# Ballistic Research Laboratories

## TECHNICAL NOTE NO. 141

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# Description and use of the Eniac Converter Code

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## ABERDEEN PROVING GROUND, MARYLAND

**Retyped from the 1949 original for [www.EniacInAction.com](www.EniacInAction.com).**
Original page numbering is preserved. The inclusion of five pages of errata, taken from the copy held in the Charles Babbage Institute (CBI 63, box 11) gives a sense of how many tweaks were made to ENIAC's configuration during this period. A revised 1951 version issued as W. B. Fritz, *BRL Memorandum Report No 582: Description of the ENIAC Converter Code*. That itself accumulated various revision, insertions, and errata over the years as ENIAC's configuration changed.

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

TECHNICAL NOTE No. 141

November 1949

# DESCRIPTION AND USE OF THE ENIAC CONVERTER CODE

A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

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# DESCRIPTION AND USE OF THE ENIAC CONVERTER CODE

## Section 1. – Introduction

The ENIAC is a high-speed, electronic, general purpose computing machine. At present it is controlled by a code which incorporates a unit called the Converter as a basic part of its operation, hence the name ENIAC Converter Code. These code digits are brought into the machine either through the Reader from standard IBM cards* or from the Function Tables, two digits at a time. The Converter then receives these digits, and initiates a sequence of operations, such that the particular order described here is carried out by the machine. The details of the programming of the particular orders, - or how the machine carries out the individual order – is published in a separate report (reference 4) and need not be considered here.

Included with the ENIAC is an IBM card Reader used as an input device and a Printer which punches on cards the numbers computed by the machine. Also available are the following items of IBM equipment:

1.) Key punch – Type 031
2.) Sorter – Type 075
3.) Tabulator – Type 405
4.) Reproducer – Type 513
5.) Interpreter – Type 552

This report attempts a complete description of what each order does and at least an introduction as to how to use the code.

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* The card control method of operation is used primarily for testing and the running of short highly iterative problems and is not discussed in this report.

## Section 2. – Listing of Symbols

| | |
|---|---|
| a, b, c, d, e, f, … | Single digits (2 such letters placed side by side as ab represent a 2-digit number, etc.) |
| α, β, ϒ, δ, ε, … | 2, 3, 4 or 6 digit numbers (used when single digit representation is not necessary |
| A, B, C, D, E, F, G, H, J, K | The signed numbers in the ten fields of the Constant Transmitter group. |
| U, V, W, X, Y, Z | 10-digit numbers in the accumulators |
| 1, 2, … 20 | Designation of the 20 ENIAC accumulators usually followed by a parenthesis to denote decades of the accumulator involved such as 6(3,2,1) to denote the 3 right-most places of accumulator 6. An 11 in the parenthesis is used to denote the PM. |
| Acc | Accumulator |
| A.V. or \| \| | Absolute value |
| A.T. | Add time (200 μ sec) |
| C.T. | Conditional transfer |
| D.S. | Drop sign |
| FTN | Function table numeric |
| L | Listen |
| M | Minus |
| M.P. | Master programmer |
| NaD | Next a digits |
| P | Plus |
| Pr | Print |
| Rd | Read |
| S.C. | Selective clear |
| SL | Shift left (followed by a digit to represent no. of places) |
| SR | Shift right (followed by a digit to represent no. of places) |
| T | talk |

## Section 3. – Description of the ENIAC Memory

There are essentially three types of memory: I – fixed, II – intermediate, and III – fluid.

I. The fixed or switch set memory consists of three function tables of 104 lines each, numbered from -2 through 101; and two lines of the constant transmitter designed JK. These lines are normally "fixed" throughout the operation of a problem, but occasional changes can be made between runs if necessary. The function table lines contain 12 digits each and 2 algebraic signs so arranged that two sides designed A and B, each contain a signed six digit number. The JK switches of the constant transmitter consist of 2 lines of 10 digits each with attached algebraic signs.

All of the 312 lines of the function tables can be used to store either numerical information, or code digits. When the line is used for code digits, these digits must start at the beginning of the line. When the line is used for numerical information, the digits are placed so as to be brought into the fluid memory in the most convenient form. Lines of code digits or numeric may be addressed with the following addresses:

| F.T. No. | ENIAC Address (000 – 599) | F.T. Line (-2 to 101) |
|---|---|---|
| I | 0 ab | ab – 2 |
| II | 1 ab | ab – 2 |
| III | 2 ab | ab – 2 |
| I | 3 ab | ab + 2 |
| II | 4 ab | ab + 2 |
| III | 5 ab | ab + 2 |

Figure – 1

It will be noted that except for the 4 lines at the beginning and at the end of each F.T., each line can be designated by either of two addresses.

II. The intermediate or relay set memory consists of eight of the constant transmitter groups, each of which contains 10 digits and an algebraic sign and designated A through H. The input cards are either prepared in advance using standard IBM equipment or produced by the machine. In the latter case, the values computed by the machine are punched on IBM cards in the Printer and the cards read back into the machine through the Reader. It might be mentioned that the access time of the numbers in the Constant Transmitter is the same as those in the accumulators (6 A.T.).

III. The fluid memory or electronic memory consists essentially of 20 accumulators numbered from 1 to 20. Each accumulator is designed to hold one signed 10-digit number. By judicious coding, two 5-digit numbers may be stored in each accumulator.

With the present code, only the following 12 accumulators can be used with no restrictions for fluid storage:

1, 2, 3, 4, 9, 10, 14, 16, 17, 18, 19, 20

The remaining 8 accumulators can be used as follows:*

Acc 5 receives the remainder following a square root or division order. Any previous number held there is lost. Acc 5 can be used for storage at any time when there is no intervening √ or ÷ .

Acc 6 is the control center of the code's operation. It is used as follows: 6(11,10,9) can be used as a signed two digit accumulator. 6(8,7) is used as a two digit accumulator. 6(6,5,4) is used to hold the new address to be used following the positive branch of a conditional transfer. 6(3,2,1) holds the current address, i.e., the designation of the line of the Function Table from which the code digits are being drawn.

Acc 7 is used as the denominator for division, but otherwise may be used for storage.

Acc 8(11-4) may be used for unrestricted storage. 8(3,2,1) is used as the FTN address. This address automatically advances by 1 at the completion of a FTN order. If there are no FTN orders, Acc 8 may be used for unrestricted storage.

Acc 11 is used primarily as the multiplier for multiplication, to receive the A side of the Function Table on FTN orders, and to receive one of the fields of the Constant Transmitter on those orders. It always clears before reception.

Acc 12 receives the multiplicand from Acc 15 following a multiply order. It is also cleared in the shift prime orders and receives the part of the number that is shifted off scale in Acc 15. It can be used for storage unless there is an intervening multiply or shift prime order.

Acc 13 adds into the product following a multiplication. It must be clear for many of the orders and should not ordinarily be used for storage.

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*These restrictions can be further clarified by referring to the definite orders involved.

Acc 15 is the arithmetic center of the code's operation and under no circumstances can it be considered a storage accumulator. It might be added however that 13 and 15 are the only true "accumulators", since they are the only accumulators which do not clear before reception.

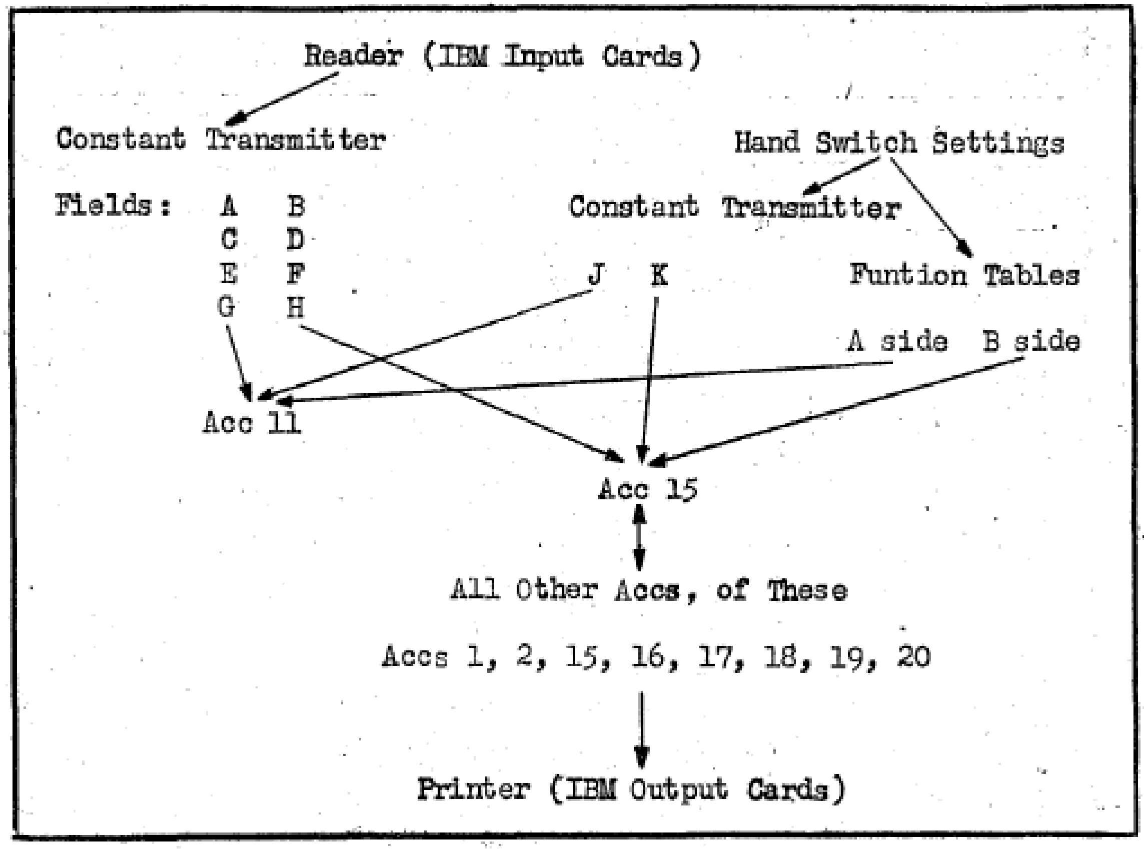


Figure 2: Transfer of numbers among the
components of the ENIAC using the Converter Code.

At this point, it would be well to describe the distinction between the ENIAC method of handling negative numbers and the way those same numbers are placed on IBM cards. For negative numbers the ENIAC stores the 10's complement; for example, -1234567890 is stored as M8765432110 in the ENIAC. The IBM card will be punched 123456780 with X's punched in the $1^{st}$ and $6^{th}$ columns of the field for this number. It is advisable to avoid one 10-digit field (in the Constant Transmitter or one of the accumulators) containing 2 distinct numbers if there is any possibility that one of the numbers is negative.

Section 4. – Listing of ENIAC Orders with Page Number of Description

| Code | Order | Page | Code | Order | Page | Code | Order | Page | Code | Order | Page |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | H | 19 | 25 | 5T | 13 | 50 | AB | 8 | 75 | N3D8 | 18 |
| 01 | 1L | 9 | 26 | 6T | 13 | 51 | CD | 8 | 76 | S’L3 | 13 |
| 02 | 2L | 9 | 27 | 7T | 13 | 52 | SR5 | 12 | 77 | S’L2 | 13 |
| 03 | 3L | 9 | 28 | 8T | 13 | 53 | SR4 | 12 | 78 | 6R3 | 16 |
| 04 | 4L | 9 | 29 | 9T | 13 | 54 | EF | 8 | 79 | 6R6 | 17 |
| 05 | 5L | 9 | 30 | 10T | 13 | 55 | GH | 8 | 80 | SL5 | 12 |
| 06 | 6L | 10 | 31 | 11T | 13 | 56 | JK | 8 | 81 | SL4 | 12 |
| 07 | 7L | 9 | 32 | SR1 | 12 | 57 | X | 14 | 82 | A.V. | 15 |
| 08 | 8L | 9 | 33 | 13T | 14 | 58 | S”R5 | 12 | 83 | N3D6 | 16 |
| 09 | 9L | 9 | 34 | 14T | 13 | 59 | S’R4 | 12 | 84 | N6D6 | 16 |
| 10 | 10L | 9 | 35 | H | 19 | 60 | SL1 | 12 | 85 | | |
| 11 | 11L | 9 | 36 | 16T | 13 | 61 | | | 86 | S’L5 | 13 |
| 12 | 12L | 9 | 37 | 17T | 13 | 62 | 12T | 13 | 87 | S’L4 | 13 |
| 13 | 13L | 10 | 38 | S’R1 | 12 | 63 | ÷ | 14 | 88 | | |
| 14 | 14L | 9 | 39 | 19T | 13 | 64 | √ | 15 | 89 | | |
| 15 | 0L | 10 | 40 | 20T | 13 | 65 | | | 90 | D | 19 |
| 16 | 16L | 9 | 41 | M | 14 | 66 | S’L1 | 13 | 91 | S.C. | 11 |
| 17 | 17L | 9 | 42 | SR3 | 12 | 67 | | | 92 | 6(11,10,9) | 10 |
| 18 | 18L | 9 | 43 | SR2 | 12 | 68 | 18T | 13 | 93 | 6(8,7) | 11 |
| 19 | 19L | 9 | 44 | Rd | 8 | 69 | C.T. | 17 | 94 | i | 17 |
| 20 | 20L | 9 | 45 | Pr | 11 | 70 | SL3 | 12 | 95 | di | 18 |
| 21 | 1T | 13 | 46 | D.S. | 15 | 71 | SL2 | 12 | 96 | cdi | 18 |
| 22 | 2T | 13 | 47 | FTN | 9 | 72 | N2D | 8 | 97 | | |
| 23 | 3T | 13 | 48 | S’R3 | 12 | 73 | N4D | 8 | 98 | | |
| 24 | 4T | 13 | 49 | S’R2 | 12 | 74 | N6D | 8 | 99 | D | 19 |

## Section 5. – Classification of ENIAC Converter Code Orders

I Numeric and Storage Orders

- A. Read Order (Rd)
- B. Constant Transmitter Orders (AB, CD, EF, GH, JK)
- C. Next Digit Orders (N2D, N4D, N6D)
- D. Function Table Numerics Order (FTN)
- E. Listen Orders (∝ L, 6L, 13L)
- F. 15 clear (cl)
- G. 6(11,10,9), 6(8,7)
- H. Selective Clear (S.C.)
- I. Print Order (Pr)

II Shift and Shift Prime Orders

- A. SR 1-5, SL 1-5
- B. S’R 1-5, S’L 1-5

III Arithmetic Orders

- A. Add or Talk Orders (+ or T)
- B. Minus (- or M)
- C. Multiply (x)
- D. Divide (÷)
- E. Square Root (√)
- F. Absolute Value (A.V.)
- G. Drop Sign (D.S.)

IV Control Orders

- A. Unconditional Transfers (N3D6, N6D6, 6R3, 6R6)
- B. Conditional Transfers (C.T.)
- C. Count Orders (I, di, cdi)
- D. FTN Address Order (N3D8)
- E. Delays (D)
- F. Stops (H)

Section 6. – Description of the Converter Code

I <u>Numerics and Storage Orders</u>

These orders are used (a) to get numbers into the machine and (b) to place numbers computed by the machine in temporary or permanent storage.

| Order and | Description | Contents of Affected Accs<br>Acc | Before | After | A.T. |
|---|---|---|---|---|---|
| | A. Read Order | | | | |
| Rd 44 | 1) Takes the eight 10-digit signed numbers from the next standard 80 column IBM card in the Reader and places these numbers in the relays of the intermediate storage unit known as the Constant Transmitter.<br>2) These input cards which are read into the ENIAC are either hand punched or outputs of previous ENIAC runs which contain values to be read back into the machine for further computation.<br>3) Recall the distinction between ENIAC numbers and IBM numbers explained on page 5. | | | | 3000 |
| | B. Constant Transmitter Orders | | | | |
| AB 50 | 1) Clears accumulator 11. | 11 | X | A | 6 |
| | 2) The Constant Transmitter field designated by the first letter of the order symbol goes to | 15 | Y | Y + b | |
| CD 51 | Acc 11 and the field designated by the | 11 | X | C | 6 |
| | second letter to Acc 15 adding to any quantity already there. | 15 | Y | Y + D | |
| EF 54 | 3) The Constant Transmitter fields retain | 11 | X | E | 6 |
| | their numbers which may be used any number of times | 15 | Y | Y + F | |
| GH 55 | 4) The numbers in the Constant Transmitter | 11 | X | G | 6 |
| | relays may be changed only by reading a new card. | 15 | Y | Y + H | |
| JK 56 | 5) The 10's complement, or the ENIAC | 11 | X | J | 6 |
| | number, is placed in JK if the number to be stored is negative. | 15 | Y | Y + K | |
| | C. Next Digit Orders | | | | |
| N2D 72ab | 1) Sends next 2, 4, or 6 digits from the FT to Acc 15. | 15 | X | X + ab | 15 |
| N4D 73abcd | 2) These digits add to 15 at the right hand side to 15(2,1), 15(4-1), and 15(6-1) respectively | 15 | X | X+abcd | 21 |
| N6D 74abcdef | 3) Occupies 2, 6, or 4 order positions respectively | 13 | 0 | 0 | |
| | 4) Acc 13 must be clear. | | | | |

| | | Contents of Affected Accs | | | |
|---|---|---|---|---|---|
| Order and | Description | Acc | Before | After | A.T. |
| | D. Function Table Numerics Order | | | | |
| FTN 47 | 1) Clears Acc 11. | 11(11-5) | ∝ | B | 13 |
| | 2) F.T. transmits 12 digits and 2 signs from the F.T. line specified by the address in Acc 8(3,2,1). | 15(11-5) | ϒ | ϒ + δ | |
| | 3) Acc 11(11-15) receives the sign and 6 digits (β) from the A side and Acc 15(11-5) receives the sign and 6 digits (δ) from the B side of the F.T. | 8(3-1) | ε | ε + 1 | |
| | 4) The address in Acc 8(3,2,1) is automatically advanced by 1. | | | | |
| | 5) To bring in a 10 digit numeric from the 12 digit positions on the F.T., it is usual to store the number with 2 zeros in the $5^{th}$ and $6^{th}$ places of the A side number: abcd00efghij. The following sequence of orders will place the 10 digit number in Acc 15: FTN, SR4, 11T. | | | | |
| | 6) The ENIAC number is placed in the F.T., in other words, negative numbers are stored as M with the 10's complement. (see order on FTN Address on page 18) | | | | |
| | E. Listen Orders | | | | |
| | 1. Regular Listen Orders (Acc ∝ ≠ 6, 13, 15) | 15 | X | 0 | 6 |
| 1L 01 | 1) Clears Acc ∝ (∝ ≠ 6, 13, or 15) | ∝ | Y | X | |
| 2L 02 | 2) Acc ∝ receives the number from Acc 15 | | | | |
| 3L 03 | 3) Acc 15 clears after transmission. | | | | |
| 4L 04 | 4) 6L and 13L are described separately below, since somewhat special conditions apply in each case. | | | | |
| 5L 05 | | | | | |
| 7L 07 | | | | | |
| 8L 08 | | | | | |
| 9L 09 | | | | | |
| 10L 10 | | | | | |
| 11L 11 | | | | | |
| 12L 12 | | | | | |
| 14L 14 | | | | | |
| 16L 16 | | | | | |
| 17L 17 | | | | | |
| 18L 18 | | | | | |
| 19L 19 | | | | | |
| 20L 20 | | | | | |

| Order and | Description | Contents of Affected Accs Acc | Before | After | A.T. |
|---|---|---|---|---|---|
| | 2. Acc 6 Listen | | | | 9 |
| 6L 06 | 1) This order is the same as the listen orders described above, except that the Right 3 digits of Acc 15 become the new address. | 6 | Y | X + Y | |
| | 2) The order following 6L will be the first order of the line now specified in 6(3,2,1). | | | | |
| | 3) This order thus serves 2 purposes:<br>a) places numbers in Acc 6(11-4)<br>b) serves as an unconditional transfer where the new address may be computed by the machine. See page 16 | 15 | X | 0 | |
| | 3. Acc 13 Listen | 13 | Y | X + Y | 6 |
| 13L 13 | 1) Acc 13 receives the number from Acc 15 Without first clearing. | 15 | X | 0 | |
| | 2) Acc 15 clears after transmission. | | | | |
| | F. Acc 15 clears | | | | |
| CL 15 | 1) Clears Acc 15. | 15 | X | 0 | 6 |
| | 2) To clear any Acc:<br>a) first clear 15<br>b) give the appropriate listen order | | | | |
| | G. 6(11,10,9) and 6(8,7) | | | | |
| | 1. 6(11,10,9) | 6(11-9 | $\alpha$ | $\alpha + \delta$ | 10 |
| 6(11,10,9) 92 | 1) The number in 15(11,2,1) adds to the number in 6(11,10,9) and the 6(8-1) sum | 6(8-1) | $\beta$ | B | |
| | goes to both 6(11,10,9) and 15(11,2,1). | 15(11 3) | + ϒ | 0 | |
| | 2) To clear 6(11,10,9) without disturbing the remainder of Acc 6 we must use the following sequence of orders: CL, | | - ϒ | | 9's |
| | (6,11,10,9), M, 6(11,10,9). | 15(11,2,1) | $\delta$ | $\alpha + \delta$ | |
| | | *13 | 0 | 0 | |

*Many of the orders require that Acc 13 be empty. This is indicated by showing that it contains 0 before and after the order.

| | | | | | |
|---|---|---|---|---|---|
| 6(8,7) 93 | 2. 6(8,7)<br>1) The number in 15(2,1) is added to the number in 6(8,7) and the sum goes to both 6(8,7) and 15(2,1). | 6(11,10,9)* | α | α | 10 |
| | 2) This order may be used only 6(6-1) when | 6(8,7) | β | B + δ | |
| | 2 digits are brought directly into 15(2,1). | 6(6-1) | ϒ | ϒ | |
| | This 2 digit number may be made minus before the order is used provided we wish | 15(11-3) | P0000000 | 0 | |
| | to subtract from a quantity already | | M9999999 | 0 | |
| | contained in 6(8,7). 6(8,7) can never be | 15(2-1) | δ | B + δ | |
| | made to store a negative. | 13 | 0 | 0 | |
| | H. <u>Selective Clear</u> | | | | |
| S.C. 91 | 1) Clears all accumulators except 6(3,2,1) | α ≠ 6(3,2,1) | X | 0 | 7 |
| | I. <u>Print Order</u> | | | | |
| Pr 45 | 1) Punches on an IBM card the contents of Acc 1, 2, 15, 16, 17, 18, 19, 20.<br>2) If any of these Accs contain numbers that are unimportant, it is not necessary to list these fields when tabulating.<br>3) Recall again the distinction between the form of the ENIAC and IBM numbers. | 1,2,15-20 | X | X | 3000 |

II <u>Shift and Shift Prime Orders</u>

These orders are used: (a) to line up the numbers so that as many significant digits as required can be saved, (b) to keep decimal points set correctly for arithmetical operations, and (c) to separate 10 digit numbers into appropriate parts.

Shift orders can be interpreted in at least two different ways. First the decimal point can be regarded as being fixed so that the accumulator contains a number less than 1, multiplied by an appropriate power of 10. In this case the shift orders can be interpreted as multiplying the number by a power of 10 according to the following table:

---

*It should be added that if a number exists in 15(4,3) it will be added to 6(11, 10, 9). Thus we may control two induction variables stored in 6(11, 10, 9) and 6(8, 7) with this one order.

| | | | |
|---|---|---|---|
| SR1 | X $10^{-1}$ | SL1 | X $10^{1}$ |
| SR2 | X $10^{-2}$ | SL2 | X $10^{2}$ |
| SR3 | X $10^{-3}$ | SL3 | X $10^{3}$ |
| SR4 | X $10^{-4}$ | SL4 | X $10^{4}$ |
| SR5 | X $10^{-5}$ | SL5 | X $10^{5}$ |

Secondly, if the decimal point is not regarded as fixed, but having any position you wish to give it without using powers of 10, (except in the case where negative powers are necessary) the shift order may be regarded as a physical movement of the number to the right or left carrying the decimal point with it.

In the shift orders the digits shifted out of 15 are lost. In the shift prime orders these digits are saved and are stored in 12.

| Order & Description | | | Contents of Affected Accs Acc | Before | After | A.T. |
|---|---|---|---|---|---|---|
| | | A. Shift Orders | | | | |
| SR1 | 32 | 1) Shift the digits in Acc 15 to the | 15 | abcdefghij | 0abcdefghi | 9 |
| SR2 | 43 | right or left the number of places | 15 | " | 00abcdefgh | |
| SR3 | 42 | indicated by the order symbol. | 15 | " | 000abcdefg | |
| SR4 | 53 | 2) When negative numbers are | 15 | " | 0000abcdef | |
| SR5 | 52 | shifted n places to the right 9's | 15 | " | 00000abcde | |
| SL1 | 60 | appear in the left n places of Acc 15. | 15 | " | bcdefghij0 | |
| SL2 | 71 | 3) In all other cases the decades | 15 | " | cedfghij00 | |
| SL3 | 70 | vacated by numbers as a result of | 15 | " | defghij000 | |
| SL4 | 81 | the shift are replaced by zeros. | 15 | " | efghij0000 | |
| SL5 | 80 | | 15 | " | fghij00000 | |
| | | | 13 | 0 | 0 | |
| | | B. Shift Prime Orders | | | | |
| S'R1 | 38 | 1) Shifts the number in Acc 15 the | 15 | abcedfghij | 0abcedfghi | 9 |
| | | the number of places to the right | 12 | X | j000000000 | |
| S'R2 | 49 | or left as indicated in the order | 15 | abcedfghij | 00abcdefgh | |
| | | symbol. | 12 | X | ij00000000 | |
| S'R3 | 48 | 2) Takes the original number in Acc | 15 | abcdefghij | 000abcdefg | |
| | | 15, shifts it (10-the number of | 12 | X | hij0000000 | |
| S'R4 | 59 | places indicated in the order | 15 | abcedfghij | 0000abcdef | |
| | | Symbol) in the opposite direction | 12 | X | ghij000000 | |
| S'R5 | 58 | and places it in Acc. 12. | 15 | abcdefghij | 00000abcde | |
| | | 3) The original number in Acc 12 | 12 | X | fghij00000 | |
| | | will be lost. | 15 | abcdefghij | bcdefghij0 | |

| | | | | | |
|---|---|---|---|---|---|
| S'L1 | 66 | 4) We thus split our 10 digit numbers in any manner we like. | 12 | X | 000000000a |
| S'L2 | 77 | 5) The sign of the number stored in | 15 | abcdefghij | bcdefghij0 |
| | | Acc 15 before this order is given is | 12 | X | 000000000a |
| S'L3 | 76 | preserved with the numbers that | 15 | abcdefghij | cdefghij00 |
| | | result from this order in Acc 12 and | 12 | X | 00000000ab |
| S'L4 | 87 | 15. | 15 | abcdefghij | defghij000 |
| | | | 12 | X | 0000000abc |
| S'L5 | 86 | | 15 | abcdefghij | efghij0000 |
| | | | 12 | X | 000000abcd |
| | | | 15 | abcdefghij | fghij00000 |
| | | | 12 | X | 00000abcde |
| | | | 13 | 0 | 0 |

III <u>Arithmetic Orders</u>

These orders are used to carry out the ordinary arithmetical operations. Often shift orders are necessary to properly place decimal points and transfer orders to correctly position numbers.

Order & Description

| | | | | | | |
|---|---|---|---|---|---|---|
| | | A. <u>Add or Talk Orders</u> | | | | |
| 1T | 21 | 1. <u>Acc α Talk (α≠13)</u> | α | X | X | 6 |
| 2T | 22 | 1) The number in Acc α (α≠13) is added | 15 | Y | X + Y | 6 |
| 3T | 23 | to the number in Acc 15 and the sum is | | | | 6 |
| 4T | 24 | held in 15. | | | | 6 |
| 5T | 25 | | | | | 6 |
| 6T | 26 | | | | | 8 |
| 7T | 27 | | | | | 6 |
| 8T | 28 | | | | | 7 |
| 9T | 29 | | | | | 6 |
| 10T | 30 | | | | | 6 |
| 11T | 31 | | | | | 6 |
| 12T | 62 | | | | | 6 |
| 14T | 34 | | | | | 6 |
| 16T | 36 | | | | | 6 |
| 17T | 37 | | | | | 6 |
| 18T | 68 | | | | | 6 |
| 19T | 39 | | | | | 6 |
| 20T | 40 | | | | | 6 |

| Order & Description | | | Contents of Affected Accs | | | |
|---|---|---|---|---|---|---|
| | | | Acc | Before | After | A.T. |
| 13T | 33 | 2. <u>Acc 13 Talk</u> | 13 | X | 0 | 6 |
| | | 1) The number in Acc 13 is added to the | | | | |
| | | number in Acc 15 and the sum is held in 15. | 15 | Y | X + Y | |
| | | 2) Acc 13 clears after transmission. | | | | |
| | | B. <u>Subtract or Minus Order</u> | | | | |
| M | 41 | 1) Changes the sign and forms the 10's | 15 | -X | +X | 8 |
| | | complement of the number in Acc 15. | 15 | +X | -X | |
| | | 2) By using the talk and listen orders in | | | | |
| | | combination with this minus order, subtraction | 13 | 0 | 0 | |
| | | can be carried out. | | | | |
| | | C. <u>Multiplication Order</u> | | | | |
| X | 57 | 1) Before this order is used the multiplier must | 11 | X | X | |
| | | be placed in 11 and the multiplicand in 15. | | | | |
| | | 2) The multiplicand goes from Acc 15 to Acc 12. | 12 | Y | W | 20 |
| | | 3) Acc 11 times Acc 15 plus Acc 13 goes to Acc | | | | |
| | | 15. | 13 | Z | 0 | |
| | | 4) Decimal points are additive, in other words if | | | | |
| | | the decimal point of the multiplier is m places | 15 | W | XW + Z | |
| | | from the left and that of the multiplicand n | | | | |
| | | places from the left, then the decimal point | | | | |
| | | of the product is m + n places from the left. | | | | |
| | | 5) Acc 13 if not clear must contain a number | | | | |
| | | where the decimal point is m + n places from | | | | |
| | | the left. | | | | |
| | | 6) All sign combinations are handled | | | | |
| | | automatically. | | | | |
| | | D. <u>Division Order:</u> | | | | |
| ÷ | 63 | 1) Before this order is used the denominator | 5 | X | Remainder | About |
| | | must be placed in Acc 7 and the numerator in | | | | 75* |
| | | Acc 15. | 7 | Y | Y | |
| | | 2) The quotient Acc 15/Acc 7 goes to Acc 15. | | | | |
| | | 3) If the decimal point of the numerator is n | 15 | Z | Z/Y | |
| | | places from the left and that of the | | | | |
| | | denominator d from the left, the decimal point | 13 | O | 0 | |
| | | of the quotient is n – d + 2 places from the left. | | | | |
| | | 4) The four combinations of signs are handled | | | | |
| | | automatically. | | | | |
| | | 5) Division by 0 will cause the machine to cycle | | | | |
| | | and operations cannot proceed further. | | | | |

6) The manner in which the divider unit works requires that there always be a zero in decade 10 of Acc 7.

7) In general $|Z| < 10^{n-d+2}\,|Y|$ or if n = d (in particular n = d = 0) then $|Z| < 100\,|Y|$

8) If the denominator is stored as a function in the F.T. of the J.A. switches it should be replaced by the reciprocal and ÷ replaced by x since ÷ is a much longer operation than x.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | E. <u>Square Root Order</u> | | | | |
| √ | 64 | 1) The number whose square root is to be extracted is placed in Acc 15 prior to giving this order. | 5 | X | Remainder | About 75* |
| | | 2) This number must be less than 2499999999. | 15 | Y | $\sqrt{Y}$ | |
| | | 3) If the decimal point of the radicand (Y) is at the far left, the decimal point of the square root is at the far left. 4) If the decimal point of the radicand is 2d places from the left, the decimal point of the root ( $\sqrt{Y}$) is d places from the left. 5) Because of round off, the ENIAC gets 0000000010 as the square root of 0000000000. 6) If the number in 15 is negative the machine will treat it as zero. | 13 | 0 | 0 | |
| A.V. | 82 | F. <u>Absolute Value</u> | 15 | +X | X | 10 |
| | | 1) Takes the absolute value of the number in Acc 15. | 15 | -X | \|X\| | |
| D.S. | 46 | G. <u>Drop Sign</u> 1) Drops the sign of the number in Acc 15. | 15 | +X | +X | 7 |
| | | 2) Only the PM decade is affected. | 15 | -X | $10^d(1-X)$ | |
| | | 3) This order is used (a) to insure the sign of a number, (b) for the storage of 2 numbers in an Acc, and (c) as a special device for computing $10^d(1-X)$ where the decimal point of X is d places from the left. The sequence of orders to accomplish this is + X to 15, M,D.S. | 13 | 0 | 0 | |

*Depending on the size of the numbers involved.

IV Control Orders

The control orders enable the coder to transfer the control of the ENIAC from one address to another either directly (unconditional transfer) or after investigating the sign of a number (conditional transfer). The Conditional Transfer order gives the ENIAC its power, since most computations involve more or less simple inductions which in turn depend upon decisions based on the sign of a number. This order enables the ENIAC to perform iterative processes, such as stepwise integrations and successive approximations.

| Order & Description | | | Contents of Affected Accs | | | |
|---|---|---|---|---|---|---|
| | | | Acc | Before | After | A.T |
| | | A. Unconditional Transfers | | | | |
| | | 1. Next 3 digits to Acc 6 | 6(11-4) | α | α + a | 21 |
| N3D6 | 83 | 1) Transfers control to the line of coding specified in | | | | |
| | | the second, third and fourth digits following the 83. | 6(3,2,1) | ghi | bcd | |
| | ab | 2) The first digit should be 0. | | | | |
| | | 3) Accumulator 6(3,2,1) is cleared and address bcd is | 13 | 0 | 0 | |
| | cd | sent to 6(3,2,1) | | | | |
| | | 4) In case this first digit is not zero, it is added into 6(4) and will alter the alternate address stored in 6(6,5,4). | | | | |
| | | 2. Next 6 digits to Acc 6 | 6(11-7) | α | α | 27 |
| N6D6 | 84 | 1) Transfers control of the machine to the first order | | | | |
| | | of the line of coding specified by def. | 6(6-4) | β | abc | |
| | ab | 2) A Conditional Transfer address abc is sent to | | | | |
| | | 6(6,5,4). | 6(3-1) | γ | def | |
| | cd | 3) Accumulator 6(6-1) is cleared and abcdef is sent | | | | |
| | | to 6(6-1). | 13 | 0 | 0 | |
| | ef | Both N3D6 and N6D6 must be the final order of the line used since control is immediately transferred to another line. Occasionally in N6D6, def is the address for the next line and the order is used only to insert a C.T. address. | | | | |
| | | 3. Right 3 digits of 15 to 6(3-1) | 6(11-4) | α | α | 13 |
| 6R3 | 78 | 1) Clears 6(3,2,1). | | | | |
| | | 2) 15(3,2,1) transmits clear to 6(3,2,1). | 6(3-1) | β | δ | |
| | | 3) This must be the last order of the line used, since | | | | |
| | | the next order will be the first one of the line now | 15(11-4) | γ | 0 | |
| | | specified in 6(3,2,1). | | | | |
| | | 4) Any other digits in 15(11-4) are lost in the process | 15(3-1) | δ | 0 | |
| | | and 15 is clear at the completion of the order. | | | | |
| | | | 13 | 0 | 0 | |

| Order & Description | | | Contents of Affected Accs Acc | Before | After | A.T |
|---|---|---|---|---|---|---|
| | | 4. Right 6 digits of 15 to 6(6-1) | 6(11-7) | α | α | 13 |
| 6R6 | 79 | 1 Clears 6(6-1). | | | | |
| | | 2) 15(6-1) transmits clear to 6(6-1). | 6(6-1) | B | δ | |
| | | 3) This must be the last order of the line used, since the next order will be the first one of the line now specified in 6(3,2,1). | 15(11-7) | ϒ | 0 | |
| | | 4) Any other digits in 15(11-7) are lost in the process and 15 is clear at the completion of the order. | 15(6-1) | δ | 0 | |
| | | 6R3 and 6R6 are used as unconditional transfers when the addresses are computed in the problem or when they are read from cards. They are special cases of 6L set up so that 6(11,10,9) and 6(8,7) are not destroyed. 6L is also an unconditional transfer order. It has already been described on page 10. | 13 | 0 | 0 | |
| | | B. Conditional Transfer | | | | |
| C.T. | 69 | 1) Examines the sign of the number in Acc 15. | 15 | X | 0 | |
| | | 2) If the sign is minus continues with the next order | 6(11-7) | α | α | |
| | | of the line specified by 6(3,2,1). | 6(6,5,4) | β | β | 7 |
| | | 3) If the sign is plus (zero is plus) transfers 6(6,5,4) to 6(3,2,1) and continue with the first order of the line | 6(3,2,1) | ϒ | ϒ | |
| | | now specified by 6(3,2,1). | 6(6,5,4) | β | 0 | 14 |
| | | 4) Acc 15 is cleared. | 6(3,2,1) | ϒ | β | |
| | | This order is frequently used in conjunction with the variable remote connection in which a sequence is required a number of times at various points during a problem. The address to which we want to return is placed in 6(6,5,4) before entering the sequence. A C.T. on a cleared Acc 15 at the end of the sequence will return control to the required address. Similarly these variable remote connection addresses may be stored in other memory positions of the ENIAC brought into 15 and then transferred to 6 by means of a 6R3 or a 6R6. | 13 | 0 | 0 | |
| i | 94 | C. Count Orders | | | | |
| | | 1. i | 15 | X | 0 | |
| | | 1) This order enables the coder to perform in succession a series of not more than three distinct iterative processes where the induction variable “counts” are pre-set on the switches of the Master Programmer unit (reference 1). | | | | |

| Order & Description | | | Contents of Affected Accs<br>Acc | Before | After | A.T |
|---|---|---|---|---|---|---|
| | | 2) i serves essentially as a C.T. returning control to the first order of the sequence each time until the "count" is reached.<br>3) When the count is reached control continues with the next order.<br>4) The address of the first line of the sequence must be placed in 6(6,5,4) during the sequence.<br>5) After we complete one count we are prepared to do the next count in cyclic order. | | | | |
| | | 2. <u>di</u> | | | | |
| di | 95 | 1) If on occasion it is desired to skip one of the pre-set counts, the "di" order is given.<br>2) For example, suppose our pre-set induction "counts" are 5,10, and 15. After completing the first count we are automatically set to do the second when the next i is given. If however, we next want to iterate 15 times we may give a di order, which will skip the 10 counts and prepare the machine to handle the 15 count. | | | | |
| | | 3. <u>cdi</u> | | | | |
| cdi | 96 | 1) The cdi order returns the count to the first count set in the machine.<br>2) The cdi is useful when we are only using the one count, or when we wish to be certain the first count is set on the M.P. control.<br><br>These count orders have proven useful in testing procedures on the ENIAC. | | | | |
| N3D8 | 75 | | | | | |
| | | D. <u>FTN Address Order</u> | | | | |
| | ab | 1) Clears 8(3,2,1). | 8(11-4) | $\alpha$ | $\alpha + a$ | 2<br>1 |
| | cd | 2) a,b,c, and d are added to 8(4,3,2,1). | 8(3-1) | $\beta$ | bcd | |
| | | 3) This order is used to introduce a new FTN address to 8. | 13 | 0 | 0 | |
| | | 4) a is usually 0<br>5) In the case where this address is computed within the problem an 8L order may be used, care being taken to preserve 8(11-4) if necessary. | | | | |

| Order & Description | | | Contents of Affected Accs Acc | Before | After | A.T |
|---|---|---|---|---|---|---|
| | | E. <u>Delays</u> | | | | |
| D | 90 | 1) Does nothing but go to next order. | | | | 6 |
| | 99 | 2) Order is used following a C.T., when first order desired must be at the beginning of a new line. | | | | |
| H | 00 | | | | | |
| | 35 | F. <u>Stop</u> | | | | |
| | | 1) Stops the machine | | | | |
| | | 2) Useful in testing the problem on the machine or in coding checks on size of numbers. | | | | |

NOTE: It may occasionally prove useful to take advantage of the effects of not having Acc 13 clear in the various orders that "require" it to be clear. Generally speaking, this quantity in Acc 13 will be added to or subtracted from one special Acc as indicated here":

I Numerics and Storage Orders:

| | |
|---|---|
| C – Next Digit Orders | 18 – 13 → 18 |
| G – 6(11, 10, 9) and 6(8, 7) | 1 + 13 → 14 |

II Shift and Shift Prime Orders: 14 – 13 → 14

III Arithmetic Orders

| | |
|---|---|
| B – Minus Order | 1 + 13 → 1 |
| D – Division Order | 4 + 13 → 4 |
| E – Square Root Order | 7 + 13 → 11 |
| G – Drop Sign Order | 11 + 13 → 11 |

IV Control Orders

A – Unconditional Transfers

| | |
|---|---|
| 1. – N3D6 and 2. – N6D6 | 18 – 13 → 18 |
| 3. – 6R3 and 4. – 6R6 | 10 – 13 → 10 |
| B – Conditional Transfer | 10 – 13 → 10 |
| D – N3D8 | 18 – 13 → 18 |

## Section 7 – Conclusion

Before this code can be applied to a particular problem the following steps are necessary:

(a) The problem must be stated in mathematical form.

(b) The mathematical form must be reduced to a series of numerical steps.

(c) A systematic study of the number size must be made of all quantities to be handled by the machine.

(d) A flow diagram must be prepared to outline the machine procedure plan for the solution of the problem.

When these steps are complete the actual coding can be done. (References 2, 5, and 6)

Experience by the ENIAC Branch has shown, however, that before the problem can be considered ready to go on the machine, the following additional preparation and checking is necessary:

1. Checking of coding:

   a. Be certain there is a zero in the $10^{th}$ decade of the denominator and that the rule concerning the relation between the numerator and denominator is not violated in any division.

   b. Check decimal points with size of numbers.

   c. Check shifting.

   d. Check the use of all accumulators so as to be certain that a number is not destroyed that must be saved. Check especially Acc 13 since it is used in many orders.

   e. Check iteration controls and addresses for the beginning of each sequence.

   f. Check 6(11,10,9) and 6(8,7) especially as to clearing.

2. Compute a test run:

   a. A sample problem or run should be solved using a desk machine to carry out the ENIAC method of solution. Where practical, the "run" should be devised so as to employ all of the coding. If sufficiently complete, it may be used as a problem test run when the problem is placed on the machine. This type of test run uses the actual coding with the ENIAC type numbers and is a useful method for a checker to correct the preliminary enumeration of the orders.

b. Additional desk computations must be carried out using the original equations to check the results in 2a. Obviously the results to be obtained by the ENIAC can not all be known in advance, but good check values are needed for a number of cases, particularly extreme cases, to check the programming.

3. <u>Preparation of input data and input cards</u>:

   a. Punch by hand the necessary input cards.

   b. List these cards with the IBM tabulator.

   c. Check input values using independent methods where possible.

   d. Prepare Function Table set-up sheets with the coding and numeric to be placed in the machine.

When these steps have been completed, the problem may be placed on the ENIAC for solution.

## Section 8 – References


1. Technical Reports on the ENIAC – Vol. 1 and Vol. 2

2. Planning and Coding of Problems for an Electronic Computing Instrument – Goldstine and von Neumann

3. Preparation of Problems for the BRL Calculating Machines – BRL Technical Note No. 104 – September 1949.

4. Detailed Programming ENIAC Converter Code.

5. A Logical Coding System Applied to the ENIAC – R. F. Clippinger – BRL Report No. 673 (description of a theoretical 60-order code similar to the present code.)

6. Notes of R. F. Clippinger and B. Dimsdale prepared for Ballistic Institute Coding Course.

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MODIFICATIONS TO BE MADE IN TECHNICAL NOTE NO. 141

Page 2. Add the following symbols:

Cl – clear
D - delay
H - halt

Page 4. Paragraph 2: In place of "only the following 12 accumulatros [sic]…" substitute "only the following 13 accumulators …" Insert "5" in the list of Accumulators. Change the "8" to "7" on the next line.

Paragraph 3: (describing Acc. 5) Delete entirely.

Paragraph 4: (describing Acc. 6) Add the following:
"In view of the fact that the symbols for the four parts of Accumulator 6 are used so frequently, an alternate simpler nomenclature has been adopted as follows:

$6_1$ – 6 (11,10,9)
$6_2$ – 6 (8,7)
$6_3$ – 6 (6,5,4)
$6_4$ – 6 (3,2,1)

The two sets of symbols may be used interchangeably."

Paragraph 8: Beginning "Acc. 12 receives…", Add to first sentence: "… and the remainder following a division or square root order."
Last sentence should read "It can be used for storage unless there is An intervening multiply, shift prime, division or square root order."

Last paragraph: Add "(see p. 19)"

Page 5. Delete the last sentence and substitute "It is not advisable to store two distinct quantities in one field of the constant transmitter or in one of the accumulators if there is any possibility that one of the quantities might be negative."

Page 6. Change the following on the list or orders:

| Code | Order |
|---|---|
| 79 | $6_3$ |
| 89 | N3D$6_3$ |

Add at the bottom of the listing: "When no order is given opposite the code digits, this code will stop the machine."

Page 7. Under IV, Control Orders, redesignate C,D,E and F as D,E,F, and G and insert the following:

"C. Preparatory Orders $6_3$, N3D$6_3$

Delete "6R6" from IV, A.

Page 8. Replace "may be" by "are", in B 4)

Add to B 5) "In this case the PM switches must be turned to minus. There are two PM switches associated with J and two with K".

Page 9. Add to D 3): "If Acc. 15 already holds a number, is added to 15 (11-5) and 15(4-1) is left unchanged. In case of a negative number it should be borne in mind that 15(4-1) is part of the tens complement."

In D 5) change "numeric" to "positive number", and after the first sentence, ending "…A side number: abcd00efghij" insert "or if the number to be brought in is negative, the number should be stored as the 10's complement in a thru j with the negative sign on only the A side number.

Page 10. In the column labeled "After" the first item should be "X" instead of "X+Y".

In 2. 3) b) After "….by the machine" insert the phrase "or brought in from cards."

To G 1. 2) add "This leaves Acc. 15 clear."

Page 11. After 2. 2) add:

"3) Assuming that the number in 6(11,10,9) must remain unaltered, the following restrictions are necessary:

a) If a positive two-digit number (k) is first put in Acc. 15(2,1) (by means of a N2D order or otherwise) followed by the order 6(8,7) then it is necessary that $k<100-\beta$, where β is the number in 6(8,7).

b) If (k) is put in Acc. 15(2,1) followed by the orders M and 6(8,7) then it is necessary that $k \leq \beta$."

"4) Frequently the coding includes subtracting a positive number (k) from 6(8,7) repeatedly. This can be done without violating the restrictions in 3) above provided that (β) is a multiple of (k) and the subtractions are discontinued when the contents of 6(8,7) becomes equal to zero."

"5) To clear 6(8,7) without disturbing the remained of Acc. 6 we must use the following sequence of orders: C1, 6(8,7), M, 6(8,7). This leaves Acc. 15 clear."

I – Print Order. Add "4) These accumulators do not clear when printing."

Page 12. A – Shift Orders. Add "4) Shifts do not affect the sign."

B – Shift Prime Orders. Add to 1) "and places this number in Acc. 12."

In 2) change the last number in the sentence to "15)

Pages 12 and 13. In the column labeled "After" in B, Shift Prime Orders interchange what appears opposite "15" and "12".

Page 13. B – Shift Prime Orders. Add:

"6) We thus have a method of performing shifts of 6 to 9 places with a single order.

"7) Note that M9999999999, which is the complement representation of – ooooooooo1, is unchanged by a shift to the right."

III A. Add or Talk Orders. Add:

"2) Acc. 15 cannot talk to itself."

Page 14. To the first sentence add "thus replacing the ENIAC representation of the original number by the ENIAC representation of its negative."

After 2), add:
"3) In connection with conditional transfers it should be noted that this order does not change the sign of zero which is always represented in the ENIAC by a plus sign with all zeros.

C. Add:
"7) When forming ac + bc, the form (a + b)c should be used to keep round-off error at a minimum."

D. Change A.T. from "75" to "150".
Change "5" to "12".

Page 15. D. 7) Affix the following to the beginning of the sentence: "Another requirement is that"

D. Add:
"9) It will be noted that when forming ab/c the order of operation should be (a/c)b to minimize round-off errors."

E. Change "5" to "12" for remainder.
Change A.T. from "75" to "150".

F. Add "13", "0", "0" respectively in the columns labeled "Acc.", "Before" and "After".

G. add the following to 2): "Thus a positive number is left unchanged but this order has the effect of replacing a negative number, represented as explained on Page 5, by the absolute value of its tens complement."

Page 15. At the end of G. 3) (a) add: "in connection with conditional transfer orders."

In G. 3) (c) and in the column labeled "After", and "$10^d$ (1-X)" should read "$10^d$ – X".

In G. 3) (c) add: "Because of the way in which this order is performed this sequence will not work if X=0 or is negative."

Page 16. IV Add to the opening paragraph: "The count orders provide a special type of conditional transfer to handle a fixed number of iterations."

IV A. 1. 1) Insert after "...control to the" the phrase "first order of the".

IV A. 3. Add: "5) 6R3 is used as an unconditional transfer when the address is computed or read from a card. It is a special case of 6L which does not destroy $6_1$, $6_2$, and $6_3$. 6L may also be used as an unconditional transfer. (see p. 10)"

At the bottom of page 16 insert the following footnote and let the words "transmits clear" of 3. 3) bear a reference to it: "*i.e., transmits without retaining the number it transmits."

Page 17. Delete 4. in its entirety and substitute:

"B. Preparatory Orders.

These orders enable the coder to put an address in $6_3$ in preparation for either a C.T. or Count order without destroying the current address in $6_1$.

| | | | | | | |
|---|---|---|---|---|---|---|
| $6_3$ | 79 | 1. Right 3 digits of 15 to $6_3$ | | | | |
| | | 1) Clears $6_3$ | $6_1$ | α | α | 8 |
| | | 2) 15 (3,2,1) transmits clear to $6_3$ | $6_2$ | β | β | |
| | | 3) Digits in 15(11-4) are lost in the | $6_3$ | ϒ | Θ | |
| | | process and 15 is clear at the | $6_a$ | δ | δ | |
| | | completion of the order | 15(11-4) | ε | 0 | |
| | | | 15(3-1) | Θ | 0 | |
| | | | 13 | 0 | 0 | |
| N3D6(3) | 89 | 2. Next 3 digits to $6_3$ | | | | |
| | ab | I) Clears $6_3$ | $6_1$ | α | α | 26 |
| | $c^0$ | 3) Sends the next 3 digits from the | $6_2$ | β | β | |
| | | T.T. to $6_3$ | $6_3$ | ϒ | abc | |
| | | | $6_a$ | δ | δ | |
| | | | 13 | 0 | 0 | " |

Change "B" to "C" and "C" to "D".

At the end of C.T. change "6R6" to "$6_3$)

Add to description of i: "13 0 0"

Page 18. Change “D” to “E”.

Page 19. Change “E” to “F”, and “F” to “G”.

Add to F: “3) 90 is used as a delay order for card control.”

Add to G: “3) A read order will serve to halt the machine when there are no more cards to read.”

Add to III: “F – Absolute Value Order 1 + 13 → 10 (If number is negative)

Change “D” to “E” in IV

Add to IV: “C – $6_3$, N3D$6_s$ 20-13→20”

“D – Count Order I 10-13→10”

Page 20. At the end of the first paragraph, after “References 2, 5, and 6) add: “The coding should include provision for identification numbers on the input and output cards to distinguish one card from another. Sometimes the identification numbers are also used in various card-sorting procedures, for example, the main problem is sometimes divided into several parts with intervening IBM operations to select or rearrange output cards from one part of the problem for use as input cards for another part.”

Between 1. and 1. a. insert: “In addition to checking the orders this includes using the results of the number size study to make sure that the capacity of the accumulators is not exceeded and that there is not too much loss of significant figures.”

After 1. f. add: “g. Before each square root be certain that the two left hand digits of Acc. 15 do not exceed 24.”

Page 21. Insert following 3 d.:

“4 Estimate of time required to complete the problem on the ENIAC. The number of A.T. per order is given in section 8 of this report. Applying this information we determine the number of A.T. in each coding box. Next the number of times each box is used in each run is multiplied by the A.T. in that box and the total number of A.T. per run is obtained. This figure is multiplied by the number of runs, including whatever duplicate runs are to be made for checking purposes, and divided by $18x10^6$ to get the number of hours of actual operation. Usually a figure about twice this will be the best estimate because of the following considerations:

a) The number of times a certain box is used may not be known exactly ahead of time. In this case the range of times can be determined and some sort of an average obtained.

b) Allowances must be made for lower frequency, ENIAC errors, test runs, set-up time required, etc.”