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DESCRIPTION OF THE ROUTINES AVAILABLE

FOR USE ON THE CSIRAC COMPUTER

COMPUTATION LABORATORY

UNIVERSITY OF MELBOURNE

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INDEX OF THE ROUTINES AVAILABLE IN CSIRAC LIBRARY

The following pages list most of the routines and give brief notes on the more important items.The list is not,however,exhaustive and additional routines are added from time to time.

Each routine tape is given two library code numbers. The first,such as T123,refers to the routine and the second,of form B112,gives the number of the box in which the library tape is stored.The tape headed T123 B112 is thus the Gamma Function routine from box 112.

Library tapes have an extra set of position holes which are not copied by the editing equipment.Each tape is headed by punched library codes which should not be copied.At the end of each tape there is an 'optional stop' punched which should only be copied if the machine is required to stop after the routine has been read into the store.

In addition to the tape,a copy of the programme with notes is held on file in the Computation Laboratory. The routines are grouped under various headings and the specifications will be found in the file bearing the group number and title.

Unless otherwise stated:-

(1) The routine is entered with the datum in A.
(2) The routine is entered at command 0.
(3) The final result is in the A-register.
(4) The linking register is D15.

Routines are grouped as follows:-

1.Executive
2.Machine Tests (omitted)
3.Input Routines
4.Output Routines
5.Division
6.Fractional Powers
7.Trigonometric
8.Other Transcendental functions
9.Unclassified
10.Double Precision
11.Floating Binary
12.Fixed/Floating
13.Complex Arithmetic
14.Matrix Inversion
15.Factorial Analysis
16.Fourier Analysis
17.Five-hole tape Routines
18.Eigen-vectors(omitted)
19.Interpretive (omitted).

1. EXECUTIVE

T001 B100 Primary and Control

Assembles and stores commands punched on 12-hole tape. Occupies cells 0 to 0,24 of the main store and uses 0,25 ... 0,24+n to store the head cell addresses of n routines. A transfer control designation must be punched following this routine to ensure the programme is stored from cell 0,24+n. Length 25

T002 B100 Tape Symbol Print (Complete Programme)

Reads a programme tape and prints the commands (including control designations) in programming symbolism.

T002.1 B100 Tape Symbol Punch with Tabs (Complete Programme)

As T002 but output is on 5-hole tape which is interpreted by the Flexowriter. Allows for printing of stored constants as 32-scale numbers by use of 3Y and 7Y control designations. Use in preference to T002. Flexowriter Settings:- Margin 4, tabs at 9,16,22.

T002.2 B101 Tape Symbol Punch without Tabs (Complete Programme)

As T002.1 but no settings are required on the Flexowriter. Slower than T002.1.

T003.1 B100 Punch Store in Binary (Complete)

Punches the contents of successive store locations in binary from address set on NA to the address given by NA + NB + 1 inclusive. Occupies cells 0-13 so can be used to punch all the store except cells occupied by this routine. Output on 12-hole tape
Registers required ABCHD. Length 14

T003.2 B100. As T003.1 but the punching of address digits is suppressed if they are zero. It should be used in preference to T003.1. Occupies cells 0-15.

T003.3 B100 Punch from Auxiliary Store in Binary

Similar to T003.2 but requires setting of MA M on NA switches.

T004 B100 Primary and Control located by NB

Stores the Primary and Control T001 in cells starting from an address set on the NB switches. Length 25

T012 B107 Check Print data (Complete Programme)

Prints numbers punched on 12-hole tape in the compact punching convention. Results are preceded by sign. The number of items printed per row is set on the upper half of NB. No extra provision required for multiple precision data. Occupies 0-1,19. Registers used:- ABC,D-D15.

T180 B111 Symbol Print from Store in Single Column

Symbol prints commands held in the main or auxiliary store as a single column, numbered serially. Stored from 0,14-4,2. Registers used:- ABCH,D-D4.

T181 B111 Symbol Print from store in Blocks of 2,3,4

Symbol prints orders from the main or auxiliary store in layout of 2,3 or 4 columns per 'page', serially numbered at the left, with line space after every eight lines and grouped in pages of 32 rows. Store space 14-4,15. Registers used:- ABCH, D-D7.

T182.1 B111 Primary and Control Storing Parameters in D-registers

Assembles and stores orders from 12-hole tape and stores head cell parameters in D-registers. Occupies 0 - 0,25 and allows for 15 S.

T182.2 B111. As T182.1 but uses D1, D2 to hold constants so only caters for 13S. Occupies 0 - 0,22.

T183.1 B111 Control Routine Storing Parameters in D and stored at the end of the store.

As T182.1 except that it occupies 23,6 to 23,31 in the main store. In fact this is achieved by a transfer designation which may be altered to store the routine anywhere in the main store.

T183.2 B111. As T182.2 except that it occupies 23,9 to 23,31. Transfer may be altered as in T183.1.

3. DATA INPUT

Data is punched either on 12-hole or 5-hole tape, preferably the latter. When the wide tape is used the numbers are punched in the compact decimal convention; two decimal digits per tape row, final row punched with Y or XY according as the number is positive or negative. The binary equivalent is assembled in A.

5-hole equipment has been added recently and routines are still being constructed. Those available are grouped in File 17 for convenience. Eventually these specifications will be corrcctly filed.

T010.1 B107 Input Fractions, Positive or Negative.

Reads compact punched 6 decimal digit fraction from 12-hole tape and converts it to binary.
Registers ABCHD. Length 27

T010.2 B107. As above, for 4 digit decimal fractions.
Length 25

T011.1 B107 Input Integers, Positive or Negative.

Reads compact punched 6 decimal digit integers from 12-hole tape and converts it to binary. The integer must lie in the range -524288 to +524287 inclusive.
Registers ABCHD. Length 21

T011.2 B107 Input Positive Integers.

Reads 6 digit integers in the range 0 - 524287 from 12-hole tape. X punch has no effect.
Registers ABCHD. Length 18

T011.3 B107 Input Positive or Negative 2 digit Integers.

Reads positive and negative 2-decimal digit integers from 12-hole tape.
Registers ABCHD. Length 15

T013 B107 Input, Store and form Check Sum.

Three routines to read in data from 12-hole tape and store it serially from cell h to h+n-1, where n and h are set in A and C initially as P11 digits. A check sum is formed and compared with a negative check sum punched at the end of the tape as specified in the notes on the routine. Machine stops if the result is not zero.

T013.1 Caters for signed 4 digit decimal fractions. Length 37

T013.2 " " " 6 " " " " 40

T013.3 " " " 2,4 or 6 " " 32

Registers required in all cases ABCH, D-D3.

4. PRINT

Results may be printed either by the teleprinter or by the Flexowriter from tape provided by the 5-hole punch. The punch is must faster than the teleprinter and should be used in preference.

Routines allow for printing the number with sign and decimal point where relevant. Layout must be designed by the programmer.

The notation used in these routines is

6D for integers in the range -524288 to+524287
5D " " " " " -99999 to +99999

and similarly for 4D, 3D, 2D,

OR

6D for factions in the range -1·000000 to +0·999998
5D " " " " " -1·00000 to +0·99999

and similarly for 4D, 3D, 2D.

T030-T033 have six routines (e.g. 030.1, 030.2 ... 030.6) to each tape. The first routine prints 6,4 or 2D according to the point of entry (command 0,1 or 2 respectively). The other five routines print 6D, 5D, 4D, 3D, 2D respectively.

T034-T038 are similar but the first routine prints 6,5,4,3 or 2D according to the point of entry.
All routines use registers A,B,C,.

T050- are the equivalent 5-hole routines and will be found listed in group 17. When complete, they will be correctly filed.

T030 B105 Print integers, positive or negative, suppressing initial zeros.

T030.1	Length 31	030.4	Length 25
030.2	Length 27	030.5	Length 22
030.3	Length 25	030.6	Length 18

Extra Registers: All use D, .1 and .2 use D1, .3.4and.5 use H

T031 B105 Print integers, positive only, suppressing initial zeros.

As for T030, except that lengths are 25,21,19,19,16,12 respectively.

T032 B105 Print integers, positive or negative not suppressing initial zeros.

As for T030, except that lengths are 27,23,21,21,18,16 respectively. T032.1,.2 use D,.3.4and.5 use H.

T033 B105 Print integers, positive only, not suppressing initial zeros.
Length 21,17,15,15,12,10 respectively.
Extra Registers: D for 033.1 and 033.2.

Extra Registers: D for 034.*1, *035.*1, 036.1, 037.1, 038.1.

T034 B106 Print fractions, positive or negative, rounded, with -1 correctly printed

Lengths 38,27,22,22,22,20 for 034.1, ... 034.6 respectively.
T034.2,.3,.4 use H

T035 B106 Print fractions, as for T034 but unrounded

Lengths 23,19,19,19,19,18. All use H.

T036 B106 Print fractions, positive or negative, unrounded and defective as to -1 (which is printed -. 00 ..)

Lengths 21,17,17,17,17,15. All use H.

T037 B106 Print fractions, positive, unrounded

Lengths 15,11,11,11,11,9. All use H.

T038 B106 Print fractions, positive, rounded

Lengths 29,18,13,13,13,11. All use H.

T039.1 B108 Print in scale 32.

Prints a 20-digit word in the standard 32-scale representation, with spaces between the four components and initial zeros suppressed. Length 19.

T039.2 B108.

Same as preceding, but omits spaces and prints initial zeros. Length 16.

T039.3 B108 Print in scale 8.

Partitions a 20-digit word into triads, starting from the left (giving six triads plus one dyad), and prints these triads as decimal digits. Length 8.

T040 B108 Angle Print in degrees, minutes, seconds (.01-.06) or radians (.07-.09) or degrees and decimals (.10)

			Length
T040.01	Prints A.180° to nearest second	$-1 \leq A < 1$	31
T040.02	Prints A.180° to nearest minute	$-1 \leq A < 1$	30
T040.03	Prints A. 90° to nearest second	$-1 \leq A < 1$	27
T040.04	Prints A. 90° to nearest minute	$-1 \leq A < 1$	28
T040.05	Prints A. 90° to nearest second	$0 \leq A < 1$	21
T040.06	Prints A. 90° to nearest minute	$0 \leq A < 1$	22
T040.07	Prints A.180° in radians to 6D	$-1 \leq A < 1$	25
T040.08	Prints A. 90° in radians to 6D	$-1 \leq A < 1$	25
T040.09	Prints radians from 0 to 3.999999		19
T040.10	Prints A. 90° in degrees and fractions of a degree; from -90.000000 to +89.999999		23

All use H.

T041 B108 Sterling Print.

Prints £.s.d. suppressing initial zeros in £'s and suppressing tens digit of shillings and pence.

T041.1 Prints A pence up to £999.19.11. Length 33.

T041.2 Prints A pounds (integer) plus C pounds (fraction up to £99999.19.11. Length 41.
Extra Registers: D1 for T041.2 and D and H for both.

T042 B108 Alpha-Numeric Print

Used for printing headings involving letters or figures or both. Full description on specification sheet. Registers ABH. Length 14.

5. DIVISION

T060.1 and T061.1 are valid for any numerator but the denominator must be non-zero and not less than the numerator. In both cases

$$A/C = A' \qquad \text{and} \qquad -A/C = D'.$$

When $|\text{numerator}| = |\text{denominator}|$, the formal positive and negative quotients are both -1.

Accuracy is such that

$$|(\text{quotient}) \times (\text{denominator}) - \text{numerator}| \leq 2^{-19}$$

Hence the quotient has, at the worst, one less significant correct figure than the denominator.

T060.2 and T061.2 are similar but the denominator must also be positive and the result is obtained only in A. The accuracy is better as the programmes include a simultaneous left shift of numerator and denominator until the latter has 19 significant binary digits and the absolute error of the quotient does not exceed 2^{-18}; these routines should be used for quotients of small fractions or integers.

All use registers ABCD

Method used is based on Wilkes 'Repetitive' formula.

T060.1 B114. Length 19

T060.2 B114. Length 15

T061.1 B114. Length 24

T061.2 B114. Length 20

T062 Division by 'Non restoring method'.

$A/C = A'$ where $|C| \geq |A|$. The result is truncated to 19 binary digits. For A = C (including A = C = 0 or -1), the result is $1 - 2^{-19}$. For A = -C the result is P20 = -1.
Registers ABCH. Length 15.

6. FRACTIONAL POWERS

These routines use registers ABCHD, unless otherwise specified. The argument must be fractional.

T080 B109 Square Root (Trial and Error).

Error does not exceed Pl[x]. Slower than T081 and 082.
Extra register D1. Length 19.

T081 B109 Square Root (Iterative).

Argument x must lie in the range $\frac{1}{4} \leq x \leq 1$. Length 16.

T082 B109 Square Root (Repetitive).

In general the error is negative and the answer is accurate to 4 or more decimal places. Length 16.

T083 B109 Cube Root (Trial and Error).

Error does not exceed 1·5Pl.
Extra register D1. Length 20.

T084 B109 Fourth Root (Trial and Error).

Error rarely exceeds Pl.
Extra register D1. Length 18.

[x] In the sense that $|(\text{nominal } \sqrt{x})^2 - x| \leq Pl$.
The number of significant correct figures in $\sqrt{x}$ cannot exceed that in x.

7. TRIGONOMETRIC

T100 B104 Sine and Cosine, for 2 rt.angle unit.
Gives sin πA or cos πA for $-1 \leq A < 1$ according as entry is at 0 or 1.
Registers ABCD. Length 28.

T101 B104 Tangent, for rt. angle unit.
Gives tan $\frac{\pi}{2}A$ for $-\frac{1}{2} \leq A \leq \frac{1}{2}$.
T101.1 max. error 3P1. Length 22.
T101.2 max. error P1. Length 22.
Both use ABCD.

T102 B104 Secant.
Gives (sec $\frac{\pi}{2}A$) - 1 for $-\frac{1}{2} \leq A < \frac{1}{2}$.
Registers ABC. Length 21.

T103 B104 Cosine and Sine for rt. angle unit.
Gives cos $\frac{\pi}{2}A$ or sin $\frac{\pi}{2}A$, according as entry is at 0 or 5.
T103.1 Valid for $-1 \leq A < 1$. Length 27.
T103.2 Valid for $-1 < A < 1$ but not for $A=-1$. Length 25.
Registers ABCD for both.

T104 B104 Sine $(\pi/2)$ A
T104.1 Valid for $-1 \leq A < 1$. Length 22.
T104.2 Valid for $-1 < A < 1$ only. Length 20.
Registers ABCD. Length 22.

T105 B112 Cosine $(\pi/2)$A
T105.1 Valid for $-1 \leq A < 1$. Length 22.
T105.2 Valid for $-1 < A < 1$ only. Length 20.
Registers ABC

T111 B112 Arctan (as a fraction of 90^0)[X]
T111.1 A rapid unlooped version, valid for all positive or negative arguments. Length 27.
T111.2 A compact looped T111.1. Length 25.
T111.3 A rapid unlooped version, valid for all arguments except -1. Length 25.
T111.4 Looped version of T111.3. Length 23.
Registers ABCD for all, T111.2 and .4 use D1 and H.

T112 B112 Arc sin (as a fraction of 90^0).
T112.1 A rapid unlooped version, valid for argument in range $-1/\sqrt{2}$ to $1/\sqrt{2}$ inclusive.
Registers ABCD. Length 25.
T112.2 A compact looped version of T112.1. Length 23.
Registers ABCD, D1 and H. Length 23.

[X] i.e. if A = xP20, the routines give
$A' = 2/\pi(x - \frac{1}{3}x^3 + \ldots)$P20
and similarly for T112.

8. OTHER TRANSCENDENTAL FUNCTIONS

T120 B101 Logarithm (to base 2).
Gives $\log_2 |2A|$ for $\frac{1}{2} \leq |A| < 1$.
Registers ABCD. Length 15.

T120.1 B126 Logarithm (to base 2).
Gives $-\frac{1}{32} \log_2 A$ for $0 < A < 1$.
Registers AB.

T121 B101 Exponential (repetitive).
Yields $e^A - 1$ for $-1 < A < 0{\cdot}69315 = \log_e 2$.
Registers ABCD. Length 12.

T122 B101 Logarithm (natural).
Evaluates $\log_e(1 + A)$ where $0 \leq A \leq 1$ with error less than $P1(2.10^{-6})$.
T122.1 Unlooped; uses ABC; Length 21.
T122.2 Looped; uses ABCDH. Length 18.

T123 B122 Gamma Function.
Evaluates the complete Gamma function $(1 + x)$ where $0 \leq x < 1$ with error less than 2P1.
T123.1 Unlooped; uses ABC; Length 27.
T123.2 Looped; uses ABCD; Length 22.

T124 B112 Positive Exponential.
Gives $e^A - 2$ for $0 \leq A < 1$.
T124.1 Rapid unlooped polynomial version using ABC. Length 19.
T124.2 Compact looped version using ABCDH. Length 18.

T125 B112 Negative Exponential.
Yields e^{-A} for $0 \leq A < 1$.
T125.1 Rapid unlooped polynomial version using ABC. Length 19.
T125.2 Compact looped version using ABCDH. Length 18.

T126 B103 Bessel Functions
T126.1 Forms $J_0(2A) = A'$ valid for $-1 \leq A < 1$. Length 23.
T126.2 As T126.1 but invalid for -1. Length 18.
T126.3 Forms $J_1(2A) = A'$ valid for $-1 \leq A < 1$. Length 25.
T126.4 As T126.3 but invalid for -1. Length 22.

9. UNCLASSIFIED.

T150 B103 Sterling Coinage Analysis.

The positive integer in A represents pence. The routine adds to D2, D3 ... D10 the number of £10, £5 ... pence which amount to the original number of pence and minimise the number of coins or notes. Valid for less than 2184/10/8. Registers used ABC D2 to D10 - these D-registers must be cleared before the routine used. Length 28.

T151 B103 Random Number Generator.

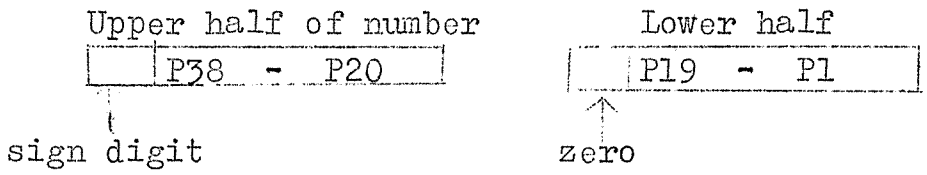
A quasi-random integer, rectangularly distributed in the range (1,524287) is obtained in A. Time 1/40 sec. Registers used ABC. Length 12.

T510 B103 Runge Kutta Integration of Simultaneous Differential Equations.

Gives a step by step integration of a set of simultaneous linear differential equations $dx_i/dt = f_i(x_j)$, for i,j = 1,2, ... n. See Specification for full details. Link register is D11. Length 45.

10. DOUBLE PRECISION.

The following routines manipulate numbers represented by 38 binary digits held in two registers as shown.



T200 B115 Double Precision Input.

These routines read a number of 12 decimal digits from 12 hole tape punched in compact decimal form as six tape rows.

a_1 b_1 *
a_2 b_2 *
.....
.....
a_6 b_6 with Y(for +) or YX (for -) *

If the first three or more pairs of digits are zero, the resulting blank tape rows may be omitted.
The upper half of the number with sign digit is assembled in A, the lower half in C.

T200.1 B115 Input of Double Precision Signed Integers.
Registers ABCHD - D3. Length 44.

T200.2 B115 Input of Double Precision Positive Integers.
Registers ABCHD - D3. Length 37.

T200.3 B115 Input of Double Precision Signed Fractions.
Registers ABCHD - D3. Length 55.

T200.5 B115 Input of Double Precision Integer Fraction.
Registers ABCHD - D1. Length 37.

T201 B115 Double Precision Print.

These routines print double precision numbers held in A and C.

T201.1 B115 Print Double Precision Signed Integers.
Initial zeros are suppressed.
Registers ABCHD - D2. Length 62.

T201.2 B115 Print Double Precision Positive Integers.
Initial zeros suppressed.
Registers ABCHD - D2. Length 55.

T201.3 B115 Print Double Precision Signed Fraction.
Gives ± 0. or -1. followed by 12 decimal digits.
Registers ABCHD - D1. Length 31.

T201.4 B115 Print Double Precision Integer Fraction.
Initial zeros not suppressed.
Registers ABCHD - D1. Length 42.

Double Precision Multiplication.

T204.1 B116 Multiplication of Double Precision Signed Integers.
Forms (AC).(D1 D2) = (A,C)' on the assumption that both factors and product lie between 2^{-38} (incl.) and 2^{38}.
Registers ABCD - D5. Length 17.

T204.2 B116 Multiplication of Double Precision Positive Integers.

Similar T204.1.
Registers ABCD - D4. Length 16.

T205.1 B116 Multiplication and Addition of Double Precision Fractions.

(Result rounded).
Entry at 0 gives $(AC).(D1\ D2) = (AC)' = (D3\ D4)'$
Entry at 2 gives $(AC).(D1\ D2) + (D3\ D4) = (AC)' = (D3\ D4)'$
Error less than $2^{-39} + 2^{-57}$
Registers ABCHD - D6. Length 31.

T205.2 B116 Similar to T205.1 but result unrounded. Error may reach 3×2^{-39}.
Registers ABCHD - D4. Length 25.

T205.3 B116 Exact Multiplication and Addition of Two Double Precision Numbers.

Entry at 0 gives $(AC).(D1\ D2) = (D3\ D4\ D5\ D6)'$
Entry at 4 gives $(AC).(D1\ D2) + (D3\ D4\ D5\ D6) = (D3\ D4\ D5\ D6)'$
Registers ABCHD - D6. Length 33.

T205.4 B116 Multiplication and Addition of Double Precision Integer-Fractions.

Entry at 0 gives $(AC).(D1\ D2) = (D3\ D4.D5)'$
Entry at 3 gives $(AC).(D1\ D2)+(D3\ D4\ D5) = (D3\ D4\ D5)'$
Registers ABCHD - D6. Length 34.

Double Precision Blocks.

These routines combine a number of operations in one programme. Specifications should be studied for full details.

T216 B117 Double Precision Function Block for range (-1,1)

Provides input, print and arithmetic operations for double precision fractions.
Registers ABCHD - D7.
Length: Main Block 0 - 3,25 optional sections 3,26 - 6,5.

T217 B115 Double Precision Arithmetic Block for range (-1,1).

Provides multiplication and division for double precision fractions.
Registers ABCHD - D7. Length 92.

T218 B117 Double Precision Arithmetic Block for range $(-2^{19}, 2^{19})$

Provides multiplication and division for integer fractions.
Registers ABCHD - D7.
Length: Main Block 52. Optional reciprocal 11.

Double Precision Miscellaneous.

T232 B116 Double Precision Arithmetic Block for fractions.

Provides multiplication, multiplication and addition, addition and subtraction.
Registers ABCHD - D5.
Length: Main Block 36, with addition 48.

T234.1 B118 Double Precision Fractions:- Square Root.

Requires T232 as 2S routine. Gives $(AC)' = (AC)^{\frac{1}{2}}$.
Registers ABCHD - D2. Length 38.

T234.2 B118 Double Precision Fractions:- Sine/cosine.

Requires T232 as 2S routine. Gives sin/cos n(A).
Registers ABCHD - D6. Length 53.

T234.3 B118 Double Precision Fractions:- Sine/cosine.

Requires T232 as 2S routine. Shorter version of T234.2.
Registers ABCHD - D6. Length 35.

T234.4 B118 Double Precision Fractions:- Exponential.

Requires T232 as 2S routine. Gives (A,C)' = exp(A,C)-1.
Registers ABCHD - D6. Length 27.

T235.1 B118 Double Precision Fractions:- Division by non-restoring method.

Gives (A,C)' = (D2 D3)' = (D D1)/(A,C).
Quotient rounded but P20 is given for +1.
Registers ABCHD-D4 Length 40

T235.2 B118 As T235.1 but unrounded. Gives 1 - p1 for +1.

Double Precision Floating Routines.

T250 B117 Rational Operations on block-floated double precision numbers.

Numbers are represented in two registers on the convention that the decimal point is i places to the right of the standard 'fraction' position in the upper register, for $0 \leq i \leq 19$. See specification for full details.

T251 B117 Print Double Precision Floating Number.

Converts to decimal and prints 2^i x where $-1 \leq x < 1$ and $0 \leq i \leq 18$. The sign is printed followed by 12 decimal digits with the point in its correct position. The full 38 binary digits of x are matched as nearly as possible in the print.
Registers ABCHD - D3, D6,D8. Length 70.

T252 B117 Double Precision Input from Floating Decimal Tape.

Assembles numbers $\pm 1D^m x$, punched on 12-hole tape as seven tape rows, index followed by 12 decimals compact punched, and converts to $\pm 2^i y$ where $0 \leq m \leq 5$, $0 \leq i \leq 19$, $10^m 2^i < 1$.
Requires T250 as 2S routine. Link D14.
Registers ABCHD - D10. Length 74.

11. FLOATING BINARY

Floating binary numbers $x.2^y$ are held in pairs of registers with x as a fraction and y as an integer, where $\frac{1}{2} \leq |x| < 1$; $-524288 \leq y < 524288$.

The routines use the convention that two such numbers are held in A,C and D,D1 so that $A.2^C$ and $D.2^{D1}$ represent the numbers.

A number of routines require the basic arithmetic block with its head parameter stored as 2S. All routines are y D15 linked. A number which is zero with respect to $x.2^y$ is represented as $0{\cdot}5x.2^{y-19}$.

Routines use ABCD,D1.

T300 B102 Basic Arithmetic Block.

Enter at 0 for subtraction (D,D1)-(A,C)
1 for addition (D,D1)+(A,C)
1,5 for multiplication (D,D1)x(A,C)
1,16 for division (D,D1)/(A,C).

Enter at 1,8 to normalise $A,B.2^{D1}$.
Results are set in A,C and also D,D1 and are normalised.
The division routine need not be copied from the library tape in which case store space used is 1,14 as against 2,1 if division is included. This routine is preceded by 2S, 1S, designations.

T300.2 B102 Input from Compact punched Tape to A,C and D,D1.

Punch three rows of 2 decimal digits in the normal convention followed by a fourth row with binary index Y-punched and X-punched if negative. Zero must be as $0.5.2^{-20}$. Requires T 300.1 as 2S-ed routine.
Registers ABCHD,D1. Length 30.

T300.4 B102 Print as Floating Binary Number.

Prints A,C as 14 characters:- signed 6D fraction, space, signed 3D index (-999 to +999).
Registers ABCHD,D1,D2. Length 27.

T300.5 B102 Print as Floating Decimal Number.

A,C printed as 13 characters including signed 6D fraction and signed 2D index (-99 to +99).
Registers ABCHD,D1,D2. Length 49.

T301 B102 Floating Binary Functions.

These routines form (A,C)' = (D,D1) = F(A,C) for various functions F(n). They use T300.1 as a 2S-ed subordinate routine. Zero results are represented as normalised round offs; $0.5 \times .2^{y-19}$.

T301.1 B102 Square Root.

$F(n) = n^{\frac{1}{2}}$.
Registers ABCHD,D1. Length 19.

T301.2 B102 Sine/cosine.

Entry at 0 gives sine x, entry at 1, cosine x.
Valid for indices $-2048 < y < 2048$.
Registers ABCHD,D1. Length 39.

T301.3 B102 As T301.2 but shorter and less accurate. Length 35.

T301.4 B102 Logarithm to base 2.

$F(n) = \log_2 |n|$.
Registers ABCHD,D1. Length 24.

T301.5 B102 Exponential.
$F(n) = e^n$.
Registers ABCHD,D1,D2. Length 31.

T301.6 B102 Arctan as a function of 90^o.
$F(n) = \arctan n\pi/2$. Valid for indices $-2048<y<2048$.
Registers ABCHD,D1. Length 46.

T302 B102 Floating Binary Integer Operations (to be revised).
Caters for operations with non zero integers in p11 units. T300.1 is used as a 2S-ed routine.
Registers ABCHD,D1. Link D15.

12. FIXED POINT/FLOATING

For these the data are taken in fixed-point representation and the results are obtained in floating-point representation, (or vice versa in the case of logarithms), the simple fixed-point representation being inapplicable because the results are generally outside the range -1,1.

T350 B113 Division for arbitrary numerator and denominator.

Gives $A/C = 2^{D'}.A'$, where the unit for A,C and A' is P20 and the unit for D' is P1. Valid for $-1 \leq A < 1$ and $-1 \leq C < 1$ provided $C \neq 0$. If $|A| = |C|$, D' = P1 (so that $A' = \pm \frac{1}{2}$) and if $|A| < |C|$, D' = 0 in all cases. Error at the most P1.
Method: long division, equivalent to trial and error.
Registers ABCD,D1. Length 29.

T351 B113 Inverse.

Four routines with minor variations giving $\pm \frac{1}{A} = 2^{D'}.C'$.
Note that the fractional component of the answer is in C not A.
All give never excessive approximations to 1/x in the sense that the rounded product of x by the approximate 1/x never exceeds 1.
Error: 1-x.1/x between 0 and 2P1 inclusive for T351.1 and T351.2; between 0 and P1 inclusive for T351.3 and T351.4. Method iterative.

T351.1 $+A^{-1}$; Reciprocal of $\pm \frac{1}{2}$ given as $2^2(\pm \frac{1}{2})$.
Registers ABCD,D1. Length 23.

T351.2 $-A^{-1}$; Negative reciprocal of +- given as $2(-1)$ and of $-\frac{1}{2}$ as $2^2(\frac{1}{2})$.
Registers ABCHD,D1. Length 23.

T351.3 $-A^{-1}$; Negative reciprocal of $\pm \frac{1}{2}$ given as $2^2(\mp \frac{1}{2})$.
Registers ABCHD,D1. Length 26.

T351.4 $+A^{-1}$; Reciprocals of $\pm \frac{1}{2}$ given as $2^2(\pm \frac{1}{2})$.
Registers ABCHD,D1. Length 26.

T352 B113 Logarithm to the base 2.

Gives $\log_2 2^C A = A'(p1) + C'(p20)$ i.e. the integral characteristic appears in A and the fractional mantissa in C. Method: Trial and error.

T352.1 Last digit of mantissa may be wrong.
Registers ABCD,D1. Length 23.

T352.2 Last digit correctly rounded.
Registers ABCHD,D1. Length 26.

T353 B113 Logarithm to base 2, 10 or e.

Gives $\log_a 2^C A = A'(P1) + C'(P20)$ where a = 2, 10 or e according as entry is at 0,1,2 respectively.
353.2 is a slightly more accurate version.

T353.1 Registers ABCHD,D1. Length 41.
T353.2 Registers ABCHD,D1,D2. Length 44.

13. COMPLEX ARITHMETIC

T400 B114 Fundamental operations on Complex Numbers.

This routine

(1) Converts x + iy to r exp(iπθ) for $-1 \leq x, y < 1$ and $0 \leq r \leq 1$, $-1 \leq \theta < 1$,
(2) performs the real operations required for
  (i) polar to cartesian conversion
  (ii) division
  (iii) square root.
(3) Multiplies complex numbers in cartesian specifications

Enter at 0 for A + iC = C'exp iπA'
" 3,8 for sin πA = A'
" 3,9 for cos πA = A'
" 1,11 for A/C = A' = C', $C \geq 0$
" 0,21 for √A,D2 = C'. This gives the square root of a double precision fraction A,D2 correct to 19 binary places.
Enter at 2,25 for (A+iC).(D1+iD2) = A' + iC'.
See specification for full details regarding limiting cases and method.
Registers used ABCHD - D5. Length 131.

T401 B114 Operations on complex numbers.

(1) Obtains C' = r, A' = θ from A + iC = x+iy where $x = r \cos \pi\theta$, $y = r \sin \pi\theta$ if $0 \leq r < 1$. Enter at 0.
(2) If A = θ, to calculate A' = sin πθ enter at 3,5
  A' = cos πθ enter at 3,6.
(3) If A = x, C = y, to calculate C' = x/y enter at 0,12. $0 \leq |x| < |y| < 1$.
(4) For cartesian multiplication (A+iC).(D1+iD2)=A'+iC' enter at 2,10.

Registers used ABCH,D - D3. Length 218.

T402 B113 Multiplication and Division of Complex Numbers using Cartesian components.

Calculates $(x+iy)(u+iv)$ and $\frac{u+iv}{x+iy}$ where x,y,u,v are real numbers between -1 (exclusive) and 1 (exclusive) represented on the standard convention. For quotient $|x+iy| < 1$, A = x, C = y, D1 = u, D2 = v.
Enter 0 for quotient
4 for product.
Registers ABCHD - D4. Length 49.

T409 B125 Floating Binary Complex Input (12 hole) and Output.

T409.1 Reads a floating complex number $(x+iy)2^z$ where x and y are punched as six decimal fractions in the compact decimal convention and z is an integer. Result is A = D = x, B = 10 = y, C = 2D = z.
Registers ABCHD - D3. Length 37.

T409.2 Prints $(A + iB)2^C$ as 24 characters; real and imaginary parts are printed as six decimal signed fractions with a three decimal signed binary index.
Registers ABCHD - D3. Length 35.

T409.3 Prints $(A + iB)2^C$ as floating decimal.
Registers ABCHD - D3. Length 52.

T410 B125 Floating Binary Complex Arithmetic Block

Adds, subtracts, multiplies and forms reciprocal of $(x+iy)2^Z$, $(u+iv)2^W$.

Enter at 0 for $(D + iD1)2^{D2} - (a + iB)2^C$

4 for $(D + iD1)2^{D2} + (A + iB)2^C$

1,29 for $(D + iD1)2^{D2} \times (A + iB)2^C$

1,5 for normalisation of D, D1 and D2.

2,1? for $1/(A + iB)2^C$

Results are always normalised so that

$$(A + iB)2^C = (D + iD1)2^{D2}.$$

This routine is headed by 2S, 1S. Reciprocal commands may be omitted if not required.

Registers ABCH,D-D4. Length 2,13 without reciprocal
3,8 with reciprocal.

14.MATRIX INVERSION

Anyone wishing to use these routines should consult the operating instructions in this file.The routines available are described briefly.

T500 B119 Matrix Inversion for dominant diagonal terms.

The diagonal elements of the matrix substantially exceed all the off-diagonal elements.The programme will usually succeed irrespective of this condition but the rounding errors may be unnecessarily large.

T501 B119 Matrix Inversion with print selection

Matrix is believed to be well conditioned.

15. FACTORIAL ANALYSIS

T511 B118 Factorial Analysis,factors at two levels

The 2^n results of a factorial experiment are analysed using Yates' Tableau process. $3 \leq n < 9$.Data assumed to 4D. See specifications for full details.

16. FOURIER ANALYSIS AND SYNTHESIS

T512 B121 Fourier Harmonic Analysis.

Calculates the Fourier harmonic components corresponding to any number of equally spaced ordinates (maximum number 120). Primary and Control are overwritten with ordinate data.See specifications for full details.

T513 B121 Fourier Harmonic Synthesis

Calculates equally spaced ordinates(maximum number 120) from Fourier harmonic components.See specifications for full details.

17. 5-HOLE TAPE ROUTINES (PROVISIONAL)

T021.1 B124 Decimal Input from 5-hole tape.

Assembles a signed 6-digit integer or fraction from Flexowriter codes on 5-hole tape. Tapes must be free from the three codes for ₹ = , End of number codes are 'tab', 'stop', 'spare', 'carriage return'.
Registers ABCHD. Length 33.

T021.2 B124 is a similar routine to read in 4 decimal digit numbers.

T050 B126 Signed Fraction Punch (unrounded).

Six routines to punch signed decimal fractions in Flexowriter codes. The first routine punches a 6,4 or 2 digit fraction according as entry is at 0,1 or 2 respectively and uses registers ABCHD. The remaining five punch a 6,5,4,3,2 digit number respectively using ABCH.

Length				
T050.1	27	T050.4	24
.2	24	.5	24
.3	24	.6	24

T051. B126 Signed Fraction Punch (rounded).

Similar to T050 but the results are rounded. The variable entry routine is not yet available.
Registers ABCHD.

Length				
T051.1	-	T051.4	27
.2	34	.5	27
.3	27	.6	27

T052 B126 Positive Fraction Punch (unrounded).

Similar to T050 but punches positive fractions only, Variable entry routine not yet available.
Registers ABCHD.

Length				
T052.1	-	T052.4	17
.2	17	.5	17
.3	17	.6	17

T053 B126 Positive Fraction Punch (rounded).

Similar to T050 but punches positive rounded fractions. Variable entry routine not yet available.
Registers ABCHD.

Length				
T053.1	-	T053.4	22
.2	23	.5	22
.3	22	.6	22

T054 B126 Signed Integer Punch.

Punches 6, 4 or 2 digit signed integer by entry at 0,1,2 respectively.
Registers ABCHD - D1. Length 35.

T059 B127 32-scale Punch.

Punches in Flexowriter codes, the contents of A in 32-scale.

T059.1 suppresses initial zeros and gives spaces including one space at the end.

T059.2 is for use when line space is limited. Prints 8 digits without spaces.

Both use ABCH. Length: T059.1 27; T059.2 23.

T305.1 B123 Floating Decimal Input from 5-hole tape (Standard format).

Assembles a floating decimal number punched in Flexowriter coding, fraction followed by index in brackets, in floating binary representation in A and C. Requires T300 with 2S designation.
Registers ABCHD - D2. Length 52.

T305.2 B123 Floating Decimal Input from 5-hole tape (Universal).

Assembles in A,C in floating binary form any decimal number, or floating decimal number with the index in brackets. Requires T300 with 2S designation.
Registers ABCHD - D3. Length 75.

T306 B123 Floating Decimal Punch.

Punches a floating binary number in A,C in floating decimal form, two decimal index in brackets.
Registers ABCHD - D2. Length 53.

T307 B123 Floating Binary Punch.

Punches a floating binary number in A,C as a decimal fraction and binary index.
Registers ABCHD - D1. Length 32.

T308 B123 Floating Decimal Punch.

Punches a floating binary number in A,C in floating decimal form, mantissa, space, two digit decimal index not in brackets.
Registers ABCHD - D2. Length 52.