

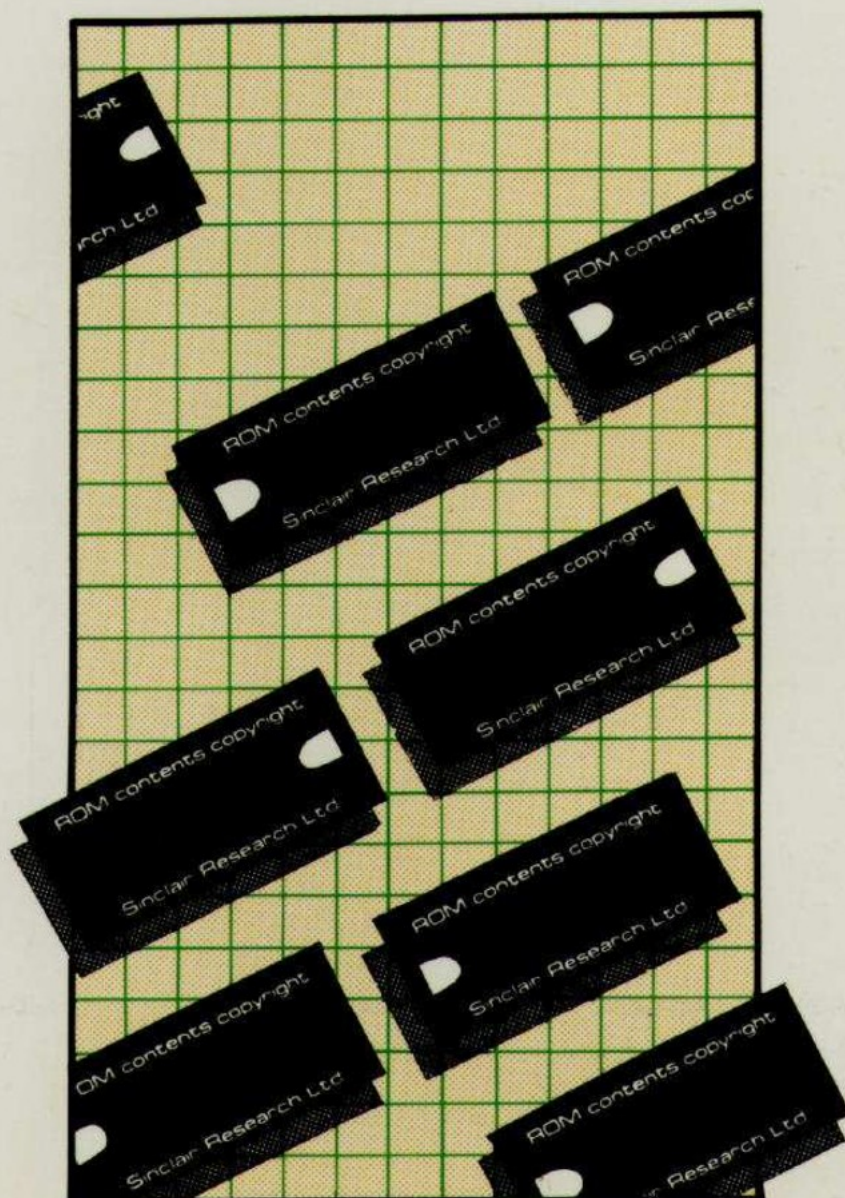
The Complete Timex TS1000/Sinclair ZX81 ROM Disassembly

Includes PART A: 0000H-0F54H &
PART B: 0F55H-1DFFH

by Dr. Ian Logan
& Dr. Frank O'Hara



ROM DISASSEMBLY



The Complete Timex TS1000 & Sinclair ZX81 ROM Disassembly

**by Dr. Ian Logan
& Dr. Frank O'Hara**

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The Complete Timex TS1000 & Sinclair ZX81 ROM Disassembly PART A: 0000H-0F54H

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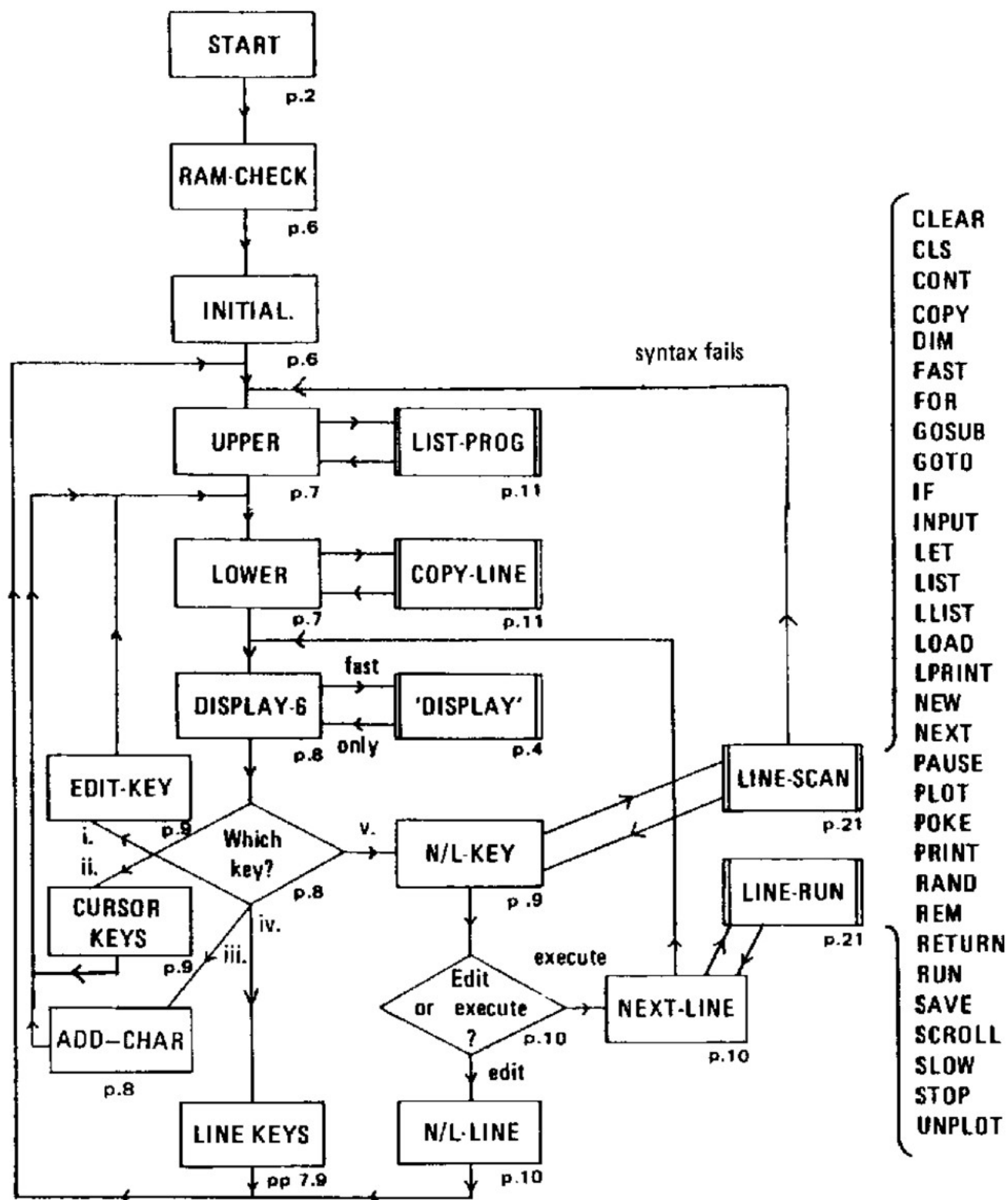
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The system variable 'labels' are those given by Sinclair Research Ltd., but the other 'labels' have been designated by the authors.

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The 'FLOW DIAGRAM' for PART A of the 8K ROM Program



NOTE: The 'display' in SLOW mode is produced by a call to 'DISPLAY' every 1/50th. of a second.

THE 'START'

The NMI generator is turned off and BC set to the 'top of possible RAM'

```
0000 START      OUT      (+ FD),A
                  LD       BC, + 7FFF
                  JP       03CB,RAM-CHECK
```

THE 'ERROR'RESTART

```
0008 ERROR-1    LD       HL,(CH-ADD)
                  LD       (X-PTR),HL
                  JR       0056,ERROR-2
```

THE 'PRINT A CHARACTER' RESTART

The code of the character to be printed is in the A register.

```
0010 PRINT-A    AND       A
                  JP       NZ,07F1.PRINT-CH
                  JP       07F5,PRINT-SP.
                  DEFB     + FF
```

THE 'COLLECT CHARACTER' RESTART

The A register is set with the character addressed by CH-ADD. Spaces are ignored.

```
0018 GET-CH.    LD       HL,(CH-ADD)
                  LD       A,(HL)
001C TEST-SP.    AND       A
                  RET      NZ
                  NOP
                  NOP
```

THE 'COLLECT NEXT CHARACTER' RESTART

CH-ADD is incremented before the character is fetched.

```
0020 NEXT-CH    CALL     0049,CH-ADD + 1
                  JR       001C,TEST-SP.
                  DEFB     + FF
                  DEFB     + FF
                  DEFB     + FF
```

THE 'FP-CALCULATOR' RESTART

A direct jump is made to the calculator routine.

```
0028 FP-CALC.   JP       199D,CALCULATE
```

THE 'END-CALC' SUBROUTINE

The byte 34 ends a RST 0028 operation.

```
002B END-CALC.  POP      AF
                  EXX
                  EX       (SP),HL
                  EXX
                  RET
```

THE 'MAKE BC SPACES' RESTART

BC spaces are made available for different purposes.

```
0030 BC-SPACES  PUSH     BC
                  LD       HL,(E-LINE)
                  PUSH     HL
                  JP       1488,RESERVE
```

THE 'INTERRUPT' RESTART

B holds the line number and C the number of the scan line.

```
0038 INTERRUPT  DEC      C
                  JR       NZ,0045,SCAN-LINE
                  POP      HL
                  DEC      B
                  RET      Z
                  SET      3,C
0041 WAIT-INT.  LD       R,A
                  EI
                  JP       (HL)
0045 SCAN-LINE  POP      DE
                  RET      Z
                  JR       0041,WAIT-INT.
```

THE 'INCREMENT CH-ADD' SUBROUTINE

The pointer CH-ADD is incremented and the cursor ignored.

```
0049 CH-ADD + 1 LD       HL,(CH-ADD)
004C CURSOR-SO INC      HL
004D TEMP-PTR.  LD       (CH-ADD),HL
                  LD       A,(HL)
                  CP       + 7F
                  RET      NZ
                  JR       004C,CURSOR-SO
```

THE 'ERROR-2' ROUTINE

L is loaded with the 'data byte'.

```
0056 ERROR-2    POP      HL
                  LD       L,(HL)
0058 ERROR-3    LD       (ERR-NR),L
                  LD       SP,(ERR-SP)
                  CALL     0207,SLOW/FAST
                  JP       14BC,SET-MEM
                  DEFB     + FF
```

THE 'NMI' ROUTINE

This routine is entered whenever a 'SLOW' NM interrupt occurs.

```
0066 NMI        EX       AF,A'F'
                  INC      A
                  JP       M,006D NMI-RET
                  JR       Z,006F NMI-CONT.
006D NMI-RET    EX       AF,A'F'
                  RET
```

THE PREPARE FOR 'SLOW' DISPLAY ROUTINE

The main registers are preserved on the stack, the NMI generator is switched off and a jump is made into the display routine. (IX holding 0281 or 028F)

006F NMI-CONT	EX	AF,A'F'
	PUSH	AF
	PUSH	BC
	PUSH	DE
	PUSH	HL
	LD	HL,(D-FILE)
	SET	7,H
	HALT	
	OUT	(+FD),A
	JP	(IX)

THE KEY TABLES

The 'unshifted' character codes.

007E	3F	3D	28	3B	Z	X	C	V
0082	26	38	29	2B	A	S	D	F
0086	2C	36	3C	2A	G	Q	W	E
008A	37	39	1D	1E	R	T	1	2
008E	1F	20	21	1C	3	4	5	0
0092	25	24	23	22	9	8	7	6
0096	35	34	2E	3A	P	O	I	U
009A	3E	76	31	30	Y	N/L	L	K
009E	2F	2D	00	1B	J	H	Sp.	.
00A2	32	33	27		M	N	B	

The 'shifted' character codes.

00A5	OE	19	OF	18	:	;	?	/
00A9	E3	E1			STOP	LPRINT		
00AB	E4	E5			SLOW	FAST		
00AD	E2	CO	D9		LLIST	" "	OR	
00B0	EO	DB	DD		STEP	<=	>	
00B3	75	DA	DE		EDIT	AND	THEN	
00B6	DF	72	77		TO	RUBOUT		
00B9	74	73	70		GRAPHICS	→	←	
00BC	71	OB	11	10	")	(
00CO	OD	DC	79		\$	=	FUNCTION	
00C3	14	15	16	D8	=	+	-	**
00C7	OC	1A	12	13	£	,	>	<
00CB	17				*			

The 'function' character codes.

00CC	CD	CE	C1	78	LN	EXP	AT	K/L
00DO	CA	CB	CC	D1	ASN	ACS	ATN	SGN
00D4	D2	C7	C8	C9	ABS	SIN	COS	TAN
00D8	CF	40	78	78	INT	RND	K/L	K/L
00DC	78	78	78	78	K/L	K/L	K/L	K/L
00E0	78	78	78	78	K/L	K/L	K/L	K/L
00E4	C2	D3	C4		TAB	PEEK	CODE	
00E7	D6	D5	78		CHR\$	STR\$	K/L	
00EA	D4	C6	C5		USR	LEN	VAL	
00ED	DO	78	78		SQR	K/L	K/L	
00FO	42	D7	41		PI	NOT	INKEY\$	

The 'graphic' character codes.

00F3	08	0A	09	8A	
00F7	89	81	82	07	
00FB	84	06	01	02	
00FF	87	04	05	77	RUBOUT

0103	78	85	03	83	K/L	
0107	8B	91	90	8D		
010B	86	78	92	95	K/L	
010F	96	88				

The 'token' tables.

0111	8F	0B	8B	26	'?	"	'''	A
0115	B9	39	26	A7	'T	'	A	'B
0119	8F	28	34	29	'?	'C	O	'D
011D	AA	3B	26	B1	'E	'V	A	'L
0121	31	2A	B3	38	'L	'E	N	'S
0125	2E	B3	28	34	'I	'N	C	'O
0129	B8	39	26	B3	'S	'T	A	'N
012D	26	38	B3	26	'A	'S	'N	'A
0131	28	B8	26	39	'C	'S	'N	'A
0135	B3	31	B3	2A	'X	'N	'P	'I
0139	3D	B5	2E	33	'T	'S	'Q	'R
013D	B9	38	36	B7	'S	'G	'N	'A
0141	38	2C	B3	26	'B	'S	'P	'E
0145	27	B8	35	2A	'E	'K	'U	'S
0149	2A	B0	3A	38	'R	'S	'T	'R
014D	B7	38	39	37	'\$	'S	'C	'H
0151	8D	28	2D	37	'\$	'N	'O	'T
0155	8D	33	34	B9	'\$	'N	'O	'T
0159	17	97	34	B7	'\$	'N	'O	'T
015D	26	33	A9	13	'A	'N	'D	'<
0161	94	12	94	13	'>	'T	'H	'<
0165	92	39	2D	2A	'>	'T	'H	'<
0169	B3	39	B4	38	'N	'T	'Q	'S
016D	39	2A	B5	31	'T	'E	'P	'L
0171	35	37	2E	33	'T	'P	'R	'I
0175	B9	31	31	2E	'T	'L	'L	'I
0179	38	B9	38	39	'S	'T	'S	'I
017D	34	B5	38	31	'S	'O	'P	'S
0181	34	BC	2B	26	'O	'W	'F	'L
0185	38	B9	33	2A	'S	'T	'N	'C
0189	BC	38	28	37	'W	'S	'L	'C
018D	34	31	B1	28	'O	'N	'L	'C
0191	34	33	B9	29	'O	'I	'M	'R
0195	2E	B2	37	2A	'M	'F	'O	'R
0199	B2	2B	34	B7	'M	'G	'O	'T
019D	2C	34	39	B4	'G	'O	'T	'O
01A1	2C	34	38	3A	'G	'O	'T	'O
01A5	A7	2E	33	35	'B	'I	'N	'L
01A9	3A	B9	31	34	'U	'T	'L	'L
01AD	26	A9	31	2E	'A	'D	'L	'L
01B1	38	B9	31	2A	'S	'T	'P	'L
01B5	B9	35	26	3A	'S	'T	'P	'L
01B9	38	AA	33	2A	'S	'E	'N	'E
01BD	3D	B9	35	34	'X	'T	'P	'O
01C1	30	AA	35	37	'K	'E	'P	'P
01C5	2E	33	B9	35	'I	'N	'T	'P
01C9	31	34	B9	37	'L	'O	'T	'P
01CD	3A	B3	38	26	'U	'N	'S	'R
01D1	3B	AA	37	26	'V	'E	'S	'R
01D5	33	A9	2E	AB	'N	'D	'I	'F
01D9	28	31	B8	3A	'C	'L	'S	'U
01DD	33	35	31	34	'N	'T	'P	'L
01E1	B9	28	31	2A	'A	'R	'R	'E
01E5	26	B7	37	2A	'A	'T	'U	'P
01E9	39	3A	37	B3	'T	'C	'O	'P
01ED	28	34	35	BE	'C	'R	'N	'K
01F1	37	33	A9	2E	'\$	'P	'I	'Y
01F5	33	30	2A	3E	'\$	'P	'I	'Y
01F9	8D	35	AE		'\$	'P	'I	'Y

THE 'LOAD/SAVE UPDATE' SUBROUTINE

HL is incremented until it matches the current value in 'E-LINE'.

```
01FC LOAD/SAVE INC HL
                     EX DE,HL
                     LD HL,(E-LINE)
                     SCF
                     SBC HL,DE
                     EX DE,HL
                     RET NC
                     POP HL
```

THE DISPLAY ROUTINES:

i) Test for SLOW or FAST Mode.

The SLOW flag, Bit 6 of CDFLAG is tested, and a return is made if the program is in FAST mode or 'SLOW' display is not available.

```
0207 SLOW/FAST LD HL, + CDFLAG
                LD A,(HL)
                RLA
                XOR (HL)
                RLA
                RET NC
                LD A, + 7F
                EX AF,A'F'
                LD B, + 11
                OUT (+FE),A
0216 LOOP-11 DJNZ 0216,LOOP-11
                OUT (+FD),A
                EX AF,A'F'
                RLA
                JR NC,0226,NO-SLOW
                SET 7,(HL)
                PUSH AF
                PUSH BC
                PUSH DE
                PUSH HL
                JR 0229,DISPLAY-1
0226 NO-SLOW RES 6,(HL)
                RET
```

11) The main display routine.

The frame counter is first collected and decremented. A return is made if the frame counter reaches zero.

```
0229 DISPLAY-1 LD HL,(FRAMES)
                DEC HL
022D DISPLAY-P LD A, + 7F
                AND H
                OR L
                LD A,H
                JR NZ,0237,ANOTHER
                RLA
                JR 0239,OVER-NC
0237 ANOTHER LD B,(HL)
                SCF
0239 OVER-NC LD H,A
                LD (FRAMES),HL
                RET NC
```

The keyboard is now read, and a return is made if a new key has been pressed. Otherwise a display is produced.

```
023E DISPLAY-2 CALL 02BB,KEYBOARD
                LD BC,(LAST-K)
                LD (LAST-K),HL
                LD A,B
                ADD A, + 02
                SBC HL,BC
                LD A,(DEBOUNCE)
                OR H
                OR L
                LD E,B
                LD B, + 0B
                LD HL, + CDFLAG
                RES 0,(HL)
                JR NZ,0264,NO-KEY
                BIT 7,(HL)
                SET 0,(HL)
                RET Z
                DEC B
                NOP
                SCF
0264 NO-KEY LD HL, + DEBOUNCE
                CCF
                RL
                B
026A LOOP-B DJNZ 026A,LOOP-B
                LD B,(HL)
                LD A,E
                CP + FE
                SBC A,A
                LD B, + 1F
                OR (HL)
                AND B
                RRA
                LD (HL),A
                OUT (+FF),A
                LD HL,(D-FILE)
                SET 7,H
                CALL 0292,DISPLAY-3
                LD A,R
                LD BC, + 1901
                LD A, + F5
                CALL 02B5,DISPLAY-5
                DEC HL
                CALL 0292,DISPLAY-3
                JP 0229,DISPLAY-1
```

The IX register is loaded with the 'return' address, and the main registers are restored after a 'slow' display.

```
0292 DISPLAY-3 POP IX
                LD C,(MARGIN)
                BIT 7,(CDFLAG)
                JR Z,02A9,DISPLAY-4
                LD A,C
                NEG A
                INC A
                EX AF,A'F'
                OUT (+FE),A
                POP HL
                POP DE
                POP BC
                POP AF
                RET
```

Sets up the A and B registers for the display.

```
02A9 DISPLAY-4 LD A, +FC
                LD B, +01
                CALL 02B5, DISPLAY-5
                DEC HL
                EX (SP), HL
                EX (SP), HL
                JP (IX)
```

Sets up the refresh register and waits for an interrupt.

```
02B5 DISPLAY-5 LD R, A
                LD A, +DD
                EI
                JP (HL)
```

THE 'KEYBOARD SCANNING' SUBROUTINE

The keyboard is scanned eight times and the result built up in the HL register pair. MARGIN is also determined.

```
02BB KEYBOARD LD HL, +FFFF
                LD BC, +FEFE
                IN A, (C)
                OR +01
02C5 EACH-LINE OR +EO
                LD D, A
                CPL
                CP +01
                SBC A, A
                OR B
                AND L
                LD L, A
                LD A, H
                AND D
                LD H, A
                RLC B
                IN A, (C)
                JR C, 02C5, EACH-LINE
                RRA
                RL H
                RLA
                RLA
                RLA
                SBC A, A
                AND +18
                ADD A, +1F
                LD (MARGIN), A
                RET
```

THE 'SET FAST MODE' SUBROUTINE

The NMI generator is turned off and bit 7 of CDFLAG is RESET. Bit 6 will remain SET if the overall mode is SLOW, i.e. in PAUSE.

```
02E7 SET-FAST BIT 7, (CDFLAG)
                RET Z
                HALT
                OUT (+FD), A
                RES 7, (CDFLAG)
                RET
```

REPORT F — No name supplied.

```
02F4 REPORT-F RST 0008, ERROR-1
                DEFB +0E
```

THE 'SAVE' COMMAND ROUTINE

HL is set to point to the start of the program name. There is a 6 second header and then the bytes of the name and the program are passed out to the cassette recorder.

```
02F6 SAVE CALL 03A8, NAME
                JR C, 02F4, REPORT-F
                EX DE, HL
                LD DE, +12CB
02FF HEADER CALL 0F46, BREAK-1
                JR NC, 0332, BREAK-2
0304 DELAY-1 DJNZ 0304, DELAY-1
                DEC DE
                LD A, D
                OR E
                JR NZ, 02FF, HEADER
030B OUT-NAME CALL 031E, OUT-BYTE
                BIT 7, (HL)
                INC HL
                JR Z, 030B, OUT-NAME
                LD HL, +VERSN
0316 OUT-PROG. CALL 031E, OUT-BYTE
                CALL 01FC, LOAD/SAVE
                JR 0316, OUT-PROG.
031E OUT-BYTE LD E, (HL)
                SCF
0320 EACH-BIT RL E
                RET Z
                SBC A, A
                AND +05
                ADD +04
                LD C, A
0329 PULSES OUT (+FF), A
                LD B, +23
032D DELAY-2 DJNZ 032D, DELAY-2
                CALL 0F46, BREAK-1
0332 BREAK-2 JR NC, 03A6, REPORT-D
                LD B, +1E
0336 DELAY-3 DJNZ 0336, DELAY-3
                DEC C
                JR NZ, 0329, PULSES
033B DELAY-4 AND A
                DJNZ 033B, DELAY-4
                JR 0320, EACH-BIT
```

THE 'LOAD' COMMAND ROUTINE

The bytes collected from the tape are matched against the program name and then the program is loaded into RAM.

```
0340 LOAD CALL 03A8, NAME
                RL D
                RRC D
0347 NEXT-PROG CALL 034C, IN-BYTE
                JR 0347, NEXT-PROG
034C IN-BYTE LD C, +01
034E NEXT-BIT LD B, +00
0350 BREAK-3 LD A, +7F
                IN A, (+FE)
                OUT (+FF), A
                RRA
                JR NC, 03A2, BREAK-4
                RLA
                RLA
```



```

JR      C,0385,GET-BIT
DJNZ    0350,BREAK-3
POP      AF
CP       D
0361 RESTART JP    NC,03E5,INITIAL.
LD       H,D
LD       L,E
0366 IN-NAME CALL   034C,IN-BYTE
BIT      7,D
LD       A,C
JR      NZ,0371,MATCHING
CP       (HL)
JR      NZ,0347,NEXT-PROG
0371 MATCHING INC    HL
RLA
JR      NC,0366,IN-NAME
INC      (E-LINE-hi.)
LD       HL, + VERSN
037B IN-PROG. LD       D,B
CALL     034C,IN-BYTE
LD       (HL),C
CALL     01FC,LOAD/SAVE
JR      037B,IN-PROG
0385 GET-BIT  PUSH   DE
LD       E, + 94
0388 TRAILER LD       B, + 1A
038A COUNTER DEC     E
IN       A,(+ FE)
RLA
BIT      7,E
LD       A,E
JR      C,0388,TRAILER
DJNZ    038A,COUNTER
POP      DE
JR      NZ,039C,BIT-DONE
CP       + 56
JR      NC,034E,NEXT-BIT
039C BIT-DONE CCF
RL       C
JR      NC,034E,NEXT-BIT
RET
03A2 BREAK-4 LD       A,D
AND      A
JR      Z,0361,RESTART

```

REPORT-D — Break pressed

```

03A6 REPORT-D RST     0008,ERROR-1
DEFB         + OC

```

THE 'PROGRAM NAME' SUBROUTINE

The name is checked for 'report C', 'FAST' mode is selected and the final letter of the name is inverted.

```

03A8 NAME CALL   0F55,SCANNING
LD       A,(FLAGS)
ADD      A,A
JP       M,0D9A,REPORT-C
POP      HL
RET      NC
PUSH     HL
CALL     02E7,SET-FAST
CALL     13F8,STK-FETCH
LD       H,D
LD       L,E
DEC      C

```

```

RET      M
ADD      HL,BC
SET      7,(HL)
RET

```

THE 'NEW' COMMAND ROUTINE

'FAST' mode is selected and BC is loaded with the present value of RAMTOP.

```

03C3 NEW CALL   02E7,SET-FAST
LD       BC,(RAMTOP)
DEC      BC

```

THE RAM-CHECK ROUTINE

Starting with location RAMTOP-1 an attempt is made to fill each location with 02. The addresses are decremented until 3FFF is reached. Each location is then read-back until the first address that does not fetch 02 is found. This address is RAMTOP.

```

03CB RAM-CHECK LD       H,B
LD       L,C
LD       A, + 3F
03CF RAM-FILL LD       (HL), + 02
DEC      HL
CP       H
JR      NZ,03CF,RAM-FILL
03D5 RAM-READ AND      A
SBC      HL,BC
ADD      HL,BC
INC      HL
JR      NC,03E2,SET-TOP
DEC      (HL)
JR      Z,03E2,SET-TOP
DEC      (HL)
JR      Z,03D5,RAM-READ
03E2 SET-TOP LD       (RAMTOP),HL

```

THE INITIALISATION ROUTINE

The different tasks of the initialisation routine are:

- i. Set the top location in RAM to hold 3E.
- ii. Set the stack pointer to point to the next location below.
- iii. Set ERR-SP to hold the address two locations below the stack pointer.
- iv. Set the I register to hold 1E.
- v. Select interrupt mode 1.
- vi. Set the IY register to hold ERR-NR as its base address.
- vii. Select 'SLOW' mode.
- viii. Set D-FILE to hold PROGRAM, i.e. No program present.
- ix. Make a collapsed D-FILE.
- x. Set VARS.
- xi. CALL CLEAR command routine.
- xii. Put the cursor in the edit line.
- xiii. Produce a 'SLOW' display.

```

03E5 INITIAL    LD    HL,(RAMTOP)
                DEC    HL
                LD    (HL), + 3E
                DEC    HL
                LD    SP,HL
                DEC    HL
                DEC    HL
                LD    (ERR-SP),HL
                LD    A, + 1E
                LD    I,A
                IM1
                LD    IY, + ERR-NR
                LD    (CDFLAG), + 40
                LD    HL, + PROGRAM
                LD    (D-FILE),HL
                LD    B, + 19
0408 LINE      LD    (HL), + 76
                INC    HL
                DJNZ   0408,LINE
                LD    (VARS),HL
                CALL   149A,CLEAR
0413 N/L-ONLY  CALL   14AD,CURSOR-IN
                CALL   0207,SLOW/FAST

```

PRODUCE THE BASIC LISTING

The 'upper' part of the display is produced by first calling the CLS command routine, then the BASIC program is listed from S-TOP.

The use of the 'cursor down' key also causes the 'upper' part of the display to be rebuilt.

```

0419 UPPER     CALL   0A2A,CLS
                LD    HL,(E-PPC)
                LD    DE,(S-TOP)
                AND    A
                SBC    HL,DE
                EX     DE,HL
                JR     NC,042D,ADDR-TOP
                ADD    HL,DE
                LD    (S-TOP),HL
042D ADDR-TOP  CALL   09D8,LINE-ADDR
                JR     Z,0433,LIST-TOP
                EX     DE,HL
0433 LIST-TOP  CALL   073E,LIST-PROG
                DEC    (BERG)
                JR     NZ,0472,LOWER
                LD    HL,(E-PPC)
                CALL   09D8,LINE-ADDR
                LD    HL,(CH-ADD)
                SCF
                SBC    HL,DE
                LD    HL, + S-TOP
                JR     NC,0457,INC-LINE
                EX     DE,HL
                LD    A,(HL)
                INC    HL
                LDI
                LD    (DE),A
                JR     0419,UPPER

```

'cursor down' entry point.

```

0454 DOWN-KEY LD    HL, + E-PPC
0457 INC-LINE LD    E,(HL)
                INC    HL

```

```

                LD    D,(HL)
                PUSH   HL
                EX     DE,HL
                INC    HL
                CALL   09D8,LINE-ADDR
                CALL   05BB,LINE-NO.
                POP    HL
0464 KEY-INPUT BIT    5,(FLAGX)
                JR     NZ,0472,LOWER
                LD    (HL),D
                DEC    HL
                LD    (HL),E
                JR     0419,UPPER

```

COPY THE EDIT-LINE

The 'lower' part of the display is formed by copying the edit-line from the workspace to the bottom of the screen.

First floating point numbers are removed, then the blank part of the screen is defined and finally the edit-line is copied over with the 'lower' part of the screen being expanded if necessary.

The EDIT-INP. entry point comes into use when EDIT is used in reply to a request for INPUT.

```

046F EDIT-INP. CALL   14AD,CURSOR-IN
0472 LOWER     LD    HL,(E-LINE)
0475 EACH-CHAR LD    A,(HL)
                CP     + 7E
                JR     NZ,0482,END-LINE
                LD    BC, + 0006
                CALL   0A60,RECLAIM-2
                JR     0475,EACH-CHAR
0482 END-LINE  CP     + 76
                INC    HL
                JR     NZ,0475,EACH-CHAR
0487 EDIT-LINE CALL   0537,CURSOR
048A EDIT-ROOM CALL   0A1F,LINE-ENDS
                LD    HL,(E-LINE)
                LD    (ERR-NR), + FF
                CALL   0766,COPY-LINE
                BIT    7,(ERR-NR)
                JR     NZ,04C1,DISPLAY-6
                LD    A,(DF-SZ)
                CP     + 18
                JR     NC,04C1,DISPLAY-6
                INC    A
                LD    (DF-SZ),A
                LD    B,A
                LD    C, + 01
                CALL   0918,LOC.-ADDR
                LD    D,H
                LD    E,L
                LD    A,(HL)
04B1 FREE-LINE DEC    HL
                CP     (HL)
                JR     NZ,04B1,FREE-LINE
                INC    HL
                EX     DE,HL
                LD    A,(RAMTOP-hi.)
                CP     + 4D
                CALL   C,0A5D,RECLAIM-1
                JR     048A,EDIT-ROOM

```


WAITING FOR A KEY

The syntax error pointer is set to zero and a display is produced. Once a key has been pressed the display is terminated. The pressing of 'multiple keys' causes a jump back to LOWER.

```

04C1 DISPLAY-6 LD HL, +0000
               LD (X-PTR),HL
               LD HL, +CFLAG
               BIT 7,(HL)
               CALL Z,0229,DISPLAY-1
04CF SLOW-DISP BIT 0,(HL)
               JR Z,04CF,SLOW-DISP
               LD BC,(LAST-K)
               CALL 0F4B,D-BOUNCE
               CALL 07BD,DECODE
               JR NC,0472,LOWER

```

MODE SORTING

The differing modes give differing values for the keys of the keyboard. These are obtained from the key tables.

```

04DF MODE-SORT LD A,(MODE)
               DEC A
               JP M,0508,FETCH-2
               JR NZ,04F7,FETCH-1
               LD (MODE),A
               DEC E
               LD A,E
               SUB +27
               JR C,04F2,FUNC-BASE
04F2 FUNC-BASE LD HL, +00CC
               JR 0505,TABLE-ADD
04F7 FETCH-1 LD A,(HL)
               CP +78
               JR Z,052B,K/L-KEY
               CP +40
               SET 7,A
               JR C,051B,ENTER
               LD HL, +00C7
0505 TABLE-ADD ADD HL,DE
               JR 0515,FETCH-3
0508 FETCH-2 LD A,(HL)
               BIT 2,(FLAGS)
               JR NZ,0516,TEST-CURS
               ADD A, +C0
               CP +E6
               JR NC,0516,TEST-CURS
0515 FETCH-3 LD A,(HL)
0516 TEST-CURS CP +F0
               JP PE,052D,KEY-SORT
051B ENTER LD E,A
               CALL 0537,CURSOR
               LD A,E
               CALL 0526,ADD-CHAR
0523 BACK-NEXT JP 0472,LOWER

```

THE 'ADD-CHAR' SUBROUTINE

All of the RAM from (HL) to STKEND is moved up by one byte and the character code in the A register is entered into the extra location.

```

0526 ADD-CHAR CALL 099B,ONE-SPACE
               LD (DE),A
               RET

```

SORTING THE CURSOR KEYS

The addresses of the different routines for the cursor keys are obtained by adding the character code twice to the base address 0482. The address is then stacked.

```

052B K/L-KEY LD A, +78
052D KEY-SORT LD E,A
               LD HL, +0482
               ADD HL,DE
               ADD HL,DE
               LD C,(HL)
               INC HL
               LD B,(HL)
               PUSH BC

```

CHOOSING K v. L MODE

The characters in the edit-line are read in turn.

Initially K-mode is selected but it will be changed to L-mode unless the line holds only the cursor or the last token is THEN. The RET Z instruction takes the program to the cursor key routines.

```

0537 CURSOR LD HL,(E-LINE)
            BIT 5,(FLAGX)
            JR NZ,0556,L-MODE
0540 K-MODE RES 2,(FLAGS)
0544 TEST-CHAR LD A,(HL)
               CP +7F
               RET Z
               INC HL
               CALL 07B4,NUMBER
               JR Z,0544,TEST-CHAR
               CP +26
               JR C,0544,TEST-CHAR
               CP +DE
               JR Z,0540,K-MODE
0556 L-MODE SET 2,(FLAGS)
               JR 0544,TEST-CHAR

```

THE 'CLEAR-ONE' SUBROUTINE

The single character (HL) is overwritten by moving all of the RAM from (HL + 1)-STKEND down by one byte.

```

055C CLEAR-ONE LD BC, +0001
               JP 0A60,RECLAIM-2

```

THE CURSOR KEY TABLE

0562	9F	05	UP-KEY	059F
0564	54	04	DOWN-KEY	0454
0566	76	05	LEFT-KEY	0576
0568	7F	05	RIGHT-KEY	057F
056A	AF	05	GRAPHICS	05AF
056C	C4	05	EDIT-KEY	05C4
056E	0C	06	N/L-KEY	060C
0570	8B	05	RUBOUT	058B
0572	AF	05	FUNCTION	05AF
0574	AF	05	FUNCTION	05AF

THE CURSOR LEFT ROUTINE

```

0576 LEFT-KEY  CALL 0593,LEFT-EDGE
                LD  A,(HL)
                LD  (HL),+7F
                INC  HL
                JR   0588,GET-CODE

```

THE CURSOR RIGHT ROUTINE

```

057F RIGHT-KEY INC  HL
                LD  A,(HL)
                CP  +7F
                JR  Z,059D,ENDED-2
                LD  (HL),+7F
                DEC  HL
0588 GET-CODE  LD  (HL),A
0589 ENDED-1   JR  0523,BACK-NEXT

```

THE RUBOUT ROUTINE

```

058B RUBOUT   CALL 0593,LEFT-EDGE
                CALL 055C,CLEAR-ONE
                JR   0589,ENDED-1

```

THE 'LEFT-EDGE' SUBROUTINE

The first character in the edit-line is tested against +7F, the cursor.

```

0593 LEFT-EDGE DEC  HL
                LD  DE,(E-LINE)
                LD  A,(DE)
                CP  +7F
                RET  NZ
                POP  DE
059D ENDED-2   JR  0589,ENDED-1

```

THE CURSOR UP ROUTINE

```

059F UP-KEY   LD  HL,(E-PPC)
                CALL 09D8,LINE-ADDR
                EX  DE,HL
                CALL 05BB,LINE-NO.
                LD  HL,+E-PPC-hi.
                JP  0464,KEY-INPUT

```

THE FUNCTION KEY ROUTINE

```

05AF FUNCTION LD  A,E
                AND  +07
                LD  (MODE),A
                JR   059D,ENDED-2

```

THE 'COLLECT LINE NUMBER' SUBROUTINE

The subroutine is entered at LINE-NO. with an address in HL. If a line number is to be found at that position then it is returned in DE, otherwise DE is returned with +0000.

```

05B7 ZERO-DE  EX  DE,HL
                LD  DE,+04C2
05BB LINE-NO. LD  A,(HL)
                AND  +00
                JR  NZ,05B7,ZERO-DE
                LD  D,(HL)
                INC  HL

```

```

LD  E,(HL)
RET

```

THE EDIT KEY ROUTINE

First the 'lower' part of the screen is cleared, then the flag that shows whether the INPUT command is being followed, is tested and a return made if the flag is set.

Next the line to be edited is located. Its number is printed, followed by the cursor, but before the line itself is copied into the workspace a test for sufficient room is made.

A return is made if there is not enough available RAM.

```

05C4 EDIT-KEY CALL 0A1F,LINE-ENDS
                LD  HL,+EDIT-INP.
                PUSH HL
                BIT  5,(FLAGX)
                RET  NZ
                LD  HL,(E-LINE)
                LD  (DF-CC),HL
                LD  HL,+1821
                LD  (S-POSN),HL
                LD  HL,(E-PPC)
                CALL 09D8,LINE-ADDR
                CALL 05BB,LINE-NO.
                LD  A,D
                OR  E
                RET  Z
                DEC  HL
                CALL 0AA5,OUT-NO.
                INC  HL
                LD  C,(HL)
                INC  HL
                LD  B,(HL)
                INC  HL
                LD  DE,(DF-CC)
                LD  A,+7F
                LD  (DE),A
                INC  DE
                PUSH HL
                LD  HL,+001D
                ADD  HL,DE
                ADD  HL,BC
                SBC  HL,SP
                POP  HL
                RET  NC
                LDIR
                EX  DE,HL
                POP  DE
                CALL 14A6,SET-STK-B
                JR   059D,ENDED-2

```

THE NEWLINE KEY ROUTINE

The NEWLINE key can be used in three separate situations and these have to be dealt with in different ways.

The first part of the routine is common to all situations.

The 'lower' part of the screen is cleared. The PRBUFF is also cleared unless the INPUT command is being used, or the direct command COPY.

The line is then scanned to check for syntax errors. The cursor is removed and the line number found, if present.

```

060C N/L-KEY    CALL    0A1F,LINE-ENDS
                LD      HL, + LOWER
                BIT     5,(FLAGX)
                JR      NZ,0629,NOW-SCAN
                LD      HL,(E-LINE)
                LD      A,(HL)
                CP      +FF
                JR      Z,0626,STK-UPPER
                CALL    08E2,CLEAR-PRB
                CALL    0A2A,CLS
0626 STK-UPPER  LD      HL, + UPPER
0629 NOW-SCAN  PUSH    HL
                CALL    0CBA, LINE-SCAN
                POP     HL
                CALL    0537,CURSOR
                CALL    055C,CLEAR-ONE
                CALL    0A73,E-LINE-NO
                JR      NZ,064E,N/L-INP.
                LD      A,B
                OR      C
                JP      NZ,06E0,N/L-LINE

```

The second part sets up the required parameters for the execution of a line, either as a BASIC line or as an INPUT line.

An empty line is detected and the program jumps back to the Initialisation routine.

```

                DEC     BC
                DEC     BC
                LD      (PPC),BC
                LD      (DF-SZ), + 02
                LD      DE,(D-FILE)
064E N/L-INP.   JR      0661,TEST-NULL
                CP      +76
                JR      Z,0664,N/L-NULL
                LD      BC,(T-ADDR)
                CALL    0918,LOC.-ADDR
                LD      DE,(NXTLIN)
                LD      (DF-SZ), + 02
0661 TEST-NULL RST     0018,GET-CH
                CP      +76
0664 N/L-NULL  JP      Z,0413,N/L-ONLY
                LD      (FLAGS), + 80
                EX      DE,HL

```

The third part of the routine is the 'line execution loop'. When a BASIC program is being RUN it is this 'loop' that leads to the execution of the BASIC lines in their correct order.

In the case of the INPUT command the 'line' is detected as input in the LINE-RUN subroutine.

```

068C NEXT-LINE LD      (NXTLIN),HL
                EX      DE,HL
                CALL    004D,TEMP-PTR
                CALL    00C1,LINE-RUN
                RES     1,(FLAGS)
                LD      A, + CO
                LD      (X-PTR-HI.),A
                CALL    14A3,X-TEMP

```

```

RES     5,(FLAGX)
BIT     7,(ERR-NR)
JR      Z,06AE,STOP-LINE
LD      HL,(NXTLIN)
AND     (HL)
JR      NZ,06AE,STOP-LINE
LD      D,(HL)
INC     HL
LD      E,(HL)
LD      (PPC),DE
INC     HL
LD      E,(HL)
INC     HL
LD      D,(HL)
INC     HL
EX      DE,HL
ADD     HL,DE
CALL    0F46,BREAK-1
JR      C,066C,NEXT-LINE

```

The third part of the routine is used to produce the report at the end of a RUN, after other direct commands and following the use of the BREAK key.

```

                LD      HL, + ERR-NR
                BIT     7,(HL)
                JR      Z,06AE,STOP-LINE
                LD      (HL), + 0C
06AE STOP-LINE BIT     7,(PR-CC)
                CALL    Z,0871,COPY-BUFF
                LD      BC, + 0121
                CALL    0918,LOC.-ADDR
                LD      A,(ERR-NR)
                LD      BC,(PPC)
                INC     A
                JR      Z,06D1,REPORT
                CP      +09
                JR      NZ,06CA,CONTINUE
                INC     BC
06CA CONTINUE  LD      (OLDPPC),BC
                JR      NZ,06D1,REPORT
                DEC     BC
06D1 REPORT    CALL    07EB,OUT-CODE
                LD      A, + 18
                RST     0010,PRINT-A
                CALL    0A98,OUT-NUM.
                CALL    14AD,CURSOR-IN
                JP      04C1,DISPLAY-6

```

The fourth part of the routine is involved in the entering of a BASIC line into its correct position in the BASIC program.

Initially a search is made to see if there is already a line with the same name number. If a line is found then it is 'reclaimed'.

The new line is then copied from the workspace to its correct place in the BASIC program.

```

06E0 N/L-LINE  LD      (E-PPC),BC
                LD      HL,(CH-ADD)
                EX      DE,HL
                LD      HL, + N/L-ONLY
                PUSH    HL
                LD      HL,(STKBOT)
                SBC     HL,DE

```

```

                                PUSH HL
                                PUSH BC
                                CALL 02E7,SET-FAST
                                CALL 0A2A,CLS
                                POP HL
                                CALL 09D8,LINE-ADDR
                                JR NZ,0705,COPY-OVER
                                CALL 09F2,NEXT-ONE
                                CALL 0A60,RECLAIM-2
0705 COPY-OVER POP BC
                                LD A,C
                                DEC A
                                OR B
                                RET Z
                                PUSH BC
                                INC BC
                                INC BC
                                INC BC
                                INC BC
                                DEC HL
                                CALL 099E,MAKE-ROOM
                                CALL 0207,SLOW/FAST
                                POP BC
                                PUSH BC
                                INC DE
                                LD HL,(STKBOT)
                                DEC HL
                                LDDR
                                LD HL,(E-PPC)
                                EX DE,HL
                                POP BC
                                LD (HL),B
                                DEC HL
                                LD (HL),C
                                DEC HL
                                LD (HL),E
                                DEC HL
                                LD (HL),D
                                RET

```

THE 'LIST' COMMAND ROUTINE

The 'LIST' command will list the BASIC program from a given line, or line zero if no number is supplied.

The first part of the routine finds the 'parameter' and saves the line number in E-PPC. The second part of the routine repeatedly calls the OUT-LINE subroutine until either the screen is full or the last line has been printed.

```

072C LLIST SET 1,(FLAGS)
0730 LIST CALL 0EA7,FIND-INT.
                                LD A,B
                                AND +3F
                                LD H,A
                                LD L,C
                                LD (E-PPC),HL
                                CALL 09D8,LINE-ADDR
                                LD E,+00
                                CALL 0745,OUT-LINE
                                JR 0740,UNTIL-END

```

THE 'PRINT A BASIC LINE' SUBROUTINE

The first part of the routine fetches the line number of the 'current cursor line' and tests it against the line number that it is to print. The line number is then printed followed by the 'current line cursor' if required, or a space if not.

```

0745 OUT-LINE LD BC,(E-PPC)
                                CALL 09EA,CP-LINES
                                LD D,+92
                                JR Z,0755,TEST-END
                                LD DE,+0000
                                RL E
0755 TEST-END LD (BERG),E
                                LD A,(HL)
                                CP +40
                                POP BC
                                RET NC
                                PUSH BC
                                CALL 0AA5.OUT-NO.
                                INC HL
                                LD A,D
                                RST 0010,PRINT-A
                                INC HL
                                INC HL

```

The second part of the routine prints the actual line. By comparing CH-ADD & X-PTR the routine tests to see if the syntax error marker should be printed. The routine also tests for floating point numbers and jumps over them. When a 'token' is found a call is made to the 'token printing' subroutine. When the cursor marker is found the appropriate cursor is printed.

```

0766 COPY-LINE LD (CH-ADD),HL
                                SET 0,(FLAGS)
076D MORE-LINE LD BC,(X-PTR)
                                LD HL,(CH-ADD)
                                AND A
                                SBC HL,BC
                                JR NZ,077C,TEST-NUM.
                                LD A,+B8
                                RST 0010,PRINT-A
077C TEST-NUM. LD HL,(CH-ADD)
                                LD A,(HL)
                                INC HL
                                CALL 07B4,NUMBER
                                LD (CH-ADD),HL
                                JR Z,076D,MORE-LINE
                                CP +7F
                                JR Z,079D,OUT-CURS.
                                CP +76
                                JR Z,07EE,OUT-CH
                                BIT 6,A
                                JR Z,079A,NOT-TOKEN
                                CALL 094B,TOKENS
                                JR 076D,MORE-LINE
079A NOT-TOKEN RST 0010,PRINT-A
                                JR 076D,MORE-LINE
079D OUT-CURS. LD A,(MODE)
                                LD B,+AB
                                AND A

```

```

                                JR      NZ,07AA,FLAGS-2
                                LD      A,(FLAGS)
                                LD      B,+B0
07AA FLAGS-2      RRA
                                RRA
                                AND     +01
                                ADD     A,B
                                CALL    07F5,PRINT-SP.
                                JR      076D,MORE-LINE

```

THE 'NUMBER' SUBROUTINE

This subroutine tests the character in the A register against the 'number marker'. If a match occurs then the value in the HL register pair is incremented five times, so as to either skip over the floating point number, or to reserve 5 bytes for such a number.

```

07B4 NUMBER      CP      +7E
                                RET     NZ
                                INC     HL
                                INC     HL
                                INC     HL
                                INC     HL
                                INC     HL
                                RET

```

THE 'KEYBOARD DECODE' SUBROUTINE

The different 'key values', held in the BC register pair, are 'decoded' into the usual ZX81 character codes by looking-up the key table at 007E. (007D + 1) The character code is specified as (HL).

```

07BD DECODE      LD      D,+00
                                SRA     B
                                SBC     A,A
                                OR      +26
                                LD      L,+05
                                SUB     L
07C7 KEY-LINE    ADD     A,L
                                SCF
                                RR      C
                                JR      C,07C7,KEY-LINE
                                INC     C
                                RET     NZ
                                LD      C,B
                                DEC     L
                                LD      L,+01
                                JR      NZ,07C7,KEY-LINE
                                LD      HL,+007D
                                LD      E,A
                                ADD     HL,DE
                                SCF
                                RET

```

THE 'PRINTING' SUBROUTINE

The two little routines WRITE-CH & WRITE-N/L are the essential parts of the printing subroutine. However before a character can be actually printed it is necessary for S-POSN to be collected and tested, and the display expanded if required.

The various entry points to the subroutine are involved with the conversion of Hex. codes to ZX81 character codes.

i) Printing digits:

```

07DC LEAD-SP.    LD      A,E
                                AND     A
                                RET     M
                                JR      07F1,PRINT-CH.
07E1 OUT-DIGIT   XOR     A
07E2 DIGIT-INC   ADD     HL,BC
                                INC     A
                                JR      C,07E2,DIGIT-INC
                                SBC     HL,BC
                                DEC     A
                                JR      Z,07DC,LEAD-SP.
07EB OUT-CODE    LD      E,+1C
                                ADD     A,E
07EE OUT-CH      AND     A
                                JR      Z,07F5,PRINT-SP.

```

ii) Printing characters:

```

07F1 PRINT-CH.   RES     0,(FLAGS)
07F5 PRINT-SP.   EXX
                                PUSH    HL
                                BIT     1,(FLAGS)
                                JR      NZ,0802,LPRINT-A
                                CALL    0808,ENTER-CH
                                JR      0805,PRINT-EXX
0802 LPRINT-A    CALL    0851,LPRINT-CH
0805 PRINT-EXX   POP     HL
                                EXX
                                RET

```

iii) Testing S-POSN:

```

0808 ENTER-CH    LD      D,A
                                LD      BC,(S-POSN)
                                LD      A,C
                                CP      +21
                                JR      Z,082C,TEST-LOW
0812 TEST-N/L    LD      A,+76
                                CP      D
                                JR      Z,0847,WRITE-N/L
                                LD      HL,(DF-CC)
                                CP      (HL)
                                LD      A,D
                                JR      NZ,083E,WRITE-CH
                                DEC     C
                                JR      NZ,083A,EXPAND-1
                                INC     HL
                                LD      (DF-CC),HL
                                LD      C,+21
                                DEC     B
                                LD      (S-POSN),BC
082C TEST-LOW    LD      A,B
                                CP      (DF-SZ)
                                JR      Z,0835,REPORT-5
                                AND     A
                                JR      NZ,0812,TEST-N/L

```

iv) REPORT-5 — insufficient room:

```

0835 REPORT-5    LD      L,+04
                                JP      0058,ERROR-3

```


v) Expand the display:

```
083A EXPAND-1  CALL 099B,ONE-SPACE
                EX   DE,HL
```

vi) Writing an actual code:

```
083E WRITE-CH  LD      (HL),A
                INC     HL
                LD      (DF-CC),HL
                DEC     (S-POSN-lo.)
                RET
```

vii) Writing a N/L:

This is performed by decrementing the 'line counter' and using LOC.ADDR to give the correct values for DF-CC & S-POSN.

```
0847 WRITE-N/L LD      C, + 21
                DEC     B
                SET     0,(FLAGS)
                JP      0918,LOC.-ADDR
```

THE 'LPRINT-CH' SUBROUTINE

Characters are added one by one to the printer buffer. Once the buffer is full, or a N/L character is entered the buffer is emptied.

```
0851 LPRINT-CH CP      + 76
                JR      Z,0871,COPY-BUFF
                LD      C,A
                LD      A,(PR-CC)
                AND     + 7F
                CP      + 5C
                LD      L,A
                LD      H, + 40
                CALL    Z,0871,COPY-BUFF
                LD      (HL),C
                INC     L
                LD      (PR-CC),L
                RET
```

THE 'COPY' COMMAND ROUTINE

The COPY command routine starts with the D register being loaded with Hex.16, being the number of lines in a full display. The Copy*D routine is then used to output these lines to the printer.

```
0869 COPY      LD      D, + 16
                LD      HL, + D-FILE
                INC     HL
                JR      0876,COPY*D
```

In COPY-BUFF the D register is only required to be given the value Hex.01.

```
0871 COPY-BUFF LD      D, + 01
                LD      HL, + PRBUFF
```

In COPY*D a loop is set up with D being the counter.

```
0876 COPY*D    CALL    02E7,SET-FAST
                PUSH    BC
```

```
087A COPY-LOOP PUSH    HL
                XOR     A
                LD      E,A
087D COPY-TIME OUT     (+ FB),A
                POP     HL
0880 COPY-BRK  CALL    0F46,BREAK-1
                JR      C,088A,COPY-CONT
                RRA
                OUT     (+ FB),A
0888 REPORT-D2 RST     0008,ERROR-1
                DEFB    + 0C
088A COPY-CONT IN      A,(+ FB)
                ADD     A,A
                JP      M,08DE,COPY-END
                JR      NC,0880,COPY-BRK
                PUSH    HL
                PUSH    DE
                LD      A,D
                CP      + 02
                SBC     A,A
                AND     E
                RLCA
                AND     E
                LD      D,A
089C COPY-NEXT LD      C,(HL)
                LD      A,C
                INC     HL
                CP      + 76
                JR      Z,08C7,COPY-N/L
                PUSH    HL
                SLA     A
                ADD     A,A
                ADD     A,A
                LD      H, + 0F
                RL      H
                ADD     A,E
                LD      L,A
                RL      C
                SBC     A,A
                XOR     (HL)
                LD      C,A
                LD      B, + 08
08B5 COPY-BITS LD      A,D
                RLC     C
                RRA
                LD      H,A
08BA COPY-WAIT IN      A,(+ FB)
                RRA
                JR      NC,08BA,COPY-WAIT
                LD      A,H
                OUT     (+ FB),A
                DJNZ    08B5,COPY-BITS
                POP     HL
08C7 COPY-N/L  JR      089C,COPY-NEXT
                IN      A,(+ FB)
                RRA
                JR      NC,08C7,COPY-N/L
                LD      A,D
                RRCA
                OUT     (+ FB),A
                POP     DE
                INC     E
                BIT     3,E
                JR      Z,087D,COPY-TIME
                POP     BC
                DEC     D
                JR      NZ,087A,COPY-LOOP
                LD      A, + 04
```

```

08DE COPY-END  OUT      (+FB),A
                CALL    0207,SLOW/FAST
                POP      BC

```

THE 'CLEAR PRINTER BUFFER' SUBROUTINE

The printer buffer is cleared by overwriting it with Hex.00 characters and setting the final location to Hex.76.

```

08E2 CLEAR-PRB LD      HL, + 405C
                LD      (HL), + 76
                LD      B, + 20
08E9 PRB-BYTES DEC     HL
                LD      (HL), + 00
                DJNZ    08E9,PRB-BYTES
                LD      A,L
                SET     7,A
                LD      (PR-CC),A
                RET

```

THE 'PRINT AT' SUBROUTINE

This routine checks the validity of the parameters given with the PRINT AT command. If the parameters are invalid an error is signalled otherwise the correct S-POSN & DF-CC is obtained by using the LOC.-ADDR routine.

```

08F5 PRINT-AT  LD      A, + 17
                SUB     B
                JR      C,0905,WRONG-VAL
08FA TEST-VAL. CP      (DF-SZ)
                JP      C,0835,REPORT-5
                INC     A
                LD      B,A
                LD      A, + 1F
                SUB     C
0905 WRONG-VAL JP      C,0EAD,REPORT-B
                ADD     A, + 02
                LD      C,A
090B SET-FIELD BIT     1,(FLAGS)
                JR      Z,0918,LOC.-ADDR

```

The LPRINT AT command sets the value of PR-CC.

```

                LD      A, + 5D
                SUB     C
                LD      (PR-CC),A
                RET

```

THE 'LOC.-ADDR' SUBROUTINE

This important subroutine sets the value of DF-CC for given values of a display location. If the display is collapsed and thereby does not truly hold the position then the required line is expanded.

```

0918 LOC.-ADDR LD      (S-POSN),BC
                LD      HL,(VARS)
                LD      D,C
                LD      A, + 22
                SUB     C
                LD      C,A
                LD      A, + 76

```

```

0927 LOOK-BACK INC      B
                DEC     HL
                CP      (HL)
                JR      NZ,0927,LOOK-BACK
                DJNZ    0927,LOOK-BACK
                INC     HL
                CPIR
                DEC     HL
                LD      (DF-CC),HL
                SCF
                RET     PO
                DEC     D
                RET     Z
                PUSH    BC
                CALL    099E,MAKE-ROOM
                POP     BC
                LD      B,C
                LD      H,D
                LD      L,E
0940 EXPAND-2  LD      (HL), + 00
                DEC     HL
                DJNZ    0940,EXPAND-2
                EX      DE,HL
                INC     HL
                LD      (DF-CC),HL
                RET

```

THE 'EXPAND TOKENS' SUBROUTINE

The character codes that are considered to be tokens are expanded using this subroutine. The address of each 'expanded token' in the 'token table' is found using TOKEN-ADD. The leading space is printed if specified by bit 0 of FLAGS, the letters of the token-word are then printed and a trailing space is added if needed.

```

094B TOKENS   PUSH     AF
                CALL    0975,TOKEN-ADD
                JR      NC,0959,ALL-CHARS
                BIT      0,(FLAGS)
                JR      NZ,0959,ALL-CHARS
                XOR      A
                RST      0010,PRINT-A
0959 ALL-CHARS LD      A,(BC)
                AND      + 3F
                RST      0010,PRINT-A
                LD      A,(BC)
                INC     BC
                ADD     A,A
                JR      NC,0959,ALL-CHARS
                POP     BC
                BIT      7,B
                RET     Z
                CP      + 1A
                JR      Z,096D,TRAIL-SP.
                CP      + 38
                RET     C
096D TRAIL-SP. XOR      A
                SET     0,(FLAGS)
                JP      07F5,PRINT-SP.

```

In TOKEN-ADD the base address of the TOKEN TABLE is Hex.0111. The words in this table are found in turn and when the required word has been located a return is made with BC pointing to the start of the word.

```

0975 TOKEN-ADD  PUSH  HL
                  LD   HL, + 0111
                  BIT   7,A
                  JR   Z,097F,TEST-HIGH
                  AND   + 3F
097F TEST-HIGH  CP    + 43
                  JR   NC,0993,FOUND
                  LD   B,A
                  INC   B
0985 WORDS      BIT   7,(HL)
                  INC   HL
                  JR   Z,0985,WORDS
                  DJNZ 0985,WORDS
                  BIT   6,A
                  JR   NZ,0992,COMP-FLAG
                  CP    + 18
0992 COMP-FLAG  CCF
0993 FOUND      LD   B,H
                  LD   C,L
                  POP   HL
                  RET   NC
                  LD   A,(BC)
                  ADD   A, + E4
                  RET

```

THE 'ONE-SPACE' SUBROUTINE

Whenever a single space is required in the program area or the display file then this subroutine is called.

```
099B ONE-SPACE LD   BC, + 0001
```

THE 'MAKE-ROOM' SUBROUTINE

This routine creates BC spaces from the location (HL).

```

099E MAKE-ROOM  PUSH  HL
                  CALL  0EC5,TEST-ROOM
                  POP   HL
                  CALL  09AD,POINTERS
                  LD   HL,(STKEND)
                  EX    DE,HL
                  LDDR
                  RET

```

THE 'CHANGE ALL POINTERS' SUBROUTINE

Whenever some of the pointers require to be changed this subroutine is called with the amount of change in BC, and HL determining which pointers are to be changed. All pointers that point lower than HL will not be altered.

```

09AD POINTERS  PUSH  AF
                PUSH  HL
                LD   HL, + D-FILE
                LD   A, + 09
09B4 NEXT-PTR  LD   E,(HL)
                INC   HL
                LD   D,(HL)
                EX    (SP),HL
                AND   A
                SBC   HL,DE
                ADD   HL,DE
                EX    (SP),HL
                JR   NC,09C8,PTR-DONE

```

```

                PUSH  DE
                EX    DE,HL
                ADD   HL,BC
                EX    DE,HL
                LD   (HL),D
                DEC   HL
                LD   (HL),E
                INC   HL
                POP   DE
09C8 PTR-DONE  INC   HL
                DEC   A
                JR   NZ,09B4,NEXT-PTR
                EX    DE,HL
                POP   DE
                POP   AF
                AND   A
                SBC   HL,DE
                LD   B,H
                LD   C,L
                INC   BC
                ADD   HL,DE
                EX    DE,HL
                RET

```

THE 'LINE-ADDR' SUBROUTINE

For a given BASIC line number this subroutine will return the starting address of the actual line (and the Z flag set) or the starting address of the following line if it does not exist (C reset).

```

09D8 LINE-ADDR  PUSH  HL
                  LD   HL, + PROGRAM
                  LD   D,H
                  LD   E,L
09DE NEXT-TEST  POP   BC
                  CALL  09EA,CP-LINES
                  RET   NC
                  PUSH  BC
                  CALL  09F2,NEXT-ONE
                  EX    DE,HL
                  JR   09DE,NEXT-TEST

```

THE 'COMPARE LINE NUMBERS' SUBROUTINE

The line number in (HL) is compared to the number in BC.

```

09EA CP-LINES   LD   A,(HL)
                  CP   B
                  RET   NZ
                  INC   HL
                  LD   A,(HL)
                  DEC   HL
                  CP   C
                  RET

```

THE 'NEXT LINE or VARIABLE' SUBROUTINE

This subroutine very cleverly finds the start of the next BASIC line or the start of the next variable in the variable area. Line numbers are identified by the high byte being less than Hex.40, and the different types of variables are identified by their differing bits 6 & 7.

```

09F2 NEXT-ONE  PUSH  HL
                  LD   A,(HL)

```

```

CP      + 40
JR      C,0A0F,LINES
BIT     5,A
JR      Z,0A10,BIT-5-NIL
ADD     A,A
JP      M,0A01,NEXT + FIVE
CCF
0A01 NEXT + FIVE LD     BC, + 0005
JR      NC,0A08,NEXT-LETT
LD      C, + 11
0A08 NEXT-LETT  RLA
INC     HL
LD      A,(HL)
JR      NC,0A08,NEXT-LETT
JR      0A15,NEXT-ADD
0A0F LINES     INC     HL
0A10 BIT-5-NIL INC     HL
LD      C,(HL)
INC     HL
LD      B,(HL)
INC     HL
0A15 NEXT-ADD  ADD     HL,BC
POP     DE

```

THE 'DIFFERENCE' SUBROUTINE

This subroutine finds the difference in value between the contents of the HL and DE register pairs. The result is returned in the BC register pair.

```

0A17 DIFFER    AND     A
SBC     HL,DE
LD      B,H
LD      C,L
ADD     HL,DE
EX      DE,HL
RET

```

THE 'LINE ENDS' SUBROUTINE

The lines of the 'lower' screen are cleared by this subroutine.

```

0A1F LINE-ENDS LD      B,(DF-SZ)
PUSH     BC
CALL     0A2C,B-LINES
POP      BC
DEC      B
JR      0A2C,B-LINES

```

THE 'CLS' COMMAND ROUTINE

i) The B register is loaded with Hex.18, the number of lines in the display file.

```

0A2A CLS      LD      B, + 18

```

ii) The address of the start of that part of the display file that is to be cleared is found and a test is made to see if more, or less, than 3¼ K. of RAM is fitted.

```

0A2C B-LINES  RES     1,(FLAGS)
LD      C, + 21
PUSH     BC
CALL     0918,LOC.-ADDR
POP      BC

```

```

LD      A,(RAMTOP-hi.)
CP      + 4D
JR      C,0A52,COLLAPSE

```

iii) As an expanded display file is required, a suitable number of spaces is printed so as to clear the specified number of lines.

```

0A42 CLEAR-LOC SET     7,(S-POSN-hi.)
XOR     A
CALL    07F5,PRINT-SP.
LD      HL,(S-POSN)
LD      A,L
OR      H
AND     + 7E
JR      NZ,0A42,CLEAR-LOC
JP      0918,LOC.-ADDR

```

iv) As a collapsed display file is required a LDIR instruction is used to copy a N/L character the number of times specified in the C register (formerly B). The system variable VARS is then found and excess memory reclaimed.

```

0A52 COLLAPSED LD      D,H
LD      E,L
DEC     HL
LD      C,B
LD      B, + 00
LDIR
LD      HL,(VARS)

```

THE 'RECLAIMING' SUBROUTINES

The pointers are first changed and then the specified area of RAM is reclaimed by using a LDIR instruction to overwrite the unwanted part of the RAM contents.

```

0A5D RECLAIM-1 CALL    0A17,DIFFER
0A60 RECLAIM-2 PUSH     BC
LD      A,B
CPL
LD      B,A
LD      A,C
CPL
LD      C,A
INC     BC
CALL    09AD,POINTERS
EX      DE,HL
POP     HL
ADD     HL,DE
PUSH     DE
LDIR
POP     HL
RET

```

THE 'E-LINE NUMBER' SUBROUTINE

This routine is used to find out whether the current E-Line starts with a valid line number. i.e. 1-9999. The pointer CH-ADD is used temporarily to point along the E-LINE. A return is made if the INPUT command is being executed. The INT-TO-FP routine is called to collect the possible number and the FP-TO-BC

routine called to form an integer value. The value is then tested against dec.0-10,000. The subroutine returns via the SET-MEM subroutine that resets STKEND.

```

0A73 E-LINE-NO  LD    HL,(E-LINE)
                  CALL  004D,TEMP-PTR
                  RST    0018,GET-CH.
                  BIT     5,(FLAGX)
                  RET     NZ
                  LD     HL, + MEMBOT
                  LD     (STKEND),HL
                  CALL  1548,INT-TO-FP
                  CALL  158A,FP-TO-BC
                  JR     C,0A91,NO-NUMBER
                  LD     HL, + D8F0
                  ADD    HL,BC
0A91 NO-NUMBER  JP     C,0D9A,REPORT-C
                  CP     A
                  JP     14BC,SET-MEM

```

THE 'REPORT & LINE NUMBER' PRINTING SUBROUTINES

The OUT-NUM. entry point is used to print the error report line numbers and the OUT-NO. entry point is used for printing line numbers at the start of BASIC lines.

```

0A98 OUT-NUM.  PUSH  DE
                PUSH  HL
                XOR    A
                BIT    7,B
                JR     NZ,0ABF,UNITS
                LD     H,B
                LD     L,C
                LD     E, + FF
                JR     0AAD,THOUSAND
0AA5 OUT-NO.  PUSH  DE
                LD     D,(HL)
                INC    HL
                LD     E,(HL)
                PUSH  HL
                EX     DE,HL
                LD     E, + 00
0AAD THOUSAND LD     BC, + FC18
                CALL  07E1,OUT-DIGIT
                LD     BC,FF9C
                CALL  07E1,OUT-DIGIT
                LD     C, + F6
                CALL  07E1,OUT-DIGIT
                LD     A,L
0ABF UNITS    CALL  07EB,OUT-CODE
                POP    HL
                POP    DE
                RET

```

THE 'UNSTACK-Z' SUBROUTINE

Bit 7 of FLAGS is set during the execution of a BASIC line but reset during syntax checking. This subroutine calls SYNTAX-Z and then either simply 'returns' using a JP (HL) instruction during the execution of a BASIC line, or uses a RET Z instruction to 'return' to the address above on the stack during syntax checking.

```

0AC5 UNSTACK-Z CALL  0DA6,SYNTAX-Z
                  POP  HL
                  RET  Z
                  JP   (HL)

```

THE 'LPRINT' COMMAND ROUTINE

Bit 1 of FLAGS is set whenever a LPRINT command is executed.

```
0ACB LPRINT  SET    1,(FLAGS)
```

THE 'PRINT' COMMAND ROUTINE

This routine is fairly complex but fortunately it can be broken into simple parts.

i) Test for PRINT alone.

```

0ACF PRINT    LD     A,(HL)
                CP     + 76
                JP     Z,0B84,PRINT-END

```

ii) A loop is now set up to deal with each constituent part of a PRINT line.

First, the next character is tested to see if it is a 'comma' or a 'semi-colon'.

```

0AD5 PRINT-1  SUB     + 1A
                ADC     A, + 00
                JR     Z,0B44,SPACING

```

iii) If the next character is an 'AT' it is dealt with as follows:

```

Test for 'AT'    CP     + A7
                  JR     NZ,0AFA,NOT-AT

```

The next character is collected.

```
RST    0020,NEXT-CH.
```

The next expression is identified.

```
CALL    0D92,CLASS-6
```

A test is made for the correct separator — a comma.

```

CP     + 1A
JP     NZ,0D9A,REPORT-C

```

The next character is collected.

```
RST    0020,NEXT-CH
```

The next expression is identified.

```
CALL    0D92,CLASS-6
```

A test is made to see if a line is being executed or syntax being checked. An indirect jump is made to PRINT-ON if syntax is being checked.

```
CALL    0B4E,SYNTAX-ON
```


The particulars of the two expressions are both on the calculator stack but they need to be switched over. This is done using a RST 0028 instruction and the literal 01.

```
RST    0028,FP-CALC.
DEFB   +01
        (exchange, 1A72)
DEFB   +34
        (end-calc.,002B)
```

The two expressions on the stack are then 'loaded' into the BC register pair by calling STK-TO-BC.

```
CALL    0BF5,STK-TO-BC
```

With the PRINT AT parameters now in BC the usual routine can be called to set DF-CC & S-POSN and a jump is then made to PRINT-ON.

```
CALL    08F5,PRINT-AT
JR      0B37,PRINT-ON
```

iv) If the next character is a 'TAB' it is dealt with as follows:

Test for 'TAB'

```
0AFA NOT-AT    CP    +A8
                JR    NZ,0B31,NOT-TAB
```

The single 'following expression' is collected. The syntax flag is checked and the value of the expression 'loaded' into the A register.

```
RST    0020,NEXT-CH.
CALL    0D92,CLASS-6
CALL    0B4E,SYNTAX-ON
CALL    0C02,STK-TO-A
```

The 'parameter' is then tested and the new values of DF-CC & S-POSN are found by calling TEST-VAL.

```
0B1E TAB-TEST  JP    NZ,0EAD,REPORT-B
                AND   +1F
                LD    C,A
                BIT    1,(FLAGS)
                JR    Z,0B1E,TAB-TEST
                SUB    (PR-CC)
                SET    7,A
                ADD    A,+3C
                CALL    NC,0871,COPY-BUFF
                ADD    A,(S-POSN-lo.)
                CP      +21
                LD      A,(S-POSN-hi.)
                SBC     A,+01
                CALL    08FA,TEST-VAL
                SET     0,(FLAGS)
                JR      0B37,PRINT-ON
```

v) The expression that comes next is collected and printed by using the PRINT-STK subroutine.

```
0B31 NOT-TAB    CALL    0F55,SCANNING
                CALL    0B55,PRINT-STK
```

vi) The routine now proceeds to check for another expression.

```
0B37 PRINT-ON  RST    0018,GET-CH.
                SUB    +1A
                ADC    A,+00
                JR     Z,0B44,SPACING
                CALL    0D1D,CHECK-END
                JP      0B84,PRINT-END
```

vii) The two characters 'comma & semi-colon' are now separated.

```
0B44 SPACING    CALL    NC,0B8B,FIELD
                RST    0020,NEXT-CH.
                CP      +76
                RET     Z
                JP      0AD5,PRINT-1
```

viii) The SYNTAX-ON subroutine causes a jump to PRINT-ON if syntax is being checked.

```
0B4E SYNTAX-ON CALL    0DA6,SYNTAX-Z
                RET     NZ
                POP     HL
                JR      0B37,PRINT-ON
```

ix) The PRINT-STK routine collects the details of a string from the calculator stack. A number is dealt with by jumping to PRINT-FP, whereas a string is dealt with in the 'print string' section. First the syntax flag is read.

```
0B55 PRINT-STK CALL    0AC5,UNSTACK-Z
                BIT     6,(FLAGS)
                CALL    Z,13F8,STK-FETCH
                JR      Z,0B6B,PR-STR-4
                JP      15DB,PRINT-FP
```

x) The string printing routine.

The length of the string is held in the BC register pair and the starting address of the string is held in the DE register pair.

```
0B64 PR-STR-1  LD      A,+0B
0B66 PR-STR-2  RST     0010,PRINT-A
0B67 PR-STR-3  LD      DE,(X-PTR)
0B6B PR-STR-4  LD      A,B
                OR      C
                DEC     BC
                RET     Z
                LD      A,(DE)
                INC     DE
                LD      (X-PTR),DE
                BIT     6,A
                JR      Z,0B66,PR-STR-2
                CP      +CO
                JR      Z,0B64,PR-STR-1
                PUSH    BC
                CALL    094B,TOKENS
                POP     BC
                JR      0B67,PR-STR-3
```

xi) The PRINT-END routine.

The syntax flag is read and a N/L character is printed during line execution.

```

0B84 PRINT-END CALL 0AC5,UNSTACK-Z
                LD  A, + 76
                RST 0010,PRINT-A
                RET

```

xii) The FIELD subroutine.

The appropriate value of S-POSN (and PR-CC if required) is found.

```

0B8B FIELD      CALL 0AC5,UNSTACK-Z
                SET  O,(FLAGS)
                XOR  A
                RST 0010,PRINT-A
                LD   BC,(S-POSN)
                LD   A,C
                BIT  1,(FLAGS)
                JR   Z,0BA4,CENTRE
                LD   A, + 5D
                SUB  (PR-CC)
0BA4 CENTRE     LD   C, + 11
                CP   C
                JR   NC,0BAB,RIGHT
                LD   C, + 01
0BAB RIGHT      CALL 090B,SET-FIELD
                RET

```

THE 'PLOT & UNPLOT' COMMAND ROUTINES

Initially the x & y co-ordinates are fetched and tested. Then they are converted to row & column numbers. The value formed in the A register distinguishes which pixel is being identified.

```

0BAF PLOT/UNP. CALL 0BF5,STK-TO-BC
                LD   (COORDS),BC
                LD   A, + 2B
                SUB  B
                JP   C,0EAD,REPORT-B
                LD   B,A
                LD   A, + 01
                SRA  B
                JR   NC,0BC5,COLUMNS
                LD   A, + 04
0BC5 COLUMNS   SRA  C
                JR   NC,0BCA,FIND-ADDR
                RLCA
0BCA FIND-ADDR  PUSH AF
                CALL 0BF5,PRINT-AT
                LD   A,(HL)
                RLCA
                CP   + 10
                JR   NC,0BDA,TABLE-PTR
                RRCA
                JR   NC,0BD9,SQ-MAVED
                XOR  + 8F
0BD9 SQ-MAVED   LD   B,A
0BDA TABLE-PTR LD   DE, + 0C9E

```

The two operations of PLOTting and UNPLOTting are distinguished by referring to T-ADDR and comparing the value against the constant 0C9E that is the value of the address of the UNPLOT command in the syntax table.

```

                LD   A,(T-ADDR)
                SUB  E
                JP   M,0BE9,PLOT

```

```

                POP  AF
                CPL
                AND  B
                JR   0BEB,UNPLOT
0BE9 PLOT       POP  AF
                OR   B
                CP   + 08
                JR   C,0BF1,PLOT-END
                XOR  + 8F
0BF1 PLOT-END   EXX
                RST 0010,PRINT-A
                EXX
                RET

```

THE 'STK-TO-BC' SUBROUTINE

This subroutine 'loads' two floating point numbers into the BC register pair. The subroutine is therefore used to pick up parameters in the range 00-FF.

```

0BF5 STK-TO-BC CALL 0C02,STK-TO-A
                LD   B,A
                PUSH BC
                CALL 0C02,STK-TO-A
                LD   E,C
                POP  BC
                LD   D,C
                LD   C,A
                RET

```

THE 'STK-TO-A' SUBROUTINE

This subroutine 'loads' the A register with the floating point number held at the top of the calculator stack. The number must be in the range 00-FF.

```

0C02 STK-TO-A   CALL 15CD,FP-TO-A
                JP   C,0EAD,REPORT-B
                LD   C, + 01
                RET  Z
                LD   C, + FF
                RET

```

THE 'SCROLL' COMMAND ROUTINE

The first part of the routine sets the correct values of DF-CC and S-POSN to allow for the next printing to occur at the start of the bottom line + 1.

Next the end address of the first line in the display file is identified and the whole of the display file moved to overwrite this line.

```

0C0E SCROLL     LD   B,(DF-SZ)
                LD   C, + 21
                CALL 0918,LOC.-ADDR
                CALL 099B,ONE-SPACE
                LD   A,(HL)
                LD   (DE),A
                INC  (S-POSN-hi.)
                LD   HL,(D-FILE)
                INC  HL
                LD   D,H
                LD   E,L
                CPIR
                JP   0A5D,RECLAIM-1

```

THE SYNTAX TABLES

i) The offset table.

There is an offset value for each of the BASIC commands and by adding this offset to the value of the address where it is found, the correct address for the command in the parameter table is obtained.

0C29	8B	LPRINT	0CB4
0C2A	8D	LLIST	0CB7
0C2B	2D	STOP	0C58
0C2C	7F	SLOW	0CAB
0C2D	81	FAST	0CAE
0C2E	49	NEW	0C77
0C2F	75	SCROLL	0CA4
0C30	5F	CONT	0C8F
0C31	40	DIM	0C71
0C32	42	REM	0C74
0C33	2B	FOR	0C5E
0C34	17	GOTO	0C4B
0C35	1F	GOSUB	0C54
0C36	37	INPUT	0C6D
0C37	52	LOAD	0C89
0C38	45	LIST	0C7D
0C39	0F	LET	0C48
0C3A	6D	PAUSE	0CA7
0C3B	2B	NEXT	0C66
0C3C	44	POKE	0C80
0C3D	2D	PRINT	0C6A
0C3E	5A	PLOT	0C98
0C3F	3B	RUN	0C7A
0C40	4C	SAVE	0C8C
0C41	45	RAND	0C86
0C42	0D	IF	0C4F
0C43	52	CLS	0C95
0C44	5A	UNPLOT	0C9E
0C45	4D	CLEAR	0C92
0C46	15	RETURN	0C5B
0C47	6A	COPY	0CB1

ii) The parameter table.

For each of the BASIC commands there are between 3 & 8 entries in the parameter table. The command classes for each of the commands are given, together with the required separators and these are followed by the address of the appropriate routine.

0C48 P-LET	01	CLASS-1
	14	'='
	02	CLASS-2
0C4B P-GOTO	06	CLASS-6
	00	CLASS-0
	81	
	0E	GOTO,0EB1
0C4F P-IF	06	CLASS-6
	DE	'THEN'
	05	CLASS-5
	AB	
	0D	IF,0DAB
0C54 P-GOSUB	06	CLASS-6

	00	CLASS-0
	B5	
	0E	GOSUB,0EB5
0C58 P-STOP	00	CLASS-0
	DC	
	0C	STOP,0CDC
0C5B P-RETURN	00	CLASS-0
	D8	
	0E	RETURN,0ED8
0C5E P-FOR	04	CLASS-4
	14	'='
	06	CLASS-6
	DF	'TO'
	06	CLASS-6
	05	CLASS-5
	B9	
	0D	FOR,0DB9
0C66 P-NEXT	04	CLASS-4
	00	CLASS-0
	2E	
	0E	NEXT,0E2E
0C6A P-PRINT	05	CLASS-5
	CF	
	0A	PRINT,0ACF
0C6D P-INPUT	01	CLASS-1
	00	CLASS-0
	E9	
	0E	INPUT,0EE9
0C71 P-DIM	05	CLASS-5
	09	
	14	DIM,1409
0C74 P-REM	05	CLASS-5
	6A	
	0D	REM,0D6A
0C77 P-NEW	00	CLASS-0
	C3	
	03	NEW,03C3
0C7A P-RUN	03	CLASS-3
	AF	
	0E	RUN,0EAF
0C7D P-LIST	03	CLASS-3
	30	
	07	LIST,0730
0C80 P-POKE	06	CLASS-6
	1A	' '
	06	CLASS-6
	92	
	0E	POKE,0E92
0C86 P-RAND	03	CLASS-3
	6C	
	0E	RAND,0E6C
0C89 P-LOAD	05	CLASS-5
	40	
	03	LOAD,0340

0C8C P-SAVE	05 F6 02	CLASS-5 SAVE,02F6
0C8F P-CONT	00 7C 0E	CLASS-0 CONT,0E7C
0C92 P-CLEAR	00 9A 14	CLASS-0 CLEAR,149A
0C95 P-CLS	00 2A 0A	CLASS-0 CLS,0A2A
0C98 P-PLOT	06 1A 06 00 AF 0B	CLASS-6 , CLASS-6 CLASS-0 PLOT/UNP.,0BAF
0C9E P-UNPLOT	06 1A 06 00 AF 0B	CLASS-6 , CLASS-6 CLASS-0 PLOT/UNP.,0BAF
0CA4 P-SCROLL	00 0E 0C	CLASS-0 SCROLL,0C0E
0CA7 P-PAUSE	06 00 32 0F	CLASS-6 CLASS-0 PAUSE,0F32
0CAB P-SLOW	00 2B 0F	CLASS-0 SLOW,0F2B
0CAE P-FAST	00 23 0F	CLASS-0 FAST,0F23
0CB1 P-COPY	00 69 08	CLASS-0 COPY,0869
0CB4 P-LPRINT	05 CB 0A	CLASS-5 LPRINT,0ACB
0CB7 P-LLIST	03 2C 07	CLASS-3 LLIST,072C

THE 'LINE SCANNING' ROUTINE

The BASIC interpreter scans each line for BASIC commands and as each one is found the appropriate command routine is followed.

The different parts of the routine are:

i) The LINE-SCAN entry point leads to the line number being checked for validity.

```
0CBA LINE-SCAN LD (FLAGS), + 01
                CALL 0A73,E-LINE-NO
```

ii) The LINE-RUN entry point is used when replying to an INPUT prompt and this fact has to be identified.

```
0CC1 LINE-RUN CALL 14BC,SET-MEM
                LD HL, + ERR-NR
                LD (HL), + FF
                LD HL, + FLAGX
                BIT 5,(HL)
                JR Z,0CDE,LINE-NULL
```

iii) The INPUT reply is tested to see if STOP was entered.

```
                CP + E3
                LD A,(HL)
                JP NZ,0D6F,INPUT-REP
                CALL 0DA6,SYNTAX-Z
                RET Z
```

iv) If appropriate, report D is given.

```
                RST 0008,ERROR-1
                DEFB + 0C
```

THE 'STOP' COMMAND ROUTINE

The only action is to give report 9.

```
0CDC STOP RST 0008,ERROR-1
          DEFB + 08
```

v) A return is made if the line is 'null'.

```
0CDE LINE-NULL RST 0018,GET-CH.
               LD B, + 00
               CP + 76
               RET Z
```

vi) The first character is tested so as to check that it is a command.

```
                LD C,A
                RST 0020,NEXT-CH.
                LD A,C
                SUB + E1
                JR C,0D26,REPORT-C2
```

vii) The offset for the command is found from the offset table.

```
                LD C,A
                LD HL, + 0C29
                ADD HL,BC
                LD C,(HL)
                ADD HL,BC
                JR 0CF7,GET-PARAM
```

viii) The parameters are fetched in turn by a loop that returns to 0CF4.

The separators are identified by the test against + 0B.

```
0CF4 SCAN-LOOP LD HL,(T-ADDR)
0CF7 GET-PARAM LD A,(HL)
```

```

INC      HL
LD       (T-ADDR),HL
LD       BC, +0CF4
PUSH     BC
LD       C,A
CP       +0B
JR       NC,0D10,SEPARATOR

```

ix) The address of the command class routine is obtained by reference to the command class table at 0D16. A jump is made to the appropriate routine.

```

LD       HL, +0D16
LD       B, +00
ADD      HL,BC
LD       C,(HL)
ADD      HL,BC
PUSH     HL
RST      0018,GET-CH.
RET

```

x) The correctness of the separator is simply tested by the following routine.

```

0D10 SEPARATOR RST 0018,GET-CH.
                CP  C
                JR  NZ,0D26,REPORT-C2
                RST 0020,NEXT-CH.
                RET

```

THE COMMAND CLASS TABLE

The addresses for the seven different command classes are found from this table.

0D16	17	CLASS-0,0D2D
0D17	25	CLASS-1,0D3C
0D18	53	CLASS-2,0D6B
0D19	0F	CLASS-3,0D28
0D1A	6B	CLASS-4,0D85
0D1B	13	CLASS-5,0D2E
0D1C	76	CLASS-6,0D92

THE 'CHECK-END' SUBROUTINE

Line scanning is finished when the N/L character is reached.

```

0D1D CHECK-END CALL 0DA6,SYNTAX-Z
                RET  NZ
                POP  BC
0D22 CHECK-2   LD  A,(HL)
                CP  +76
                RET  Z
0D26 REPORT-C2 JR  0D9A,REPORT-C

```

THE 'COMMAND CLASS 3' ROUTINE

The commands RUN, LIST, RAND and LLIST can be followed by a N/L or a number.

```

0D28 CLASS-3   CP  +76
                CALL 0D9C,NO-TO-STK

```

THE 'COMMAND CLASS 0' ROUTINE

An entry here will cause the zero flag to be set prior to a call to CHECK-END.

```
0D2D CLASS-0   CP  A
```

THE 'COMMAND CLASS 5' ROUTINE

The commands IF, FOR, PRINT, DIM, REM, LOAD, SAVE and LPRINT all have class 5 as their last command class. A jump is made to the command routine directly.

```

0D2E CLASS-5   POP  BC
                CALL Z,0D1D,CHECK-END
                EX   DE,HL
                LD   HL,(T-ADDR)
                LD   C,(HL)
                INC  HL
                LD   B,(HL)
                EX   DE,HL
0D3A CLASS-END PUSH BC
                RET

```

THE 'COMMAND CLASS 1' ROUTINE

The commands LET and INPUT both require that a variable be specified. The command class 1 routine collects the details of the variable and stores them in the required places.

```

0D3C CLASS-1   CALL 111C,LOOK-VARS
0D3F CLASS-4-2 LD   (FLAGX), +00
                JR   NC,0D4D,SET-STK
                SET  1,(FLAGX)
                JR   NZ,0D63,SET-STRLN
0D4B REPORT-2  RST  0008,ERROR-1
                DEFB +01
0D4D SET-STK   CALL Z,11A7,STK-VAR
                BIT  6,(FLAGX)
                JR   NZ,0D63,SET-STRLN
                XOR  A
                CALL 0DA6,SYNTAX-Z
                CALL NZ,13F8,STK-FETCH
                LD   HL, + FLAGX
                OR   (HL)
                LD   (HL),A
                EX   DE,HL
0D63 SET-STRLN LD   (STRLN),BC
                LD   (DEST),HL
0D6A REM       RET

```

THE 'COMMAND CLASS 2' ROUTINE

The value assigned to a variable in a LET command or in reply to an INPUT prompt is evaluated by calling SCANNING. If the value is appropriate then an indirect jump is made to the LET routine at 1321.

```

0D6B CLASS-2   POP  BC
                LD   A,(FLAGX)
0D6F INPUT-REP PUSH AF
                CALL 0F55,SCANNING
                POP  AF
                LD   BC, + 1321
                LD   D,(FLAGX)

```



```

XOR    D
AND    +40
JR      NZ,0D9A,REPORT-C
BIT    7,D
JR      NZ,0D3A,CLASS-END
JR      0D22,CHECK-2

```

THE 'COMMAND CLASS 4' ROUTINE

The specified variable for the FOR and the NEXT commands are dealt with by this routine. Only single character variables are allowed and these are identified by their having both bits 5 & 6 set.

```

0D85 CLASS-4  CALL    111C,LOOK-VARS
               PUSH    AF
               LD      A,C
               OR      +9F
               INC     A
               JR      NZ,0D9A,REPORT-C
               POP     AF
               JR      0D3F,CLASS-4-2

```

THE 'COMMAND CLASS 6' ROUTINE

CLASS-6 denotes that the following expression must yield an integer value.

The SCANNING routine evaluates the expression and a numeric value will give bit 6 of FLAGS set.

```

0D92 CLASS-6  CALL    0F55,SCANNING
               BIT     6,(FLAGS)
               RET     NZ

```

REPORT-C — no numeric value.

```

0D9A REPORT-C RST     0008,ERROR-1
               DEFB    +0B

```

THE 'NO-TO-STK' SUBROUTINE

During execution of a line this routine leads to a number being placed on the calculator stack. If the zero flag is reset on entry the number put on the stack will be the result of evaluating the 'next' expression, but if the zero flag is set then zero will be placed on the stack by using a RST 0028 instruction.

```

0D9C NO-TO-STK JR      NZ,0D92,CLASS-6
               CALL    0DA6,SYNTAX-Z
               RET     Z
               RST     0028,FP-CALC.
               DEFB    +A0
               DEFB    (stk-zero,1A51)
               DEFB    +34
               DEFB    (end-calc.,002B)
               RET

```

THE 'SYNTAX-Z' SUBROUTINE

A simple test of bit 7 of FLAGS will give the zero flag reset during execution and set during syntax checking.

i.e. SYNTAX gives Z set.

```

0DA6 SYNTAX-Z BIT     7,(FLAGS)
               RET

```

THE 'IF' COMMAND ROUTINE

At this point the value of the expression between the 'IF' and the 'THEN' is known, and is on the top of the calculator stack.

During execution the result is deleted from the stack but the pointer DE is still available. The logical value of (DE) is tested and a return made if zero, otherwise the routine jumps to LINE-NULL to execute the rest of the line.

```

0DAB IF        CALL    0DA6,SYNTAX-Z
               JR      Z,0DB6,IF-END
               RST     0028,FP-CALC.
               DEFB    +02
               DEFB    (delete,19E3)
               DEFB    +34
               DEFB    (end-calc.,002B)
               LD      A,(DE)
               AND     A
               RET     Z
0DB6 IF-END    JP      0CDE,LINE-NULL

```

THE 'FOR' COMMAND ROUTINE

This routine is made up of the following parts:

i) If a STEP variable is given then this is found and put on the stack, otherwise the value one is used.

```

0DB9 FOR        CP      +EO
               JR      NZ,0DC6,USE-ONE
               RST     0020,NEXT-CH.
               CALL    0D92,CLASS-6
               CALL    0D1D,CHECK-END
               JR      0DCC,REORDER
0DC6 USE-ONE    CALL    0D1D,CHECK-END
               RST     0028,FP-CALC.
               DEFB    +A1
               DEFB    (stk-one,1A51)
               DEFB    +34
               DEFB    (end-calc.,002B)

```

ii)

The top three values on the stack, the 'value', the 'limit' & the 'step' are re-ordered to give 'limit-step-value'.

```

0DCC REORDER    RST     0028,FP-CALC.
               DEFB    +C0
               DEFB    (st-mem-0,1A63)
               DEFB    +02
               DEFB    (delete,19E3)
               DEFB    +01
               DEFB    (exchange,1A72)
               DEFB    +E0
               DEFB    (get-mem-0,1A45)
               DEFB    +01
               DEFB    (exchange,1A72)
               DEFB    +34
               DEFB    (end-calc.,002B)

```

iii) The LET routine is used to locate an address in the VARS area for the FOR variable. If the variable already exists then it is overwritten, if not then the variable is added to the end of the VARS. The 'limit' & the 'step' are then transferred.

```

CALL 1321,LET
LD (MEM),HL
DEC HL
LD A,(HL)
SET 7,(HL)
LD BC,+0006
ADD HL,BC
RLCA
JR C,0DEA,LMT + STEP
SLA C
CALL 099E,MAKE-ROOM
INC HL
0DEA LMT + STEP PUSH HL
RST 0028,FP-CALC.
DEFB +02
      (delete,19E3)
DEFB +02
      (delete,19E3)
DEFB +34
      (end-calc.,002B)
POP HL
EX DE,HL
LD C,+0A
LDIR

```

iv) The current line number is fetched, incremented and added to the variable.

```

LD HL,(PPC)
EX DE,HL
INC DE
LD (HL),E
INC HL
LD (HL),D

```

v) The NEXT-LOOP subroutine is called to check that a 'looping' is possible. If it is not possible then NXTLIN is set to the appropriate line number for jumping over the whole of the FOR-NEXT loop.

```

CALL 0E5A,NEXT-LOOP
RET NC
BIT 7,(PPC-hi.)
RET NZ
LD B,(STRLEN)
RES 6,B
LD HL,(NXTLIN)
0E0E NXTLIN-NO LD A,(HL)
AND +C0
JR NZ,0E2A,FOR-END
PUSH BC
CALL 09F2,NEXT-ONE
POP BC
INC HL
INC HL
INC HL
CALL 004C,CURSOR-SO
RST 0018,GET-CH.
CP +F3

```

```

EX DE,HL
JR NZ,0E0E,NXTLIN-NO
EX DE,HL
RST 0020,NEXT-CH
EX DE,HL
CP B
JR NZ,0E0E,NXTLIN-NO
0E2A FOR-END LD (NXTLIN),HL
RET

```

THE 'NEXT' COMMAND ROUTINE

In this routine the address of the variable is collected from DEST. Next MEM is loaded with this address so that a RST 0028 instruction can be used to manipulate the different parts of the variable when the 'step' is added to the 'value'.

```

0E2E NEXT BIT 1,(FLAGX)
JP NZ,0D4B,REPORT-2
LD HL,(DEST)
BIT 7,(HL)
JR Z,0E58,REPORT-1
INC HL
LD (MEM),HL
RST 0028,FP-CALC.
DEFB +E0
      (get-mem-0,1A45)
DEFB +E2
      (get-mem-2,1A45)
DEFB +0F
      (addition,1755)
DEFB +C0
      (st-mem-0,1A63)
DEFB +02
      (delete,19E3)
DEFB +34
      (end-calc.,002B)
CALL 0E5A,NEXT-LOOP
RET C

```

An indirect jump is now made to the line number given in the last two bytes of the variable.

```

LD HL,(MEM)
LD DE,+000F
ADD HL,DE
LD E,(HL)
INC HL
LD D,(HL)
EX DE,HL
JR 0E86,GOTO-2

```

REPORT-1 — 'NEXT' without 'FOR' error

```

0E58 REPORT-1 RST 0008,ERROR-1
DEFB +00

```

THE 'NEXT-LOOP' SUBROUTINE

This subroutine is called by both the 'FOR' and the 'NEXT' command routines.

When called by the 'FOR' routine it determines whether or not a jump past the whole of the FOR-NEXT loop is to be made.

When called by the 'NEXT' command routine it determines whether another loop is, or is not, possible.

The routine tests the 'step' and then compares the 'limit' and the 'value'. The carry flag is set, or reset, as required.

```

0E5A NEXT-LOOP RST    0028,FP-CALC.
                DEFB    + E1
                (get-mem-1,1A45)
                DEFB    + E0
                (get-mem-0,1A45)
                DEFB    + E2
                (get-mem-2,1A45)
                DEFB    + 32
                (less-0,1ACE)
                DEFB    + 00
                (jump-true,1C2F)
                DEFB    + 02, to 0E62
                DEFB    + 01
                (exchange,1A72)
0E62 LMT-V-VAL DEFB    + 03
                (subtract,174C)
                DEFB    + 33
                (greater-0,1ADB)
                DEFB    + 00
                (jump-true,1C2F)
                DEFB    + 04, to 0E69
                DEFB    + 34
                (end-calc.,002B)
                AND
                RET
0E69 IMPOSS.   DEFB    + 34
                (end-calc.,002B)
                SCF
                RET

```

THE 'RAND' COMMAND ROUTINE

The FIND-INT. subroutine is called to show whether a number was given with the RAND command. If not then FRAMES is used.

```

0E6C RAND      CALL    0EA7,FIND-INT.
                LD      A,B
                OR      C
                JR      NZ,0E77,SET-SEED
                LD      BC,(FRAMES)
0E77 SET-SEED  LD      (SEED),BC
                RET

```

THE 'CONT' COMMAND ROUTINE

The value of OLDPPC is fetched and used.

```

0E7C CONT      LD      HL,(OLDPPC)
                JR      0E86,GOTO-2

```

THE 'GOTO' COMMAND ROUTINE

The line number is collected, tested and then passed to LINE-ADDR. The address returned is loaded into NXTLIN.

```

0E81 GOTO      CALL    0EA7, FIND-INT.
                LD      H,B
                LD      L,C

```

```

0E86 GOTO-2    LD      A,H
                CP      + F0
                JR      NC,0EAD,REPORT-B
                CALL    09D8,LINE-ADDR.
                LD      (NXTLIN),HL
                RET

```

THE 'POKE' COMMAND ROUTINE

The value to be entered is collected from the stack using FP-TO-A and the address of the location to be filled is collected using FIND-INT.

```

0E92 POKE      CALL    15CD,FP-TO-A
                JR      C,0EAD,REPORT-B
                JR      Z,0E9B,POKE-SAVE
                NEG
0E9B POKE-SAVE PUSH    AF
                CALL    0EA7,FIND-INT.
                POP     AF
                BIT     7,(ERR-NR)
                RET     Z
                LD      (BC),A
                RET

```

THE 'FIND-INT.' SUBROUTINE

The integer value of the floating point number on the top of the stack is found. Report B is given if the value exceeds 65535 decimal.

```

0EA7 FIND-INT. CALL    158A,FP-TO-BC
                JR      C,0EAD,REPORT-B
                RET     Z

```

REPORT-B — integer out of range

```

0EAD REPORT-B  RST     0008,ERROR-1
                DEFB    + 0A

```

THE 'RUN' COMMAND ROUTINE

The line number is determined and a jump made to the CLEAR command routine.

```

0EAF RUN       CALL    0E81,GOTO
                JP      149A,CLEAR

```

THE 'GOSUB' COMMAND ROUTINE

The current line number is fetched, incremented and stacked. The line number of the subroutine is determined and the registers set up for the TEST-ROOM subroutine.

```

0EB5 GOSUB     LD      HL,(PPC)
                INC     HL
                EX      (SP),HL
                PUSH    HL
                LD      (ERR-SP),SP
                CALL    0E81,GOTO
                LD      BC, + 0006

```

THE 'TEST-ROOM' SUBROUTINE

This subroutine tests the value of STKEND against the stack pointer allowing 36 bytes for other variables. Report 4 is given if there is insufficient room.

```
0EC5 TEST-ROOM LD HL,(STKEND)
                ADD HL,BC
                JR C,0ED3,REPORT-4
                EX DE,HL
                LD HL,+0024
                ADD HL,DE
                SBC HL,SP
                RET C
```

REPORT-4 — out of RAM

```
0ED3 REPORT-4 LD L,+03
                JP 0058,ERROR-3
```

THE 'RETURN' COMMAND ROUTINE

The 'return' line number is taken off the 'gosub stack' and tested to show that it is a real line number. Report 7 is given if there is a mistake.

```
0ED8 RETURN POP HL
              EX (SP),HL
              LD A,H
              CP +3E
              JR Z,0EE5,REPORT-7
              LD (ERR-SP),SP
              JR 0E86,GOTO-2
```

REPORT-7 — return without gosub

The stack is restored and report 7 given.

```
0EE5 REPORT-7 EX (SP),HL
                PUSH HL
                RST 0008,ERROR-1
                DEFB +06
```

THE 'INPUT' COMMAND ROUTINE

A test for report 8 is made and the workspace cleared. Then the appropriate prompt characters are printed and the cursor marker added. Finally a jump to LOWER is made so that the edit-line can be printed.

```
0EE9 INPUT BIT 7,(PPC-hi.)
              JR NZ,0F21,REPORT-8
              CALL 14A3,X-TEMP
              LD HL,+FLAGX
              SET 5,(HL)
              RES 6,(HL)
              LD A,(FLAGS)
              AND +40
              LD BC,+0002
              JR NZ,0F05,PROMPT
              LD C,+04
0F05 PROMPT OR (HL)
              LD (HL),A
              RST 0030,BC-SPACES
              LD (HL),+76
```

```
LD A,C
RRCA
RRCA
JR C,0F14,ENTER-CUR
LD A,+0B
LD (DE),A
DEC HL
LD (HL),A
DEC HL
LD (HL),+7F
LD HL,(S-POSN)
LD (T-ADDR),HL
POP HL
JP 0472,LOWER
```

REPORT-8 — input as direct command

```
0F21 REPORT-8 RST 0008,ERROR-1
                DEFB +07
```

THE 'FAST' COMMAND ROUTINE

The SET-FAST routine is called to reset bit 7 of CDFLAG, and then bit 6 is reset.

```
0F23 FAST CALL 02E7,SET-FAST
              RES 6,(CDFLAG)
              RET
```

THE 'SLOW' COMMAND ROUTINE

The 'true' slow/fast flag — bit 6 of CDFLAG is set and a jump made to SLOW/FAST that copies this flag to bit 7 for compute and display.

```
0F2B SLOW SET 6,(CDFLAG)
              JP 0207,SLOW/FAST
```

THE 'PAUSE' COMMAND ROUTINE

The parameter of the PAUSE command is determined. Fast mode is selected for the period of the PAUSE and the DISPLAY-P routine called.

On returning the correct mode, SLOW or FAST, is selected and the value of FRAMES-hi. set to hex.FF. A jump to D-BOUNCE is then made.

Note: In the 'unimproved' ROM the value given to FRAMES-hi. was determined by a SET 7, (FRAMES-hi.) instruction and this failed to ensure that the 15th. bit of FRAMES would remain set as the first action of DISPLAY routine is to decrement FRAMES.

```
0F32 PAUSE CALL 0EA7,FIND-INT.
              CALL 02E7,SET-FAST
              LD H,B
              LD L,C
              CALL 022D,DISPLAY-P
              CALL 0207,SLOW/FAST
              LD (FRAMES-hi.),+FF
              JR 0F4B,D-BOUNCE
```

THE 'BREAK-1' SUBROUTINE

The 'break' key is tested.

```
0F46 BREAK-1  LD      A,+7F
               IN      A,(+FE)
               RRA
```

THE 'DEBOUNCE' SUBROUTINE

The system variable is set to its required value of Hex.FF.

```
0F4B D-BOUNCE RES      0,(CDFLAG)
               LD      A,+FF
               LD      (DEBOUNCE),A
               RET
```

The forward references:

```
0F55  SCANNING
111C  LOOK-VARS
11A7  STK-VAR
1321  LET
13F8  STK-FETCH
1488  RESERVE
149A  CLEAR
14A3  X-TEMP
14A6  SET-STK-B
14AD  CURSOR-IN
14BC  SET-MEM
1548  INT-TO-FP
158A  FP-TO-BC
15CD  FP-TO-A
15DB  PRINT-FP
199D  CALCULATE
```

RST 0028 literals:

```
00  jump-true      1C2F
01  exchange      1A72
02  delete        19E3
03  subtract      174C
0F  addition      1755
32  less-0        1ADB
33  greater-0     1ACE
34  end-calc.     002B
A0  stk-zero      1A51
A1  stk-one       1A51
C0  st-mem-0      1A63
C1  st-mem-1      1A63
C2  st-mem-2      1A63
E0  get-mem-0     1A45
E1  get-mem-1     1A45
E2  get-mem-2     1A45
```

Notes on the SYSTEM VARIABLES

dec.	Hex.	Name.	Notes.
16384	4000	ERR-NR	The 'report code'. The value is incremented before being printed.
16385	4001	FLAGS	Bit 0 — suppression of leading space. Bit 1 — control flag for the printer. Bit 2 — selects K or L mode; or, F or G. Bit 6 — F.P. number or string parameters. Bit 7 — Reset during syntax checking.
16386	4002 4003	ERR-SP	Points to the GOSUB stack.
16388	4004 4005	RAMTOP	The top of available RAM, or as specified.
16390	4006	MODE	Holds the code for K or F.
16391	4007 4008	PPC	The line number of the current statement.
16393	4009	VERSN	Marks the start of RAM that is SAVED.
16394	400A 400B	E-PPC	The BASIC line with the cursor.
16396	400C 400D	D-FILE	Pointer for the display file.
16398	400E 400F	DF-CC	Address for the PRINT AT position.
16400	4010 4011	VARS	Pointer for the variable area.
16402	4012 4013	DEST	The address of the current variable within the program area.
16404	4014 4015	E-LINE	The pointer for the workspace.
16406	4016 4017	CH-ADD	The pointer for scanning a line, either in the program area or the workspace.
16408	4018 4019	X-PTR	The syntax error address.
16410	401A 401B	STKBOT	The pointer for the bottom of the calculator stack.
16412	401C 401D	STKEND	The pointer for the top of the calculator stack.
16414	401E	BERG	A location used for many different counting purposes.
16415	401F 4020	MEM	The pointer to the base of a table of floating point numbers, either in the calculator stack or the variable area.

16417	4021	—	Not used.
16418	4022	DF-SZ	The number of lines in the lower screen.
16419	4023 4024	S-TOP	The current line number for the automatic listing.
16421	4025 4026	LAST-K	The 'key-value' of the last key that was pressed.
16423	4027	DEBOUNCE	The debounce status.
16424	4028	MARGIN	Adjusts for differing T.V. standards.
16425	4029 402A	NXTLIN	The line number of the next BASIC line to be interpreted.
16427	402B 402C	OLDPPC	The last line number is saved in case needed.
16429	402D	FLAGX	Bit 0 — Reset indicates an arrayed variable. Bit 1 — Reset indicates a given variable exists. Bit 5 — Set during INPUT mode. Bit 6 — Set when the INPUT is to be numeric.
16430	402E 402F	STRLEN	Length of string variable , or a BASIC line.
16432	4030 4031	T-ADDR	Pointer for the 'parameter' table. Also used to distinguish between PLOT and UNPLOT.
16434	4032 4033	SEED	The random function seed value.
16436	4034 4035	FRAMES	The counter for the frames.
16438	4036 4037	COORDS	The X & Y values of PLOT.
16440	4038	PR-CC	The counter for the printer buffer.
16441	4039 403A	S-POSN	The column and line numbers for PRINT AT.
16443	403B	CDFLAG	Bit 0 — set whenever a key is pressed. Bit 6 — the 'true' fast/slow flag. Bit 7 — the 'copy' of the fast/slow flag. It will be reset when FAST is needed.
16444	403C — 405C	PRBUFF	The printer buffer.
16477	405D — 407A	MEMBOT	A memory area that can hold 6 floating point numbers. (mem-0, mem-5.)
16507	407B 407C	—	Not used.
16509	407D	PROGRAM	The BASIC program starts here.

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Note: Readers of this book who are using machines fitted with the 'unimproved' ROM will have to bear the following points in mind.

- * Three bytes were added at 0EEF, hence the code formerly at 0EEF-102E is now at 0EF2-1031.
- * The code at 102F-1034 was rewritten using an extra location and is now at 1032-1038.
- * The code formerly at 1035-1732 is now at 1039-1736.
- * The three bytes formerly at 1733-1735 have been deleted, hence the code formerly at 1736-1DFD is now at 1737-1DFE.

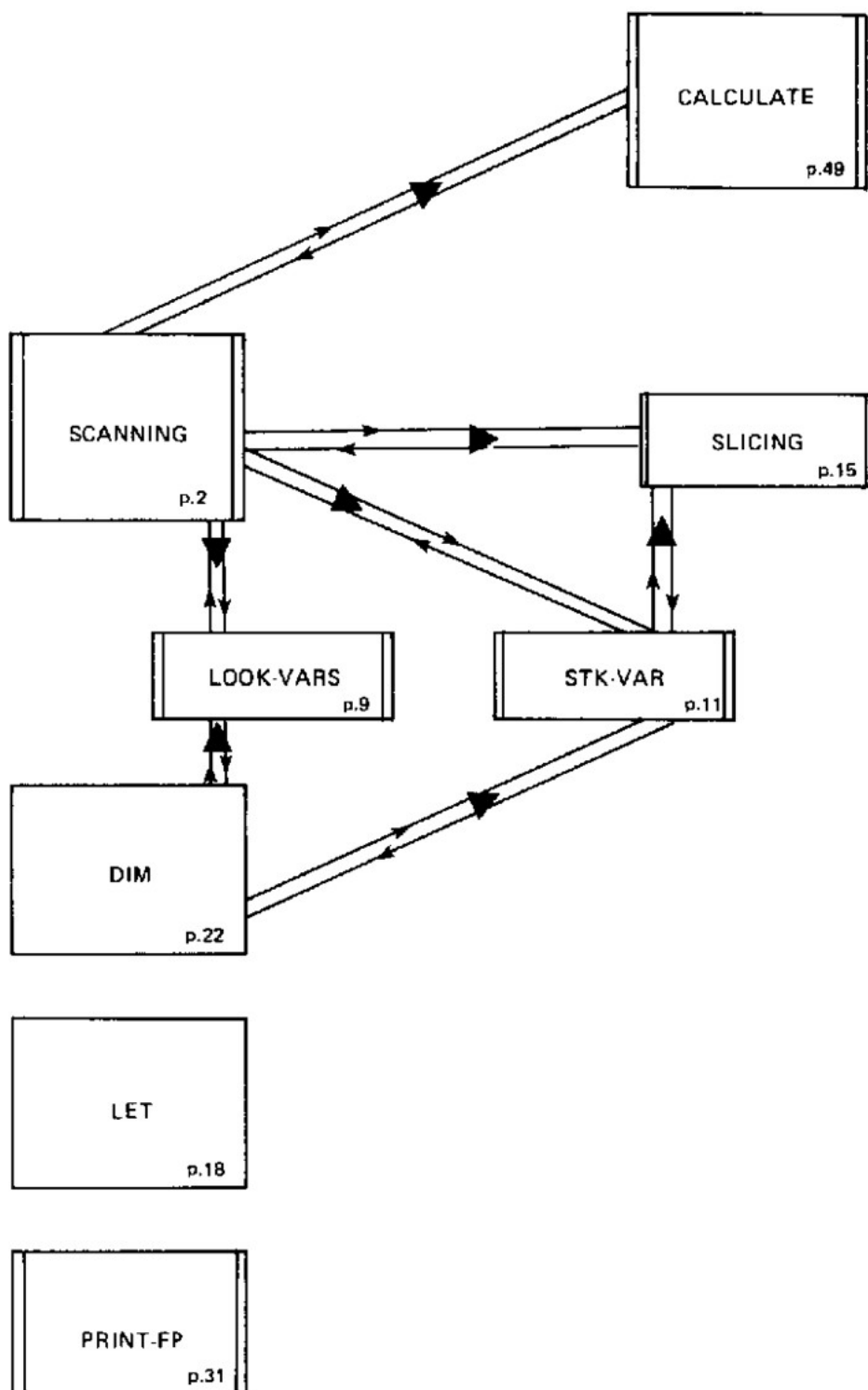
AUTHORS' COMMENTS:

The production of this book has only been possible because of the immense help given by Dr. Frank O'Hara, to whom floating point arithmetic is almost second nature. I therefore wish to record my grateful thanks to Frank.

Ian Logan, Lincoln January 1982

I am very pleased to have been able to help Ian Logan sort out the arithmetic of the ZX81. I remain amazed at the ease with which he works out what the machine is doing, without any help from the people who designed the hardware or those who wrote the programs.

Frank O'Hara, London January 1982



jump-true
 exchange
 delete
 subtract
 multiply
 division
 to-power
 or
 no.-&-no.
 no.-l-eql
 no.-gr-eq
 nos.-neql
 no.-grtr
 no.-less
 nos.-eql
 addition
 str-&-no.
 str-l-eql
 str-gr-eq
 str-neql
 str-grtr
 str-less
 str-eql
 str-add
 negate
 code
 val
 len
 sin
 cos
 tan
 asn
 acs
 atn
 ln
 exp
 int
 sqr
 sgn
 abs
 peek
 usr
 str
 chrs
 not
 duplicate
 n-mod-m
 jump
 stk-data
 dec-jr-nz
 less-0
 greater-0
 end-calc.
 get-argt.
 truncate
 fp-calc-2
 e-to-fp
 series-06 etc.
 stk-zero etc.
 st-mem-0 etc.
 get-mem-0 etc.

THE 'SCANNING' SUBROUTINE

This subroutine is used to produce an evaluation result of the 'next expression'.

The result is returned as the 'last value' on the calculator stack. For a numerical result, the 'last value' will be the actual floating-point number. However for a string result the 'last value' will consist of a set of parameters. The first of the five bytes is unspecified, the second and third bytes hold the address of the 'start' of the string and the fourth and fifth bytes hold the 'length' of the string.

Bit 6 of FLAGS is set for a numeric result and reset for a string result.

When a 'next expression' consists of only a single operand, e.g. ...A..., ...RND..., ...A\$(4,3 TO 7) ..., then the 'last value' is simply the value that is obtained from evaluating the operand.

However when the 'next expression' contains a function and an operand, e.g. ...CHR\$ A..., ...NOT A..., ...SIN 1..., the operation code of the function is stored on the machine stack until the 'last value' of the operand has been calculated. This 'last value' is then subjected to the appropriate operation to give a new 'last value'.

In the case of there being an arithmetic or logical operation to be performed, e.g. ...A+B..., ...A**B..., ...A=B..., then both the 'last value' of the first argument and the operation code have to be kept until the 'last value' of the second argument has been found. Indeed the calculation of the 'last value' of the second argument may also involve the storing of 'last values' and operation codes whilst the calculation is being performed.

It can therefore be shown that as a complex expression is evaluated, e.g. ...CHR\$ (T+A-26*INT ((T+A)/26)+38) ..., a hierarchy of operations yet to be performed is built up until the point is reached from which it must be dismantled to produce the final 'last value'.

Each operation code has associated with it an appropriate priority code and operations of higher priority are always performed before those of lower priority.

The subroutine begins with the A register being set to hold the first character of the expression and a starting priority marker — zero — being put on the machine stack.

OF55	SCANNING	RST	0018,GET-CH.	The first character is fetched.
		LD	B,+00	The starting priority marker.
		PUSH	BC	It is stacked.

The character is tested against the code for 'RND' and a jump made if it does not match.

OF59	S-RND	CP	+40	Is it 'RND'?
		JR	NZ,OF8C,S-PI	Jump if it is not so.

Unless syntax is being checked the required random number is calculated and forms a 'last value' on the calculator stack.

CALL	ODA6,SYNTAX-Z	Test for syntax checking.
JR	Z,OF8A,S-RND-END	Jump if required.
LD	BC,(SEED)	Fetch the current value of SEED.
CALL	1520,STACK-BC	Put it on the calculator stack.
RST	0028,FP-CALC.	Now use the calculator.
DEFB	+A1,stk-one,1A51	The 'last value' is now
DEFB	+0F,addition,1755	SEED+1.
DEFB	+30,stk-data,19FC	Put the decimal number 75
DEFB	+37,exponent 87	on the calculator stack.
DEFB	+16,(+00,+00,+00)	
DEFB	+04,multiply,17C6	'Last value' = (SEED+1)*75.
DEFB	+30,stk-data,19FC	See STACK LITERALS to see how
DEFB	+80,four bytes	bytes are expanded so as to put the
DEFB	+41,exponent 91	decimal number 65537 on the
DEFB	+00,+00,+80,(+00)	calculator stack.

DEFB +2E,n-mod-m,1C37		Divide (SEED+1)*75 by 65537 to give a 'remainder' and an 'answer'.
DEFB +02,delete,19E3		Discard the 'answer'.
DEFB +A1,stk-one,1A51		The 'last value' is now
DEFB +03,subtract,174C		'remainder'-1.
DEFB +2D,duplicate,19F6		Make a copy of the 'last value'.
DEFB +34,end-calc.,002B		The calculation is finished.
CALL 158A,FP-TO-BC		Use the 'last value' to give the new value for SEED.
LD (SEED),BC		Fetch the exponent of 'last value'.
LD A,(HL)		Jump forward if the exponent is zero.
AND A		Reduce the exponent, i.e. divide 'last value' by 65536 to give the required 'last value'.
JR Z,0F8A,S-RND-END		
SUB +10		
LD (HL),A		
0F8A S-RND-END JR	0F99,S-PI-END	Jump past the 'PI' routine.

The character is tested against the code for 'PI' and a jump made if it does not match.

0F8C S-PI	CP +42	Is it 'PI'?
	JR NZ,0F9D,S-INKEY\$	Jump if it is not so.

Unless syntax is being checked the value of 'PI' is calculated and forms the 'last value' on the calculator stack.

	CALL 0DA6,SYNTAX-Z	Test for syntax checking.
	JR Z,0F99,S-PI-END	Jump if required.
	RST 0028,FP-CALC.	Now use the calculator.
	DEFB +A3,stk-pi/2,1A51	The value of PI/2 is put on the calculator stack as the 'last value'.
	DEFB +34,end-calc.,002B	The exponent is incremented thereby doubling the 'last value' giving 'PI'.
	INC (HL)	
0F99 S-PI-END	RST 0020,NEXT-CH	Move on to the next character.
	JP 1083,S-NUMERIC	Jump forward.

The character is tested against the code for 'INKEY\$' and a jump made if it does not match.

0F9D S-INKEY\$	CP +41	Is it 'INKEY\$'?
	JR NZ,0FB2,S-ALPHNUM	Jump if it is not so.

The keyboard is now scanned and the parameters for the INKEY\$ string calculated. A null string will result in the BC register pair holding the value zero, whereas when a key has been pressed it holds the value one. The DE register pair points to the appropriate character in the key tables and that entry forms the actual string.

	CALL 02BB,KEYBOARD	Scan the keyboard & reset carry flag.
	LD B,H	Copy the 'key value' into the BC register pair.
	LD C,L	Set the zero flag when dealing with a null string.
	LD D,C	
	INC D	Decode the 'key value'. The carry flag is set when only one key is pressed.
	CALL NZ,07BD,DECODE	D register always holds zero.
		A now holds the value of the carry.
	LD A,D	Clears the B register.
	ADC A,D	C holds zero or one.
	LD B,D	The start pointer goes into DE.
	LD C,A	Jump forward.
	EX DE,HL	
	JR OFED,S-STRING	

The character is tested to see if it is alphanumeric.

0FB2 S-ALPHNUM	CALL 14D2,ALPHNUM	Test the character.
	JR C,1025,S-LET-NUM	Jump if a letter or a digit.

The character is tested against the code for '.', hence identifying a decimal number without a leading zero.

CP	+1B	Is it a '.' ?
JP	Z,1047,S-DECIMAL	Jump forward if it is so.

The character is tested against the code for '-', hence identifying the 'unary minus' operation.

Before the actual test the B register is set to hold the priority 9 and the C register the operation code D8 that are required for this operation.

LD	BC,+09D8	Priority 9, operation code D8.
CP	+16	Is it a '-' ?
JR	Z,1020,S-PUSH-PO	Jump forward if it is 'unary minus'.

The character is tested against the code for '(', hence identifying the presence of a parenthesised expression.

CP	+10	Is it a '(' ?
JR	NZ,0FD6,S-QUOTE	Jump if it is not so.

A parenthesised expression is dealt with in a recursive manner. An error is reported if there is no closing bracket.

CALL	0049,CH-ADD+1	Points to the next character.
CALL	0F55,SCANNING	Call the present subroutine.
CP	+11	Is the present character a ')' ?
JR	NZ,0FFF,S-RPRT-C1	Report C if no closing bracket.
CALL	0049,CH-ADD+1	Point to the next character.
JR	0FF8,S-CONT-1	Jump forward.

The character is tested against the code for '""', hence identifying a string of characters.

0FD6 S-QUOTE	CP	+0B	Is it a '""' ?
	JR	NZ,1002,S-FUNCT	Jump if it is not so.

The parameters for this string of characters are now calculated.

	CALL	0049,CH-ADD+1	Point to the next character.
	PUSH	HL	Save the 'start' address.
	JR	0FE3,S-Q-END?	Jump past the re-entry point.
0FE0 S-Q-NEXT	CALL	0049,CH-ADD+1	Point to the next character.
0FE3 S-Q-END?	CP	+0B	Is it another '""' ?
	JR	NZ,0FFB,S-N/L-ERR	Before re-entering the loop check that the line has not been finished.
	POP	DE	Get the 'start' into DE.
	AND	A	Clear the carry flag.
	SBC	HL,DE	Now find the 'length'.
	LD	B,H	Move the 'length' to the
	LD	C,L	BC register pair.

A string result has now been identified, either an INKEY\$ or a string of characters, therefore bit 6 of FLAGS must be reset. Unless syntax is being checked the parameters of the string are put on the calculator stack to form a 'last value'.

0FED S-STRING	LD	HL,+FLAGS	Make HL point to FLAGS.
	RES	6,(HL)	Reset this bit — string result.
	BIT	7,(HL)	Test for line execution.
	CALL	NZ,12C3,STK-STORE	Stack the parameters if executing a line.
	RST	0020,NEXT-CH	Move to the next character.
0FF8 S-CONT-1	JP	1088,S-CONT-3	Jump forward.

A NEWLINE character will lead to an error being reported.

OFFB	S-N/L-ERR	CP	+76	Is it a 'N/L' ?
		JR	NZ,0FE0,S-Q-NEXT	Re-enter the loop if it is not the end of a line.
0FFF	S-RPRT-C1	JP	0D9A,REPORT-C	Jump back to give report C.

The present character must now represent a function.

1002	S-FUNCT	SUB	+C4	The range of the functions is changed from C4-D7 to 00-13 Hex.
		JR	C,0FFF,S-RPRT-C1	Report an error if out of range.

The function 'NOT' is identified and dealt with separately from the others.

LD	BC,+04EC	Priority 4, operation code EC.
CP	+13	Is it the function 'NOT' ?
JR	Z,1020,S-PUSH-PO	Jump if it is so.
JR	NC,0FFF,S-RPRT-C1	Check the range again.

The remaining functions have priority 16 decimal. The operation codes for these functions are now calculated. Functions that operate on strings need bit 6 reset and functions that give string results need bit 7 reset in their operation codes.

	LD	B,+10	Priority 16 decimal.	
	ADD	A,+D9	The function range is now D9-EB.	
	LD	C,A	Transfer the operation code.	
	CP	+DC	Separate CODE, VAL & LEN which	
	JR	NC,101A,S-N0-T0-\$	operate on strings to give	
	RES	6,C	numerical results.	
101A	S-N0-T0-\$	CP	+EA	Separate STR\$ & CHR\$ which operate
	JR	C,1020,S-PUSH-PO	on numbers to give string results.	
	RES	7,C	Mark the operation codes.	
			The other operation codes have	
			bits 6 & 7 both set.	

The priority code and the operation code for the function being considered are now pushed to the machine stack. A hierarchy of operations is thereby built up.

1020	S-PUSH-PO	PUSH	BC	Stack the priority and operation codes
		RST	0020,NEXT-CH	before moving on to consider the
		JP	0F59,S-RND	next part of the expression.

The present character has been identified as being alphanumeric. If it is a letter then a variable name has been found; however if it is a digit then a decimal number has been found.

1025	S-LET-NUM	CP	+26	Jump if dealing with a digit.
		JR	C,1047,S-DECIMAL	

When a variable name has been identified a call is made to LOOK-VARS, which looks through those variables that already exist in the variable area. If an appropriate numeric value is found then it is copied to the calculator stack using MOVE-FP. However a string or string array entry has to have the appropriate parameters passed to the calculator stack by the STK-VAR subroutine.

CALL	111C,LOOK-VARS	Look in the existing variables for the matching entry.
JP	C,0D4B,REPORT-2	An error is reported if there is no existing entry.
CALL	Z,11A7,STK-VAR	Stack the parameters of the string entry/return numeric element base address.
LD	A,(FLAGS)	Fetch FLAGS.

CP	+CO	Test bits 6 & 7 together.
JR	C,1087,S-CONT-2	One or both bits are reset.
INC	HL	A numeric value is to be stacked.
LD	DE,(STKEND)	Fetch the 'old' STKEND.
CALL	19F6,MOVE-FP	Move the actual number.
EX	DE,HL	Move the pointer to HL.
LD	(STKEND),HL	Enter the 'new' STKEND.
JR	1087,S-CONT-2	Jump forward.

When a decimal number has been identified the action taken is very different for syntax checking and line execution.

If syntax is being checked then the floating-point form has to be calculated and copied into the actual BASIC line. However when a line is being executed the floating-point form will always be available so it is copied to the calculator stack to form a 'last value'.

1047	S-DECIMAL	CALL	0DA6,SYNTAX-Z		
		JR	NZ,106F,S-STK-DEC		Jump forward if a line is being executed.

During syntax checking:

CALL	14D9,DEC-TO-FP	The floating-point form is found.
RST	0018,GET-CH.	Set HL to point one — past the last digit.
LD	BC,+0006	Six locations are required.
CALL	099E,MAKE-ROOM	Make the room in the BASIC line.
INC	HL	Point to the first 'new' location.
LD	(HL),+7E	Enter the number marker character.
INC	HL	Point to the second location.
EX	DE,HL	This pointer is wanted in DE.
LD	HL,(STKEND)	Fetch the 'old' STKEND.
LD	C,+05	There are 5 bytes to move.
AND	A	Clear the carry flag.
SBC	HL,BC	The 'new' STKEND = 'old' STKEND - 5.
LD	(STKEND),HL	Move the floating-point number from the calculator stack to the line.
LDIR		Put the line pointer in HL.
EX	DE,HL	Point to the last byte added.
DEC	HL	This sets CH-ADD.
CALL	004C,CURSOR-S0	
JR	1083,S-NUMERIC	Jump forward.

During line execution:

106F	S-STK-DEC	RST	0020,NEXT-CH		Move on to the next character in turn until the number marker character is found.
		CP	+7E		
		JR	NZ,106F,S-STK-DEC		Point to the first byte of the number.
		INC	HL		Fetch the 'old' STKEND.
		LD	DE,(STKEND)		Move the floating point number.
		CALL	19F6,MOVE-FP		Save the 'new' STKEND.
		LD	(STKEND),DE		This sets CH-ADD.
		LD	(CH-ADD),HL		

A numeric result has now been identified, coming from RND, PI or a decimal number, therefore bit 6 of FLAGS must be set.

1083	S-NUMERIC	SET	6,(FLAGS)	Set the numeric marker flag.
------	-----------	-----	-----------	------------------------------

The scanning of the line now continues. The present argument may be followed by a '(', a binary operator or, if the end of the expression has been reached, a NEWLINE character or a command.

1087	S-CONT-2	RST	0018,GET-CH.	Fetch the present character.
1088	S-CONT-3	CP	+10	Jump forward if it is not a '(', which indicates a parenthesised expression.
		JR	NZ,1098,S-OPERTR	

If the 'last value' is numeric then the parenthesised expression is a true sub-expression and must be evaluated by itself. However if the 'last value' is a string then the parenthesised expression represents an element of an array or a slice of a string. A call to SLICING modifies the parameters of the string as required.

BIT	6,(FLAGS)	Jump forward if dealing with a numeric
JR	NZ,10BC,S-LOOP	parenthesised expression.
CALL	1263,SLICING	Modify the parameters of the 'last value'.
RST	0020,NEXT-CH	Move on to consider the next character.
JR	1088,S-CONT-3	

If the present character is indeed a binary operator it will be given an operation code in the range C3-CF Hex., and the appropriate priority code.

1098	S-OPERTR	LD	BC,+00C3	Set default priority zero and the operation code offset to C3.
		CP	+12	Compare the character against the lowest operator. Jump if out of range.
		JR	C,10BC,S-LOOP	The ranges of the operators are changed from 12-18 & D8-DD to FC-FF, 00-02 & C2-C7 Hex.
		SUB	+16	Jump forward with 00-02 & C2-C7. The original range 12-15 is now 09-0C Hex.
		JR	NC,10A7,S-HIGH-OP	Jump forward.
		ADD	A,+0D	Leave the original range 16-18 as 00-02 Hex.
10A7	S-HIGH-OP	JR	10B5,S-END-OP	The original range C2-C7 is now 00-05 Hex.
		CP	+03	Again jump if out of range.
		JR	C,10B5,S-END-OP	Test the upper limit.
		SUB	+C2	Again jump if out of range.
		JR	C,10BC,S-LOOP	The original range C2-C7 is now 03-08 Hex.
		CP	+06	The offset C3 is added to give the range of operation codes C3-CF Hex.
		JR	NC,10BC,S-LOOP	The pointer to the priority table. i.e. 104C+C3=110F the first address.
		ADD	A,+03	Index into the table.
10B5	S-END-OP	ADD	A,C	Fetch the appropriate priority.
		LD	C,A	
		LD	HL,+104C	
		ADD	HL,BC	
		LD	B,(HL)	

The main loop of this subroutine is now entered. At this stage there are:

- i A 'last value' on the calculator stack.
- ii The starting priority marker on the machine stack below a hierarchy, of unknown size, of function and binary operation codes. This hierarchy may be null.
- iii The BC register pair holding the 'present' operation and priority, which if the end of an expression has been reached will be priority zero.

Initially the 'last' operation and priority is taken off the machine stack and is compared against the 'present' operation and priority.

If the 'present' priority is higher than the 'last' priority then an exit is made from the loop as the 'present' priority is considered to bind tighter than the 'last' priority.

However if the priorities are less binding then the operation specified as the 'last' operation is performed. The 'present' operation and priority go back on the machine stack to be carried round the loop again. In this manner the hierarchy of functions and binary operations that have been queued are dealt with in the correct order.

10BC	S-LOOP	POP	DE	Get the 'last' operation and priority.
		LD	A,D	The priority goes to the A register.

CP	B	Compare 'last' against 'present'.
JR	C,10ED,S-TIGHTER	Exit to wait for the argument.
AND	A	Are both priorities zero?
JP	Z,0018, GET-CH.	Exit via GET-CH. thereby making 'last value' the required result.
PUSH	BC	Stack the 'present' values.
PUSH	DE	Stack the 'last' values briefly.
CALL	0DA6,SYNTAX-Z	Do not perform the actual operation if syntax is being checked.
JR	Z,10D5,S-SYNTTEST	The 'last' operation code.
LD	A,E	Strip off bits 6 & 7 to convert the operation code to a calculator-offset.
AND	+3F	It is required in the B register.
LD	B,A	Now use the calculator.
RST	0028,FP-CALC.	Perform the actual operation.
DEFB	+37,fp-calc-2,19E4	It has been done.
DEFB	+34,end-calc.,002B	Jump forward.
JR	10DE,S-RUNTEST	

An important part of syntax checking involves the testing of the operations to ensure that the nature of the 'last value' is of the correct type for the operation under consideration.

10D5 S-SYNTTEST	LD A,E	Get the 'last' operation code.
	XOR (FLAGS)	This tests the nature of the 'last value' against the requirement of the operation.
	AND +40	They are to be the same for correct syntax.
10DB S-RPRT-C2	JP NZ,0D9A,REPORT-C	Jump if syntax fails.

Before jumping back to go round the loop again the nature of the 'last value' must be recorded in FLAGS.

10DE S-RUNTEST	POP DE	Get the 'last' operation code.
	LD HL,+FLAGS	Point to FLAGS.
	SET 6,(HL)	Assume result to be numeric.
	BIT 7,E	Jump forward if the nature of 'last value' is numeric.
	JR NZ,10EA,S-ENDLOOP	It is string.
	RES 6,(HL)	Get the 'present' values into BC.
10EA S-ENDLOOP	POP BC	Jump back.
	JR 10BC,S-LOOP	

Whenever the operations bind tighter, the 'last' and the 'present' values go back on the machine stack. However if the 'present' operation requires a string as its operand then the operation code is modified to indicate this requirement.

10ED S-TIGHTER	PUSH DE	The 'last' values go on the stack.
	LD A,C	Get the 'present' operation code.
	BIT 6,(FLAGS)	Do not modify the operation code if dealing with a numeric operand.
	JR NZ,110A,S-NEXT	Clear bits 6 & 7.
	AND +3F	Increase the code by 08 Hex.
	ADD A,+08	Return the code to the C register.
	LD C,A	Is the operation 'AND' ?
	CP +10	Jump if it is not so.
	JR NZ,1102,S-NOT-AND	'AND' requires a numeric operand.
	SET 6,C	Jump forward.
1102 S-NOT-AND	JR 110A,S-NEXT	The operations -, *, /, ** & OR are not possible.
	JR C,10DB,S-RPRT-C2	Is the operation '+' ?
	CP +17	Jump if it is so.
	JR Z,110A,S-NEXT	The other operations yield a numeric result.
	SET 7,C	The 'present' values go on the stack.
110A S-NEXT	PUSH BC	

RST 0020,NEXT-CH

Move on to consider the next character in the expression.

JP 0F59,S-RND

Start by testing against 'RND'.

THE PRIORITY TABLE

address	priority	operation	address	priority	operation
110F	06	-	1116	05	>=
1110	08	*	1117	05	<>
1111	08	/	1118	05	>
1112	0A	**	1119	05	<
1113	02	OR	111A	05	=
1114	03	AND	111B	06	+
1115	05	<=			

THE 'LOOK-VARS' SUBROUTINE

This subroutine is called whenever a search of the variable area is required. The subroutine is entered with CH-ADD pointing to the first letter of the variable name as it occurs in the BASIC line, either in the program area or the work space.

The subroutine initially builds up a discriminator byte, in the C register, that is based on the first letter of the variable name. Bits 5 & 6 of this byte indicate which type of variable is being handled.

The B register is used as a bit register to hold flags.

111C	LOOK-VARS	SET 6,(FLAGS)	Presume a numeric variable.
	RST	0018,GET-CH.	Get the first character into A.
	CALL	14CE,ALPHA	Is it alphabetic?
	JP	NC,0D9A,REPORT-C	Give an error report if it is not so.
	PUSH	HL	Save the pointer to the first letter.
	LD	C,A	Transfer the letter to C.
	RST	0020,NEXT-CH	Get the 2nd character into A.
	PUSH	HL	Save the pointer to the 2nd character.
	RES	5,C	Start with bit 5 reset.
	CP	+10	Is the 2nd character a '(' ?
	JR	Z,1148,V-RUN/SYN	Separate arrays of numbers.
	SET	6,C	Now set bit 6.
	CP	+0D	Is the 2nd character a '\$' ?
	JR	Z,1143,V-STR-VAR	Separate all the strings.
	SET	5,C	Now set bit 5.

Now find the end character of a variable name which has more than one character.

1139	V-CHAR	CALL 14D2,ALPHANUM	Is the character alphanumeric?
	JR	NC,1148,V-RUN/SYN	Jump when the end is reached.
	RES	6,C	Mark the discriminator byte.
	RST	0020,NEXT-CH	Get the next character.
	JR	1139,V-CHAR	Go back to test it.

Simple strings and arrays of strings require that bit 6 of FLAGS is reset.

1143	V-STR-VAR	RST 0020,NEXT-CH	Move CH-ADD on past the '\$'.
	RES	6,(FLAGS)	Reset the bit 6 to indicate a string.

Now test the syntax flag.

1148	V-RUN/SYN	LD B,C	Copy the discriminator to B.
	CALL	0DA6,SYNTAX-Z	Test for syntax checking.

JR	NZ,1156,V-RUN	Jump forward if executing a line.
LD	A,C	Move it to A for manipulation.
AND	+E0	Drop the character code part.
SET	7,A	Indicate syntax by setting bit 7.
LD	C,A	Restore the discriminator to C.
JR	118A,V-SYNTAX	Jump forward.

A BASIC line is being executed so make a search of the variable area.

1156	V-RUN	LD	HL,(VARS)	Pick up the VARS pointer.
1159	V-EACH	LD	A,(HL)	The 1st letter of each variable.
		AND	+7F	Match on bits 0-6.
		JR	Z,1188,V-80-BYTE	Jump when the '80-byte' is reached.
		CP	C	The actual comparison.
		JR	NZ,1180,V-NEXT	Jump if the 1st letter does not match the discriminator byte.
		RLA		Rotate A leftwards and then double it to test bits 5 & 6.
		ADD	A,A	Strings and array variables.
		JP	P,1195,V-FOUND-2	Simple numeric and FOR-NEXT variables.
		JR	C,1195,V-FOUND-2	
		POP	DE	Get the pointer to the 2nd character.
		PUSH	DE	Put it back.
		PUSH	HL	Save the variable pointer.
116B	V-MATCHES	INC	HL	Go on to consider the next character.
116C	V-SPACES	LD	A,(DE)	Fetch each character in turn.
		INC	DE	Point to the next.
		AND	A	Is the character a 'space' ?
		JR	Z,116C,V-SPACES	Ignore the spaces.
		CP	(HL)	Make the comparison.
		JR	Z,116B,V-MATCHES	Back for another if it does match.
		OR	+80	Will it match with bit 7 set?
		CP	(HL)	Try it.
		JR	NZ,117F,V-GET-PTR	Jump if it does not match after all.
		LD	A,(DE)	Get the next character.
		CALL	14D2,ALPHANUM	Is it alphanumeric?
		JR	NC,1194,V-FOUND-1	Jump if the correct entry has been located in the variable area.
117F	V-GET-PTR	POP	HL	Fetch the variable pointer.
1180	V-NEXT	PUSH	BC	Save B & C briefly.
		CALL	09F2,NEXT-ONE	DE will then point to the next variable in the variable area.
		EX	DE,HL	Transfer the pointer to HL.
		POP	BC	Get B & C back.
		JR	1159,V-EACH	Round the loop again.

The variable name was not present in the variable area.

1188	V-80-BYTE	SET	7,B	Indicates — no variable found.
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The syntax path re-enters here.

118A	V-SYNTAX	POP	DE	Drop the pointer to the 2nd character.
		RST	0018,GET-CH.	Fetch the present character.
		CP	+10	Is it a '(' ?
		JR	Z,1199,V-PASS	Jump forward.
		SET	5,B	Indicate not dealing with an array.
		JR	11A1,V-END	Jump forward.

The matching variable has been found in the variable area.

1194	V-FOUND-1	POP	DE	Drop the saved variable pointer.
1195	V-FOUND-2	POP	DE	Drop the 2nd character pointer.
		POP	DE	Drop the first letter pointer.
		PUSH	HL	Save the 'last' letter pointer.
		RST	0018,GET-CH.	Fetch the current character.

If the matching variable name has more than a single letter then the other characters must be passed-over.

1199	V-PASS	CALL	14D2,ALPHANUM	Is it alphanumeric?
		JR	NC,11A1,V-END	Jump when the end of the name is reached, otherwise test again.
		RST	0020,NEXT-CH	Fetch the next character.
		JR	1199,V-PASS	Go back to test it.

The exit-parameters require to be set.

11A1	V-END	POP	HL	HL holds the 'first' or the 'last' letter pointer.
		RL	B	Rotate the whole register.
		BIT	6,B	The zero flag is specified.
		RET		Finished.

The exit-parameters for the subroutine are:

The system variable CH-ADD points to the first character after the variable name as it occurs in the BASIC line.

If no matching variable name was found in the variable area then:

- i The carry flag is set.
- ii The zero flag is set when the search was for an array variable.
- iii The HL register pair points to the first letter of the variable name.

If the search yielded a matching entry in the variable area then:

- i The carry flag is reset.
- ii The zero flag is set for both simple string variables and all array variables.
- iii The HL register pair points to the letter of a single lettered variable name, or the last character of a long variable name, as it occurs in the variable area.

Bit 6 of the C register is reset when dealing with an array of numbers and set when dealing with an array of strings.

Bit 7 of the C register is reset during line execution and set during syntax checking.

THE 'STK-VAR' SUBROUTINE

This subroutine is usually used either to find the parameters that define an existing string entry in the variable area, or to return in the HL register pair the base address of a particular element of an array of numbers. When called from DIM the subroutine only checks the syntax of the BASIC line.

Note that the parameters that define a string may be altered by calling SLICING if this should be specified.

Initially the A and B registers are cleared and bit 7 of the C register is tested to determine whether syntax is being checked.

11A7	STK-VAR	XOR	A	Clear the array flag.
		LD	B,A	Clear the B register for later.
		BIT	7,C	Jump forward if syntax is being checked.
		JR	NZ,11F8,SV-COUNT	

Next, simple strings are separated from array variables.

BIT	7,(HL)	
JR	NZ,11BF,SV-ARRAYS	Jump forward if dealing with an array variable.

The parameters for a simple string are readily found.

11B2	SV-SMPLE\$	INC A	Specify a simple string.
		INC HL	Move along the variable entry.
		LD C,(HL)	Pick up the low length counter.
		INC HL	On one.
		LD B,(HL)	Pick up the high length counter.
		INC HL	On one.
		EX DE,HL	Transfer the start pointer to DE.
		CALL 12C3,STK-STORE	Pass these parameters to the stack.
		RST 0018,GET-CH.	Fetch the present character.
		JP 125A,SV-SLICE?	Jump to see if a 'slice' is required.

The base address of an element of an array is now found. Initially the 'number of dimensions' is collected.

11BF	SV-ARRAYS	INC HL	
		INC HL	Go past the total length counter.
		INC HL	
		LD B,(HL)	Collect the 'number of dimensions'.
		BIT 6,C	Jump forward if dealing with an array of numbers.
		JR Z,11D1,SV-PTR	

If an array of strings has its 'number of dimensions' equal to '1' then such an array can be handled as a simple string.

DEC	B	
JR	Z,11B2,SV-SMPLE\$	Decrease the 'number of dimensions'. Jump if the number is now zero.

Next a check is made to ensure that in the BASIC line the variable is followed by a subscript.

EX	DE,HL	Save the variable pointer in DE.
RST	0018,GET-CH.	Get the present character.
CP	+10	Is it a '{' ?
JR	NZ,1231,REPORT-3	Report the error if it is not so.
EX	DE,HL	Restore the variable pointer.

For both numeric arrays and arrays of strings the variable pointer is transferred to the DE register pair before the subscript is evaluated.

11D1	SV-PTR	EX DE,HL	Variable pointer into DE.
		JR 11F8,SV-COUNT	Jump forward.

The following loop is used to find the parameters of a specified element within an array.

The loop is entered at the mid-point — SV-COUNT —, where the element counter is set to zero.

The loop is accessed 'B' times, this being, for a numeric array, equal to the number of dimensions that are being used, but for an array of strings 'B' is one less than the number of dimensions in use as the last subscript is used to specify a 'slice' of the string.

11D4	SV-COMMA	PUSH HL	Save the 'counter'.
		RST 0018,GET-CH.	Get the present character.
		POP HL	Restore the 'counter'.
		CP +1A	Is the present character a ',' ?
		JR Z,11FB,SV-LOOP	Jump to consider another subscript.
		BIT 7,C	If a line is being executed then
		JR Z,1231,REPORT-3	there is an error.

BIT	6,C	Jump if dealing with an array of strings.
JR	NZ,11E9,SV-CLOSE	Is the present character a '}' ?
CP	+11	Report an error if it is not so.
JR	NZ,1223,SV-RPT-C	Move CH-ADD to point to the next character in the BASIC line.
RST	0020,NEXT-CH	Return as the syntax is correct.
RET		

For an array of strings the present subscript may represent a 'slice', or the subscript for a 'slice' may yet be present in the BASIC line.

11E9	SV-CLOSE	CP	+11	Is the present character a '}' ?
		JR	Z,1259,SV-DIM	Jump forward and check whether there is another subscript.
		CP	+DF	Is the present character a 'TO' ?
		JR	NZ,1223,SV-RPT-C	It must not be otherwise.
11F1	SV-CH-ADD	RST	0018,GET-CH.	Get the present character.
		DEC	HL	Point to the preceding character.
		LD	(CH-ADD),HL	Make CH-ADD point to this location.
		JR	1256,SV-SLICE	Evaluate this 'slice'.

Enter the loop here.

11F8	SV-COUNT	LD	HL,+0000	Set the 'counter' to zero.
11FB	SV-LOOP	PUSH	HL	Save the 'counter' briefly.
		RST	0020,NEXT-CH	Makes CH-ADD point to the next character.
		POP	HL	Restore the 'counter'.
		LD	A,C	Fetch the discriminator byte.
		CP	+CO	Jump unless checking the syntax for an array of strings.
		JR	NZ,120C,SV-MULT	Get the present character.
		RST	0018,GET-CH.	Is it a '}' ?
		CP	+11	Jump forward as finished counting elements.
		JR	Z,1259,SV-DIM	Is it a 'TO' ?
		CP	+DF	Jump back if dealing with a 'slice'.
		JR	Z,11F1,SV-CH-ADD	Save the dimension-number counter and the discriminator byte.
120C	SV-MULT	PUSH	BC	Save the element 'counter'.
		PUSH	HL	Get a 'dimension-size' into DE.
		CALL	12FF,DE,(DE+1)	The 'counter' moves to HL and the variable pointer is stacked.
		EX	(SP),HL	The 'counter' moves to DE and the 'dimension-size' to HL.
		EX	DE,HL	Evaluate the next subscript.
		CALL	12DD,INT.-EXP1	Give the error if out of range.
		JR	C,1231,REPORT-3	The result of the evaluation is decremented as the 'counter' is to count the elements occurring before the specified element.
		DEC	BC	Multiply 'counter' by 'dimension-size'.
		CALL	1305,HL=HL*DE	Add the result of 'INT.-EXP1'-1 to the 'present counter'.
		ADD	HL,BC	Fetch the variable pointer.
		POP	DE	Fetch the dimension-number counter and the discriminator byte.
		POP	BC	Keep going round the loop until 'B' equals zero.
		DJNZ	11D4,SV-COMMA	

The syntax flag is checked before arrays of strings are separated from numeric arrays.

BIT 7,C

Syntax or line execution?

1223	SV-RPT-C	JR	NZ,128B,SL-RPT-C	Report the error if checking syntax.
		PUSH	HL	Save the 'counter'.
		BIT	6,C	Jump forward if dealing with
		JR	NZ,123D,SV-ELEM\$	an array of strings.

When dealing with a numeric array the present character must be a ') '.

LD	B,D	Transfer the variable pointer to
LD	C,E	the BC register pair.
RST	0018,GET-CH.	Fetch the present character.
CP	+11	Is it a ') ' ?
JR	Z,1233,SV-NUMBER	Report an error if it is not so.

Give report 3.

1231	REPORT-3	RST	0008,ERROR-1	Subscript out of range.
		DEFB	+02	

The address of the location before the actual floating-point number can now be calculated.

1233	SV-NUMBER	RST	0020,NEXT-CH	Move CH-ADD on one location.
		POP	HL	Fetch the 'counter'.
		LD	DE,+0005	There are 5 bytes to each element.
		CALL	1305,HL=HL*DE	Compute the total number of bytes.
		ADD	HL,BC	Add this number to the variable
				pointer, thereby HL will point to the
				location before the required element.
		RET		Finished with numeric arrays.

When dealing with an array of strings the length of an element is given by the last dimension-size. The appropriate parameters are calculated before being put on the calculator stack.

123D	SV-ELEM\$	CALL	12FF,DE,(DE+1)	Fetch the last 'dimension-size'.
		EX	(SP),HL	The variable pointer goes on the
				stack and the 'counter' to HL.
		CALL	1305,HL=HL*DE	Multiply 'counter' by 'dimension-size'.
		POP	BC	Fetch the 'variable pointer'.
		ADD	HL,BC	This gives HL pointing to the location
				before the actual element.
		INC	HL	So point to the start of the string.
		LD	B,D	Transfer the last 'dimension-size'
		LD	C,E	to BC to form the length.
		EX	DE,HL	Transfer the start pointer to DE.
		CALL	12C2,STK-ST-0	Pass the parameters to the
				calculator stack.

There are three possible forms of the last subscript. The first is illustrated by A\$(2,4 TO 8), the second by A\$(2) (4 TO 8) and the third by A\$(2) which is the default value indicating that the whole string is required.

		RST	0018,GET-CH.	Get the present character.
		CP	+11	Is it a ') ' ?
		JR	Z,1259,SV-DIM	Jump if it is so.
		CP	+1A	Is it a ', ' ?
		JR	NZ,1231,REPORT-3	Report an error if it is not so.
1256	SV-SLICE	CALL	1263,SLICING	Use SLICING to modify the parameters.
1259	SV-DIM	RST	0020,NEXT-CH	Get the next character.
125A	SV-SLICE?	CP	+10	Is it a '(', ' ?
		JR	Z,1256,SV-SLICE	Jump back to evaluate the 'slice'.
		RES	6,(FLAGS)	Indicate a string result.
		RET		Finished with arrays of strings.

THE 'SLICING' SUBROUTINE

The present string can be sliced using this subroutine. The subroutine is entered with the parameters of the string being present on the top of the calculator stack.

Initially the syntax flag is checked and the parameters of the string are fetched only if a line is being executed.

1263	SLICING	CALL 0DA6,SYNTAX-Z CALL NZ,13F8,STK-FETCH	Check the syntax flag. Collect the parameters if a line is being executed.
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The possibility of the 'slice' being '()' has to be considered.

RST	0020,NEXT-CH	Get the next character.
CP	+11	Is it a ')' ?
JR	Z,12BE,SL-STORE	Jump forward if it is so.

Before proceeding the registers are set up as required.

PUSH	DE	The 'start' goes on the stack.
XOR	A	The A register is cleared and also saved on the stack.
PUSH	AF	Save the 'length' briefly.
PUSH	BC	Assume that the 'slice' is to begin with the first character.
LD	DE,+0001	Get the first character into A.
RST	0018,GET-CH.	Put the 'length' into HL.
POP	HL	

The first parameter of the 'slice' is now evaluated.

CP	+DF	Is the present character a 'TO' ?
JR	Z,1292,SL-SECOND	The first parameter by default will be the current value of DE, i.e. '1'.
POP	AF	At this stage A will hold zero.
CALL	12DE,INT.-EXP2	BC will hold the first parameter and A will hold Hex.FF if there has been an 'out of range' error.
PUSH	AF	Transfer the first parameter to the DE register pair.
LD	D,B	Save the 'length' briefly.
LD	E,C	Get the present character.
PUSH	HL	Restore the 'length'.
RST	0018,GET-CH.	Is the present character a 'TO' ?
POP	HL	Jump forward to consider the second parameter.
CP	+DF	Is the present character a ')' ?
JR	Z,1292,SL-SECOND	There must be a closing bracket.
CP	+11	
1288	SL-RPT-C	JP NZ,0D9A,REPORT-C

There is no second value to the 'slice' under consideration.

LD	H,D	The last character of the 'slice' is also the first character.
LD	L,E	Jump forward.
JR	12A5,SL-DEFINE	

The second parameter of the 'slice' is now evaluated.

1292	SL-SECOND	PUSH HL	Save the 'length' briefly.
		RST 0020,NEXT-CH	Get the next character.
		POP HL	Restore the 'length'.
		CP +11	Is the present character a ')' ?

JR	Z,12A5,SL-DEFINE	Jump if there is no second parameter.
POP	AF	If the first parameter was in range
CALL	12DE,INT.-EXP2	A will hold zero, otherwise Hex. FF.
PUSH	AF	BC will hold the second parameter.
RST	0018,GET-CH.	Save the error register again.
LD	H,B	Get the present character.
LD	L,C	The value held in BC is the last
CP	+11	character of the 'slice'.
JR	NZ,128B,SL-RPT-C	Is the present character a '}'?
		Report the error if it is not so.

The 'new' parameters are now defined.

12A5	SL-DEFINE	POP	AF	Fetch the error register.
		EX	(SP),HL	Second parameter goes on the stack
		ADD	HL,DE	and the start goes to HL.
		DEC	HL	Add the first parameter to the start
		EX	(SP),HL	of the string.
		AND	A	Go back a location to get it correct.
		SBC	HL,DE	The 'new start' goes on the stack and
		LD	BC,+0000	the second parameter to HL.
		JR	C,12B9,SL-OVER	Prepare for subtraction.
		INC	HL	Finds the 'new length'.
		AND	A	By default the 'new length' is zero.
		JP	M,1231,REPORT-3	A 'negative slice' is a null string.
		LD	B,H	Add the inclusive byte.
		LD	C,L	Now test the error register.
12B9	SL-OVER	POP	DE	Jump if there was an 'out of range'
		RES	6,(FLAGS)	error whilst in INT.-EXP2.
				Transfer the 'new length' to the
				BC register pair.
				Get the 'new start' from the stack.
				Ensure a string is indicated.

When a line is being executed this subroutine enters the STK-STORE subroutine directly so as to stack the parameters of the string.

12BE	SL-STORE	CALL	0DA6,SYNTAX-Z	Check the syntax flag and return if
		RET	Z	syntax is being checked.

THE 'STK-STORE' SUBROUTINE

This subroutine passes the values held in the A, B, C, D and E registers to the calculator stack. The stack thereby grows in size by 5 bytes.

Although this subroutine could be used to transfer floating-point numbers it is, however, only used to transfer the parameters of strings.

Note that the A register is used as a flag to show whether the string is a simple string or part of an array of strings. However this flag would appear to be redundant in the final program.

12C2	STK-ST-0	XOR	A	Clear the array flag.
12C3	STK-STORE	PUSH	BC	Save the BC register pair briefly.
		CALL	19EB, TEST-5-SP	Is there room for the 5 bytes?
		POP	BC	Restore BC.
		LD	HL,(STKEND)	Fetch the current value of STKEND.
		LD	(HL),A	Pass the array flag.
		INC	HL	On one.
		LD	(HL),E	Pass the low address pointer.
		INC	HL	On one.
		LD	(HL),D	Pass the high address pointer.

INC	HL	On one.
LD	(HL),C	Pass the low length counter.
INC	HL	On one.
LD	(HL),B	Pass the high length counter.
INC	HL	On one.
LD	(STKEND),HL	Save the value in HL as STKEND.
RES	6,(FLAGS)	Show that the 'last value' is a string.
RET		Finished.

THE 'INT.-EXP' SUBROUTINE

This subroutine returns to the calling routine the evaluation result of the 'next expression' as an integer value held in the BC register pair. The subroutine also tests this result against a limit value supplied in the HL register pair. The carry flag becomes set if there is an 'out of range' error.

The A register is used as an error register and holds Hex.00 if there has not been a previous error and Hex.FF if there was an error when the subroutine was last called.

12DD	INT.-EXP1	XOR	A	Clear the error register.
12DE	INT.-EXP2	PUSH	DE	Save both DE and HL for the duration
		PUSH	HL	of the subroutine.
		PUSH	AF	Save the error register briefly.
		CALL	0D92,CLASS-6	The 'next expression' is evaluated to give
				a 'last value'.
		POP	AF	Restore the error register.
		CALL	0DA6,SYNTAX-Z	Jump forward if syntax is being
		JR	Z,12FC,I-RESTORE	checked.
		PUSH	AF	Save the error register briefly.
		CALL	0EA7,FIND-INT.	The 'last value' is compressed into the
				16 bits of the BC register pair.
		POP	DE	Get the error register into D.
		LD	A,B	Test the evaluation result.
		OR	C	
		SCF		Presume the error condition.
		JR	Z,12F9,I-CARRY	Jump if evaluation result is zero.
		POP	HL	Copy the 'limit value'. This will be
		PUSH	HL	either 'dimension-size', 'DIM-limit'
				or 'string length'.
		AND	A	Prepare for the subtraction.
		SBC	HL,BC	Make the test.
12F9	I-CARRY	LD	A,D	Fetch the error register.
		SBC	A,+00	If there is no error and no previous
				error then A holds zero and carry
				is reset.
				Otherwise A holds Hex.FF or FE, and
				carry is set.
12FC	I-RESTORE	POP	HL	Restore the HL and DE
		POP	DE	register pairs.
		RET		Finished.

THE 'DE,(DE+1)' SUBROUTINE

This subroutine performs the construction — LD DE,(DE+1) — and returns HL pointing to DE+2.

12FF	DE,(DE+1)	EX	DE,HL	Use HL for the construction.
		INC	HL	Points to 'DE+1'.
		LD	E,(HL)	In effect — LD E,(DE+1).
		INC	HL	Points to 'DE+2'.
		LD	D,(HL)	In effect — LD D,(DE+2).
		RET		Finished.

THE 'HL=HL*DE' SUBROUTINE

Unless syntax is being checked this subroutine performs the multiplication as stated.

Overflow of the 16 bits available gives 'REPORT 4'. This is not exactly the true situation but it implies that the machine is not large enough for the task envisaged by the programmer.

1305	HL=HL*DE	CALL	0DA6,SYNTAX-Z	Return if syntax is being checked.
		RET	Z	BC is saved.
		PUSH	BC	It is to be a 16 bit multiplication.
		LD	B,+10	A holds the high byte.
		LD	A,H	C holds the low byte.
		LD	C,L	Initialise the result to zero.
		LD	HL,+0000	Double the result.
1311	HL-LOOP	ADD	HL,HL	Jump if overflow.
		JR	C,131A,HL-OVER	Rotate bit 7 of C into the carry.
		RL	C	Rotate the carry into bit 0 and bit 7 into the carry flag.
		RLA		Jump if the carry flag is reset.
		JR	NC,131D,HL-AGAIN	Otherwise add DE in once.
		ADD	HL,DE	Report the overflow error.
131A	HL-OVER	JP	C,0ED3,REPORT-4	Until 16 passes have been made.
131D	HL-AGAIN	DJNZ	1311,HL-LOOP	Restore BC.
		POP	BC	Finished.
		RET		

THE 'LET' COMMAND ROUTINE

This is the actual assignment routine for both the LET and the INPUT commands.

When the destination variable is a newly declared variable then DEST will point to the first letter of the variable name as it occurs in the current BASIC line. Bit 1 of FLAGX will be set.

However if the destination variable has been used previously then bit 1 of FLAGX will be reset and DEST will point for a numeric variable to the location *before* the five bytes of the existing number; and for a string variable to the *first* location used by the existing string. The use of DEST in this manner applies to simple variables and to the elements of arrays.

Bit 0 of FLAGX is reset if the variable name indicates an array variable.

Initially the current value of DEST is collected and bit 1 of FLAGX tested.

1321	LET	LD	HL,(DEST)	Fetch the present value of DEST.
		BIT	1,(FLAGX)	Jump if dealing with an existing variable.
		JR	Z,136E,L-EXISTS	

A new variable is being used so the length of the name is found.

		LD	BC,+0005	Assume a numeric variable.
132D	L-EACH-CH	INC	BC	For each character of a name:
132E	L-NO-SP	INC	HL	Move along the name.
		LD	A,(HL)	Put the character in the A register.
		AND	A	Is the character a 'space'?
		JR	Z,132E,L-NO-SP	Ignore any spaces in a name.
		CALL	14D2,ALPHANUM	Is the character alphanumeric?
		JR	C,132D,L-EACH-CH	Jump back for another if it is so.
		CP	+0D	Is the present character a '\$'?
		JP	Z,13C8,L-NEWS	Jump as dealing with a new string variable — a simple string.

The appropriate amount of room for the variable name and its value is made available in the work space. The characters of a long name, with the exception of the first letter, are transferred. The last letter is ORed with Hex.80.

	RST	0030,BC-SPACES	Make the appropriate amount of free space available in the work space.
	PUSH	DE	DE points to the 2nd new space.
	LD	HL,(DEST)	Pointer to the start of the name.
	DEC	DE	DE points to the 1st new space.
	LD	A,C	Get the size of the variable.
	SUB	+06	The minimum size is 6.
	LD	B,A	B equals the number of extra letters.
	LD	A,+40	Prepare to mark the first letter.
	JR	Z,1359,L-SINGLE	Jump forward if name is short.
134B L-CHAR	INC	HL	For each letter of a long name:
	LD	A,(HL)	Put the character in the A register.
	AND	A	Again ignore any spaces.
	JR	Z,134B,L-CHAR	Jump back if it is a 'space'.
	INC	DE	For each location in the work space.
	LD	(DE),A	Transfer the character of the name.
	DJNZ	134B,L-CHAR	Until the whole name is done.
	OR	+80	Prepare to mark the last letter.
	LD	(DE),A	Now mark it.
	LD	A,+80	Prepare to mark the first letter.
1359 L-SINGLE	LD	HL,(DEST)	Pointer to the start of the name.
	XOR	(HL)	Mark the first letter as is required.
	POP	HL	Fetch the pointer to the 2nd free location.

The work space is now cleared up to the current entry and this entry is included in the variable area.

CALL	13E7,L-CLEAR	Clear the work space from E-LINE to (HL) & include the new entry in the variable area by changing the pointers.
------	--------------	---

An RST 002B instruction is used to 'delete' the 'last value' on the calculator stack. However this value is not overwritten.

1361	L-NUMERIC	PUSH	HL	Save the pointer to the location after the 'value' of the variable.
	RST	002B,FP-CALC.		Now use the calculator.
	DEFB	+02,delete,19E3		This moves STKEND back five
	DEFB	+34,end-calc.,002B		locations.
	POP	HL		Restore the pointer.

The HL register pair is made to point to the first location of the 'value' of the variable.

LD	BC,+0005	There are 5 locations.
AND	A	Prepare for subtraction.
SBC	HL,BC	HL now points to the first location.
JR	13AE,L-ENTER	Jump forward to enter the value.

Enter here if dealing with a variable name that has already been used. Bit 6 of FLAGS is tested to separate numeric variables from string, or array of string variables.

136E L-EXISTS	BIT	6,(FLAGS)	Jump forward if dealing with a string variable.
	JR	Z,137A,L-DELETE\$	

The new numeric value overwrites the old value, but first the HL register pair must be set to point 'one location past' the old value.

```
LD    DE,+0006
ADD   HL,DE
JR    1361,L-NUMERIC
```

Six bytes for a numeric variable.
HL now points one past.
Jump back to do the actual overwriting.

The parameters of the string variable are fetched and simple string variables separated from array of string variables.

```
137A L-DELETE$ LD    HL,(DEST)
              LD    BC,(STLEN)
              BIT    0,(FLAGX)
              JR    NZ,1387,L-ADD$
```

Fetch the start pointer.
Fetch the length counter.
Jump if dealing with a simple string.

The new string must not be a null string.

```
LD    A,B
OR    C
RET   Z
```

High length counter.
Low length counter.
Return if the string is null.

The next stage involves making available an appropriate amount of room for the new string in the work space.

```
PUSH HL
RST   0030,BC-SPACES
PUSH DE
PUSH BC
LD    D,H
LD    E,L
INC   HL
LD    (HL),+00
LDDR
```

Save the start pointer.
Make room in the work space.
Save the pointer to the 2nd space.
Save the length.
HL holds the address of STKBOT - 1.
HL now points to STKBOT.
A space is entered.
All of the new locations are now set to zero (except the 1st space).

The pointer to this 'new' area in the workspace is saved whilst the parameters of the 'new' string are fetched from the calculator stack.

```
PUSH HL
CALL  13F8,STK-FETCH
POP   HL
```

Save the 'new' area pointer.
Fetch the parameters.
Restore the pointer.

The length of the string is now compared to the amount of room that has been made available for it.

```
EX    (SP),HL
AND   A
SBC   HL,BC
ADD   HL,BC
JR    NC,13A3,L-LENGTH
LD    B,H
LD    C,L
13A3 L-LENGTH EX    (SP),HL
```

'Length' of new area to HL.
'Pointer' to new area to stack.
Prepare for subtraction.
Find the difference in the lengths.
Add it back.
Jump if the 'new' string will fit.
The procrustean shortening of a string that is too long.
'Length' of new area to stack.
'Pointer' to new area to HL.

As long as the new string is not a null string it is copied into the workspace. Procrustean lengthening is achieved by only moving the number of characters specified in the BC register pair.

```
EX    DE,HL
LD    A,B
OR    C
JR    Z,13AB,L-IN-W-S
LDIR
```

'Start' of string to HL.
'Pointer' to new area to DE.
Test the 'length' of the new string.
Jump forward if a null string.
The string is copied to the area reserved for it in the work space.

13AB	L-IN-W-S	POP	BC	'Length' of new area.
		POP	DE	Pointer to the 2nd space.
		POP	HL	The pointer to the start of the element in the array.

The string is now copied from the work space to its specified place in the variable area.

Note: Also used to transfer numeric values.

13AE	L-ENTER	EX	DE,HL	Change pointers over.
		LD	A,B	There is no need to move a string or number that has 'no length' attributed to it.
		OR	C	
		RET	Z	Save the address of the element.
		PUSH	DE	Move the string or number.
		LDIR		The address of the element is in HL.
		POP	HL	Finished with array variables.
		RET		

When a new string is to replace an old string the new string is entered as if it were a totally new variable before the old copy of that variable is reclaimed.

13B7	L-ADD\$	DEC	HL	HL is made to point to the variable name of the old copy of the string in the variable area.
		DEC	HL	The name goes into the A register.
		DEC	HL	The pointer to the name is saved.
		LD	A,(HL)	The length of the old copy is saved.
		PUSH	HL	
		PUSH	BC	

The new string is copied into the work space and included in the variable area by calling L-STRING before the old copy is reclaimed.

	CALL	13CE,L-STRING	Add the new string to the variables.
	POP	BC	The length of the old copy.
	POP	HL	The starting address of the old copy.
	INC	BC	The total length of a string variable is given by adding three to the number of characters.
	INC	BC	
	INC	BC	
	JP	0A60,RECLAIM-2	Exit by jumping to RECLAIM-2 which reclaims BC bytes starting at (HL).

A totally new string variable is added to the variable area as follows:

The variable's name is collected from the BASIC line and marked as representing a simple string.

13C8	L-NEWS\$	LD	A,+60	Prepare for the marking of the name.
		LD	HL,(DEST)	Fetch the address of the name.
		XOR	(HL)	Mark the name.

The parameters of the string are fetched and the appropriate amount of room is made for the string in the work space.

13CE	L-STRING	PUSH	AF	Save the name.
		CALL	13F8,STK-FETCH	Fetch the parameters of the string.
		EX	DE,HL	Switch over the pointers.
		ADD	HL,BC	Find the end of the new string + 1.
		PUSH	HL	Save the pointer to the 'end + 1'.
		INC	BC	Add three to the number of characters to make the full length that is required.
		INC	BC	
		INC	BC	
		RST	0030,BC-SPACES	Make the room in the work space.
		EX	DE,HL	End of the work space in DE.
		POP	HL	Restore 'end + 1' of string.

The new string can now be copied into the room prepared for it in the work space. The 'length' is calculated and added to the variable.

DEC BC	Move the new string and
DEC BC	one extra byte.
PUSH BC	Save the count of the bytes.
LDDR	Copy the string to the work space.
EX DE,HL	The location before the string to HL.
POP BC	Restore the count.
DEC BC	The length of the new string.
LD (HL),B	Enter high-length.
DEC HL	Back one.
LD (HL),C	Enter low-length.
POP AF	Restore the variable name.

All of the work space before the location pointed to by the HL register pair is reclaimed and the variable name is entered into the '80 byte'.

13E7 L-CLEAR	PUSH AF	Save the variable name briefly.
	CALL 14C7,RECLAIM-3	Reclaim the work space up to (HL).
	POP AF	Restore the variable name.
	DEC HL	Now point to the '80 byte'.
	LD (HL),A	Overwrite with the variable name.

The system variable E-LINE is set to equal STKBOT and hence clears the work space and an '80' is entered into the extra location at the end of the new string.

LD HL,(STKBOT)	Get the pointer STKBOT.
LD (E-LINE),HL	Make E-LINE equal STKBOT.
DEC HL	The extra byte after the new string.
LD (HL),+80	Make the new '80 byte'.
RET	Finished adding a new string.

THE 'STK-FETCH' SUBROUTINE

This subroutine collects either a five byte floating-point number, or a set of parameters that define a string, from the calculator stack. These five bytes represent the current 'last value'.

13F8 STK-FETCH	LD HL,(STKEND)	Get STKEND.
	DEC HL	Back one.
	LD B,(HL)	The fifth value.
	DEC HL	Back one.
	LD C,(HL)	The fourth value.
	DEC HL	Back one.
	LD D,(HL)	The third value.
	DEC HL	Back one.
	LD E,(HL)	The second value.
	DEC HL	Back one.
	LD A,(HL)	The first value.
	LD (STKEND),HL	The new value for STKEND.
	RET	Finished.

THE 'DIM' COMMAND ROUTINE

The routine starts with a search of the variable area to ascertain if a variable with the same variable name already exists. If such a variable is found then it is deleted by reclaiming the bytes involved.

The size of the new array is calculated and the appropriate amount of room is made available in the variable area. The parameters of the variable are entered and all of the elements are set to zero.

1409	DIM	CALL	111C,LOOK-VARS	Look for an existing variable.
140C	D-RPORT-C	JP	NZ,0D9A,REPORT-C	Give report C as there is an error.
		CALL	0DA6,SYNTAX-Z	Jump forward to D-RUN unless syntax is being checked.
		JR	NZ,141C,D-RUN	Presume a numeric array.
		RES	6,C	Check the syntax further.
		CALL	11A7,STK-VAR	Exit via CHECK-END.
141C	D-RUN	CALL	0D1D,CHECK-END	Jump if no existing variable.
		JR	C,1426,D-LETTER	Save the variable name.
		PUSH	BC	Find the start of the next variable.
		CALL	09F2,NEXT-ONE	Reclaim the bytes of the existing variable.
		CALL	0A60,RECLAIM-2	Restore the variable name.
		POP	BC	

The initial parameters of the variable are set.

1426	D-LETTER	SET	7,C	An array variable name has bit 7 set.
		LD	B,+00	Make the dimension counter zero.
		PUSH	BC	Save the counter and the name.
		LD	HL,+0001	Element length for an array of strings.
		BIT	6,C	Jump if dealing with an array of strings.
		JR	NZ,1434,D-SIZE	Element length for a numerical array.
1434	D-SIZE	LD	L,+05	Element length is to be in DE.
		EX	DE,HL	

The following loop is passed for each dimension that is specified in the BASIC line. The total number of bytes required for the elements of the array is built up in the DE register pair.

1435	D-NO-LOOP	RST	0020,NEXT-CH	Move CH-ADD on one byte.
		LD	H,+40	Set a 'limit-value'.
		CALL	12DD,INT.-EXP1	Evaluate the parameter.
		JP	C,1231,REPORT-3	Give an error if out of range.
		POP	HL	Restore the counter and the name.
		PUSH	BC	Stack the result of INT.-EXP1.
		INC	H	Increase the dimension count.
		PUSH	HL	Save the counter and the name.
		LD	H,B	Result of INT.-EXP1 is required in HL.
		LD	L,C	Check that enough RAM is available and transfer the byte total to DE.
		CALL	1305,HL=HL*DE	Get the present character.
		EX	DE,HL	Is it a ',' ?
		RST	0018,GET-CH.	Jump back if there is another dimension to be included.
		CP	+1A	
		JR	Z,1435,D-NO-LOOP	

The final values of the parameters are calculated.

CP	+11	Is it a ')' ?
JR	NZ,140C,D-RPORT-C	Jump if there has been an error.
RST	0020,NEXT-CH	Move CH-ADD on one byte.
POP	BC	Restore the counter and the name.
LD	A,C	Move the variable name to A.
LD	L,B	Move the dimension counter to L.
LD	H,+00	Clear the H register.
INC	HL	Increase the dimension count by two and then double the result to obtain the number of bytes required for the parameters.
INC	HL	
ADD	HL,HL	Add to this the number of bytes required for the elements.
ADD	HL,DE	'Out of RAM' if result too great.
JP	C,0ED3,REPORT-4	Save the element-byte total.
PUSH	DE	

PUSH BC	Save the counter and the name.
PUSH HL	Save the 'total'.
LD B,H	Move the 'total' to the
LD C,L	BC register pair.

The appropriate amount of room is now made in the variable area.

LD HL,(E-LINE)	Fetch E-LINE.
DEC HL	Point to the '80 byte'.
CALL 099E,MAKE-ROOM	Make BC spaces before the '80 byte'.
INC HL	Make HL point to the first space.

The parameters are now entered.

LD (HL),A	Enter the variable name.
POP BC	Fetch the 'total' and
DEC BC	decrease it by three to give
DEC BC	the required number.
DEC BC	
INC HL	Now point to the second location.
LD (HL),C	Enter the low-total.
INC HL	Point to the third location.
LD (HL),B	Enter the high-total.
POP AF	Fetch the 'dimension counter'.
INC HL	Point to the fourth location.
LD (HL),A	Enter the counter.

The elements of the array are all set to zero.

LD H,D	HL is made to point to the last
LD L,E	byte.
DEC DE	DE now points to the last but one.
LD (HL),+00	Enter a 'zero'.
POP BC	Fetch the element-byte total.
LDDR	Enter a 'zero' into all the other bytes
	and finish with HL pointing to the
	byte before the first element.

The 'dimension-sizes' are now entered.

147F DIM-SIZES	POP BC	Get the last dimension-size.
	LD (HL),B	Enter the high byte.
	DEC HL	Go back one location.
	LD (HL),C	Enter the low byte.
	DEC HL	Go back another location.
	DEC A	Decrease the dimension counter.
	JR NZ,147F,DIM-SIZES	Repeat the operation until the
		counter reaches zero.
	RET	Finished.

THE 'RESERVE' SUBROUTINE

This subroutine is a continuation of RST 0030,BC-SPACES, and is used to increase the size of the work space by the number of bytes specified.

1488 RESERVE	LD HL,(STKBOT)	Fetch the current value of STKBOT.
	DEC HL	Make HL point to the last location of
		the current work space.
	CALL 099E,MAKE-ROOM	Create BC spaces in the work space
		before the last location.

INC	HL	HL points to the 1st new space.
INC	HL	HL points to the 2nd new space.
POP	BC	Fetch the old value of E-LINE
LD	(E-LINE),BC	and restore it unaltered.
POP	BC	Restore BC, the number of new spaces.
EX	DE,HL	Now DE points to the 2nd new space.
INC	HL	Make HL point to the last location
		of the work space once again.
RET		Finished.

THE 'CLEAR' COMMAND ROUTINE

This routine 'clears' the variable area.

149A	CLEAR	LD	HL,(VARS)	Fetch the current value of VARS.
		LD	(HL),+80	Make this byte the '80 byte'.
		INC	HL	Point to the next location.
		LD	(E-LINE),HL	Make E-LINE point to this location.

THE 'X-TEMP' SUBROUTINE

This subroutine 'clears' the work space.

14A3	X-TEMP	LD	HL,(E-LINE)	Fetch the current value of E-LINE.
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THE 'SET-STK-B' SUBROUTINE

This subroutine 'places' an 'empty' calculator stack at the position pointed to by the HL register pair.

14A6	SET-STK-B	LD	(STKBOT),HL	Set the bottom of the stack.
14A9	SET-STK-E	LD	(STKEND),HL	Set the top of the stack.
		RET		Finished.

THE 'CURSOR-IN' SUBROUTINE

This subroutine sets the workspace to hold a line consisting of only the cursor marker and the NEWLINE characters. The lower screen is set to be two lines in size and the calculator stack is cleared.

14AD	CURSOR-IN	LD	HL,(E-LINE)	Fetch the current value of E-LINE.
		LD	(HL),+7F	Enter the cursor marker.
		INC	HL	Move to the next location.
		LD	(HL),+76	Enter the NEWLINE character.
		INC	HL	Make HL point to the next location.
		LD	(DF-SZ),+02	Lower screen is to be two lines.
		JR	14A6,SET-STK-B	Jump back to clear the calculator stack.

THE 'SET-MEM' SUBROUTINE

This subroutine makes MEM point to MEMBOT and returns STKEND pointing to the top of the calculator stack.

14BC	SET-MEM	LD	HL,+MEMBOT	Make HL point to MEMBOT.
		LD	(MEM),HL	Make MEM point to MEMBOT.
		LD	HL,(STKBOT)	Make HL point to the bottom of the
				calculator stack.
		JR	14A9,SET-STK-E	Jump back to make STKEND once
				again refer to the calculator stack.

THE 'RECLAIM-3' SUBROUTINE

This subroutine 'clears' the work space from its start to the location before that pointed to by the HL register pair.

14C7	RECLAIM-3	LD	DE,(E-LINE)	Fetch the current value of E-LINE.
		JP	0A5D,RECLAIM-1	Jump back to perform the clearance.

THE 'ALPHA' SUBROUTINE

This subroutine returns with the carry flag set if the present value of the A register denotes a valid letter of the alphabet.

14CE	ALPHA	CP	+26	Test against Hex. 26. The code for 'A'.
		JR	14D4,ALPHA-2	Jump forward.

THE 'ALPHANUM' SUBROUTINE

This subroutine returns with the carry flag set if the present value of the A register denotes a valid digit or letter.

14D2	ALPHANUM	CP	+1C	Test against Hex. 1C. The code for '0'.
14D4	ALPHA-2	CCF		Complement the carry flag.
		RET	NC	Return if not a valid character code.
		CP	+40	Test against the upper limit.
		RET		Finished.

THE 'DECIMAL TO FLOATING-POINT' SUBROUTINE

As part of syntax checking decimal numbers that occur in a BASIC line are converted to their floating-point forms. This subroutine reads the decimal number digit by digit and gives its result as a 'last value' on the calculator stack.

Firstly any integer part is converted.

14D9	DEC-TO-FP	CALL	1548,INT-TO-FP	Forms a 'last value' of the integer.
------	-----------	------	----------------	--------------------------------------

If the next character is a '.', then consider the decimal fraction.

	CP	+1B	Is the character a '.' ?
	JR	NZ,14F5,E-FORMAT	Jump forward to see if it is an 'E'.
	RST	0028,FP-CALC.	Now use the calculator.
	DEFB	+A1,stk-one,1A51	Find the floating-point form of the
	DEFB	+C0,stk-mem-0,1A63	decimal number '1', and save it in
	DEFB	+02,delete,19E3	the memory area.
	DEFB	+34,end-calc.,002B	
14E5	NXT-DGT-1	RST	0020,NEXT-CH
	CALL	1514,STK-DIGIT	Get the next character.
	JR	C,14F5,E-FORMAT	If it is a digit then stack it.
	RST	0028,FP-CALC.	If not jump forward.
	DEFB	+E0,get-mem-0,1A45	Now use the calculator.
	DEFB	+A4,stk-ten,1A51	For each passage of the loop, the
	DEFB	+05,division,1882	number saved in the memory area is
	DEFB	+C0,stk-mem-0,1A63	fetched, divided by 10 and restored.
	DEFB	+04,multiply,17C6	i.e. going from .1 to .01 to .001 etc.
	DEFB	+0F,addition,1755	The present digit is multiplied by
	DEFB	+34,end-calc.,002B	the 'saved number' and added to the
	JR	14E5,NXT-DGT-1	'last value'.
			Jump back to consider the next
			character.

Next consider any 'E-notation', i.e. the form xEm where m is a positive or negative integer.

14F5	E-FORMAT	CP	+2A	Is the present character an 'E' ?
		RET	NZ	Finished unless it is so.
		LD	(MEMBOT),+FF	Use the first byte of 'mem-O' as a sign-flag.
		RST	0020,NEXT-CH	Get the next character.
		CP	+15	Is it a '+' ?
		JR	Z,1508,SIGN-DONE	Jump forward.
		CP	+16	Is it a '-' ?
		JR	NZ,1509,ST-E-PART	Jump if neither '+' nor '-'.
		INC	(MEMBOT)	Change the sign of the flag.
1508	SIGN-DONE	RST	0020,NEXT-CH	Point to the first digit.
1509	ST-E-PART	CALL	1548,INT-TO-FP	Use this subroutine to stack the whole of the exponent, i.e. ABS m.
		RST	0028,FP-CALC.	Now use the calculator.
		DEFB	+E0,get-mem-0,1A45	Fetch the sign-flag.
		DEFB	+00,jump-true,1C2F	Jump if the sign-flag denotes '+'.
		DEFB	+02,to 1511,E-FP	
		DEFB	+18,negate,1AA0	Negate the value of the exponent.
1511	E-FP	DEFB	+38,e-to-fp,155A	The 'last value' is given the result of $x \cdot 10^m$.
		DEFB	+34,end-calc.,002B	
		RET		Finished.

THE 'STK-DIGIT' SUBROUTINE

This subroutine simply returns if the current value held in the A register does not represent a digit but if it does then the floating-point form for the digit becomes the 'last value' on the calculator stack.

1514	STK-DIGIT	CP	+1C	Is the value Hex.1C ?
		RET	C	Return if not in range.
		CP	+26	Is the value Hex.26 ?
		CCF		Complement the carry flag.
		RET	C	Return if not in range.
		SUB	+1C	Replace code by the actual digit.

THE 'STACK-A' SUBROUTINE

This subroutine gives the floating-point form for the absolute binary value currently held in the A register.

151D	STACK-A	LD	C,A	Transfer the value to the C register.
		LD	B,+00	Clear the B register.

THE 'STACK-BC' SUBROUTINE

This subroutine gives the floating-point form for the absolute binary value currently held in the BC register pair.

1520	STACK-BC	LD	IY,+ERR-NR	Re-initialise the IY register pair.
		PUSH	BC	Save BC briefly.
		RST	0028,FP-CALC.	Use the calculator.
		DEFB	+A0,stk-zero,1A51	Put zero on the stack so as to reserve 5 bytes. (Last value = 0)
		DEFB	+34,end-calc.,002B	Restore BC.
		POP	BC	
		LD	(HL),+91	Set exponent to 17 decimal for a 16-bit number, and then test whether B is in fact zero.
		LD	A,B	
		AND	A	

	JR	NZ,1536,NORML-FP	Jump forward when B is non-zero.
	LD	(HL),A	Else, zero to exponent byte.
	OR	C	Return if C is also zero as the
	RET	Z	'last value' is to be zero.
	LD	B,C	Transfer C to B.
	LD	C,(HL)	Clear the C register.
	LD	(HL),+89	Set exponent to 9 decimal for an
			8-bit number.
1536	NORML-FP	DEC (HL)	Normalize the floating-point form by
	SLA	C	shifting C & B left until a set
	RL	B	bit is found. The exponent is
	JR	NC,1536,NORML-FP	decremented on each loop.
	SRL	B	Now shift B & C right, resetting the
	RR	C	set bit for a positive number.
	INC	HL	Point to the 2nd byte.
	LD	(HL),B	Copy over the B register.
	INC	HL	Point to the 3rd byte.
	LD	(HL),C	Copy over the C register.
	DEC	HL	Return with the HL register
	DEC	HL	pair pointing to the exponent.
	RET		Finished.

THE 'INTEGER TO FLOATING-POINT' SUBROUTINE

This subroutine returns a 'last value' on the calculator stack that is the result of converting an integer in a BASIC line, i.e. the integer part of a decimal number or the line number, to its floating-point form.

Repeated calls to NEXT-CH fetch each digit of the integer in turn. An exit is made when a character that is not a digit has been fetched.

1548	INT-TO-FP	PUSH AF	Save the first digit — in A.
		RST 0028,FP-CALC.	Use the calculator.
		DEFB +A0,stk-zero,1A51	The 'last value' is now zero.
		DEFB +34,end-calc.,002B	
		POP AF	Restore the first digit.

Now a loop is set up. As long as the character is a digit then its floating-point form is found and stacked under the 'last value'. The 'last value' is then multiplied by decimal 10 and added to the 'digit' to form a new 'last value' which is carried back to the start of the loop.

154D	NXT-DGT-2	CALL 1514,STK-DIGIT	If the character is a digit then
		RET C	stack its floating-point form.
		RST 0028,FP-CALC.	Use the calculator.
		DEFB +01,exchange,1A72	'Digit' goes under 'last value'.
		DEFB +A4,stk-ten,1A51	Define decimal 10.
		DEFB +04,multiply,17C6	'Last value' = 'last value' * 10.
		DEFB +0F,addition,1755	'Last value' = 'last value' + 'digit'.
		DEFB +34,end-calc.,002B	
		RST 0020,NEXT-CH	Next character goes into A.
		JR 154D,NXT-DGT-2	Loop back with this character.

THE 'E-FORMAT TO FLOATING-POINT' SUBROUTINE (Offset 38 — see CALCULATE below: 'e-to-fp')

This subroutine gives a 'last value' on the top of the calculator stack that is the result of converting a number given in the form xEm, where m is a positive or negative integer. The subroutine is entered with m at the top of the calculator stack and x underneath m.

The method used is to find the absolute value of m, say p, and to multiply or divide x by 10**p according to whether m is positive or negative.

To achieve this, p is reduced by 7 for as long as possible and then by 1 until it is exhausted. Since p is usually less than decimal 38, no more than 8 loops are commonly taken.

- i Once again the first byte of mem-0 is used as a sign flag. It shows whether multiplication or division by $10^{**}p$ is required.

			Calculator Stack
155A	e-to-fp	RST 0028,FP-CALC.	x, m
		DEFB +2D,duplicate,19F6	x, m, m
		DEFB +32,less-0,1ADB	x, m, (1/0)
		DEFB +C0,st-mem-0,1A63	x, m, (1/0)
		DEFB +02,delete,19E3	x, m
		DEFB +27,abs,1AAA	x, p
			Logical value of m. Store sign flag in first byte of mem-0. $p = \text{ABS } m$.

- ii Now the main loop is entered. It starts by testing p to see whether it is exhausted.

1560	E-YET	DEFB +A1,stk-one,1A51	x, p, 1
		DEFB +03,subtract,174C	x, p-1
		DEFB +2D,duplicate,19F6	x, p-1, p-1
		DEFB +32,less-0,1ADB	x, p-1, (1/0)
		DEFB +00,jump-true,1C2F	x, p-1
		DEFB +22, to 1587,END-E	x, p-1

- iii Next p is reduced by 7 if possible, by 1 otherwise; and $10^{**}7$ or $10^{**}1$ is put on the calculator stack preparatory to multiplying or dividing.

		DEFB +2D,duplicate,19F6	x, p-1, p-1
		DEFB +30,stk-data,19FC	x, p-1, p-1, 6
		DEFB +33,exponent 83	
		DEFB +40,(+00,+00,+00)	
		DEFB +03,subtract,174C	x, p-1, p-7
		DEFB +2D,duplicate,19F6	x, p-1, p-7, p-7
		DEFB +32,less-0,1ADB	x, p-1, p-7, (1/0)
		DEFB +00,jump-true,1C2F	x, p-1, p-7
		DEFB +0C, to 157A,E-ONE	x, p-1, p-7
		DEFB +01,exchange,1A72	x, p-7, p-1
		DEFB +02,delete,19E3	x, p-7
		DEFB +01,exchange,1A72	p-7, x
		DEFB +30,stk-data,19FC	p-7, x, $10^{**}7$
		DEFB +80,four bytes	
		DEFB +48,exponent 98	
		DEFB +18,+96,+80,(+00)	
		DEFB +2F,jump,1C23	p-7, x, $10^{**}7$
		DEFB +04, to 157D,E-M/D	p-7, x, $10^{**}7$
157A	E-ONE	DEFB +02,delete,19E3	x, p-1
		DEFB +01,exchange,1A72	p-1, x
		DEFB +A4,stk-ten,1A51	p-1, x, 10

- iv The sign-flag is collected and tested thereby showing whether to multiply or divide by $10^{**}i$, where $i=1$ or 7. After the arithmetic operation a jump is made back to E-YET.

157D	E-M/D	DEFB +E0,get-mem-0,1A45	p-i, x, $10^{**}i$, (1/0)
		DEFB +00,jump-true,1C2F	p-i, x, $10^{**}i$
		DEFB +04, to 1583,E-DIV	p-i, x, $10^{**}i$
		DEFB +04,multiply,17C6	p-i, $x*10^{**}i$
		DEFB +2F,jump,1C23	p-i, $x*10^{**}i$
		DEFB +02, to 1584,E-EXC	p-i, $x*10^{**}i$
1583	E-DIV	DEFB +05,division,1882	p-i, $x*10^{**}-i$
1584	E-EXC	DEFB +01,exchange,1A72	$x*10^{**} +/-i$, p-i
		DEFB +2F,jump,1C23	$x*10^{**} +/-i$, p-i
		DEFB +DA, to 1560,E-YET	$x*10^{**} +/-i$, p-i

v An exit is made from the subroutine with the required 'last value'.

```
1587 END-E      DEFB +02,delete,19E3      x*10**m
                DEFB +34,end-calc.,002B
                RET
```

THE 'FLOATING-POINT TO BC' SUBROUTINE

This subroutine is called from four different places for various purposes and is used to compress the floating-point 'last value' into the BC register pair.

If the result is too large, i.e. greater than 65535 decimal, then the subroutine returns with the carry flag set. If the 'last value' is negative then the zero flag is reset.

The low-byte of the result is also copied to the A register.

```
158A FP-TO-BC  CALL 13F8,STK-FETCH      Get the 'last value'.
                AND  A                  Is the exponent zero?
                JR   NZ,1595,NOT-ZERO   Jump if it is not so.
                LD   B,A                Set B to hold zero.
                LD   C,A                Set C to hold zero.
                PUSH AF                 Save the carry and the zero flag.
                JR   15C6,FBC-END       Jump forward.
```

Once the special case of zero has been excluded, the upper limit is considered by comparing the value of the exponent against Hex.91.

```
1595 NOT-ZERO  LD   B,E                1st byte of mantissa to B.
                LD   E,C                3rd byte of mantissa to E.
                LD   C,D                2nd byte of mantissa to C.
                SUB  +91                Reduce the exponent by 145 decimal.
                CCF                      Complement the carry flag.
                BIT  7,B                The zero flag complements the sign bit,
                                        i.e. NZ for -ve numbers.
                PUSH AF                 Save the zero and the carry flags.
                SET  7,B                Restore the true numeric bit.
                JR   C,15C6,FBC-END     Jump to the end if the exponent is
                                        too great.
```

Note that the exponent byte e holds 128 decimal plus the true exponent, e'.

So far the cases of the exponent byte being zero, or greater than 144 decimal, have been dealt with. The exponent byte is currently in the A register and now has the range -144 to -1 decimal which corresponds to the true exponent e' range of -127 to 16 decimal.

Numbers whose true exponent is in the range 1 to 8 decimal, will compress into a single register, whereas an exponent in the range 9 to 16 requires two registers. Numbers whose true exponents are negative will vanish.

```
INC  A                Range is now -143 to 0 decimal.
NEG                      Range is now 143 to 0 decimal.
CP   +08              Define the true exponents 9 to 16
JR   C,15AF,SHIFT-TST and jump forward with them.
LD   E,C              Move 2nd byte of mantissa to E.
LD   C,B              Move 1st byte of mantissa to C.
LD   B,+00            Clear the B register.
SUB  +08              Range is now 135 to 0 decimal here.
```

Note that if the A register now holds zero it means that no shift of BC is needed (e' is 8 or 16 dec.). Otherwise the A register gives the length of the shift right needed. If the shift is to be greater than 8 places then the number will vanish (for true exponents -127 to -1).

15AF	SHIFT-TST	AND	A		
		LD	D,A		
		LD	A,E		
		RLCA			
		JR	Z,15BC,IN-PLACE		
15B5	SHIFT-BC	SRL	B		
		RR	C		
		DEC	D		
		JR	NZ,15B5,SHIFT-BC		
15BC	IN-PLACE	JR	NC,15C6,FBC-END		
		INC	BC		
		LD	A,B		
		OR	C		
		JR	NZ,15C6,FBC-END		
		POP	AF		
		SCF			
		PUSH	AF		
15C6	FBC-END	PUSH	BC		
		RST	0028,FP-CALC.		
		DEFB	+34,end-calc.,002B		
		POP	BC		
		POP	AF		
		LD	A,C		
		RET			

If zero then no shift is needed.
Transfer shift counter to D.
Prepare 9th/17th bit for
rounding up.

Jump if A was zero; no shift.
Shift B & C right D times to
produce the correct number.
Decrement the shift counter.

Loop until D becomes zero.
End if no rounding-up needed;
else round up.

Test if number now equals 65536 dec.
i.e. BC now zero — out of range.
Jump if in range.

Fetch zero and carry flags.

Set carry flag as out of range.

Save the zero and carry flags.

Save the result briefly.

Use the calculator.

This makes HL point to STKEND - 5.

Restore the result.

Restore the zero and the carry flags.

Copy over the low byte of the result.

Finished.

THE 'FLOATING-POINT TO A' SUBROUTINE

This short but vital subroutine is called at least 5 times for various purposes. It uses the previous subroutine, FP-TO-BC, to get the 'last value' into the A register where this is possible. It therefore tests whether the modulus of the number rounds to more than 255 and if it does the subroutine returns with the carry flag set. Otherwise it returns with the modulus of the number, rounded to the nearest integer, in the A register, and the zero flag set to imply that the number was positive, or reset to imply that it was negative.

15CD	FP-TO-A	CALL	158A,FP-TO-BC		
		RET	C		
		PUSH	AF		
		DEC	B		
		INC	B		
		JR	Z,15D9,FP-A-END		
		POP	AF		
		SCF			
		RET			
15D9	FP-A-END	POP	AF		
		RET			

Compress the 'last value' into BC.

Return if out of range already.

Save the result and the flags.

Again it will be out of range

if the B register does not hold zero.

Jump if in range.

Fetch the result and the flags.

Signal the result is out of range.

Finished — unsuccessful.

Fetch the result and the flags.

Finished — successful.

THE 'PRINT A FLOATING-POINT NUMBER' SUBROUTINE

This subroutine is called by the PRINT command routine at 0B61 and by STR\$ at 1BD5, which converts to a string the number as it would be printed. The subroutine prints X, the 'last value' on the calculator stack. The print format never occupies more than 14 spaces. The subroutine first calculates:

$$n = \text{INT} ((e' - .5) * \log_{10} 2), \text{ where } e' \text{ is the true exponent.}$$

The number of digits before the decimal point of X is always n, n+1 or n+2.

Next the subroutine calculates:

$m = \text{INT} (10^{**} (8-n) * \text{ABS } X + .5)$, the decimal representation of which is stored in an *ad hoc* print buffer in mem-2 to mem-4.

The 8 most significant digits of X, correctly rounded, are printed out from m; 1 or 2 leading zeros in m as needed ensure that the correct number of digits are printed before the decimal point (without the leading zeros of course); trailing zeros are suppressed; and E-format is printed if needed.

So many cases are possible that it is best to try examples, referring to the ZX81 manual as needed.

i First the sign of X is taken care of:

If X is negative, the subroutine jumps to P-NEG, takes ABS X and prints the minus sign.

If X is zero, X is deleted from the calculator stack, a '0' is printed and a return is made from the subroutine.

If X is positive, the routine just continues.

15DB	PRINT-FP	RST 0028,FP-CALC.	Use the calculator.
		DEFB +2D,duplicate,19F6	X, X
		DEFB +32,less-0,1ADB	X, (1/0) Logical value of X.
		DEFB +00,jump-true,1C2F	X
		DEFB +0B, to 15EA,P-NEG	X
		DEFB +2D,duplicate,19F6	X, X
		DEFB +33,greater-0,1ACE	X, (1/0) Logical value of X.
		DEFB +00,jump-true,1C2F	X
		DEFB +0D, to 15F0,P-POS	X Hereafter X' = ABS X.
		DEFB +02,delete,19E3	—
		DEFB +34,end-calc., 002B	—
		LD A,+1C	Enter the character code for '0'.
		RST 0010,PRINT-A	Print the '0'.
		RET	Finished as the 'last value' is equal to zero.
15EA	P-NEG	DEFB +27,abs,1AAA	X' X' = ABS X.
		DEFB +34,end-calc.,002B	X'
		LD A,+1B	Enter the character code for '-'
		RST 0010,PRINT-A	Print the '-'.
		RST 0028,FP-CALC.	Use the calculator again.
15F0	P-POS	DEFB +34,end-calc.,002B	Exit with HL pointing to the exponent byte of X'.

ii The number n is calculated and stored in mem-1, to be recalled for use after the 'print buffer' has been set up. Note that e' is obtained by subtracting Hex.80 from the full exponent e presently addressed by the HL register pair. In fact 128.5 decimal is subtracted all at once. It and log of 2 to base 10 are both stacked as immediate data by calling 'stk-data' at 19FC.

LD A,(HL)	Fetch the exponent e of X'.
CALL 151D,STACK-A	X', e
RST 0028,FP-CALC.	Use the calculator.
DEFB +30,stk-data,19FC	X', e, 128.5 (dec)
DEFB +78,exponent 88	
DEFB +00,+80,(+00,+00)	
DEFB +03,subtract,174C	X', e'-.5
DEFB +30,stk-data,19FC	X', e'-.5, log 2 (base 10)
DEFB +EF,exponent 7F	
DEFB +1A,+20,+9A,+85	
DEFB +04,multiply,17C6	X', (e'-.5)*log 2
DEFB +24,int,1C46	X', n
DEFB +C1,st-mem-1,1A63	X', n (n is copied to mem-1)

iii Next m is calculated, providing enough digits to give a print buffer from which the 8 most significant digits of X, correctly rounded, can be printed out.

DEFB +30,stk-data,19FC	X', n, 8
DEFB +34,exponent 84	
DEFB +00,(+00,+00,+00)	
DEFB +03,subtract,174C	X', n-8
DEFB +18,negate,1AA0	X', 8-n

DEFB +38,e-to-fp,155A	$10^{*(8-n)*X'}$
DEFB +A2,stk-half,1A51	$10^{*(8-n)*X'}, .5$
DEFB +0F,addition,1755	$10^{*(8-n)*X'}+.5$
DEFB +24,int,1C46	m
DEFB +34,end-calc.,002B	m

- iv Ten digits from m are now stored in mem-3 and mem-4 in reverse order. This means that up to 2 leading zeros are stored (since m has 8 to 10 digits) and this will ensure that the correct number of digits are printed before the decimal in X.

LD HL,+406B	Address of last byte of mem-2.
LD (HL),+90	Marker byte Hex.90 – see 1620 below.
LD B,+0A	B will count the 10 digits.

Perform the following loop 10 times.

1615	NXT-DGT-3	INC HL	Each byte of mem-3 and mem-4.
		PUSH HL	Save the pointer.
		PUSH BC	Save the digit-counter.
		RST 0028,FP-CALC.	Use the calculator.
		DEFB +A4,stk-ten,1A51	m, 10
		DEFB +2E,n-mod-m,1C37	$m \bmod 10$, INT (m/10)
		DEFB +01,exchange,1A72	INT (m/10), m mod 10
		DEFB +34,end-calc.,002B	
		CALL 15CD,FP-TO-A	A will hold m mod 10.
1620		OR +90	Add left nibble of Hex.9 to each digit;
			this ensures full carry on half carry
			after DAA.
		POP BC	Restore the digit-counter.
		POP HL	Restore the pointer.
		LD (HL),A	Store this digit in the buffer.
		DJNZ 1615,NXT-DGT-3	Until 10 digits have been stored.

Pass over any leading zeros.

		INC HL	Point one-past the end of mem-4.
		LD BC,+0008	Looking for 8 digits.
		PUSH HL	Save the pointer.
162C	GET-FIRST	DEC HL	Pass over any leading zeros; the
		LD A,(HL)	first non-zero digit will be the
		CP +90	first digit of X to be printed.
		JR Z,162C,GET-FIRST	Jump back if digit is zero.

Round up the digits if necessary.

		SBC HL,BC	Point to the 9th digit; use it to
		PUSH HL	round up 8th digit; first save the
		LD A,(HL)	pointer here, then add Hex.6B.
		ADD A,+6B	(6B + 95 = 0100 Hex. & carry set)
		PUSH AF	Save the carry flag.
1639	ROUND-UP	POP AF	Restore the carry inside loop.
		INC HL	Increment the pointer.
		LD A,(HL)	Get the digit and round it up by
		ADC A,+00	adding in the carry.
		DAA	Set the carry if the digit becomes
			10 decimal.
		PUSH AF	Save the new carry.
		AND +0F	Remove the left nibble of the digit.
		LD (HL),A	Store the digit.
		SET 7,(HL)	This changes Hex.00 to Hex.80 and
			prevents any final 0's after the decimal
			from being printed. (see 164B,MARKERS)

	JR	Z,1639,ROUND-UP	Go for any carry ripple or further final zeros.
	POP	AF	Discard the carry.
	POP	HL	Restore the pointer to the 9th digit.

Enter six marker bytes.

164B	MARKERS	LD	B,+06	These six markers will end output by setting the overflow flag after DEC and INC — see 16C4 and 16CA below.
		LD	(HL),+80	
		DEC	HL	
		DJNZ	164B,MARKERS	

Note that the markers are in the 6 locations which precede the 8 significant digits of the number; so they will end the output even after 13 digits are printed; a marker will turn into a '0' when its left nibble is cleared.

v The digits can now be printed.

		RST	0028,FP-CALC.	Use the calculator.
		DEFB	+02,delete,19E3	Delete the '0' left on the stack.
		DEFB	+E1,get-mem-1,1A45	Get the number n from mem-1.
		DEFB	+34,end-calc.,002B	
		CALL	15CD,FP-TO-A	Put ABS n into the A register.
		JR	Z,165B,SIGND-EXP	If n positive (Z flag set), jump.
		NEG		Else, negate A.
165B	SIGND-EXP	LD	E,A	A now holds true n; copy to E.
		INC	E	
		INC	E	E now holds n+2.
		POP	HL	Get the pointer to one-past the end of mem-4.
165F	GET-FST-2	DEC	HL	Find first non-zero digit of X
		DEC	E	again, thus passing over the 1 or 2
		LD	A,(HL)	leading zeros that may be present;
		AND	+0F	decrease E to ensure that the correct
		JR	Z,165F,GET-FST-2	number of digits before the decimal
				are printed.
		LD	A,E	Put count back into A; at this point
				-5 and 12 are the critical values of
				the counter.
		SUB	+05	Subtract 5; -10 and 7 are now the
		CP	+08	critical values; i.e. the jump to
		JP	P,1682,E-NEEDED	E-NEEDED will now occur, unless A
		CP	+F6	is less than 8, or greater than 245.
		JP	M,1682,E-NEEDED	(245 dec. is -11 in 2's comp.)
		ADD	A,+06	Add 6, giving the true critical values,
				i.e. -4 and 13.

Note that A now contains the correct number of digits before the decimal in X, and that these digits will be printed in full if they are not more than 13 decimal, while up to 4 initial zeros will be printed after the decimal if A is negative. Outside that range E-format will be needed.

		JR	Z,16BF,OUT-ZERO	If A holds zero then go and print a '0' and continue into decimal part.
		JP	M,16B2,EXP-MINUS	If A is minus then go and print the 'decimal-point' and the digits.
		LD	B,A	A is positive, so transfer to B.
167B	OUT-B-CHS	CALL	16DO,OUT-NEXT	Print B characters.
		DJNZ	167B,OUT-B-CHS	Then jump forward to test whether
		JR	16C2,TEST-INT	just an integer, or a 'decimal-point' is needed.

E-format is required.

```

1682 E-NEEDED LD B,E
          CALL 16D0,OUT-NEXT
          CALL 16C2,TEST-INT

          LD A,+2A
          RST 0010,PRINT-A
          LD A,B
          AND A
          JP P,1698,PLUS-SIGN
          NEG
          LD B,A
          LD A,+16
          JR 169A,OUT-SIGN
1698 PLUS-SIGN LD A,+15
169A OUT-SIGN RST 0010,PRINT-A
          LD A,B
          LD B,FF
169E TEN-MORE INC B
          SUB +0A
          JR NC,169E,TEN-MORE
          ADD A,+0A
          LD C,A
          LD A,B
          AND A
          JR Z,16AD,BYTE-TWO
          CALL 07EB,OUT-CODE
16AD BYTE-TWO LD A,C
          CALL 07EB,OUT-CODE
          RET

```

B now contains the correct integer to follow 'E' of E-format.
 Print the first digit.
 Test whether there are more non-zero digits, in which case a 'decimal-point' will be needed.
 Enter the character code for 'E'.
 Print the 'E'.
 Transfer the 'exponent' integer to A.
 Set the flags.
 If positive, jump and print a '+'.
 Else, change its sign.
 Transfer back to B, briefly.
 Enter the character code for '-'.
 Jump forward.
 Enter the character code for '+'.
 Print the sign character.
 Transfer the 'exponent' back to A.
 Now reduce A mod 10 to give B equal to INT (A/10); initialise B to -1 (2's comp.) and increment it each time A is decreased by 10.
 After the loop, restore the last 10 to A; and store A in the C register.
 Transfer the 'tens' to A.
 Test to see if there are any 'tens'.
 Jump forward if no 'tens'.
 Print the first digit.
 Fetch the 'unit' digit.
 Print the digit.
 Finished with E-format.

Decimal format is required.

```

16B2 EXP-MINUS NEG

          LD B,A
          LD A,+1B
          RST 0010,PRINT-A
          LD A,+1C
16BA OUT-ZEROS RST 0010,PRINT-A
          DJNZ 16BA,OUT-ZEROS
          JR 16C8,TEST-DONE

```

A was negative but in range for simple printing so the format is .000...dddd with up to 4 zeros.
 B will count out the zeros.
 Enter the character code for '.'.
 Now print the 'decimal-point'.
 Enter the character code for '0'.
 Print the '0'.
 Until B reaches zero.
 Exit via TEST-DONE to print the digits until they also are finished.

The special case of the 'exponent' being zero.

```

16BF OUT-ZERO LD A,+1C
          RST 0010,PRINT-A

```

Enter the character code for '0'.
 Print the '0' and continue with TEST-INT to print the decimal part.

THE 'TEST-INT' SUBROUTINE

If the next digit to be printed is a 'marker' byte then the subroutine returns, otherwise the decimal point is printed and the subroutine enters TEST-DONE.

```

16C2 TEST-INT DEC (HL)
          INC (HL)

```

This gives PE (overflow/parity flag set) if (HL) was Hex.80.
 PE is kept, incrementing to Hex.80.

16C4	RET	PE	So a 'marker' byte forces a return.
	LD	A,+1B	Enter the character code for '.'.
	RST	0010,PRINT-A	Now print the 'decimal-point'.

Note that the decimal point is not printed if the number is an integer, all printed, or if there is just one digit to go before the 'E' of the exponent part.

THE 'TEST-DONE' SUBROUTINE

The digits in the *ad hoc* print buffer, mem-2 to mem-4, are printed in turn until a 'marker' byte is found.

16C8	TEST-DONE	DEC	(HL)	Test the digit to see if it is a
		INC	(HL)	'marker' (see TEST-INT).
16CA		RET	PE	Return when a 'marker' is found.
		CALL	16D0,OUT-NEXT	Print the digit.
		JR	16C8,TEST-DONE	Jump back to consider the next digit.

THE 'OUT-NEXT' SUBROUTINE

This subroutine prepares the current digit for printing, passes it to OUT-CODE and moves the pointer to the next digit.

16D0	OUT-NEXT	LD	A,(HL)	Fetch the present digit.
		AND	+0F	Mask off any unwanted bits.
		CALL	07EB,OUT-CODE	Pass the digit for actual printing.
		DEC	HL	Move the pointer back an address.
		RET		Finished.

THE 'PREPARE TO ADD' SUBROUTINE

This subroutine is the first of four subroutines that are used by the main arithmetic operation routines – SUBTRACTION, ADDITION, MULTIPLICATION and DIVISION.

This particular subroutine prepares a floating-point number for addition, mainly by replacing the sign bit with a true numerical bit, 1, and negating the number (2's complement) if it is negative. The exponent is returned in the A register and the first byte is set to Hex.00 for a positive number and Hex.FF for a negative number.

16D8	PREP-ADD	LD	A,(HL)	Transfer the exponent to A.
		LD	(HL),+00	Presume a positive number.
		AND	A	If the number is zero then the
		RET	Z	preparation is already finished.
		INC	HL	Now point to the sign byte.
		BIT	7,(HL)	Set the zero flag for positive number.
		SET	7,(HL)	Restore the true numeric bit.
		DEC	HL	Point to the first byte again.
		RET	Z	Positive numbers have been prepared,
				but negative numbers need to be 2's
				complemented.
		PUSH	BC	Save any earlier exponent.
		LD	BC,+0005	There are 5 bytes to be handled.
		ADD	HL,BC	Point one-past the last byte.
		LD	B,C	Transfer the '5' to B.
		LD	C,A	Save the exponent in C.
		SCF		Set carry flag for negation.
16EC	NEG-BYTE	DEC	HL	Point to each byte in turn.
		LD	A,(HL)	Get each byte.
		CPL		One's complement the byte.

ADC	A,+00	Add in carry for negation.
LD	(HL),A	Restore the byte.
DJNZ	16EC,NEG-BYTE	Loop the '5' times.
LD	A,C	Restore the exponent to A.
POP	BC	Restore any earlier exponent.
RET		Finished.

THE 'FETCH TWO NUMBERS' SUBROUTINE

This subroutine is called by ADDITION, MULTIPLICATION and DIVISION to get two numbers from the calculator stack and put them into the registers, including the exchange registers.

On entry to the subroutine the HL register pair points to the first byte of the first number and the DE register pair points to the first byte of the second number.

When the subroutine is called from MULTIPLICATION or DIVISION the sign of the result is saved in the second byte of the first number.

16F7	FETCH-TWO	PUSH HL	HL is preserved.
		PUSH AF	AF is preserved.

Call the five bytes of the first number — M1, M2, M3, M4 & M5.
and for the second number — N1, N2, N3, N4 & N5.

LD	C,(HL)	M1 to C.
INC	HL	Next.
LD	B,(HL)	M2 to B.
LD	(HL),A	Copy the sign of the result to (HL).
INC	HL	Next.
LD	A,C	M1 to A.
LD	C,(HL)	M3 to C.
PUSH	BC	Save M2 & M3 on the machine stack.
INC	HL	Next.
LD	C,(HL)	M4 to C.
INC	HL	Next.
LD	B,(HL)	M5 to B.
EX	DE,HL	HL now points to N1.
LD	D,A	M1 to D.
LD	E,(HL)	N1 to E.
PUSH	DE	Save M1 & N1 on the machine stack.
INC	HL	Next.
LD	D,(HL)	N2 to D.
INC	HL	Next.
LD	E,(HL)	N3 to E.
PUSH	DE	Save N2 & N3 on the machine stack.
EXX		Get the exchange registers.
POP	DE	N2 to D' & N3 to E'.
POP	HL	M1 to H' & N1 to L'.
POP	BC	M2 to B' & M3 to C'.
EXX		Get the original set of registers.
INC	HL	Next.
LD	D,(HL)	N4 to D.
INC	HL	Next.
LD	E,(HL)	N5 to E.
POP	AF	Restore the original AF.
POP	HL	Restore the original HL.
RET		Finished.

Summary : M1 — M5 are in: H', B', C', C, B.
N1 — N5 are in: L', D', E', D, E.
HL points to the first byte of the first number.

THE 'SHIFT ADDEND' SUBROUTINE

This subroutine shifts a floating-point number up to 32 decimal, Hex.20, places right to line it up properly for addition. The number with the smaller exponent has been put in the addend position before this subroutine is called. Any overflow to the right, into the carry, is added back into the number. If the exponent difference is greater than 32 decimal, or the carry ripples right back to the beginning of the number then the number is set to zero so that the addition will not alter the other number (the augend).

171A	SHIFT-FP	AND A	If the exponent difference is zero,
		RET Z	the subroutine returns at once.
		CP +21	If the difference is greater than
		JR NC,1736,ADDEND-0	Hex.20, jump forward.
		PUSH BC	Save BC briefly.
		LD B,A	Transfer the exponent difference to
1722	ONE-SHIFT	EXX	B to count the shifts right.
		SRA L	Arithmetic shift right for L',
		RR D	preserving the sign marker bits.
		RR E	Rotate right with carry D', E',
		EXX	D & E.
		RR D	Thereby shifting the whole five bytes
		RR E	of the number to the right as
		DJNZ 1722,ONE-SHIFT	many times as B counts.
		POP BC	Loop back until B reaches zero.
		RET NC	Restore the original BC.
		CALL 1741,ADD-BACK	Done if no carry to retrieve.
		RET NZ	Retrieve carry.
1736	ADDEND-0	EXX	Return unless the carry rippled
		XOR A	right back. (In this case there is nothing
1738	ZEROS-4/5	LD L,+00	to add)
		LD D,A	Fetch L', D' & E'.
		LD E,L	Clear the A register.
		EXX	Set the addend to zero in D', E',
		LD DE,+0000	D & E, together with its marker byte
			(sign indicator) L', which was
			Hex.00 for a positive number and
			Hex.FF for a negative number.
			ZEROS-4/5 produces only 4 zero bytes
			when called for near underflow at 1833.
			Finished.
		RET	

Note: The original 8K ROM had 3 further bytes in this subroutine, immediately after the EXX at the label ADDEND-0 (address 1733 in the old ROM), namely LD A,H; SUB L; & LD H,A. These bytes would seem to have been a mistaken attempt to counteract the effect of bytes 177D — 177F below. In fact they caused errors in subtraction and, through the LN function at byte 1D15, in exponentiation and SQR as well. These three bytes were simply omitted when the program was improved. It is interesting to note also that the hardware add-on, fitted to some 'unimproved' machines worked by changing the instruction LD H,A to a DAA instruction and thereby prevented any corruption of the H register.

THE 'ADD-BACK' SUBROUTINE

This subroutine adds back into the number any carry which has overflowed to the right. In the extreme case, the carry ripples right back to the left of the number.

When this subroutine is called during addition, this ripple means that a mantissa of 0.5 was shifted a full 32 places right, and the addend will now be set to zero; when called from MULTIPLICATION, it means that the exponent must be incremented, and this may result in overflow.

1741	ADD-BACK	INC E	Add carry to rightmost byte.
		RET NZ	Return if no overflow to left.

	INC	D	Continue to the next byte.
	RET	NZ	Return if no overflow to left.
	EXX		Get the next byte.
	INC	E	Increment it too.
	JR	NZ,174A,ALL-ADDED	Jump if no overflow.
	INC	D	Increment the last byte.
174A	ALL-ADDED	EXX	Restore the original registers.
	RET		Finished.

THE 'SUBTRACTION' OPERATION (Offset 03 — see CALCULATE below: 'subtract')

This subroutine simply changes the sign of the subtrahend and carries on into ADDITION. Note that HL points to the minuend and DE points to the subtrahend. (See ADDITION for more details.)

174C	SUBTRACT	LD	A,(DE)	Get the exponent byte of subtrahend.
		AND	A	Test whether zero.
		RET	Z	If so, return.
		INC	DE	Point to the sign byte.
		LD	A,(DE)	Transfer the sign byte to A.
		XOR	+80	Change the sign bit.
		LD	(DE),A	Replace the byte.
		DEC	DE	Point to the exponent byte again.
				Continue on into ADDITION.

THE 'ADDITION' OPERATION (Offset 0F — see CALCULATE below: 'addition')

The first of three major arithmetical subroutines, this subroutine carries out floating-point addition of two numbers, each with a 4-byte mantissa and a 1-byte exponent. In these three subroutines, the two numbers at the top of the calculator stack are added/multiplied/divided to give one number at the top of the calculator stack, a 'last value'. HL points to the second number from the top, the augend/multiplier/dividend. DE points to the number at the top of the calculator stack, the addend/multiplicand/divisor. Afterwards HL points to the resultant 'last value' whose address can also be considered to be STKEND - 5.

ADDITION first calls PREP-ADD for each number, then gets the 2 numbers from the calculator stack and puts the one with the smaller exponent into the addend position. It then calls SHIFT-FP to shift the addend up to 32 decimal places right to line it up for addition. The actual addition is done in a few bytes, a single shift is made for carry (overflow to the left) if needed, the result is 2's complemented if negative, and any arithmetic overflow is reported; otherwise the subroutine jumps to TEST-NORM to normalize the result and return it to the stack with the correct sign bit inserted into the second byte.

1755	addition	EXX		Exchange the registers.
		PUSH	HL	Save the next literal address.
		EXX		Exchange the registers.
		PUSH	DE	Save pointer to the addend.
		PUSH	HL	Save pointer to the augend.
		CALL	16D8,PREP-ADD	Prepare the augend.
		LD	B,A	Save its exponent in B.
		EX	DE,HL	Exchange the pointers.
		CALL	16D8,PREP-ADD	Prepare the addend.
		LD	C,A	Save its exponent in C.
		CP	B	If the first exponent is smaller,
		JR	NC,1769,SHIFT-LEN	keep the first number in the
		LD	A,B	addend position; otherwise
		LD	B,C	change the exponents and the
		EX	DE,HL	pointers back again.
1769	SHIFT-LEN	PUSH	AF	Save the larger exponent in A.
		SUB	B	The difference between the exponents
				is the length of the shift right.

	CALL 16F7, FETCH-TWO	Get the two numbers from the stack.
	CALL 171A, SHIFT-FP	Shift the addend right.
	POP AF	Restore the larger exponent.
	POP HL	HL is to point to the result.
	LD (HL), A	Store the exponent of the result.
	PUSH HL	Save the pointer again.
	LD L, B	M4 to L & M5 to H,
	LD H, C	(see FETCH-TWO).
	ADD HL, DE	Add the two right bytes.
	EXX	N2 to H' & N3 to L',
	EX DE, HL	(see FETCH-TWO).
	ADC HL, BC	Add left bytes with carry.
	EX DE, HL	Result back in D'E'.
	LD A, H	Add H', L' and the carry; the
	ADC A, L	resulting mechanism will ensure
	LD L, A	that a single shift right is called
	RRA	if the sum of 2 positive numbers
	XOR L	has overflowed left, or the sum of 2
	EXX	negative numbers has not overflowed left.
	EX DE, HL	The result is now in DED'E'.
	POP HL	Get the pointer to the exponent.
	RRA	The test for shift (H', L' were
	JR NC, 1790, TEST-NEG	Hex.00 for positive numbers and
		Hex.FF for negative numbers).
	LD A, +01	A counts a single shift right.
	CALL 171A, SHIFT-FP	The shift is called.
	INC (HL)	Add 1 to the exponent; this may
	JR Z, 17B3, ADD-REP-6	lead to arithmetic overflow.
1790 TEST-NEG	EXX	Test for negative result: get
	LD A, L	sign bit of L' into A (this now
	AND +80	correctly indicates the sign of
	EXX	the result).
	INC HL	Store it in the second byte
	LD (HL), A	position of the result on
	DEC HL	the calculator stack.
	JR Z, 17B9, GO-NC-MLT	If it is zero, then do not
		2's complement the result.
	LD A, E	Get the first byte.
	NEG	Negate it.
	CCF	Complement the carry for continued
	LD E, A	negation, and store byte.
	LD A, D	Get the next byte.
	CPL	One's complement it.
	ADC A, +00	Add in the carry for negation.
	LD D, A	Store the byte.
	EXX	Proceed to get next byte into the
	LD A, E	A register.
	CPL	One's complement it.
	ADC A, +00	Add in the carry for negation.
	LD E, A	Store the byte.
	LD A, D	Get the last byte.
	CPL	One's complement it.
	ADC A, +00	Add in the carry for negation.
	JR NC, 17B7, END-COMPL	Done if no carry.
	RRA	Else, get .5 into mantissa and add 1
	EXX	to the exponent; this will be needed
	INC (HL)	when two negative numbers add to give
		an exact power of 2, and it may lead to
		arithmetic overflow.
		Give the error if required.
17B3 ADD-REP-6	JP Z, 1880, REPORT-6	
	EXX	

17B7	END-COMPL	LD	D,A	Store the last byte.
		EXX		
17B9	GO-NC-MLT	XOR	A	Clear the carry flag.
		JR	1828,TEST-NORM	Exit via TEST-NORM.

THE 'PREPARE TO MULTIPLY OR DIVIDE' SUBROUTINE

This subroutine prepares a floating-point number for multiplication or division, returning with carry set if the number is zero, getting the sign of the result into the A register, and replacing the sign bit in the number by the true numeric bit, 1.

17BC	PREP-M/D	SCF		Set the carry flag.
		DEC	(HL)	Test the exponent byte.
		INC	(HL)	
		RET	Z	If the number is zero, return with both the zero and the carry flags set.
		INC	HL	Point to the sign byte.
		XOR	(HL)	Get sign for result into A (like signs give plus, unlike give minus); also reset carry flag.
		SET	7,(HL)	Set the true numeric bit.
		DEC	HL	Point to the exponent again.
		RET		Return with carry flag reset.

THE 'MULTIPLICATION' OPERATION (Offset 04 — see CALCULATE below: 'multiply')

This subroutine prepares the first number for multiplication by calling PREP-M/D, returning if it is zero; otherwise the second number is prepared by again calling PREP-M/D, and if it is zero the subroutine goes to set the result to zero. Next it fetches the two numbers from the calculator stack and multiplies their mantissas in the usual way, rotating the first number (treated as the multiplier) right and adding in the second number (the multiplicand) to the result whenever the multiplier bit is set. The exponents are then added together and checks are made for overflow and for underflow (giving the result zero). Finally, the result is normalized and returned to the calculator stack with the correct sign bit in the second byte.

17C6	multiply	XOR	A	A is set to Hex.00 so that the sign of the first number will go into A.
		CALL	17BC,PREP-M/D	Prepare the first number, and return if zero. (Result already zero.)
		RET	C	
		EXX		Exchange the registers.
		PUSH	HL	Save the next literal address.
		EXX		Exchange the registers.
		PUSH	DE	Save the pointer to the multiplicand.
		EX	DE,HL	Exchange the pointers.
		CALL	17BC,PREP-M/D	Prepare the 2nd number.
		EX	DE,HL	Exchange the pointers again.
		JR	C,1830,ZERO-RSLT	Jump forward if 2nd number is zero.
		PUSH	HL	Save the pointer to the result.
		CALL	16F7,FETCH-TWO	Get the two numbers from the stack.
		LD	A,B	M5 to A (see FETCH-TWO).
		AND	A	Prepare for a subtraction.
		SBC	HL,HL	Initialise HL to zero for the result.
		EXX		Exchange the registers.
		PUSH	HL	Save M1 & N1 (see FETCH-TWO).
		SBC	HL,HL	Also initialise H'L' for the result.
		EXX		Exchange the registers.
		LD	B,+21	B counts 33 decimal, Hex.21, shifts.
		JR	17F8,STRT-MLT	Jump forward into the loop.

Now enter the multiplier loop.

```

17E7 MLT-LOOP JR    NC,17EE,NO-ADD
                ADD  HL,DE
                EXX
                ADC  HL,DE
                EXX
17EE NO-ADD     EXX
                RR   H
                RR   L
                EXX
                RR   H
                RR   L

17F8 STRT-MLT  EXX
                RR   B
                RR   C
                EXX
                RR   C
                RRA
                DJNZ 17E7,MLT-LOOP
                EX   DE,HL
                EXX
                EX   DE,HL
                EXX

```

Jump forward to NO-ADD if no carry, i.e. the multiplier bit was reset; Else, add the multiplicand in D'E'DE (see FETCH-TWO) into the result being built up in H'L'HL.

Whether multiplicand was added or not, shift result right in H'L'HL, i.e. the shift is done by rotating each byte with carry, so that any bit that drops into the carry is picked up by the next byte, and the shift continues into B'C'CA. Shift right the multiplier in B'C'CA (see FETCH-TWO & above). A final bit dropping into the carry will trigger another add of the multiplicand to the result.

Loop 33 times to get all the bits. Move the result from:

H'L'HL to D'E'DE.

Next add the exponents together.

```

                POP  BC
                POP  HL
                LD   A,B
                ADD  A,C
                JR   NZ,180E,MAKE-EXPT
                AND  A
180E MAKE-EXPT DEC  A
                CCF

```

Restore the exponents — M1 & N1. Restore the pointer to the exponent byte. Get the sum of the two exponent bytes in A, and the correct carry. If the sum equals zero then clear the carry; else leave it unchanged. Prepare to increase the exponent by Hex.80.

The rest of the subroutine is common to both MULTIPLICATION and DIVISION.

```

1810 DIVN-EXPT RLA
                CCF
                RRA

                JP   P,1819,OFLW1-CLR

                JR   NC,1880,REPORT-6
                AND  A
1819 OFLW1-CLR INC  A
                JR   NZ,1824,OFLW2-CLR
                JR   C,1824,OFLW2-CLR
                EXX
                BIT  7,D
                EXX
                JR   NZ,1880,REPORT-6

1824 OFLW2-CLR LD   (HL),A
                EXX
                LD   A,B
                EXX

```

These few bytes very cleverly make the correct exponent byte. Rotating left then right gets the exponent byte (true exponent plus Hex.80) into A. If the sign flag is reset, no report of arithmetic overflow needed. Report the overflow if carry reset. Clear the carry now. The exponent byte is now complete; but if A is zero a further check for overflow is needed. If there is no carry set and the result is already in normal form (bit 7 of D' set) then there is overflow to report; but if bit 7 of D' is reset, the result is just in range, i.e. just under 2^{127} . Store the exponent byte, at last. Pass the fifth result byte to A for the normalization sequence, i.e. the overflow from L into B'.

The remainder of the subroutine that deals with normalization is common to all the arithmetic routines.

1828	TEST-NORM	JR	NC,183F,NORMALIZE	If no carry then normalize now.
		LD	A,(HL)	Else, deal with underflow (zero result)
		AND	A	or near underflow
182C	NEAR-ZERO	LD	A,+80	(result $2^{**} - 128$):
		JR	Z,1831,SKIP-ZERO	return exponent to A, test if A is
1830	ZERO-RSLT	XOR	A	zero (case $2^{**} - 128$) and if so
1831	SKIP-ZERO	EXX		produce $2^{**} - 128$ if number is normal;
		AND	D	otherwise produce zero.
		CALL	1738,ZEROS-4/5	The exponent must then be set to
		RLCA		zero (for zero) or 1 (for $2^{**} - 128$).
		LD	(HL),A	Restore the exponent byte.
		JR	C,1868,OFLOW-CLR	Jump if case $2^{**} - 128$.
		INC	HL	Otherwise, put zero into second
		LD	(HL),A	byte of result on the calculator
		DEC	HL	stack.
		JR	1868,OFLOW-CLR	Jump forward to transfer the result.

The actual normalization operation.

183F	NORMALIZE	LD	B,+20	Normalize the result by up to 32
1841	SHIFT-ONE	EXX		decimal. Hex.20, shifts left of
		BIT	7,D	D'E'DE (with A adjoined) until bit 7
		EXX		of D' is set. A holds zero after
		JR	NZ,1859,NORMML-NOW	addition, so no precision is
		RLCA		gained or lost; A holds the fifth
		RL	E	byte from B' after multiplication
		RL	D	or division; but as only about 32
		EXX		bits can be correct, no precision
		RL	E	is lost. Note that A is rotated
		RL	D	circularly, with branch at carry...
		EXX		...eventually a random process.
		DEC	(HL)	The exponent is decremented on
				each shift.
		JR	Z,182C,NEAR-ZERO	If the exponent becomes zero, then
				numbers from $2^{**} - 129$ are rounded
				up to $2^{**} - 128$.
		DJNZ	1841,SHIFT-ONE	Loop back, up to 32 times.
		JR	1830,ZERO-RSLT	If bit 7 never became 1 then the
				whole result is to be zero.

Finish the normalization by considering the 'carry'.

1859	NORMML-NOW	RLA		After normalization add back any
		JR	NC,1868,OFLOW-CLR	final carry that went into A.
		CALL	1741,ADD-BACK	Jump forward if the carry does not
		JR	NZ,1868,OFLOW-CLR	ripple right back.
		EXX		If it should ripple right back then
		LD	D,+80	set mantissa to 0.5 and increment
		EXX		the exponent.
		INC	(HL)	This action may lead to arithmetic
		JR	Z,1880,REPORT-6	overflow (final case).

The final part of the subroutine involves passing the result to the bytes reserved for it on the calculator stack and resetting the pointers.

1868	OFLOW-CLR	PUSH	HL	Save the result pointer.
		INC	HL	Point to the sign byte in the result.

EXX		The result is moved from its present
PUSH	DE	registers, D'E'DE, to BCDE; and
EXX		then to ACDE.
POP	BC	
LD	A,B	The sign bit is retrieved from its
RLA		temporary store and transferred to
RL	(HL)	its correct position of bit 7 of the
RRA		first byte of the mantissa.
LD	(HL),A	The first byte is stored.
INC	HL	Next.
LD	(HL),C	The second byte is stored.
INC	HL	Next.
LD	(HL),D	The third byte is stored.
INC	HL	Next.
LD	(HL),E	The fourth byte is stored.
POP	HL	Restore the pointer to the result.
POP	DE	Restore the pointer to second number.
EXX		Exchange the registers.
POP	HL	Restore the next literal address.
EXX		Exchange the registers.
RET		Finished.

REPORT-6 — Arithmetic overflow

```
1880 REPORT-6 RST 0008,ERROR-1
          DEFB +05
```

THE 'DIVISION' OPERATION (Offset 05 — see CALCULATE below: 'division')

This subroutine first prepares the divisor by calling PREP-M/D, reporting arithmetic overflow if it is zero; then it prepares the dividend by again calling PREP-M/D, returning if it is zero. Next it fetches the two numbers from the calculator stack and divides their mantissas by means of the usual restoring division, trial subtracting the divisor from the dividend and restoring if there is carry, otherwise adding 1 to the quotient. The maximum precision is obtained for a 4-byte division, and after subtracting the exponents the subroutine exits by joining the later part of MULTIPLICATION.

1882	division	EX DE,HL	Exchange the pointers.
		XOR A	A is set to Hex.00, so that the sign of
			the first number will go into A.
		CALL 17BC,PREP-M/D	Prepare the divisor and give the
		JR C,1880,REPORT-6	report for arithmetic overflow if it
			is zero.
		EX DE,HL	Exchange the pointers.
		CALL 17BC,PREP-M/D	Prepare the dividend and return if
		RET C	it is zero (result already zero).
		EXX	Exchange the registers.
		PUSH HL	Save the next literal address.
		EXX	Exchange the registers.
		PUSH DE	Save pointer to divisor.
		PUSH HL	Save pointer to dividend.
		CALL 16F7,FETCH-TWO	Get the two numbers from the stack.
		EXX	Exchange the registers.
		PUSH HL	Save M1 & N1 on the machine stack.
		LD H,B	Copy the four bytes of the dividend
		LD L,C	from registers B'C'CB (i.e. M2, M3,
		EXX	M4 & M5; see FETCH-TWO) to the
		LD H,C	registers H'L'HL.
		LD L,B	
		XOR A	Clear A and reset the carry flag.

```

LD    B,+DF

JR    18B2,DIV-START

```

B will count upwards from -33 to -1, 2's complement, Hex.DF to FF, looping on minus and will jump again on zero for extra precision.
Jump forward into the division loop for the first trial subtraction.

Now enter the division loop.

```

18A2  DIV-LOOP  RLA
                RL    C
                EXX
                RL    C
                RL    B
                EXX
                ADD   HL,HL
                EXX
                ADC   HL,HL
                EXX

18B2  DIV-START  JR    C,18C2,SUBN-ONLY
                SBC   HL,DE
                EXX
                SBC   HL,DE
                EXX
                JR    NC,18C9,NO-RSTORE
                ADD   HL,DE
                EXX
                ADC   HL,DE
                EXX
                AND   A
                JR    18CA,COUNT-ONE

18C2  SUBN-ONLY AND   A
                SBC   HL,DE
                EXX
                SBC   HL,DE
                EXX

18C9  NO-RSTORE SCF

18CA  COUNT-ONE INC   B
                JP    M,18A2,DIV-LOOP
                PUSH  AF

                JR    Z,18B2,DIV-START

                LD    E,A
                LD    D,C
                EXX
                LD    E,C
                LD    D,B
                POP   AF
                RR    B
                POP   AF
                RR    B
                EXX
                POP   BC
                POP   HL
                LD    A,B
                SUB   C

                JP    1810,DIVN-EXPT

```

Shift the result left into B'C'CA, shifting out the bits already there, picking up 1 from the carry whenever it is set, and rotating left each byte with carry to achieve the 32 bit shift.
Move what remains of the dividend left in H'L'HL before the next trial subtraction; if a bit drops into the carry, force no restore and a bit for the quotient, thus retrieving the lost bit and allowing a full 32-bit divisor.
Trial subtract divisor in D'E'DE from rest of dividend in H'L'HL; there is no initial carry (see previous step).
Jump forward if there is no carry. Otherwise restore, i.e. add back the divisor. Then clear the carry so that there will be no bit for the quotient (the divisor 'did not go').

Jump forward to the counter.
Just subtract with no restore and go on to set the carry flag because the lost bit of the dividend is to be retrieved and used for the quotient.
One for the quotient in B'C'CA.
Step the loop count up by one.
Loop 32 times for all bits.
Save any 33rd bit for extra precision (the present carry).
Trial subtract yet again for any 34th bit; the PUSH AF above saves this bit too.
Now move the four bytes that form the mantissa bytes of the result from B'C'CA to D'E'DE.

Then put any 34th and 33rd bits into B' to be picked up on normalization.

Restore the exponent bytes, M1 & N1.
Restore the pointer to the result.
Get the difference between the two exponent bytes into A and set the carry flag if required.
Exit via DIVN-EXPT.

THE 'INTEGER TRUNCATION TOWARDS ZERO' SUBROUTINE

(Offset 36 — see CALCULATE below: 'truncate')

This subroutine (say I (X)) returns the result of integer truncation of X, the 'last value', towards zero. Thus, I (2.4) is 2 and I (-2.4) is -2. The subroutine returns zero if the exponent byte of X is less than Hex.81 (mod X less than 1). It returns X if the exponent byte is Hex.A0 or greater (X has no significant non-integral part). Otherwise the correct number of bytes of X are set to zero and, if needed, one more byte is split with a mask.

18E4	truncate	LD	A,(HL)	Get the exponent byte of X into A.
		CP	+81	Compare e, the exponent, to Hex.81.
		JR	NC,18EF,X-LARGE	Jump if e is greater than Hex.80.
		LD	(HL),+00	Else, set the exponent to zero;
		LD	A,+20	enter 32 decimal, Hex.20, into A
		JR	18F4,NIL-BYTES	and jump forward to NIL-BYTES to
				make all the bits of X be zero.
18EF	X-LARGE	SUB	+A0	Subtract 160 decimal, Hex.A0, from e.
		RET	P	Return on plus — X has no significant
				non-integral part. (If the true exponent
				were reduced to zero, the 'binary point'
				would come at or after the end of the
				four bytes of the mantissa.)
		NEG		Else, negate the remainder; this gives
				the number of bits to become zero
				(the number of bits after the
				'binary point').

Now the bits of the mantissa can be cleared.

18F4	NIL-BYTES	PUSH	DE	Save the current value of DE (STKEND).
		EX	DE,HL	Make HL point one-past the 5th byte.
		DEC	HL	HL now points to the 5th byte of X.
		LD	B,A	Get the number of bits to be set to
		SRL	B	zero into B and divide it by 8 to give
		SRL	B	the number of whole bytes
		SRL	B	implied.
		JR	Z,1905,BITS-ZERO	Jump forward if the result is zero.
1900	BYTE-ZERO	LD	(HL),+00	Else, set the bytes to zero; B
		DEC	HL	counts them.
		DJNZ	1900,BYTE-ZERO	
1905	BITS-ZERO	AND	+07	
		JR	Z,1912,IX-END	Get A (mod 8): this is the number of
		LD	B,A	bits still to be set to zero.
		LD	A,+FF	Jump to the end if nothing more to do.
190C	LESS-MASK	SLA	A	B will count the bits now.
		DJNZ	190C,LESS-MASK	Prepare the mask.
		AND	(HL)	With each loop a zero enters the
		LD	(HL),A	mask from the right and thereby a mask
		EX	DE,HL	of the correct 'length' is produced.
1912	IX-END	POP	DE	The unwanted bits of (HL) are lost
		RET		as the masking is performed.
				Return the pointer to HL.
				Return the pointer to DE, (STKEND).
				Finished.

THE CALCULATOR TABLES

The table of constants:

This first table holds the five useful and frequently needed numbers zero, one, a half, a half of pi and ten. The numbers are held in a condensed form which is expanded by the STACK LITERALS subroutine, see below, to give the required floating-point form.

	data:	constant:	when expanded gives: exp. mantissa: (Hex.)
1915 stk-zero	DEFB +00 DEFB +B0 DEFB +00	zero	00 00 00 00 00
1918 stk-one	DEFB +31 DEFB +00	one	81 00 00 00 00
191A stk-half	DEFB +30 DEFB +00	a half	80 00 00 00 00
191C stk-pi/2	DEFB +F1 DEFB +49 DEFB +0F DEFB +DA DEFB +A2	a half of pi	81 49 0F DA A2
1921 stk-ten	DEFB +34 DEFB +20	ten	84 20 00 00 00

The table of addresses:

This second table is a look-up table of the addresses of the 61 decimal, operational subroutines of the calculator. The offsets used to index into the table are derived either from the operation codes used in SCANNING, see 10BC etc., or from the literals that follow an RST 0028 instruction.

offset	label address	offset	label address	offset	label address
1923 00	jump-true 2F 1C	194D 15	str-less 03 1B	1977 2A	strs D5 1B
1925 01	exchange 72 1A	194F 16	strs-eql 03 1B	1979 2B	chrs 8F 1B
1927 02	delete E3 19	1951 17	strs-add 62 1B	197B 2C	not D5 1A
1929 03	subtract 4C 17	1953 18	negate A0 1A	197D 2D	duplicate F6 19
192B 04	multiply C6 17	1955 19	code 06 1C	197F 2E	n-mod-m 37 1C
192D 05	division 82 18	1957 1A	val A4 1B	1981 2F	jump 23 1C
192F 06	to-power E2 1D	1959 1B	len 11 1C	1983 30	stk-data FC 19
1931 07	or ED 1A	195B 1C	sin 49 1D	1985 31	dec-jr-nz 17 1C
1933 08	no.-&-no. F3 1A	195D 1D	cos 3E 1D	1987 32	less-0 DB 1A
1935 09	no.-l-eql 03 1B	195F 1E	tan 6E 1D	1989 33	greater-0 CE 1A
1937 0A	no.-gr-eq 03 1B	1961 1F	asn C4 1D	198B 34	end-calc. 2B 00
1939 0B	nos.-neql 03 1B	1963 20	acs D4 1D	198D 35	get-argt. 18 1D
193B 0C	no.-grtr 03 1B	1965 21	atn 76 1D	198F 36	truncate E4 18
193D 0D	no.-less 03 1B	1967 22	ln A9 1C	1991 37	fp-calc-2 E4 19
193F 0E	nos.-eql 03 1B	1969 23	exp 5B 1C	1993 38	e-to-fp 5A 15
1941 0F	addition 55 17	196B 24	int 46 1C	1995 39	series-06 7F etc. 1A
1943 10	str-&-no. F8 1A	196D 25	sqr DB 1D	1997 3A	stk-zero 51 etc. 1A
1945 11	str-l-eql 03 1B	196F 26	sgn AF 1A	1999 3B	st-mem-0 63 etc. 1A
1947 12	str-gr-eq 03 1B	1971 27	abs AA 1A	199B 3C	get-mem-0 45 etc. 1A
1949 13	strs-neql 03 1B	1973 28	peek BE 1A		
194B 14	str-grtr 03 1B	1975 29	usr C5 1A		

Note: The last four subroutines are multi-purpose subroutines and are entered with a parameter that is a copy of the righthand five bits of the original literal. The full set follows:—

Offset 39 : series-06, series-08 & series-0C.

Offset 3A : stk-zero, stk-one, stk-half, stk-pi/2 & stk-ten.

Offset 3B : st-mem-0, st-mem-1, st-mem-2, st-mem-3, st-mem-4 & st-mem-5.

Offset 3C : get-mem-0, get-mem-1, get-mem-2, get-mem-3, get-mem-4 & get-mem-5.

Note: TABLE-CON EQU 1915

TABLE-ADD EQU 1923

THE 'CALCULATOR' SUBROUTINE

This subroutine is used to perform floating-point calculations. These can be considered to be of three types:

- i. Binary operations, e.g. addition, where two numbers in floating-point form are added together to give one 'last value'.
- ii. Unary operations, e.g. sin, where the 'last value' is changed to give the appropriate function result as a new 'last value'.
- iii. Manipulatory operations, e.g. st-mem-0, where the 'last value' is copied to the first five bytes of the calculator's memory area.

The operations to be performed are specified as a series of data-bytes, the literals, that follow an RST 0028 instruction that calls this subroutine. The last literal in the list is always '34' which leads to an end to the whole operation.

In the case of a single operation needing to be performed, the operation offset can be passed to the CALCULATOR in the B register, and operation '37', the SINGLE CALCULATION operation, performed.

It is also possible to call this subroutine recursively, i.e. from within itself, and in such a case it is possible to use the system variable BERG as a counter that controls how many operations are performed before returning.

The first part of this subroutine is complicated but essentially it performs the two tasks of setting the registers to hold their required values, and to produce an offset, and possibly a parameter, from the literal that is currently being considered.

The offset is used to index into the calculator's table of addresses, see above, to find the required subroutine address.

The parameter is used when the multi-purpose subroutines are called.

Note: A floating-point number may in reality be a set of string parameters.

199D CALCULATE CALL 1B85,STK-PNTRS

19A0 GEN-ENT-1 LD A,B
LD (BERG),A

19A4 GEN-ENT-2 EXX
EX (SP),HL
EXX

19A7 RE-ENTRY LD (STKEND),DE

EXX
LD A,(HL)
INC HL
19AE SCAN-ENT. PUSH HL

Presume a unary operation and therefore set HL to point to the start of the 'last value' on the calculator stack and DE one-past this floating-point number (STKEND).

Either, transfer a single operation offset to BERG temporarily, or, when using the subroutine recursively pass the parameter to BERG to be used as a counter.

The return address of the subroutine is stored in H'L'. This saves the pointer to the first literal. Entering the CALCULATOR at GEN-ENT-2 is used whenever BERG is in use as a counter and is not to be disturbed.

A loop is now entered to handle each literal in the list that follows the calling instruction; so first, always set STKEND. Go to the alternate register set, and fetch the literal for this loop. Make H'L' point to the next literal. This pointer is saved briefly on the machine stack.

SCAN-ENT. is used by the SINGLE CALCULATION subroutine to find the subroutine that is required.

	AND A	Test the A register.
	JP P,19C2,FIRST-38	Separate the simple literals from the multi-purpose literals. Jump with literals 00 – 38.
	LD D,A	Save the literal in D.
	AND +60	Continue only with bits 5 & 6.
	RRCA	Four right shifts make them now bits 1 & 2.
	RRCA	
	RRCA	
	ADD A,+72	
	LD L,A	The offsets required are 39 – 3C, and L will now hold double the required offset.
	LD A,D	Now produce the parameter by taking bits 0,1,2,3 & 4 of the literal; keep the parameter in A.
	AND +1F	Jump forward to find the address of the required subroutine.
	JR 19DO,ENT-TABLE	Jump forward if performing a unary operation.
19C2 FIRST-38	CP +18	All of the subroutines that perform binary operations require that HL points to the first operand and DE points to the second operand (the 'last value') as they appear on the calculator stack.
	JR NC,19CE,DOUBLE-A	As each entry in the table of addresses takes up two bytes the offset produced is doubled.
	EXX	The base address of the table.
	LD BC,FFFFB	The address of the required table entry is formed in HL; and the required subroutine address is loaded into the DE register pair.
	LD D,H	
	LD E,L	
	ADD HL,BC	
	EXX	
19CE DOUBLE-A	RLCA	
	LD L,A	
19DO ENT-TABLE	LD DE,+TABLE-ADD	
	LD H,+00	
	ADD HL,DE	
	LD E,(HL)	
	INC HL	
	LD D,(HL)	
	LD HL,+RE-ENTRY	
	EX (SP),HL	
	PUSH DE	
	EXX	
	LD BC,(STKEND-hi.)	
19E3 delete	RET	The RE-ENTRY address of 19A7 is put on the machine stack underneath the subroutine address.

THE 'DELETE' SUBROUTINE (Offset 02: 'delete')

This subroutine contains only the single RET instruction at 19E3, above. The literal '02' results in this subroutine being considered as a binary operation that is to be entered with a first number addressed by the HL register pair and a second number addressed by the DE register pair, and the result produced again addressed by the HL register pair.

The single RET instruction thereby leads to the first number being considered as the resulting 'last value' and the second number considered as being deleted. Of course the number has not been deleted from the memory but remains inactive and will probably soon be overwritten.

THE 'SINGLE OPERATION' SUBROUTINE (Offset 37: 'fp-calc-2')

This subroutine is only called from SCANNING, see page 2, and is used to perform a single arithmetic operation. The offset that specifies which operation is to be performed is supplied to the calculator in the B register and subsequently transferred to the system variable BERG.

The effect of calling this subroutine is essentially to make a jump to the appropriate subroutine for the single operation.

19E4	fp-calc-2	POP AF LD A,(BERG) EXX JR 19AE,SCAN-ENT.	Discard the RE-ENTRY address. Transfer the offset to A. Enter the alternate register set. Jump back to find the required address; stack the RE-ENTRY address and jump to the subroutine for the operation.
------	-----------	---	---

THE 'TEST 5-SPACES' SUBROUTINE

This subroutine tests whether there is sufficient room in memory for another 5-byte floating-point number to be added to the calculator stack.

19EB	TEST-5-SP	PUSH DE PUSH HL LD BC,+0005 CALL 0EC5,TEST-ROOM POP HL POP DE RET	Save DE briefly. Save HL briefly. Specify the test is for 5 bytes. Make the test. Restore HL. Restore DE. Finished.
------	-----------	---	---

THE 'MOVE A FLOATING-POINT NUMBER' SUBROUTINE (Offset 2D: 'duplicate')

This subroutine moves a floating-point number to the top of the calculator stack (3 cases) or from the top of the stack to the calculator's memory area (1 case). It is also called through the calculator when it simply duplicates the number at the top of the calculator stack, the 'last value', thereby extending the stack by five bytes.

19F6	MOVE-FP	CALL 19EB,TEST-5-SP LDIR RET	A test is made for room. Move the five bytes involved. Finished.
------	---------	------------------------------------	--

THE 'STACK LITERALS' SUBROUTINE (Offset 30: 'stk-data')

This subroutine places on the calculator stack, as a 'last value', the floating-point number supplied to it as 2, 3, 4 or 5 literals.

When called by using offset '30' the literals follow the '30' in the list of literals; when called by the SERIES GENERATOR, see below, the literals are supplied by the subroutine that called for a series to be generated; and when called by SKIP CONSTANTS & STACK A CONSTANT the literals are obtained from the calculator's table of constants (1915-1922).

In each case, the first literal supplied is divided by Hex.40, and the integer quotient plus 1 determines whether 1, 2, 3 or 4 further literals will be taken from the source to form the mantissa of the number. Any unfilled bytes of the five bytes that go to form a 5-byte floating-point number are set to zero. The first literal is also used to determine the exponent, after reducing mod Hex.40, unless the remainder is zero, in which case the second literal is used, as it stands, without reducing mod Hex.40. In either case, Hex.50 is added to the literal, giving the augmented exponent byte, e (the true exponent e' plus Hex.80). The rest of the 5 bytes are stacked, including any zeros needed, and the subroutine returns.

19FC	STK-DATA	LD H,D LD L,E	This subroutine performs the manipulatory operation of adding a 'last value' to the calculator stack; hence HL is set to point one-past the present 'last value' and hence point to the result.
------	----------	------------------	---


```

19FE STK-CONST CALL 19EB,TEST-5-SP
                EXX
                PUSH HL
                EXX
                EX (SP),HL

                PUSH BC
                LD A,(HL)
                AND +CO
                RLCA
                RLCA
                LD C,A
                INC C

                LD A,(HL)
                AND +3F
                JR NZ,1A14,FORM-EXP
                INC HL
1A14 FORM-EXP  LD A,(HL)
                ADD A,+50
                LD (DE),A

                LD A,+05
                SUB C
                INC HL
                INC DE
                LD B,+00
                LDIR
                POP BC
                EX (SP),HL
                EXX
                POP HL
                EXX
                LD B,A
                XOR A
1A27 STK-ZEROS DEC B
                RET Z
                LD (DE),A
                INC DE
                JR 1A27,STK-ZEROS

```

Now test that there is indeed room.
Go to the alternate register set and stack the pointer to the next literal.

Switch over the result pointer and the next literal pointer.

Save BC briefly.

The first literal is put into A and divided by Hex.40 to give the integer values 0, 1, 2 or 3.

The integer value is transferred to C and incremented, thereby giving the range 1, 2, 3 or 4 for the number of literals that will be needed.

The literal is fetched anew, reduced mod Hex.40 and discarded as inappropriate if the remainder is zero; in which case the next literal is fetched and used unreduced.

The exponent, e, is formed by the addition of Hex.50 and passed to the calculator stack as the first of the five bytes of the result.

The number of literals specified in C are taken from the source and entered into the bytes of the result.

Restore BC.

Return the result pointer to HL and the next literal pointer to its usual position in H' & L'.

The number of zero bytes required at this stage is given by 5-C-1; and this number of zeros is added to the result to make up the required five bytes.

THE 'SKIP CONSTANTS' SUBROUTINE

This subroutine is entered with the HL register pair holding the base address of the calculator's table of constants and the A register holding a parameter that shows which of the five constants is being requested.

The subroutine performs the null operations of loading the five bytes of each unwanted constant into the locations 0000, 0001, 0002, 0003 and 0004 at the beginning of the ROM until the requested constant is reached.

The subroutine returns with the HL register pair holding the base address of the requested constant within the table of constants.

```

1A2D SKIP-CONS AND A
1A2E SKIP-NEXT RET Z

                PUSH AF

```

The subroutine returns if the parameter is zero, or when the requested constant has been reached.
Save the parameter.

PUSH DE	Save the result pointer.
LD DE,+0000	The dummy address.
CALL 19FE,STK-CONST	Perform imaginary stacking of an expanded constant.
POP DE	Restore the result pointer.
POP AF	Restore the parameter.
DEC A	Count the loops.
JR 1A2E,SKIP-NEXT	Jump back to consider the value of the counter.

THE 'MEMORY LOCATION' SUBROUTINE

This subroutine finds the base address for each five byte portion of the calculator's memory area to or from which a floating-point number is to be moved from or to the calculator stack. It does this operation by adding five times the parameter supplied to the base address for the area which is held in the HL register pair.

Note that when a FOR-NEXT variable is being handled then the pointers are changed so that the variable is treated as if it were the calculator's memory area (part A, pp.23-25).

1A3C LOC-MEM	LD C,A	Copy the parameter to C.
	RLCA	Double the parameter.
	RLCA	Double that result.
	ADD A,C	Add the value of the parameter to give five times the original value.
	LD C,A	This result is wanted in the
	LD B,+00	BC register pair.
	ADD HL,BC	Produce the new base address.
	RET	Finished.

THE 'GET FROM MEMORY AREA' SUBROUTINE (Offsets E0 to E5: 'get-mem-0' to 'get-mem-5')

This subroutine is called using the literals E0 to E5 and the parameter derived from these literals is held in the A register. The subroutine calls MEMORY LOCATION to put the required source address into the HL register pair and MOVE A FLOATING-POINT NUMBER to copy the five bytes involved from the calculator's memory area to the top of the calculator stack to form a new 'last value'.

1A45 get-mem-0 etc.	PUSH DE	Save the result pointer.
	LD HL,(MEM)	Fetch the pointer to the current memory area (see above).
	CALL 1A3C,LOC-MEM	The base address is found.
	CALL 19F6,MOVE-FP	The five bytes are moved.
	POP HL	Set the result pointer.
	RET	Finished.

THE 'STACK A CONSTANT' SUBROUTINE (Offsets A0 to A4: 'stk-zero', 'stk-one', 'stk-half', 'stk-pi/2' & 'stk-ten')

This subroutine uses SKIP CONSTANTS to find the base address of the requested constant from the calculator's table of constants and then calls STACK LITERALS, entering at STK-CONST, to make the expanded form of the constant the 'last value' on the calculator stack.

1A51 stk-zero etc.	LD H,D	Set HL to hold the result pointer.
	LD L,E	
	EXX	Go to the alternate register set and
	PUSH HL	save the next literal pointer.
	LD HL,+TABLE-CON	The base address of the calculator's table of constants.

EXX		Back to the main set of registers.
CALL 1A2D,SKIP-CONS		Find the requested base address.
CALL 19FE,STK-CONST		Expand the constant.
EXX		
POP HL		Restore the next literal pointer.
EXX		
RET		Finished.

THE 'STORE IN MEMORY AREA' SUBROUTINE (Offsets C0 to C5: 'st-mem-0' to 'st-mem-5')

This subroutine is called using the literals C0 to C5 and the parameter derived from these literals is held in the A register. This subroutine is very similar to the GET FROM MEMORY subroutine but the source and destination pointers are exchanged.

1A63	st-mem-0 etc.	PUSH HL	Save the result pointer.
		EX DE,HL	Source to DE briefly.
		LD HL,(MEM)	Fetch the pointer to the current memory area.
		CALL 1A3C,LOC-MEM	The base address is found.
		EX DE,HL	Exchange source and destination pointers.
		CALL 19F6,MOV-FP	The five bytes are moved.
		EX DE,HL	'Last value' +5, i.e. STKEND to DE.
		POP HL	Result pointer to HL.
		RET	Finished.

Note that the pointers HL and DE remain as they were, pointing to STKEND-5 and STKEND respectively, so that the 'last value' remains on the calculator stack. If required it can be removed by using 'delete'.

THE 'EXCHANGE' SUBROUTINE (Offset 01: 'exchange')

This binary operation 'exchanges' the first number with the second number, i.e. the topmost two numbers on the calculator stack are exchanged.

1A72	EXCHANGE	LD B,+05	There are five bytes involved.
1A74	SWAP-BYTE	LD A,(DE)	Each byte of the second number.
		LD C,(HL)	Each byte of the first number.
		EX DE,HL	Switch source and destination.
		LD (DE),A	Now to the first number.
		LD (HL),C	Now to the second number.
		INC HL	Move to consider the next pair of bytes.
		INC DE	
		DJNZ 1A74,SWAP-BYTE	Exchange the five bytes.
		EX DE,HL	Get the pointers correct as the number 5 is an odd number.
		RET	Finished.

THE 'SERIES GENERATOR' SUBROUTINE (Offsets 86, 88 & 8C: 'series-06', 'series-08' & 'series-0C')

This important subroutine generates the series of Chebyshev polynomials which are used to approximate to SIN, ATN, LN and EXP and hence to derive the other arithmetic functions which depend on these (COS, TAN, ASN, ACS, ** and SQR).

The polynomials are generated, for $n=1, 2, \dots$, by the recurrence relation:

$$T_{n+1}(z) = 2zT_n(z) - T_{n-1}(z), \text{ where } T_n(z) \text{ is the } n\text{th Chebyshev polynomial in } z.$$

The series in fact generates:

$$T_0, 2T_1, 2T_2, \dots, 2T_{n-1}, \text{ where } n \text{ is 6 for SIN, 8 for EXP and 12 decimal, for LN and ATN.}$$

The coefficients of the powers of z in these polynomials may be found in the *Handbook of Mathematical Functions* by M. Abramowitz and I.A. Stegun (Dover 1965), page 795.

BASIC programs showing the generation of each of the four functions are given here in the Appendix.

In simple terms this subroutine is called with the 'last value' on the calculator stack, say Z , being a number that bears a simple relationship to the argument, say X , when the task is to evaluate, for instance, $\text{SIN } X$. The calling subroutine also supplies the list of constants that are to be required (six constants for SIN). The SERIES GENERATOR then manipulates its data and returns to the calling routine a 'last value' that bears a simple relationship to the requested function, for instance, $\text{SIN } X$.

This subroutine can be considered to have four major parts:—

i. The setting of the loop counter:

The calling subroutine passes its parameter in the A register for use as a counter. The calculator is entered at GEN-ENT-1 so that the counter can be set.

1A7F	series-06 etc.	LD B,A CALL 19A0,GEN-ENT-1	Move the parameter to B. In effect an RST 0028 instruction but sets the counter.
------	-------------------	-------------------------------	--

ii. The handling of the 'last value', Z :

The loop of the generator requires $2*Z$ to be placed in mem-0, zero to be placed in mem-2 and the 'last value' to be zero.

	calculator stack
DEFB +2D,duplicate,19F6	Z, Z
DEFB +0F,addition,1755	$2*Z$
DEFB +C0,st-mem-0,1A63	$2*Z$ mem-0 holds $2*Z$
DEFB +02,delete,19E3	—
DEFB +A0,stk-zero,1A51	0
DEFB +C2,st-mem-2,1A63	0 mem-2 holds 0

iii. The main loop:

The series is generated by looping, using BERG as a counter; the constants in the calling subroutine are stacked in turn by calling STK-DATA; the calculator is re-entered at GEN-ENT-2 so as not to disturb the value of BERG; and the series is built up in the form:

$B(R) = 2*Z*B(R-1) - B(R-2) + A(R)$, for $R = 1, 2, \dots, N$, where $A(1), A(2), \dots, A(N)$ are the constants supplied by the calling subroutine (SIN, ATN, LN and EXP) and $B(0) = 0 = B(-1)$.

The $(R+1)$ th loop starts with $B(R)$ on the stack and with $2*Z, B(R-2)$ and $B(R-1)$ in mem-0, mem-1 and mem-2 respectively.

1A89	G-LOOP	DEFB +2D,duplicate,19F6 DEFB +E0,get-mem-0,1A45 DEFB +04,multiply,17C6 DEFB +E2,get-mem-2,1A45 DEFB +C1,st-mem-1,1A63 DEFB +03,subtract,174C DEFB +34,end-calc.,0028	$B(R), B(R)$ $B(R), B(R), 2*Z$ $B(R), 2*B(R)*Z$ $B(R), 2*B(R)*Z, B(R-1)$ mem-1 holds $B(R-1)$ $B(R), 2*B(R)*Z-B(R-1)$
------	--------	--	--

The next constant is placed on the calculator stack.

CALL 19FC,STK-DATA	$B(R), 2*B(R)*Z-B(R-1), A(R+1)$
--------------------	---------------------------------

The Calculator is re-entered without disturbing BERG.

CALL 19A4,GEN-ENT-2	
DEFB +0F,addition,1755	B(R), $2*B(R)*Z-B(R-1)+A(R+1)$
DEFB +01,exchange,1A72	$2*B(R)*Z-B(R-1)+A(R+1)$, B(R)
DEFB +C2,st-mem-2,1A63	mem-2 holds B(R)
DEFB +02,delete,19E3	$2*B(R)*Z-B(R-1)+A(R+1) = B(R+1)$
DEFB +31,dec-jr-nz,1C17	B(R+1)
DEFB +EE, to 1A89,G-LOOP	

- iv. The subtraction of B(N-2):
The loop above leaves B(N) on the stack and the required result is given by B(N) - B(N-2).

DEFB +E1,get-mem-1,1A45	B(N), B(N-2)
DEFB +03,subtract,174C	B(N)-B(N-2)
DEFB +34,end-calc.,002B	
RET	Finished

THE 'UNARY MINUS' OPERATION (Offset 18: 'negate')

This subroutine performs its unary operation by changing the sign of the 'last value' on the calculator stack.

1AA0 negate	LD A,(HL)	Fetch the exponent, e.
	AND A	Test it.
	RET Z	Return if the 'last value' is zero.
	INC HL	Point to the sign byte.
	LD A,(HL)	Fetch the sign byte.
	XOR +80	Change the sign bit.
	LD (HL),A	Return the sign byte.
	DEC HL	Set the result pointer.
	RET	Finished.

THE 'ABSOLUTE MAGNITUDE' FUNCTION (Offset 27: 'abs')

This subroutine performs its unary operation by ensuring that the sign bit of a floating-point number is reset.

1AAA abs	INC HL	Point to the sign bit of the 'last value'.
	RES 7,(HL)	The bit must be reset always.
	DEC HL	Set the result pointer.
	RET	Finished.

THE 'SIGNUM' FUNCTION (Offset 26: 'sgn')

This subroutine handles the function $\text{SGN } X$ and therefore returns a 'last value' of 1 if X is positive, zero if X is zero and -1 if X is negative.

1AAF sgn	INC HL	Point to the sign byte of the present 'last value'.
	LD A,(HL)	Fetch the sign byte.
	DEC HL	Point to the exponent.
	DEC (HL)	Test the exponent byte; the zero flag is set for zero.
	INC (HL)	
	SCF	Set the carry flag.
	CALL NZ,1AE0,FP-0/1	If the value is not zero then call FP-0/1 with carry set to give a 'last value' of 1.

```

INC    HL
RLCA
RR     (HL)
DEC    HL
RET

```

Point to the sign byte again.
The sign bit of X is passed into the carry, and hence into the result.
Set the result pointer.
Finished.

THE 'PEEK' FUNCTION (Offset 28: 'peek')

This subroutine handles the function PEEK X. The 'last value' is unstacked by calling FIND-INT. and replaced by the value of the contents of the required location.

```

1ABE peek      CALL 0EA7,FIND-INT.

                LD    A,(BC)
                JP    151D,STACK-A

```

Evaluate the 'last value', rounded to the nearest integer; test that it is in range and return it in BC.
Fetch the required byte.
Exit by jumping to STACK-A.

THE 'USR' FUNCTION (Offset 29: 'usr')

This subroutine handles the function USR X. The value of X is evaluated, a return address is stacked and the machine code executed from location X.

```

1AC5 usr      CALL 0EA7,FIND-INT.

                LD    HL,+STACK-BC
                PUSH  HL
                PUSH  BC
                RET

```

Evaluate the 'last value', rounded to the nearest integer; test that it is in range and return it in BC.
Make the return address be that of the subroutine STACK-BC.
Make an indirect jump to the required location.

Note: It is interesting that the IY register pair is re-initialised when the return to STACK-BC has been made, but the important H'L' that holds the next literal pointer is not restored should it have been disturbed.

THE 'GREATER THAN ZERO' OPERATION (Offset 33: 'greater-0')

This subroutine returns a 'last value' of 1 if the present 'last value' is greater than zero and zero otherwise. It is also used by other subroutines to 'jump on plus'.

```

1ACE GREATER-0 LD    A,(HL)
                AND    A
                RET    Z
                LD    A,+FF
                JR     1ADC,SIGN-TO-C

```

Fetch the exponent byte.
Test it.
Return if the 'last value' is zero.
Jump forward to LESS THAN ZERO but signal the opposite action is needed.

THE 'NOT' FUNCTION (Offset 2C: 'not')

This subroutine returns a 'last value' of 1 if the present 'last value' is zero and zero otherwise. It is also used by other subroutines to 'jump on zero'.

```

1AD5 NOT      LD    A,(HL)
                NEG
                CCF
                JR     1AE0,FP-0/1

```

Fetch the exponent byte.
Negating and complementing ensure that the carry is set only if the 'last value' is zero; this gives the correct return.
Jump forward.

THE 'LESS THAN ZERO' OPERATION (Offset 32: 'less-0')

This subroutine returns a 'last value' of 1 if the present 'last value' is less than zero and zero otherwise. It is also used by other subroutines to 'jump on minus'.

1ADB less-0	XOR A	Clear the A register.
1ADC SIGN-TO-C	INC HL	Point to the sign byte.
	XOR (HL)	The sign bit is collected and stored
	DEC HL	in the carry; when entered from
	RLCA	GREATER-0 the opposite sign goes to
		the carry.

THE 'ZERO OR ONE' SUBROUTINE

This subroutine gives the 'last value' as zero if the carry flag is reset and the value 1 if it is set.

1AE0 FP-0/1	PUSH HL	Save the result pointer.
	LD B,+05	There are five bytes.
1AE3 FP-ZERO	LD (HL),+00	Enter zero on each loop.
	INC HL	Move to next byte.
	DJNZ 1AE3,FP-ZERO	Until the five bytes are done.
	POP HL	Restore the result pointer.
	RET NC	Return the zero if carry reset.
	LD (HL),+81	Return 1 if the carry flag is
	RET	set.

THE 'OR' OPERATION (Offset 07: 'or')

This subroutine performs the binary operation 'X OR Y' and returns X if Y is zero and the value 1 otherwise.

1AED or	LD A,(DE)	Fetch the exponent of the second
	AND A	number; test it and return with the
	RET Z	first number as the 'last value' if it
		is zero.
	SCF	Set the carry flag and jump back to
	JR 1AE0,FP-0/1	give the 'last value' as 1.

THE 'NUMBER AND NUMBER' OPERATION (Offset 08: 'no.-&-no.')

This subroutine performs the binary operation 'X AND Y' and returns X if Y is non-zero and the value zero otherwise.

1AF3 no.-&-no.	LD A,(DE)	Fetch the exponent of the second
	AND A	number; test it and return with the
	RET NZ	first number as the 'last value' if it
		is not zero.
	JR 1AE0,FP-0/1	With the carry flag reset, jump back to
		give the 'last value' as zero.

THE 'STRING AND NUMBER' OPERATION (Offset 10: 'str-&-no.')

This subroutine performs the binary operation 'A\$ AND Y' and returns A\$ if Y is non-zero and a null string otherwise.

1AF8 str-&-no.	LD A,(DE)	Fetch the exponent of the number;
	AND A	test it and return with the string as the
	RET NZ	'last value' if it is not zero.

PUSH DE	Save the pointer to the number.
DEC DE	Point to the 5th byte of the string parameters i.e. length-high.
XOR A	Clear the A register.
LD (DE),A	Length-high is now set to zero.
DEC DE	Point to length-low.
LD (DE),A	Length-low is now set to zero.
POP DE	Restore the pointer.
RET	Return with the string parameters being the 'last value'.

THE 'COMPARISON' OPERATIONS (Offsets 09 to 0E & 11 to 16: 'no.-l-eql', 'no.-gr-eq', 'nos.-neql', 'no.-grtr', 'no.-less', 'nos.-eql', 'str-l-eql', 'str-gr-eql', 'strs-neql', 'str-grtr', 'str-less' & 'strs-eql')

This subroutine is used to perform the twelve possible comparison operations. The single operation offset is present in the B register at the start of the subroutine.

1B03	no.-l-eql etc.	LD A,B	The single operation offset goes to the A register.
		SUB +08	The range is now 01-06 & 09-0E.
		BIT 2,A	This range is changed to:
		JR NZ,1B0B,EX-OR-NOT	00-02, 04-06, 08-0A & 0C-0E.
		DEC A	Then reduced to 00-07 with carry set for 'greater than or equal to' & 'less than'; the operations with carry set are then treated as their complementary operations once the values have been exchanged.
1B0B	EX-OR-NOT	RRCA	
		JR NC,1B16,NU-OR-STR	
		PUSH AF	
		PUSH HL	
		CALL 1A72,EXCHANGE	
		POP DE	
		EX DE,HL	
		POP AF	
1B16	NU-OR-STR	BIT 2,A	The numerical comparisons are now separated from the string comparisons by testing bit 2.
		JR NZ,1B21,STRINGS	The numerical operations now have the range 00-01 with carry set for 'equal' and 'not equal'.
		RRCA	Save the offset.
		PUSH AF	The numbers are subtracted for the final tests.
		CALL 174C,SUBTRACT	The string comparisons now have the range 02-03 with carry set for 'equal' and 'not equal'.
1B21	STRINGS	JR 1B54,END-TESTS	Save the offset.
		RRCA	The lengths and starting addresses of the strings are fetched from the calculator stack.
		PUSH AF	
		CALL 13F8,STK-FETCH	
		PUSH DE	
		PUSH BC	
		CALL 13F8,STK-FETCH	
		POP HL	The length of the second string.
1B2C	BYTE-COMP	LD A,H	
		OR L	
		EX (SP),HL	
		LD A,B	
		JR NZ,1B3D,SEC-PLUS	Jump unless the second string is null.
		OR C	
1B33	SECND-LOW	POP BC	Here the second string is either null or less than the first.
		JR Z,1B3A,BOTH-NULL	

		POP AF	
		CCF	
1B3A	BOTH-NULL	JR 1B50,STR-TEST	
		POP AF	The carry is complemented to give the correct test results.
		JR 1B50,STR-TEST	Here the carry is used as it stands.
1B3D	SEC-PLUS	OR C	
		JR Z,1B4D,FRST-LESS	The first string is now null, the second not.
		LD A,(DE)	Neither string is null, so their next bytes are compared.
		SUB (HL)	The first byte is less.
		JR C,1B4D,FRST-LESS	The second byte is less.
		JR NZ,1B33,SECND-LOW	The bytes are equal; so the lengths, are decremented and a jump is made to BYTE-COMP to compare the next bytes of the reduced strings.
		DEC BC	
		INC DE	
		INC HL	
		EX (SP),HL	
		DEC HL	
1B4D	FRST-LESS	JR 1B2C,BYTE-COMP	
		POP BC	
		POP AF	
		AND A	The carry is cleared here for the correct test results.
1B50	STR-TEST	PUSH AF	For the string tests, a zero is put on to the calculator stack.
		RST 0028,FP-CALC.	
		DEFB +A0,stk-zero,1A51	
		DEFB +34,end-calc.,002B	
1B54	END-TESTS	POP AF	
		PUSH AF	
		CALL C,1AD5,NOT	
		CALL 1ACE,GREATER-0	
		POP AF	
		RRCA	
		CALL NC,1AD5,NOT	
		RET	These three tests, called as needed, give the correct results for all twelve comparisons. The initial carry is set for 'not equal' and 'equal', and the final carry is set for 'greater than', 'less than' and 'equal'. Finished.

THE 'STRING CONCATENATION' OPERATION (Offset 17: 'strs-add')

This subroutine performs the binary operation 'A\$+B\$'. The parameters for these strings are fetched and the total length found. Sufficient room to hold both the strings is made available in the work space and the strings are copied over. The result of this subroutine is therefore to produce a temporary variable A\$+B\$ that resides in the work space.

1B62	strs-add	CALL 13F8,STK-FETCH	
		PUSH DE	The parameters of the second string are fetched and saved.
		PUSH BC	
		CALL 13F8,STK-FETCH	The parameters of the first string are fetched.
		POP HL	
		PUSH HL	
		PUSH DE	The lengths are now in HL and BC.
		PUSH BC	The parameters of the first string are saved.
		ADD HL,BC	The total length of the two strings is calculated and passed to BC.
		LD B,H	
		LD C,L	
		RST 0030,BC-SPACES	Sufficient room is made available.
		CALL 12C3,STK-STORE	The parameters of the new string are passed to the calculator stack.
		POP BC	The parameters of the first string are retrieved and the string copied to the work space as long as it is not a null string.
		POP HL	
		LD A,B	
		OR C	
		JR Z,1B7D,OTHER-STR	
		LDIR	

```

1B7D OTHER-STR POP BC
                POP HL
                LD A,B
                OR C
                JR Z,1B85,STK-PNTRS
                LDIR

```

Exactly the same procedure is followed for the second string thereby giving 'A\$+B\$'.

THE 'STK-PNTRS' SUBROUTINE

This subroutine resets the HL register pair to point to the first byte of the 'last value', i.e. STKEND-5, and the DE register pair to point one-past the 'last value', i.e. STKEND.

```

1B85 STK-PNTRS LD HL,(STKEND)
                LD DE,+FFFB
                PUSH HL
                ADD HL,DE
                POP DE
                RET

```

Fetch the current value of STKEND.

Set DE to -5, 2's complement.

Stack the value for STKEND.

Calculate STKEND-5.

DE now holds STKEND and HL holds STKEND-5.

THE 'CHRS' FUNCTION (Offset 2B: 'chrs')

This subroutine handles the function CHR\$ X and creates a single character string in the work space.

```

1B8F chrs      CALL 15CD,FP-TO-A
                JR C,1BA2,REPORT-B2
                JR NZ,1BA2,REPORT-B2
                PUSH AF
                LD BC,+0001
                RST 0030,BC-SPACES
                POP AF
                LD (DE),A
                CALL 12C3,STK-STORE
                EX DE,HL
                RET

```

The 'last value' is compressed into the A register.

Give the error report if X was greater than 255 decimal, or X was a negative number.

Save the compressed value of X.

Make one space available in the work space.

Fetch the value.

Copy the value to the work space.

Pass the parameters of the new string to the calculator stack.

Reset the pointers.

Finished.

REPORT-B2 — integer out of range

```

1BA2 REPORT-B2 RST 0008,ERROR-1
                DEFB +0A

```

THE 'VAL' FUNCTION (Offset 1A: 'val')

This subroutine handles the function VAL A\$ and returns a 'last value' that is the result of evaluating the string as an arithmetical expression.

```

1BA4 val      LD HL,(CH-ADD)
                PUSH HL
                CALL 13F8,STK-FETCH
                PUSH DE
                INC BC
                RST 0030,BC-SPACES
                POP HL

```

The current value of CH-ADD is preserved on the machine stack.

The parameters of the string are fetched; the starting address is saved; one byte is added to the length and room made available for the string (+1) in the work space.

The starting address of the string goes to HL as a source address.

LD (CH-ADD),DE	The pointer to the 2nd new space goes to CH-ADD and the machine stack.
PUSH DE	The string is copied to the work space, together with an extra byte.
LDIR	Switch the pointers.
EX DE,HL	The extra byte is replaced by a NEWLINE character.
DEC HL	The syntax flag is reset and the string scanned for correct syntax.
LD (HL),+76	A check is made that the end of a line has been reached.
RES 7,(FLAGS)	The starting address of the string is fetched and copied to CH-ADD.
CALL 0D92,CLASS-6	The flag is set for line execution.
CALL 0D22,CHECK-2	The string is treated as a 'next expression' and a 'last value' produced.
POP HL	The original value of CH-ADD is restored.
LD (CH-ADD),HL	The subroutine exits via STK-PNTRS which resets the pointers.
SET 7,(FLAGS)	
CALL 0F55,SCANNING	
POP HL	
LD (CH-ADD),HL	
JR 1B85,STK-PNTRS	

THE 'STR\$' FUNCTION (Offset 2A: 'strs')

This subroutine handles the function STR\$ X and returns a 'last value' which is a set of parameters that defines a string containing what would appear on the screen if X were displayed by a PRINT command.

1BD5	strs	LD BC,+0001	One space is made in the work space and a NEWLINE character put into the location after it.
		RST 0030,BC-SPACES	The current value of S-POSN is preserved on the machine stack.
		LD (HL),+76	The column number of the PRINT position is set to a high value.
		LD HL,(S-POSN)	The current value of DF-CC is preserved on the machine stack.
		PUSH HL	The pointer to the NEWLINE character becomes the destination pointer of the PRINT operation. A copy is saved on the machine stack.
		LD L,+FF	The 'last value', X, is now printed out in the work space and the work space is expanded with each character as DF-CC points to a NEWLINE character.
		LD (S-POSN),HL	In effect now the start address.
		LD HL,(DF-CC)	Now the NEWLINE character is one-past the end of the string and hence the difference is the length.
		PUSH HL	Transfer the length to BC.
		LD (DF-CC),DE	
		PUSH DE	
		CALL 15DB,PRINT-FP	
		POP DE	Restore the original value of DF-CC.
		LD HL,(DF-CC)	Restore the original value of S-POSN.
		AND A	Pass the parameters of the new string to the calculator stack.
		SBC HL,DE	Reset the pointers.
		LD B,H	Finished.
		LD C,L	
		POP HL	
		LD (DF-CC),HL	
		POP HL	
		LD (S-POSN),HL	
		CALL 12C3,STK-STORE	
		EX DE,HL	
		RET	

THE 'CODE' FUNCTION (Offset 19: 'code')

This subroutine handles the function CODE A\$ and returns the ZX81 code of the first character in A\$, or zero if A\$ should be null.

1C06	code	CALL 13F8,STK-FETCH	The parameters of the string are fetched.
		LD A,B	The length is tested and the A
		OR C	register holding zero is carried forward
		JR Z,1C0E,STK-CODE	if A\$ is a null string.
		LD A,(DE)	The code of the first character is put
			into A otherwise.
1C0E	STK-CODE	JP 151D,STACK-A	The subroutine exits via STACK-A
			which gives the correct 'last value'.

THE 'LEN' FUNCTION (Offset 1B: 'len')

This subroutine handles the function LEN A\$ and returns a 'last value' that is equal to the length of the string.

1C11	len	CALL 13F8,STK-FETCH	The parameters of the string are fetched.
		JP 152D,STACK-BC	The subroutine exits via STACK-BC
			which gives the correct 'last value'.

THE 'DECREASE THE COUNTER' SUBROUTINE (Offset 31: 'dec-jr-nz')

This subroutine is only called by the SERIES GENERATOR subroutine and in effect is a 'DJNZ' operation but the counter is the system variable, BERG, rather than the B register.

1C17	dec-jr-nz	EXX	Go to the alternate register set and
		PUSH HL	save the next literal pointer on the
			machine stack.
		LD HL,+BERG	Make HL point to BERG.
		DEC (HL)	Decrease BERG.
		POP HL	Restore the next literal pointer.
		JR NZ,1C24,JUMP-2	The jump is made on non-zero.
		INC HL	The next literal is passed over.
		EXX	Return to the main register set.
		RET	Finished.

THE 'JUMP' SUBROUTINE (Offset 2F: 'jump')

This subroutine executes an unconditional jump when called by the literal '2F'. It is also used by the subroutines DECREASE THE COUNTER and JUMP ON TRUE.

1C23	JUMP	EXX	Go to the alternate register set.
1C24	JUMP-2	LD E,(HL)	The next literal (jump length) is put
			in the E' register.
		XOR A	The A register is cleared.
		BIT 7,E	If E' is negative, indicating a backwards
		JR Z,1C2B,NEW-ADDR.	jump then Hex.FF is formed in the
		CPL	A register instead of the Hex.00.
1C2B	NEW-ADDR.	LD D,A	Hex.00 or Hex.FF goes to D.
		ADD HL,DE	The registers H' & L' now hold the
		EXX	new next literal pointer.
		RET	Finished.

THE 'JUMP ON TRUE' SUBROUTINE (Offset 00: 'jump-true')

This subroutine executes a conditional jump if the 'last value' on the calculator stack, or more precisely the number addressed currently by the DE register pair, is true.

1C2F	jump-true	LD	A,(DE)	Fetch the exponent.
		AND	A	Test it.
		JR	NZ,1C23,JUMP	Make the jump on true, or more precisely, on not-false.
		EXX		Go to the alternate register set.
		INC	HL	Pass over the jump length.
		EXX		Back to the main set of registers.
		RET		Finished.

THE 'MODULUS' SUBROUTINE (Offset 2E: 'n-mod-m')

This subroutine calculates $N \pmod{M}$, where M is a positive integer held at the top of the calculator stack, the 'last value', and N is an integer held on the stack beneath M .

The subroutine returns the integer quotient $INT(N/M)$ at the top of the calculator stack, the 'last value', and the remainder $N-INT(N/M)$ in the second place on the stack.

This subroutine is called by PRINT-FP to reduce $N \pmod{10}$ decimal, and during the calculation of a random number to reduce $N \pmod{65537}$ decimal.

1C37	n-mod-m	RST	0028,FP-CALC.	N, M	
		DEFB	+C0,st-mem-0,1A63	N, M	mem-0 holds M
		DEFB	+02,delete,19E3	N	
		DEFB	+2D,duplicate,19F6	N, N	
		DEFB	+E0,get-mem-0,1A45	N, N, M	
		DEFB	+05,division,1882	N, N/M	
		DEFB	+24,int,1C46	N, INT(N/M)	
		DEFB	+E0,get-mem-0,1A45	N, INT(N/M), M	
		DEFB	+01,exchange,1A72	N, M, INT(N/M)	
		DEFB	+C0,st-mem-0,1A63	N, M, INT(N/M)	mem-0 holds INT(N/M)
		DEFB	+04,multiply,17C6	N, M*INT(N/M)	
		DEFB	+03,subtract,174C	N-M*INT(N/M)	
		DEFB	+E0,get-mem-0,1A45	N-M*INT(N/M), INT(N/M)	
		DEFB	+34,end-calc.,002B		
		RET		Finished.	

THE 'INT' FUNCTION (Offset 24: 'int')

This subroutine handles the function $INT\ X$ and returns a 'last value' that is the 'integer part' of the value supplied. Thus $INT\ 2.4$ gives 2 but as the subroutine always rounds the result down $INT\ -2.4$ gives -3.

The subroutine uses the INTEGER TRUNCATION TOWARDS ZERO subroutine at 18E4 to produce $I(X)$ such that $I(2.4)$ gives 2 and $I(-2.4)$ gives -2. Thus, $INT\ X$ is given by $I(X)$ for values of X that are greater than or equal to zero, and $I(X)-1$ for negative values of X that are not already integers, when the result is, of course, $I(X)$.

1C46	int	RST	0028,FP-CALC.	X
		DEFB	+2D,duplicate,19F6	X, X
		DEFB	+32,less-0,1ADB	X, (1/0)
		DEFB	+00,jump-true,1C2F	X
		DEFB	+04, to 1C4E,X-NEG	X

For values of X that have been shown to be greater than or equal to zero there is no jump and $I(X)$ is readily found.

DEFB +36,truncate,18E4	I (X)
DEFB +34,end-calc.,002B	
RET	Finished.

When X is a negative integer I (X) is returned, otherwise I (X)-1 is returned.

1C4E X-NEG	DEFB +2D,duplicate,19F6	X, X	
	DEFB +36,truncate,18E4	X, I (X)	
	DEFB +C0,st-mem-0,1A63	X, I (X)	mem-0 holds I (X)
	DEFB +03,subtract,174C	X-I (X)	
	DEFB +E0,get-mem-0,1A45	X-I (X), I (X)	
	DEFB +01,exchange,1A72	I (X), X-I (X)	
	DEFB +2C,not,1AD5	I (X), (1/0)	
	DEFB +00,jump-true,1C2F	I (X)	
	DEFB +03, to 1C59,EXIT	I (X)	

The jump is made for values of X that are negative integers, otherwise there is no jump and I (X)-1 is calculated.

DEFB +A1,stk-one,1A51	I (X), 1
DEFB +03,subtract,174C	I (X)-1

In either case the subroutine finishes with;

1C59 EXIT	DEFB +34,end-calc.,002B	I (X) or I (X)-1
	RET	

THE 'EXPONENTIAL' FUNCTION (Offset 23: 'exp')

This subroutine handles the function EXP X and is the first of the four routines that use SERIES GENERATOR to produce Chebyshev polynomials.

The approximation to EXP X is found as follows:

- X is divided by LN 2 to give Y, so that 2 to the power Y is now the required result.
- The value N is found, such that N=INT Y.
- The value W is found, such that W=Y-N, where 0<=W <=1, as required for the series to converge.
- The argument Z is formed, such that Z=2*W-1.
- The SERIES GENERATOR is used to return 2**W.
- Finally N is added to the exponent, giving 2**(N+W), which is 2**Y and therefore the required answer for EXP X.

The method is illustrated using a BASIC program in the Appendix.

1C5B EXP	RST 0028,FP-CALC.	X
----------	-------------------	---

Perform step i.

DEFB +30,stk-data,19FC	X, 1/LN 2
DEFB +F1,exponent 81	
DEFB +38,+AA,+3B,+29	
DEFB +04,multiply,17C6	X/LN 2 = Y

Perform step ii.

DEFB +2D,duplicate,19F6	Y, Y	
DEFB +24,int,1C46	Y, INT Y = N	
DEFB +C3,st-mem-3, 1A63	Y, N	mem-3 holds N

Perform step iii.

DEFB +03,subtract,174C	Y-N = W
------------------------	---------

Perform step iv.

DEFB +2D,duplicate,19F6	W, W
DEFB +0F,addition,1755	$2*W$
DEFB +A1,stk-one,1A51	$2*W, 1$
DEFB +03,subtract,174C	$2*W-1 = Z$

Perform step v, passing to the SERIES GENERATOR the parameter '8' and the eight constants required.

	DEFB +88,series-08,1A7F	Z
1.	DEFB +13,exponent 63	
	DEFB +36,(+00,+00,+00)	
2.	DEFB +58,exponent 68	
	DEFB +65,+66,(+00,+00)	
3.	DEFB +9D,exponent 6D	
	DEFB +78,+65,+40,(+00)	
4.	DEFB +A2,exponent 72	
	DEFB +60,+32,+C9,(+00)	
5.	DEFB +E7,exponent 77	
	DEFB +21,+F7,+AF,+24	
6.	DEFB +EB,exponent 7B	
	DEFB +2F,+B0,+B0,+14	
7.	DEFB +EE,exponent 7E	
	DEFB +7E,+BB,+94,+58	
8.	DEFB +F1,exponent 81	
	DEFB +3A,+7E,+F8,+CF	

At the end of the last loop the 'last value' is $2**W$.

Perform step vi.

	DEFB +E3,get-mem-3,1A45	$2**W, N$
	DEFB +34,end-calc.,002B	
	CALL 15CD,FP-TO-A	The absolute value of N mod 256 decimal, is put into the A register.
	JR NZ,1C9B,N-NEGTV	Jump forward if N was negative.
	JR C,1C99,REPORT6-2	Error if ABS N greater than 255 dec.
	ADD A,(HL)	Now add ABS N to the exponent.
1C99 REPORT6-2	JR NC,1CA2,RESULT-OK	Jump unless e greater than 255 dec.
	RST 0008,ERROR-1	Otherwise report the overflow.
	DEFB +05	
1C9B N-NEGTV	JR C,1CA4,RSLT-ZERO	The result is to be zero if N is less than -255 decimal.
	SUB (HL)	Subtract ABS N from the exponent as N was negative.
	JR NC,1CA4,RSLT-ZERO	Zero result if e less than zero.
	NEG	Minus e is changed to e.
1CA2 RESULT-OK	LD (HL),A	The exponent, e, is entered.
	RET	Finished: 'last value' is EXP X.
1CA4 RSLT-ZERO	RST 0028,FP-CALC.	Use the calculator to make the 'last value' zero.
	DEFB +02,delete,19E3	
	DEFB +A0,stk-zero,1A51	
	DEFB +34,end-calc.,002B	
	RET	Finished, with EXP X = 0.

THE 'NATURAL LOGARITHM' FUNCTION (Offset 22: 'ln')

This subroutine handles the function LN X and is the second of the four routines that use SERIES GENERATOR to produce Chebyshev polynomials.

The approximation to LN X is found as follows:

- X is tested and report A is given if X is not positive.
- X is then split into its true exponent, e' , and its mantissa $X' = X/(2^{*}e')$, where X' is greater than, or equal to, 0.5 but still less than 1.
- The required value Y1 or Y2 is formed. If X' is greater than 0.8 then $Y1 = e' * \text{LN } 2$ and if otherwise $Y2 = (e'-1) * \text{LN } 2$.
- If X' is greater than 0.8 then the quantity $X'-1$ is stacked; otherwise $2 * X'-1$ is stacked.
- Now the argument Z is formed, being, if X' is greater than 0.8, $Z = 2.5 * X'-3$; otherwise $Z = 5 * X'-3$. In each case, $-1 \leq Z \leq 1$, as required for the series to converge.
- The SERIES GENERATOR is used to produce the required function.
- Finally a simple multiplication and addition leads to LN X being returned as the 'last value'.

1CA9 In RST 0028,FP-CALC. X

Perform step i.

DEFB +2D,duplicate,19F6	X, X
DEFB +33,greater-0,1ACE	X, (1/0)
DEFB +00,jump-true,1C2F	X
DEFB +04, to 1CB1,VALID	X
DEFB +34,end-calc.,002B	X
RST 0008,ERROR-1	
DEFB +09	Give report A — invalid argument.

Perform step ii.

1CB1 VALID	DEFB +A0,stk-zero,1A51	X, 0	The deleted 1 is overwritten
	DEFB +02,delete,19E3	X	with zero.
	DEFB +34,end-calc.,002B	X	
	LD A,(HL)		The exponent, e, goes into A.
	LD (HL),+80		X is reduced to X' .
	CALL 151D,STACK-A		The stack holds: X' , e.
	RST 0028,FP-CALC.	X' , e	
	DEFB +30,stk-data,19FC	X' , e, 128 (decimal)	
	DEFB +38,exponent 88		
	DEFB +00,(+00,+00,+00)		
	DEFB +03,subtract,174C	X' , e'	

Perform step iii.

	DEFB +01,exchange,1A72	e' , X'
	DEFB +2D,duplicate, 19F6	e' , X' , X'
	DEFB +30,stk-data,19FC	e' , X' , X' , 0.8 (decimal)
	DEFB +FD,exponent 80	
	DEFB +4C,+CC,+CC,+CD	
	DEFB +03,subtract,174C	e' , X' , $X'-0.8$
	DEFB +33,greater-0,1ACE	e' , X' , (1/0)
	DEFB +00,jump-true,1C2F	e' , X'
	DEFB +08, to 1CD2,GRE.8	e' , X'
	DEFB +01,exchange,1A72	X' , e'
	DEFB +A1,stk-one,1A51	X' , e' , 1
	DEFB +03,subtract,174C	X' , $e'-1$
	DEFB +01,exchange,1A72	$e'-1$, X'
	DEFB +34,end-calc.,002B	$e'-1$, X'
	INC (HL)	Double X' to give $2 * X'$.
	RST 0028,FP-CALC.	$e'-1, 2 * X'$
1CD2 GRE.8	DEFB +01,exchange, 1A72	X' , e' — X' large.
		$2 * X'$, $e'-1$ — X' small.

DEFB +30,stk-data,19FC	$X', e', LN\ 2$
	$2*X', e'-1, LN\ 2$
DEFB +F0,exponent 80	
DEFB +31,+72,+17,+F8	
DEFB +04,multiply,17C6	$X', e'*LN\ 2 = Y1$
	$2*X', (e'-1)*LN\ 2 = Y2$

Perform step iv.

DEFB +01,exchange,1A72	$Y1, X'$ — X' large.
	$Y2, 2*X'$ — X' small.
DEFB +A2,stk-half,1A51	$Y1, X', .5$ (decimal)
	$Y2, 2*X', .5$
DEFB +03,subtract,174C	$Y1, X'-.5$
	$Y2, 2*X'-.5$
DEFB +A2,stk-half,1A51	$Y1, X'-.5, .5$
	$Y2, 2*X'-.5, .5$
DEFB +03,subtract,174C	$Y1, X'-1$
	$Y2, 2*X'-1$

Perform step v.

DEFB +2D,duplicate,19F6	$Y, X'-1, X'-1$
	$Y2, 2*X'-1, 2*X'-1$
DEFB +30,stk-data,19FC	$Y1, X'-1, X'-1, 2.5$ (decimal)
	$Y2, 2*X'-1, 2*X'-1, 2.5$
DEFB +32,exponent 82	
DEFB +20,(+00,+00,+00)	
DEFB +04,multiply,17C6	$Y1, X'-1, 2.5*X'-2.5$
	$Y2, 2*X'-1, 5*X'-2.5$
DEFB +A2,stk-half,1A51	$Y1, X'-1, 2.5*X'-2.5, .5$
	$Y2, 2*X'-1, 5*X'-2.5, .5$
DEFB +03,subtract,174C	$Y1, X'-1, 2.5*X'-3 = Z$
	$Y2, 2*X'-1, 5*X'-3 = Z$

Perform step vi, passing to the SERIES GENERATOR the parameter '12' decimal, and the twelve constant required.

	DEFB +8C,series-0C,1A7F	$Y1, X'-1, Z$ or $Y2, 2*X'-1, Z$
1.	DEFB +11,exponent 61	
	DEFB +AC,(+00,+00,+00)	
2.	DEFB +14,exponent 64	
	DEFB +09,(+00,+00,+00)	
3.	DEFB +56,exponent 66	
	DEFB +DA,+A5,(+00,+00)	
4.	DEFB +59,exponent 69	
	DEFB +30,+C5,(+00,+00)	
5.	DEFB +5C,exponent 6C	
	DEFB +90,+AA,(+00,+00)	
6.	DEFB +9E,exponent 6E	
	DEFB +70,+6F,+61,(+00)	
7.	DEFB +A1,exponent 71	
	DEFB +CB,+DA,+96,(+00)	
8.	DEFB +A4,exponent 74	
	DEFB +31,+9F,+B4,(+00)	
9.	DEFB +E7,exponent 77	
	DEFB +A0,+FE,+5C,+FC	

```

10.  DEFB +EA,exponent 7A
      DEFB +1B,+43,+CA,+36
11.  DEFB +ED,exponent 7D
      DEFB +A7,+9C,+7E,+5E
12.  DEFB +F0,exponent 80
      DEFB +6E,+23,+80,+93

```

At the end of the last loop the 'last value' is:

```

either LN X'/(X'-1) for the larger values of X'
or      LN (2*X')/(2*X'-1) for the smaller values of X'.

```

Perform step vii.

```

DEFB +04,multiply,17C6      Y1=LN (2**e'), LN X'
                             Y2=LN (2**(e'-1)), LN (2*X')
DEFB +0F,addition,1755      LN ((2**e')*X') = LN X
                             LN(2**(e'-1)*2*X') = LN X
DEFB +34,end-calc.,002B      LN X
RET                           Finished: 'last value' is LN X.

```

THE 'REDUCE ARGUMENT' SUBROUTINE (Offset 35: 'get-argt.')

This subroutine transforms the argument X of SIN X or COS X into a value V.

The subroutine first finds a value Y such that:

$$Y = X/(2*PI) - \text{INT}(X/(2*PI) + 0.5), \text{ where } Y \text{ is greater than, or equal to, } -.5 \text{ but less than } +.5.$$

The subroutine returns with:

```

V = 4*Y   if -1<=4*Y<=1   -- case i.
or, V = 2-4*Y if 1<4*Y<2   -- case ii.
or, V = -4*Y-2 if -2<=4*Y<-1. -- case iii.

```

In each case, $-1 \leq V \leq 1$ and $\text{SIN}(PI*V/2) = \text{SIN } X$.

```

1D18 get-argt.  RST 0028,FP-CALC.      X
                  DEFB +30,stk-data,19FC  X, 1/(2*PI)
                  DEFB +EE,exponent 7E
                  DEFB +22,+F9,+83,+6E
                  DEFB +04,multiply,17C6   X/(2*PI)
                  DEFB +2D,duplicate,19F6   X/(2*PI), X/(2*PI)
                  DEFB +A2,stk-half,1A51    X/(2*PI), X/(2*PI), 0.5
                  DEFB +0F,addition,1755    X/(2*PI), X/(2*PI)+0.5
                  DEFB +24,int,1C46         X/(2*PI), INT(X/(2*PI)+0.5)
                  DEFB +03,subtract,174C     X/(2*PI)-INT(X/(2*PI)+0.5) = Y

```

Note: Adding 0.5 and taking INT rounds the result to the nearest integer.

```

DEFB +2D,duplicate,19F6      Y, Y
DEFB +0F,addition,1755      2*Y
DEFB +2D,duplicate,19F6      2*Y, 2*Y
DEFB +0F,addition,1755      4*Y
DEFB +2D,duplicate,19F6      4*Y, 4*Y
DEFB +27,abs,1AAA           4*Y, ABS(4*Y)
DEFB +A1,stk-one,1A51       4*Y, ABS(4*Y), 1
DEFB +03,subtract,174C      4*Y, ABS(4*Y)-1 = Z
DEFB +2D,duplicate,19F6      4*Y, Z, Z
DEFB +33,greater-0,1ACE     4*Y, Z, (1/0)
DEFB +C0,stk-mem-0,1A63     Mem-0 holds the result of the test.

```


DEFB +00,jump-true,1C2F	4*Y, Z
DEFB +04, to 1D35,ZPLUS	4*Y, Z
DEFB +02,delete,19E3	4*Y
DEFB +34,end-calc.,002B	4*Y = V — case i.
RET	Finished.

If the jump was made then continue.

1D35 ZPLUS	DEFB +A1,stk-one,1A51	4*Y, Z, 1
	DEFB +03,subtract,174C	4*Y, Z-1
	DEFB +01,exchange,1A72	Z-1, 4*Y
	DEFB +32,less-0,1ADB	Z-1, (1/0)
	DEFB +00,jump-true,1C2F	Z-1
	DEFB +02, to 1D3C,YNEG	Z-1
	DEFB +18,negate,1AA0	1-Z
1D3C YNEG	DEFB +34,end-calc.,002B	1-Z = V — case ii.
		Z-1 = V — case iii.
	RET	Finished.

THE 'COSINE' FUNCTION (Offset 1D: 'cos')

This subroutine handles the function COS X and returns a 'last value' that is an approximation to COS X.

The subroutine uses the expression:

$$\text{COS } X = \text{SIN } (\text{PI} * W / 2), \text{ where } -1 \leq W \leq 1.$$

In deriving W from X the subroutine uses the test result obtained in the previous subroutine and stored for this purpose in mem-0. It then jumps to the SINE subroutine, entering at C-ENT, to produce a 'last value' of COS X.

1D3E cos	RST 0028,FP-CALC.	X
	DEFB +35,get-argt.,1D18	V
	DEFB +27,abs,1AAA	ABS V
	DEFB +A1,stk-one,1A51	ABS V, 1
	DEFB +03,subtract,174C	ABS V-1
	DEFB +E0,get-mem-0,1A45	ABS V-1, (1/0)
	DEFB +00,jump-true,1C2F	ABS V-1
	DEFB +06, to 1D4B, C-ENT	ABS V-1 = W

If the jump was not made then continue.

DEFB +18,negate,1AA0	1-ABS V
DEFB +2F,jump,1C23	1-ABS V
DEFB +03, to 1D4B,C-ENT	1-ABS V = W

THE 'SINE' FUNCTION (Offset 1C: 'sin')

This subroutine handles the function SIN X and is the third of the four routines that use SERIES GENERATOR to produce Chebyshev polynomials.

The approximation to SIN X is found as follows:

- i. The argument X is reduced and in this case $W = V$ directly.
Note that $-1 \leq W \leq 1$, as required for the series to converge.
- ii. The argument Z is formed, such that $Z = 2 * W * W - 1$.
- iii. The SERIES GENERATOR is used to return $(\text{SIN } (\text{PI} * W / 2)) / W$.
- iv. Finally a simple multiplication gives SIN X.

1D49 sin	RST 0028,FP-CALC.	X
----------	-------------------	---

Perform step i.

```
DEFB +35,get-argt.,1D18      W
```

Perform step ii. The subroutine from now on is common to both the SINE and COSINE functions.

```
1D4B C-ENT    DEFB +2D,duplicate,19F6      W, W,
              DEFB +2D,duplicate,19F6      W, W, W
              DEFB +04,multiply,17C6        W, W*W
              DEFB +2D,duplicate,19F6      W, W*W, W*W
              DEFB +0F,addition,1755        W, 2*W*W
              DEFB +A1,stk-one,1A51        W, 2*W*W, 1
              DEFB +03,subtract,174C        W, 2*W*W-1 = Z
```

Perform step iii, passing to the SERIES GENERATOR the parameter '6' and the six constants required.

```
          DEFB +86,series-06,1A7F      W, Z
1.  DEFB +14,exponent 64
    DEFB +E6,(+00,+00,+00)
2.  DEFB +5C,exponent 6C
    DEFB +1F,+0B,(+00,+00)
3.  DEFB +A3,exponent 73
    DEFB +8F,+38,+EE,(+00)
4.  DEFB +E9,exponent 79
    DEFB +15,+63,+BB,+23
5.  DEFB +EE,exponent 7E
    DEFB +92,+0D,+CD,+ED
6.  DEFB +F1,exponent 81
    DEFB +23,+5D,+1B,+EA
```

At the end of the last loop the 'last value' is $\{\sin(\pi W/2)\}/W$.

Perform step v.

```
DEFB +04,multiply,17C6      SIN (PI*W/2) = SIN X (or = COS X)
DEFB +34,end-calc.,002B
RET                          Finished: 'last value' = SIN X.
                              or
                              ('last value' = COS X ).
```

THE 'TAN' FUNCTION (Offset 1E: 'tan')

This subroutine handles the function TAN X. The subroutine simply returns SIN X/COS X, with arithmetic overflow if COS X=0.

```
1D6E tan      RST  0028,FP-CALC.      X
              DEFB +2D,duplicate,19F6  X, X
              DEFB +1C,sin,1D49        X, SIN X
              DEFB +01,exchange,1A72    SIN X, X
              DEFB +1D,cos,1D3E        SIN X, COS X
              DEFB +05,division,1882    SIN X/COS X = TAN X
                                          Report arithmetic overflow if needed.
              DEFB +34,end-calc.,002B   TAN X
              RET                       Finished: 'last value' = TAN X.
```

THE 'ARCTAN' FUNCTION (Offset 21: 'atn')

This subroutine handles the function ATN X and is the last of the four routines that use SERIES GENERATOR to produce Chebyshev polynomials. It returns a real number between $-\pi/2$ and $\pi/2$, which is equal to the value in radians of the angle whose tan is X.

The approximation to $\text{ATN } X$ is found as follows:

- i. The values W and Y are found for three cases of X , such that:

if $-1 < X < 1$ then $W = 0$ & $Y = X$ — case i.
 if $1 \leq X$ then $W = \pi/2$ & $Y = -1/X$ — case ii.
 if $X \leq -1$ then $W = -\pi/2$ & $Y = -1/X$ — case iii.

In each case, $-1 \leq Y \leq 1$, as required for the series to converge.

- ii. The argument Z is formed, such that:

if $-1 < X < 1$ then $Z = 2*Y*Y-1 = 2*X*X-1$ — case i.
 if $1 < X$ then $Z = 2*Y*Y-1 = 2/(X*X)-1$ — case ii.
 if $X \leq -1$ then $Z = 2*Y*Y-1 = 2/(X*X)-1$ — case iii.

- iii. The SERIES GENERATOR is used to produce the required function.

- iv. Finally a simple multiplication and addition give $\text{ATN } X$.

Perform stage i.

1D76	atn	LD A,(HL)	Fetch the exponent of X .
		CP +81	
		JR C,1D89,SMALL	Jump forward for case i: $Y = X$.
		RST 0028,FP-CALC.	X
		DEFB +A1,stk-one,1A51	$X, 1$
		DEFB +18,negate,1AA0	$X, -1$
		DEFB +01,exchange,1A72	$-1, X$
		DEFB +05,division,1882	$-1/X$
		DEFB +2D,duplicate,19F6	$-1/X, -1/X$
		DEFB +32,less-0,1ADB	$-1/X, (1/0)$
		DEFB +A3,stk-pi/2,1A51	$-1/X, (1/0), \pi/2$
		DEFB +01,exchange,1A72	$-1/X, \pi/2, (1/0)$
		DEFB +00,jump-true,1C2F	$-1/X, \pi/2$
		DEFB +06, to 1D8B,CASES	Jump forward for case ii: $Y = -1/X$
			$W = \pi/2$
		DEFB +18,negate,1AA0	$-1/X, -\pi/2$
		DEFB +2F,jump,1C23	$-1/X, -\pi/2$
		DEFB +03, to 1D8B,CASES	Jump forward for case iii: $Y = -1/X$
			$W = -\pi/2$
1D89	SMALL	RST 0028,FP-CALC.	Y
		DEFB +A0,stk-zero,1A51	$Y, 0$
			Continue for case i: $W = 0$

Perform step ii.

1D8B	CASES	DEFB +01,exchange,1A72	W, Y
		DEFB +2D,duplicate,19F6	W, Y, Y
		DEFB +2D,duplicate,19F6	W, Y, Y, Y
		DEFB +04,multiply,17C6	$W, Y, Y*Y$
		DEFB +2D,duplicate,19F6	$W, Y, Y*Y, Y*Y$
		DEFB +0F,addition,1755	$W, Y, 2*Y*Y$
		DEFB +A1,stk-one,1A51	$W, Y, 2*Y*Y, 1$
		DEFB +03,subtract,174C	$W, Y, 2*Y*Y-1 = Z$

Perform step iii, passing to the SERIES GENERATOR the parameter '12' decimal, and the twelve constants required.

	DEFB +8C,series-0C,1A7F	W, Y, Z
1.	DEFB +10,exponent 60	
	DEFB +B2,(+00,+00,+00)	

2. DEFB +13,exponent 63
DEFB +0E,(+00,+00,+00)
3. DEFB +55,exponent 65
DEFB +E4,+8D,(+00,+00)
4. DEFB +58,exponent 68
DEFB +39,+BC,(+00,+00)
5. DEFB +5B,exponent 6B
DEFB +98,+FD,(+00,+00)
6. DEFB +9E,exponent 6E
DEFB +00,+36,+75,(+00)
7. DEFB +A0,exponent 70
DEFB +DB,+E8,+B4,(+00)
8. DEFB +63,exponent 73
DEFB +42,+C4,(+00,+00)
9. DEFB +E6,exponent 76
DEFB +B5,+09,+36,+BE
10. DEFB +E9,exponent 79
DEFB +36,+73,+1B,+5D
11. DEFB +EC,exponent 7C
DEFB +D8,+DE,+63,+BE
12. DEFB +F0,exponent 80
DEFB +61,+A1,+B3,+0C

At the end of the last loop the 'last value' is:

ATN X/X — case i.
ATN (-1/X)/(-1/X) — case ii.
ATN (-1/X)/(-1/X) — case iii.

Perform step iv.

DEFB +04,multiply,17C6

DEFB +0F,addition,1755
DEFB +34,end-calc.,002B
RET

W, ATN X — case i.
W, ATN (-1/X) — case ii.
W, ATN (-1/X) — case iii.
ATN X — all cases now.

Finished: 'last value' = ATN X.

THE 'ARCSIN' FUNCTION (Offset 1F; 'asn')

This subroutine handles the function ASN X and returns a real number from -PI/2 to PI/2 inclusive which is equal to the value in radians of the angle whose sine is X. Thereby if Y = ASN X then X = SIN Y.

This subroutine uses the trigonometric identity:

$$\tan(Y/2) = \sin Y / (1 + \cos Y)$$

to obtain TAN (Y/2) and hence (using ATN) Y/2 and finally Y.

1DC4	asn	RST	0028,FP-CALC.	X
		DEFB	+2D,duplicate,19F6	X, X
		DEFB	+2D,duplicate,19F6	X, X, X
		DEFB	+04,multiply,17C6	X, X*X
		DEFB	+A1,stk-one,1A51	X, X*X, 1
		DEFB	+03,subtract,174C	X, X*X-1
		DEFB	+18,negate,1AA0	X, 1-X*X
		DEFB	+25,sqr,1DD8	X, SQR (1-X*X)
		DEFB	+A1,stk-one,1A51	X, SQR (1-X*X), 1
		DEFB	+0F,addition,1755	X, 1+SQR (1-X*X)
		DEFB	+05,division,1882	X/(1+SQR (1-X*X)) = TAN (Y/2)

DEFB +21,atn,1D76	Y/2
DEFB +2D,duplicate,19F6	Y/2, Y/2
DEFB +0F,addition,1755	Y = ASN X
DEFB +34,end-calc.,002B	
RET	Finished: 'last value' = ASN X.

THE 'ARCCOS' FUNCTION (Offset 20: 'acs')

This subroutine handles the function ACS X and returns a real number from zero to PI inclusive which is equal to the value in radians of the angle whose cosine is X.

This subroutine uses the relation:

$$\text{ACS } X = \text{PI}/2 - \text{ASN } X$$

1DD4 acs	RST 0028,FP-CALC.	X
	DEFB +1F,asn,1DC4	ASN X
	DEFB +A3,stk-pi/2,1A51	ASN X, PI/2
	DEFB +03,subtract,174C	ASN X-PI/2
	DEFB +18,negate,1AA0	PI/2-ASN X = ACS X
	DEFB +34,end-calc.,002B	
	RET	Finished: 'last value' = ACS X.

THE 'SQUARE ROOT' FUNCTION (Offset 25: 'sqr')

This subroutine handles the function SQR X and returns the positive square root of the real number X if X is positive, and zero if X is zero. A negative value of X gives rise to report A — invalid argument (via ln in the EXPONENTIATION subroutine).

This subroutine treats the square root operation as being $X^{.5}$ and therefore stacks the value .5 and proceeds directly into the EXPONENTIATION subroutine.

1DDB sqr	RST 0028,FP-CALC.	X
	DEFB +2D,duplicate,19F6	X, X
	DEFB +2C,not,1AD5	X, (1/0)
	DEFB +00,jump-true,1C2F	X
	DEFB +1E, to 1DFD, LAST	X

The jump is made if X = 0, otherwise continue with:

DEFB +A2,stk-half,1A51	X, .5
DEFB +34,end-calc.,002B	

and then find the result of $X^{.5}$.

THE 'EXPONENTIATION' OPERATION (Offset 06: 'to-power')

This subroutine performs the binary operation of raising the first number, X, to the power of the second number, Y.

The subroutine treats the result X^Y as being equivalent to $\text{EXP}(Y \cdot \text{LN } X)$. It returns this value unless X is zero, in which case it returns 1 if Y is also zero ($0^0 = 1$), returns zero if Y is positive and reports arithmetic overflow if Y is negative.

1DE2 to-power	RST 0028,FP-CALC.	X, Y
	DEFB +01,exchange,1A72	Y, X
	DEFB +2D,duplicate,19F6	Y, X, X
	DEFB +2C,not,1AD5	Y, X, (1/0)
	DEFB +00,jump-true,1C2F	Y, X
	DEFB +07, to 1DEE,XIS0	Y, X

The jump is made if $X = 0$, otherwise $\text{EXP}(Y * \text{LN } X)$ is formed.

DEFB +22,ln,1CA9	Y, LN X
DEFB +04,multiply,17C6	Giving report A if X is negative.
DEFB +34,end-calc.,002B	$Y * \text{LN } X$
JP 1C5B,EXP	Exit via EXP to form $\text{EXP}(Y * \text{LN } X)$.

The value of X is zero so consider the three possible cases involved.

1DEE XISO	DEFB +02,delete,19E3	Y
	DEFB +2D,duplicate,19F6	Y, Y
	DEFB +2C,not,1AD5	Y, (1/0)
	DEFB +00,jump-true,1C2F	Y
	DEFB +09, to 1DFB,ONE	Y

The jump is made if $X = 0$ and $Y = 0$, otherwise proceed.

DEFB +A0,stk-zero,1A51	Y, 0
DEFB +01,exchange,1A72	0, Y
DEFB +33,greater-0,1ACE	0, (1/0)
DEFB +00,jump-true,1C2F	0
DEFB +06, to 1DFD, LAST	0

The jump is made if $X = 0$ and Y is positive, otherwise proceed.

DEFB +A1,stk-one,1A51	0, 1
DEFB +01,exchange,1A72	1, 0
DEFB +05,division,1882	Exit via 'division' as dividing by zero gives 'arithmetic overflow'.

The result is to be 1 for the operation.

1DFB ONE	DEFB +02,delete,19E3	—
	DEFB +A1,stk-one,1A51	1

Now return with the 'last value' on the stack being $0 * Y$.

1DFD LAST	DEFB +34,end-calc.,002B	(1/0)
	RET	Finished: 'last value' is 0 or 1.

APPENDIX

BASIC PROGRAMS FOR THE MAIN SERIES

The following BASIC programs have been included as they give a good illustration of how Chebyshev polynomials are used to produce the approximations to the functions SIN, EXP, LN and ATN.

The series generator:

This subroutine is called by all the 'function' programs.

```

500 REM SERIES GENERATOR, ENTER
510 REM USING THE COUNTER BERG
520 REM AND ARRAY-A HOLDING THE
530 REM CONTANTS.
540 REM FIRST VALUE IN Z.
550 LET M0=2*Z
560 LET M2=0
570 LET T=0
580 FOR I=BERG TO 1 STEP -1
590 LET M1=M2
600 LET U=T*M0-M2+A(BERG+1-I)
610 LET M2=T
620 LET T=U
630 NEXT I
640 LET T=T-M1
650 RETURN
660 REM LAST VALUE IN T.

```

In the above subroutine the variable are:

Z	—	the entry value.
T	—	the exit value.
M0	—	mem-0
M1	—	mem-1
M2	—	mem-2
I	—	the counter for BERG.
U	—	a temporary variable for T.
A(1) to		
A(BERG)	—	the constants.
BERG	—	the number of constants to be used.

To see how the Chebyshev polynomials are generated, record on paper the values of U, M1, M2 and T through the lines 550 to 630, passing, say 6 times, through the loop, and keeping the algebraic expressions for A(1) to A(6) without substituting numerical values. Then record T-M1. The multipliers of the constants A(1) to A(6) will then be the required Chebyshev polynomials. More precisely, the multiplier of A(1) will be $2*T_5(Z)$, for A(2) it will be $2*T_4(Z)$ and so on to $2*T_1(Z)$ for A(5) and finally $T_0(Z)$ for A(6).

Note that $T_0(Z)=1$, $T_1(Z)=Z$ and, for $n \geq 2$, $T_n(Z)=2*Z*T_{n-1}(Z)-T_{n-2}(Z)$.

SIN X

```

10 REM DEMONSTRATION FOR SIN X
20 SLOW
30 DIM A(6)
40 LET A(1)=-.000000003
50 LET A(2)=0.000000592
60 LET A(3)=-.000068294
70 LET A(4)=0.004559008
80 LET A(5)=-.142630785
90 LET A(6)=1.276278962
100 PRINT
110 PRINT "ENTER START VALUE IN DEGREES"
120 INPUT C
130 CLS
140 LET C=C-10
150 PRINT "BASIC PROGRAM", "ROM PROGRAM"
160 PRINT "-----", "-----"
170 PRINT
180 FOR J=1 TO 4
190 LET C=C+10
200 LET Y=C/360-INT (C/360+.5)
210 LET W=4*Y
220 IF W>1 THEN LET W=2-W
230 IF W<-1 THEN LET W=-W-2
240 LET Z=2*W*W-1
250 LET BERG=6
260 REM USE "SERIES GENERATOR"
270 GOSUB 550
280 PRINT TAB 6; "SIN ";C;" DEGREES"
290 PRINT
300 PRINT T*W,SIN (PI*C/180)
310 PRINT
320 NEXT J
330 GOTO 100

```

NOTES:

- i. As it stands the above program requires more than 1K of RAM.
- ii. When C is entered this program calculates and prints SIN C degrees, SIN (C+10) degrees, SIN (C+20) degrees and SIN (C+30) degrees. It also prints the values obtained by using the ROM program. For a specimen of results, try entering these values in degrees:—
0; 5; 100; -80; -260; 3600; -7200.
- iii. The constants A(1) to A(6) in lines 40 to 90 are given (apart from a factor of ½) in Abramowitz and Stegun *Handbook of Mathematical Functions* (Dover 1965) page 76. They can be checked by integrating $(\sin(\pi X/2))/X$ over the interval $U=0$ to π , after first multiplying by $\cos(N*U)$ for each constant (ie. $N=1,2,\dots,6$) and substituting $\cos U=2*X*X-1$. Each result should then be divided by π . (This integration can be performed by approximate methods e.g. using Simpson's Rule if there is a reasonable computer or programmable calculator to hand.)

EXP X

```

10 REM DEMONSTRATION FOR EXP X
20 SLOW
30 LET T=0 (This makes T the first variable.)
40 DIM A(8)
50 LET A(1)=0.000000001
60 LET A(2)=0.000000053
70 LET A(3)=0.000001851
80 LET A(4)=0.000053453
90 LET A(5)=0.001235714
100 LET A(6)=0.021446556
110 LET A(7)=0.248762434
120 LET A(8)=1.456999875
130 PRINT
140 PRINT "ENTER START VALUE"
150 INPUT C
160 CLS
170 LET C=C-10
180 PRINT "BASIC PROGRAM", "ROM PROGRAM"
190 PRINT "-----", "-----"
200 PRINT
210 FOR J=1 TO 4
220 LET C=C+10
230 LET D=C*1.442695041 (D=C*(1/LN 2);EXP C=2**D)
240 LET N=INT D
250 LET Z=D-N (2**(N+Z) is now required).
260 LET Z=2*Z-1
270 LET BERG=8
280 REM USE "SERIES GENERATOR"
290 GOSUB 550
300 LET V=PEEK 16400+256*PEEK 16401+1 (V=(VARS)+1)
310 LET N=N+PEEK V
320 IF N>255 THEN POKE 16384,5 (Gives report 6, arithmetic overflow;
330 IF N<0 THEN GOTO 360 program stops).
340 POKE V,N
350 GOTO 370
360 LET T=0
370 PRINT TAB 11;"EXP ";C
380 PRINT
390 PRINT T,EXP C
400 PRINT
410 NEXT J
420 GOTO 130

```

NOTES:

- i. The above program requires more than 1K of RAM.
- ii. When C is entered this program calculates and prints EXP C, EXP (C+10), EXP (C+20) and EXP (C+30). It also prints the values obtained by using the ROM program. For a specimen of results, try entering these values:— 0; 15; 65 (with overflow at the end); -100; -40.
- iii. The exponent is tested for overflow and for a zero result in lines 320 and 330. These tests are simpler in BASIC than in machine code, since the variable N, unlike the A register, is not confined to one byte.
- iv. The constants A(1) to A(8) in lines 50 to 120 can be obtained by integrating $2^{**}X$ over the interval $U=0$ to π , after first multiplying by $\cos(N*U)$ for each constant (i.e. for $N=1, 2, \dots, 8$) and substituting $\cos U = 2^{**}X - 1$. Each result should then be divided by π .

LN X:

```

10 REM DEMONSTRATION FOR LN X
20 SLOW
30 LET D=0 (This makes D the first variable).
40 DIM A(12)
50 LET A(1)=-.0000000003
60 LET A(2)=0.0000000020
70 LET A(3)=-.0000000127
80 LET A(4)=0.0000000823
90 LET A(5)=-.0000005389
100 LET A(6)=0.0000035828
110 LET A(7)=-.0000243013
120 LET A(8)=0.0001693953
130 LET A(9)=-.0012282837
140 LET A(10)=0.0094766116
150 LET A(11)=-.0818414567
160 LET A(12)=0.9302292213
170 PRINT
180 PRINT "ENTER START VALUE"
190 INPUT C
200 CLS
210 PRINT "BASIC PROGRAM", "ROM PROGRAM"
220 PRINT "-----", "-----"
230 PRINT
240 LET C=SQR C
250 FOR J=1 TO 4
260 LET C=C*C
270 IF C=0 THEN POKE 16384,9 (Gives report A, invalid argument;
280 LET D=C program stops).
290 LET V=PEEK 16400+256*PEEK 16401+1
300 LET N=PEEK V-128 (N holds e').
310 POKE, V, 128
320 IF D<=0.8 THEN GOTO 360 (D holds X').
330 LET S=D-1
340 LET Z=2.5*D-3
350 GOTO 390
360 LET N=N-1
370 LET S=2*D-1
380 LET Z=5*D-3
390 LET R=N*0.6931471806 (R holds N*LN 2).
400 LET BERG=12
410 REM USE "SERIES GENERATOR"
420 GOSUB 550
430 PRINT TAB 8;"LN ";C
440 PRINT
450 PRINT S*T+R, LN C
460 PRINT
470 NEXT J
480 GOTO 170

```

NOTES:

- i The above program requires more than 1K of RAM.
- ii. When C is entered this program calculates and prints LN C, LN (C**2), LN (C**4) and LN (C**8). It also prints the values obtained by using the ROM program.
For a specimen of results, try entering these values:— 1.1; 0.9; 300; 0.004; 1E5 (for overflow) and 1E-5 (for report A).
- iii. The constants A(1) to A(12) in lines 50 to 160 can be obtained by integrating $5 \cdot \text{LN} \{4 \cdot (X+1)/5\} / (4 \cdot X - 1)$ over the interval $U=0$ to π , after first multiplying by $\text{COS}(N \cdot U)$ for each constant (i.e. for $N=1, 2, \dots, 12$) and substituting $\text{COS } U = 2 \cdot X - 1$. Each result should then be divided by π .

ATN X:

```

10 REM DEMONSTRATION FOR ATN X
20 SLOW
30 DIM A(12)
40 LET A(1)=-.0000000002
50 LET A(2)=0.0000000010
60 LET A(3)=-.0000000066
70 LET A(4)=0.0000000432
80 LET A(5)=-.0000002850
90 LET A(6)=0.0000019105
100 LET A(7)=-.0000131076
110 LET A(8)=0.0000928715
120 LET A(9)=-.0006905975
130 LET A(10)=0.0055679210
140 LET A(11)=-.0529464623
150 LET A(12)=0.8813735870
160 PRINT
170 PRINT "ENTER START VALUE"
180 INPUT C
190 CLS
200 PRINT "BASIC PROGRAM", "ROM PROGRAM"
210 PRINT "-----", "-----"
220 PRINT
230 FOR J=1 TO 4
240 LET B=J*C
250 LET D=B
260 IF ABS B>=1 THEN LET D=-1/B
270 LET Z=2*D*D-1
280 LET BERG=12
290 REM USE "SERIES GENERATOR"
300 GOSUB 550
310 LET T=D*T
320 IF B>=1 THEN LET T=T+PI/2
330 IF B<=-1 THEN LET T=T-PI/2
340 PRINT TAB 8;"ATN ";B
350 PRINT
360 PRINT T,ATN B           (or PRINT T*180/PI,ATN B*180/PI
370 PRINT                   to obtain the answers in degrees)
380 NEXT J
390 GOTO 160

```

NOTES:

- i. The above program requires more than 1K of RAM.
- ii. When C is entered this program calculates and prints ATN C, ATN (C*2), ATN (C*3) and ATN (C*4).
For a specimen of results, try entering these values:— 0.2; -1; 10 and -100. The results may be found more interesting if converted to yield degrees by multiplying the answers in line 360 by 180/PI.
For those readers who are using an unimproved ROM it is interesting to note the results given by entering 4.2E9 and then 4.3E9.
- iii. The constants A(1) to A(12) in lines 40 to 150 are given (apart from a factor of ½) in Abramowitz and Stegun *Handbook of Mathematical Functions* (Dover 1965) page 82. They can be checked by integrating ATN X/X over the interval U=0 to PI, after first multiplying by COS (N*U) for each parameter (i.e. for N=1,2,..., 12) and substituting COS U=2*X*X-1. Each result should then be divided by PI.

An alternative subroutine for SIN X:

It is fairly straightforward to produce the full expansion of the Chebyshev polynomials and this can be written in BASIC as follows:

```

550 LET T=(32*Z*Z*Z*Z*Z-40*Z*Z*Z+10*Z)*A(1)
      +(16*Z*Z*Z*Z-16*Z*Z+2)*A(2)
      +(8*Z*Z*Z-6*Z)*A(3)
      +(4*Z*Z-2)*A(4)
      +(2*Z)*A(5)
      +A(6)
560 RETURN

```

This subroutine is called instead of the SERIES GENERATOR and can be seen to be of a similar accuracy.

An alternative subroutine for EXP X:

The full expansion for EXP X is:

```

550 LET T=(128*Z*Z*Z*Z*Z*Z*Z-224*Z*Z*Z*Z*Z+112*Z*Z*Z-14*Z)*A(1)
      +(64*Z*Z*Z*Z*Z*Z-96*Z*Z*Z*Z+36*Z*Z-2)*A(2)
      +(32*Z*Z*Z*Z*Z-40*Z*Z*Z+10*Z)*A(3)
      +(16*Z*Z*Z*Z-16*Z*Z+2)*A(4)
      +(8*Z*Z*Z-6*Z)*A(5)
      +(4*Z*Z-2)*A(6)
      +(2*Z)*A(7)
      +A(8)
560 RETURN

```

It is left as an exercise for the reader to produce the alternative subroutine for LN X and ATN X.

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The book for the programmer that needs those answers about the Timex TS1000/Sinclair ZX81 ROM.

Dr. Logan and Dr. Frank O'Hara have examined all routines in the ROM and comment on each one. This book is a must for the experienced programmer.

Part A covers all functions that can be used except for the floating point calculator.

Part B covers all the routines involved in the 'evaluation of an expression' and a detailed explanation of the 'floating-point calculator'.

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