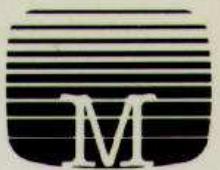
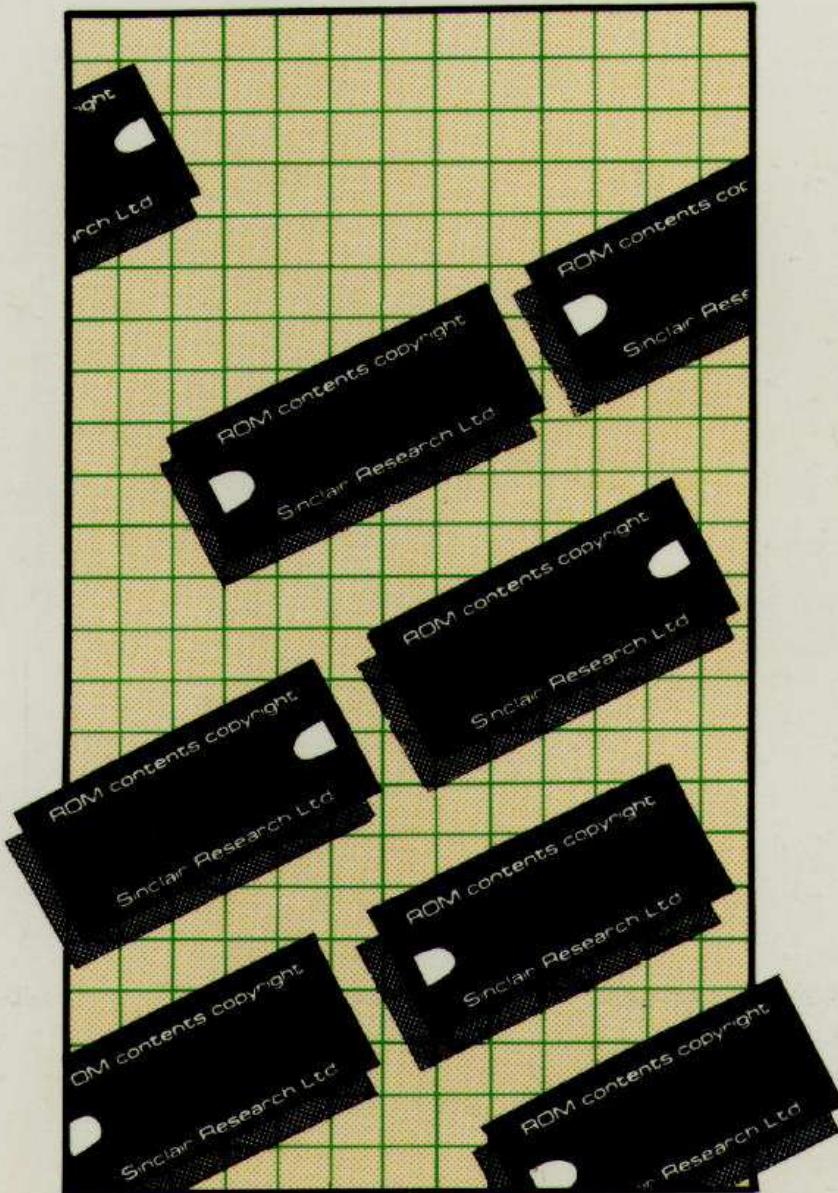


The Complete Timex TS1000/Sinclair ZX81 ROM Disassembly

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**

Due to popular demand Melbourne House Publishers have combined "ROM Disassembly Part A" and "ROM Disassembly Part B" into one accessible volume. PART A starts page 1 through to page 30, PART B begins again at page 1 (2 pages after page 30) through to page 82.

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

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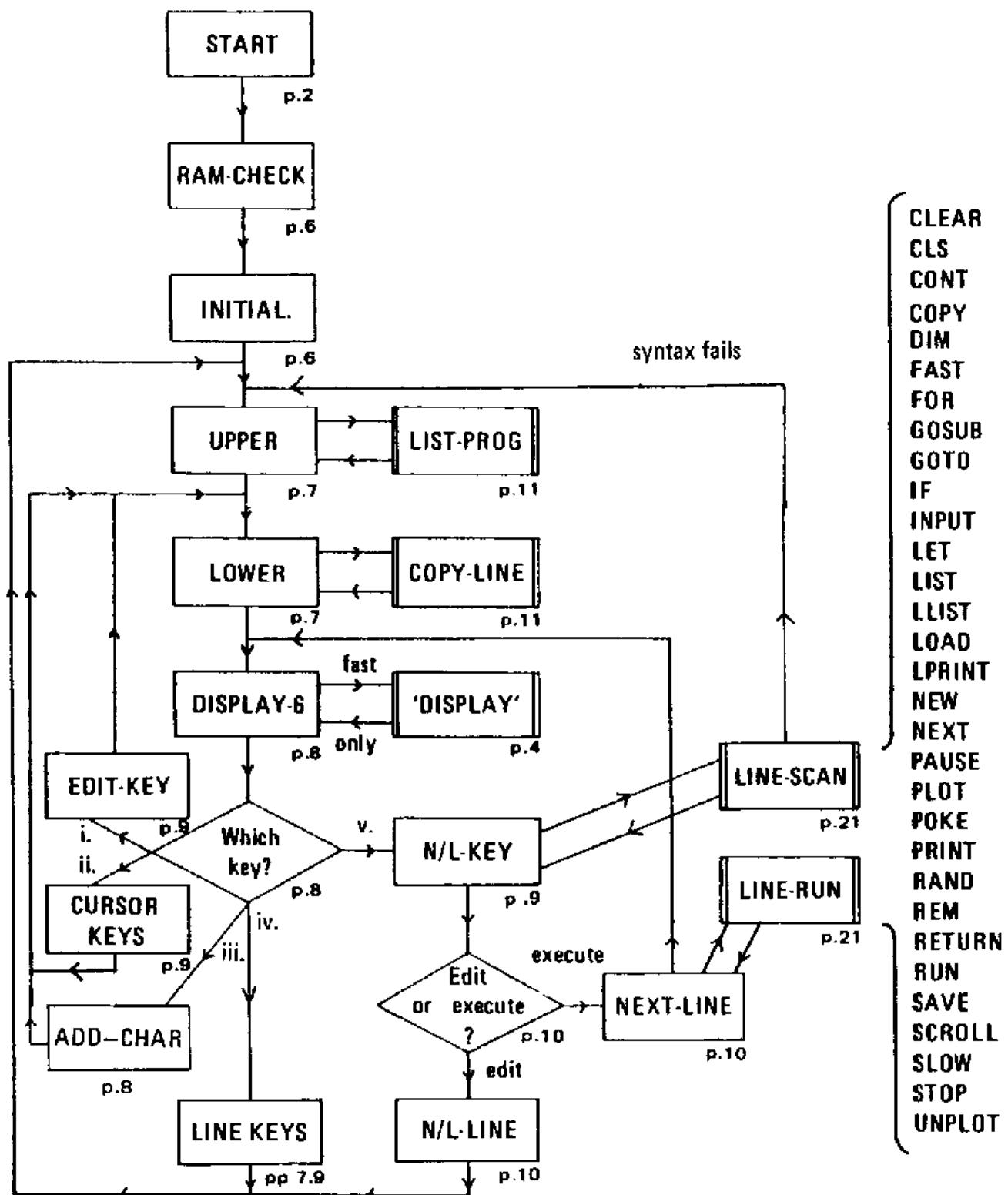
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The system variable 'labels' are those given by Sinclair Research Ltd., but the other 'labels' have been designated by the authors.

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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		
00BO	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
00EO	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	█	█	█	█
010F	96	88			█	█	█	█

The 'token' tables.

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

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
```

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	O,(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	
	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
              CALL 0F46,BREAK-1
02FF HEADER 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
              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	RET	M
	POP	AF	ADD	HL,BC
	CP	D	SET	7,(HL)
0361 RESTART	JP	NC,03E5,INITIAL.	RET	
	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		
0385 GET-BIT	JR	037B,IN-PROG		
	PUSH	DE	03CB RAM-CHECK	LD H,B
	LD	E,+94		LD L,C
0388 TRAILER	LD	B,+1A		LD A,+3F
038A COUNTER	DEC	E	03CF RAM-FILL	LD (HL),+02
	IN	A,(+FE)		DEC HL
	RLA			CP H
	BIT	7,E		JR NZ,03CF,RAM-FILL
	LD	A,E		A
	JR	C,0388,TRAILER		SBC HL,BC
	DJNZ	038A,COUNTER		ADD HL,BC
	POP	DE		INC HL
	JR	NZ,039C,BIT-DONE		JR NC,03E2,SET-TOP
	CP	+56		DEC (HL)
	JR	NC,034E,NEXT-BIT		JR Z,03E2,SET-TOP
039C BIT-DONE	CCF	C		DEC (HL)
	RL			JR Z,03D5,RAM-READ
	JR	NC,034E,NEXT-BIT		03E2 SET-TOP LD (RAMTOP),HL
03A2 BREAK-4	RET			
	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
03D5 RAM-READ	AND	NZ,03CF,RAM-FILL
	SBC	A
	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)
i.	DEC	HL
	LD	(HL), + 3E
ii.	DEC	HL
	LD	SP,HL
	DEC	HL
	DEC	HL
iii.	LD	(ERR-SP),HL
	LD	A, + 1E
iv.	LD	I,A
v.	IM1	
vi.	LD	IY, + ERR-NR
vii.	LD	(CDFLAG), + 40
	LD	HL, + PROGRAM
viii.	LD	(D-FILE),HL
ix.	LD	B, + 19
0408 LINE	LD	(HL), + 76
	INC	HL
	DJNZ	0408,LINE
x.	LD	(VARS),HL
xi.	CALL	149A,CLEAR
0413 N/L-ONLY	CALL	14AD,CURSOR-IN
xiii.	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)

0464 KEY-INPUT	LD	D,(HL)
	PUSH	HL
	EX	DE,HL
	INC	HL
	CALL	09D8,LINE-ADDR
	CALL	05BB,LINE-NO.
	POP	HL
	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
0482 END-LINE	JR	0475,EACH-CHAR
	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, + CDFLAG
	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
	LD	E,A
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.

```
056C 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 + 76
    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 + CO
    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)
	JR	0661,TEST-NUL
064E N/L-INP.	CP	+76
	JR	Z,0664,N/L-NUL
	LD	BC,(T-ADDR)
	CALL	0918,LOC.-ADDR
	LD	DE,(NXTLIN)
	LD	(DF-SZ),+02
0661 TEST-NUL	RST	0018,GET-CH
	CP	+76
0664 N/L-NUL	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.

066C NEXT-LINE	LD	(NXTLIN),HL
	EX	DE,HL
	CALL	004D,TEMP-PTR
	CALL	0C1,LINE-RUN
	RES	1,(FLAGS)
	LD	A,+ CO
	LD	(X-PTR-hl.),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)
INC	(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 LIST 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
073E LIST-PROG LD E,+00
0740 UNTIL-END 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)
07AA FLAGS-2	LD	B,+B0
	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
	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
0802 LPRINT-A	JR	0805,PRINT-EXX
0805 PRINT-EXX	CALL	0851,LPRINT-CH
	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 (+ FB),A
0888 REPORT-D2	OUT 0008,ERROR-1
	RST +0C
088A COPY-CONT	DEFB A,(+ FB)
	IN A,A
	ADD M,08DE,COPY-END
	JP NC,0880,COPY-BRK
	PUSH HL
	PUSH DE
	LD A,D
	CP +02
	SBC A,A
	AND E
089C COPY-NEXT	RLCA
	AND E
	LD D,A
	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 H,A
	LD A,(+ FB)
08BA COPY-WAIT	IN NC,08BA,COPY-WAIT
	RRA A,H
	JR (+ FB),A
	OUT 08B5,COPY-BITS
	DJNZ HL
	POP 089C,COPY-NEXT
08C7 COPY-N/L	JR IN A,(+ FB)
	RRA NC,08C7,COPY-N/L
	JR A,D
	RRCA (+ FB),A
	OUT DE
	POP E
	INC 3,E
	BIT Z,087D,COPY-TIME
	JR BC
	POP D
	DEC NZ,087A,COPY-LOOP
	JR A,+04
	LD

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
08FA TEST-VAL. JR C,0905,WRONG-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
0908 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 LO (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
096D TRAIL-SP.	RET	C
	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

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
	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	
0A08 NEXT-LETT	LD	C, + 11	
	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 3½ 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-LO	
	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
0ABF UNITS	LD	A,L
	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  
DEFB (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.

```
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  
0B1E TAB-TEST 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)  
0B68 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)
LD C,+11
CP C
JR NC,0BAB,RIGHT
LD C,+01
0BA4 CENTRE CALL 090B,SET-FIELD
RET

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
08CA FIND-ADDR PUSH AF
CALL 08F5,PRINT-AT
LD A,(HL)
RLCA
CP +10
JR NC,0BDA,TABLE-PTR
RRCA
JR NC,0BD9,SQ-SAVED
XOR +8F
0BD9 SQ-SAVED LD B,A
OBDA 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 B
AND JR 0BEB,UNPLOT
0BE9 PLOT POP AF
OR B
0BEB UNPLOT 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	GOTO,0E81	
	0E		
0C4F P-IF	06	CLASS-6	
	DE	'THEN'	
	05	CLASS-5	
	AB	IF,0DAB	
0C54 P-GOSUB	06	CLASS-6	

0C58 P-STOP	00	CLASS-0
	B5	GOSUB,0EB5
	0E	
0C5B P-RETURN	00	CLASS-0
	D8	
	0E	RETURN,0ED8
0C5E P-FOR	04	CLASS-4
	14	'=
	06	CLASS-6
0C66 P-NEXT	DF	'TO'
	06	CLASS-6
	05	CLASS-5
0C6A P-PRINT	B9	FOR,0DB9
	0D	
	04	CLASS-4
0C6D P-INPUT	00	CLASS-0
	2E	
	0E	NEXT,0E2E
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
0C86 P-RAND	92	
	0E	POKE,0E92
	03	
0C89 P-LOAD	6C	CLASS-3
	0E	
	05	RAND,0E6C
0C89 P-LOAD	40	CLASS-5
	03	
	03	LOAD,0340

0C8C P-SAVE	05 F6 02	CLASS-5 SAVE,02F6	0CBA LINE-SCAN LD (FLAGS), + 01 CALL 0A73,E-LINE-NO
0C8F P-CONT	00 7C 0E	CLASS-0 CONT,0E7C	i) The LINE-RUN entry point is used when replying to an INPUT prompt and this fact has to be identified.
0C92 P-CLEAR	00 9A 14	CLASS-0 CLEAR,149A	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
0C95 P-CLS	00 2A 0A	CLASS-0 CLS,0A2A	iii) The INPUT reply is tested to see if STOP was entered.
0C98 P-PLOT	06 1A 06 00 AF 0B	CLASS-6 CLASS-6 CLASS-0 PLOT/UNP.,0BAF	CP + E3 LD A,(HL) JP NZ,0D6F,INPUT-REP CALL 0DA6,SYNTAX-Z RET Z
0C9E P-UNPLOT	06 1A 06 00 AF 0B	CLASS-6 CLASS-6 CLASS-0 PLOT/UNP.,0BAF	iv) If appropriate, report D is given. RST 0008,ERROR-1 DEFB + 0C
0CA4 P-SCROLL	00 0E 0C	CLASS-0 SCROLL,0C0E	THE 'STOP' COMMAND ROUTINE The only action is to give report 9.
0CA7 P-PAUSE	06 00 32 0F	CLASS-6 CLASS-0 PAUSE,0F32	0CDC STOP RST 0008,ERROR-1 DEFB + 08
0CAB P-SLOW	00 2B 0F	CLASS-0 SLOW,0F2B	v) A return is made if the line is 'null'. 0CDE LINE-NULL RST 0018,GET-CH. LD B, + 00 CP + 76 RET Z
0CAE P-FAST	00 23 0F	CLASS-0 FAST,0F23	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
0CB1 P-COPY	00 69 08	CLASS-0 COPY,0869	vii) The offset for the command is found from the offset table.
0CB4 P-LPRINT	05 CB 0A	CLASS-5 LPRINT,0ACB	LD C,A LD HL, + 0C29 ADD HL,BC LD C,(HL) ADD HL,BC JR 0CF7,GET-PARAM
0CB7 P-LLIST	03 2C 07	CLASS-3 LLIST,072C	viii) The parameters are fetched in turn by a loop that returns to 0CF4. The separators are identified by the test against + 0B.
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.			
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
                  JR    1,(FLAGX)
                  NZ,0D63,SET—STRLN
0D4B REPORT-2  RST
                  DEFB + 01
0D4D SET-STK   CALL  Z,11A7,STK-VAR
                  BIT   6,(FLAGS)
                  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    (STRLEN),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,(FLAGS)
0D6F INPUT-REP PUSH AF
                  CALL  0F55,SCANNING
                  POP   AF
                  LD    BC, + 1321
                  LD    D,(FLAGS)

```

```

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
      (stk-zero,1A51)
DEFB  +34
      (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
      (delete,19E3)
DEFB +34
      (end-calc.,002B)
LD   AND
AND  A,(DE)
RET  A
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
      (stk-one,1A51)
DEFB +34
      (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
      (st-mem-0,1A63)
DEFB +02
      (delete,19E3)
DEFB +01
      (exchange,1A72)
DEFB +E0
      (get-mem-0,1A45)
DEFB +01
      (exchange,1A72)
DEFB +34
      (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
ODEA 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
LDI R

```

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)
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
0E2A FOR-END JR NZ,0E0E,NXTLIN-NO	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	A
0E69	IMPOSS.	RET	
		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
0E77	SET-SEED	LD	BC,(FRAMES)
		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
                 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
0F14 ENTER-CUR 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	ERR-SP	Points to the GOSUB stack.
	4003		
16388	4004	RAMTOP	The top of available RAM, or as specified.
	4005		
16390	4006	MODE	Holds the code for K or F.
16391	4007	PPC	The line number of the current statement.
	4008		
16393	4009	VERSN	Marks the start of RAM that is SAVED.
16394	400A	E-PPC	The BASIC line with the cursor.
	400B		
16396	400C	D-FILE	Pointer for the display file.
	400D		
16398	400E	DF-CC	Address for the PRINT AT position.
	400F		
16400	4010	VARS	Pointer for the variable area.
	4011		
16402	4012	DEST	The address of the current variable within the program area.
	4013		
16404	4014	E-LINE	The pointer for the workspace.
	4015		
16406	4016	CH-ADD	The pointer for scanning a line, either in the program area or the workspace.
	4017		
16408	4018	X-PTR	The syntax error address.
	4019		
16410	401A	STKBOT	The pointer for the bottom of the calculator stack.
	401B		
16412	401C	STKEND	The pointer for the top of the calculator stack.
	401D		
16414	401E	BERG	A location used for many different counting purposes.
16415	401F	MEM	The pointer to the base of a table of floating point numbers, either in the calculator stack or the variable area.
	4020		

16417	4021	—	Not used.
16418	4022	DF-SZ	The number of lines in the lower screen.
16419	4023	S-TOP	The current line number for the automatic listing.
	4024		
16421	4025	LAST-K	The 'key-value' of the last key that was pressed.
	4026		
16423	4027	DEBOUNCE	The debounce status.
16424	4028	MARGIN	Adjusts for differing T.V. standards.
16425	4029	NXTLIN	The line number of the next BASIC line to be interpreted.
	402A		
16427	402B	OLDPPC	The last line number is saved in case needed.
	402C		
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	STRLEN	Length of string variable , or a BASIC line.
	402F		
16432	4030	T-ADDR	Pointer for the 'parameter' table.
	4031		Also used to distinguish between PLOT and UNPLOT.
16434	4032	SEED	The random function seed value.
	4033		
16436	4034	FRAMES	The counter for the frames.
	4035		
16438	4036	COORDS	The X & Y values of PLOT.
	4037		
16440	4038	PR-CC	The counter for the printer buffer.
16441	4039	S-POSN	The column and line numbers for PRINT AT.
	403A		
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	PRBUFF	The printer buffer.
	—		
	405C		
16477	405D	MEMBOT	A memory area that can hold 6 floating point numbers. (mem-0, mem-5.)
	—		
	407A		
16507	407B	—	Not used.
	407C		
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 OEEF, hence the code formerly at OEEF-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.

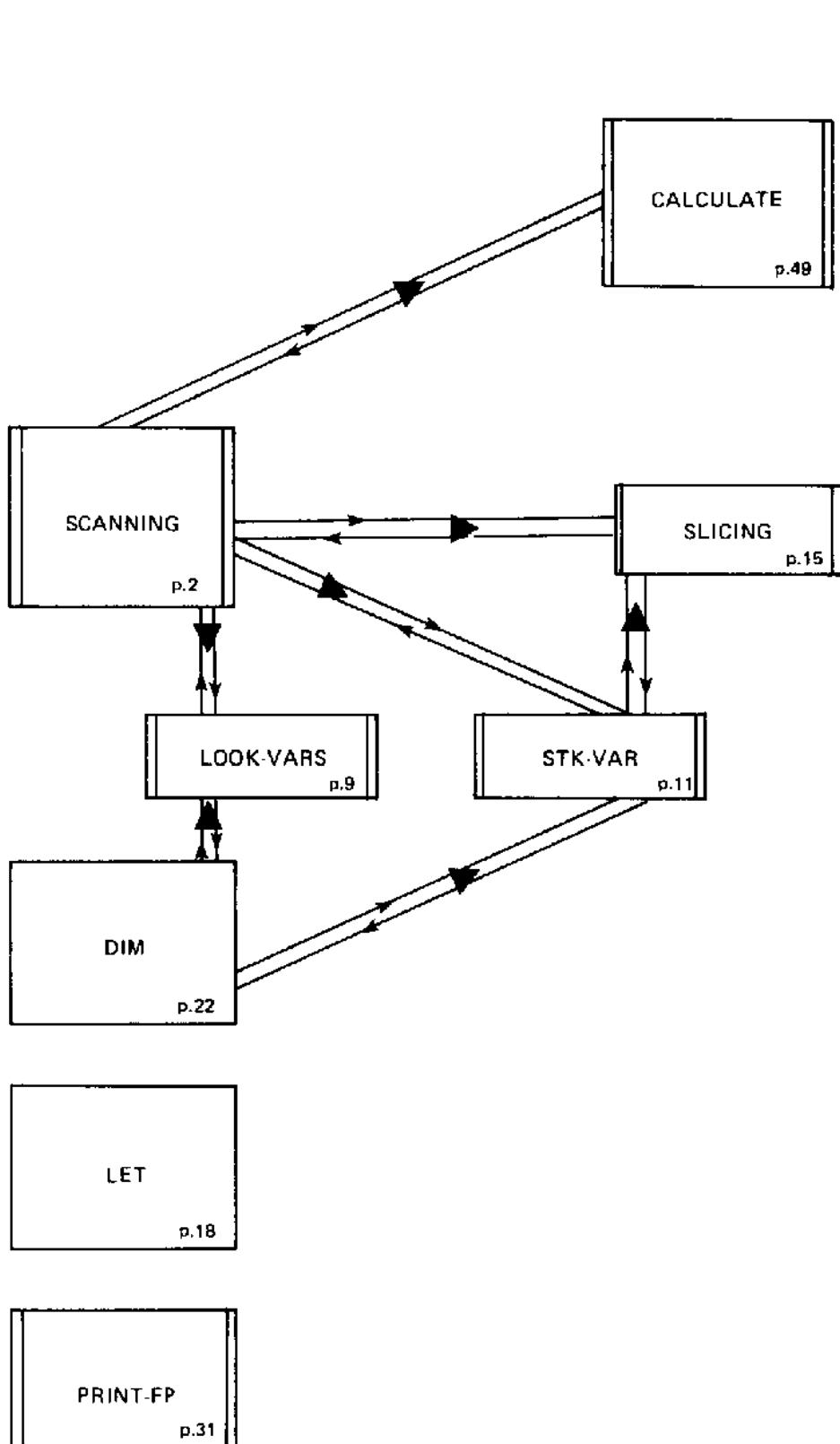
Ian Logan, Lincoln January 1982

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

THE 'FLOW DIAGRAM' FOR PART B of the 8K ROM Program

1



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 N2,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 'remainder'-1.
	DEFB +03,subtract,174C	Make a copy of the 'last value'.
	DEFB +2D,duplicate,19F6	The calculation is finished.
	DEFB +34,end-calc.,002B	Use the 'last value' to give the new value for SEED.
	CALL 158A,FP-TO-BC	Fetch the exponent of 'last value'.
	LD (SEED),BC	Jump forward if the exponent is zero.
	LD A,(HL)	Reduce the exponent, i.e. divide 'last value' by 65536 to give the required 'last value'.
	AND A	Jump past the 'PI' routine.
	JR Z,OF8A,S-RND-END	
	SUB +10	
	LD (HL),A	
OF8A S-RND-END	JR OF99,S-PI-END	

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,OF9D,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,OF99,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)	Move on to the next character.
OF99 S-PI-END	RST 0020,NEXT-CH	Jump forward.
	JP 1083,S-NUMERIC	

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	Decode the 'key value'. The carry flag is set when only one key is pressed.
	INC D	D register always holds zero.
	CALL NZ,07BD,DECODE	A now holds the value of the carry.
		Clears the B register.
	LD A,D	C holds zero or one.
	ADC A,D	The start pointer goes into DE.
	LD B,D	Jump forward.
	LD C,A	
	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,OFFF,S-RPRT-C1	Report C if no closing bracket.
CALL	0049,CH-ADD+1	Point to the next character.
JR	OFF8,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.

0FE0 S-Q-NEXT 0FE3 S-Q-END?	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.
	CALL	0049,CH-ADD+1	Point to the next character.
POP DE AND A SBC HL,DE LD B,H LD C,L	CP	+0B	Is it another '''''?
	JR	NZ,OFFB,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'.

OFED S-STRING OFF8 S-CONT-1	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.
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 operate on strings to give numerical results.
JR NC,101A,S-NO-T0-\$	Separate STR\$ & CHR\$ which operate on numbers to give string results.
RES 6,C	Mark the operation codes.
101A S-NO-T0-\$ CP +EA	The other operation codes have bits 6 & 7 both set.
JR C,1020,S-PUSH-PO	
RES 7,C	

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 before moving on to consider the next part of the expression.
RST 0020,NEXT-CH	
JP 0F59,S-RND	

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	Jump forward.
JR 1083,S-NUMERIC	

During line execution:

106F S-STK-DEC RST 0020,NEXT-CH
CP +7E
JR NZ,106F,S-STK-DEC
INC HL
LD DE,(STKEND)
CALL 19F6,MOVE-FP
LD (STKEND),DE
LD (CH-ADD),HL

Move on to the next character in turn until the number marker character is found.
Point to the first byte of the number.
Fetch the 'old' STKEND.
Move the floating point number.
Save the 'new' STKEND.
This sets CH-ADD.

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.
1088 S-CONT-3 CP +10
JR NZ,1098,S-OPERTR

Fetch the present character.
Jump forward if it is not a '(', which indicates a parenthesised expression.

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 parenthesised expression.
JR	NZ,10BC,S-LOOP	Modify the parameters of the 'last value'.
CALL	1263,SLICING	Move on to consider the next character.
RST	0020,NEXT-CH	
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.
		ADD	A,+03	i.e. 104C+C3=110F the first address.
10B5	S-END-OP	ADD	A,C	Index into the table.
		LD	C,A	Fetch the appropriate priority.
		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'
AND +40	against the requirement of the operation.
10DB S-RPRT-C2 JP NZ,0D9A,REPORT-C	They are to be the same for correct syntax.
	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'
JR NZ,10EA,S-ENDLOOP	is numeric.
RES 6,(HL)	It is string.
10EA S-ENDLOOP POP BC	Get the 'present' values into BC.
JR 10BC,S-LOOP	Jump back.

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

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 registeres 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.

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

The parameters for a simple string are readily found.

<pre>11B2 SV-SMPLES INC A INC HL LD C,(HL) INC HL LD B,(HL) INC HL EX DE,HL CALL 12C3,STK-STORE RST 0018,GET-CH. JP 125A,SV-SLICE?</pre>	Specify a simple string. Move along the variable entry. Pick up the low length counter. On one. Pick up the high length counter. On one. Transfer the start pointer to DE. Pass these parameters to the stack. Fetch the present character. 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.

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

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

<pre>DEC B JR Z,11B2,SV-SMPLES</pre>	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.

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

<pre>11D1 SV-PTR EX DE,HL JR 11F8,SV-COUNT</pre>	Variable pointer into DE. 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.

<pre>11D4 SV-COMMA PUSH HL RST 0018,GET-CH. POP HL CP +1A JR Z,11FB,SV-LOOP BIT 7,C JR Z,1231,REPORT-3</pre>	Save the 'counter'. Get the present character. Restore the 'counter'. Is the present character a ',' ? Jump to consider another subscript. If a line is being executed then 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'. Add the result of 'INT.-EXP1'-1 to the 'present counter'.
		CALL	1305,HL=HL*DE	Fetch the variable pointer.
		ADD	HL,BC	Fetch the dimension-number counter and the discriminator byte.
		POP	DE	Keep going round the loop until 'B' equals zero.
		POP	BC	
		DJNZ	11D4,SV-COMMA	

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

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

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

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

Give report 3.

1231 REPORT-3	RST 0008,ERROR-1 DEFB +02	Subscript out of range.
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The address of the location before the actual floating-point number can now be calculated.

1233 SV-NUMBER	RST 0020,NEXT-CH POP HL LD DE,+0005 CALL 1305,HL=HL*DE ADD HL,BC RET	Move CH·ADD on one location. Fetch the 'counter'. There are 5 bytes to each element. Compute the total number of bytes. Add this number to the variable pointer, thereby HL will point to the location before the required element. 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) EX (SP),HL CALL 1305,HL=HL*DE POP BC ADD HL,BC INC HL LD B,D LD C,E EX DE,HL CALL 12C2,STK-ST-O	Fetch the last 'dimension-size'. The variable pointer goes on the stack and the 'counter' to HL. Multiply 'counter' by 'dimension-size'. Fetch the 'variable pointer'. This gives HL pointing to the location before the actual element. So point to the start of the string. Transfer the last 'dimension-size' to BC to form the length. Transfer the start pointer to DE. 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.

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

The possibility of the 'slice' being ')' has to be considered.

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

Before proceeding the registers are set up as required.

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

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

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

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

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

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

1292 SL-SECOND PUSH HL RST 0020,NEXT-CH POP HL CP +11	Save the 'length' briefly. Get the next character. Restore the 'length'. 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 of the subroutine.
		PUSH	HL	Save the error register briefly.
		PUSH	AF	The 'next expression' is evaluated to give a 'last value'.
		CALL	0D92,CLASS-6	Restore the error register.
		POP	AF	Jump forward if syntax is being checked.
		CALL	0DA6,SYNTAX-Z	Save the error register briefly.
		JR	Z,12FC,I-RESTORE	The 'last value' is compressed into the 16 bits of the BC register pair.
		PUSH	AF	Get the error register into D.
		CALL	0EA7,FIND-INT.	Test the evaluation result.
		POP	DE	Presume the error condition.
		LD	A,B	Jump if evaluation result is zero.
		OR	C	Copy the 'limit value'. This will be either 'dimension-size', 'DIM-limit' or 'string length'.
		SCF		Prepare for the subtraction.
		JR	Z,12F9,I-CARRY	Make the test.
		POP	HL	Fetch the error register.
		PUSH	HL	If there is no error and no previous error then A holds zero and carry is reset.
		AND	A	Otherwise A holds Hex.FF or FE, and carry is set.
		SBC	HL,BC	Restore the HL and DE register pairs.
12F9	I-CARRY	LD	A,D	Finished.
		SBC	A,+00	
12FC	I-RESTORE	POP	HL	
		POP	DE	
		RET		

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 QDA6,SYNTAX-Z	
		RET Z	Return if syntax is being checked.
		PUSH BC	BC is saved.
		LD B,+10	It is to be a 16 bit multiplication.
		LD A,H	A holds the high byte.
		LD C,L	C holds the low byte.
		LD HL,+0000	Initialise the result to zero.
1311	HL-LOOP	ADD HL,HL	Double the result.
		JR C,131A,HL-OVER	Jump if overflow.
		RL C	Rotate bit 7 of C into the carry.
		RLA	Rotate the carry into bit 0 and bit 7 into the carry flag.
		JR NC,131D,HL-AGAIN	Jump if the carry flag is reset.
		ADD HL,DE	Otherwise add DE in once.
131A	HL-OVER	JP C,0ED3,REPORT-4	Report the overflow error.
131D	HL-AGAIN	DJNZ 1311,HL-LOOP	Until 16 passes have been made.
		POP BC	Restore BC.
		RET	Finished.

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 FLAGS 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.

132D	L-EACH-CH	LD BC,+0005	Assume a numeric variable.
132E	L-NO-SP	INC BC	For each character of a name:
		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.
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An RST 0028 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 0028,FP-CALC.	Now use the calculator.
DEFB +02,delete,19E3	This moves STKEND back five locations.
DEFB +34,end-calc.,002B	
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	Six bytes for a numeric variable.
ADD HL,DE	HL now points one past.
JR 1361,L-NUMERIC	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)	Fetch the start pointer.
LD BC,(STRLEN)	Fetch the length counter.
BIT 0,(FLAGX)	Jump if dealing with a
JR NZ,1387,L-ADD\$	simple string.

The new string must not be a null string.

LD A,B	High length counter.
OR C	Low length counter.
RET Z	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	Save the start pointer.
RST 0030,BC-SPACES	Make room in the work space.
PUSH DE	Save the pointer to the 2nd space.
PUSH BC	Save the length.
LD D,H	HL holds the address of STKBOT - 1.
LD E,L	HL now points to STKBOT.
INC HL	A space is entered.
LD (HL),+00	All of the new locations are now set to zero (except the 1st space).
LDDR	

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	Save the 'new' area pointer.
CALL 13F8,STK-FETCH	Fetch the parameters.
POP HL	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	'Length' of new area to HL.
AND A	'Pointer' to new area to stack.
SBC HL,BC	Prepare for subtraction.
ADD HL,BC	Find the difference in the lengths.
JR NC,13A3,L-LENGTH	Add it back.
LD B,H	Jump if the 'new' string will fit.
LD C,L	The procrustean shortening of a string that is too long.
13A3 L-LENGTH EX (SP),HL	'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	'Start' of string to HL.
LD A,B	'Pointer' to new area to DE.
OR C	Test the 'length' of the new string.
JR Z,13AB,L-IN-W-S	Jump forward if a null string.
LDIR	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	Save the address of the element.
	RET Z	Move the string or number.
	PUSH DE	The address of the element is in HL.
	LDIR	Finished with array variables.
	POP HL	
	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 one extra byte.
DEC BC	Save the count of the bytes.
PUSH BC	Copy the string to the work space.
LDDR	The location before the string to HL.
EX DE,HL	Restore the count.
POP BC	The length of the new string.
DEC BC	Enter high-length.
LD (HL),B	Back one.
DEC HL	Enter low-length.
LD (HL),C	Restore the variable name.
POP AF	

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
	JR NZ,141C,D-RUN	syntax is being checked.
	RES 6,C	Presume a numeric array.
	CALL 11A7,STK-VAR	Check the syntax further.
	CALL 0D1D,CHECK-END	Exit via CHECK-END.
141C D-RUN	JR C,1426,D-LETTER	Jump if no existing variable.
	PUSH BC	Save the variable name.
	CALL 09F2,NEXT-ONE	Find the start of the next variable.
	CALL 0A60,RECLAIM-2	Reclaim the bytes of the existing variable.
	POP BC	Restore the variable name.

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
	JR NZ,1434,D-SIZE	array of strings.
	LD L,+05	Element length for a numerical array.
1434 D-SIZE	EX DE,HL	Element length is to be in DE.

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
	LD L,C	required in HL.
	CALL 1305,HL=HL*DE	Check that enough RAM is available
	EX DE,HL	and transfer the byte total to DE.
	RST 0018,GET-CH.	Get the present character.
	CP +1A	Is it a '/'?
	JR Z,1435,D-NO-LOOP	Jump back if there is another dimension
		to be included.

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
INC HL	two and then double the result to
ADD HL,HL	obtain the number of bytes required
ADD HL,DE	for the parameters.
JP C,0ED3,REPORT-4	Add to this the number of bytes
PUSH DE	required for the elements.
	'Out of RAM' if result too great.
	Save the element-byte total.

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

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 decrease it by three to give the required number.
DEC BC	
DEC BC	
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 byte.
LD L,E	DE now points to the last but one.
DEC DE	Enter a 'zero'.
LD (HL),+00	Fetch the element-byte total.
POP BC	Enter a 'zero' into all the other bytes and finish with HL pointing to the byte before the first element.
LDDR	

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

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.
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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,st-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	Get the next character.
CALL 1514,STK-DIGIT	If it is a digit then stack it.
JR C,14F5,E-FORMAT	If not jump forward.
RST 0028,FP-CALC.	Now use the calculator.
DEFB +E0,get-mem-0,1A45	For each passage of the loop, the
DEFB +A4,stk-ten,1A51	number saved in the memory area is
DEFB +05,division,1882	fetched, divided by 10 and restored.
DEFB +C0,st-mem-0,1A63	i.e. going from .1 to .01 to .001 etc.
DEFB +04,multiply,17C6	The present digit is multiplied by
DEFB +0F,addition,1755	the 'saved number' and added to the
DEFB +34,end-calc.,002B	'last value'.
JR 14E5,NXT-DGT-1	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 $x \times 10^{**m}$.
		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	Set exponent to 17 decimal for a 16-bit number, and then test whether B is in fact zero.
		LD (HL),+91	
		LD A,B	
		AND A	

	JR NZ,1536,NORML-FP LD (HL),A OR C RET Z LD B,C LD C,(HL) LD (HL),+89	Jump forward when B is non-zero. Else, zero to exponent byte. Return if C is also zero as the 'last value' is to be zero. Transfer C to B. Clear the C register. Set exponent to 9 decimal for an 8-bit number.
1536 NORML-FP	DEC (HL) SLA C RL B JR NC,1536,NORML-FP SRL B RR C INC HL LD (HL),B INC HL LD (HL),C DEC HL DEC HL RET	Normalize the floating-point form by shifting C & B left until a set bit is found. The exponent is decremented on each loop. Now shift B & C right, resetting the set bit for a positive number. Point to the 2nd byte. Copy over the B register. Point to the 3rd byte. Copy over the C register. Return with the HL register pair pointing to the exponent. 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 RST 0028,FP-CALC. DEFB +A0,stk-zero,1A51 DEFB +34,end-calc.,002B POP AF	Save the first digit – in A. Use the calculator. The 'last value' is now zero. Restore the first digit.
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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 RET C RST 0028,FP-CALC. DEFB +01,exchange,1A72 DEFB +A4,stk-ten,1A51 DEFB +04,multiply,17C6 DEFB +0F,addition,1755 DEFB +34,end-calc.,002B RST 0020,NEXT-CH JR 154D,NXT-DGT-2	If the character is a digit then stack its floating-point form. Use the calculator. 'Digit' goes under 'last value'. Define decimal 10. 'Last value' = 'last value' * 10. 'Last value' = 'last value' + 'digit'. Next character goes into A. Loop back with this character.
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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 $x \times 10^m$, 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. DEFB +2D,duplicate,19F6 DEFB +32,less-0,1ADB DEFB +CO,st-mem-0,1A63 DEFB +02,delete,19E3 DEFB +27,abs,1AAA	x, m x, m, m x, m, (1/0) Logical value of m. x, m, (1/0) Store sign flag in x, m first byte of mem-0. x, p p = 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 DEFB +03,subtract,174C DEFB +2D,duplicate,19F6 DEFB +32,less-0,1ADB DEFB +00,jump-true,1C2F DEFB +22, to 1587,END-E	x, p, 1 x, p-1 x, p-1, p-1 x, p-1, (1/0) x, p-1 x, p-1
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- 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.

157A	E-ONE	DEFB +2D,duplicate,19F6 DEFB +30,stk-data,19FC DEFB +33,exponent 83 DEFB +40,(+00,+00,+00) DEFB +03,subtract,174C DEFB +2D,duplicate,19F6 DEFB +32,less-0,1ADB DEFB +00,jump-true,1C2F DEFB +0C, to 157A,E-ONE DEFB +01,exchange,1A72 DEFB +02,delete,19E3 DEFB +01,exchange,1A72 DEFB +30,stk-data,19FC DEFB +80,four bytes DEFB +48,exponent 98 DEFB +18,+96,+80,(+00) DEFB +2F,jump,1C23 DEFB +04, to 157D,E-M/D	x, p-1, p-1 x, p-1, p-1, 6 x, p-1, p-7 x, p-1, p-7, p-7 x, p-1, p-7, (1/0) x, p-1, p-7 x, p-1, p-7 x, p-7, p-1 x, p-7 p-7, x p-7, x, $10^{**}7$ p-7, x, $10^{**}7$ p-7, x, $10^{**}7$
		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 DEFB +00,jump-true,1C2F DEFB +04, to 1583,E-DIV DEFB +04,multiply,17C6 DEFB +2F,jump,1C23 DEFB +02, to 1584,E-EXC	p-i, x, $10^{**}i$, (1/0) p-i, x, $10^{**}i$ p-i, x, $10^{**}i$ p-i, x $^{*}10^{**}i$ p-i, x $^{*}10^{**}i$ p-i, x $^{*}10^{**}i$
1583	E-DIV	DEFB +05,division,1882	p-i, x $^{*}10^{**}-i$
1584	E-EXC	DEFB +01,exchange,1A72 DEFB +2F,jump,1C23 DEFB +DA, to 1560,E-YET	x $^{*}10^{**} +/-i$, p-i x $^{*}10^{**} +/-i$, p-i 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	If zero then no shift is needed.
		LD D,A	Transfer shift counter to D.
		LD A,E	Prepare 9th/17th bit for rounding up.
		RLCA	
		JR Z,15BC,IN-PLACE	Jump if A was zero; no shift.
15B5	SHIFT-BC	SRL B	Shift B & C right D times to produce the correct number.
		RR C	Decrement the shift counter.
		DEC D	Loop until D becomes zero.
		JR NZ,15B5,SHIFT-BC	End if no rounding-up needed;
15BC	IN-PLACE	JR NC,15C6,FBC-END	else round up.
		INC BC	Test if number now equals 65536 dec.
		LD A,B	i.e. BC now zero — out of range.
		OR C	Jump if in range.
		JR NZ,15C6,FBC-END	Fetch zero and carry flags.
		POP AF	Set carry flag as out of range.
		SCF	Save the zero and carry flags.
		PUSH AF	Save the result briefly.
15C6	FBC-END	PUSH BC	Use the calculator.
		RST 0028,FP-CALC.	This makes HL point to STKEND - 5.
		DEF8 +34,end-calc.,0028	Restore the result.
		POP BC	Restore the zero and the carry flags.
		POP AF	Copy over the low byte of the result.
		LD A,C	Finished.
		RET	

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	Compress the 'last value' into BC.
		RET C	Return if out of range already.
		PUSH AF	Save the result and the flags.
		DEC B	Again it will be out of range if the B register does not hold zero.
		INC B	Jump if in range.
		JR Z,15D9,FP-A-END	Fetch the result and the flags.
		POP AF	Signal the result is out of range.
		SCF	Finished — unsuccessful.
		RET	Fetch the result and the flags.
15D9	FP-A-END	POP AF	Finished — successful.
		RET	

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:

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

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. DEFB +2D,duplicate,19F6 DEFB +32,less-0,1ADB DEFB +00,jump-true,1C2F DEFB +0B, to 15EA,P-NEG DEFB +2D,duplicate,19F6 DEFB +33,greater-0,1ACE DEFB +00,jump-true,1C2F DEFB +0D, to 15FO,P-POS DEFB +02,delete,19E3 DEFB +34,end-calc.,002B LD A,+1C RST 0010,PRINT-A RET	Use the calculator. X, X X, (1/0) Logical value of X. X X, X X, (1/0) Logical value of X. X X — — Enter the character code for '0'. Print the '0'. Finished as the 'last value' is equal to zero. X' X' = ABS X. X'
15EA P-NEG	DEFB +27,abs,1AAA DEFB +34,end-calc.,002B LD A,+16 RST 0010,PRINT-A RST 0028,FP-CALC.	Enter the character code for '-'. Print the '-'. Use the calculator again.
15FO 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 mod 10, INT (m/10)
	DEFB +01,exchange,1A72	INT (m/10), m mod 10
	DEFB +34,end-calc.,002B	
	CALL 15CD,FP-TO-A	
1620	OR +90	A will hold m mod 10.
	POP BC	Add left nibble of Hex.9 to each digit;
	POP HL	this ensures full carry on half carry
	LD (HL),A	after DAA.
	DJNZ 1615,NXT-DGT-3	Restore the digit-counter.
		Restore the pointer.
		Store this digit in the buffer.
		Until 10 digits have been stored.

Pass over any leading zeros.

162C GET-FIRST	INC HL	Point one-past the end of mem-4.
	LD BC,+0008	Looking for 8 digits.
	PUSH HL	Save the pointer.
	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.

1639 ROUND-UP	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.
	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 LD (HL),+80 DEC HL DJNZ 164B,MARKERS	These six markers will end output by setting the overflow flag after DEC and INC — see 16C4 and 16CA below.
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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.

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

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

1682 E-NEEDED	LD	B,E	B now contains the correct integer to follow 'E' of E-format.
	CALL	16D0,OUT-NEXT	Print the first digit.
	CALL	16C2,TEST-INT	Test whether there are more non-zero digits, in which case a 'decimal-point' will be needed.
	LD	A,+2A	Enter the character code for 'E'.
	RST	0010,PRINT-A	Print the 'E'.
	LD	A,B	Transfer the 'exponent' integer to A.
	AND	A	Set the flags.
	JP	P,1698,PLUS-SIGN	If positive, jump and print a '+'.
	NEG		Else, change its sign.
	LD	B,A	Transfer back to B, briefly.
	LD	A,+16	Enter the character code for '-'.
	JR	169A,OUT-SIGN	Jump forward.
1698 PLUS-SIGN	LD	A,+15	Enter the character code for '+'.
169A OUT-SIGN	RST	0010,PRINT-A	Print the sign character.
	LD	A,B	Transfer the 'exponent' back to A.
	LD	B,+FF	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.
169E TEN-MORE	INC	B	After the loop, restore the last 10 to A; and store A in the C register.
	SUB	+0A	Transfer the 'tens' to A.
	JR	NC,169E,TEN-MORE	Test to see if there are any 'tens'.
	ADD	A,+0A	Jump forward if no 'tens'.
	LD	C,A	Print the first digit.
	LD	A,B	Fetch the 'unit' digit.
	AND	A	Print the digit.
	JR	Z,16AD,BYTE-TWO	Finished with E-format.
	CALL	07EB,OUT-CODE	
16AD BYTE-TWO	LD	A,C	
	CALL	07EB,OUT-CODE	
	RET		

Decimal format is required.

16B2 EXP-MINUS NEG

	LD	B,A	A was negative but in range for simple printing so the format is .000...dddd with up to 4 zeros.
	LD	A,+1B	B will count out the zeros.
	RST	0010,PRINT-A	Enter the character code for '.'.
	LD	A,+1C	Now print the 'decimal-point'.
16BA OUT-ZEROS	RST	0010,PRINT-A	Enter the character code for '0'.
	DJNZ	16BA,OUT-ZEROS	Print the '0'.
	JR	16C8,TEST-DONE	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	Enter the character code for '0'.
	RST	0010,PRINT-A	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 LD A,+1B RST 0010,PRINT-A	So a 'marker' byte forces a return. Enter the character code for '.'. Now print the 'decimal-point'.
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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) 16CA RET PE CALL 16D0,OUT-NEXT JR 16C8,TEST-DONE	Test the digit to see if it is a 'marker' (see TEST-INT). Return when a 'marker' is found. Print the digit. Jump back to consider the next digit.
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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) AND +OF CALL 07EB,OUT-CODE DEC HL RET	Fetch the present digit. Mask off any unwanted bits. Pass the digit for actual printing. Move the pointer back an address. Finished.
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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) LD (HL),+00 AND A RET Z INC HL BIT 7,(HL) SET 7,(HL) DEC HL RET Z	Transfer the exponent to A. Presume a positive number. If the number is zero then the preparation is already finished. Now point to the sign byte. Set the zero flag for positive number. Restore the true numeric bit. Point to the first byte again. Positive numbers have been prepared, but negative numbers need to be 2's complemented. PUSH BC LD BC,+0005 ADD HL,BC LD B,C LD C,A SCF	Save any earlier exponent. There are 5 bytes to be handled. Point one-past the last byte. Transfer the '5' to B. Save the exponent in C. Set carry flag for negation.
16EC NEG-BYTE DEC HL LD A,(HL) CPL		Point to each byte in turn. Get each byte. 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.
 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, the subroutine returns at once.
	RET Z	If the difference is greater than Hex.20, jump forward.
	CP +21	Save BC briefly.
	JR NC,1736,ADDEND-0	Transfer the exponent difference to B to count the shifts right.
	PUSH BC	Arithmetic shift right for L', preserving the sign marker bits.
	LD B,A	Rotate right with carry D', E', D & E.
1722 ONE-SHIFT	EXX	Thereby shifting the whole five bytes of the number to the right as many times as B counts.
	SRA L	Loop back until B reaches zero.
	RR D	Restore the original BC.
	RR E	Done if no carry to retrieve.
	EXX	Retrieve carry.
	RR D	Return unless the carry rippled right back. (In this case there is nothing to add)
	RR E	Fetch L', D' & E'.
	DJNZ 1722,ONE-SHIFT	Clear the A register.
	POP BC	Set the addend to zero in D', E', 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.
	RET NC	ZEROS-4/5 produces only 4 zero bytes when called for near underflow at 1833.
	CALL 1741,ADD-BACK	Finished.
	RET NZ	
1736 ADDEND-0	EXX	
	XOR A	
1738 ZEROS-4/5	LD L,+00	
	LD D,A	
	LD E,L	
	EXX	
	LD DE,+0000	
	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, (see FETCH-TWO).
	LD H,C	Add the two right bytes.
	ADD HL, DE	N2 to H' & N3 to L', (see FETCH-TWO).
	EXX	Add left bytes with carry.
	EX DE, HL	Result back in D'E'.
	ADC HL, BC	Add H', L' and the carry; the resulting mechanism will ensure that a single shift right is called if the sum of 2 positive numbers has overflowed left, or the sum of 2 negative numbers has not overflowed left.
	EX DE, HL	The result is now in DED'E'.
	LD A,H	Get the pointer to the exponent.
	ADC A,L	The test for shift (H', L' were Hex.00 for positive numbers and Hex.FF for negative numbers).
	LD L,A	A counts a single shift right.
	RRA	The shift is called.
	XOR L	Add 1 to the exponent; this may lead to arithmetic overflow.
	EXX	Test for negative result: get sign bit of L' into A (this now correctly indicates the sign of the result).
	EX DE, HL	Store it in the second byte position of the result on the calculator stack.
	POP HL	If it is zero, then do not 2's complement the result.
	RRA	Get the first byte.
1790 TEST-NEG	JR NC, 1790, TEST-NEG	Negate it.
	LD A,+01	Complement the carry for continued negation, and store byte.
	CALL 171A, SHIFT-FP	Get the next byte.
	INC (HL)	One's complement it.
	JR Z, 17B3, ADD-REP-6	Add in the carry for negation.
	EXX	Store the byte.
	LD A,L	Proceed to get next byte into the A register.
	AND +80	One's complement it.
	EXX	Add in the carry for negation.
	INC HL	Store the byte.
	LD (HL), A	Get the last byte.
	DEC HL	One's complement it.
	JR Z, 17B9, GO-NC-MLT	Add in the carry for negation.
	LD A,E	Done if no carry.
	NEG	Else, get .5 into mantissa and add 1 to the exponent; this will be needed when two negative numbers add to give an exact power of 2, and it may lead to arithmetic overflow.
	CCF	Give the error if required.
	LD E,A	
	LD A,D	
	CPL	
	ADC A,+00	
	LD D,A	
	EXX	
	LD A,E	
	CPL	
	ADC A,+00	
	LD E,A	
	LD A,D	
	CPL	
	ADC A,+00	
	JR NC, 17B7, END-COMPL	
	RRA	
	EXX	
	INC (HL)	
17B3 ADD-REP-6	JP Z, 1880, REPORT-6	
	EXX	

17B7	END-COMPL	LD D,A EXX	Store the last byte.
17B9	GO-NC-MLT	XOR A JR 1828,TEST-NORM	Clear the carry flag. 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 DEC (HL) INC (HL) RET Z	Set the carry flag. Test the exponent byte.
		INC HL XOR (HL)	If the number is zero, return with both the zero and the carry flags set. Point to the sign byte.
		SET 7,(HL) DEC HL RET	Get sign for result into A (like signs give plus, unlike give minus); also reset carry flag. Set the true numeric bit. Point to the exponent again. 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 CALL 17BC,PREP-M/D RET C EXX PUSH HL EXX PUSH DE EX DE,HL CALL 17BC,PREP-M/D EX DE,HL JR C,1830,ZERO-RSLT PUSH HL CALL 16F7,FETCH-TWO LD A,B AND A SBC HL,HL EXX PUSH HL SBC HL,HL EXX LD B,+21 JR 17F8,STRT-MLT	A is set to Hex.00 so that the sign of the first number will go into A. Prepare the first number, and return if zero. (Result already zero.) Exchange the registers. Save the next literal address. Exchange the registers. Save the pointer to the multiplicand. Exchange the pointers. Prepare the 2nd number. Exchange the pointers again. Jump forward if 2nd number is zero. Save the pointer to the result. Get the two numbers from the stack. M5 to A (see FETCH-TWO). Prepare for a subtraction. Initialise HL to zero for the result. Exchange the registers. Save M1 & N1 (see FETCH-TWO). Also initialise H'L' for the result. Exchange the registers. B counts 33 decimal, Hex.21, shifts. Jump forward into the loop.
------	----------	---	---

Now enter the multiplier loop.

17E7	MLT-LOOP	JR	NC,17EE,NO-ADD	
		ADD	HL,DE	Jump forward to NO-ADD if no carry, i.e. the multiplier bit was reset;
		EXX		Else, add the multiplicand in
		ADC	HL,DE	D'E'DE (see FETCH-TWO) into the result being built up in H'L'HL.
		EXX		
17EE	NO-ADD	EXX		Whether multiplicand was added
		RR	H	or not, shift result right in
		RR	L	H'L'HL, i.e. the shift is done by
		EXX		rotating each byte with carry, so that
		RR	H	any bit that drops into the carry is
		RR	L	picked up by the next byte, and the
		EXX		shift continues into B'C'CA.
17F8	STRT-MLT	EXX		Shift right the multiplier in
		RR	B	B'C'CA (see FETCH-TWO & above).
		RR	C	A final bit dropping into the carry
		EXX		will trigger another add of the
		RR	C	multiplicand to the result.
		RRA		
		DJNZ	17E7,MLT-LOOP	Loop 33 times to get all the bits.
		EX	DE,HL	Move the result from:
		EXX		
		EX	DE,HL	H'L'HL to D'E'DE.
		EXX		

Next add the exponents together.

180E	MAKE-EXPT	POP	BC	Restore the exponents – M1 & N1.
		POP	HL	Restore the pointer to the exponent byte.
		LD	A,B	Get the sum of the two exponent
		ADD	A,C	bytes in A, and the correct carry.
		JR	NZ,180E,MAKE-EXPT	If the sum equals zero then clear
		AND	A	the carry; else leave it unchanged.
		DEC	A	Prepare to increase the exponent by
		CCF		Hex.80.

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

1810	DIVN-EXPT	RLA		These few bytes very cleverly make
		CCF		the correct exponent byte.
		RRA		Rotating left then right gets the
			exponent byte (true exponent plus	
		JP	P,1819,OFLW1-CLR	Hex.80) into A.
				If the sign flag is reset, no report of
		JR	NC,1880,REPORT-6	arithmetic overflow needed.
		AND	A	Report the overflow if carry reset.
1819	OFLW1-CLR	INC	A	Clear the carry now.
		JR	NZ,1824,OFLW2-CLR	The exponent byte is now complete;
		JR	C,1824,OFLW2-CLR	but if A is zero a further check for
		EXX		overflow is needed.
		BIT	7,D	If there is no carry set and the
		EXX		result is already in normal form
		JR	NZ,1880,REPORT-6	(bit 7 of D' set) then there is overflow to
				report; but if bit 7 of D' is reset, the
1824	OFLW2-CLR	LD	(HL),A	result is just in range, i.e. just under
		EXX		2**127.
		LD	A,B	Store the exponent byte, at last.
		EXX		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,NORML-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
JR Z,182C,NEAR-ZERO	each shift.
DJNZ 1841,SHIFT-ONE	If the exponent becomes zero, then
JR 1830,ZERO-RSLT	numbers from $2^{**} - 129$ are rounded
	up to $2^{**} - 128$.
	Loop back, up to 32 times.
	If bit 7 never became 1 then the
	whole result is to be zero.

Finish the normalization by considering the 'carry'.

1859 NORML-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 registers, D'E'DE, to BCDE; and then to ACDE.
PUSH DE		
EXX		
POP BC		
LD A,B		
RLA		The sign bit is retrieved from its temporary store and transferred to its correct position of bit 7 of the first byte of the mantissa.
RL (HL)		
RRA		The first byte is stored.
LD (HL),A		Next.
INC HL		The second byte is stored.
LD (HL),C		Next.
INC HL		The third byte is stored.
LD (HL),D		Next.
INC HL		The fourth byte is stored.
LD (HL),E		Restore the pointer to the result.
POP HL		Restore the pointer to second number.
POP DE		Exchange the registers.
EXX		Restore the next literal address.
POP HL		Exchange the registers.
EXX		Finished.
RET		

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 report for arithmetic overflow if it is zero.
		JR C,1880,REPORT-6	
		EX DE,HL	Exchange the pointers.
		CALL 17BC,PREP-M/D	Prepare the dividend and return if it is zero (result already zero).
		RET C	Exchange the registers.
		EXX	Save the next literal address.
		PUSH HL	Exchange the registers.
		EXX	Save pointer to divisor.
		PUSH DE	Save pointer to dividend.
		PUSH HL	Get the two numbers from the stack.
		CALL 16F7,FETCH-TWO	Exchange the registers.
		EXX	Save M1 & N1 on the machine stack.
		PUSH HL	Copy the four bytes of the dividend from registers B'C'CB (i.e. M2, M3, M4 & M5; see FETCH-TWO) to the registers H'L'HL.
		LD H,B	
		LD L,C	
		EXX	
		LD H,C	
		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	JR C,18C2,SUBN-ONLY
18B2 DIV-START	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	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	SR 18C9,NO-RSTORE
18C9 NO-RSTORE	SCF	One for the quotient in B'C'CA.
18CA COUNT-ONE	INC B JP M,18A2,DIV-LOOP PUSH AF	Step the loop count up by one. Loop 32 times for all bits. Save any 33rd bit for extra precision (the present carry).
	JR Z,18B2,DIV-START	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.
	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	Then put any 34th and 33rd bits into B' to be picked up on normalization.
	JP 1810,DIVN-EXPT	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. HL now points to the 5th byte of X.
		DEC HL	Get the number of bits to be set to zero into B and divide it by 8 to give the number of whole bytes implied.
		LD B,A	
		SRL B	
		SRL B	
		SRL B	
		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 counts them.
		DEC HL	
		DJNZ 1900,BYTE-ZERO	
1905	BITS-ZERO	AND +07	Get A (mod 8): this is the number of bits still to be set to zero.
		JR Z,1912,IX-END	Jump to the end if nothing more to do.
		LD B,A	B will count the bits now.
		LD A,+FF	Prepare the mask.
190C	LESS-MASK	SLA A	With each loop a zero enters the mask from the right and thereby a mask of the correct 'length' is produced.
		DJNZ 190C,LESS-MASK	The unwanted bits of (HL) are lost as the masking is performed.
		AND (HL)	Return the pointer to HL.
		LD (HL),A	Return the pointer to DE, (STKEND).
1912	IX-END	EX DE,HL	Finished.
		POP DE	
		RET	

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	
1925	01	exchange	72	1A	194F	16	strs-eql	03	1B	1979	2B	chrs	8F	
1927	02	delete	E3	19	1951	17	strs-add	62	1B	197B	2C	not	D5	
1929	03	subtract	4C	17	1953	18	negate	A0	1A	197D	2D	duplicate	1A	
192B	04	multiply	C6	17	1955	19	code	06	1C	197F	2E	n-mod-m	19	
192D	05	division	82	18	1957	1A	val	A4	1B	1981	2F	jump	37	
192F	06	to-power	E2	1D	1959	1B	len	11	1C	1983	30	stk-data	1C	
1931	07	or	ED	1A	195B	1C	sin	49	1985	31	dec-jr-nz	19		
1933	08	no.-&-no.	F3	1A	195D	1D	cos	3E	1D	1987	32	less-0	1C	
1935	09	no.-l-eql	03	18	195F	1E	tan	6E	1D	1989	33	greater-0	CE	
1937	0A	no.-gr-eq	03	1B	1961	1F	asn	C4	1D	198B	34	end-calc.	1A	
1939	0B	nos.-neql	03	1B	1963	20	acs	D4	1D	198D	35	get-argt.	2B	
193B	0C	no.-grtr	03	1B	1965	21	atn	76	1D	198F	36	truncate	00	
193D	0D	no.-less	03	1B	1967	22	In	A9	1D	1991	37	fp-calc-2	E4	
193F	0E	nos.-eql	03	1B	1969	23	exp	5B	1C	1993	38	e-to-fp	18	
1941	0F	addition	55	17	196B	24	int	46	1C	1995	39	series-06	19	
1943	10	str-&-no.	F8	1A	196D	25	sqr	DB	1D	1997	3A	etc.	5A	
1945	11	str-l-eql	03	1B	196F	26	sgn	DB	1C	1999	3B	stk-zero	15	
1947	12	str-gr-eq	03	1B	1971	27	abs	AF	1D	199B	3C	etc.	63	
1949	13	strs-neql	03	1B	1973	28	peek	AA	1A	1998	etc.	st-mem-0	45	
194B	14	str-grtr	03	1B	1975	29	usr	BE	1A			etc.	1A	
								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

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).

19A0 GEN-ENT-1 LD A,B
LD (BERG),A

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.

19A4 GEN-ENT-2 EXX
EX (SP),HL
EXX

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.

19A7 RE-ENTRY LD (STKEND),DE

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.

EXX
LD A,(HL)
INC HL
19AE SCAN-ENT. PUSH HL

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 JP P,19C2,FIRST-38	Test the A register. Separate the simple literals from the multi-purpose literals. Jump with literals 00 – 38.
	LD D,A AND +60 RRCA RRCA RRCA RRCA ADD A,+72 LD L,A	Save the literal in D. Continue only with bits 5 & 6. Four right shifts make them now bits 1 & 2.
	LD A,D AND +1F	The offsets required are 39 – 3C, and L will now hold double the required offset.
	JR 19D0,ENT-TABLE	Now produce the parameter by taking bits 0,1,2,3 & 4 of the literal; keep the parameter in A. Jump forward to find the address of the required subroutine.
19C2 FIRST-38	CP +18 JR NC,19CE,DOUBLE-A EXX LD BC,+FFFFB LD D,H LD E,L ADD HL,BC EXX	Jump forward if performing a unary operation.
19CE DOUBLE-A	RLCA LD L,A	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.
19D0 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.)	As each entry in the table of addresses takes up two bytes the offset produced is doubled. The base address of the table. The address of the required table entry is formed in HL; and the required subroutine address is loaded into the DE register pair.
19E3 delete	RET	The RE-ENTRY address of 19A7 is put on the machine stack underneath the subroutine address. Return to the main set of registers. The current value of BERG is transferred to the B register thereby returning the single operation offset. (See COMPARISON at 1B03) An indirect jump to the required subroutine.

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.
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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.
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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.
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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.
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	19FE STK-CONST	CALL 19EB,TEST-5-SP	Now test that there is indeed room.
		EXX	Go to the alternate register set and
		PUSH HL	stack the pointer to the next
		EXX	literal.
		EX (SP),HL	Switch over the result pointer and the
		PUSH BC	next literal pointer.
		LD A,(HL)	Save BC briefly.
		AND +CO	The first literal is put into A
		RLCA	and divided by Hex.40 to give the
		RLCA	integer values 0, 1, 2 or 3.
		LD C,A	
		INC C	The integer value is transferred to
		LD A,(HL)	C and incremented, thereby giving
		AND +3F	the range 1, 2, 3 or 4 for the number
		JR NZ,1A14,FORM-EXP	of literals that will be needed.
		INC HL	The literal is fetched anew, reduced
		LD A,(HL)	mod Hex.40 and discarded as
1A14 FORM-EXP	ADD A,+50		inappropriate if the remainder is
	LD (DE),A		zero; in which case the next literal
		LD A,+05	is fetched and used unreduced.
		SUB C	The exponent, e, is formed by the
		INC HL	addition of Hex.50 and passed to the
		INC DE	calculator stack as the first of the
		LD B,+00	five bytes of the result.
		LDIR	The number of literals specified
		POP BC	in C are taken from the source
		EX (SP),HL	and entered into the bytes of the
		EXX	result.
		POP HL	
		EXX	Restore BC.
		LD B,A	Return the result pointer to HL
		XOR A	and the next literal pointer to
1A27 STK-ZEROS	DEC B		its usual position in H' & L'.
	RET Z		
	LD (DE),A		The number of zero bytes required
	INC DE		at this stage is given by 5-C-1;
	JR 1A27,STK-ZEROS		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 BC register pair.
	LD B,+00	
	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	PUSH DE	Save the result pointer.
etc.	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	LD H,D	Set HL to hold the result pointer.
etc.	LD L,E	
	EXX	Go to the alternate register set and save the next literal pointer.
	PUSH HL	
	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	PUSH HL	Save the result pointer.
	etc.	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	Exchange the five bytes.
		DJNZ 1A74,SWAP-BYTE	Get the pointers correct as the number 5 is an odd number.
		EX DE,HL	
		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:

$$T_{n+1}(z) = 2zT_n(z) - T_{n-1}(z), \text{ where } T_n(z) \text{ is the nth Chebyshev polynomial in } z.$$

The series in fact generates:

$T_0, 2T_1, 2T_2, \dots, 2T_{n-1}$, where n 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, 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, 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	LD B,A	Move the parameter to B.
	etc.	CALL 19A0,GEN-ENT-1	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	$B(R), B(R)$
		DEFB +E0,get-mem-0,1A45	$B(R), B(R), 2^*Z$
		DEFB +04,multiply,17C6	$B(R), 2^*B(R)*Z$
		DEFB +E2,get-mem-2,1A45	$B(R), 2^*B(R)*Z, B(R-1)$
		DEFB +C1,st-mem-1,1A63	mem-1 holds $B(R-1)$
		DEFB +03,subtract,174C	$B(R), 2^*B(R)*Z-B(R-1)$
		DEFB +34,end-calc.,0028	

The next constant is placed on the calculator stack.

CALL 19FC,STK-DATA	$B(R), 2^*B(R)*Z-B(R-1), A(R+1)$
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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	
DEFB +EE,to 1A89,G-LOOP	B(R+1)

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 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)	Set the carry flag.
	SCF	If the value is not zero then call FP-0/1 with carry set to give a 'last value' of 1.
	CALL NZ,1AE0,FP-0/1	

INC HL	Point to the sign byte again.
RLCA	The sign bit of X is passed into the carry, and hence into the result.
RR (HL)	Set the result pointer.
DEC HL	
RET	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.	Evaluate the 'last value', rounded to the nearest integer; test that it is in range and return it in BC.
	LD A,(BC)	Fetch the required byte.
	JP 151D,STACK-A	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.	Evaluate the 'last value', rounded to the nearest integer; test that it is in range and return it in BC.
	LD HL,+STACK-BC	Make the return address be that of the subroutine STACK-BC.
	PUSH HL	
	PUSH BC	Make an indirect jump to the required location.
	RET	

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)	Fetch the exponent byte.
	AND A	Test it.
	RET Z	Return if the 'last value' is zero.
	LD A,+FF	Jump forward to LESS THAN ZERO
	JR 1ADC,SIGN-TO-C	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)	Fetch the exponent byte.
	NEG	Negating and complementing ensure
	CCF	that the carry is set only if the 'last value' is zero; this gives the correct return.
	JR 1AE0,FP-0/1	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 number; test it and return with the first number as the 'last value' if it is zero.
	AND A	
	RET Z	
	SCF	Set the carry flag and jump back to give the 'last value' as 1.
	JR 1AE0,FP-0/1	

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 number; test it and return with the first number as the 'last value' if it is not zero.
	AND A	
	RET NZ	
	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; test it and return with the string as the 'last value' if it is not zero.
	AND A	
	RET NZ	

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	LD A,B etc.	SUB +08 BIT 2,A JR NZ,1B0B,EX-OR-NOT DEC A	The single operation offset goes to the A register. The range is now 01-06 & 09-0E. This range is changed to: 00-02, 04-06, 08-0A & 0C-0E.
1B0B EX-OR-NOT	RRCA		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.
1B16 NU-OR-STR	JR NC,1B16,NU-OR-STR PUSH AF PUSH HL CALL 1A72,EXCHANGE POP DE EX DE,HL POP AF		The numerical comparisons are now separated from the string comparisons by testing bit 2.
	BIT 2,A JR NZ,1B21,STRINGS		The numerical operations now have the range 00-01 with carry set for 'equal' and 'not equal'.
1B21 STRINGS	RRCA PUSH AF CALL 174C,SUBTRACT JR 1B54,END-TESTS		Save the offset. The numbers are subtracted for the final tests.
	RRCA PUSH AF CALL 13F8,STK-FETCH PUSH DE PUSH BC CALL 13F8,STK-FETCH POP HL		The string comparisons now have the range 02-03 with carry set for 'equal' and 'not equal'. Save the offset.
1B2C BYTE-COMP	LD A,H OR L EX (SP),HL LD A,B JR NZ,1B3D,SEC-PLUS OR C		The lengths and starting addresses of the strings are fetched from the calculator stack.
1B33 SECND-LOW	POP BC JR Z,1B3A,BOTH-NULL		The length of the second string.
			Jump unless the second string is null.
			Here the second string is either null or less than the first.

	POP AF	The carry is complemented to give the correct test results.
1B3A BOTH-NULL	JR 1B50,STR-TEST	Here the carry is used as it stands.
POP AF	JR 1B50,STR-TEST	
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	
	JR 1B2C,BYTE-COMP	
1B4D FRST-LESS	POP BC	
	POP AF	
	AND A	
1B50 STR-TEST	PUSH AF	The carry is cleared here for the correct test results.
	RST 0028,FP-CALC.	For the string tests, a zero is put on to the calculator stack.
	DEFB +A0,stk-zero,1A51	
	DEFB +34,end-calc.,0028	
1B54 END-TESTS	POP AF	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'.
	PUSH AF	
	CALL C,1AD5,NOT	
	CALL 1ACE,GREATER-0	
	POP AF	Finished.
	RRCA	
	CALL NC,1AD5,NOT	
	RET	

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	The parameters of the second string are fetched and saved.
	PUSH DE	
	PUSH BC	
	CALL 13F8,STK-FETCH	
	POP HL	The parameters of the first string are fetched.
	PUSH HL	
	PUSH DE	
	PUSH BC	
	ADD HL,BC	The lengths are now in HL and BC.
	LD B,H	The parameters of the first string are saved.
	LD C,L	The total length of the two strings is calculated and passed to BC.
	RST 0030,BC-SPACES	
	CALL 12C3,STK-STORE	Sufficient room is made available. The parameters of the new string are passed to the calculator stack.
	POP BC	
	POP HL	
	LD A,B	
	OR C	
	JR Z,1B7D,OTHER-STR	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.
	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)	Fetch the current value of STKEND.
	LD DE,+FFFF	Set DE to -5, 2's complement.
	PUSH HL	Stack the value for STKEND.
	ADD HL,DE	Calculate STKEND-5.
	POP DE	DE now holds STKEND and HL holds STKEND-5.
	RET	

THE 'CHR\$' FUNCTION (Offset 2B: 'chr\$')

This subroutine handles the function CHR\$ X and creates a single character string in the work space.

1B8F chr\$	CALL 15CD,FP-TO-A	The 'last value' is compressed into the A register.
	JR C,1BA2,REPORT-B2	Give the error report if X was greater than than 255 decimal, or X was a negative number.
	JR NZ,1BA2,REPORT-B2	Save the compressed value of X.
	PUSH AF	Make one space available in the work space.
	LD BC,+0001	Fetch the value.
	RST 0030,BC-SPACES	Copy the value to the work space.
	POP AF	Pass the parameters of the new string to the calculator stack.
	LD (DE),A	Reset the pointers.
	CALL 12C3,STK-STORE	Finished.
	EX DE,HL	
	RET	

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)	The current value of CH-ADD is preserved on the machine stack.
	PUSH HL	
	CALL 13F8,STK-FETCH	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.
	PUSH DE	
	INC BC	
	RST 0030,BC-SPACES	
	POP HL	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 13FB,STK-FETCH LD A,B OR C JR Z,1C0E,STK-CODE LD A,(DE)	The parameters of the string are fetched. The length is tested and the A register holding zero is carried forward if A\$ is a null string. 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 JP 1520,STACK-BC	The parameters of the string are fetched. The subroutine exits via STACK-BC which gives the correct 'last value'.
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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 PUSH HL LD HL,+BERG DEC (HL) POP HL JR NZ,1C24,JUMP-2 INC HL EXX RET	Go to the alternate register set and save the next literal pointer on the machine stack. Make HL point to BERG. Decrease BERG. Restore the next literal pointer. The jump is made on non-zero. The next literal is passed over. Return to the main register set. Finished.
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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 jump then Hex.FF is formed in the A register instead of the Hex.00.
		JR Z,1C2B,NEW-ADDR.	Hex.00 or Hex.FF goes to D.
		CPL	The registers H' & L' now hold the new next literal pointer.
1C2B	NEW-ADDR.	LD D,A ADD HL,DE EXX 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 (mod 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 mod 10 decimal, and during the calculation of a random number to reduce N mod 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:

- i. X is divided by LN 2 to give Y, so that 2 to the power Y is now the required result.
- ii. The value N is found, such that N=INT Y.
- iii. The value W is found, such that W=Y-N, where $0 \leq W \leq 1$, as required for the series to converge.
- iv. The argument Z is formed, such that $Z=2^*W-1$.
- v. The SERIES GENERATOR is used to return $2^{**}W$.
- vi. 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
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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
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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.

1. DEFB +88,series-08,1A7F	Z
2. DEFB +13,exponent 63	
DEFB +36,(+00,+00,+00)	
3. DEFB +58,exponent 68	
DEFB +65,+66,(+00,+00)	
4. DEFB +9D,exponent 6D	
DEFB +78,+65,+40,(+00)	
5. DEFB +A2,exponent 72	
DEFB +60,+32,+C9,(+00)	
6. DEFB +E7,exponent 77	
DEFB +21,+F7,+AF,+24	
7. DEFB +EB,exponent 7B	
DEFB +2F,+B0,+B0,+14	
8. DEFB +EE,exponent 7E	
DEFB +7E,+BB,+94,+58	
9. 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.

1C99 REPORT6-2	DEFB +E3,get-mem-3,1A45 DEFB +34,end-calc.,002B CALL 15CD,FP-TO-A	$2^{**}W$, N
1C9B N-NEGTIV	JR NZ,1C9B,N-NEGTIV JR C,1C99,REPORT6-2 ADD A,(HL) JR NC,1CA2,RESULT-OK	The absolute value of N mod 256 decimal, is put into the A register. Jump forward if N was negative. Error if ABS N greater than 255 dec. Now add ABS N to the exponent. Jump unless e greater than 255 dec. Otherwise report the overflow.
1CA2 RESULT-OK	RST 0008,ERROR-1 DEFB +05 JR C,1CA4,RSLT-ZERO	The result is to be zero if N is less than -255 decimal. Subtract ABS N from the exponent as N was negative. Zero result if e less than zero. Minus e is changed to e. The exponent, e, is entered. Finished: 'last value' is EXP X.
1CA4 RSLT-ZERO	LD (HL),A RET RST 0028,FP-CALC. DEFB +02,delete,19E3 DEFB +A0,stk-zero,1A51 DEFB +34,end-calc.,002B RET	Use the calculator to make the 'last value' zero. 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:

- i. X is tested and report A is given if X is not positive.
- ii. 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.
- iii. The required value Y1 or Y2 is formed. If X' is greater than 0.8 then $Y1 = e' * \ln 2$ and if otherwise $Y2 = (e'-1) * \ln 2$.
- iv. If X' is greater than 0.8 then the quantity $X'-1$ is stacked; otherwise $2^*X'-1$ is stacked.
- v. 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.
- vi. The SERIES GENERATOR is used to produce the required function.
- vii. 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 with zero.
	DEFB +02,delete,19E3	X	
	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.

1CD2 GRE.8	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'	
	DEFB +01,exchange, 1A72	X', e' - X' large. 2*X', e'-1 - X' small.	

DEFB +30,stk-data,19FC	X', e', LN 2
DEFB +F0,exponent 80	2*X', e'-1, LN 2
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
DEFB +30,stk-data,19FC	Y2, 2*X'-1, 2*X'-1 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.

- | | |
|----------------------------|------------------------------|
| 1. DEFB +8C,series-0C,1A7F | Y1, X'-1, Z or Y2, 2*X'-1, Z |
| 2. DEFB +11,exponent 61 | |
| DEFB +AC,(+00,+00,+00) | |
| 3. DEFB +14,exponent 64 | |
| DEFB +09,(+00,+00,+00) | |
| 4. DEFB +56,exponent 66 | |
| DEFB +DA,+A5,(+00,+00) | |
| 5. DEFB +59,exponent 69 | |
| DEFB +30,+C5,(+00,+00) | |
| 6. DEFB +5C,exponent 6C | |
| DEFB +90,+AA,(+00,+00) | |
| 7. DEFB +9E,exponent 6E | |
| DEFB +70,+6F,+61,(+00) | |
| 8. DEFB +A1,exponent 71 | |
| DEFB +CB,+DA,+96,(+00) | |
| 9. DEFB +A4,exponent 74 | |
| DEFB +31,+9F,+B4,(+00) | |
| 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	$Y_1 = \ln(2^{**e'})$, $\ln X'$
DEFB +0F,addition,1755	$Y_2 = \ln(2^{**e'} - 1)$, $\ln(2^*X')$
DEFB +34,end-calc.,002B	$\ln((2^{**e'})^*X') = \ln X$
RET	$\ln(2^{**e'} - 1)^*2^*X' = \ln X$
	LN X
	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 $-1 \leq 4^*Y \leq 1$ — case i.
or, $V = 2 - 4^*Y$ if $1 < 4^*Y < 2$ — case ii.
or, $V = -4^*Y - 2$ if $-2 \leq 4^*Y < -1$. — case iii.

In each case, $-1 \leq V \leq 1$ and $\sin(\pi^*V/2) = \sin X$.

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	$X/(2^*\pi), \text{INT}(X/(2^*\pi)+0.5)$
	DEFB +03,subtract,174C	$X/(2^*\pi)-\text{INT}(X/(2^*\pi)+0.5) = Y$

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	$4^*Y, \text{ABS}(4^*Y)$
DEFB +A1,stk-one,1A51	$4^*Y, \text{ABS}(4^*Y), 1$
DEFB +03,subtract,174C	$4^*Y, \text{ABS}(4^*Y)-1 = Z$
DEFB +2D,duplicate,19F6	$4^*Y, Z, Z$
DEFB +33,greater-0,1ACE	$4^*Y, Z, (1/0)$
DEFB +C0,st-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. Finished.
	RET	

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 $Z=2*W^2-1$.
- 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 DEFB +2D,duplicate,19F6 DEFB +04,multiply,17C6 DEFB +2D,duplicate,19F6 DEFB +0F,addition,1755 DEFB +A1,stk-one,1A51 DEFB +03,subtract,174C	W, W, W, W, W W, W*W W, W*W, W*W W, 2*W*W W, 2*W*W, 1 W, 2*W*W-1 = Z
------------	--	--

Perform step iii, passing to the SERIES GENERATOR the parameter '6' and the six constants required.

1.	DEFB +86,series-06,1A7F DEFB +14,exponent 64 DEFB +E6,{+00,+00,+00}	W, Z
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 $(\text{SIN } (\text{PI} * \text{W}/2))/\text{W}$.

Perform step v.

DEFB +04,multiply,17C6 DEFB +34,end-calc.,0028 RET	SIN ($\text{PI} * \text{W}/2$) = SIN X (or = COS X) 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. DEFB +2D,duplicate,19F6 DEFB +1C,sin,1D49 DEFB +01,exchange,1A72 DEFB +1D,cos,1D3E DEFB +05,division,1882 DEFB +34,end-calc.,002B RET	X X, X X, SIN X SIN X, X SIN X, COS X SIN X/COS X = TAN X Report arithmetic overflow if needed. TAN X 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 - $\text{PI}/2$ and $\text{PI}/2$, which is equal to the value in radians of the angle whose tan is X.

The approximation to 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 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.

1. DEFB +8C,series-0C,1A7F W, Y, Z
- 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	W, ATN X — case i.
DEFB +0F,addition,1755	W, ATN (-1/X) — case ii.
DEFB +34,end-calc.,002B	W, ATN (-1/X) — case iii.
RET	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,1DDB	X, SQR (1-X*X)
	DEFB +A1,stk-one,1A51	X, SQR (1-X*X), 1
	DEFB +QF,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 In 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 EXP (Y*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 EXP ($Y^* \ln X$) is formed.

DEFB +22,In,1CA9	Y, LN X
	Giving report A if X is negative.
DEFB +04,multiply,17C6	$Y^* \ln X$
DEFB +34,end-calc.,002B	
JP 1C5B,EXP	Exit via EXP to form EXP ($Y^* \ln X$).

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 $\frac{1}{2}$) in Abramowitz and Stegun *Handbook of Mathematical Functions* (Dover 1965) page 76. They can be checked by integrating $(\sin(\pi \cdot x/2))/x$ over the interval $U=0$ to π , after first multiplying by $\cos(n \cdot U)$ for each constant (ie. $N=1, 2, \dots, 6$) and substituting $\cos U=2 \cdot x \cdot x - 1$. 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)=0.00000001
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 PI, after first multiplying by COS (N*U) for each constant (i.e. for N=1, 2, ..., 8) and substituting COS U = 2^*X-1 . Each result should then be divided by PI.

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*.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*LN (4*(X+1)/5)/(4*X-1) over the interval U=0 to PI, after first multiplying by COS (N*U) for each constant (i.e. for N =1,2,...,12) and substituting COS U= 2*X-1. Each result should then be divided by PI.

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 $\frac{1}{2}$) 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-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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