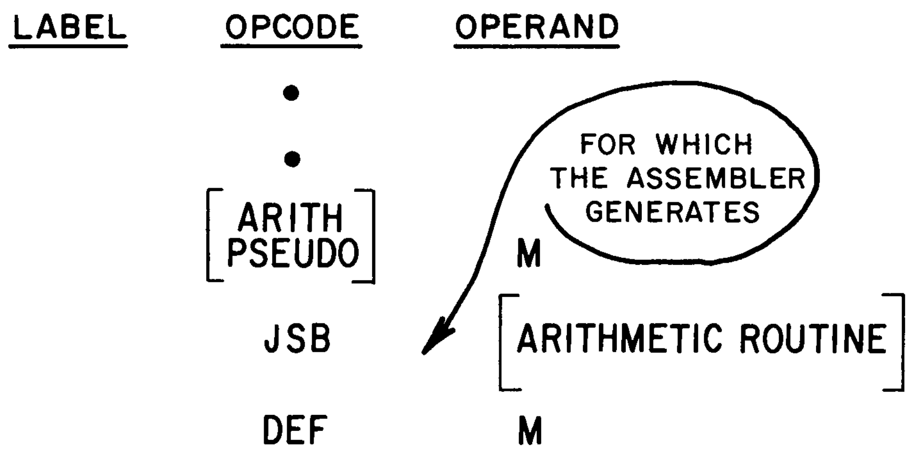
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0

THE FRACTIONAL VALUE (MANTISSA) OF THE FLOATING POINT NUMBER IS ALWAYS IN THE RANGE $0 \leq n < 1$. IN THE EXAMPLE ABOVE THE VALUE OF THE MANTISSA IS APPROXIMATELY 1. THE EXPONENT VALUE IS 2^7-1 (127_{10}), THE VALUE OF THE NUMBER IS 1×2^{127}; BY RAISING 2 TO THE 127th POWER (USING A LOG TABLE) IT BECOMES APPROXIMATELY 1.7×10^{38}

ARITHMETIC PSEUDO INSTRUCTIONS

AN ADDITIONAL SET OF PSEUDO INSTRUCTIONS ARE INCLUDED IN THE ASSEMBLER TO ALLOW THE PROGRAMMER TO CONVENIENTLY USE THE ARITHMETIC SUBROUTINES DEVELOPED FOR THE COMPUTER.

ALL OF THE ARITHMETIC PSEUDO INSTRUCTIONS HAVE THE FOLLOWING FORM:



```
LABEL     OPCODE      OPERAND
            •
            •
         [ARITH ]
         [PSEUDO]      M
          JSB         [ARITHMETIC ROUTINE]
          DEF          M
```

REFERENCES TO ARITHMETIC PSEUDO INSTRUCTIONS DO NOT HAVE TO BE DECLARED AS EXTERNAL SYMBOLS.

ARITHMETIC PSEUDO INSTRUCTIONS

PSEUDO	FUNCTION	OPERATION
MPY	Only works in A. FIXED POINT MULTIPLICATION	(A) X (m) → (B± MSB and ALSB)
DIV	FIXED POINT DIVISION	(B± MSB and ALSB)/(m) → A, remainder → B
FAD	FLOATING POINT ADDITION	(AB) + (m, m+1) → AB
FSB	FLOATING POINT SUBTRACTION	(AB) − (m, m+1) → AB
FMP	FLOATING POINT MULTIPLICATION	(m, m+1) X (AB) → AB
FDV	FLOATING POINT DIVISION	(AB / (m, m+1) → AB
DLD	DOUBLE LOAD	(m) and (m+1) → A and B
DST	DOUBLE STORE	(A) and (B) → m and m+1

LEGEND:

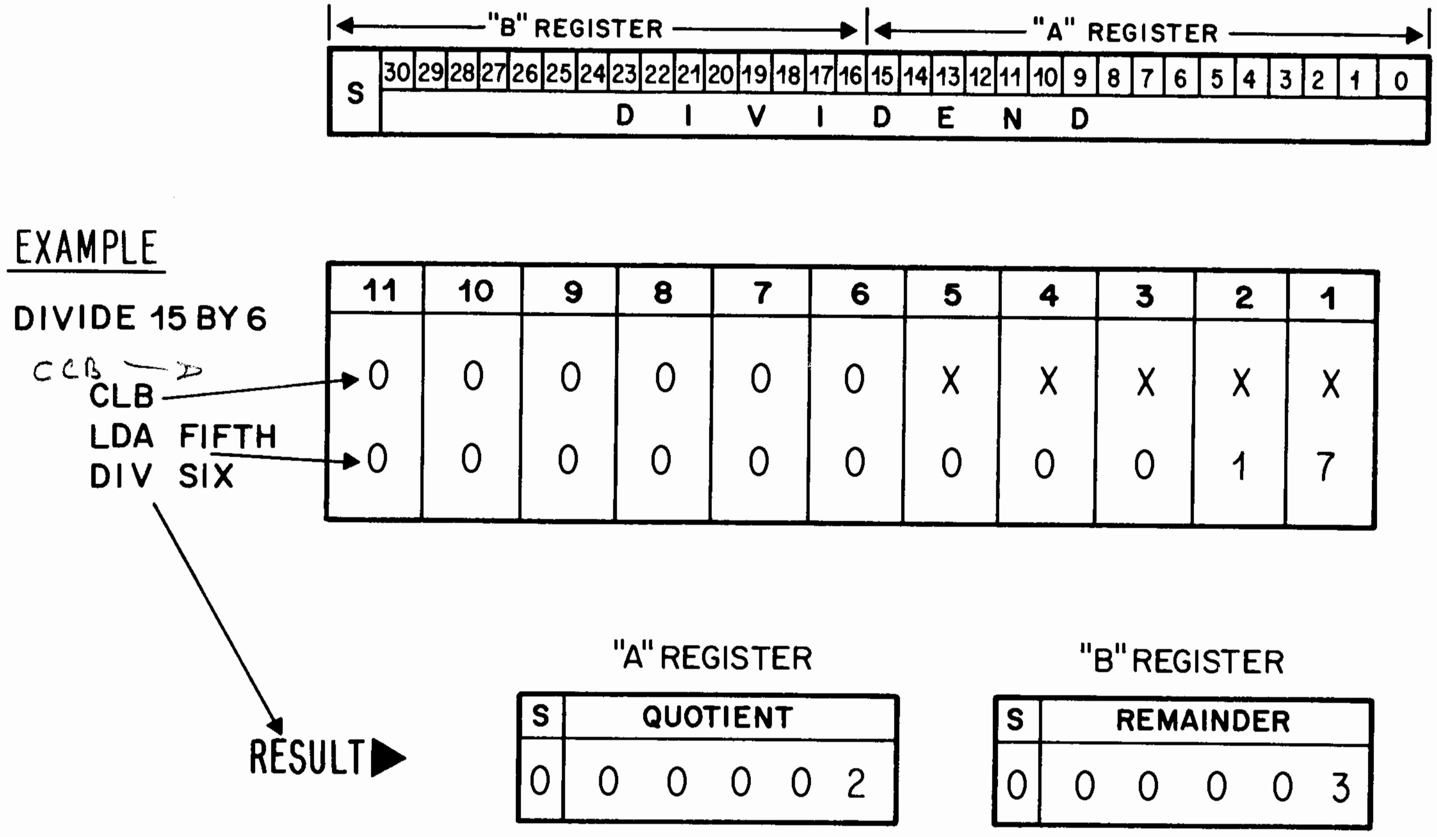
A = Reg. A	m = Operand
B = Reg. B	MSB/LSB = Most/Least Significant Bits
± = Sign	

MPY - FIXED POINT MULTIPLY EXAMPLE

	REGISTER "B"						REGISTER "A"				
	15, 14	13 12, 11	10 9, 8	7 6, 5	4 3, 2	1 0 | 15,	14 13 12,	11 10 9,	8 7 6,	5 4 3,	2 1 0
	S | 30	29—27	26—24	23—21	20—18	17—15	14—12	11—9	8—6	5—3	2—0
EXAMPLE 1	11	10	9	8	7	6	5	4	3	2	1
MULTIPLY 7x 3 LDA SEVEN	X	X	X	X	X	0	0	0	0	0	7
MPY THREE	0	0	0	0	0	0	0	0	0	2	5
EXAMPLE 2 MULTIPLY (-1) x 1 LDA NGONE	X	X	X	X	X	1	7	7	7	7	7
MPY ONE	3	7	7	7	7	7	7	7	7	7	7

FORMAT OF PRODUCT

DIV - FIXED POINT DIVIDE EXAMPLE



"B" REGISTER																"A" REGISTER															
S	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	D I V I D E N D																													

EXAMPLE

DIVIDE 15 BY 6

For division of negative Number

CCB →
CLB
LDA FIFTH
DIV SIX

11	10	9	8	7	6	5	4	3	2	1
0	0	0	0	0	0	X	X	X	X	X
0	0	0	0	0	0	0	0	0	1	7

RESULT ▶

"A" REGISTER

S	QUOTIENT
0	0 0 0 0 2

"B" REGISTER

S	REMAINDER
0	0 0 0 0 3

FLOATING POINT ARITHMETIC

EXAMPLE: CONSIDER THE FOLLOWING ASSEMBLY LANGUAGE STATEMENTS

```
LABEL    OP CODE    OPERAND       REMARKS

X        DEC        3000.
Y        DEC        25.
A        DEC        265.               NOTE
B        DEC        100.          (THE DECIMAL POINTS WILL CAUSE
C        BSS        2             THE ASSEMBLER TO CONVERT THE
Z        BSS        2             NUMBERS TO 32 BIT FLOATING
                                  POINT REPRESENTATION)

*        TO CALCULATE  X *Y       To Reserve two memory
         DLD        X             locations for Floating point
         FMP        Y
         DST        Z             Z = X*Y

*        TO CALCULATE A/B
         DLD        A
         FDV        B
         DST        C             C = A/B
```

MATH LIBRARY FUNCTIONS

all ARGUMENTS ARE REAL

TO PERFORM THE FOLLOWING OPERATIONS:
(FLOATING POINT QUANTITIES)

Y =	ABS (X)	ABSOLUTE VALUE
Y =	ATAN (X)	ARCTANGENT
Y =	ALOG (X)	NATURAL LOG
Y =	COS (X)	COSINE
Y =	EXP (X)	Y = e^x
Y =	SIN (X)	SINE
Y =	SQRT (X)	SQUARE ROOT
Y =	TAN (X)	TANGENT
Y =	TANH (X)	HYPERBOLIC TANGENT

THE FOLLOWING INSTRUCTIONS
CAN BE USED:

```
EXT   (NAME)
LDA   X
LDB   X + 1
JSB   (NAME)
STA   Y
STB   Y + 1
```

NOTES

- LIBRARY FUNCTIONS MUST BE DEFINED AS EXTERNAL (EXT) SYMBOLS.
- THEY MAY ONLY BE REFERENCED BY RELOCATABLE PROGRAMS.

EXAMPLE: FIND THE SQUARE ROOT OF QUANTITY "X" AND STORE TO LOCATION "Y"

METHOD 1

```
EXT SQRT
LDA X
LDB X+1
JSB SQRT
STA Y
STB Y+1
```

OR

METHOD 2

```
EXT SQRT
DLD X
JSB SQRT
DST Y
```

USING A LIBRARY FUNCTION

PROBLEM STATEMENT

FIND THE HYPOTENUSE OF A RIGHT TRIANGLE

WHERE: HYPOT = SQRT $(X^2 + Y^2)$

PROBLEM SOLUTION

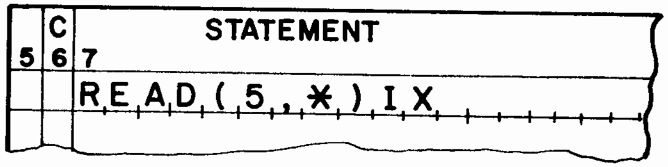
LABEL	OP CODE	OPERAND	REMARKS
	NAM	HYPOT	
	EXT	SQRT	
X	BSS	2	
Y	BSS	2	
HYPOT	BSS	2	
TEMP	BSS	2	
	•		JSB DLD
	•		DLF X
START	NOP		
	DLD	X	
	FMP	X	$X^2 = X*X$
	DST	TEMP	
	DLD	Y	
	FMP	Y	$Y^2 = Y*Y$
	FAD	TEMP	$X^2 + Y^2$
	JSB	SQRT	
	DST	HYPOT	$HYPOT = \sqrt{X^2 + Y^2}$
	•		
	•		
	END	START	

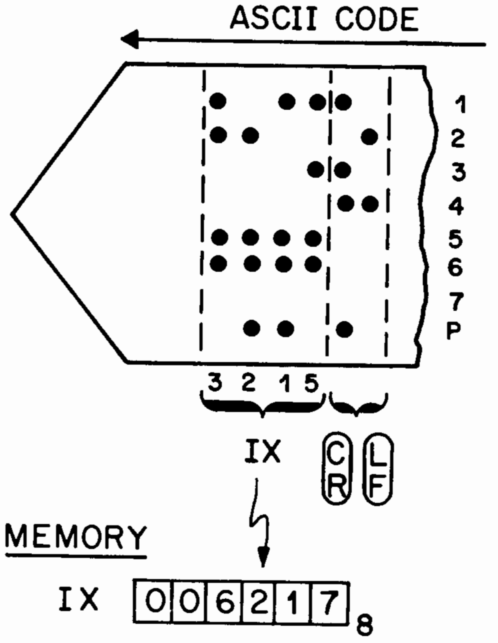
DATA CONVERSION

EXTERNAL(INPUT)		INTERNAL(COMPUTER)		EXTERNAL(OUTPUT)
ASCII	→	BINARY	→	ASCII

THE DATA CONVERSION PROCESS IS NOT APPARENT TO THE FORTRAN PROGRAMMER.

FOR EXAMPLE:





AS A RESULT OF THE READ STATEMENT MEMORY LOCATION "IX" WOULD CONTAIN 006217_8

QUESTIONS!

1. HOW WAS THE CONVERSION PERFORMED?
2. HOW CAN A PROGRAMMER PERFORM THE EQUIVALENT OPERATION USING ASSEMBLY LANGUAGE?

THE FORMATTER

THE FORMATTER IS A LIBRARY ROUTINE DESIGNED PRIMARILY TO PROVIDE DATA CONVERSION AND INPUT-OUTPUT CAPABILITY FOR FORTRAN PROGRAMS. ASSEMBLY LANGUAGE PROGRAMS MAY USE THE FORMATTER BY CODING THE CORRECT CALLING SEQUENCE AND PROVIDING THE PROPER PARAMETERS. THE FORMATTER HAS 7 ENTRY POINTS.

THE FORMATTER CONTAINS 7 SUB-PROGRAMS, EACH DESIGNED TO PERFORM A SPECIFIC PART OF THE TOTAL INPUT-OUTPUT OPERATION. FOR EXAMPLE:

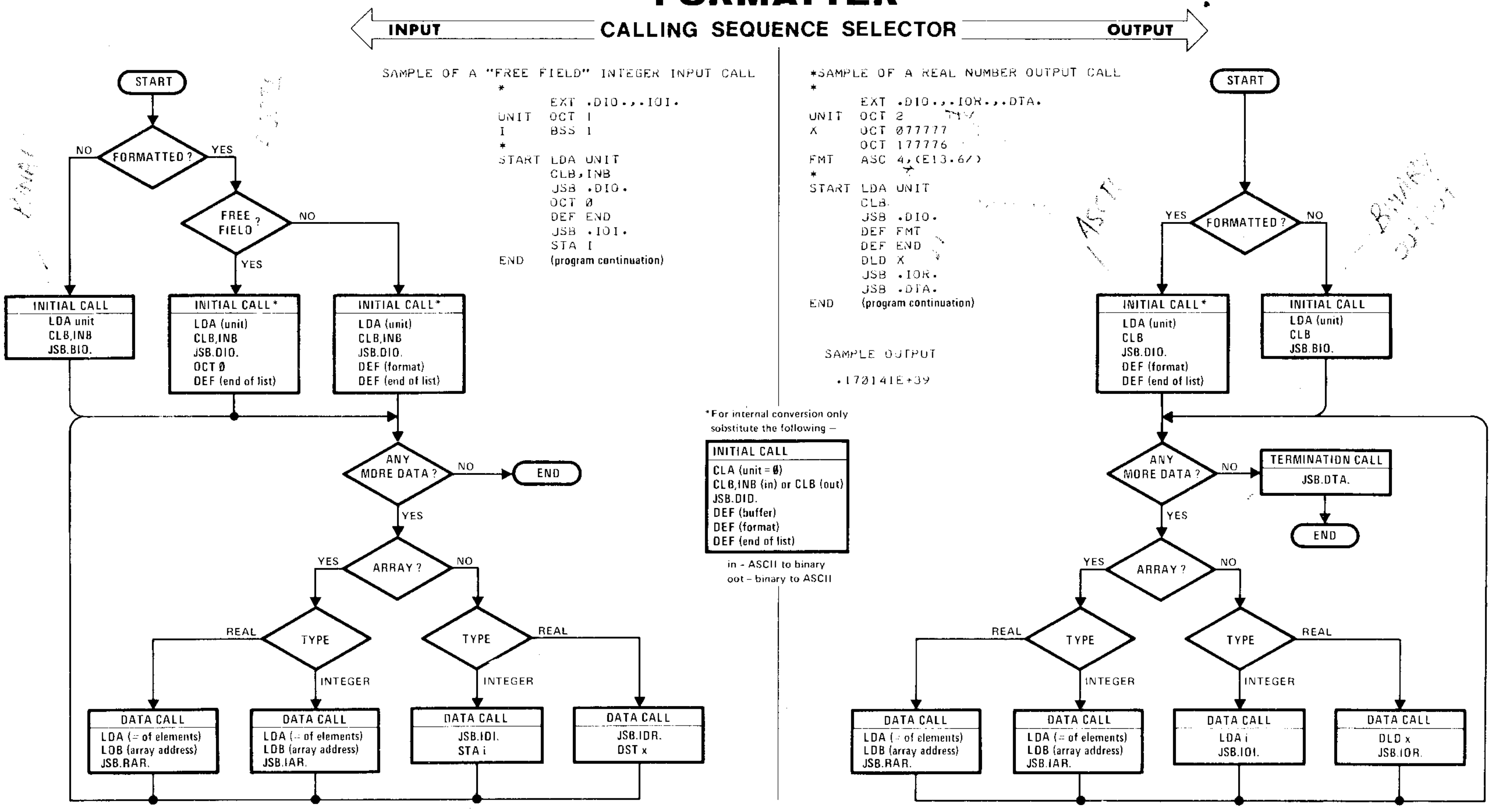
Consists Binary to ASCII & ASC- to Binary.

See Page [illegible] Pocket manual.

FORMATTER
.DIO. (DECIMAL INPUT/OUTPUT)
.BIO. (BINARY INPUT/OUTPUT)
.IOR. (INPUT/OUTPUT REAL)
.IOI. (INPUT/OUTPUT INTEGER)
.RAR. (REAL ARRAY)
.IAR. (INTEGER ARRAY)
.DTA. (TERMINATOR)

FORMATTER

CALLING SEQUENCE SELECTOR



```
SAMPLE OF A "FREE FIELD" INTEGER INPUT CALL
         *
               EXT .DIO.,.IOI.
         UNIT  OCT 1
         I     BSS 1
         *
         START LDA UNIT
               CLB,INB
               JSB .DIO.
               OCT Ø
               DEF END
               JSB .IOI.
               STA I
         END   (program continuation)
```

```
*SAMPLE OF A REAL NUMBER OUTPUT CALL
*
      EXT .DIO.,.IOR.,.DTA.
UNIT  OCT 2
X     OCT Ø77777
      OCT 177776
FMT   ASC 4,(E13.6/)
*
START LDA UNIT
      CLB.
      JSB .DIO.
      DEF FMT
      DEF END
      DLD X
      JSB .IOR.
      JSB .DTA.
END   (program continuation)
```

```
SAMPLE OUTPUT

 .17Ø141E+39
```

*For internal conversion only substitute the following –

```
INITIAL CALL
CLA (unit = Ø)
CLB,INB (in) or CLB (out)
JSB.DIO.
DEF (buffer)
DEF (format)
DEF (end of list)
```

in - ASCII to binary
oot - binary to ASCII

USING THE FORMATTER

```
                         EXT .IOC.,.DIO.,.IOI.,.RAR.,.IAR.,.BIO.,.DTA.
*DATA STORAGE AND CONSTANTS
*   .
                  BUFFR DEC 1,2,3,4,5,6,7,8,9,10
                  N     DEC 10
                  UNIT2 OCT 2
                  UNIT4 OCT 4
                  IARRY DEF BUFFR
                  FMT2  ASC 16,("PRINT ELEMENTS 3,5,AND 7"/3I5)

*CALLING SEQUENCE TO PUNCH AN INTEGER ARRAY IN BINARY FORM
*
                        LDA UNIT4     LOAD"A"WITH UNIT #
                        CLB           0 TO "B" FOR OUTPUT
                        JSB .BIO.     INITIAL CALL (BINARY)
                        LDA N         # OF ELEMENTS
                        LDB IARRY     ARRAY ADDRESS
                        JSB .IAR.     DATA CALL
                        JSB .DTA.     NO MORE ITEMS ON DATA LIST
                         :
*CALLING SEQUENCE TO PRINT THE 3RD, 5TH, AND 7TH ELEMENTS OF BUFFR
*
                        LDA UNIT2     LOAD "A" WITH UNIT#
                        CLB           0 TO "B" FOR OUTPUT
                        JSB .DIO.     INITIAL CALL (FORMATTED)
                        DEF FMT2      ADDRESS OF ASCII FORMAT STRING
                        DEF EOL3      END OF LIST ADDRESS
                        LDA BUFFR+2   GET 3RD ELEMENT
                        JSB .IOI.     DATA CALL
                        LDA BUFFR+4   GET 5TH ELEMENT
                        JSB .IOI.     DATA CALL
                        LDA BUFFR+6   GET 7TH ELEMENT
                        JSB .IOI.     DATA CALL
                        JSB .DTA.     NO MORE ITEMS ON DATA LIST
                  EOL3  (Program Continuation)
```

LESSON X OBJECTIVES

THE OBJECTIVES OF LESSON X ARE:

1 - TO INTRODUCE THE STUDENT TO THE HEWLETT-PACKARD BASIC CONTROL SYSTEM.

2 - TO INSTRUCT THE STUDENT IN THE USE OF THE INPUT/OUTPUT CONTROL (IOC) AND I/O EQUIPMENT DRIVER SUBROUTINES.

INTRODUCTION TO THE BASIC CONTROL SYSTEM

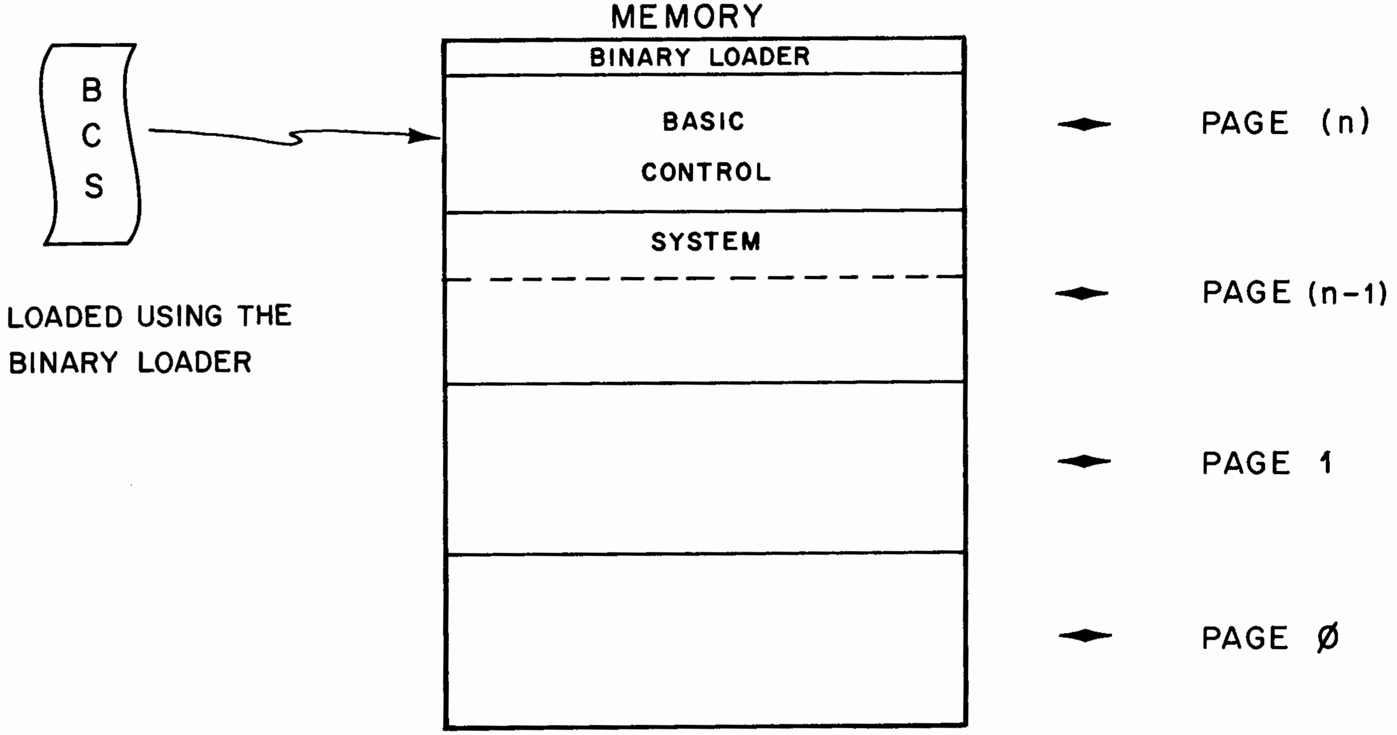
THE BASIC CONTROL SYSTEM PROVIDES 2 MAIN FUNCTIONS TO THE COMPUTER SYSTEM.

1. Provides a flexible, systematic structure to handle input/output requests from system and user programs.

2. Provides the loading and linking capability required for relocatable object programs produced by FORTRAN and the ASSEMBLER.

BASIC CONTROL SYSTEM

THE BASIC CONTROL SYSTEM IS AN ABSOLUTE PROGRAM ON PAPER TAPE

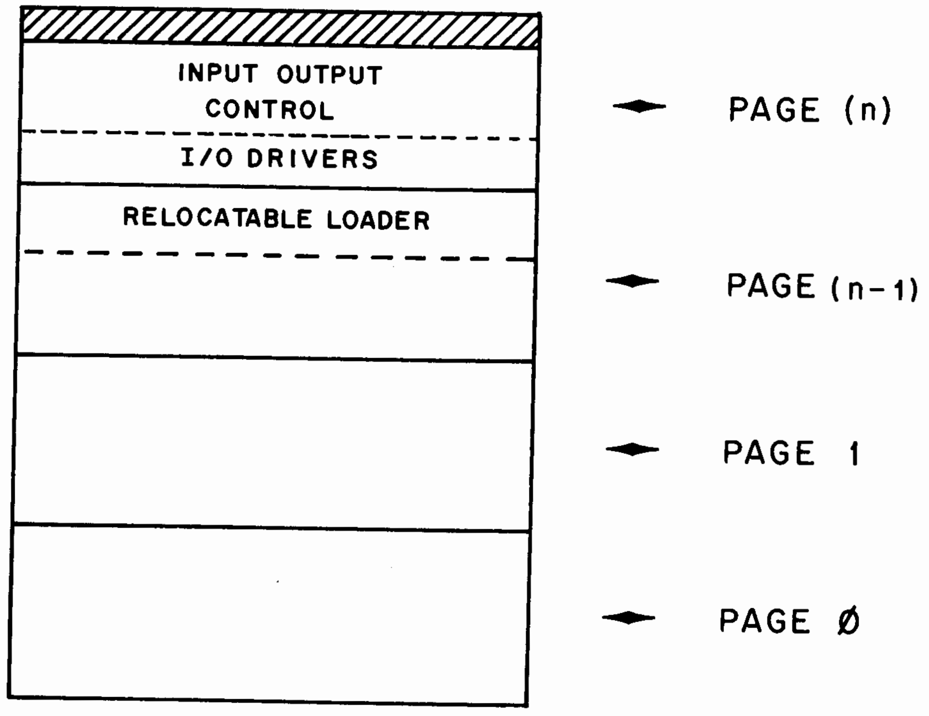


THE BASIC CONTROL SYSTEM ALWAYS RESIDES IN UPPER MEMORY

THE BASIC CONTROL SYSTEM IS MADE UP OF THREE INTEGRAL PARTS ———

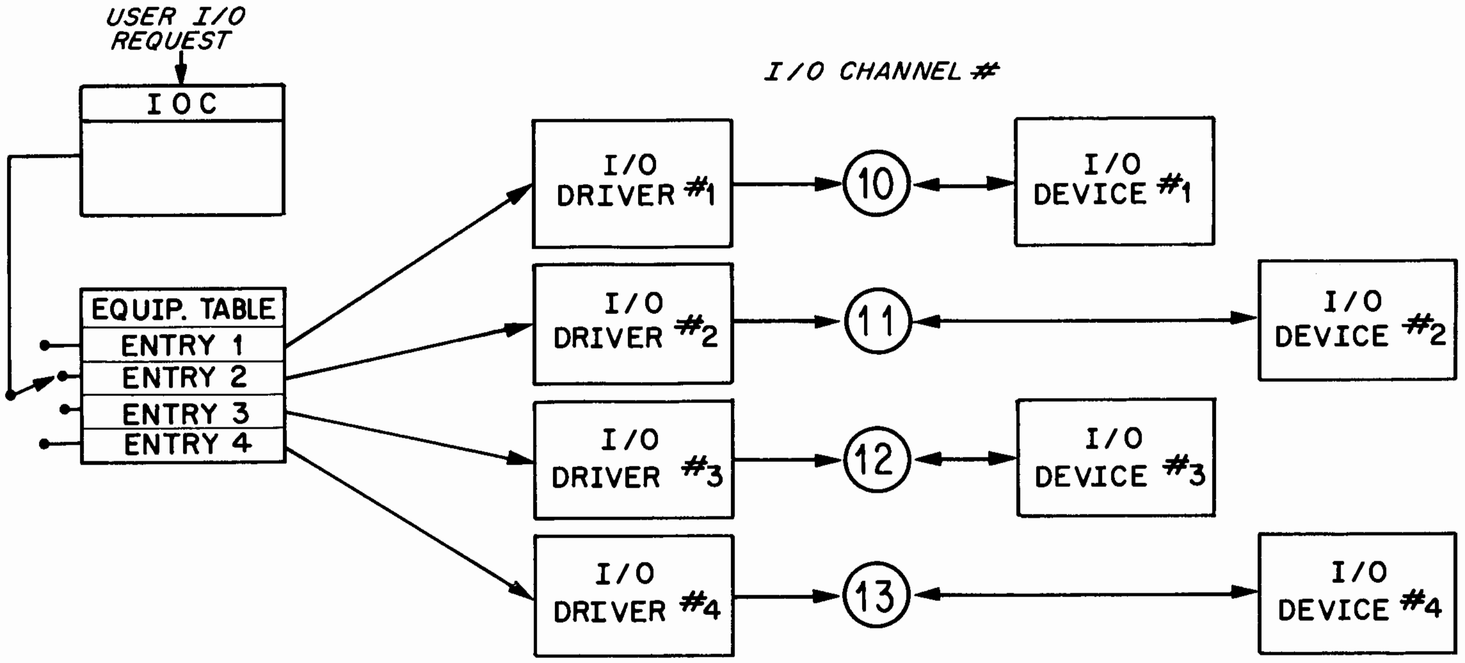
1 *INPUT OUTPUT CONTROL*
2 *I/O DRIVERS*
3 *RELOCATABLE LOADER*

} Relocatable



BCS MODULES

SIMPLIFIED IOC BLOCK DIAGRAM



① The user requests an I/O operation using a logical unit number.

② IOC finds the logical unit entry in the equipment table.

③ The equipment table entry contains the address of the driver.

UNIT REFERENCE NUMBERS

IN ORDER TO ALLOW NEW INPUT/OUTPUT HARDWARE TO BE INTEGRATED INTO THE COMPUTER SYSTEM, USER REQUESTS TO IOC NEVER REFER TO THE PHYSICAL I/O DEVICE CHANNEL NUMBER. EACH I/O DEVICE IS ASSIGNED A LOGICAL NUMBER CALLED THE UNIT REFERENCE NUMBER.

UNIT REFERENCE NUMBERS REFER TO ONE OF TWO TABLES:

1 - STANDARD UNIT TABLE
2 - EQUIPMENT TABLE

1 Standard unit teletype. Keyboard.

EQUIPMENT TABLE

UNIT REFERENCE NUMBER$_8$	I/O CHANNEL (S)$_8$	DEVICE
1-6 stand.ard equipment. 7	14	TELEPRINTER
10	15	H. S. TAPE READER
11	16	H. S. TAPE PUNCH
•	•	•
•	•	•
•	•	•

EACH I/O DEVICE MAKES ONE ENTRY IN THE EQUIPMENT TABLE, HOWEVER THE FIRST ENTRY IS ASSIGNED UNIT REFERENCE NUMBER 7.

EXAMPLE OF AN INITIAL EQUIPMENT TABLE

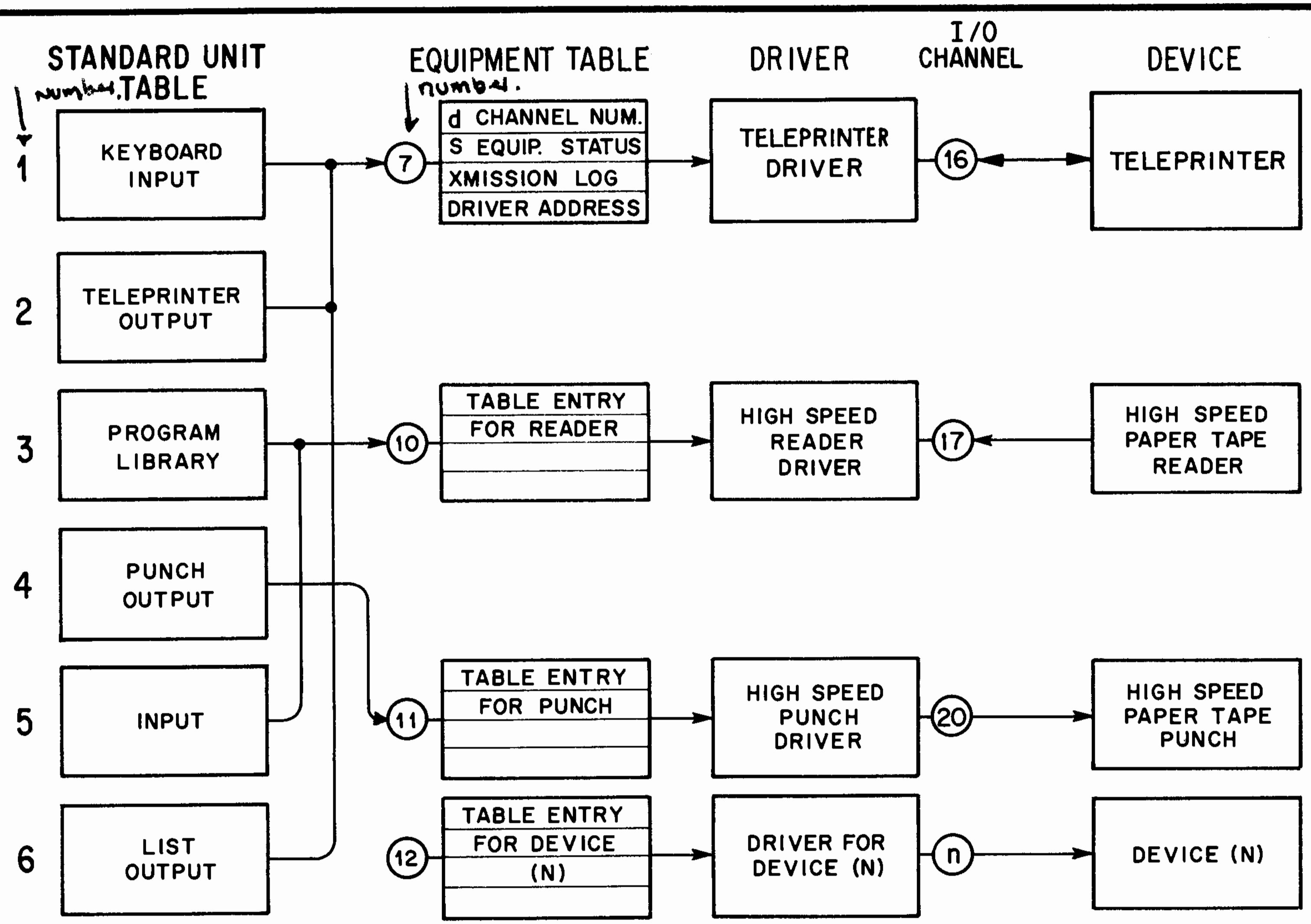
EQUIPMENT TABLE

UNIT REFERENCE NUMBER$_8$	I/O CHANNEL (S)$_8$	DEVICE
7	16	TELEPRINTER
10	17	H.S. TAPE READER
11	20	H.S. TAPE PUNCH
12	14/15	MAGNETIC TAPE
•	•	•
•	•	•

ALTHOUGH NEW CHANNEL ASSIGNMENTS FOR THE DEVICES ARE SHOWN. REFERENCES TO UNIT 7 WILL STILL BE ROUTED TO THE TELEPRINTER. THE EQUIPMENT TABLE PROVIDES THE LOGICAL/PHYSICAL FLEXIBILITY REQUIRED TO CHANGE OR UPGRADE A COMPUTER INSTALLATION WITHOUT CHANGE TO EXISTING PROGRAMS.

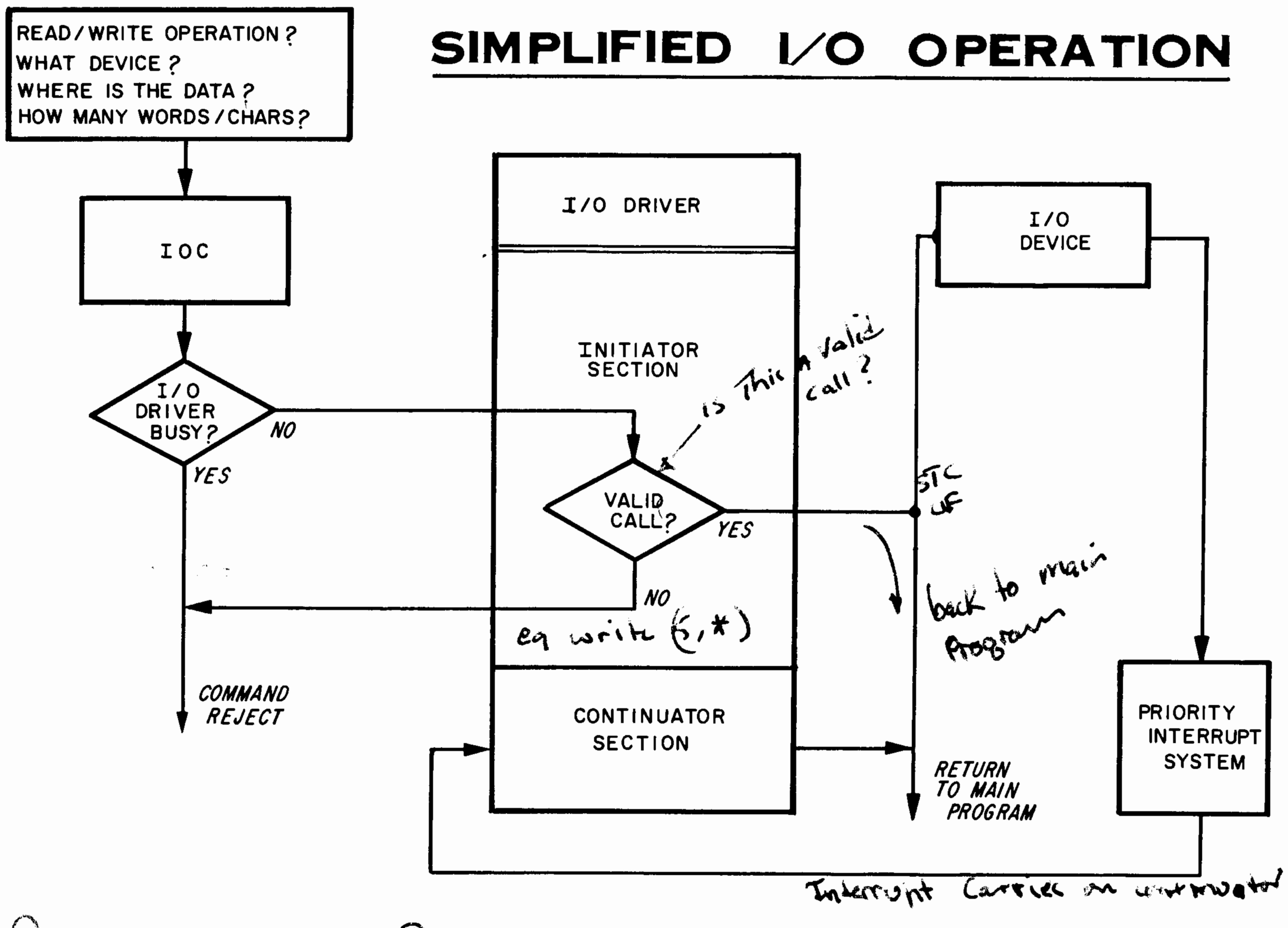
EXAMPLE OF UPGRADING THE SYSTEM

To functions To devices



LOGICAL TO PHYSICAL TRANSLATION PROCESS

SIMPLIFIED I/O OPERATION



Page 4-2 BCS

Any call to .IOC. will automatically enable the Interrupt System

EXT .IOC.

JSB .IOC.

read/write binary/ASC

OCT (<FUNCTION><SUBFUNCTION><UNIT REF.>)

DRIVER OR DEVICE BUSY
ILLEGAL CALL OR DMA
CHANNEL NOT AVAILABLE....
IOC WILL RETURN HERE

JMP (REJECT ADDRESS)

DEF (BUFFER ADDRESS) buffer address where is data

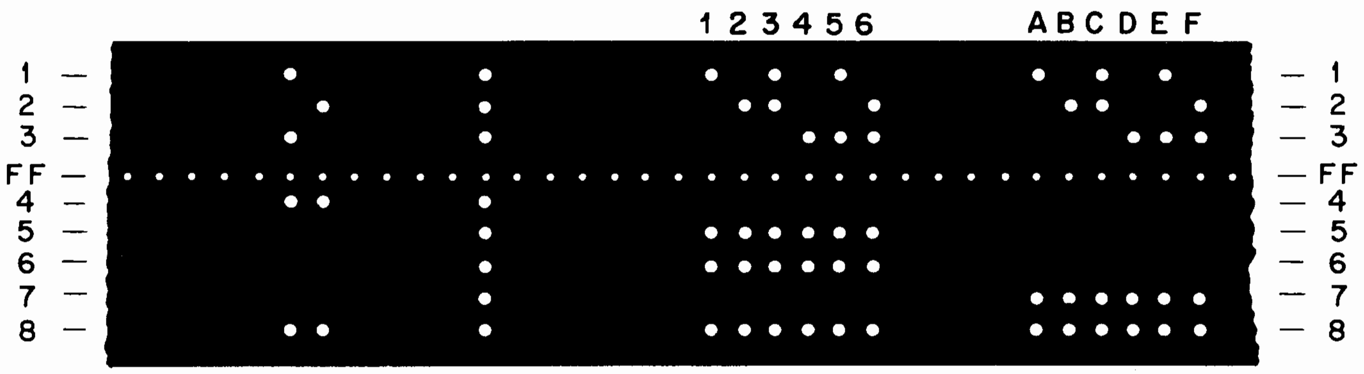
DEC (BUFFER LENGTH OR COUNT) how much data

IF THE REQUEST IS ACCEPTED
IOC WILL RETURN TO THE
LOCATION FOLLOWING THE
COUNT PARAMETER

PROGRAM CONTINUATION

Computer Museum

INPUT OUTPUT REQUESTS



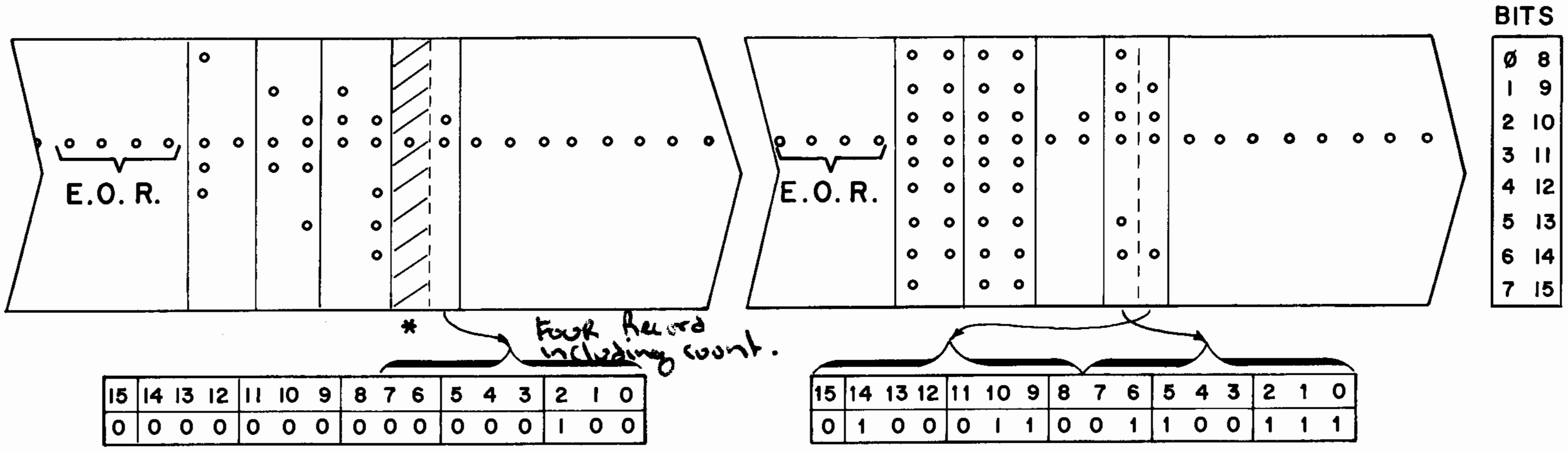
1) LEVELS 1 - 7 CONSTITUTE THE ASCII CODE

2) THE DRIVERS WITHIN BCS REMOVE THE 8th LEVEL ON INPUT AND PUNCH THE 8th LEVEL ON OUTPUT WHEN READING/WRITING

3) CARRIAGE RETURN, LINE FEED IS THE ASCII END OF RECORD MARK

4) A 'RUB OUT' CHARACTER FOLLOWED BY C.R., L.F. WILL CAUSE THE DRIVER TO IGNORE THE PRECEDING RECORD

(TELETYPE) 8 LEVEL TAPE



BITS	
Ø	8
1	9
2	10
3	11
4	12
5	13
6	14
7	15

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

8 BIT WORD COUNT FORMAT

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	1	1	0	0	1	1	0	0	1	1	1

16 BIT BINARY WORD FORMAT

A VARIABLE LENGTH BINARY RECORD (SHOWN WITH 4 WORDS)

A FIXED LENGTH BINARY RECORD (SHOWN WITH 4 WORDS)

1. Feed frames prior to the first character are ignored by the driver. Therefore the 1st frame of a binary record must be non-zero.

2. Four feed frames separate binary records.

3. To output a record in variable binary form, the number of words in the data block must be in the range $1 \leq n \leq 255_{10}$. The second frame of the word count * is ignored on input.

4. Variable binary input uses the word count, or the specified buffer size to terminate transmission, whichever value is smaller.

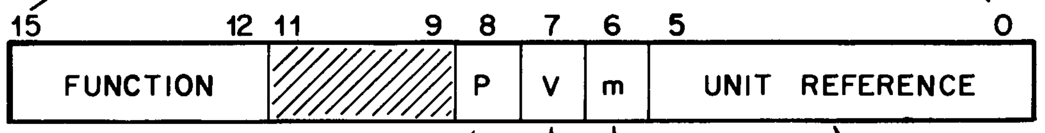
8 LEVEL PAPER TAPE (BINARY)

No checksum error checking on data tapes using BCS drive

IOC CALL (PARAMETER 1)

```
LABEL   OPCODE   OPERAND
        EXT      .IOC.
        JSB      .IOC.
        OCT      010005
        JMP      *-2
        DEF      BUFFR
        DEC      -10
```

- sign indicates
characters
+5 = [illegible]



CODE (OCTAL)

READ 01
WRITE 02

P=1 PRINT TTY
INPUT
(KEYBOARD READER)

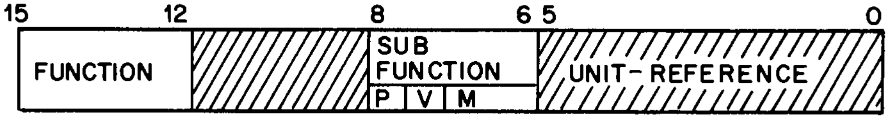
P=Ø TTY looks dead
on keyboard input

V=1 VARIABLE
BINARY INPUT

m=1 BINARY
=0 ASCII

UNIT REFERENCE VALUES

STANDARD UNIT NUMBERS 1-6
OR
UNIT REFERENCE NUMBERS 7-n



OPERATION	FUNCTION			SUB FUNCTION
READ ASCII RECORD	0	1	0	0
READ ASCII RECORD AND PRINT	0	1	0	4
READ BINARY RECORD	0	1	0	1
READ VARIABLE LENGTH BINARY RECORD	0	1	0	3
WRITE ASCII RECORD	0	2	0	0
WRITE BINARY RECORD	0	2	0	1

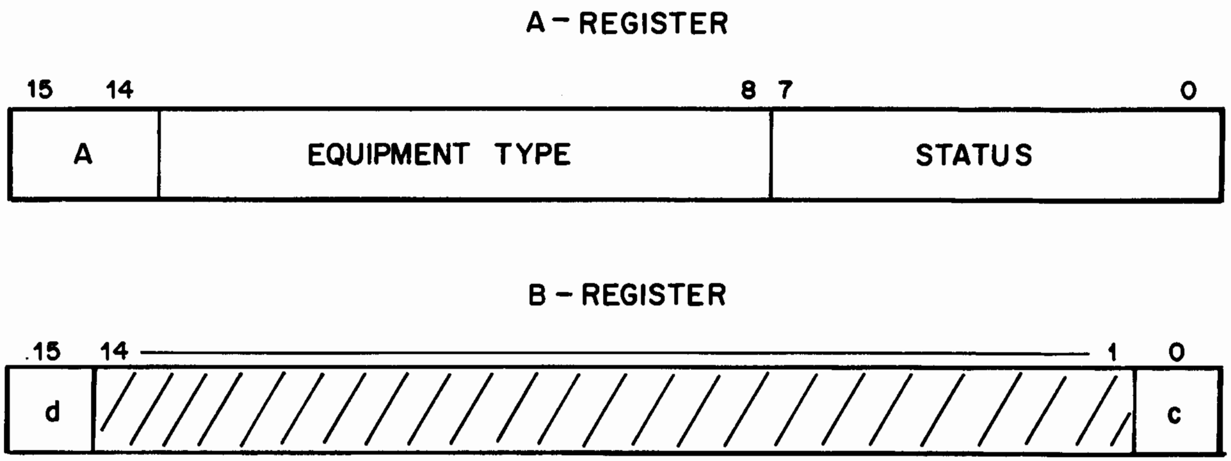
ALLOWABLE COMBINATIONS OF READ/WRITE FUNCTIONS

COMMAND REJECT

AN I/O REQUEST THAT IS REJECTED WILL CAUSE IOC TO RETURN CONTROL HERE

```
LABEL  OP CODE  OPERAND
       JSB      .IOC.
       OCT      XXXXX
       JMP      *-2
       DEF      ADDR
       DEC      COUNT
```

THE CAUSE OF THE REJECT WILL BE RETURNED IN THE B REGISTER.



d = 1 DEVICE OR DRIVER BUSY
c = 1 DMA CHANNEL NOT AVAILABLE
d = c = Ø ILLEGAL FUNCTION OR SUBFUNCTION

```
LABEL     OP CODE     OPERAND     REMARKS

          EXT         .IOC.
           |            |
           |            |
           |            |
          JSB         .IOC.
          OCT         10005       READ ASCII, STD INPUT
          JMP         *-2
          DEF         TABL        ADDRESS OF BUFFER
          DEC         10          NUMBER OF WORDS
           |
           |
           |
           |
           |
TABL      BSS         10
           |
           |
           |
          END
```

1 - THE ADDRESS OF THE FIRST WORD OF THE BUFFER IS DEFINED USING THE DEF PSEUDO.

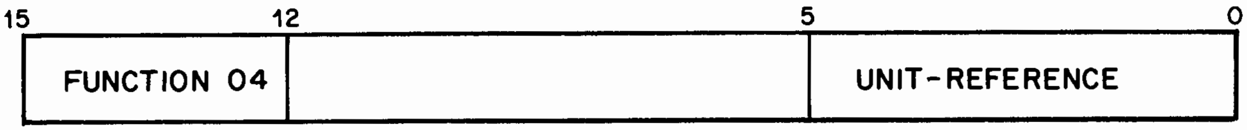
2 - THE NUMBER OF WORDS/CHARACTERS TO BE TRANSFERRED IS DEFINED BY:
WORDS = A POSITIVE VALUE
CHARACTERS = A NEGATIVE VALUE

EXAMPLE CALL TO IOC

```
LABEL          OP CODE      OPERAND       REMARKS

                  .
                  .
                  .
LINE           EXT          .IOC.         .IOC. EXTERNAL
               BSS          36            36 WORD PROGRAM  BUFFER
               COM          BKB(100)      100 WORD  COMMON  BUFFER
                  .
                  .
                  .
READ1          JSB          .IOC.
               OCT          10005         READ  ASCII
               JMP          *-2
15 bit address line DEF     LINE          PROGRAM BUFFER
               DEC          -72           72 ASCII  CHARS
                                          don't include (CR)(LF)
                  .
                  .
                  .
WRITE#         JSB          .IOC.         WRITE BINARY
               OCT          20111
               JMP          *-2
               DEF          BKB           COMMON  BUFFER
               DEC          100           100 BINARY  WORDS
                  .
                  .
                  .
```

EXAMPLE OF IOC CALLING SEQUENCES

STATUS REQUEST (DEVICE)

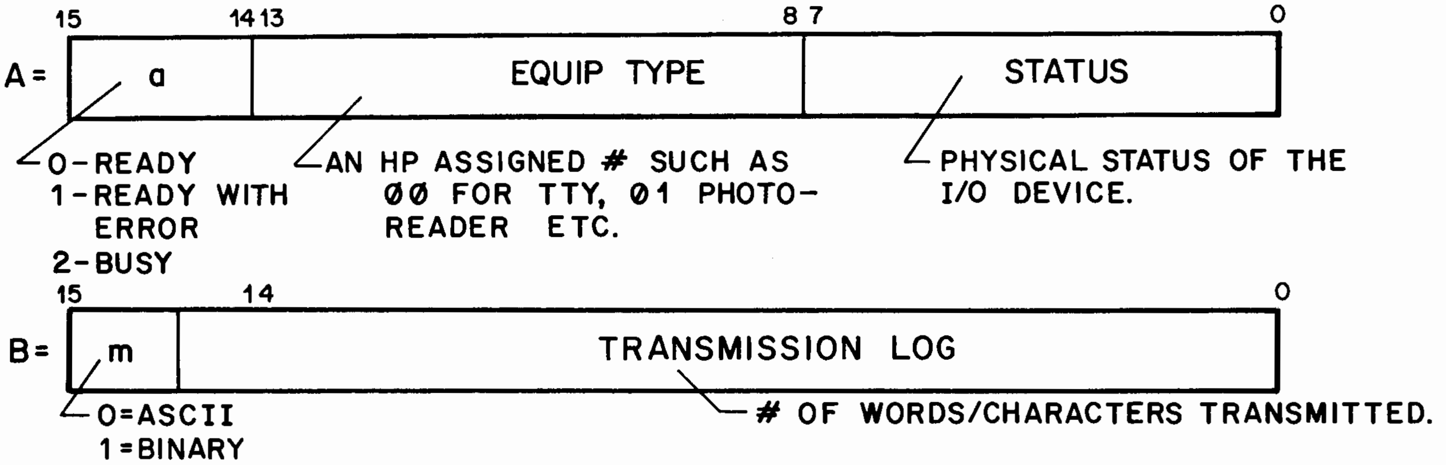


(CALLING SEQUENCE)

```
JSB     .IOC.
OCT     <FUNCTION> <UNIT-REF>
```

01 Read
02 write
04 STATUS.

IOC **WILL RETURN TO THE MAIN PROGRAM WITH WORD 2 OF THE EQT IN THE A REGISTER, AND WORD 3 OF THE EQT IN THE 'B' REGISTER.**



0-READY
1-READY WITH ERROR
2-BUSY

AN HP ASSIGNED # SUCH AS ØØ FOR TTY, Ø1 PHOTO-READER ETC.

PHYSICAL STATUS OF THE I/O DEVICE.

0=ASCII
1=BINARY

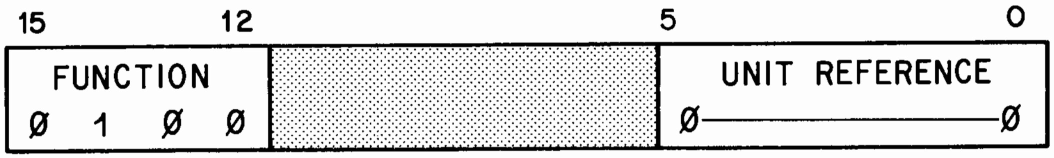
OF WORDS/CHARACTERS TRANSMITTED.

```
LABEL       OP CODE       OPERAND       REMARKS

            COMMAND  INITIATION

READ        JSB           .IOC.
            OCT           10Ø15         READ ASCII
            JMP           REJECT
            DEF           INBUF         BUFFER ADDRESS
            DEC           -2Ø           2Ø CHARACTERS
            JMP           STAT
             :
REJECT      SSB                         IS DRIVER BUSY?
            JMP           READ          YES, RE-INITIATE  COMMAND
            JSB           ABORT         NO, GO TO ERROR ROUTINE
INBUF       BSS           1Ø

              STATUS  CHECKING

STAT        JSB           .IOC.
            OCT           4ØØ15         REQUEST  STATUS
            SSA                         IS DRIVER BUSY?
            JMP           STAT          YES, LOOP UNTIL FREE
            RAL                         NO,  ROTATE & TEST BIT 14
            SSA, RSS                    ANY ERROR ?
            JMP           PROCS         NO,  CONTINUE PROCESSING.
            ALF, ALF                    YES, POSITION BIT 5
            RAL                         FOR STATUS TEST
            SSA                         EOT CONDITION ?
            JMP           ENDPR         YES, GO TO EOT ROUTINE
            JSB           ABORT         NO, GO TO ERROR ROUTINE
```

Not defined in this example.

CODING EXAMPLE TO CHECK STATUS CONDITIONS

STATUS REQUEST (SYSTEM)



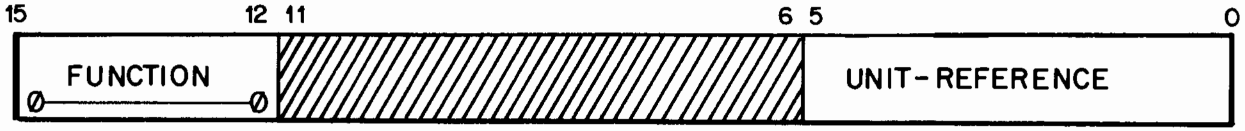
CALLING SEQUENCE

```
JSB .IOC.
OCT 4ØØØØ
(RETURN)
```

IOC WILL RETURN TO THE MAIN PROGRAM WITH REGISTER "A":

POSITIVE - No system devices are busy
NEGATIVE - A system device is busy

THE SECOND WORD CONSISTS OF THE FOLLOWING:



THE ONLY OTHER PARAMETER REQUIRED IS THE UNIT-REFERENCE NUMBER.

THE CLEAR REQUEST TERMINATES A PREVIOUSLY ISSUED INPUT OR OUTPUT OPERATION BEFORE ALL DATA IS TRANSMITTED. IT HAS THE FOLLOWING FORM:

```
(CALLING SEQUENCE)
  JSB     .IOC.
  OCT      <FUNCTION> <UNIT-REFERENCE>
                0
```

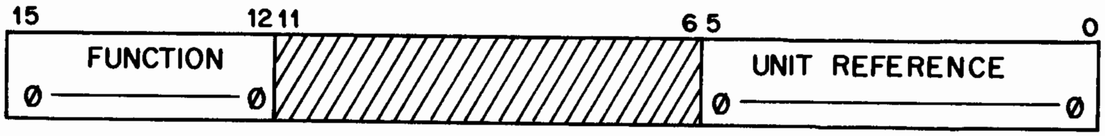
1 Read
2 Write
4. Status
0 clear.

CLEAR REQUEST (DEVICE)

```
LABEL      OP CODE     OPERAND       REMARKS

             •
             •
             •
READM        JSB       .IOC.         OPEN TTY INPUT CHANNEL
             OCT       10401         READ FROM KEYBOARD
             JMP       *-2           BUSY, TRY AGAIN
             DEF       MSG           DATA BUFFER
             DEC       -72           72 CHARACTERS MAX
             JSB       TIMER         RTN TO TIME OPERATOR RESPONSE
             •
             •
             •
CLRRD        JSB       .IOC.         CLEAR REQUEST
             OCT       1             ON UNIT 1
             •
             •
             •
```

EXAMPLE OF A CLEAR REQUEST

The second word consists of the following:



CALLING SEQUENCE

```
JSB .IOC.
OCT Ø
(RETURN)
```

THE SYSTEM CLEAR REQUEST CAUSES IOC TO CLEAR ALL DEVICES AND DRIVERS DEFINED BY THE EQUIPMENT TABLE. THIS MAKES ALL DEVICES AVAILABLE FOR INITIATING AN OPERATION.

CLEAR REQUEST (SYSTEM)

INTERNAL CONVERSION EXAMPLE

Internal Conversion is Fairly quick then initiate .IOC. so that data can be output [illegible] efficient interrupt control

If you just use format then you get [illegible] in formatter until the data is outputted

```
*CALLING SEQUENCE TO INTERNALLY CONVERT A REAL ARRAY (BINARY)
*TO ASCII AND OUTPUT WITH A CALL DIRECTLY TO .IOC.
*

      EXT .IOC.,.DIO.,.RAR.,.DTA.
      ~~ENT START~~
```

JSD Start

```
START NOP
      CLA               UNIT =Ø MEANS INTERNAL CONVERSION
      CLB               Ø TO "B" FOR OUTPUT
      JSB .DIO.         INITIAL CALL (FORMATTED)
      DEF ABUFR         ADDRESS OF BUFFER FOR ASCII DATA
      DEF FMT4          ADDRESS OF ASCII FORMAT STRING
      DEF EOL5          END OF LIST ADDRESS
      LDA N             #OF ELEMENTS
      LDB RARRY         ARRAY ADDRESS
      JSB .RAR.         DATA CALL
      JSB .DTA.         NO MORE ITEMS ON DATA LIST
EOL5  LDA CNT           INITIALIZE COUNTER
      STA CNTR
      LDA ADDRS         PICK UP BUFFER ADDRESS
      STA POINT         INITIALIZE ADDRESS
LOOP  JSB .IOC.         CALL .IOC.
      OCT 2ØØØ2         OUTPUT ON UNIT #2
      JMP *-2           REJECT
POINT OCT Ø             BUFFER ADDRESS
      DEC -6            6 ASCII CHARACTERS
      JSB .IOC.         STATUS CHECK
      OCT 4ØØØ2         UNIT #2
      SSA               BUSY?
      JMP *-3           YES, CHECK STATUS AGAIN
      LDA POINT         NO, MODIFY BUFFER
      ADA P6            ADDRESS TO OUTPUT
      STA POINT         NEXT ELEMENT
      ISZ CNTR          IS CNTR Ø?
      JMP LOOP          NO, OUTPUT NEXT ELEMENT
```

Calling Sequence to .IOC.

JSB-IOC.
Out count
[illegible] [illegible]
[illegible]

(Program Continuation)

```
*DATA STORAGE AND CONSTANTS

BUFFX DEC 1.,2.,.....,9.,1Ø.
N     DEC 1Ø
CNT   DEC -1Ø
CNTR  OCT Ø
P6    OCT 3
FMT4  ASC 3,(F6.2)
ABUFR BSS 3Ø
ADDRS DEF ABUFR
RARRY DEF BUFFX
```

LESSON XI OBJECTIVES

THE PRIMARY OBJECTIVES OF LESSON XI ARE:

1. TO DISCUSS THE OPERATION OF THE HP RELOCATING LOADER IN MORE DETAIL AND DESCRIBE ADDITIONAL LOADER FEATURES.

2. TO TEACH THE STUDENT HOW TO USE THE "CONFIGURATION" ROUTINES—

   PREPARE CONTROL SYSTEM.
   SYSTEM INPUT/OUTPUT DUMP.

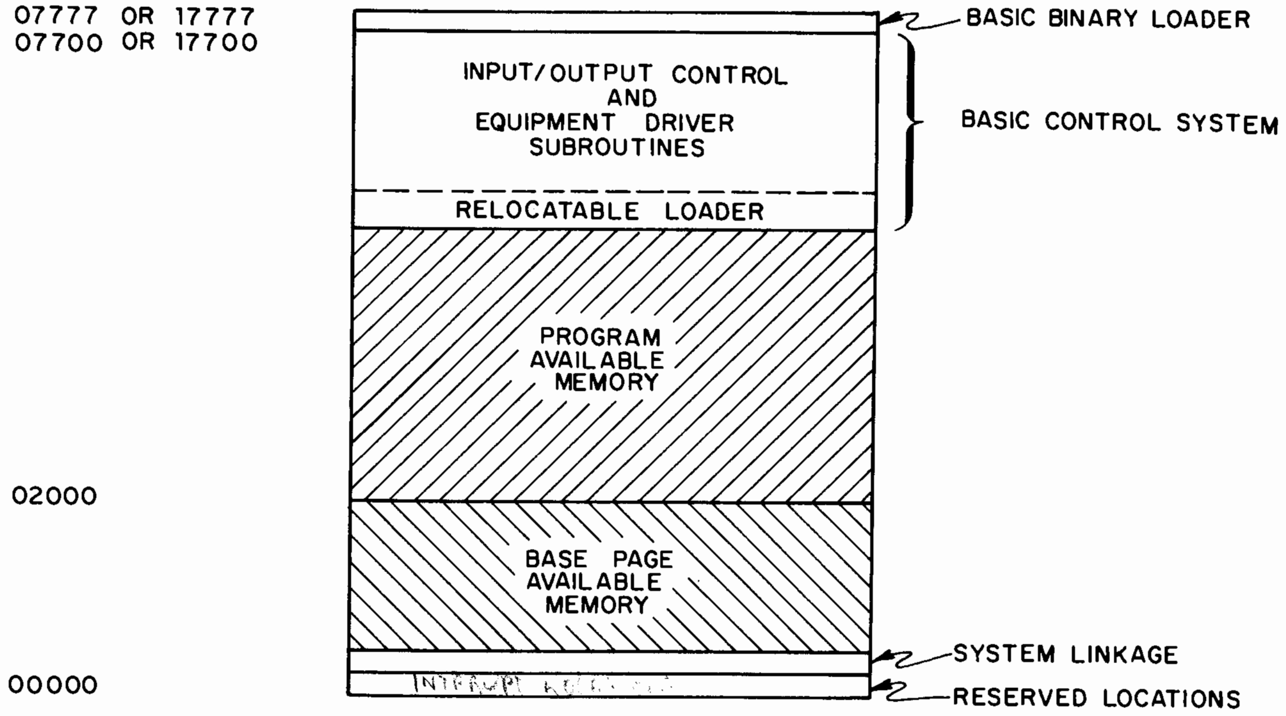
THE RELOCATABLE LOADER:

- LOADS RELOCATABLE OBJECT PROGRAMS.
- ESTABLISHES COMMON STORAGE BOUNDARIES.
- PROVIDES LINKAGES WHEN THE OBJECT PROGRAM IS LOADED ACROSS PAGE BOUNDARIES.
- WILL PUNCH AN ABSOLUTE BINARY TAPE OF THE OBJECT PROGRAM. (OPTION)
- PROVIDES A MEMORY LISTING OF PROGRAM BOUNDARIES AND THE ABSOLUTE ADDRESS OF ALL 'ENT' POINTS DECLARED IN THE SOURCE PROGRAM.
- PROVIDES A 'LOAD AND GO' FEATURE OR THE OPTION OF MANUAL ENTRY OF THE STARTING ADDRESS.

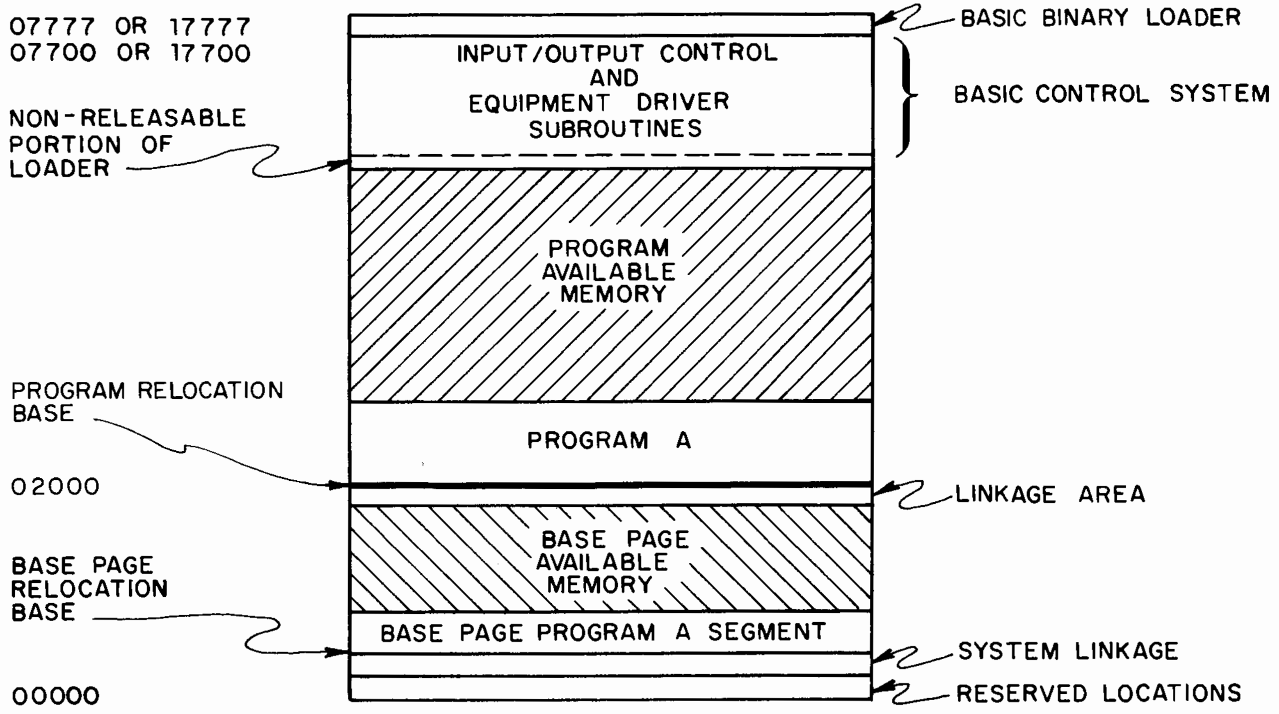
	LABEL	OP CODE	OPERAND
		⋮	
	1776	DEF	B
PAGE 0	1777	DEF	A
PAGE 1	ABSOLUTE START OF PROGRAM		
		⋮	
		ISZ	~~A~~ 1777,I
		LDA	~~A~~ 1777,I
		ADA	~~B~~ 1776,I
PAGE 1			
PAGE 2		ADA	C
		JMP	X
	A	BSS	1
	B	BSS	1
	C	BSS	1
	X	LDA	A
		HLT	

IN THE EXAMPLE, SYMBOLIC TERMS ARE USED FOR SIMPLICITY AND TO DESCRIBE THE 'EFFECT' OF THE LOADERS ACTION.

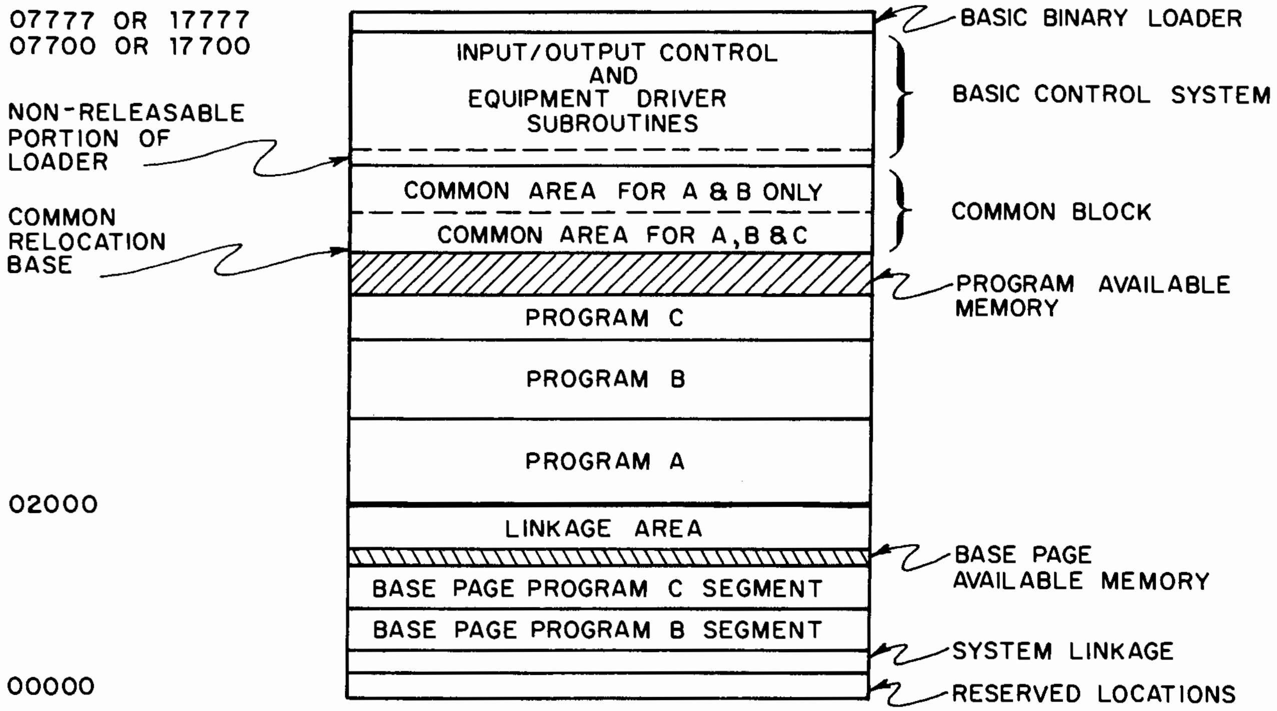
LOADER PROVIDED LINKAGES


07777 OR 17777
07700 OR 17700
02000
00000
INPUT/OUTPUT CONTROL AND EQUIPMENT DRIVER SUBROUTINES
RELOCATABLE LOADER
PROGRAM AVAILABLE MEMORY
BASE PAGE AVAILABLE MEMORY
INTERRUPT ADDRESSES
BASIC BINARY LOADER
BASIC CONTROL SYSTEM
SYSTEM LINKAGE
RESERVED LOCATIONS

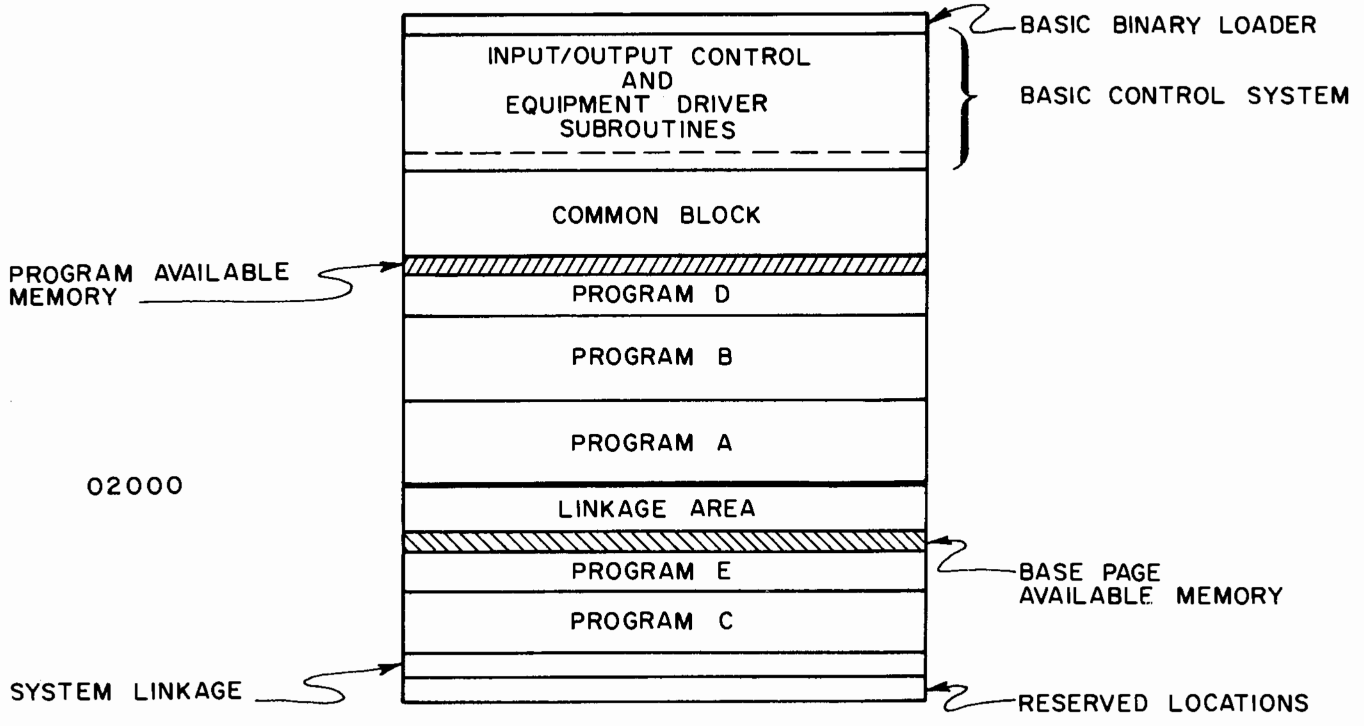
MEMORY MAP 1


07777 OR 17777
07700 OR 17700
NON-RELEASABLE PORTION OF LOADER
PROGRAM RELOCATION BASE
02000
BASE PAGE RELOCATION BASE
00000
INPUT/OUTPUT CONTROL AND EQUIPMENT DRIVER SUBROUTINES
PROGRAM AVAILABLE MEMORY
PROGRAM A
BASE PAGE AVAILABLE MEMORY
BASE PAGE PROGRAM A SEGMENT
BASIC BINARY LOADER
BASIC CONTROL SYSTEM
LINKAGE AREA
SYSTEM LINKAGE
RESERVED LOCATIONS

MEMORY MAP 2


07777 OR 17777
07700 OR 17700
NON-RELEASABLE PORTION OF LOADER
COMMON RELOCATION BASE
02000
00000
INPUT/OUTPUT CONTROL AND EQUIPMENT DRIVER SUBROUTINES
COMMON AREA FOR A & B ONLY
COMMON AREA FOR A, B & C
PROGRAM C
PROGRAM B
PROGRAM A
LINKAGE AREA
BASE PAGE PROGRAM C SEGMENT
BASE PAGE PROGRAM B SEGMENT
BASIC BINARY LOADER
BASIC CONTROL SYSTEM
COMMON BLOCK
PROGRAM AVAILABLE MEMORY
BASE PAGE AVAILABLE MEMORY
SYSTEM LINKAGE
RESERVED LOCATIONS

MEMORY MAP 3


BASIC BINARY LOADER
INPUT/OUTPUT CONTROL AND EQUIPMENT DRIVER SUBROUTINES
BASIC CONTROL SYSTEM
COMMON BLOCK
PROGRAM AVAILABLE MEMORY
PROGRAM D
PROGRAM B
PROGRAM A
02000
LINKAGE AREA
BASE PAGE AVAILABLE MEMORY
PROGRAM E
PROGRAM C
SYSTEM LINKAGE
RESERVED LOCATIONS

MEMORY MAP 4

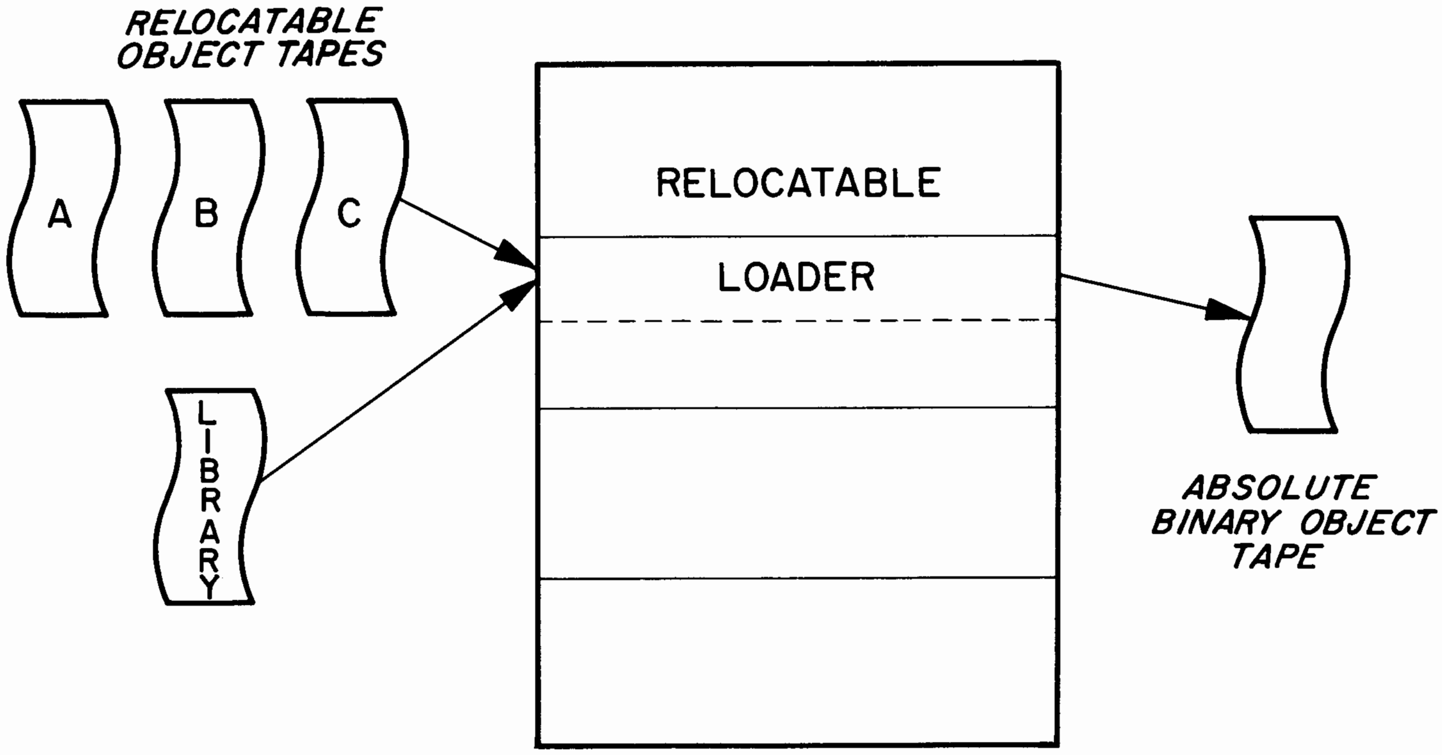
```
LABEL       OP CODE     OPERAND          REMARKS

ASMB, R, B, L, T
            NAM         PROGA
            EXT         .IOC.
            ENT         BEGIN
START       NOP
BEGIN       MPY         SAM              PROGA
             .                           SEGMENT
            STA         MIKE
            COM         MIKE(512)
             .
             .
            END         START


ASMB, R, B, L, T
            NAM         PROGB
            EXT         FLOAT, BEGIN
             .
             .
            JSB         FLOAT
             .
            LDA         TABL             PROGB
            COM         TABL (255)       SEGMENT
             .
             .
            JMP         BEGIN
             .
             .
            END
```

Program with the largest block must be loaded First

LOADING EXAMPLE

LOADER LISTING

LOADER MESSAGES		COMMENTS
PROGA		
02000	03002	PROGRAM "A" IS LOADED
LOAD		MORE PROGRAMS?
PROGB		
03003	04006	YES, LOAD PROGRAM "B"
LOAD		LIST UNDEFINED EXT SYMBOLS; SW.Ø UP&PRESS RUN
MPY		
FLOAT		
LOAD		MORE PROGRAMS? YES, LOAD FROM LIBRARY
MPY		
04007	04117	LIBRARY ROUTINE
FLOAT		
04120	04124	LIBRARY ROUTINE
.PACK		
04125	04231	FLOAT CALLS .PACK
*LST		PRINT LOADER SYMBOL TABLE? SW. 15=Ø , YES-SW. 15=1, NO.
.IOC.	17515	ENTRY POINTS WITH ABSOLUTE ADDRESSES
.MEM.	16113	
BEGIN	02001	
MPY	04007	
FLOAT	04120	
.PACK	04125	
*COM		
15112	16111	COMMON STORAGE BOUNDS
*LINKS		
01773	01777	LOADER PROVIDED LINKAGES
*RUN		READY TO EXECUTE



BINARY OUTPUT OPTION SWITCH 14=1

THE LOADER PRODUCES THE ABSOLUTE BINARY OBJECT TAPE DURING A 'PSEUDO LOAD' OPERATION. THE ABSOLUTE BINARY TAPE CAN BE LOADED BY THE <u>BINARY</u> LOADER.

ABSOLUTE BINARY OUTPUT

MESSAGE	EXPLANATION	ACTION
*L01	CHECKSUM ERROR	REREAD THE RECORD
*L02	ILLEGAL RECORD	RIGHT TAPE? REREAD THE RECORD
*L03	MEMORY OVERFLOW	REVISE PROGRAM
*L04	LINKAGE AREA OVERFLOW	REVISE LOADING ORDER, OR REVISE PROGRAM
*L05	LOADER SYMBOL TABLE OVERFLOW	REVISE PROGRAM
*L06	COMMON BLOCK ERROR (Current common declaration exceeds initial common declaration)	LOAD PROGRAM CONTAINING THE LARGEST COMMON BLOCK FIRST
*L07	DUPLICATE ENTRY POINTS	REVISE PROGRAM
*L08	NO TRANSFER ADDRESS	LOAD STARTING ADDRESS IN 'A' REGISTER, PUSH RUN.
*L09	RECORD OUT OF SEQUENCE	REASSEMBLE PROGRAM OR RELOAD BCS AND TRY AGAIN

LOADER DIAGNOSTICS

	'T' REGISTER	EXPLANATION	ACTION
HALT 66	(102066)	TAPE SUPPLY ON 2753A PUNCH IS LOW	REPLENISH TAPE SUPPLY , PUSH RUN
HALT 55	(102055)	A LINE IS ABOUT TO BE PRINTED ON THE BINARY OUTPUT DEVICE	TURN PUNCH OFF, PUSH RUN
HALT 56	(102056)	A LINE HAS BEEN PRINTED WHILE THE PUNCH UNIT WAS OFF	TURN PUNCH ON, PUSH RUN

HALT INDEX, BINARY OUTPUT OPTION

PREPARE CONTROL SYSTEM (P.C.S.)

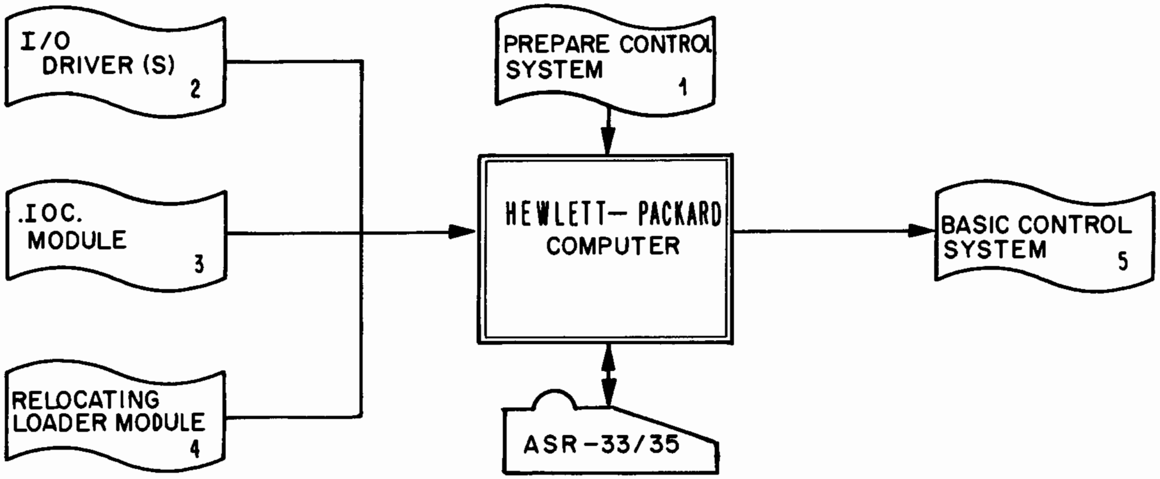
WHAT IS IT?

A COMPUTER PROGRAM WHICH PROCESSES RELOCATABLE MODULES OF THE BASIC CONTROL SYSTEM AND PRODUCES AN ABSOLUTE VERSION OF B.C.S. TAILORED TO THE SPECIFIC HARDWARE CONFIGURATION.

WHAT DOES IT DO?

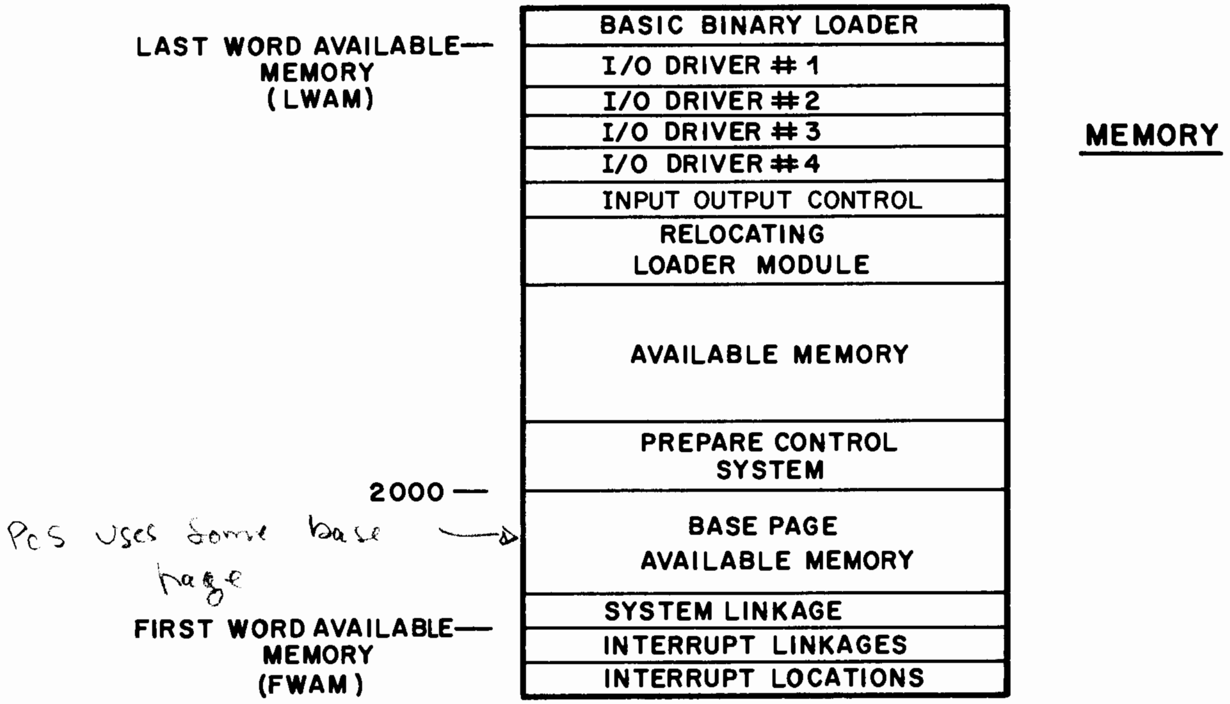
IT CREATES AN OPERATING SYSTEM CONSISTING OF THE INPUT/OUTPUT SUBROUTINE (I.O.C.), THE RELOCATABLE LOADER (LDR) AND THE REQUIRED PERIPHERAL EQUIPMENT INPUT/OUTPUT DRIVER SUBROUTINES.

PROCESSING ENVIRONMENT



P.C.S. OVER VIEW

P.C.S PROVIDES THE CAPABILITY OF CREATING A COMPLETE BASIC CONTROL SYSTEM IN THE COMPUTERS MEMORY.



WHEN ALL INDIVIDUAL ELEMENTS ARE PRESENT IN MEMORY. P.C.S. WILL PUNCH AN ABSOLUTE BINARY VERSION OF THE COMPLETE BASIC CONTROL SYSTEM.

PLANNING THE SYSTEM

THE FIRST CONSIDERATION TO BE MADE IS THE PHYSICAL PLACEMENT OF THE I/O INTERFACE CARDS. CHANNEL #10 HAS THE HIGHEST PRIORITY, #11 NEXT HIGHEST, ETC. GENERALLY, THE DEVICE THAT GENERATES THE GREATEST NUMBER OF INTERRUPTS PER UNIT OF TIME IS ASSIGNED THE <u>HIGHEST</u> PRIORITY.

FOR EXAMPLE:

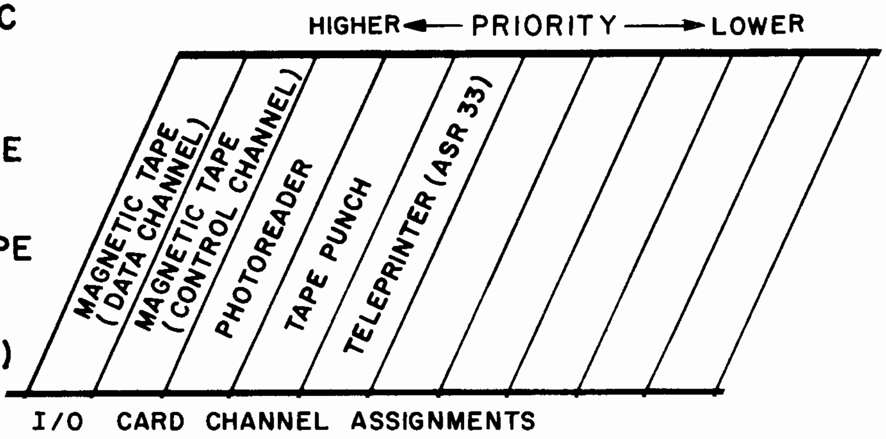
ASSUME A COMPUTER SYSTEM IS MADE UP OF THE FOLLOWING UNITS:

1. - READ/WRITE MAGNETIC TAPE (REQUIRES TWO INTERFACE BOARDS)

2. - HIGH-SPEED PAPER TAPE READER

3. - HIGH-SPEED PAPER TAPE PUNCH

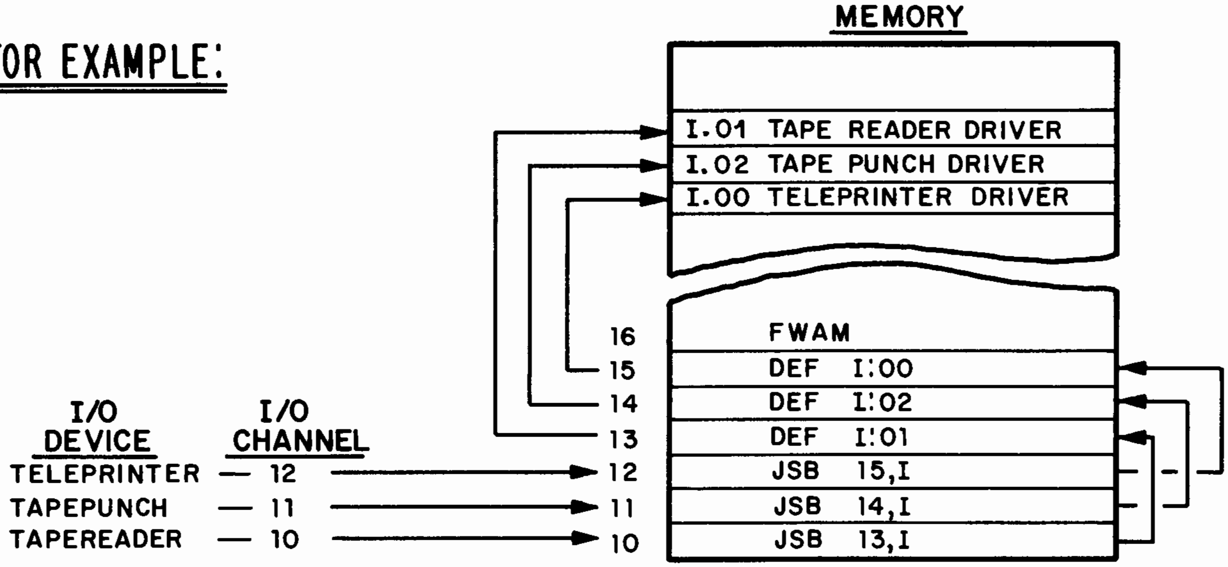
4. - TELEPRINTER (ASR-33)


HIGHER ← PRIORITY → LOWER
MAGNETIC TAPE (DATA CHANNEL)
MAGNETIC TAPE (CONTROL CHANNEL)
PHOTOREADER
TAPE PUNCH
TELEPRINTER (ASR 33)
I/O CARD CHANNEL ASSIGNMENTS

INTERRUPT LINKAGE

WHEN AN I/O DEVICE CAUSES AN INTERRUPT IT FORCES THE COMPUTER TO EXECUTE THE CONTENTS OF THE INTERRUPT LOCATION. SINCE ALL INTERRUPT LOCATIONS ARE ON THE BASE PAGE AND THE I/O DRIVERS ARE IN HIGH MEMORY THE TRANSFER TO THE DRIVER MUST USE INDIRECT ADDRESSING.

FOR EXAMPLE:



EQUIPMENT TABLE NUMBERS

EQUIPMENT TABLE NUMBERS BEGIN WITH 7. EACH DEVICE IS ASSIGNED A SEQUENTIAL OCTAL NUMBER. WITHIN THIS FRAMEWORK THE INITIAL NUMBER ASSIGNMENTS ARE ARBITRARY.

FOR EXAMPLE:

EQT

1st ENTRY - PHOTOREADER
2nd ENTRY - TAPE PUNCH
3rd ENTRY - TELEPRINTER
4th ENTRY - MAG TAPE

	MAGNETIC TAPE (DATA CHANNEL)	MAGNETIC TAPE (CONTROL CHANNEL)	PHOTOREADER	TAPE PUNCH	TELEPRINTER (ASR 33)				
EQUIPMENT TABLE →	12		7	10	11				

INTERRUPTS, LINKAGE, DRIVER I.D.

INTERRUPT LOCATION — P.C.S. WILL CAUSE A COMPUTER INSTRUCTION TO BE STORED HERE. (USUALLY A JSB, I)

LINKAGE LOCATION — P.C.S. WILL CAUSE THE ADDRESS OF THE CONTINUATOR SECTION OF THE I/O DRIVER TO BE STORED HERE.

DRIVER IDENTIFICATION — THE SYMBOLIC NAME OF THE I/O DRIVER INITIATOR SECTION ENTRY POINT.

INTERRUPT IDENTIFICATION — THE SYMBOLIC NAME OF THE I/O DRIVER CONTINUATOR SECTION ENTRY POINT.

FWAM — THE FIRST WORD OF AVAILABLE MEMORY.

NOTE: DRIVER AND INTERRUPT ID CODES ASSIGNED BY H-P. THE SYMBOLS USED MUST BE UNIQUE.

Initiator Sect'n

	MAG TAPE (DATA CHANNEL)	MAG TAPE (CONTROL CHANNEL)	PHOTOREADER	TAPE PUNCH	TELEPRINTER (ASR 33)
DRIVER IDENTIFICATION	D.21	—	D.01	D.02	D.00
INTERRUPT LOCATION	10	11	12	13	14
LINKAGE LOCATION	15	16	17	20	21
INTERRUPT IDENT.	I.21	C.21	I.01	I.02	I.00
EQUIPMENT TABLE →	12		7	10	11

(22) FWAM

[illegible] slot ||

Continuator Sect'n

STANDARD UNIT NUMBERS

The standard unit numbers are simply pointers to the appropriate equipment table entries.

To assign standard units place a checkmark at the intersection of the standard unit table number (x-axis), and the correct equipment table number (y-axis)

	MAG TAPE (DATA CHANNEL)	MAG TAPE (CONTROL CHANNEL)	PHOTOREADER	TAPE PUNCH	TELEPRINTER (ASR 33)
DRIVER IDENTIFICATION	D.21	–	D.Ø1	D.Ø2	D.ØØ
INTERRUPT LOCATION	10	11	12	13	14
LINKAGE LOCATION	15	16	17	20	21
INTERRUPT IDENT.	I.21	C.21	I.Ø1	I.Ø2	I.ØØ
EQUIPMENT TABLE →	12		7	10	11
STANDARD UNIT TABLE					
1. KEYBOARD INPUT					✓
2. TELEPRINTER OUTPUT					✓
3. PROGRAM LIBRARY			✓		
4. PUNCH OUTPUT				✓	
5 INPUT			✓		
6. LIST OUTPUT					✓

This is Reference number
IE OCT 20012

I/O [illegible]

D.xx Initiator ENTERED FROM [illegible]

I.xx Continuator ENTERED FROM INTERRUPT

P.C.S. OPERATIONS

THE NEXT FEW CHARTS WILL DESCRIBE A SIMPLE B.C.S. CONFIGURATION. THE SYSTEM WILL CONSIST OF A COMPUTER SYSTEM WITH 8K OF MEMORY AND THE FOLLOWING PERIPHERALS:

1. **READ/WRITE MAGNETIC TAPE — I/O CHANNELS 10,11**
2. **PHOTOELECTRIC PUNCHED PAPER TAPE READER — I/O CHANNEL 12**
3. **HIGH SPEED PAPER TAPE PUNCH — I/O CHANNEL 13**
4. **TELEPRINTER (ASR 33) — I/O CHANNEL 14**

THE ACTUAL CONFIGURATION PROCESS MAY BE DESCRIBED IN FIVE PHASES.

PHASE 1— INITIALIZATION

PHASE 2— LOADING THE I/O EQUIPMENT DRIVER

PHASE 3— LOADING THE IOC MODULE

a. CREATING THE EQUIPMENT TABLE
b. CREATING THE STANDARD UNIT TABLE

PHASE 4— LOADING THE RELOCATING LOADER MODULE

a. ESTABLISH THE INTERRUPT LINKAGES

PHASE 5— PUNCH THE ABSOLUTE OUTPUT TAPE

INITIALIZATION PHASE

Switch Reg. Load P.C.S SA 2000B.
~~LOO~~ SC ASR 33

THE P.C.S. PROGRAM INITIALIZATION PHASE

COMMUNICATIONS	REMARKS
HS INP?	Is H.S. input unit available ?
17	Channel number of photo-reader
HS PUN?	Is H.S punch available ?
2Ø	Channel number of tape punch
FWA MEM?	Request first word address of available memory
22	First word following required interrupt locations
LWA MEM?	Request last word address of available memory
17677	Word preceding basic loader (8K memory)
*LOAD	Request to load first BCS module

THESE ENTRIES REFER TO THE "CONFIGURING" SYSTEM.

LOADING THE I/O EQUIPMENT DRIVERS

COMMUNICATIONS		REMARKS
D.21	→	MAGNETIC TAPE DRIVER PROCESSED*
16220 17677	→	MEMORY BOUNDS OF THE DRIVER
* LOAD	→	REQUEST TO LOAD NEXT MODULE
D.Ø1 15661 16217		PHOTO-READER DRIVER PROCESSED
* LOAD		
D.Ø2 15351 1566Ø		TAPE PUNCH DRIVER PROCESSED
* LOAD		
D.ØØ 14615 1535Ø		TELEPRINTER DRIVER PROCESSED
* LOAD		

I/O Control module

*WHEN PRESENT, THIS DRIVER SHOULD BE LOADED FIRST DUE TO ITS LARGE SIZE

To avoid crossing page boundaries load the mag tape driver first

LOADING THE IOC MODULE

COMMUNICATIONS		REMARKS
IOC 14376 14614	→	IOC MODULE PROCESSED
* TABLE ENTRY	→	EQUIPMENT TABLE UNIT #
EQT?		
12,D.Ø1	→	7
13,D.Ø2	→	10
14,D.ØØ	→	11
1Ø,D.21	→	12
/E		
SQT?	→	STANDARD UNIT TABLE
-KYBD? — unit number		
11		
-TTY?		
11		
-LIB?		
7		
-PUNCH?		
1Ø		
-INPUT?		
7		
-LIST?		
11		
DMA?	→	DIRECT MEMORY ACCESS OPTION. Ø INDICATES DMA NOT AVAILABLE.
Ø - 6,7 — change [illegible] 16		
* LOAD		

	MAGNETIC TAPE (DATA CHANNEL)	MAGNETIC TAPE (CONTROL CHANNEL)	PHOTOREADER	TAPE PUNCH	TELEPRINTER (ASR 33)
DRIVER IDENTIFICATION	D.21	—	D.Ø1	D.Ø2	D.ØØ
INTERRUPT LOCATION	10	11	12	13	14
LINKAGE LOCATION	15	16	17	20	21
INTERRUPT IDENT.	I.21	C.21	I.Ø1	I.Ø2	I.ØØ
EQUIPMENT TABLE →	12		7	10	11

STANDARD UNIT TABLE					
1. KEYBOARD INPUT					✓
2. TELEPRINTER OUTPUT					✓
3. PROGRAM LIBRARY			✓		
4. PUNCH OUTPUT				✓	
5 INPUT			✓		
6. LIST OUTPUT					✓

THE RELOCATING LOADER MODULE

DRIVER IDENTIFICATION	D.21	–	D.Ø1	D.Ø2	D.ØØ
INTERRUPT LOCATION	10	11	12	13	14
LINKAGE LOCATION	15	16	17	20	21
INTERRUPT IDENT.	I.21	C.21	I.Ø1	I.Ø2	I.ØØ

COMMUNICATIONS

```
LOADR
 12115 14346

 INTERRUPT LINKAGE?

1Ø,15,I.21
11,16,C.21
12,17,I.01   (ERROR)
*UN NAME     ( 0≠Ø )
12,17,I.Ø1
13,2Ø,I.Ø2
14,21,I.ØØ
/E           ──► LIST TERMINATOR
```

Note ch!

MEANING	ENTRY POINT LIST	
ADDRESS OF SYSTEM TABLE	.SQT.	14347
ADDRESS OF EQUIP. TABLE	.EQT.	14355
I/O DRIVER – INITIATOR AND CONTINUATOR ENTRY POINTS	D.21	1622Ø
	I.21	17216
	C.21	1713Ø
	D.Ø1	15661
	I.Ø1	15776
	D.Ø2	15351
	I.Ø2	15465
MAINTAINS COMPATABILITY BETWEEN BUFFERED AND UNBUFFERED VERSIONS OF I.O.C.	.BUFR	14544
	D.ØØ	14615
	I.ØØ	14771
ADDRESS OF .IOC. ENTRY POINT	.IØC.	14376
DMA STATUS WORD CH #1	DMAC1	14613
DMA STATUS WORD CH #2	DMAC2	14614
ADDRESS OF I/O ERROR HALT	IOERR	14572
SYSTEM TABLE LINK WORD	XSQT	14611
EQUIPMENT TABLE LINK WORD	XEQT	14612
RELOCATING LOADER ENTRY POINT	.LDR.	136Ø1
ADDRESS OF MEMORY TABLE*	.MEM.	14342
LOADER SYMBOL TABLE ADDRESS	LST	12141

*SYSTEM LINK
ØØØ22 00153

These are no
Released after
BCS has been
overwritten

* MEMORY TABLE

FWABP ______
LWABP ______
FWAM ______
LWAM ______

*BCS ABSOLUTE OUTPUT

ADDITIONAL P.C.S./B.C.S. CAPABILITIES

SETTING CONSTANTS INTO INTERRUPT LOCATIONS

```
1Ø, 15, I.ØØ
11, 16, I.Ø4
12, 17, I.Ø2
13, 1Ø6713
14, Ø
```

These entries will cause P.C.S. to do this

LOC.	CONTENTS$_8$
13	1Ø6713
14	ØØØØØØ

SPECIFYING INTERRUPT AND/OR SYSTEM ROUTINES AS EXTERNAL

11, 16, I.Ø4	Original input entry.
* UN NAME	P.C.S. diagnostic message.
!	Response to establish the name as external. — OR —
11, 16, I.Ø3	Response to indicate a corrected input entry.

SPECIFYING I/O DRIVERS AS EXTERNAL

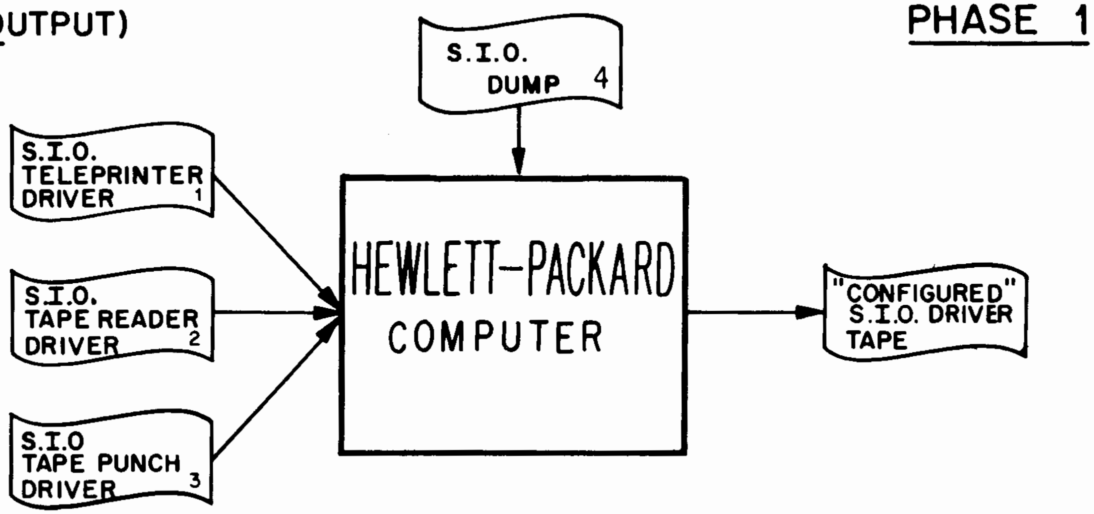
I/O DRIVER ? D . XX	P.C.S. diagnostic message indicating the referenced driver has not been loaded.
!	Response to define the driver as external
* UNDEFINED SYMBOL: XXXX	P.C.S. diagnostic caused by specifying a driver as external. The computer will halt. Push run to continue. Each undefined symbol is given the dummy address 77777.

NON Interrupt (Absolute)

SYSTEM INPUT-OUTPUT DUMP ROUTINE

(SYSTEM INPUT OUTPUT)

PHASE 1



S.I.O. DUMP 4

S.I.O. TELEPRINTER DRIVER 1

S.I.O. TAPE READER DRIVER 2

S.I.O TAPE PUNCH DRIVER 3

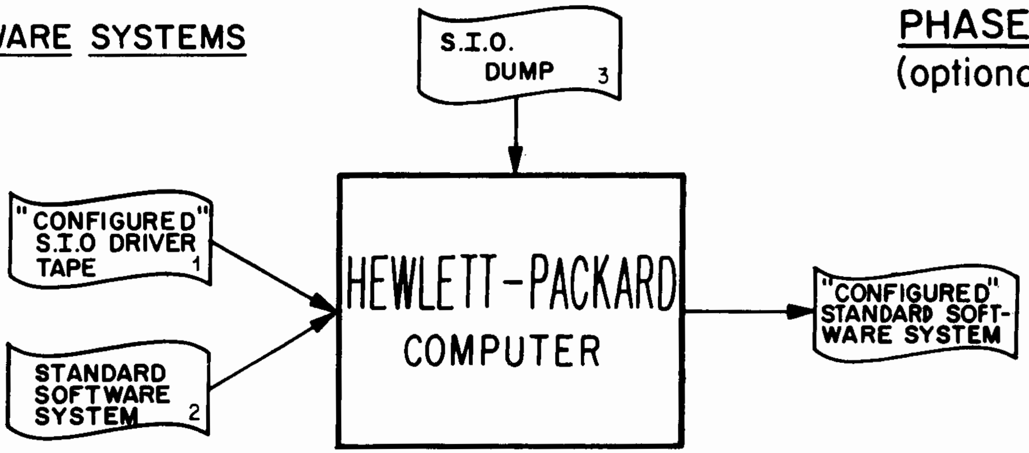
HEWLETT-PACKARD COMPUTER

"CONFIGURED" S.I.O. DRIVER TAPE

STANDARD SOFTWARE SYSTEMS

PHASE 2
(optional)

FORTRAN
ALGOL
ASSEMBLER
SYMBOLIC EDITOR



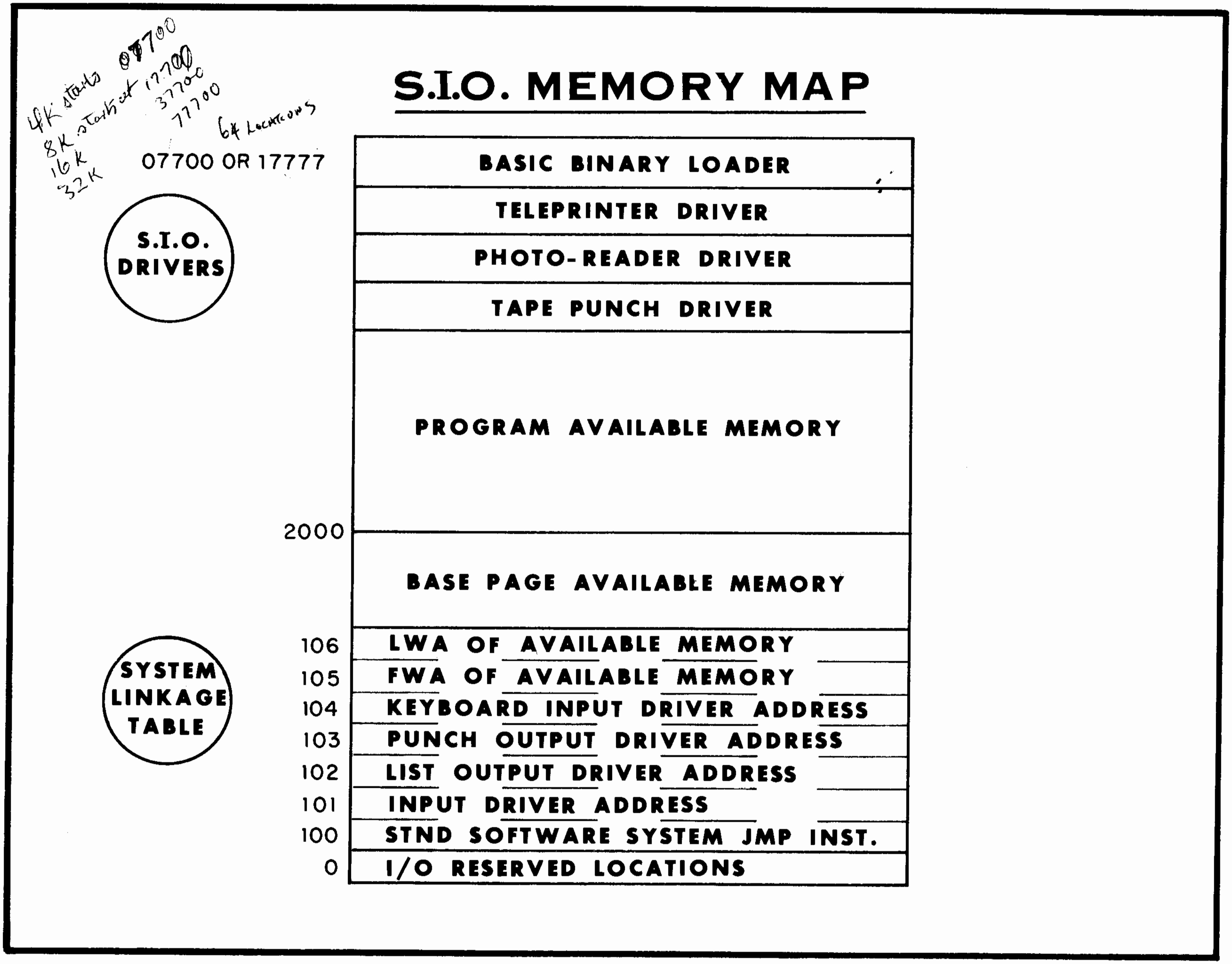
S.I.O. DUMP 3

"CONFIGURED" S.I.O DRIVER TAPE 1

STANDARD SOFTWARE SYSTEM 2

HEWLETT-PACKARD COMPUTER

"CONFIGURED" STANDARD SOFTWARE SYSTEM



S.I.O. MEMORY MAP

4K starts 07700
8K starts at 17700
16K 37700
32K 77700
64 Locations

S.I.O. DRIVERS

07700 OR 17777

BASIC BINARY LOADER

TELEPRINTER DRIVER

PHOTO-READER DRIVER

TAPE PUNCH DRIVER

PROGRAM AVAILABLE MEMORY

2000

BASE PAGE AVAILABLE MEMORY

SYSTEM LINKAGE TABLE

106 LWA OF AVAILABLE MEMORY

105 FWA OF AVAILABLE MEMORY

104 KEYBOARD INPUT DRIVER ADDRESS

103 PUNCH OUTPUT DRIVER ADDRESS

102 LIST OUTPUT DRIVER ADDRESS

101 INPUT DRIVER ADDRESS

100 STND SOFTWARE SYSTEM JMP INST.

0 I/O RESERVED LOCATIONS

CONFIGURING A PROGRAM SYSTEM

THE SYSTEMS TO BE CONFIGURED

- ASSEMBLER SYSTEM
- SYMBOLIC EDITOR SYSTEM
- FORTRAN COMPILER SYSTEM-PASS 1 TAPE ONLY
- ALGOL COMPILER

THE S.I.O. DRIVERS (ONLY PROVIDED WHEN I/O DEVICE ORDERED)

- TELEPRINTER
- TAPE READER
- TAPE PUNCH

THE PROCEDURE (BASIC BINARY LOADER USED FOR ALL MODULE LOADING)

1. LOAD A DRIVER. (THE TELEPRINTER MUST BE LOADED FIRST)(PHOTOREADER SECOND)(PUNCH LAST)
2. PLACE THE ADDRESS 2 INTO THE P-REGISTER; SET SWITCHES 5-0 OF THF SWITCH REGISTER TO THE CHANNEL NUMBER ASSOCIATED WITH THAT DEVICE AND PRESS RUN.
3. REPEAT ABOVE STEPS FOR EACH DRIVER TO BE INCLUDED.
4. LOAD THE PERTINENT PROGRAMMING SYSTEM.
5. LOAD THE S.I.O. DUMP ROUTINE.
6. PLACE THE ADDRESS 2 INTO THE P-REGISTER & SET SWITCH 15 OF THE SWITCH REGISTER TO OBTAIN THE FOLLOWING OPTIONS:

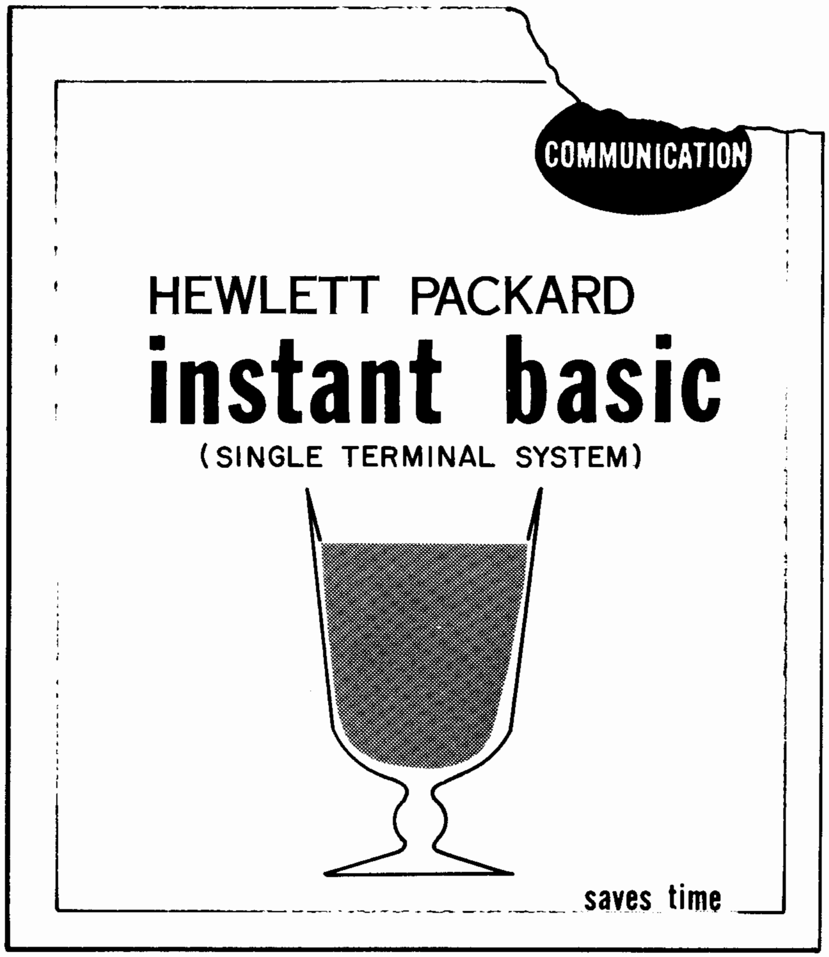
   0 = OUTPUT TO CONTAIN ONLY S.I.O. DRIVERS AND SYSTEM LINKAGE TABLE.
   1 = PROGRAM SYSTEM IS TO BE INCLUDED ON OUTPUT.
7. PRESS RUN TO COMMENCE PUNCH-OUT.
8. MULTIPLE COPIES MAY BE OBTAINED BY REPEATING FROM SWITCH 15 SETTING OF STEP 6.

LESSON XII OBJECTIVES

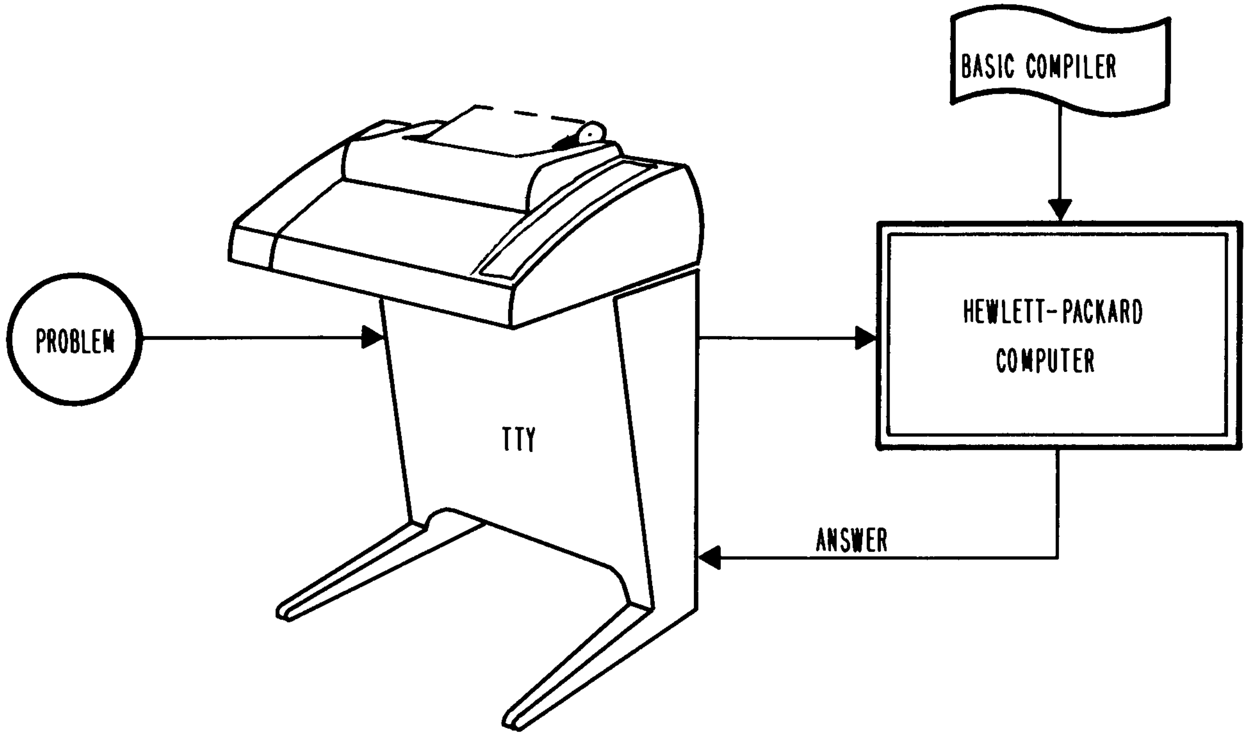
THE PRINCIPLE OBJECTIVES OF LESSON XII ARE:

1. TO INTRODUCE THE STUDENT TO THE ELEMENTS OF THE HEWLETT- PACKARD SINGLE TERMINAL BASIC COMPILER.
2. TO PRESENT THE LANGUAGE AND OPERATING CAPABILITIES IN SUFFICIENT DETAIL TO PERMIT THE STUDENT TO CREATE SOLUTIONS TO SIMPLE PROBLEMS WITH RELATIVELY LITTLE INSTRUCTION TIME REQUIRED.
3. TO ILLUSTRATE THE EASE AND FLEXIBILITY OF USING THE SYSTEM, BY PROVIDING SAMPLE PROBLEM SOLUTIONS, FOR ANALYSIS, AND SUGGESTIONS FOR PROGRAMMING.

NOTE: THE "BASIC" LANGUAGE WAS DEVELOPED BY DARTMOUTH COLLEGE, UNDER THE DIRECTION OF PROFESSORS JOHN G. KEMENY AND THOMAS E. KURTZ. THE HEWLETT-PACKARD BASIC COMPILER IS AN ADAPTATION OF THAT DEVELOPMENT.


COMMUNICATION
HEWLETT PACKARD
instant basic
(SINGLE TERMINAL SYSTEM)
saves time

BASIC OPERATING ENVIRONMENT



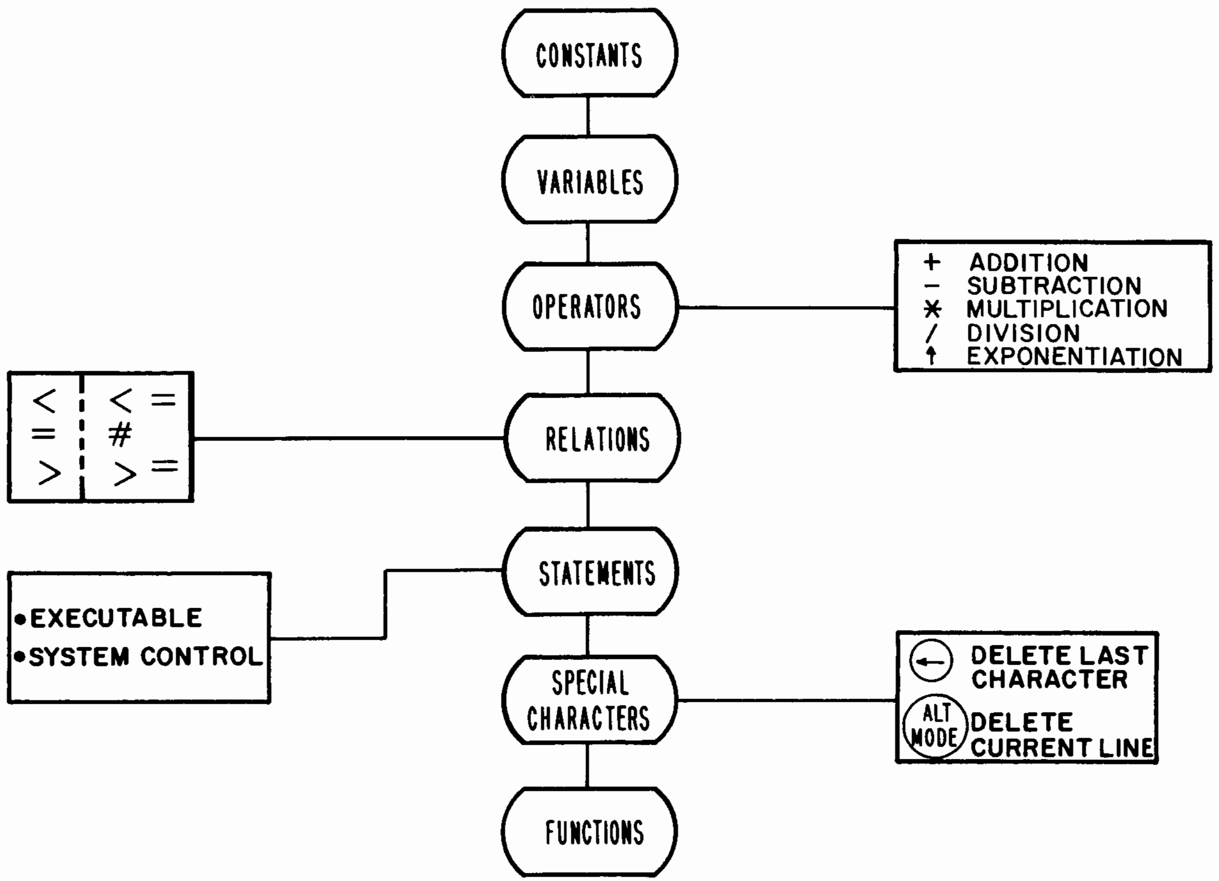
USING THE HP BASIC LANGUAGE

```
READY

1Ø   FOR N = 1 TO 7

2Ø   PRINT N, SQR (N)

31   NEXT N

43   PRINT "DONE"

5Ø   END
```

NOTE

1. CONVERSATIONAL MODE
2. EACH STATEMENT MUST HAVE A STATEMENT NUMBER WHICH IDENTIFIES ITS SEQUENCE WITHIN THE PROGRAM.
3. FREE FORM — SELF TEACHING
4. ALL STATEMENTS ARE TERMINATED BY (CR)
5. THE HIGHEST NUMBERED STATEMENT MUST BE AN END STATEMENT.

THE BASIC LANGUAGE COMPONENTS



CONSTANTS

VARIABLES

OPERATORS

RELATIONS

STATEMENTS

SPECIAL CHARACTERS

FUNCTIONS

+	ADDITION
−	SUBTRACTION
∗	MULTIPLICATION
/	DIVISION
↑	EXPONENTIATION

<	<=
=	#
>	>=

- EXECUTABLE
- SYSTEM CONTROL

←	DELETE LAST CHARACTER
ALT MODE	DELETE CURRENT LINE

STATEMENTS

EXECUTABLE

ARITHMETIC

- LET

CONTROL

- GO TO
- IF
- FOR
- NEXT
- END

INPUT / OUTPUT

- READ
- DATA
- PRINT
- INPUT

SYSTEM CONTROL

- LIST
- RUN
- SCRATCH
- STOP

FUNCTIONS

SIN (X)	SINE X
COS (X)	COSINE X
TAN (X)	TANGENT X
ATN (X)	ARCTANGENT X
EXP (X)	e^x
LOG (X)	Ln x
ABS (X)	Absolute value of x
SQR (X)	$\sqrt{x}$
INT (X)	INTeger part of x
SGN (X)	Sign of x

CONSTANTS

ALL NUMBERS ARE REPRESENTED IN THE COMPUTER IN FLOATING-POINT FORMAT. THE RANGE IS -10^{38} TO 10^{38}.

EXAMPLES: 3 , 5 , 7 , − 65

1.5, 14.7E-2, .45E7, 1ØØØ

VARIABLES

GENERAL FORM: $\alpha\,\lambda$

WHERE α MUST BE A LETTER (A-Z)
λ MUST BE A NUMERIC (0-9)

EXAMPLES: B2, K2, K6, R7, Z, F

LINE NUMBERS

$1 \leq \text{Line \#} \leq 9999$

STATEMENTS → **EXECUTABLE**

ARITHMETIC — the LET statement

GENERAL FORM: line # LET variable = formula

EXAMPLE:

```
152 LET X   =  12.Ø
3Ø1 LET A1  =   4 + 3 * X
451 LET Z   =  (TAN(X) ↑ A1)/88.98
```

INPUT-OUTPUT — the PRINT statement

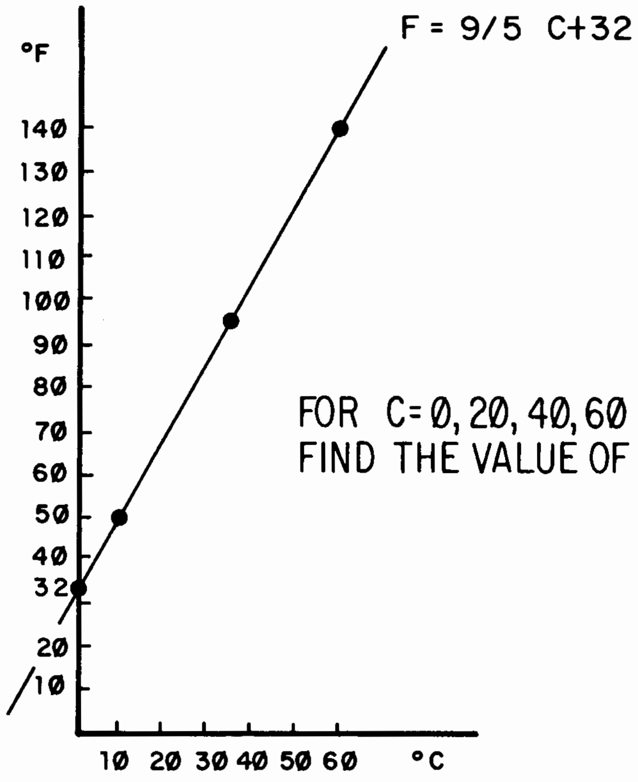
GENERAL FORM: line # PRINT variable / formula / message

EXAMPLE:

```
657 PRINT A1;X
737 PRINT TAN(X);(4*5) ↑ 2; A1
8Ø8 PRINT "START PROCESS", A1*COS(X), 367
```

EXAMPLE

CENTIGRADE TO FAHRENHEIT CONVERSION



FOR C=Ø,2Ø,4Ø,6Ø
FIND THE VALUE OF F

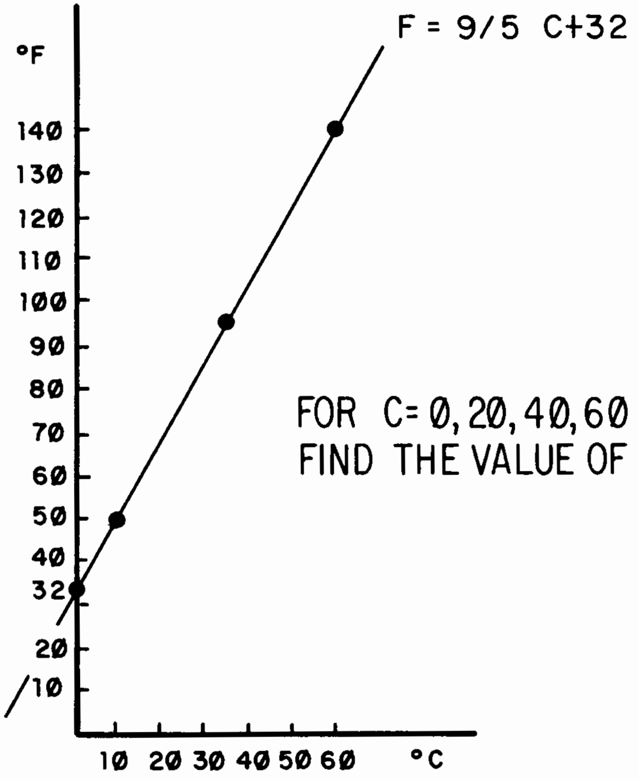
```
10   LET C = Ø
20   LET F = 9/5*C+32
30   PRINT "FOR C = "; C; "THEN F = "; F
35   LET C = 2Ø
40   LET F = (9/5)*C+32
45   PRINT "FOR C = "; C; "THEN F= "; F
 .          .
 .          .
 .          .
150  LET C = 6Ø
155  LET F= 9/5*C +32
160  PRINT "FOR C = "; C; "THEN F = ";
170  PRINT 9/5*C+32
                .
                .
                .
               ETC
```

THE GO TO STATEMENT

GENERAL FORM: line # GO TO line #

EXAMPLE: 1Ø1 GO TO 35

EXAMPLE:



FOR C=Ø,2Ø,4Ø,6Ø
FIND THE VALUE OF F

```
10   LET C = Ø
2Ø   LET F = 9/5*C + 32
3Ø   PRINT "FOR C ="; C; "THEN F ="; F
4Ø   LET C = C + 2Ø
5Ø   GO TO 2Ø
99   END
```

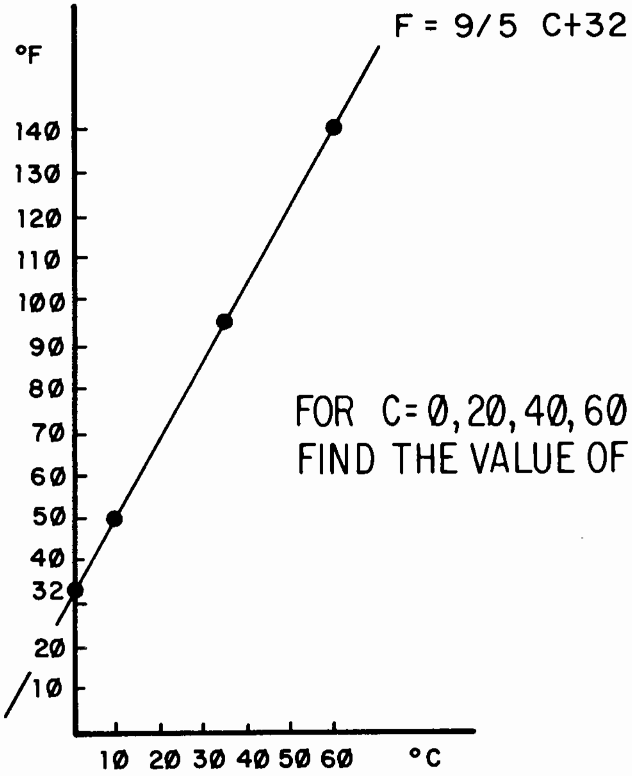
THE IF STATEMENT

GENERAL FORM: line # IF {formula} {relation} {formula} THEN {line #}

EXAMPLES:

```
1Ø IF  (A+B)*C  < T↑ 2 THEN 461
2Ø IF   K > 4.7 THEN 34
3Ø IF   X < = SQR(6932)  THEN 9Ø
```

EXAMPLE:



FOR C=Ø,2Ø,4Ø,6Ø
FIND THE VALUE OF F

```
1Ø  LET  C = Ø
2Ø  LET  F = 9/5*C + 32
3Ø  PRINT "FOR C = "; C; " THEN F = "; F
4Ø  LET C = C+2Ø
5Ø  IF  C < = 6Ø THEN 2Ø
6Ø  PRINT "THAT IS IT"
99  END
```

INPUT OUTPUT STATEMENTS

THE READ STATEMENT
THE DATA STATEMENT

GENERAL FORM:

```
line # READ {variable, variable, variable....}
line # DATA {value, value, value ...........}
```

EXAMPLE:

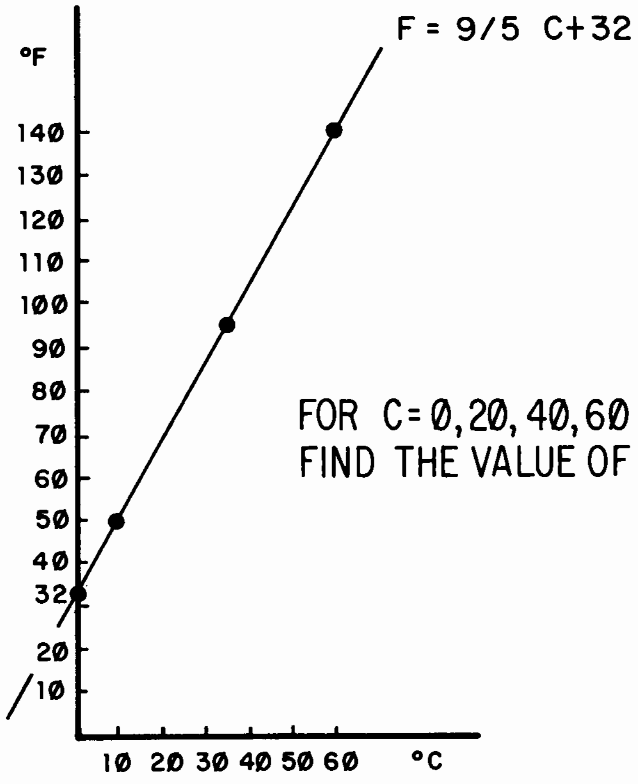
```
READ  A1,  A2,  A3,  A4,  A5 \
                              }
DATA  2,  13,  4,  8,  1.7E2 /
```

```
A1 = 2      A3 = 4
A2 = 13     A4 = 8
    A5 = 1.7E2
```

EXAMPLE:

```
READ  A1,  A2,  A3,  A4,  A5 \
DATA  2,  13,  4              }
DATA  8,  1.7E2              /
```

EXAMPLE



FOR C=Ø,2Ø,4Ø,6Ø
FIND THE VALUE OF F

```
1Ø   READ C1, C4, CØ
2Ø   DATA Ø, 6Ø, 2Ø
3Ø   LET C = C1
4Ø   LET F = C*9/5 + 32
5Ø   PRINT "FOR C ="; C; "THEN F ="; F
6Ø   LET C = C + CØ
7Ø   IF C < = C4 THEN 4Ø
99   END
```

THE INPUT STATEMENT

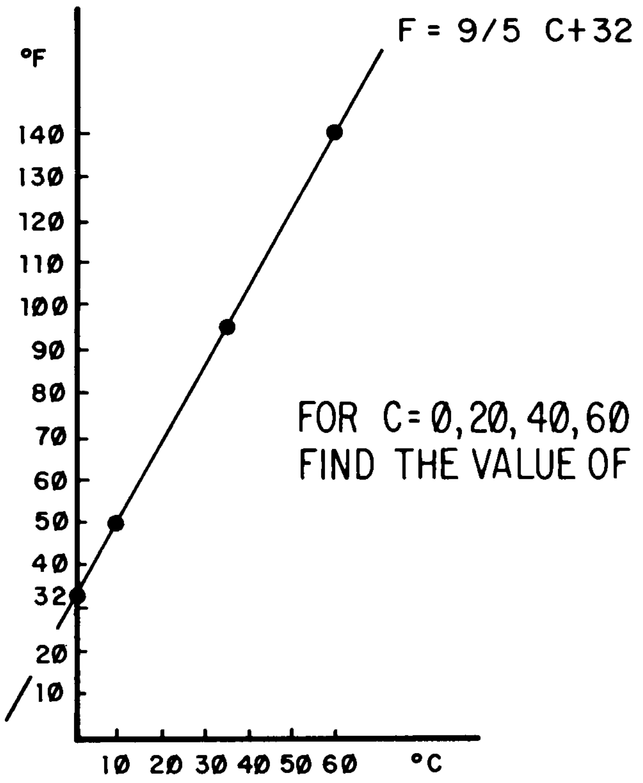
GENERAL FORM:

line # INPUT $\left\{ \text{variable} \right\}, \left\{ \text{variable} \right\}, \cdots \left\{ \text{variable} \right\}$

EXAMPLES:

```
35   INPUT  A1, A2, A3

56   INPUT  B1, B, C, X, A(3)
```

EXAMPLE



FOR C=0,20,40,60
FIND THE VALUE OF F

```
20    INPUT  C1,C4,CØ
30    LET C = C1
40    LET F = C*9/5 + 32
50    PRINT "FOR C ="; C; "THEN F ="; F
60    LET C = C + CØ
70    IF C < = C4 THEN 40
99    END
```

THE FOR AND NEXT STATEMENTS

GENERAL FORM:

```
line # FOR     {Variable} = {formula} TO {formula} STEP {formula}
line # NEXT      {Variable}
```

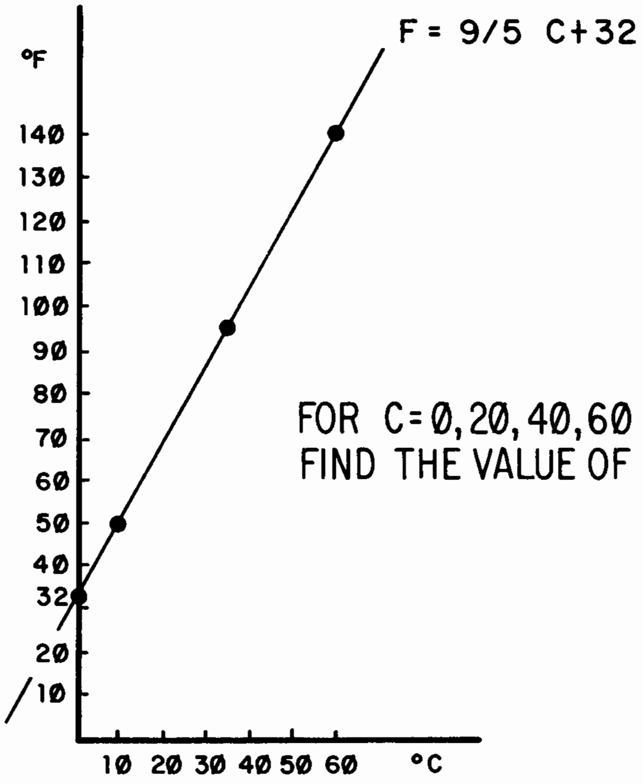
EXAMPLE:

```
753   FOR A3 = B+7  TO B+21  STEP 2

856   NEXT  A3
```

EXAMPLE:

```
333   FOR A7 = 3 TO 10 STEP 1

36Ø   LET A9 = A7 ↑ 2

37Ø   PRINT A7, A9

4ØØ   NEXT A7
```

EXAMPLE



FOR C=Ø,2Ø,4Ø,6Ø
FIND THE VALUE OF F

```
10   READ C1,  C4, CØ
2Ø   DATA Ø, 6Ø, 2Ø
3Ø   FOR C = C1  TO C4 STEP CØ
45   PRINT "FOR C ="; C; "THEN F =";
47   PRINT C*9/5 + 32
5Ø   NEXT C
6Ø   PRINT "FINISHED"
99   END
```

USING SUBROUTINES

THE GO SUB STATEMENT

GENERAL FORM: GO SUB line #

THE RETURN STATEMENT

GENERAL FORM: RETURN

EXAMPLE:

```
10   PRINT "READ FIRST SET OF VALUES"
20   GO SUB 666
30   PRINT "READ SECOND SET OF VALUES"
40   GO SUB 666
50   PRINT "READ THIRD SET OF VALUES"
55   GO SUB 666
6Ø   GO TO 777
666  INPUT A,B,C
676  IF A<=Ø THEN 777
686  IF B<=Ø THEN 777
696  IF C<=Ø THEN 777
7ØØ  RETURN
777  END
```

SYSTEM CONTROL STATEMENTS

LIST

▶ GENERAL FORM: LIST {line #}

EXAMPLE: LIST 30 LIST FROM STATEMENT 30 UNTIL THE END STATEMENT

EXAMPLE: LIST LIST THE ENTIRE PROGRAM

SCRATCH

▶ GENERAL FORM: SCRATCH
IT DELETES THE CURRENT PROGRAM IN MEMORY

RUN

▶ GENERAL FORM: RUN
IT STARTS EXECUTION OF THE PROGRAM

STOP

▶ GENERAL FORM: STOP
IT STOPS EXECUTION OF THE PROGRAM

HELPFUL HINTS

FREQUENTLY TYPING ERRORS TAKE PLACE AND CORRECTIONS ARE NEEDED, THEREFORE:

1. ALT MODE KEY DELETES CURRENT LINE

EXAMPLE

```
37 LET A-B+C\ ← TYPED BY BASIC TO INDICATE
                DELETION
```

2. ← DELETES THE PREVIOUS CHARACTER

EXAMPLE

```
42 FER ← ← OR X = 3 TO 7 STEP Ø.1

   (42 FOR X = 3 TO 7 STEP Ø.1)
```

3. TO DELETE A LINE, TYPE THE LINE # WITH CR

EXAMPLE

```
151 CR
```

DATA FORMATTING

(SPECIAL USE OF THE COMMA AND SEMI-COLON)

WHEN USING PRINT COMMANDS THE TELETYPE IS DIVIDED INTO 5 ZONES STARTING AT POSITIONS Ø, 15, 3Ø, 45, AND 6Ø.

COMMA-CONTROLS PRINT ZONES FROM POSITIONS Ø, 15, 3Ø, 45 AND 6Ø.

SEMI-COLON-INHIBITS ZONE SPACING.

EXAMPLES

1.

```
35 FOR X=4 TO 1Ø STEP 2
6Ø PRINT X, X + 1
7Ø NEXT X
```

2.

```
35 FOR X=4 TO 1Ø STEP 2
6Ø PRINT X, X + 1,
7Ø NEXT X
```

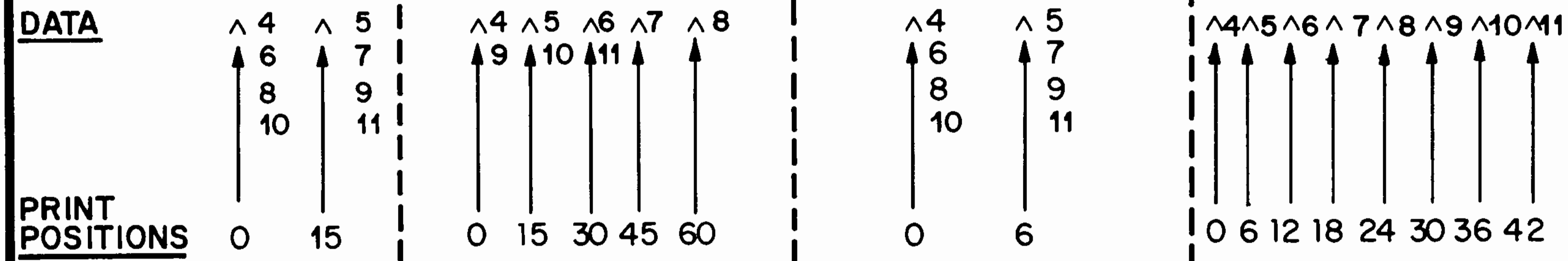
3.

```
35 FOR X=4 TO 1Ø STEP 2
4Ø PRINT X; X + 1
7Ø NEXT X
```

4.

```
35 FOR X=4 TO 1Ø STEP 2
4Ø PRINT X; X + 1;
7Ø NEXT X
```

OUTPUT RESULTS



NOTE: ^= space

THE TAB FEATURE

GENERAL FORM: TAB (POS #)

EXAMPLE: PRINT THE MESSAGE "THREE" BEGINNING IN POSITION 36 AND THE VALUE FOR 10+3 ↑ IN POSITION 48

```
17 PRINT TAB (36), "THREE", TAB(48), 10+3↑2

          THREE           ∧19
            ↑               ↑
         Position        Position
            36              48
```

ERROR DIAGNOSTICS

FORMAT: ERROR XX IN LINE NN

9 MISSING OR INCORRECT FUNCTIO

10 MISSING PARAMETER IN DEF STATEMENT.

11 MISSING ASSIGNMENT OPERATOR.

12 MISSING THEN.

13 MISSING OR INCORRECT FOR-VARIABLE.

14 MISSING TO.

15 INCORRECT STEP IN FOR STATEMENT.

16 CALLED ROUTINE DOES NOT EXIST.

17 WRONG NUMBER OF PARAMETERS IN CALL STATEMENT.

18 MISSING OR INCORRECT CONSTANT IN DATA STATEMENT.

19 MISSING OR INCORRECT VARIABLE IN READ STATEMENT.

20 NO CLOSING QUOTE FOR PRINT STRING.

21 MISSING PRINT DELIMITER OR BAD PRINT QUANTITY.

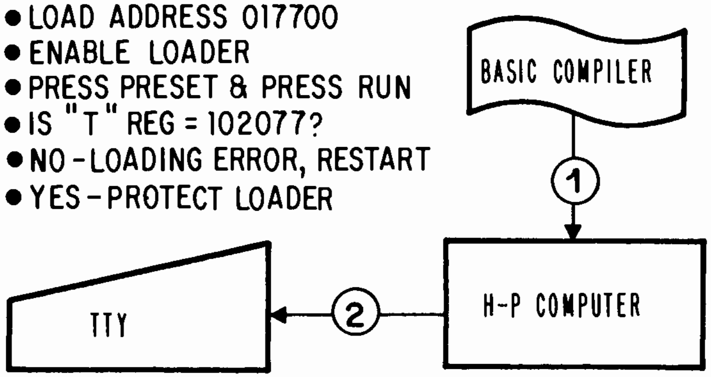
22 ILLEGAL WORD FOLLOWS MAT.

23 MISSING DELIMITER.

24 IMPROPER MATRIX FUNTION

SINGLE TERMINAL BASIC

LOADING INSTRUCTIONS



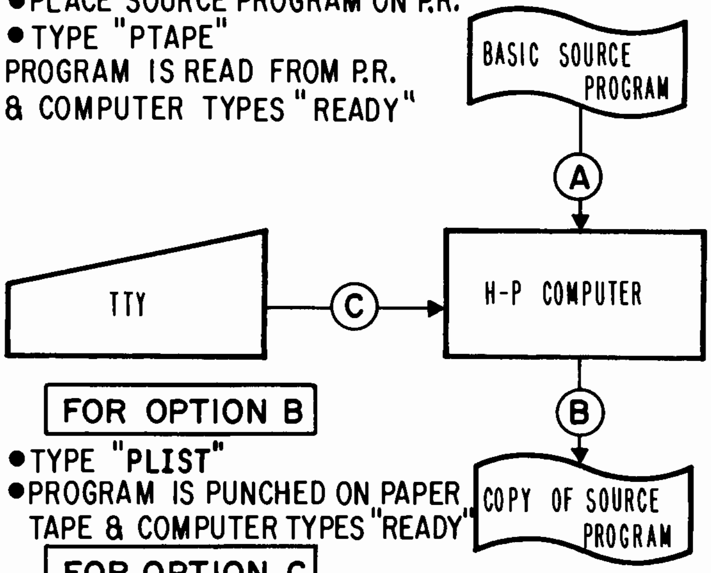
FOR 1

- LOAD ADDRESS 017700
- ENABLE LOADER
- PRESS PRESET & PRESS RUN
- IS "T" REG = 102077?
- NO-LOADING ERROR, RESTART
- YES-PROTECT LOADER

FOR 2

- LOAD ADDRESS 000100
- PRESS PRESET/ PRESS RUN
- "READY" ON TTY

EXECUTION OPTIONS



FOR OPTION A

- PLACE SOURCE PROGRAM ON P.R.
- TYPE "PTAPE"

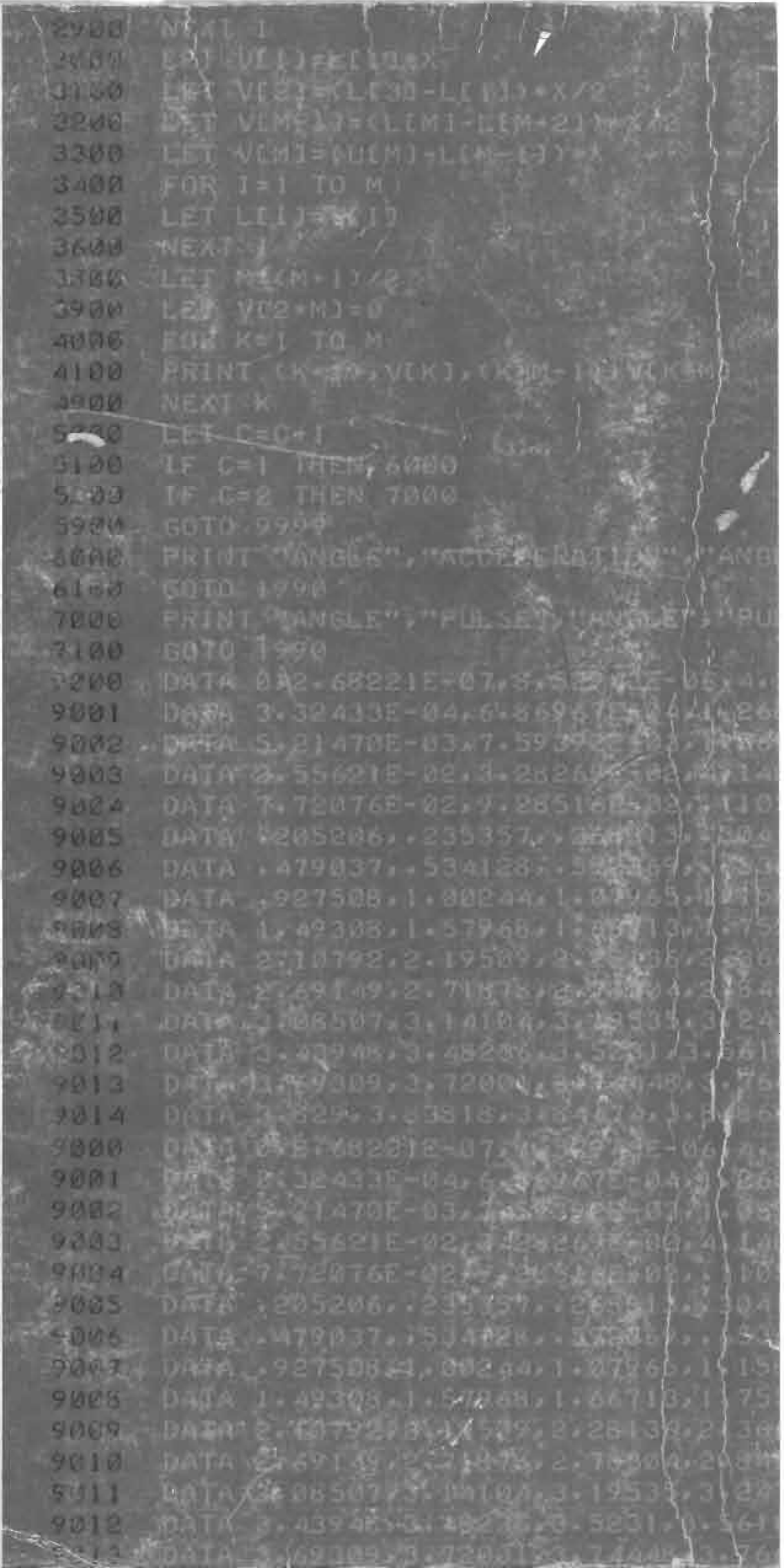
PROGRAM IS READ FROM P.R. & COMPUTER TYPES "READY"

FOR OPTION B

- TYPE "PLIST"
- PROGRAM IS PUNCHED ON PAPER TAPE & COMPUTER TYPES "READY"

FOR OPTION C

- PLACE SOURCE PROGRAM ON TTY RDR
- TYPE "TAPE"
- PROGRAM IS READ FROM TTY & COMPUTER TYPES "READY"



```
2900  NEXT I
3000  LET V[1]=L[1]*X
3100  LET V[2]=(L[3]-L[1])*X/2
3200  LET V[M+1]=(L[M]-L[M+2])*X/2
3300  LET V[M]=(U[M]-L[M-1])*X
3400  FOR I=1 TO M
3500  LET L[I]=K[I]
3600  NEXT I
3700  LET M=(M-1)/2
3900  LET V[2*M]=0
4000  FOR K=1 TO M
4100  PRINT (K-1)*M,V[K],(K+M-1)*V[K+M]
4900  NEXT K
5000  LET C=C+1
5100  IF C=1 THEN 6000
5200  IF C=2 THEN 7000
5900  GOTO 9999
6000  PRINT "ANGLE","ACCELERATION","ANG
6100  GOTO 1990
7000  PRINT "ANGLE","PULSE","ANGLE","PU
7100  GOTO 1990
9000  DATA 0,2.68221E-07,[illegible]E-05,
9001  DATA 3.32433E-04,6.86967E-04,[illegible]
9002  DATA 5.21470E-03,7.59[illegible]
9003  DATA 2.55621E-02,3.2826[illegible]
9004  DATA 7.72076E-02,9.28516E-02,.110
9005  DATA .205206,.235357,.26[illegible]
9006  DATA .479037,.534128,.5[illegible]
9007  DATA .927508,1.00244,1.07[illegible]
9008  DATA 1.49308,1.57968,1.66713,1.75
9009  DATA 2.10792,2.19509,2.[illegible]
9010  DATA 2.69149,2.71878,2.[illegible]
9011  DATA 3.08507,3.14104,3.19533,3.24
9012  DATA 3.43948,3.48286,3.5231,3.561
9013  DATA 3.69309,3.72001,3.74[illegible]
9014  DATA 3.829,3.83818,3.84[illegible]
9000  DATA 0,2.68221E-07,[illegible]E-06,
9001  DATA 3.32433E-04,6.[illegible]E-04,
9002  DATA 5.21470E-03,[illegible]
9003  DATA 2.55621E-02,[illegible]
9004  DATA 7.72076E-02,[illegible]
9005  DATA .205206,.235357,.26[illegible]
9006  DATA .479037,.534128,.[illegible]
9007  DATA .927508,1.00244,1.07265,1.15
9008  DATA 1.49308,1.57968,1.66713,1.75
9009  DATA 2.10792,2.19509,2.28138,2.36
9010  DATA 2.69149,2.71878,2.7[illegible]
9011  DATA 3.08507,3.14104,3.19533,3.24
9012  DATA 3.43948,3.48286,3.5231,3.561
9013  DATA 3.69309,3.72001,3.74[illegible]
```

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