W&W SOFTWARE PRODUCTS GMBH

CCO - Module

Owner's Manual

For the HP-41

Foreword

The CCD-Module was developed with the goal of providing a tool for improving all applications of the HP-41, and to simplify programming. User friendliness was an objective of particular importance in obtaining this goal.

The CCD-Module should support the programmer to such an extent that he can concentrate on the actual problem he is attempting to solve, rather than expend a great deal of effort in the mechanics of programming. Other sections of the program such as the formatting of input and output, can be assembled with the new functions supplied by the module, and problems which were previously insoluble can be solved.

More than a year was required for the development of this module. Special thanks are due for the support furnished by all of members of CCD (Computer Club of Germany), who made possible the production of this module in its present form, by their strong interest, by proposing routines for functions to be included in the module, and not least by the patience they exhibited. Further thanks are due to Dr. Baltes, the spiritual father of the module, through whose work in coordinating the programming much room was created for new functions; also to Mr. Holger Adelmann by whose stimulus and programming efforts the CCD-Module was optimized. Furthermore I thank everyone who tested our module during its development phase, and who enhanced the success of this hanbook by contributing applications for individual function. In this regard I am particularly grateful to Mr. Gerhard Kruse, who has written a variety of excellent and optimized programs for the handbook, and to Mr. Andreas Meyer for his literary work and for his superb preparation of figures. Furthermore I thank the Hewlett-Packard Company in Germany for their support, and last but not least, my friends Ken Emery, Stephan Abramson and Jeremy Smith who by their assistance in translation, have helped to make this module known throughout the world.

W&W Software Products GmbH

Wilfried Kötz

Wilfried Kötz, President

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Introduction

The CCD-Module is an extension for the HP-41 handheld calculator, which expands the calculator's vocabulary by nearly a 100 new functions. The module also provides several enhancements to the operating system of the HP-41, such as new catalogs and the capability of direct keyboard entry of lower case letters.

The ideas and wishes of many members of CCD (Computer Club of Germany) were particularly taken into account in planning the module; thus the module is named after the group.

The CCD-Module was programmed in machine code (MCODE), which sets it apart from other application modules. This design approach affords accuracy and rapid execution of the functions of the CCD-Module, which would have otherwise been unattainable.

The CCD-Module is a valuable addition to a "bare-bones" (i.e. an otherwise unenhanced) HP-41; however, as the size of the system increases, so do the possibilities afforded by the module. Thus, in particular, the CCD-Module supports all printer characters, the Extended Functions/Memory module and the Hewlett-Packard Interface Loop (HP-IL).

Chapter 1

Internal Design of the HP-41

Contents Chapter 1

Internal Design of the HP-41

Internal Design of the HP-41

Many functions of the CCD-Module (PEEK, POKE and "Synthetic") operate on all of the HP-41's RAM. This RAM includes the main memory (data registers, programs, key assignments and I/O buffers), the status registers (stack, flag register and other informations for the operating system) and extendend memory. The operating system uses memory locations to store status information. The careless use of some registers can crash your HP-41, lose the memory contents but will never harm the machine itself.

First, we will explain the design and the organization of RAM.

The HP 41 has two different types of memory

- Random Access Memory (RAM)
- Read Only Memory (ROM)

As only RAM can be altered by the user, its design and logical organization is the most interesting for us and will be covered first.

The RAM of the HP-41

HP-41 RAM comprises space for 1024 registers which are each 56 bits wide. The CPU is only capable of reading one register at a time. If it wants to alter one bit, it has to read the whole register, set or clear the bit and then write the whole register back again. Inside the CPU the register contents can be altered all together or in parts. The smallest part is the bit. Other parts are a nybble (4 bits) or a byte (8 bits). Bits, nybbles and bytes in a register are numbered starting with 0 from right to left. The bits are counted from 0 to 55, the nybbles from 0 to 13, and the bytes from 0 to 6.

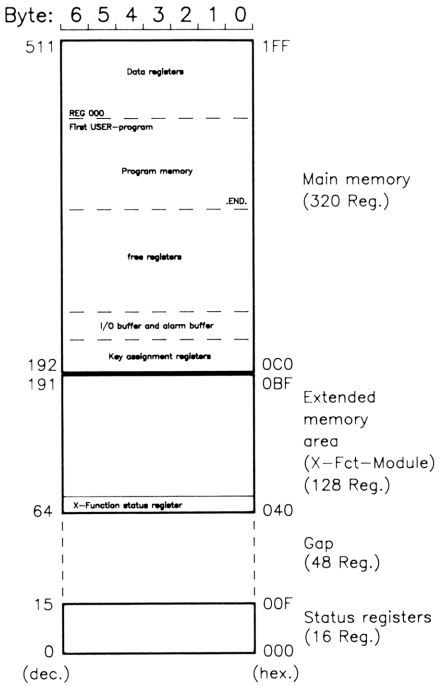
6		5		4		3		2		1		0		Byte number
13	12	11	10	9	8	7	6	5	4	3	2	1	0	Nybble number
55...	....	....	....	....	....	....	....	....	....	....	....	7654	3210	Bit number

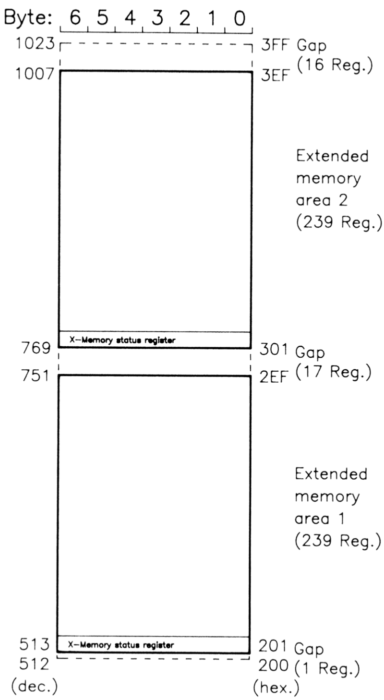
We should not not forget that this is only a logical division in a register.

The HP-41 CPU is able to address 1024 registers. The registers are numbered from 0 to 1023. The register number is an absolute value. It is only dependent on the physical location of the register in RAM. That the CPU is able to address 1024 registers does not mean that they are available to the user because the operating system needs certain gaps for its own use.

The Structure of RAM

HP-41 Memory Configuration





Up to now we only talked about the physical configuration of RAM. We shall now discuss the logical configuration of RAM. RAM is subdivided into three parts, according to its use:

1) status registers
2) main memory
3) extended memory

Designation	Start Address - End Address decimal			Start Address - End Address hexadecimal		
Status Registers	0	–	15	000	–	00F
Main Memory	192	–	511	0C0	–	1FF
Extended Memory:						
X Function Mem.	64	–	191	040	–	0BF
X Memory 1	513	–	751	201	–	2EF
X Memory 2	769	–	1007	301	–	3EF

We recognize that the extended memory is split in 3 parts (extendend functions and 2 extended memory). In the HP-41 C main memory ranges from register 192 to 255. It can be expanded in 64 register increments till the limit of 511 is reached.

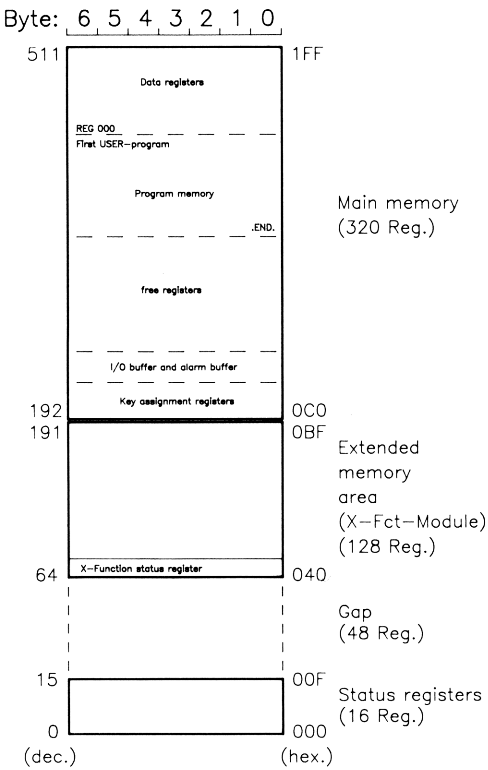
Main Memory

Four different kinds of data can be stored in the main memory:

- alphanumeric data
- programs
- key assignments
- I/O buffers

There is a special place in memory reserved for each data type. The operating system allocates space for each type of data on request.

Main Memory Configuration:



The operating system has four different modes of data storage:

- data storage
- program storage
- KA-storage
- I/O Buffer storage

Free memory is allocated for use by the operating system.

Data Registers

The data registers are located in the upper part of main memory. The commands **STO** and **ASTO** are used to save all kinds of numeric and alphanumeric data in the data registers. The register numbers used for that will be called "relative numbers" in this book.

The upper boundary for data registers is 511 absolute in the CV and CX, but in the C it is dependent on the number of memory modules plugged in.

Memory modules	Address (decimal)	Address (hexadecimal)	Remarks
0	192 – 255	0C0 – 0FF	HP-41 C basic configuration
1	256 – 319	100 – 13F	or Quad RAM; note that for the HP-41 CV and HP-41 CX all of these addresses are permanently built in.
2	320 – 383	140 – 17F	
3	384 – 447	180 – 1BF	
4	448 – 511	1C0 – 1FF	

The lower boundary is assigned by the operating system after executing the **SIZE** function.

Lower boundary = upper boundary + 1 - SIZE

As the upper boundary is 511 in most cases the formula reduces to:

lower boundary = 512 - SIZE

The lower boundary is called the **curtain** because it separates data registers from programs. In numbering the data registers, which is assigning relative addresses to the data registers, one starts at the curtain with 00.

The relation between absolute and relative addresses is shown by the table below:

Absolute Address	**Relative Address**
upper boundary	Size-1
Curtain	0
Curtain + nnn	Register nnn

One can imagine that the operating system needs the curtain to change relative into absolute addresses. Because of this the address of the curtain is stored in one of the status registers. The curtain is only a logical division between data and program registers.

Having explained where the data registers are, and how they are counted, numbered and addressed we will now explain how the data is actually stored in a register.

Data Registers (Inner Structure)

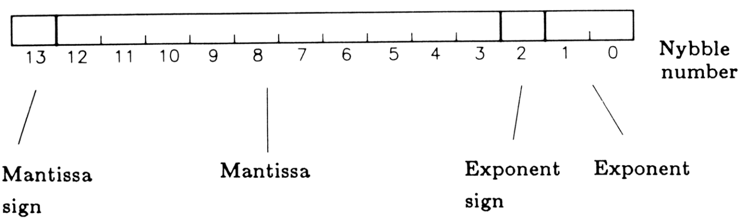
An important rule for this:

1) Everything we store with **STO** or **ASTO** occupies a whole register
2) There are no physical boundaries, only logical boundaries

The Register Structure

We distinguish between **numeric data** (numbers) and **alphanumeric** or **ASCII data.**

Layout of a Numeric Register



Examples of the Contents in a Numeric Register

9	8	7	5	1	2	0	0	0	0	0	0	0	0	≙ −8,7512
0	8	7	5	1	2	0	0	0	0	0	0	0	0	≙ 8,7512
0	1	0	0	0	0	0	0	0	0	0	0	1	2	≙ 1,0000 12
0	1	0	0	0	0	0	0	0	0	0	0	0	0	≙ 1,0000
9	8	7	5	1	2	0	0	0	0	0	9	8	5	≙ −8,7512 −15

The digit 0 indicates a positive number and the digit 9 indicates a negative number. The system in which each nybble contains a number between 0 and 9 is called BCD (Binary Coded Decimal). This means that nybble 13 of a numeric data register must either contain a 0 or a 9.

Design of an ASCII Register

1	X													
13	12	11	10	9	8	7	6	5	4	3	2	1	0	Nybble number
6		5		4		3		2		1		0		Byte number

All ASCII registers have the digit 1 in nybble 13. In the bytes 0 to 5 there can be up to 6 ASCII letters right justified. If a register contains only one letter the bytes 1 to 5 are null bytes and byte 0 contains the letter.

Examples for the Contents of an ASCII Register:

1	0	0	0	0	0	4	1	4	2	4	3	2	0	≙ "A B C "
1	0	0	0	0	0	2	0	4	1	4	2	4	3	≙ " A B C"
1	0	0	0	0	0	0	0	4	1	4	2	4	3	≙ "A B C"
1	0	0	0	2	0	4	1	4	2	4	3	2	0	≙ " A B C "

It is simple to determine the difference between number and ASCII registers: one must only analyse nybble 13. If it is 1 it is an ASCII register, if it is 0 or 9 it is a data register. The nybble 12 can have any value in calculators manufactured with serial numbers less than 2036.... All machines manufactured since then place a zero in nybble 12.

The CCD-Module contains a function which makes it very simple to analyse a register: **DCD** (DeCoDe the X register).

Program Memory (Design)

Program memory starts with the register below the curtain (see the main memory map). It ends with the **.END.** instruction. The structure of the program registers is excactly the opposite of the data registers, the first program is in the topmost register and later programs are in lower numbered registers.

The Meaning of the END Instruction

The significance of the **END** instruction. The beginning of a program is either behind the **END** of the last program or directly below the curtain. Every **END** instruction contains information for how far away is the next highest **LBL** or **END**. The shortest possible program is only an **END**.

When we start with a "MEMORY LOST" and key in some program steps then we have a program with an **END** already attached. That is easy to see: just key **RTN** and **R/S** (in run mode). The operating system has a permanent **END**: the **.END.** instruction. This means that after "MEMORY LOST" there already exists a program in memory: the **.END.**

The **.END.** has a special function: it is the last **END** in program memory and can not be deleted by normal means, nor should it be deleted by any other means.

When one writes or debugs programs and new steps are written into memory, null bytes are overwritten. When there are no null bytes available the operating system produces some. To do this the operating system shifts program memory down 1 register into the free memory space. By doing that 7 null bytes are produced. The information about the program length in the **END** is renewed.

"PACKING" removes unnecessary null bytes from program memory. Here too, the length information in the **END** is renewed.

Program Memory (Inner Structure)

How a Program Consists of Instructions

The operating system of the HP-41 has a list of all functions (CAT 3) each having a special code. When a function is keyed in (with **XEQ ALPHA function ALPHA**), the operating system searches this list. When the function is found the operating system stores the code and branches (if necessary) to the prompt for the argument byte. Then the function code and argument can be saved as program step.

A special feature of the HP-41 is that the function list can be increased by plug-in modules (such as the CCD-Module) and with programs created by the user.

The function list is made visible with the **CAT** instruction.

When the operating system searches for a program or a function it does so in the following sequence :

- user programs in the reverse order than they appear in catalog 1
- instructions from plug in modules starting with page 5 (TIME module)
- internal function list (CAT 3)

After keying in a function the operating system first makes a **syntax check**, making it normally impossible for us to key in functions like **STO M** or **TONE 57**. After the syntax check the operating system stores the function and argument code in the memory.

While executing a program the operating system reads the program line by line and interprets each instruction by branching to the appropriate machine code program. (There is a machine code program for every instruction). This part of the operating system is called the interpreter.

The interpreter works without knowing how the program code was assembled.

An understanding of this is the basics of synthetic programming. Synthetic programming is nothing more than making a program code by bypassing the syntax check.

Up to here we have only explained how an instruction is produced in program memory via the syntax check. We will now explain what the instruction itself looks like.

The Program Code of the HP-41

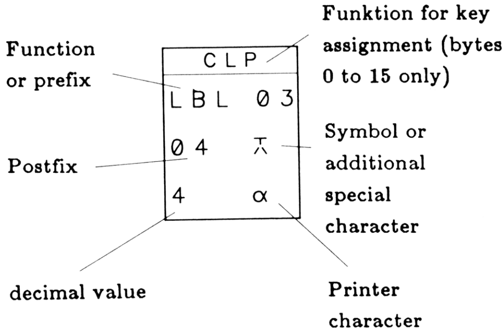
The program code of the HP-41 is byte oriented. This means that the interpreter works byte by byte through program memory. It works from top to bottom, or from high addresses to low.

256 instructions can be coded with one byte. However, the number of instructions alone from **STO**, **RCL** and **ASTO** with register numbers 00-99 is greater than 256. This problem is avoided in the HP-41 by using an argument byte (the second byte is an argument byte for an **STO** instruction). Depending on the number of argument bytes used we **may have one, two, three** or **multiple byte instructions.**

In all program lines the first byte is the instruction and all following bytes are the arguments.

In the following byte table all possible instructions are shown. The table is shown as a 16 * 16 matrix. This is because every byte can be sliced into two nybbles, the first nybble is the row number the second is the column number. Instructions in one row are always of the same type.

On the next two pages you will see the **HEX table** for the HP-41. Every square is structured like the following diagram:



Hexadecimal Byte/Function Table

HP-41C QUICK REFERENCE CARD FOR SYNTHETIC PROGRAMMING © 1982, SYNTHETIX

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
	CAT	@c (GTO..)	DEL	COPY	CLP	R/S	SIZE	BST	SST	ON	PACK	←(PRGM)	USR/P/A	2 _ _	SHIFT	ASN	
0	NULL 00 0 ◆	LBL 00 01 1 ×	LBL 01 02 2	LBL 02 03 3 ←	LBL 03 04 4 α	LBL 04 05 5 β	LBL 05 06 6 Γ	LBL 06 07 7 ↓	LBL 07 08 8 Δ	LBL 08 09 9 σ	LBL 09 10 10 ◆	LBL 10 11 11	LBL 11 12 12 μ	LBL 12 13 13 ∡	LBL 13 14 14 τ	LBL 14 15 15 Φ	0
1	0 16 16 Θ	1 17 17 Ω	2 18 18 δ	3 19 19 Å	4 20 20 å	5 21 21 Ä	6 22 22 ä	7 23 23 Ö	8 24 24 ö	9 25 25 Ü	. 26 26 ü	EEX 27 27 Æ	NEG 28 28 œ	GTO T 29 29 ≠	XEQ T 30 30 £	W T 31 31	1
2	RCL 00 32 32	RCL 01 33 33 !	RCL 02 34 34 "	RCL 03 35 35 #	RCL 04 36 36 $	RCL 05 37 37 %	RCL 06 38 38 &	RCL 07 39 39 '	RCL 08 40 40 (	RCL 09 41 41)	RCL 10 42 42 *	RCL 11 43 43 +	RCL 12 44 44 ,	RCL 13 45 45 −	RCL 14 46 46 .	RCL 15 47 47 /	2
3	STO 00 48 48 0	STO 01 49 49 1	STO 02 50 50 2	STO 03 51 51 3	STO 04 52 52 4	STO 05 53 53 5	STO 06 54 54 6	STO 07 55 55 7	STO 08 56 56 8	STO 09 57 57 9	STO 10 58 58 :	STO 11 59 59 ;	STO 12 60 60 <	STO 13 61 61 =	STO 14 62 62 >	STO 15 63 63 ?	3
4	+ 64 64 @	− 65 65 A	✱ 66 66 B	/ 67 67 C	X<Y? 68 68 D	X>Y? 69 69 E	X≤Y? 70 70 F	Σ+ 71 71 G	Σ− 72 72 H	HMS+ 73 73 I	HMS− 74 74 J	MOD 75 75 K	% 76 76 L	%CH 77 77 M	P→R 78 78 N	R→P 79 79 O	4
5	LN 80 80 P	X↑2 81 81 Q	SQRT 82 82. R	Y↑X 83 83 S	CHS 84 84 T	E↑X 85 85 U	LOG 86 86 V	10↑X 87 87 W	E↑X-1 88 88 X	SIN 89 89 Y	COS 90 90 Z	TAN 91 91 [	ASIN 92 92 \	ACOS 93 93]	ATAN 94 94 ↑	→DEC 95 95 _	5
6	1/X 96 96 ᵀ	ABS 97 97 a	FACT 98 98 b	X≠0? 99 99 c	X>0? 100 100 d	LN1+X 101 101 e	X<0? A 102 f	X=0? B 103 g	INT C 104 h	FRC D 105 i	D→R E 106 j	R→D F 107 k	→HMS G 108 l	→HR H 109 m	RND I 110 n	→OCT J 111 o	6
7	CLΣ T 112 p	X<>Y Z 113 q	PI Y 114 r	CLST X 115 s	R↑ L 116 t	RDN M [117 u	LASTX N \ 118 v	CLX O] 119 w	X=Y? P ↑ 120 x	X≠Y? Q _ 121 y	SIGN ⊢ ᵀ 122 z	X≤0? a 123 π	MEAN b 124 |	SDEV c 125 →	AVIEW d 126 Σ	CLD e 127 ⊢	7
	0 0000	1 0001	2 0010	3 0011	4 0100	5 0101	6 0110	7 0111	8 1000	9 1001	A 1010	B 1011	C 1100	D 1101	E 1110	F 1111	
	00 01 02 03	04 05 06 07	08 09 10 11	12 13 14 15	16 17 18 19	20 21 22 23	24 25 26 27	28 29 30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48 49 50 51	52 53 54 55	← bit numbers in a 7-byte register		

FLAGS (Register d)

00-10 general purpose
11 auto execute
12 doublewide
13 lower case
14 overwrite
15-16 IL printer
0 0 MAN
0 1 NORM
1 0 TRACE
1 1 TR/STACK
17 record incomplete
18 general use
19 cleared at
20 turn-on
21 prtr enable
22 num. entry
23 alpha entry
24 range ignore
25 error ignore
26 audio enable
27 USER mode
28 dec./comma
29 digit grouping
30 CAT
31 timer DMY/MDY
32 manual IL I/O
33 IL absolute manual
34 not used
35 not used
36-39 number of digits
40-41 display
0 0 SCI
0 1 ENG
1 0 FIX
1 1 FIX/ENG
42-43 trig mode
0 0 DEG
0 1 RAD
1 0 GRAD
1 1 RAD
44 cont. ON
45 system data entry
46 partial key sequence
47 SHIFT
48 ALPHA
49 low BAT
50 message
51 SST
52 PGRM
53 I/O
54 PSE
55 printer existence

HP-41C QUICK REFERENCE CARD FOR SYNTHETIC PROGRAMMING

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
8	DEG IND 00 128 ◆	RAD IND 01 129 ×	GRAD IND 02 130 x̄	ENTER↑ IND 03 131 ←	STOP IND 04 132 α	RTN IND 05 133 β	BEEP IND 06 134 Γ	CLA IND 07 135 ↓	ASHF IND 08 136 Δ	PSE IND 09 137 σ	CLRG IND 10 138 ◆	AOFF IND 11 139 λ	AON IND 12 140 μ	OFF IND 13 141 ∡	PROMPT IND 14 142 τ	ADV IND 15 143 Φ	8
9	RCL IND 16 144 Θ	STO IND 17 145 Ω	ST+ IND 18 146 δ	ST− IND 19 147 Ä	ST ✱ IND 20 148 á	ST/ IND 21 149 Ä	ISG IND 22 150 ä	DSE IND 23 151 Ö	VIEW IND 24 152 ö	Σ REG IND 25 153 Ü	ASTO IND 26 154 ü	ARCL IND 27 155 Æ	FIX IND 28 156 œ	SCI IND 29 157 ≠	ENG IND 30 158 £	TONE IND 31 159 ▒	9
A	XR 0-3 IND 32 160	XR 4-7 IND 33 161 !	XR8-11 IND 34 162 "	X12-15 IND 35 163 #	X16-19 IND 36 164 $	X20-23 IND 37 165 %	X24-27 IND 38 166 &	X28-31 IND 39 167 '	SF IND 40 168 (	CF IND 41 169)	FS?C IND 42 170 ✱	FC?C IND 43 171 +	FS? IND 44 172 ,	FC? IND 45 173 −	GTO XEQ IND IND 46 174 .	SPARE IND 47 175 /	A
B	SPARE IND 48 176 0	GTO 00 IND 49 177 1	GTO 01 IND 50 178 2	GTO 02 IND 51 179 3	GTO 03 IND 52 180 4	GTO 04 IND 53 181 5	GTO 05 IND 54 182 6	GTO 06 IND 55 183 7	GTO 07 IND 56 184 8	GTO 08 IND 57 185 9	GTO 09 IND 58 186 :	GTO 10 IND 59 187 ;	GTO 11 IND 60 188 <	GTO 12 IND 61 189 =	GTO 13 IND 62 190 >	GTO 14 IND 63 191 ?	B
C	GLOBAL IND 64 192 @	GLOBAL IND 65 193 A	GLOBAL IND 66 194 B	GLOBAL IND 67 195 C	GLOBAL IND 68 196 D	GLOBAL IND 69 197 E	GLOBAL IND 70 198 F	GLOBAL IND 71 199 G	GLOBAL IND 72 200 H	GLOBAL IND 73 201 I	GLOBAL IND 74 202 J	GLOBAL IND 75 203 K	GLOBAL IND 76 204 L	GLOBAL IND 77 205 M	X<>-- IND 78 206 N	LBL -- IND 79 207 O	C
D	GTO -- IND 80 208 P	GTO -- IND 81 209 Q	GTO -- IND 82 210 R	GTO -- IND 83 211 S	GTO -- IND 84 212 T	GTO -- IND 85 213 U	GTO -- IND 86 214 V	GTO -- IND 87 215 W	GTO -- IND 88 216 X	GTO -- IND 89 217 Y	GTO -- IND 90 218 Z	GTO -- IND 91 219 [	GTO -- IND 92 220 \	GTO -- IND 93 221]	GTO -- IND 94 222 ↑	GTO -- IND 95 223 _	D
E	XEQ -- IND 96 224 ᵀ	XEQ -- IND 97 225 a	XEQ -- IND 98 226 b	XEQ -- IND 99 227 c	XEQ -- IND100 228 d	XEQ -- IND101 229 e	XEQ -- IND102 230 f	XEQ -- IND103 231 g	XEQ -- IND104 232 h	XEQ -- IND105 233 i	XEQ -- IND106 234 j	XEQ -- IND107 235 k	XEQ -- IND108 236 l	XEQ -- IND109 237 m	XEQ -- IND110 238 n	XEQ -- IND111 239 o	E
F	TEXT 0 IND T 240 p	TEXT 1 IND Z 241 q	TEXT 2 IND Y 242 r	TEXT 3 IND X 243 s	TEXT 4 IND L 244 t	TEXT 5 IND M [245 u	TEXT 6 IND N \ 246 v	TEXT 7 IND O] 247 w	TEXT 8 IND P ↑ 248 x	TEXT 9 IND Q _ 249 y	TEXT10 IND ⊢ᵀ 250 z	TEXT11 IND a 251 π	TEXT12 IND b 252 |	TEXT13 IND c 253 →	TEXT14 IND d 254 Σ	TEXT15 IND e 255 ⊢	F
	0 0000	1 0001	2 0010	3 0011	4 0100	5 0101	6 0110	7 0111	8 1000	9 1001	A 1010	B 1011	C 1100	D 1101	E 1110	F 1111	

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Structure of multi-byte instructions

Two-byte instructions
- STO16 = 145,16   DSE IND 55 = 151,183
- LBL e = 207,127   FS?C IND Y = 170,242
- RCL b = 144,124   TONE 89 = 159,89
- X<>M = 206,117   ST+ IND N = 146,246
- LBL Q = 207,121   VIEW H(109) = 152,109

Two-byte special cases
- GTO IND = 174,reg. XEQ IND = 174,128+r
- GTO IND 09 = 174,9 XEQ IND X = 174,243
- XROM i,j = 160+i/4,64(i mod 4)+j
- WSTS = XROM 30,10 = 167,138
- short form GTO = 177+label,0
- GTO 12 = 189,0

Three-byte instructions
- long form GTO = 208,0,label
- GTO 32 = 208,0,32
- XEQ = 224,0,label
- XEQ D = 224,0,105
- END = 192,0,9+sum of status indicators 32(.END.), 4(rePACK), 2(decompile)

Variable length instructions
- TEXT = 240+n, n character bytes
- Append symbol counts as first char.
- ᵀ& = 241,38   ᵀ⊢)? = 243,127,41,63
- GTO ᵀ = 29,240+n, n character bytes
- GTO ᵀXYZ = 29,243,88,89,90
- XEQ ᵀ = 30,240+n, n character bytes
- XEQ ᵀA = 30,241,65 (synthetic)
- LBL ᵀ = 192,0,241+n, (key), n chars.
- LBL ᵀ. = 192,0,242,0,58 (synthetic)

One Byte Instructions

Without exception all instructions in row 0 and 2 through 8 are one byte instructions.

Register Functions

The functions **ARCL, ASTO, DSE, ISG, RCL,ΣREG, ST+, ST-, ST*,** **ST/** and **X<>** are register instructions. All expect a register number as an argument. These instructions are two byte instructions. The first byte specifies the action, the second the register number (**coded hexadecimally**). The codes are hex 00 to hex 63 for the registers numbered 0-99 and hex 70 to hex 74 are used for the stack registers T, Z, Y, X and L.

The instruction **RCL 87** is coded as follows: Hex 90 57

The first byte (instruction Byte) is the **RCL**, the second (argument byte) is 87.

What happens when there is a **RCL IND 87** in the program memory?

When a register is used indirectly, hex 80 is added to the argument byte, that means hex 57 + hex 80 = D7. You can see the different arguments and their hex equivalents in the byte Table.

There is one special thing with **RCL** and **STO** Instructions: As they are very often used with register numbers up to 15 there are special one byte instructions used for this purpose (rows 2 and 3). This not only helps to save memory space but even speeds up instruction time.

Flag and Display Format Instructions

The functions **CF, FC?, FC?C, FS?, FS?C, SF, ENG, FIX** and **SCI** are similar to the register functions. They are also placed in program memory in the same format with an instruction and an argument byte.

Register, flag and display format instructions all have the following bit structure : *bbbb bbbb iaaa aaaa*

Each letter stands for one **bit** of the code. The b's signify the instruction byte, the *i* means **indirect** (if it is one) and the 7 *a*'s stand for the argument.

Label Instructions

We need to distinguish between numeric and ALPHA labels. The numeric ones are coded like register instructions except that there is no "indirect". Again the labels 0 to 14 are coded as one byte instructions.

The bit structure of an ALPHA label is:

1100 *bbbr rrrrrrrr* 1111 *nnnn kkkkkkkk tttt tttt ...*

In the field *bbbrrrrrrrr* the distance to the highest label or **END** in memory is stored. *bbb* shows the byte difference and *rrrrrrrr* the register difference.

All ALPHA labels and **END**'s are linked together into a **global chain**. In every global instruction (ALPHA labels and **END** instructions) the distance to the preceding global instruction is stored.

The operating system administers these links by keeping them up to date when you write or change any program. When the operating system searches for a program it starts searching the global chain with the **.END.** instruction, again demonstrating the significance of the **.END.** instruction.

The end of the chain is found when a global instruction with the link value of "0" is found.

As the operating system thinks that all links are correct, the careless change of any data in the link can cause a "MEMORY LOST" or lock up your calculator.

What do these links look like: When you calculate the difference between the addresses of the first two bytes of two neighboring global instructions and express these in bytes and registers, you get the information which is stored in *bbbr rrrr rrrr array*. In our example (4 bytes and 1 register) this would be bin 1000 0000 0001 or hex 108.

The bits 1111*nnnn* follow the link array. The four ones (hex F) signify a character string (or rather, the byte hex F*n*; see also **text instructions!**). This means that we are dealing with an ALPHA label (and not an **END** instruction). The *nnnn* array indicates the number of letters in the label plus one, which follow this third byte. The first letter of this chain is reserved for the possible key assignment byte or keycode. The following bytes are the ASCII codes of the letters in the name. Thus the program line **LBL** *"ABCD"* consists of:

hex C0 00 F5 00 41 42 43 44

(here the distance and key code arrays are set to 0.)

END Instructions

The general bit structure of an **END** instruction is:

1100 *bbbr rrrr rrrr* 00*e*0 *xpdx*

As already explained in the section "Label instructions", the first 4 nybbles of this instruction are identical to those of an ALPHA label. The next eight bits though have a totally different meaning:

e bit: This bit is usually a 0. Only the **.END.** instruction sets this bit.

p bit: In a newly written program this bit is set in the **END** to indicate whether the program is packed. A packed program has all the null bytes removed, or "PACKed" away.

d bit: This bit is used by the operating system to signify that a program has been changed.

GTO and XEQ Instructions

Here too, we must distinguish between numeric and ALPHA arguments.

ALPHA **GTO**'s and **XEQ**'s have a simple structure:

GTO: bin 0001 1101 1111 *nnnn*
XEQ: bin 0001 1110 1111 *nnnn*

The first byte indicates whether we are dealing with a **GTO** (hex 1D) or an **XEQ** (hex 1E) instruction. The second byte (hex F*n*) indicates, similar to an ALPHA **LBL**, that a character string follows. These *n* letters indicate the name of the ALPHA **LBL** to which we want to jump. The instruction contains **no** information about the distance to the ALPHA **LBL** and no information about a possible key assignment!

If, during a running program, an ALPHA **GTO** or **XEQ** is executed, the operating system will first search the **global chain** starting at the **.END.**, up to the topmost label in the chain. If the corresponding ALPHA label is not found, the operating system will search for the instruction in catalogs 2 and 3.

Now to the instructions **GTO** and **XEQ** with numeric arguments. Their structure is:

Two byte	**GTO**:	bin 1011 *n'n'n'n'dbbb rrrr*
Three byte	**GTO**:	bin 1101 *bbbr rrrr rrrr dnnn nnnn*
	XEQ:	bin 1110 *bbbr rrrr rrrr dnnn nnnn*

You will surely recognize some of these arrays. The *nnnn* array of the two and three byte instructions contains the label number that program execution will branch to. In the two byte **GTO** this corresponds to the n'n'n'n'array, only here we have the label number plus 1.

When first executing one of these instructions, the *b*, *d* and *r* bits are set to 0. The calculator starts to search for the corresponding numeric label. As soon as this is found, the distance to the label is stored in the *b* and *r* bits. The *d* bit is the direction bit, one for backwards and zero for a forwards jump. Program execution continues at the label. The next time the leap instruction is executed, the operating system will know that the jump distance is already calculated, and therefore must not search for the label again. It branches directly to the calculated place without checking to see if the **employed label is the correct one, or if one even exists at all!**

The jump distance is measured from the byte containing the first part of the distance code to the byte which is directly in front of the label.

The short form **GTO** instruction is the two byte **GTO**. On the one hand program memory is saved, but on the other hand there is less space for the leap distance than in the three byte **GTO**, namely only 4 bits. This corresponds to a maximum leap of 15 * 7 + 6 = 111 bytes (*bbb rrrr* = 111 1111). This holds true for labels 0 to 14.

Text Instructions

All text instructions start with a byte of the format bin 1111 *nnnn*. The *nnnn* array indicates how many letters are in the text instruction, with a maximum of 15 letters.

How are letters stored? Corresponding to the *American Standard Code* for *Information Interchange* one byte is used for each letter. The abbreviation for this is **ASCII**.

Using the CCD-Module lower case mode it is possible to enter a byte of any value (this mode will be explained in detail later).

The byte hex 7F, depending on its position in the text string, has a different meaning. If it immediately follows the text byte (hex F*n*), it is not interpreted as a letter, instead indicating that the letters are to be appended to the ALPHA register without first erasing it. At any other place in the text string this byte will be interpreted as a "lazy T".

Number Input

If a number is entered as a program line, each digit has a correponding byte in program memory. Each of these bytes represents a one byte instruction, which simulates the manual pressing of a key:

hex code	digit keystrokes
10	0
11	1
12	2
13	3
.	.
.	.
.	.
19	9
1A	decimal comma
1B	EEX key
1C	CHS key

Just as manual number input is closed by pressing the **ENTER** key or by the execution of some other function, the operating system will treat numeric input from a program line as terminated as soon as a byte is read having a value other than hex 10 to 1C.

Instructions from Plug In Modules

The possibility of extending the instruction set of the HP-41 by plug in modules represents one of the strong points of this calculating system. How are these extra instructions coded? This calls for a detailed explanation of the behavior of the operating system:

As mentioned before, the HP-41, besides having RAM (for data), also possesses a ROM address space for the operating system and plug in modules. Just like RAM, this ROM has a predefined address area, which is divided into 16 sections of identical size (4k blocks). The first 8 sections are occupied by the operating system and several hard-addressed modules: TIME, Printer and HP-IL module. The other 8 sections are assigned to the ports, each getting two sections (max. 8k byte). Therefore a module always occupies exactly one or two of these 4k blocks. If a module is plugged into the calculator, the microprocessor is able to read instructions out of the corresponding addresses. Otherwise the ROM area will seem empty.

The first two bytes within such a plug in ROM have a special meaning. They are the identity number and the number of functions within this module. The following bytes form the function list of the module, and then begins the actual function coding. Thus each function is clearly identified by two numbers:

- by the identity number of the module containing the function

- by its place in the module list: the function number.

These two numbers comprise the familiar **XROM** number. This XROM number appears in program memory instead of a ROM function when the corresponding module has been removed from the calculator.

Since the calculator can display these two numbers without the module being plugged in, we can be sure that they are contained in the code for the corresponding function. Furthermore we know that these numbers characterize the function sufficiently and do not expect further information in the instruction. Now for the structure:

bin *1010 0iii iiff ffff*.

The *i* array indicates the ROM-ID, and the *f* array the function number. The ROM-ID and numbers of the functions are listed in the module handbooks. For example:

The function **RNDM** from the CCD-Module has the number 4 and the module ID is 9. Thus:

iiiii = 01001
ffffff = 000100

XROM 09,04 = bin 1010 0010 0100 0100 = hex A2 44

This coding allows 31 different ROM-IDs (The ID = 0 is not allowed!) and 64 functions per ROM.

Summary

Besides needing instruction codes, some functions also need information about a register address, a numeric label or such. Using the CCD-Module it is possible to build the single instruction codes by filling in the appropriate parameters. The following paragraphs will hopefully answer a variety of questions, and others may be solved simply by trying them out! The CCD-Module contains the necessary functions to execute this in a simple way.

Program Line Numbering

When talking about the structure of each instruction nothing was indicated for the program line number as these are not coded in the same way. A program, whose address is fixed by the global chain, is always interpreted starting at line 01. From that point on the operating system must keep track of where an instruction starts and how many bytes it needs. The leap distances stored in **GTO**'s and **XEQ**'s naturally support this regulation during program execution. This means that each byte must, from the beginning, be looked at as the first or postfix byte of a multiple byte instruction. If we are moving forwards in program memory, this poses no problem. But if we are moving backwards (for example with **BST**), the operating system must calculate where the preceding step starts.

Instructions in Plug In Modules (Parameter)

Why do programmable instructions from plug in modules not have parameters, as, for example, the **STO** instruction? If the operating system recognizes an **XROM** instruction, it supposes that it is a two byte instruction. Of course it would have been possible to plan an extra parameter. Since not every instruction is to be extended by a parameter, it would have to be possible to distinguish between those with and those without, **even if the corresponding module is not plugged in**, because otherwise the extra argument byte would be interpreted as a new program line and therefore cause confusion when counting the program lines (see above). Unfortunately, a distinction like this is not planned in the operating system; moreover there would hardly be any space for this in the XROM instructions.

Key Assignments (Design and Inner Structure)

Key assignments are of two different types:

- assignments of USER programs in the main memory
- assignments of functions and programs of plug in modules and mainframe functions.

Assignments of programs which are located in the main memory store the keycode in the fourth byte of the corresponding **LBL**. Therefore the information is not lost when saving a program to cards, tape, or extended memory.

Assignments of functions and programs of plug in modules (XROM numbers) store the assignment information in the key assignment registers. These key assignment registers start in the main memory at address 192 (hex 0C0). As soon as new assignments are made the old ones are pushed upward (to the higher addresses), and the new assignment is now at address 192. Thus, since registers from the main memory are needed, the number of free registers which are left for programming is diminished by one register per two key assignments.

To show the layout of the key assignment registers, we will look at the following example:

First we assign the function **BEEP** to key -11 and the function **SAS** (XROM 09,05) to key 15. These assignments can later be checked with **CAT'6**. If we now decode the register at address 192 with the key sequence 192 **PEEKR DCD ALPHA**, we can see the following ALPHA characters (the bytes are represented hexadecimally):

F0 A245 41 0486 09

or to be more exact:

F0	:	recognizing byte for key assignment registers (always F0)
A245	:	code of the two byte function **SAS** (XROM 09,05)
41	:	key code of key 15
0486	:	code of the function **BEEP**. The byte 04 serves only as filler byte and is "prefix" of all one byte functions from **CAT 3**
09	:	key code of the key -11

After erasing the key assignment **BEEP** on key -11, the contents of the key assignment register change as follows:

F0 A245 41 0486 00

We can see, when erasing a key assignment, that only the key code is set to 00. By this means the operating system knows that the key assignment is not active anymore. Still the plain existence of key assignment registers does not suffice for the calculator to recognize such. To be able to quickly recognize these assignments, so called "key assignment bits" are contained for all keys in the status registers * and e. When pressing a key, the operating system of the HP-41 first checks if the corresponding key assignment bit is set. If this is the case, the assigned function becomes active (only in USER mode!). If the bit is cleared, it does not even search for a possible assignment in the key assignment registers and program labels. This allows for a fast distinction of whether an assignment is present or not.

I/O Buffers (Design and Inner Structure)

I/O usually stands for input and output. Here it means 'dialog with RAM memory while avoiding the operating system'. The I/O buffer may be used by plug in modules. Some modules for example, the TIME and CCD-Module, each construct an I/O buffer and manage it independently. The I/O buffer appears to the operating system as a closed register block.

Each I/O buffer is identified by the base register which, is the lowest numbered register in the block. The four nybbles at the very right contain the most important information:

Base register: hex *ii ll*........

A copy of the buffer ID number is contained in nybbles 12 and 13 (*ii*), an ID number between hex 1 and hex E (hex F is reserved for the key assignment registers) is allowed. The two nybbles *ll* indicate the length of the buffer in registers.

When switching on the calculator, the operating system searches for buffers. If one is found, it erases the ID in nybble 13. Then it jumps to the register above the buffer and checks if there is another buffer there, and so on. If no more buffers are found, it branches into the plug in modules, which can reclaim their buffers by restoring nybble 13. Once all of the modules are checked we branch back into the operating system, which now erases the unclaimed buffers using a special PACK-I/O routine, and packs the buffer registers. This elucidates why, if the appropriate module is not plugged in when the calculator is turned on, the I/O buffer is erased.

Chapter 2

Operating System Enhancements

Contents Chapter 2

Operating System Enhancements

O. S. Enhancements

Enhancements of the Operating System

In contrast to the application modules commonly used with the HP-41, the CCD-Module expands the operating system of the calculator; thus as soon as the module is inserted, in addition to the CATalog 2 functions provided by the module, several functions "native" to the HP-41 are expanded in their scope and utility. In particular, the module provides the HP-41 with additional CATalogs and catalog functions, improvements for the **XEQ** and **ASN** functions, the capability of executing and programming synthetic functions directly from the keyboard and an enhanced alpha mode for the input of lower case and special characters (these extensions for the operating system are not available in very early HP-41s; see appendix entitled Compatibility).

The Catalogs

With the CCD-Module plugged into the calculator, the three previously existing CATalogs (6 in the HP-41CX) are expanded to a total of 16, and their functions are considerably enhanced. All of the new catalogs may be halted during execution by **R/S**, and subsequently stepped through in either direction using **SST** or **BST**. In contrast to the operation of the native catalogs of the HP-41, the SHIFT annunciator remains lit during the use of **BST**. The key sequence **SHIFT R/S** will even cause the catalog listings to be run in reverse. A running catalog may be speeded up by pressing any key other than **R/S** or **ON**. The catalogs will now be individually described.

CAT'0

CAT'0 shows the ID or AID of all devices in the Hewlett-Packard Interface Loop if any are present. When the catalog is stopped the displayed device can be selected by pressing **ENTER**, if you press **C**, and the selected device is displayed, a Selected Device Clear message will be sent to that device.

Pressing the back arrow key terminates the stopped catalog. When there is no HP-IL module in the calculator, the message "NO HPIL" is displayed.

CAT'1

This catalog executes the normal **CAT 1** of the HP-41 with no enhancements in the manner of execution. More information can be found in the HP-41 handbook.

CAT'2

This catalog is greatly enhanced in its operation in comparison to the standard CAT 2 of the HP-41. When it is first executed only the "headers" of each ROM are displayed (like the HP-41CX). If the catalog is halted with **R/S** the user may press **ENTER** to view the function block of the currently displayed "header". When the desired function is located, it may be executed directly from the catalog by pressing **XEQ** (the function will be inserted in program mode), or the function may be assigned to a key by pushing the **A** key. A second press of the **ENTER** button returns you to the catalog listing of only the ROM "headers".

CAT'3

This catalog executes the normal **CAT 3** of the HP-41. There are no changes in the manner of execution. More information can be found in the HP-41 handbook.

CAT'4

Like the function **EMDIR** of the Extended Functions module and CAT 4 of the HP-41CX, **CAT'4** displays the names lengths, and types of all files in extended memory. It has the additional feature of displaying the three additional file types used by the CCD-Module. The three file types are, I/O buffers (displayed as **B**), matrices (**M**), and key assignment files (**K**). If no extended memory is present the error message "**NO XF/M**" is displayed.

CAT'5

Executes the function **ALMCAT** of the TIME module. When there is no TIME module in the calculator the message "NO TIMER" is displayed.

A note regarding use of this instruction: If you have an older HP-41 equipped with an early revision of the 82104A card reader, and if no alarms exist, the calculator will appear to lock up with "**CAT'5**" in the display. This is not a system failure but a trivial quirk of the older machine; the next keystroke will cause the message to disappear and the pressed key will be executed.

CAT'6

CAT'6 shows all key assignments in keycode order, starting at the sigma + key and working its way horizontially and then dropping down to the next row etc.. On the right side you will see the keycode and on the left side the function will be displayed. Even synthetic key assignments ("RCL M", "TEXT 7") are shown correctly and not as an XROM number. Pressing "C" deletes the shown key assignment when the catalog is stopped. When there are no key assignments the message "NO KEYS"is generated.

CAT'7

Executes the function **DIR** of the HP-IL module. For a detailed description of this function see the owners handbook for the HP-IL module. When there is no HP-IL module in the calculator, the message "NO HPIL" is shown.

CAT'8 - CAT'F

These catalogs operate in a manner similar to the enhanced **CAT' 2** function of the CCD-Module, except that each of these catalogs addresses a single "ROM page" of the I/O ports of the HP-41. Both the catalogs and the ROM pages are numbered from 8_h to F_h; as one might therefore expect, each of the catalogs in this group has a number identical to the ROM page whose contents it examines. The I/O ports are addressed as follows:

Port 1:	Page 8 and 9
Port 2:	Page A and B
Port 3:	Page C and D
Port 4:	Page E and F

Each port of the HP-41 can thus be occupied by up to 8 Kbytes of program material. Since most application modules address the lower 4K of the port in which they reside (if it is a 4K application module), then the upper page of that I/O port is inaccessible under normal circumstances, and the appropriate catalog will display the message "NO ROM" for that address block.

The operating system of the HP-41 addresses 16 4k Byte pages. They are used in the following manner:

Page	**Used for**
0	*operating system (System ROM 0)*
1	*operating system (System ROM 1)*
2	*operating system (System ROM 2)*
3	*Not used by HP-41C and CV. Extended operating system of the HP-41 CX (System ROM 3)*
4	*Service Module or disabled IL printer*

5	*Used for the TIME module in the HP-41 C and CV. Extended operating system in the CX (system 5a and 5b with bank switching)*
6	*Used for by the printer ROM*
7	*Used for the HP-IL module (note: the printer ROM is contained in the HP-IL module, but can, using a certain switch, be put on the address area 4, and therefore be switched off)*
8	*Port 1 lower 4 kByte*
9	*Port 1 upper 4 kByte*
A	*Port 2 lower 4 kByte*
B	*Port 2 upper 4 kByte*
C	*Port 3 lower 4 kByte*
D	*Port 3 upper 4 kByte*
E	*Port 4 lower 4 kByte*
F	*Port 4 upper 4 kByte*

The read/write memory of the main and extended RAM expansion modules is managed in a different manner from ROM, and is not addressed to the port in which it occupies; thus it is possible to have all of your memory modules built into the HP-41, leaving the four I/O ports free for application pacs. One could even have the CCD-Module installed internally and addressed to port 3, leaving that port free for the HP-IL or printer modules; since the addresses of these ROMs are fixed internally by the HP-41, other modules may be inserted in the "ports" they occupy if special electronic modifications are arranged to enable this (for more information on this subject contact any W&W Software Products division).

ROM Memory Configuration

Page		Switched bank
F	PORT 4	
E	(Card Reader)	
D	PORT 3	
C		
B	PORT 2	
A		
9	PORT 1	
8		
7	HP-IL Module (MASS ST)	
6	Printer Module	
5	Time Module	CX : -EXT FCN
4	Reserved	
3	CX : -EXT FCN	
2	Operating system	
1		
0		

The Functions ASN and XEQ

To understand the following you should carefully read the section entitled *Functions for advanced programming* or have at least basic knowledge about synthetic programming.

O. S. Enhancements

ASN

The enhanced ASN function permits the following keyboard entries:

a) **The normal ASN function:** If the user presses **ASN** followed by **ALPHA**, the standard ASN function of the unenhanced HP-41 will be run.

b) **The assignment of any two byte function:** When you press the ASN key with the CCD-Module present you will see the following prompt: "ASN:____:____". The calculator is prompting for two decimal byte values. When you key in two bytes and press any key after that the two byte function is assigned to that key. If you first press the **H** key the operating system will prompt for hexadecimal values. With **ENTER** or "." you return to the decimal prompt.

c) **Assigning an XROM number:** The ASN function of the CCD-Module allows the assignment of XROM numbers without the module with that XROM number in the calculator. After you have pressed **ASN** you simply press **XEQ** and you will see: "ASN XROM:___". This prompt initially requests input of the ROM ID (i. e., the portion of the XROM number which precedes the comma, such as 9 or 11 for the CCD-Module). After the entry of these digits, the prompt becomes "ASN XROM:09:___", which indicates that input of the function ID, which is to say, the portion of the XROM number which follows the comma, is now expected (e. g. 01, for the function "**B?**" of the CCD-Module). The prompt becomes "XROM:09:01 _", which requests input of the code for the key to which the function is to be assigned.

XEQ

The enhanced **XEQ** function allows the following keyboard entries:

a) **The normal XEQ function:** If **ALPHA** or a number key is pressed after **XEQ**, we obtain the normal **XEQ** function. it is the same as the unenhanced **XEQ** function of the HP-41.

b) **The execution of any two byte function:** When you press **XEQ** and then **ENTER** you will see the prompt: "XEQ:____:____". The calculator is prompting for two decimal byte values. When you key in two values the function is executed or inserted into a program. If you press **H** before keying in any value you will see "XEQ"___"___"and the calculator prompts for a hexadecimal input. By pressing **ENTER** or "." you are returned to the decimal prompt.

c) **The execution of an XROM number:** The expanded **XEQ** function provided by the CCD-Module also permits the execution of function or application programs by XROM number, even if the module is not present in the HP-41. The key sequence **XEQ ENTER XEQ** generates the prompt "XEQ XROM:___"; this initially the input of the ROM ID number (the portion of the which precedes the comma, such as 09 or 11 for the CCD-Module). After the entry of these digit, the prompt becomes "XEQ XROM:09:___", which indicates that the input of the function ID, which is to say, the portion of the XROM number following the comma, is now expected (e. g., 01, for the function **B?** of the CCD-Module). If the calculator is in run mode and the appropriate module is present (the CCD-Module in our example), the function is immediately executed; otherwise the error message "NONEXISTENT" is displayed. If the HP-41 is in program mode then the instruction is inserted as a program line.

NOTE

To avoid confusion, throughout this manual, and in the programming of the CCD-Module, the appearance of the colon (:) preceding and input prompt indicates that the number to be input is of the decimal form, and if the colon is replaced by an apostrophe ('), the input is in the hexadecimal format.

Direct and Indirect Memory Access Functions

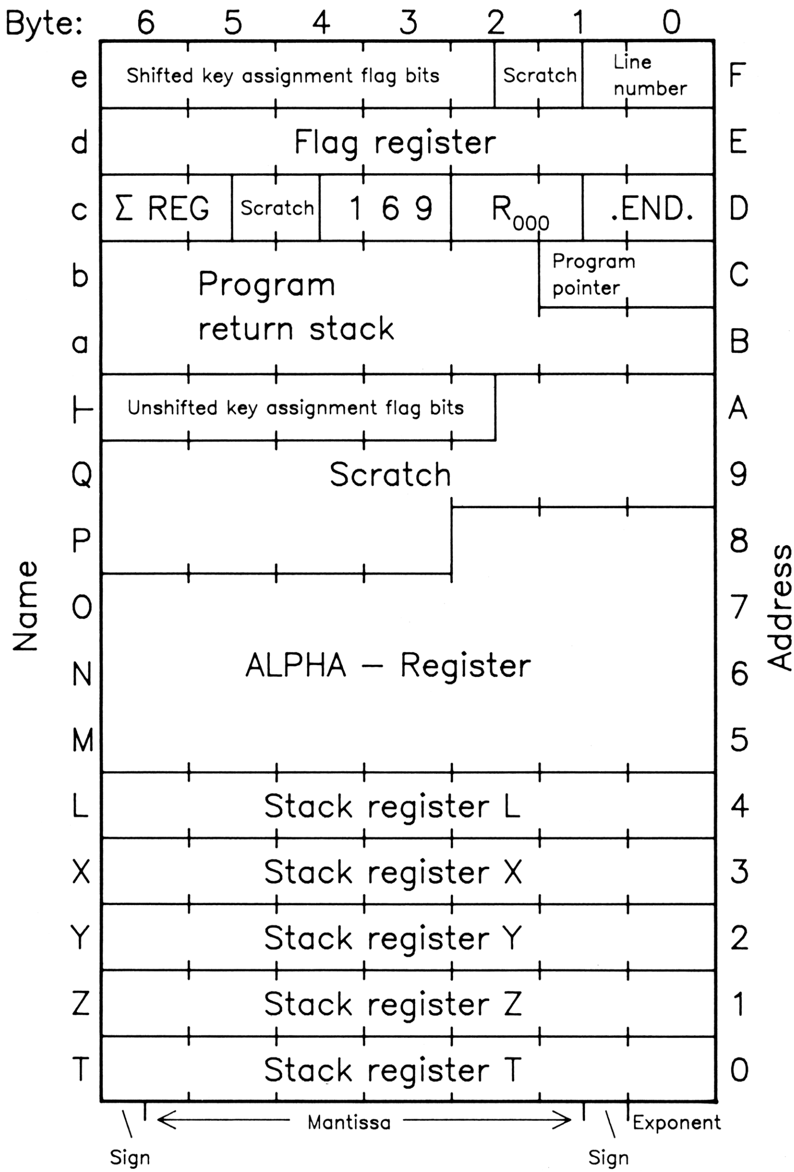
To simplify the insertion of synthetic program lines, the CCD-Module provides the capability for the direct entry of synthetic instructions. Note that for very early HP-41's these capabilities are not available, so one must use synthetic key assignments if this capability is desired from a very early machine (see appendix on **compatability**).

All memory access functions (**RCL**, **STO** ,**X<>**) can now be accessed directly from the keyboard and used to address all of the status registers of the HP-41. Thus access to and manipulation of the contents of registers **M**, **N**, **O**, **P**, **Q**, **a**, **b**, **c**, **d**, **e**, and lazy T is now no more complex than working with **X**, **Y**, **Z**, **T**, and **L**. The keystroke sequence used to apply these functions to the status registers is **RCL . d**.

Exercise caution in manipulating status register contents:

Altering the contents of registers ⊢ and a through e can lead to a "MEMORY LOST" condition or to a system crash if the register contents are improperly altered. Alteration of the "cold start constant" 169 in register c will always result in "MEMORY LOST". Before experimenting with these registers the user should throughly familiarize himself with the theory and practical applications of synthetic programming. Several of the references listed in the bibliography provide excellent discussion on the subject.

Physical Address Structure of the HP-41 Status Registers



Status registers

The Input of Any Alpha Character String

The CCD-Module enables the user to place in the ALPHA register, or enter directly into a program line, any of the 256 character bytes available on the HP-41 (see byte table, pages 1.20 - 1.21). This was previously possible using the Extended Functions module or synthetic programming techniques. Previously undreamed of possibilities, exploiting the use of direct entry of lower case and special characters, are presented especially to programmers making extensive use of printers and HP-IL peripherals. The short sample programs which follow make it apparent as to the extent to which memory space may be conserved by taking advantage of these functional enhancements:

Printout of the Text Line "Hewlett-Packard"

Using standard programming techniques

```
01◆LBL "HP"
02 "H"
03 ACA
04 SF 13
05 "EWLETT-
          "
06 ACA
07 CF 13
08 "P"
09 ACA
10 SF 13
11 "ACKARD"
12 ACA
13 CF 13
14 PRBUF
15 END

  PLNG "HP"
   46 BYTES
```

Using the lower case mode of the CCD-Module

```
01◆LBL "HP"
02 "Hewlett
  -Packard"
03 AVIEW
04 END

  PLNG "HP"
   26 BYTES
```


Sending an ESC-Sequence to the Think Jet Printer

using standard programming techniques

```
01♦LBL "WID
            E"
02 27
03 ACCHR
04 38
05 ACCHR
06 107
07 ACCHR
08 49
09 ACCHR
10 83
11 ACCHR
12 END

PLNG "WIDE"
   32 BYTES
```

by exploiting the lower case mode of the CCD-Module

```
01♦LBL "WID
           E"
02 "Æ&k1S"
03 ACA
04 END

PLNG "WIDE"
   19 BYTES
```

Thus it is readily apparent that the direct entry of lower case and special characters greatly facilitates the ease and "byte economy" in programming.

The lower case and special character entry mode of the CCD-Module is available in ALPHA mode when user mode is off. The special keyboard overlay included with your CCD-Module has the printer control characters and other special characters listed according to the color code which is described in the table on the next page.

User Mode on	Normal Alpha keyboard is active
Blue letters on key faces	Capital letters A-Z and some special characters
Blue letters overlay	Special characters available by pressing SHIFT
User mode off	Lower case mode active
Red letters on overlay	Special characters for unshifted keys (note: that there are no special notations for the lower case letters, which have normal key locations).
Green letters on overlay	Special characters available by pressing SHIFT

If the desired character is not available on the keyboard you can key it in by its decimal or hexadecimal value by pressing **SHIFT ENTER** for the decimal, or press **SHIFT ENTER H** if you want to enter the character in hex.

Warning:
It is not possible to cancel this byte prompt. If you see the prompt, just key in any character (except zero) and delete it afterwards. If the lower case mode is not desired it can be suspended by using the program TLC (*Advanced Programmers Functions*).

When a special character is also a printer or IL device control code it is shown on the right side of the key with its control code function name (see the overlay included with the CCD-Module).

Please note:
In version **-W&W CCD A** you must not key in a space in a program line while your are in lower case mode because program memory could be altered. If you want to key a space in a program line either turn the lower case mode off or use the byte prompt!

Chapter 3

Functions from Catalog 2

W&W FNS

Contents Chapter 3

Functions Appearing in Catalog 2

Functions from Catalog 2

B?

B? is used when you wish to determine whether a given I/O buffer exists. The buffer ID number, a decimal number from 1 to 14 which identifies the ROM which generated the buffer, is expected in X. If the function is executed as part of a running program, the program line immediately following it is executed if the buffer is present; the step is skipped if the buffer does not exist. If **B?** is executed from the keyboard, then a **YES** or **NO** is displayed depending on whether the buffer is present in the machine. This behavior is analogous to standard HP-41 conditional functions such as, **X=Y?**. If the absolute value of the integer portion of X is greater than 14 then a "DATA ERROR" message is generated.

Many modules create I/O buffers for intermediate data storage. For these I/O buffers the free memory space between the key assignments and the last program (starting with the **.END.**) is used. The room used by the I/O buffers is taken away from space available for programs. The following I/O buffers are known up to now:

Module	ID	Used for
DAVID-ASSEM	1 and 2	Where the program counter is and to save labels. Buffer 2 is for jumps to nonexistent labels.
CCD-Module	5	Wordsize, random number, active matrix
HP Advantage ROM	5	Same as the CCD-Module Matrix functions
TIME Module	10	Time alarms
Plotter Module	11	Intermediate storage for plotter and bar code instructions
HP-IL Development	12	Scope Mode and used for saving HP-IL commands
CMT 300	13	Used for I/O of the CMT measurement system
DATAFILE ROM	14	Active data file

Input

X register: *aa* (Buffer ID)

Example

We wish to determine if the Time Module has an active alarm buffer. This is accomplished by using the keystroke sequence

10 **B?**

If the buffer exists you will see a "**YES**" in the display, otherwise the message "**NO**" will be displayed.

Further Hints

The function **B?** uses only the absolute integer part of the number in the X register. Executing -5.678 **B?** will show the same result as 5 **B?**

Related Functions

CLB, GETB, SAVEB

CLB

The function **CLB** clears an I/O buffer. The buffer ID number (between 1 and 14) is expected in X.

Input

X register: *aa* (Buffer ID)

Example

In order to create more free registers in RAM we wish to clear the time alarms currently in our HP-41. We do this with the key sequence

10 **CLB**

Further Hints

The function **CLB** uses only the absolute integer part of the number in the X register. Executing -5.678 **CLB** will show the same result as 5 **CLB**. If the specified buffer does not exist no error message is generated.

Related Functions

B?, GETB, SAVEB

SAS

This sets the autostart flag of the CCD-Module. When this flag is set, the HP-41 begins program execution from its current position in program memory whenever the calculator is turned on using the **ON** key. Its operation is different from user flag 11 which is cleared every time the HP-41 is turned on and must be set each time before the calculator is turned off. With **SAS** one can turn off the calculator without interrupting a program, since execution will resume at the next step when the HP-41 is turned on.

Input

none

Example

The following program must not be interrupted even by toggling the calculator off then on with the **ON** key. You only have to put the **SAS** function in your program and if you turn the calculator off and on again your program will continue from the same location. In our example the program may not be stopped when **PMTK** is executed.

```
01  SAS
02  "YES/NO YN"
03  PMTK
04  CAS
05  END
```

Further Hints

The flag that controls this function resides in byte 4 of the c status register. It uses bit 6 of this byte. Therefore this flag is not one of the 56 standard HP-41 user flags.

Related Function

CAS

CAS

The function **CAS** (clear autostart) clears the autostart flag of the CCD-Module.

Input

none

Further Hints

The CCD-Module autostart flag is not in flag register d but is in status register c (Reg. 13, Byte 4, Bit 6).

Related Function

SAS

– W & W FNS

RNDM

The function **RNDM** creates a random number which is written into the X register. The random number has a value between 0 and 1.

Input

none, but you can create a starting value with the function **SEED**.

Examples

With a starting value of 0.1 the following random numbers are generated:

0.1 **SEED**
RNDM 0.311327
RNDM 0.753794
RNDM 0.222201
RNDM 0.447348 etc.

Further Hints

The most recent random number will be saved in the I/O buffer of the CCD-Module. Any new random numbers will be created from the previous one using the following Algorithm: X=FRC (Buffer*9821+0.211327). If there is not enough memory for the I/O buffer, the message "NO ROOM " is displayed.

Caution:

In the version **-W&W CCD A** of the CCD-Module values output by **RNDM** which are less than 0.1 are not normalized correctly. When you use the random number instantly there will be no mistake, but if it is to be saved in a data register you must use **FRC** right after **RNDM** because otherwise all random numbers smaller than 0.1 are changed to zero.

Related Function

SEED

SEED

SEED furnishes an initial value, which is stored in the I/O buffer of the CCD-Module, for the computation of a random number using the function **RNDM**. Only the fractional part of the X register is used for the starting value.

Input

X register: starting value, only the part to the right of the decimal point is used.

Further Hints

With **CLX SEED** you can clear the random number register from the buffer, thus freeing one more register for program storage.

Related Function

RNDM

SORT

This function sorts the contents of registers starting with register R_{iii} up to register R_{jjj}. Alpha Data may also be intermingled with the data to be sorted. The largest value will be stored in register R_{jjj}. By choosing clever parameters you can either sort high to low or low to high.

Input

X register: *iii.jjj*

Examples:

The contents of the registers 1-10 will be sorted first low to high and then high to low. The original order of the register contents is

```
R01=   0.1356
R02=   3.5462
R03=   9.7363
R04=   2.4138
R05=   7.8467
R06=   4.0629
R07=   4.0506
R08=   2.9577
R09=   9.2921
R10=   0.1220
```

W & W FNS

1) 1.010 **SORT**

R01=	0.1220
R02=	0.1356
R03=	2.4138
R04=	2.9577
R05=	3.5462
R06=	4.0506
R07=	4.0629
R08=	7.8467
R09=	9.2921
R10=	9.7363

2) 10.001 **SORT**

R01=	9.7363
R02=	9.2921
R03=	7.8467
R04=	4.0629
R05=	4.0506
R06=	3.5462
R07=	2.9577
R08=	2.4138
R09=	0.1356
R10=	0.1220

Further Hints

When ALPHA and numerical data are sorted together, ALPHA data is considered greater than numerical data.

Related Function

SORTFL

Chapter 4

Matrix Functions

– ARR FNS

Contents Chapter 4

Matrix Functions

– ARR FNS

Functions for the Construction and Manipulation of Arrays

In this section we shall describe the use of the CCD-Module in the construction and manipulation of one and twodimensional arrarys. We shall begin with two observations:

The arrays may contain numeric as well as alphanumeric data. Arrays with only numeric elements are called twodimensional matrices. All mathematic functions can be performed only on arrays such as this. In this chapter all arrays are illustrated in square cells with borders to convey the relationships between these elements and the memory locations used in storing them. For example,

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \end{pmatrix} \;\hat{=}$$

a_{11}	a_{12}	a_{13}	a_{14}
a_{21}	a_{22}	a_{23}	a_{24}
a_{31}	a_{32}	a_{33}	a_{34}

Arrays can be constructed and stored in either main or extended memory. In the first case they are called RAM Arrays, and in the second they are called XM Arrays. Except some few differences in names and arrangements both kinds of arrays are the same. In Catalog 4 of the CCD-Module the XM Arrays can be recognized by the letter M (for Matrix).

Organization and Construction of Arrays

Each array consists of status information and its element values. The status information contains the array name, the array dimensions, and a pointer. A status register is set aside for RAM Arrays and it contains this information except for the name. The name is given by the position of the register: the RAM Array "R012" has its status register in register 12. Its elements are saved in the registers immediately following. So that the status information cannot be destroyed when handling register 12, (for example **ST+ 12** or **RCL 12**) it is arranged in the form of ALPHA data. The status information of XM Arrays is contained within the file status register of the extended memory file (usually called the "file header") and therefore no extra memory is needed.

Each element is marked through its position in the array, i.e., by specifying the row and column in which it is found. We shall call these positional numbers the row and column indices, and designate them by the letters **i** and **j**. The smallest possible value for *i* and *j* is 1, the greatest possible for *i* is **m** and for *j* it is **n**. Therefore:

Row index $1 <= i <= m$

Column index $1 <= j <= n$

For all array functions: **If the value 0 should be given for *i* or *j*, it is changed to 1.**

To construct an array the command **MDIM** is used. By giving the array name (in the ALPHA register) and the array dimensions (X value= *mmm.nnn*) the suitable file is constructed. The dimension may be input later, however, using the function **DIM**.

The position and size of the arrays (matrices, vectors, etc.) are managed automatically using new functions provided in the CCD-Module. Therefore the user does not have to keep track of the position of single registers or rather, single elements. For example, matrix arrays can be arranged in the extended memory, and these arrays can be combined with matrix arrays that are positioned in main memory. The CCD-Module makes possible a wide variety of unified input instructions for performing these combinations.

Input Commands for Array Functions:

All CCD-Module matrix combination functions expect their input parameters in the ALPHA register. If, for instance, there are three matrices of the same size, "A", "B", and "C", which have previously been dimensioned with **MDIM**, then the functions for combining matrices have to obey the following rules with regard to the alpha register:

1) We want to combine matrix "A" with matrix "B" and put the resultant array in matrix "C". The input into the ALPHA register would be "A,B,C," with the operands being separated by commas. Now the desired function (for example M*M) may be executed.
2) Matrix "A" is to be combined with matrix "B" the resultant matrix is placed in array "B". The ALPHA register should look as follows: "A,B,B" or simply "A,B". If the resultant array is not mentioned, the result is placed in the second array. (Caution: When using the function **M*M** the resultant array should not have the same dimensions as one of the operands, as this will lead to an error message!)
3) We want to matrix "A" with itself and put the resulting array in matrix "C". The ALPHA register would look as follows: "A,A,C" or simply "A,,C". Since the second operand is identical to the first one, it does not have to be mentioned. But in no case should you forget the second separating comma. (Rule: There should always be two commas to the left of the resultant matrix unless the result matrix is the same as the second operand.)

4) We want to multiply matrix "A" with itself and put the resultant matrix into "A". So the ALPHA register contains: "A,A,A" or simply "A". This is a logical presumption after having read all of the above. If a combination function finds only one name in the ALPHA register, the operation will only be done on this array and the result put there as well.
5) If one operand is given the name "X", the other operand will be combined with the contents of the X register.

Matrices that are located in the main memory always have a name consisting of four characters. The first letter must always be "R" (for register). The next three characters consist of numbers which specify the relative address of the first register of the matrix (see the next section **MDIM**). In the rest of the chapter the abbreviations *OP1*, *OP2*, and *RES* are used as names for the data arrays (Operand 1, operand 2, result).

Functions for the Construction of Data Arrays

MDIM

MDIM is used to create one or two dimensional arrays, and to redimension them.

Input

ALPHA register: name of array

The array name is also the name of the file. For files in main memory, this name must take on the form "Rxxx", where xxx is a three digit decimal number giving the relative address of the status register, which is also the first register of the stored array (subsequent registers contain the matrix elements). For arrays in extended memory the first seven characters in alpha are used. The name "X" may not be used, since for several matrix functions it names the X register as an operand. If ALPHA is cleared when **MDIM** is executed, then no array has been specified, and the function operates on the current extended memory file which must be of file type M.

X register : *mmm.nnn* (Array dimensions)

mmm is the number of rows and *nnn* is the number of columns. If either *m* or *n* have the value 0, it will be changed to 1.

Examples

To construct an array named "MATRIX" with 3 rows and 4 columns, in extended memory, the following key sequence is used:

"MATRIX"
3.004
MDIM

To build the same array in the main memory, starting with register 10, we execute:

"R010"
3.004
MDIM

In this case registers R11 through R22 will contain the twelve elements of the 3 * 4 array. The field created by either of these operations will have elements which we designate a_{11} to a_{34}, as shown below

Column

	a_{11}	a_{12}	a_{13}	a_{14}
Row	a_{21}	a_{22}	a_{23}	a_{24}
	a_{31}	a_{32}	a_{33}	a_{34}

Using

"MATRIX"
4.004
MDIM

the array "MATRIX" is redimensioned so it now has the elements a_{11} - a_{44}.

Further Hints

When a new array is created, all of its elements are set to 0. This is true for arrays both in main memory and XM. However, when an array is redimensioned, only the newly added elements are cleared; the values in the old elements constituting the original array are retained. When the dimension of an array is reduced, the values which were in the elements are now superfluous, and are lost.

The values of the array elements are saved row by row, i. e., the value of the last element of the first row is followed by the value of the first element of the second row. When redimensioning an array the sequence of the rows is preserved, although as a rule, their relative positions are altered after the redimensioning).

Example: Array "A" is formed with dimensions of 2 * 3 and contains the values 1-6 in the following order:

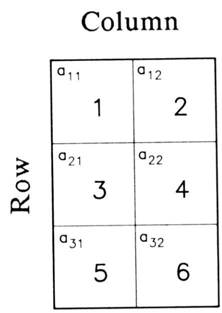
Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

After redimensioning using the key sequence

"A"
3.002
MDIM

we obtain the following array



If an array is enlarged while redimensioning, the new elements are initialized with the value 0. If an array in XM is made smaller by redimensioning the extra elements are lost after the operation. In a RAM array only the dimension which is stored in the status register is changed, the registers and their contents are preserved.

Related Function

DIM

DIM

DIM is used to recall the dimensions of an array.

Input

ALPHA register: Array name

Output

X register : *mmm.nnn* (this number represents the array dimensions. *mmm* accounts for the number of rows, and *nnn* for the number of columns.)

Further Hints

If, while dimensioning an array, *m* or *n* have the value 0, the value 1 is used. This is shown in the output of **DIM**, by the following example:

"R000"
CLX
MDIM
DIM

the result is the number 1.001 in the X register.

Related Function

MDIM

Functions for the Manipulation of Element Pointers

?IJ

The function **?IJ** places in X the current pointer position *iii.jjj* of the current data array (the stack is lifted).

Input

None

Example

In an existing matrix named "MAT" we shall set the element pointer to a_{12}, the second element of the first row, using the function **IJ=A**, and the keystroke sequence:

"MAT"
1.002
IJ=A

At a later point in the program we want to recall the pointer position. We do this using:

?IJ

In this case, the function **?IJ** puts the value 1.002 into the X register.

Further Hints

The function **?IJ** does not need an ALPHA input. The output is always the pointer position of the current data array!

Related Functions

?IJA, IJ=, IJ=A

?IJA

The function **?IJA** places the pointer position *iii.jjj* of the **specified** data array into the X register (the stack is lifted).

Input

ALPHA register: Name of the data array

Example

After dimensioning a matrix we wish to determine the location of the element pointer and to make it the current array. This is accomplished by performing
"MAT"
3.003
MDIM
?IJA

Now the matrix "MAT" is the *current* matrix. Since the value 1.001 has been placed in X, the pointer is set to a_{11} after the array was redimensioned.

Further Hints

After executing the function **?IJA** the specified data array has become the *current* data array. The information about the *current* data array is stored in the I/O buffer of the CCD-Module, i.e. if there are no existing registers for this buffer, the error messages "PACKING" and "TRY AGAIN" show up. If there is no name mentioned, the error message "NAME ERR" will be displayed.

Related Functions

?IJ, IJ=, IJ=A

– ARR FNS

IJ=

Through the function **IJ=** the pointer of the *current* data array is put on the element with the row index *iii* and the column index *jjj*.

Input

X register : *iii.jjj*

Example

The pointer of the current data array should be positioned to the element a_{12}, so that the value of this element can be recalled. This is accomplished by

1.002
IJ=
C>+

Further Hints

If there is no existing *current* data array (for example because of loss of the I/O buffers) the error message "NONEXISTENT" will be generated.

Related Functions

?IJ, ?IJA, IJ=A

IJ=A

With the function **IJ=A** the pointer of the *specified* data array will be positioned to the element with the row index *iii* and the column index *jjj*.

Input

X register	:	*iii.jjj*
ALPHA register	:	Name of the data array

Example

After dimensioning a matrix with the name of "R010", the pointer may be set to the last element of this matrix. This happens with the following steps:

"R010"
5.005
MDIM
IJ=A

Further Hints

After executing the function **IJ=A** the specified data array is the *current* data array. Information about the *current* data array is saved in the I/O buffer of the CCD-Module, i.e. if there are no free registers present to create this buffer, the error messages "PACKING" and "TRY AGAIN" are generated. If no name is mentioned, the error message "NAME ERR" will be displayed.

Related Functions

?IJ, IJA, IJ=

– ARR FNS

Input and Output Functions for Data Arrays

>C+, >R+, C>+, C>-, R>+, R>-

These six functions are the input and output functions that the CCD-Module uses for all data arrays. Storage or recalling is always done from the current pointer position (see **IJ=** and **IJ=A**). The following nomenclature has been established for this group of functions.

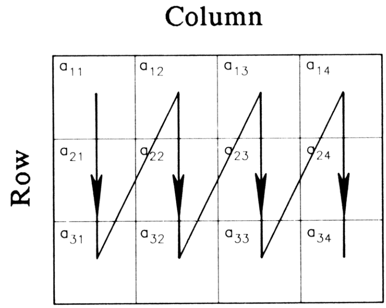
A preceding ">" sign means input function: The element at the current pointer position will be filled the value in the X register.

A following ">" sign denotes an output function: The stack is lifted and the element at the current pointer position will be written to the X register. The "+" sign means that the pointer will be incremented by one position, and the "-" sign means that the pointer will be decremented one position.

The letter "C" (column) means that storing and recalling will be done columnwise, the letter "R" (row) signifies that this will be done rowwise.

>C+

The function **>C+** enabes us to fill in data array elements column by column, i.e. in an array with *i* rows and *j* columns, the value of *i* is incremented by 1. The order of element input is shown clearly in the diagram below:



Input

X register: value to be placed in array element (may be Alpha data!)

Example

The following program shows how to input the elements of a matrix columnwise.

```
01*LBL  "CIN"
02 "R010"
03 CLX
04 IJ=A

05*LBL 01
06 STOP        input your data here and then hit R/S
07 >C+
08 GTO 01
09 END
```

– ARR FNS

A similar program for the output of elements of a matrix is explained in the section for the function **C>+**.

Further Hints

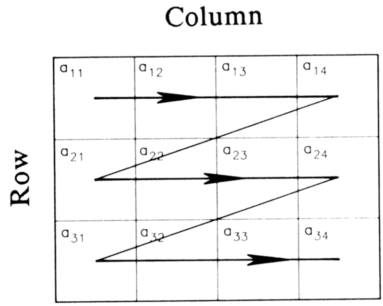
When the last element of a matrix has been input, the pointer is positioned on a nonexistent element. Attempts to store or recall further elements will result in the error message "END OF FL".

Related Functions

>R+, C>+, C>-, R>+, R>-

>R+

The function **>R+** makes it possible to store data array elements row by row, thus in an array with *i* rows and *j* columns the value of *j* will be incremented by one after the input of each element. The order of the element input can be clearly seen in the diagram below:



– ARR FNS

Input

X register: value to be placed in array element (may be ALPHA data)

Example

The following program shows how to input the elements of a matrix row by row:

```
01*LBL "RIN"
02 "R010"
03 CLX
04 IJ=A

05*LBL 01
06 STOP          enter your data here and then hit R/S
07 >R+
08 GTO 01
09 END
```

A corresponding program for the output of elements of a matrix row by row is explained under **R>+**.

Further Hints

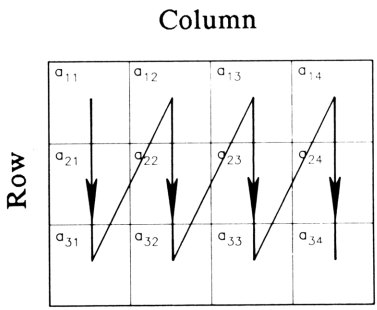
When the last element of a matrix has been input, the pointer is positioned to a nonexistent element. Attempts to put in or recall further elements will generate the error message "END OF FL".

Related Functions

>C+, C>+, C>-, R>+, R>-

C>+

The function **C>+** allows the recalling data array elements column by column, i.e. in an array with *i* rows and *j* columns the value of *i* will be incremented by one after each element is output. The stack is raised and the data element will be written to X. The order of the element output can be clearly seen in the diagram below:



Input

none

Example

The following program is a simple way to recall the elements of a matrix:

```
01*LBL "COU
          T"
02 "R010"
03 CLX
04 IJ=A

05*LBL 01
06 C>+
07 PSE
08 GTO 01
09 END
```


Further Hints

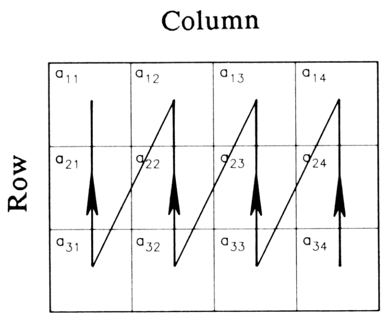
When the last element of a matrix has been output, the pointer will be positioned to a nonexistent element. Attempts to recall further elements will generate the error message "END OF FL".

Related Functions

>C+, >R+, C>-, R>+, R>-

C>-

The function **C>-** allows us to recall data array elements column by column, i.e. however, an array with *i* rows and *j* columns will the value of *i* reduced by 1 after each execution of the function. The stack is raised and the array element is written to X. The order of the element output can be seen clearly in the diagram below:



Input

none

Example

The following program shows a simple way to output the elements of a matrix column by column, but in reverse order.

```
01*LBL "CBO
        UT"
02 "R010"
03 DIM
04 IJ=A

05*LBL 01
06 C>-
07 PSE
08 GTO 01
09 END
```

Further Hints

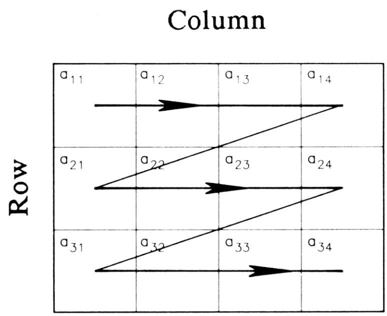
When the last element of a matrix has been output, the pointer will be positioned to a nonexistent element (in this case, the element 0.000). Attempts to recall further elements will result in the error message "END OF FL".

Related Functions

>C+, >R+, C>+, R>+, R>-

R>+

The function **R>+** enables us to output data array elements row by row, i.e. in an array with *i* rows and *j* columns, the value of *j* will be incremented by 1 after the element is output. The stack is be raised and the array element is written to X. The order of the element output is shown clearly in the diagram below:



Input

none

Example

The following program shows how to output the elements of a matrix row by row:

```
01*LBL "CBO
          UT"
02 "R010"
03 CLX
04 IJ=A

05*LBL 01
06 R>+
07 PSE
08 GTO 01
09 END
```

– ARR FNS

Further Hints

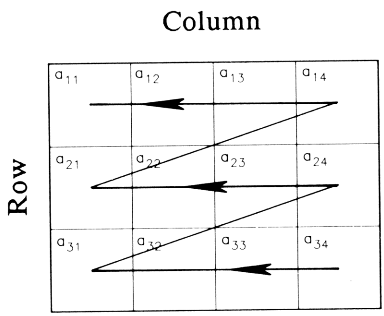
When the last element of a matrix has been output, the pointer will be positioned to a nonexistent element. Attempts to further recall elements will generate the error message "END OF FL".

Related Functions

>C+, >R+, C>+, C>-, R>-

R>-

The function **R>-** allows us to output data array elements row by row, i.e. for an array with *i* rows and *j* columns, the value of *j* will be decremented by 1 after each element is output. The stack is raised and the array element is written to X. The order of the element output is clearly shown in the diagram below:



Input

none

Example

The following program shows how to recall the elements of a matrix backwards, row by row

```
01*LBL "RBO
        UT"
02 "R010"
03 DIM
04 IJ=A
05*LBL 01
06 R>-
07 PSE
08 GTO 01
09 END
```

Further Hints

When the last element of a matrix has been output, the pointer will be positioned to a nonexistent element. Attempts to recall further elements will generate the error message "END OF FL".

Related Functions

>C+, >R+, C>+, C>-, R>

Functions for Shifting and Exchanging Elements

C<>C

The function **C<>C** exchanges column *kkk* with column *lll* of the specified data array.

Input

X register : *kkk.lll*
ALPHA register : array name

Example

We want to exchange the first column of the data array shown below with the second column; the original data array is:

Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

After the sequence 2.001 **C<>C** we get the following array:

Column

Row	a_{11} 2	a_{12} 1	a_{13} 3
	a_{21} 5	a_{22} 4	a_{23} 6

Related Functions

R<>R, MOVE, SWAP

R<>R

The function **R<>R** exchanges row *kkk* with row *lll* of the specified data array.

Input

X register : *kkk.lll*
ALPHA register : array name

Example

We want to exchange the first row of the data shown below with the second row; the original data array is:

Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

After the sequence 2.001 **R<>R** the following array is left:

Column

Row			
	a_{11} 4	a_{12} 5	a_{13} 6
	a_{21} 1	a_{22} 2	a_{23} 3

Further Hints

The exchanging of rows occurs when pivoting a matrix.

Related Functions

C<>C, MOVE, SWAP

MOVE

The function **MOVE** copies the specified elements from the *OP1* array to the specified elements in the *RES* array. Only "rectangular" parts of a matrix can be moved; the block is determined by the description of two opposing corner elements *iii.jjj* and *kkk.lll* of the *OP1* matrix. The upper left corner, *mmm.nnn* of the goal block must be specified in the Z register.

Input

X register : *iii.jjj*
Y register : *kkk.lll*
Z register : *mmm.nnn*
ALPHA register : *OP1,RES*

Example

We wish to transfer the elements a_{32}, a_{33}, a_{42} and a_{43} of the illustrated 4*3 data array "A" into data array "B". The goal elements in array "B" shall be b_{22}, b_{23}, b_{32} and b_{33}. The data arrays "A" and "B" are shown below:

Matrix A

Column

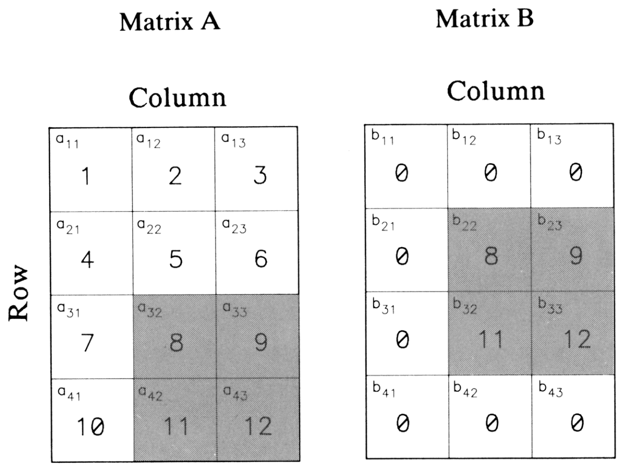
Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6
	a_{31} 7	a_{32} 8	a_{33} 9
	a_{41} 10	a_{42} 11	a_{43} 12

Matrix B

Column

b_{11} 0	b_{12} 0	b_{13} 0
b_{21} 0	b_{22} 0	b_{23} 0
b_{31} 0	b_{32} 0	b_{33} 0
b_{41} 0	b_{42} 0	b_{43} 0

Naturally the data arrays may have different dimensions. After the sequence **ALPHA** *A,B* **ALPHA** 2.002 **ENTER** 4.003 **ENTER** 3.002 **MOVE** the following picture of the data arrays "A" and "B" develops:



The array "A" was not changed in any way, in array "B" all elements are in their desired places.

Further Hints

The block that is to be moved can be described in several ways:

1) the upper left and the lower right element or
2) the lower left and the upper right element

The contents of the X and Y registers may be exchanged, i.e. *kkk.lll* may be placed in X and *iii.jjj* may be placed in Y.

Related Functions

C<>C, R<>R, SWAP

SWAP

The function **SWAP** exchanges selected elements of a specified data array with the elements of a different data array. Only "rectangular" parts of a matrix may be exchanged. The block is determined by the description of two opposing corner elements *iii.jjj* and *kkk.lll* (much like **MOVE**). The upper left corner of the second data array, *mmm.nnn* must be placed in Z.

Input

X register	:	*iii.jjj*
Y register	:	*kkk.lll*
Z register	:	*mmm.nnn*
ALPHA register	:	*OP1,OP2*

Example

We want to exchange the elements a_{32}, a_{33}, a_{42} and a_{43} of the illustrated 4*3 data array "A" with the elements b_{22}, b_{23}, b_{32} and b_{33} of data array "B". Data arrays "A" and "B" are depicted below:

Matrix A

Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6
	a_{31} 7	a_{32} 8	a_{33} 9
	a_{41} 10	a_{42} 11	a_{43} 12

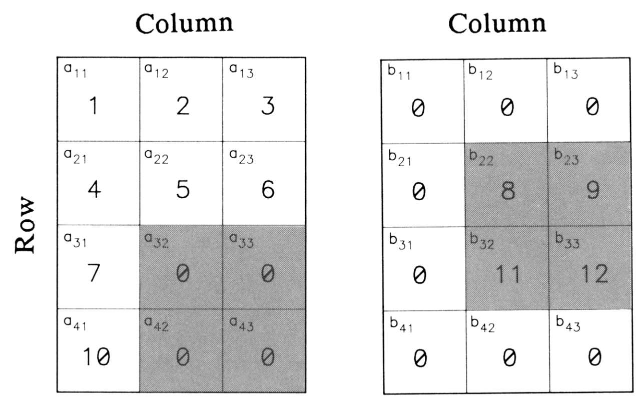
Matrix B

Column

b_{11} 0	b_{12} 0	b_{13} 0
b_{21} 0	b_{22} 0	b_{23} 0
b_{31} 0	b_{32} 0	b_{33} 0
b_{41} 0	b_{42} 0	b_{43} 0

Naturally the data arrays may have different dimensions. After the sequence **ALPHA** *A,B* **ALPHA** 2.002 **ENTER** 4.003 **ENTER** 3.002 **SWAP** the following picture of data arrays "A" and "B" develops:

Matrix A Matrix B



The selected elements of arrays "A" and "B" have been exchanged.

Further Hints

The block to be moved can be described in several different ways:

1) the upper left and the lower right element or
2) the lower left and the upper right element

Moreover the X and Y registers may be exchanged, i.e. *kkk.lll* may be placed in X and *iii.jjj* may be put into Y.

Related Functions

C<>C, R<>R, MOVE

Functions for Determining the Extreme Values of Array Elements

These functions are needed for numeric solution procedures and Algorithms.

MAX

The function **MAX** sets the pointer to the greatest element of the given data array. This element is placed in the X register.

Input

ALPHA register : *OP1*

Example

Column

Row				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 0	a_{22} −4	a_{23} −8	a_{24} −12
	a_{31} 0	a_{32} −8	a_{33} −16	a_{34} −24
	a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

When using the function **MAX** on the above depicted data array, the pointer is set to element a_{14} and a value of 4 is output to X.

Further Hints

The function **MAX** outputs the largest element, and **not**, contrary to **MAXAB**, the greatest absolute element. If there is no element greater than element a_{11} (for example all array elements equal 0), then it is output. In this case the pointer will be positioned on element a_{11} as well.

Related Functions

CMAXAB, MAX, MAXAB, MIN, PIV, R>R?, RMAXAB

MAXAB

The function **MAXAB** sets the pointer to the element with the largest absolute value in the given data array. The absolute value of this element is placed in X.

Input

ALPHA register : *OP1*

Example

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 0	a_{22} −4	a_{23} −8	a_{24} −12
a_{31} 0	a_{32} −8	a_{33} −16	a_{34} −24
a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

The greatest absolute element of the depicted array is -36. The function **MAXAB** sets the pointer on the element a_{44} and gives its absolute value (thus 36) in the X register.

Further Hints

The element that is output to the X register is only equal to the element in the given position when this element is positive. If the element is negative, its absolute value will be placed in the X register. If there is no element whose absolute value is greater than element a_{11} (for example all array elements equal 0), it will be output. The pointer will be positioned on element a_{11} as well.

Related Functions

CMAXAB, MAX, MIN, PIV, R>R?, RMAXAB

CMAXAB

The function **CMAXAB** sets the pointer to the greatest absolute element of column *jjj* of the given data array. This element is output in the X register.

Input

X register : *jjj*
ALPHA register : *OP1*

Example

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 0	a_{22} −4	a_{23} −8	a_{24} −12
a_{31} 0	a_{32} −8	a_{33} −16	a_{34} −24
a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

After the key sequence 3 **CMAXAB** the pointer is positioned to element a_{43} and its absolute value (24) is placed into X.

Further Hints

The search for the greatest absolute element occurs only in the given column. If there is no element of column *j* whose absolute value is greater than element a_{1j} (for example all column elements equal 0), it is output. The pointer is positioned to element a_{1j} as well.

Related Functions

CMAXAB, MAX, MIN, PIV, R>R?, RMAXAB

RMAXAB

The function **RMAXAB** sets the pointer to the position of the element with the greatest absolute value in the specified row *iii* of the given data array.

Input

X register : *iii*
ALPHA register : *OP1*

Example

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 0	a_{22} −4	a_{23} −8	a_{24} −12
a_{31} 0	a_{32} −8	a_{33} −16	a_{34} −24
a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

After the key sequence 2 **RMAXAB** the pointer is set to element a_{24} and the number 12 can be seen in the X register.

Further Hints

The search for the greatest absolute element takes place only in the given row. If in row *i* there is no element of greater absolute value than element a_{i1} (for example all row elements equal 0), it is output. The pointer is positioned to this element a_{i1} as well.

Related Functions

CMAXAB, MAX, MAXAB, MIN, PIV, R<R?

MIN

The function **MIN** sets the pointer to the smallest element of the specified data array. This element is output to the X register.

Input

ALPHA register : *OP1*

Example

Column

Row				
	a_{11}: 1	a_{12}: 2	a_{13}: 3	a_{14}: 4
	a_{21}: 0	a_{22}: −4	a_{23}: −8	a_{24}: −12
	a_{31}: 0	a_{32}: −8	a_{33}: −16	a_{34}: −24
	a_{41}: 0	a_{42}: −12	a_{43}: −24	a_{44}: −36

After executing the function **MIN** the pointer is set to a_{44} and the value -36 is placed into X.

Further Hints

If a_{11} is the smallest element of the array (for example all array elements equal 0), it is output. The pointer is positioned to this element a_{11} as well.

Related Functions

CMAXAB, MAX, MAXAB, PIV, R>R?, RMAXAB

PIV

The function **PIV** sets the element pointer to the coordinates of the element, under the principal diagonal of the selected column *jjj* of the specified array, with the greatest absolute value. The absolute value of this element is placed in X.

Input

X register : *jjj*
ALPHA register : *OP1*

Example

Column

Row				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
	a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

With the key sequence 2 **PIV** the pointer is set to element a_{42} and the absolute value of this element (12) is put into the X register.

Further Hints

The function **PIV** uses only the integer part of the X register. The fractional part is ignored during the procedure. The search for the greatest absolute element starts with element a_{jj} (on the main diagonal) and is continued downward in column *j*.

Related Functions

CMAXAB, MAX, MAXAB, MIN, R>R?, RMAXAB

R>R?

The function **R>R?** compares the elements of row *kkk* with those of row *lll* of the specified data array. The elements are compared columnwise, starting with column one. If the elements of this column are the same, the two elements of the next column are compared until there are either two unequal elements or until the end of the row is reached. The answer is "YES", as soon as an element of the row *lll* is greater than the element in the same column of row *kkk*. When finding an element in row *lll* which is smaller than the corresponding element in row *kkk*, the answer is "NO" and a step is skipped in a running program.

Input

X register	: *kkk.lll*
ALPHA register	: *OP1*

Example

We want to check if the first row of the depicted data array is greater than the third:

Column

Row				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
	a_{31} 9	a_{32} −8	a_{33} −16	a_{34} −24
	a_{41} 13	a_{42} −12	a_{43} −24	a_{44} −36

After keying in the sequence 1.003 **R>R?** we get the answer "NO", since the element in row 3 of the first column is greater than that in row 1.

Further Hints

In a running program if the answer is "YES", the next program line is executed, otherwise a line is skipped.

Related Functions

MAX, MAXAB, MIN, CMAXAB, RMAXAB, PIV

Sums and Norms

These functions are, like the functions for finding the extreme values, needed for numeric solution methods and algorithms. Using norms it can be established whether a linear equation is singular, i.e. whether it is definitely solvable or not. Moreover, norms can give information about the reliability of a result; in this case we talk about the conditional number of the matrix.

SUM

SUM adds all elements of the specified data array and writes the result in X.

Input

ALPHA register: *OP1*

Example

Column

Row				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
	a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

After keying the sequence **ALPHA** *A* **ALPHA SUM** the sum of all array elements (6), is put into the X register.

Further Hints

The function **SUM** does not have any influence on the pointer, therefore its position is not changed.

Related Functions

SUMAB, CSUM, RSUM

SUMAB

SUMAB adds the absolute values of all elements of the specified data array and writes the result to X.

Input

ALPHA register: *OP1*

Example

Column

Row				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
	a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

After the sequence **ALPHA** *A* **ALPHA SUMAB** the sum of the absolute values of all the array elements (150), is placed into X.

Further Hints

The function **SUMAB** does not have any influence on the position of the pointer, so its position remains the same.

Related Functions

SUM, CSUM, RSUM

CSUM

CSUM adds all elements of each column of the *OP1* data array and places the results into the *RES* data array.

Input

ALPHA register: *OP1,RES*

Example

To form the column sums of the depicted data array "A" (2 rows and 3 columns), one more data array is needed, which must also have 3 columns, but need only have one row. After the key sequence **ALPHA** *A,B* **ALPHA CSUM** the data array "B" contains the following elements:

	Column		
Row	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

b_{11} 5	b_{12} 7	b_{13} 9

Further Hints

The only inputs needed prior to the execution of **CSUM** are the *OP1* and the *RES* matrices. The *RES* matrix must have the same number of columns as *OP1* but needs only one row.

Related Functions

SUM, SUMAB, RSUM

RSUM

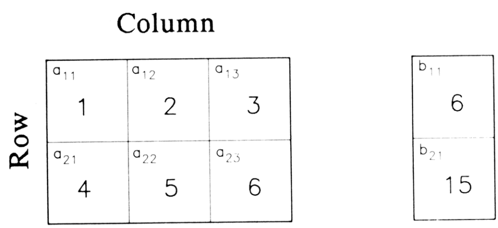
RSUM adds all elements of each row of the given data array and writes the results in the second given data array.

Input

ALPHA register: *OP1,RES*

Example

To form the row sums of the depicted data array "A" (2 rows and 3 columns) a second data array is needed, which must also have 2 rows, but need only have one column. After keying the sequence **ALPHA** *A,B* **ALPHA RSUM** the data array "B" contains the respective row sums:



Further Hints

To calculate the results, **RSUM** always needs a data array which has the same number of rows as the data array whose row sums are to be calculated.

Related Functions

SUM, SUMAB, CSUM

CNRM

The function **CNRM** computes the column norm, defined as the largest column sum of absolute values for a matrix, for the array specified in ALPHA and places the result in X. This norm is computed using the equation

$$\| A \|_C = \max_{1 < j < n} \sum_{i=1}^{m} | a_{ij} |$$

Input

ALPHA register : *OP1*

Example

Column

Row				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
	a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

The key sequence **ALPHA** *OP1* **ALPHA CNRM** yields the value 60 in the X register; this is the sum of the absolute values of the elements in the fourth column, which is the largest sum of absolute values of the array.

Related Functions

RNRM, FNRM

RNRM

The function **RNRM** calculates row norm, defined as the largest row sum of absolute values for a matrix, for the array specified in ALPHA. The result is written to the X register. The formula for this is:

$$\| A \|_R = \max_{1 < i < m} \sum_{j=1}^{n} | a_{ij} |$$

Input

ALPHA register : *OP1*

Example

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

Using the key sequence **ALPHA** ***A*** **ALPHA RSUM** the sum of the absolute values of the elements in the fourth row, which is the largest row sum of absolute values of the depicted array. This sum (in this case 72) is put into the X register.

Related Functions

CNRM, FNRM

FNRM

The function **FNRM** calculates the frobenius norm of the specified data array and writes the result to the X register. The formula for this is:

$$\| A \|_F = \left(\sum a_{ij}^2 \right)^{1/2}$$

Input

ALPHA register : *OP1*

Example

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

After the key sequence **ALPHA** *OP1* **ALPHA FNRM** we get the value 51.6333 in the X register. This number is the calculated value of the frobenius norm of the depicted data array.

Further Hints

The frobenius norm of a square matrix corresponds to its euclidial length.

Related Functions

CNRM, RNRM

Functions for Mathematical Manipulation of Arrays

This section of routines for manipulating arrays includes eight functions with two subgroups of related functions. Included in the first of these groups are the functions M+, M-, M* and M/ which are very versatile, since many different possibilities for the manipulation of data arrays can be exploited by the judicious selection of operands. The execution time, compared to user code programs, is extremely short.

M+

The function **M+** adds the elements with the same indices of two data arrays (only numerical data is allowed). The formula for this is:

$$c_{ij} = a_{ij} + b_{ij}$$

Input

ALPHA register : *OP1,OP2,RES*

Example

We want to add the depicted arrays "A" and "B":

Matrix A

Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

Matrix B

Column

b_{11} 50	b_{12} −47	b_{13} 9
b_{21} 20	b_{22} 7	b_{23} 12

Following the key sequence **ALPHA** *A*,*B*,*C* **ALPHA M+** the array "C" contains the following elements:

Matrix C

Column

Row			
	c_{11} 51	c_{12} −45	c_{13} 12
	c_{21} 24	c_{22} 12	c_{23} 18

Further Hints

If only *OP1* is mentioned in the ALPHA register, the value of each element in the specified data array is doubled. If, while executing the function, the error message "OUT OF RANGE" shows up, it signifies that parts of the data array have already been worked on, meaning that the result can not be used. If one of the operands is called "X", the value in the X register is supposed to be added to each element. The given data arrays must have the same dimensions.

Related Functions

M-, M*, M/

M-

The function M- subtracts elements with identical indices of two data arrays (only numeric data is allowed). The formula for this is:

$$c_{ij} = a_{ij} - b_{ij}$$

Input

ALPHA register : *OP1,OP2,RES*

Example

We want to subtract the depicted array "B" from array "A":

Matrix A

Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

Matrix B

Column

b_{11} 50	b_{12} −47	b_{13} 9
b_{21} 20	b_{22} 7	b_{23} 12

After the key sequence **ALPHA A,B,C ALPHA M-** the array "C" contains the following elements:

Matrix C

Column

Row			
	c_{11} −49	c_{12} 49	c_{13} −6
	c_{21} −16	c_{22} −2	c_{23} −6

Further Hints

If only *OP1* is specified in ALPHA, then the value of each element will be 0. If during the execution of this function the error message "OUT OF RANGE" is generated, then parts of the data array have already been worked on, and the result can not be used. If one of the operands is "X" the value in the X register is subtracted from each element. The given data arrays must have the same dimensions.

Related Functions

M+, M*, M/

M*

The function **M*** multiplies elements of two data arrays with the same indices (only numerical data is allowed). The formula for this is:

$$c_{ij} = a_{ij} \cdot b_{ij}$$

Input

ALPHA register: *OP1,OP2,RES*

Example

We want to multiply the elements of the depicted arrays "A" and "B":

Matrix A

Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

Matrix B

Column

b_{11} 50	b_{12} −47	b_{13} 9
b_{21} 20	b_{22} 7	b_{23} 12

After the key sequence **ALPHA** *A*,*B*,*C* **ALPHA M*** array "C" contains the following elements:

Matrix C

Column

Row	c_{11} 50	c_{12} −94	c_{13} 27
	c_{21} 80	c_{22} 35	c_{23} 72

Further Hints

The squaring of the elements of a data array is accomplished if only *OP1* is placed in the ALPHA register. If, during execution of this function, the error message "OUT OF RANGE" is displayed, then parts of the data array have already been worked on, and the result can not be used. The given data arrays must have the same dimensions, if one of the operands is "X" then we want to multiply each element by the value in the X register (scalar multiplication).

Related Functions

M+, M-, M/

M/

The function M/ divides the elements of two data arrays with the same indices (only numeric data is allowed). The formula for this is:

$$c_{ij} = a_{ij} / b_{ij}$$

Input

ALPHA register : *OP1,OP2,RES*

Example

To prepare this example we want to transfer the elements of array "C" into array "A": **ALPHA** *C,A* **ALPHA** 1.001 **ENTER** 2.003 **ENTER MOVE**. After doing this the arrays "A" and "B" contain the following elements:

Matrix A

Column

Row			
	a_{11} 50	a_{12} −94	a_{13} 27
	a_{21} 80	a_{22} 35	a_{23} 72

Matrix B

Column

b_{11} 50	b_{12} −47	b_{13} 9
b_{21} 20	b_{22} 7	b_{23} 12

With the help of key sequence **ALPHA** *A,B,C* **ALPHA M/** we now divide the elements of array "A" by the elements of array "B". Now array "C" contains the following elements:

Matrix C

Column

Row	c_{11} 1	c_{12} 2	c_{13} 3
	c_{21} 4	c_{22} 5	c_{23} 6

Further Hints

If only *OP1* is mentioned in ALPHA, and if none of the elements in the matrix are zero, then a unit matrix is obtained (all elements equal to 1). If, during execution of this function, the error message "OUT OF RANGE" shows up, it signifies that parts of the data array have already been worked on, meaning the result can not be used. The given data arrays must have the same dimensions, unless one of the operands is "X" in which case the value of the X register is used.

Related Functions

M+, M-, M*

M*M

The function **M*M** allows the multiplication of matrices. This multiplication is done according to the following rule:

$$c_{ik} = \sum_{j=1}^{n} a_{ij} \cdot b_{jk}$$

Input

ALPHA register : *OP1,OP2,RES*

Example

Using the given matrix "A" and the given column vector "B" and the key sequence **ALPHA A,B,C ALPHA M*M** we get the resultant column vector "C" of a series of equations with a unique solution. For this application, the dimensions of the matrices must be linked, so that if "A" is a square 4 * 4 matrix then any operand "B" must have four rows. Since in this case "B" is a column vector, this array has only one column. The resultant array is then an array of the dimension 4 * 1. The arrays "A", "B", and "C" and their elements are shown below:

Column

Row				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
	a_{41} 13	a_{42} 14	a_{43} 15	a_{44} 16

b_{11} −3
b_{21} 5
b_{31} 1
b_{41} 2

c_{11} 18
c_{21} 38
c_{31} 58
c_{41} 78

Further Hints

The dimensions of the given data arrays *OP1* and *OP2* must be linked i.e. if the array *OP1* has the dimension i*j, array *OP2* must have the dimension j*k. If the dimensions of the operands are not related in this manner then the error message "DIM ERR" appears. The result of this operation is a data array of the dimension i*k, meaning the array *RES* must already exist with this dimension before executing this function.

An important application of M*M lies in the solution of non singular, linear equation systems: if an inverse (square matrix which has dimensions i*i) matrix is multiplied with a column vector, the result will also be a vector. This operation is especially rewarding if one fixed array is multiplied by a number of different column vectors (for example, for the analysis of a series of many measurements with a single system). In this case it is not necessary to solve the equation system anew every time, it suffices to execute the function M*M with successive column vector.

Related Functions

M+, M-, M*, M/

YC+C

The function **YC+C** makes it possible to add a multiple (factor in Y) of column *i* to column *j*.

Input

ALPHA register : *OP1*
X register : *iii.jjj*
Y register : factor

Examples

We want to work on the given data array "A":

Column

Row			
	a_{11} 1	a_{12} 2	a_{13} 3
	a_{21} 4	a_{22} 5	a_{23} 6

The key sequence **ALPHA A ALPHA 5 ENTER** 1.001 **YC+C** yields the array:

Column

Row			
	a_{11} 6	a_{12} 2	a_{13} 3
	a_{21} 24	a_{22} 5	a_{23} 6

The first column was multiplied by 5 and added to itself.

In the second example we shall also start with array "A":

$$\begin{array}{cc} & \text{Column} \\ \text{Row} & \begin{array}{|c|c|c|}\hline a_{11} & a_{12} & a_{13} \\ 1 & 2 & 3 \\ \hline a_{21} & a_{22} & a_{23} \\ 4 & 5 & 6 \\ \hline \end{array} \end{array}$$

After the key sequence **ALPHA A ALPHA** -50 **ENTER** 3.001 **YC+C** the following picture develops:

$$\begin{array}{cc} & \text{Column} \\ \text{Row} & \begin{array}{|c|c|c|}\hline a_{11} & a_{12} & a_{13} \\ -149 & 2 & 3 \\ \hline a_{21} & a_{22} & a_{23} \\ -296 & 5 & 6 \\ \hline \end{array} \end{array}$$

The elements of the third column were multiplied by -50 and then added to the elements of the first column.

Further Hints

If, during execution of this function, the error "OUT OF RANGE" is displayed, then parts of the data array have been worked on, and the result is useless.

R-QR

The function **R-QR** performs one step of a Gauss procedure, which transforms an array so that all the elements under the principal diagonal become equal to zero. Using this method a system of equations may be solved by backwards insertion. execution of the function proceeds according to the following protocol:

$$\text{for } Q = a_{kl} \,/\, a_{ll} \text{ we obtain:}$$

$$\text{for } 1 \leqslant j \leqslant n : \; a_{kj} = a_{kj} - Q \cdot a_{lj}$$

The element coordinates *kkk.lll* are of course specified as input. After execution, the element a_{kj} is transformed to zero. Thus *lll* specifies the row which, after being multiplied by Q, is subtracted from row *kkk*; so $Q = a_{kl}/a_{ll}$. Note that for the matrix upon which this operation is performed, no diagonal element may equal zero.

Input

X register : *kkk.lll*

Example

As an example we will work on the equation system A * x = 0, "A" is a 4 * 4 matrix and is shown on the next page.

– ARR FNS

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
a_{41} 13	a_{42} 14	a_{43} 15	a_{44} 16

using 4.001 **R-QR** we get:

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

with 3.001 **R-QR** we get:

Column

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
a_{31} 0	a_{32} −8	a_{33} −16	a_{34} −24
a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

with 2.001 **R-QR** we get:

Row \ Column				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 0	a_{22} −4	a_{23} −8	a_{24} −12
	a_{31} 0	a_{32} −8	a_{33} −16	a_{34} −24
	a_{41} 0	a_{42} −12	a_{43} −24	a_{44} −36

with 4.002 **R-QR** we get:

Row \ Column				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 0	a_{22} −4	a_{23} −8	a_{24} −12
	a_{31} 0	a_{32} −8	a_{33} −16	a_{34} −24
	a_{41} 0	a_{42} 0	a_{43} 0	a_{44} 0

with 3.002 **R-QR** we get:

Row \ Column				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 0	a_{22} −4	a_{23} −8	a_{24} −12
	a_{31} 0	a_{32} 0	a_{33} 0	a_{34} 0
	a_{41} 0	a_{42} 0	a_{43} 0	a_{44} 0

It is plain to see that by repeated use of **R-QR** results in the formation of an upper triangular array, as the shaded lower elements are successively transformed to zero. Note that in the course of transforming the array for this example we have used additional elements from the upper triangular portion of the array and these have also become zero. At each step, the element which must be transformed is shaded darker gray. An example of a system of inhomogeneous solutions of the **A * x = b** (with a matrix consisting of **A** and the column vector **b**) is relinquished.

Further Hints

In contrast to the so called "L-R analysis" (see **R-PR**) no column vector may be introduced at a later stage of execution.

Related Function

R-PR

R-PR

The function **R-PR** works similar to the function **Q-QR**. Since, when working with Gausian algorithms, all elements of the lower triangle matrix become equal to 0. Thus it is possible to restore the original matrix by working backwards from the transformed array. Furthermore, it is possible to introduce a new column vector as part of the process. The algorithm works exactly the same way as in **R-QR**:

$$\text{for } Q = a_{kl} / a_{ll} \text{ we obtain:}$$

$$\text{for } l < j \leqslant n \quad : \quad a_{kj} = a_{kj} - Q \cdot a_{lj}$$

$$\text{for } j = l \quad : \quad a_{kl} = Q$$

$$\text{for } 1 \leqslant j < l \quad : \quad a_{kj} = a_{kj}$$

For the elements *l+1* to *n* of line *k* the same operation as in **R-QR** is used; the element a_{kl} gets the value Q and all elements to the left of a_{kl} stay the same. *kkk.lll* is placed in the X register. *lll* gives us the row that multiplied by Q and then is subtracted from row *kkk*. Thus

$Q=a_{kl}/a_{ll}$

In this operation the elements may not be equal to 0!

Input

X register	: *kkk.lll*
ALPHA register	: array name

– ARR FNS

Example

As an example we will work on the equation system A * x = b. "A" is a 4 * 4 matrix and the column vector "b" (inhomogenous part) is moved into the matrix, so that there arises a 4*5 matrix:

Matrix A

Row \ Column				
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12
	a_{41} 13	a_{42} 14	a_{43} 15	a_{44} 16

Vektor b

Row \ Column	
	b_1 0
	b_2 1
	b_3 2
	b_4 3

Depicted above are matrix "A" and column vector "b", and below the new 4*5 matrix which has been combined with the column vector.

Row \ Column					
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4	a_{15} 0
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8	a_{25} 1
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12	a_{35} 2
	a_{41} 13	a_{42} 14	a_{43} 15	a_{44} 16	a_{45} 3

using 4.001 **R-PR** we get:

Column

Row					
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4	a_{15} 0
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8	a_{25} 1
	a_{31} 9	a_{32} 10	a_{33} 11	a_{34} 12	a_{35} 2
	a_{41} 13	a_{42} −12	a_{43} −24	a_{44} −36	a_{45} 3

using 3.001 **R-PR** we get:

Row					
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4	a_{15} 0
	a_{21} 5	a_{22} 6	a_{23} 7	a_{24} 8	a_{25} 1
	a_{31} 9	a_{32} −8	a_{33} −16	a_{34} −24	a_{35} 2
	a_{41} 13	a_{42} −12	a_{43} −24	a_{44} −36	a_{45} 3

using 2.001 **R-PR** we get:

Row					
	a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4	a_{15} 0
	a_{21} 5	a_{22} −4	a_{23} −8	a_{24} −12	a_{25} 1
	a_{31} 9	a_{32} −8	a_{33} −16	a_{34} −24	a_{35} 2
	a_{41} 13	a_{42} −12	a_{43} −24	a_{44} −36	a_{45} 3

using 4.002 **R-PR** we get:

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4	a_{15} 0
a_{21} 5	a_{22} −4	a_{23} −8	a_{24} −12	a_{25} 1
a_{31} 9	a_{32} 2	a_{33} 0	a_{34} 0	a_{35} 0
a_{41} 13	a_{42} 3	a_{43} 0	a_{44} 0	a_{45} 0

using 3.002 **R-PR** we get:

Row

a_{11} 1	a_{12} 2	a_{13} 3	a_{14} 4	a_{15} 0
a_{21} 5	a_{22} −4	a_{23} −8	a_{24} −12	a_{25} 1
a_{31} 9	a_{32} −8	a_{33} −16	a_{34} −24	a_{35} 2
a_{41} 13	a_{42} 3	a_{43} 0	a_{44} 0	a_{45} 0

Further Hints

The L-R analysis is practically the same as the Gauss procedure, except that here the moving in of a new column vector is possible, since the factors Q are saved. These factors Q are placed in the lower triangle matrix, whose elements would otherwise be equal to 0. For the backwards input though only the upper triangle matrix may be examined.

Related Function

R-QR

Program Examples

We shall now present two helpful programs that will show you the use of some CCD-Module matrix functions to demonstrate their use.

Gaussian-algorithm

The first program allows the solving of a linear equation system with a quadratic coefficent matrix by the Gauss elimination procedure. The program consists of several exchangable parts that need information in any of two registers. In this case the registers 00 and 05 were chosen.

Using the program:

Using the program subroutine "ABIN", all values of the expanded coefficient matrix are input. The transformation into a triangular form as well as the final output of the resultant vector are handled by the subroutine "TRANS".

01*LBL "ABIN"	Start of the input routine (R01 is used as the control register.)
02 "DIM(N)?	Requests the input of the dimension *n* of the equation system
03 PROMPT	and stores it in R00
04 STO 00	
05 E	Lines 5 - 10 generante the number *nnn.mmm* which is produced for the dimensioning of the matrix, where mmm = n+1
06 +	
07 E3	
08 /	
09 RCL 00	
10 +	
11 "NAME"	Input of the matrix name (for example "R006" for a matrix in the main memory) maximum 6 letters
12 PMTA	
13 ASTO 05	Saves this name in R05
14 MDIM	Creation of the matrix
15 STO 01	Storage of the control index for data input
16 CLX	Using **IJ=A**, set pointer to a_{11} (not necessary when working with register matrices, see **MDIM**)

17*LBL "COR R"	If wrong element input, there is a possibility of correction. Input in X: *iii.jjj*
18 CLA	
19 ARCL 05	Selection of the chosen matrix (name in
20 IJ=A	R05) as the current matrix
21*LBL 00	Start of the input routine
22 RCL 01	
23 ?IJ	
24 X>Y?	Has the last element already been read?
25 RTN	Yes, End of input loop
26 "A("	Production of message "A("
27 ARCLI	Appending of i: "A(i"
28 FRC	X: current pointer *iii.jjj*
29 E3	Production of *j*
30 *	
31 "⊢,"	ALPHA: "A(i,"
32 X>Y?	Is *j* greater than the dimension *n*?
33 "B("	Yes, input of Y values. ALPHA: "Y("
34 X>Y?	Is *j* greater than dimension *n*?
35 ?IJ	Yes,in X *j* is substituted by *iii.jjj*
36 ARCLI	Appending of the integer value to ALPHA
37 "⊢): "	ALPHA: "A(i,j):" or "B(i):
38 ?IJ	Reading of the current pointer position
39 C>-	and the element on this position
40 ARCL X	Appending of this element to ALPHA
41 X<>Y	
42 IJ=	Obtain the current pointer position
43 RDN	Old element to X
44 PROMPT	Input of a new value or use
45 >C+	of the old as well as storing the value
46 GTO 00	Back to the start of the input routine
47*LBL "TRA NS"	Start of the program for the transformation of the matrix to triangle shape
48 CLA	The matrix name must, for **PIV**
49 ARCL 05	and **R-QR** (or **R-PR**), be in ALPHA
50 RCL 00	All in all the pivoting is executed n-1
51 DSE X	times

52*LBL 02	Outer routine *i*=1-(*n*-1)
53 RCL 00	Calculation of the pivot line number
54 RCL Y	Y runs from (*n-1*) to *1*
55 -	*i=n-Y*
56 RCL X	Calculate *iii.iii*
57 E3	This **E3** moves the Y contents, as
58 /	after **LBL 02** to T.
59 +	Outer counter now in Z
60 PIV	Search for the pivot element
61 X=0?	If this element is equal to 0, there exists
62 RTN	no one definite solution: Backtrack with X=0
63 RDN	Pivot element is of no interest
64 ?IJ	If the pointer of the pivot element is
65 X=Y	unequal to the calculated one:
66 R<>R	exchange lines
67 RDN	Put current pointer on *iii.iii*
68 IJ=	
69*LBL 03	Inner routine: *j=n-i+1*
70 RDN	Calculate pointer *jjj.iii*
71 ?IJ	Pivot pointer
72 RCL Y	Counter from (*n-1*)*-1*
73 +	
74 R-PR or R-QR	Transformation of line *j* starting from column *i*
75 DSE Y	If counter is greater than 0
76 GTO 03	work on next highest row
77 RDN	Bring outer counter to X
78 RDN	
79 DSE X	If counter is greater than 0, work on
80 GTO 02	next row under matrix
81 SIGN	X not equal to 0 if definite solution (if called out as a subprogram)
82*LBL "X"	Calculation of the resultant vector
83 CLA	ALPHA: matrix name
84 ARCL 05	
85 DIM	Production of *0*,(*nnn+1*)
86 FRC	
87 STO [	Use of register M as scratch register
88 LASTX	X: *nnn*.(*nnn*+1)

– ARR FNS

89*LBL 04	Main routine: *i=n-1*
90 INT	Calculation of *iii.iii*
91 RCL X	
92 E3	
93 /	
94 +	
95*LBL 05	
96 IJ=	Put pointer on *iii.iii*
97 INT	Get pointer of the result element to be
98 RCL [	calculated:*iii.(nnn+1)*
99 +	
100 C>-	Read element *iii.iii*, decrement line
101 ?IJ	pointer. This pointer is 0, if the upper
102 X<> Z	line has been worked on see comparison X=0?
103 IJ=	Put pointer on *iii.*(*nnn*+1)
104 C>-	Read element
105 X<>Y	Again put pointer on *iii.*(*nnn*+1)
106 IJ=	
107 RDN	
108 X<>Y	Calculate result element x_i
109 /	$x_i=a_{i,n+1}/a_{i,n}$
110 STO	Storing in help register N as well
111 >C+	as at his result place *iii.*(*nnn*+1)
112 RDN	
113 X=0?	If first line has been worked on:
114 GTO 07	ready, output!
115*LBL 06	Inner routine:*j=i-1 -1*
116 IJ=	Put pointer to *jjj.iii*
117 C>-	Product $a_{j,i}$*x_i
118 RCL \	
119 *	
120 ?IJ	Read pointer (*jjj*-1).*iii* and
121 X<> Z	save
122 INT	Calculation of *jjj.*(*nnn*+1)
123 RCL [	
124 +	

125 IJ=	Subtraction of product $a_{j,i}*x_i$
126 X<>Y	from current value x_i
127 R>-	read $a_{j,n+1}$
128 X<>Y	
129 -	Subtract product
130 X<>Y	
131 IJ=	Put pointer on *jjj.*(*nnn*+1)
132 X<>Y	
133 >R+	Store difference
134 X<>Z	If pointer on $a_{i,i}$ has not yet jumped
135 X<Y?	to line *n* (by C-), *j* has not yet
136 GTO 06	reached 1
137 FRC	Line *i-1* is next to be worked on
138 E3	
139 *	
140 GTO 04	Back to main routine
141*LBL 07	End of calculation and
142*LBL "XOUT"	output of the result vector (x_i values)
143 CLA	Matrix name in ALPHA
144 ARCL 05	
145 DIM	Produce pointer *1.*(*nnn*+1)
146 FRC	
147 ISG X	
148 IJ=A	Put pointer on x_1 Start of output routine
149*LBL 08	
150 ?IJ	Set for message "X(i)="
151 "X("	
152 ARCLI	
153 RDN	
154 "⊢)= "	Reading of the value x_i and
155 C>+	appending to ALPHA
156 ARCL X	
157 SF 25	Print, if printer present

– ARR FNS

```
158 PRA
159 FC?C 25
160 PROMPT          Otherwise message of x_i values
161 GTO 08          Back to start of output routine
162 END             End of program
```

PLNG "ABIN"
301 BYTES

Calculation of the Inverse Matrix

The program "INV" calculates the inverse "A^{-1}" of a given quadratic matrix "A". After calculating the inverse the linear equation systems of the form A*x=b are easily solved with the help of a simple matrix multiplication (for example using the function M*M of the CCD-Module):

$$x = A^{-1} * b$$

The program INV solves singular matrices as well. For this, INV calculates a conditional number that allows for a statement about the exactness of the solution to be made. The relative error of the solution x can now be determined by multiplying the conditional number with the relative error of the column vector b (thus on the HP- 41 minimal 1E-10).

Use:

A name of a previously arranged quadratic data array is expected in the ALPHA register. After execution of "INV" this data array contains the inverse of the original array. The X register displays the conditional number. "INV" changes the stack as well as the registers R00 to R02. Furthermore, "INV" needs just as many **extra** registers as the data array given in the ALPHA register occupies. If the data array finds itself in the data memory area of the HP-41 (name R*xxx*), then "INV" expects these extra data registers after the data array. Example: So that "INV" can calculate the inverse of a data array with the name R010 of dimension 5*5, beforehand there has to be at least **SIZE** 61, otherwise the message "NONEXESTENT" appears. If the data array is located in the extended memory, the function **EMDIR** has to show at least 25 empty registers after arranging of the data array, otherwise the message "NO ROOM" will appear.

– ARR FNS

Description of the function:

The procedure employed calculates the inverse of matrix "A" columnwise by solving the equation systems $A*y_k=e_k$. e_k are the columns of the unit matrix "E", the solutions y_k are the columns of the inverses "A^{-1}".

For the solving of the equation systems an algorithm after Gauss-Jordan is employed. Since the hereby appearing shape changes of matrix "A" have to be used on all "right sides" e_k, there is produced a matrix whose left half contains the matrix "A" and whose right half contains the unit matrix "E". Since the functions of the CCD-Module store the matrices linewise, the number of lines of the matrix to be inverted is doubled (program lines 4-8). **MDIM** zeros all newly added elements, so that the matrix will look as depicted below:

a_{11}	a_{12}	a_{13}
a_{21}	a_{22}	a_{23}
a_{31}	a_{32}	a_{33}
0	0	0
0	0	0
0	0	0

Now all lines are switched in a way so that between two lines of the original matrix there is always an empty line (program lines 9-16):

a_{11}	a_{12}	a_{13}
0	0	0
a_{21}	a_{22}	a_{23}
0	0	0
a_{31}	a_{32}	a_{33}
0	0	0

A sub program, starting at LBL 20, now exchanges the number of lines of the dimension with their column number:

a_{11}	a_{12}	a_{13}	0	0	0
a_{21}	a_{22}	a_{23}	0	0	0
a_{31}	a_{32}	a_{33}	0	0	0

– ARR FNS

The program lines 18-30 produce the unit matrix in the still empty right half.

a_{11}	a_{12}	a_{13}	1	0	0
a_{21}	a_{22}	a_{23}	0	1	0
a_{31}	a_{32}	a_{33}	0	0	1

The changing of the matrix after Gauss-Jordan happens with two program routines. The outer one, with the pointer *l* in R01 (initiation in program lines 31-35, starting at LBL 02) now executes the so called pivoting: The function **PIV** (program line 43) searches the *l* column from the *l* to the last line for the greatest absolute element. Now two lines are exchanged in a way that this element gets to the *l* line (program line 49). Here it is used as a so called pivot in the following inner routine, with the pointer *k* in R02 (initiation in program lines 37-41), starting at LBL 03. The order **R-QR** (program line 60) subtracts a manifold of the line of the pivot from the *k* line in such a way, that the element lying in the column of the pivot becomes equal to 0. The necessary factor for this is calculated beforehand by **R-QR** by a division of the later to become equal to a 0 element by the pivot (see description of function **R-QR**). So as to cut down on the errors occuring during the division, the pivoting is executed before. If the number 0 is found as a pivot, matrix "A" was either singular or or least practically singular; because of the occuring round up mistakes the calculator can not distinguish between these. So that during the division the program does not break off with the message "DATA ERROR", a 0 pivot is substituted with a number that is 1E-10 times the greatest absolute in the column of the pivot appearing number, or at least 1E-99 (sub program starting at LBL 30). This number usually lies within the number range of the occuring round up mistakes.

After the working off of both routines, the left half of the matrix, thus the original matrix "A", has been changed into a diagonal matrix:

a_{11}	0	0	z_{11}	z_{12}	z_{13}
0	a_{22}	0	z_{21}	z_{22}	z_{23}
0	0	a_{33}	z_{31}	z_{32}	z_{33}

The solution matrix "A^{-1}" is reached, when all elements of the right half are divided by the same line positioned diagonal element of the left half. This happens in the routines, starting with LBL 05 and LBL 06, as well as the pointers R 01 on the diagonal element and R 02 on the columns in the right half. If a diagonal element is equal to 0, it is substituted by the greatest absolute element of the column, or at least by 1E-99 (sub program starting with LBL 35). This is possible, because the preceding change made all other elements of the column, except the round up mistakes, equal to 0. Therefore a number is found that is unequal to 0, but still in the number range of the occuring round up mistakes.

After the routines are done calculating the solution "A^{-1}" lies in the right half of the matrix. This solution is now transferred to the place of the original matrix "A" by exchanging of the dimensions (program line 106), changing of the lines (program lines 107-116) and then finally by redimensioning to a quadratic matrix (program lines 117-120). The conditional number is calculated by multiplication of the frobenius norm of matrix "A" before the change (program lines 2-3) with the frobenius norm of its inverses (program lines 121-123).

```
01♦LBL "INV"
02 FNRM
03 STO 00
04 DIM
05 INT
06 LASTX
07 +
08 MDIM
09 1
10 -

11♦LBL 11
12 R<>R
13 1.001
14 -
15 DSE X
16 GTO 11
17 XEQ 20
18 INT
19  E3
20 /
21 1
22 +
23 IJ=A
24 LASTX

25♦LBL 01
26 R>+
27 RDN
28 >C+
29 ISG Y
30 GTO 01
31 RDN
32 FRC
33 1
```

```
34 +
35 STO 01

36♦LBL 02
37 RCL 01
38 FRC
39 1
40 +
41 STO 02
42 RCL 01
43 PIV
44 ?IJ
45 X<>Y
46 X=0?
47 XEQ 30
48 RDN
49 R<>R

50♦LBL 03
51 RCL 02
52 INT
53 RCL 01
54 INT
55 X=Y?
56 GTO 04
57  E3
58 /
59 +
60 R-QR

61♦LBL 04
62 ISG 02
63 GTO 03
64 ISG 01
65 GTO 02
66 RCL 01
67 FRC
68 1
69 +
70 STO 01
71♦LBL 05
72 DIM
73 1
74 +
75 STO 02
76 RCL 01
77 INT
78 1,001
79 *
80 IJ=
81 R>+
82 X=0?
83 XEQ 35
84 RCL 02
85  E3
86 /
87 RCL 01
88 INT
89 +
90 IJ=
91 RDN
92♦LBL 06
93 ?IJ
94 R>+
95 X<>Y
96 IJ=
97 RDN
98 X<>Y
99 /
100 >R+
101 LASTX
102 ISG 02
103 GTO 06
104 ISG 01
105 GTO 05
106 XEQ 20
107 INT
108 2
109 /
110 0
```

```
111♦LBL 12
112 1,002
113 +
114 R<>R
115 DSE Y
116 GTO 12
117 INT
118 1,001
119 *
120 MDIM
121 FNRM
122 RCL 00
123 *
124 RTN

125♦LBL 20
126 DIM
127 FRC
128 LASTX
129 INT
130  E3
131 /
132 X<>Y
133 LASTX
134 *
135 +
136 MDIM
137 RTN

138♦LBL 30
139 RDN
140 RCL 01
141 CMAXAB
142  E10
143 /
144  E-99
145 +
146 RCL Z
147 IJ=
148 X<>Y
149 >R+
150 RTN

151♦LBL 35
152 RCL 01
153 CMAXAB
154  E-99
155 +
156 END

    PLNG "INV"
     247 BYTES
```


Chapter 5

Binary Functions
(Hexadecimal Functions)

HEX FNS

Contents Chapter 5

Hexadecimal Functions

-HEX FNS

Hexadecimal Functions

The hexadecimal or logical function set consists of the functions **1CMP**, **2CMP**, **AND**, **bC?**, **bS?**, **Cb**, **NOT**, **OR**, **R<**, **R>**, **S<**, **S>**, **Sb**, **UNS**, **WSIZE** and **XOR**. Furthermore these functions are completed by **ARCLH**, **PMTH**, **VIEWH** and **XTOAH** from the input and output function set (-I/O FNS) of the CCD-Module.

Familiarity with the use of sign modes and number systems in different bases is essential for understanding the descriptions of the functions presented here. Although this knowledge is presupposed, in order to define the meanings and connotations of these concepts to best reflect their use for the functions in the CCD-Module, we shall briefly review them below.

All the hexadecimal functions in the module follow the logical protocol outlined in the flow chart on page 5.15 in their execution, and thus they automatically correct for word size and sign mode.

Number Systems

The Binary Number System

The base of the binary number system is the number 2; all numbers are represented by combinations of the numbers **0** and 1. binary numbers are denoted in this text by the subscript b; thus $1001_b = 9_d$ (decimal). The transition to the next higher digits place in binary occurs at 2_d. The table on the next page presents the decimal numbers 0 to 10 and their binary equivalents.

Note that there are two representations given for the binary equivalent of 10_d. The first is the standard notation that would be obtained, for example by adding 0010_b to 1000_b. The second is the way 10_d is represented in the notation referred to as binary coded decimal (or BCD), for which each decimal digit is represented by a separate grouping of 4 binary digits; this is the way the numbers are coded internally by the HP-41.

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	0001 0000

The Octal Number System

This is a number system of base 8_d, which utilizes the standard digits 0 through 7 (there is no 8 in this notation); thus the correspondence with decimal 0 through 10 is

Decimal	Octal
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	10
9	11
10	12

Numbers in octal notation in this text will be identified by the subscript o. In the octal number system the carryover to the next highest place occurs at decimal 8. Each octal digit represents 3 binary digits (3 bits); through this the octal number system uses the full value range of these 3 places (dec 0 to 7 representing 000_b to 111_b).

The functions **OCT** and **DEC** of the HP 41 operating system give the possibility for calculations in the octal number range.

The Decimal Number System

The decimal number system is the customary number system. The functions of the HP-41 support calculations in the base 10 system for all operations. Numbers to base 10 are marked by the subscript d: 136_d = decimal number 136. Numbers whose number base has not been clearly given, are assumed to be decimal numbers.

The Hexadecimal Number System

The base of this number system is 16_d. The numbers **0**, **1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**, and **9** as well as the letters **A**, **B**, **C**, **D**, **E** and **F** are used to represent 11 through 15_d. The carry over to the next highest place takes place at 16_d. The correspondence between binary, decimal and hexadecimal numbers is:

Hexa-decimal	Binary	Decimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

Warning:

Hexadecimal numbers "arise" through the use of the full 4 binary digits (4 bits); therefore the hexadecimal number system uses the 4 bits of a nybble in the full value range. Each nybble can represent values from bin 0000 to 1111, in hexadecimal from 0_h to F_h. This number system is often used in the computer field.

Representation of Negative Numbers

In a given, limited digit number *m* (in this case between 0 and 32 binary digits) the value range of the numbers to be represented is $0<=n<=2^m-1$; note that no negative numbers are included in this system of notation. To get rid of this deficiency, a complement is introduced.

The Complement

The complement KOM of a number X is defined as:

$$KOM\ (X) = K - X$$

for which the value of *K* is fixed by the chosen complement. Since in the binary number system the usual values of K are 2^m and $(2^m - 1)$, we usually speak of the "one's Complement" or the "two's complement". In general complement's exist in every number system of *base B* (for example *B=10* in the decimal system, *B = 16* in the hexadecimal system, etc.). For any base *B* there will be a *(B-1)* and a *B* Complement, in the decimal system these are the 9's and 10's Complements.

Distribution of Ranges of Values

If there seems no reason for the existence of complement notation, recall that up to this point we have not dealt with negative numbers. We shall include these by adopting an arbitrary distribution of ranges of values in our number systems: in the binary system, for example, we shall define a negative number as one whose most significant (leftmost) bit is set (has a value of 1). By manipulating number distributions and employing complements, the ranges of values are changed as follows:

before complement

$$0 <= X <= (B^m)-1$$

after employing the complement

(B complementation): $- B^{(m-1)} <= X <= B^{(m-1)}-1$

(($B-1$) complementation): $- B^{s(m-1)}-1 <= X <= B^{(m-1)}-1$

Complement (Signed) Modes

The transformation of decimally represented numbers into binary numbers and vice versa, varies with the signed mode that is used. The three modes are:

- **1's Complement mode**
- **2's Complement mode**
- **unsigned mode**

When complement notation is used, it becomes simpler for an arithmetic processor to execute subtraction, since this has now been reduced to an addition operation. In addition, it is quite simple for a calculator to construct the complement of a number in a number in binary notation (see below).

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The 1's Complement Mode

The 1's complement of a number is created by subtracting this number from the greatest representable number in the chosen word size, i.e. imagining a word size of 5 bits, the 1's Complement of (- a_b) is (11111 - a_b). The processor simply inverts all bits of the original number, it executes the logical function "not". Through this arbitrary but definite segmentation of the value range all negative numbers have their highmost bit set which plays the role of the "-" sign. In the 1's Complement mode the number of positive and negative numbers represented are the same, i.e. even zero has two possible representations: 0 and - 0, in binary this would mean 00000 and 11111 (still a word size of 5 bits assumed).

The 2's Complement Mode

The 2's Complement of a number is created by subtraction of this number from the greatest representable number and following addition of 1, i.e., supposing a word size of 5 bit the 2's Complement of (- a_b) = (11111 - a_b) + 1. The 2's Complement of bin (10001) is the number bin (01111). We notice, that by segmenting even in the 2's Complement mode the very left bit is set for all negative numbers and therefore takes over the role of the "-" sign. In the 2's Complement mode there is one more negative number than in in the positive number range, since zero only has the representation 0.

The Unsigned Mode

Since the Complement mode employs a bit as the negative sign, the range of values for a word size of 8 bits in the 1's complement is from $+127_d$ to -127_d or $+127_d$to -128_d for 2's complement. Although these are 256 values sometimes only the positive number range is needed. In this case the Unsigned mode is used, having no preceding sign bit. Therefore, assuming the same wordsize of 8 bits, the value range from dec 0 to 255 is covered.

In the table below, decimal values are assigned to the corresponding binary numbers in the three sign modes for a four bit word size.

Complement Notation

Binary	1's Complement mode	2's Complement mode	Unsigned mode
0111	7	7	7
0110	6	6	6
0101	5	5	5
0100	4	4	4
0011	3	3	3
0010	2	2	2
0001	1	1	1
0000	0	0	0
1111	−0	−1	15
1110	−1	−2	14
1101	−2	−3	13
1100	−3	−4	12
1011	−4	−5	11
1010	−5	−6	10
1001	−6	−7	9
1000	−7	−8	8

General Conventions for Hexadecimal Functions

We shall now consider the arrangement of the hexadecimal functions. All functions in the CCD-Module observe the following protocol:

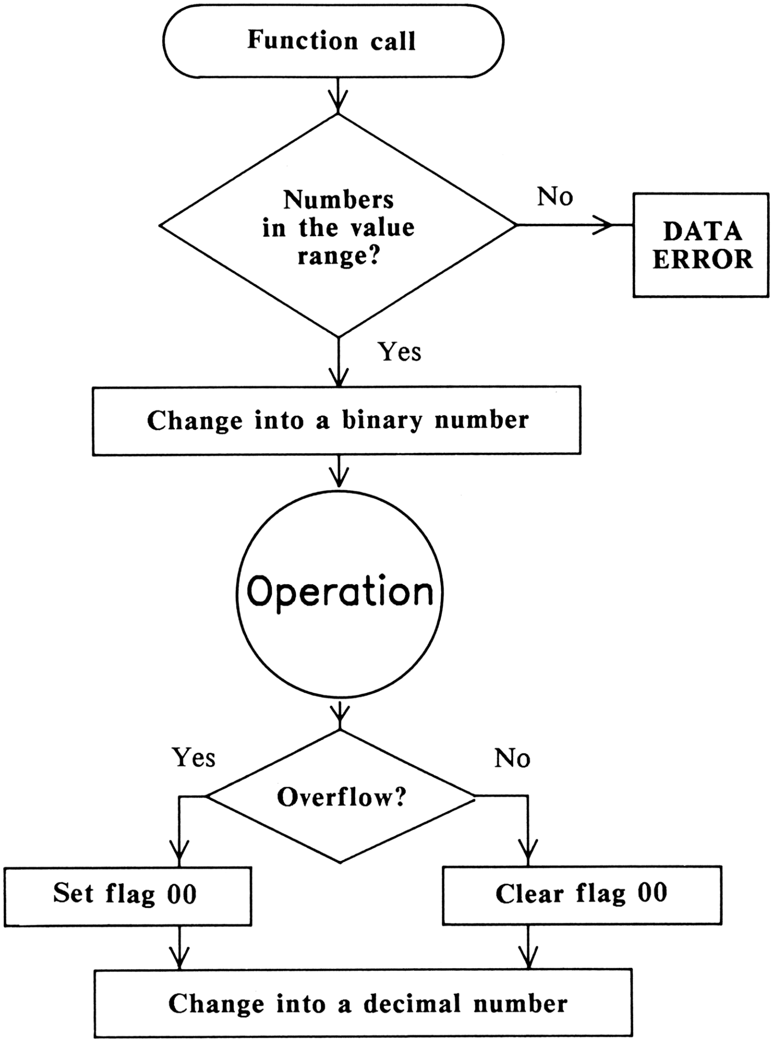
1) The current wordsize. It is defined with the function **WSIZE**.

2) The current sign mode. The decimal representation and the internal hexadecimal representation are linked by the complement, or sign mode employed. Before executing a certain arithmetic function the display always decimally represents the number which is first transformed into binary. The binary result is then retransformed into decimal depending on the current mode.

3) The functions only use the integer portion of the decimal number in X.

The principle operation of the hexadecimal functions is shown in the following flow chart:

Flow Chart for the Functions AND, OR, XOR, NOT, S<, S>, R< and R>



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Keynotes to the Flowchart:

1) It is checked, if all for the operation needed values are representable in the current wordsize and the chosen signs.
2) The numbers, decimally represented in the stack of the HP-41, are changed into binary numbers (dependent on the sign mode).
3) The actual operation is executed.
4) It is checked, if an overflow has taken place during the executed operation (check if the carry has been set). The flag 0 is used as a carry bit.
5) The binary numbers are changed to decimal numbers and placed in the stack.

Basic Setup

Following setups are available after first insertion of the CCD-module, or after a "MEMORY LOST" with the CCD-Module in place:

- Wordsize is set to 8 bits.
- Unsigned mode is set.

Description of the functions

To enable the above mentioned conditions at any time, execute the following steps:

UNS	turn on the Unsigned mode
CLX WSIZE	set wordsize to 8 bits.

Functions for Setting Wordsize and Signed Mode

WISZE

The function **WSIZE** sets the wordsize *bb* for all hexadecimal functions of the CCD-Module. The range of *bb* is 1 to 32 bits. The wordsize is stored in the CCD-Module's I/O buffer. **CLX WSIZE** clears the wordsize input in the I/O buffer. If the CCD-Module buffer does not exist a wordsize of 8 bits is assumed. The stack is not changed by this function.

Input

X register: *bb*

Examples

Key sequence	Description
9 **WSIZE**	Selected wordsize 9 bits, operations possible between 0_d to 511_d.
33 **WSIZE**	Error message:"DATA ERROR". Wordsize was not changed, since values greater than 32 are not allowed.
16 **WSIZE**	Selected wordsize is 16 bits.

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Further Hints

The number in the X register may be negative as well as contain digits after the decimal point; only the absolute integer value is used. "DATA ERROR" will show when numbers outside the range of 32_d to -32_d are used, "NONEXISTENT" will be displayed when numbers over 1,000 are used. The selected wordsize has no influence on the contents of the stack or the memory registers. When executing **WSIZE**, the error message "NO ROOM" may occur, since the wordsize is stored in the I/O buffer of the CCD-Module. In this case new memory space has to be made available before selcting the word size.

1CMP

The function **1CMP** puts the HP-41 into the 1's Complement mode. Other sign modes (2's Complements or Unsigned modes) are cancelled. The contents of the X register are placed in the LASTX register and are then substituted by the new representation of the hexadecimal number; i.e. the number from the X register is first changed into a binary number in the old mode and after switching to the new mode is changed back into a decimal number.

Input

none

Example

Key sequence	Description
1CMP	The HP-41 is put into the 1's Complement mode (only valid for binary functions of the CCD-Module).

Further Hints

If the number in the X register with the new sign mode can not be represented, the error message "DATA ERROR X" will result and the Signed mode will not be changed.

Related Functions

2CMP, UNS

2CMP

The function **2CMP** puts the HP-41 into the 2's Complement mode. Other sign modes (1's Complement or Unsigned mode) are deleted. The contents of the X register are put into the LASTX register and then replaced by the new representation of the hexadecimal number, i.e. the number in the X register is first changed into a binary number in the old mode and after switching to the new mode is changed back into a decimal number.

Input

none

Example

Key sequence	Description
2CMP	The HP-41 is put into 2's Complement mode (only valid for binary functions of the CCD-Module).

Further Hints

If the number in the X register can not be represented in the new mode, the error message "DATA ERROR X" will occur and the mode will not be changed.

Related Functions

1CMP, UNS

UNS

The function **UNS** puts the HP-41 into Unsigned mode. The other signed modes (1's or 2's Complement modes) are cancelled. The contents of the X register are stored in the LASTX register and are then replaced by the new representation of the hexadecimal number, i.e. the number in the X register is first changed into a binary number in the old mode and after switching to the Unsigned mode is changed back into a decimal number.

Input

none

Example

Key sequence	Description
UNS	The HP-41 is put into the Unsigned mode only valid for binary functions of the CCD-Module)

Further Hints

If the number in the X register can not be represented in the new mode, the error message "DATA ERROR X" will occur and the mode will not be changed.

Related Functions

1CMP, 2CMP

Input and Output Functions for Use with -HEX FNS

These functions are also described in the chapter on **-I/O FNS**, but for completeness these input and output aides for the CCD-Module hexadecimal functions are also explained in this chapter.

PMTH

The function **PMTH** allows for the input of hexadecimal numbers. It writes the equivalent decimal value into the X register. The stack is rolled up before the value is copied to X.

Input

The number of the digits to be put in is dependent on the current wordsize.

Example

Key sequence	Description
UNS	switches on the Unsigned mode
CLX WSIZE	sets the wordsize to 8 bits
PMTH 8E	Input of the value hex 8E. Immediately after input of the last digit (in this case E). The decimal value will be shown in the X register (in this case 142).

Example program:

"ADDRESS"
PMTH

Using these two steps, the message "ADDRESS'___" will show, after the input of two numbers the program will be continued.

Further Hints

Text can be shown during the execution of **PMTH** to specify the data wanted for the prompt. The function rejects input values which are too large. Only the keys *0* to *9* and *A* to *F* are active. Terminating the function can be done with the backarrow or ON keys.

VIEWH

The function **VIEWH** views the hexadecimal equivalent of the number in X.

Input

X register	:	decimal number in the permitted value range (dependent on the current wordsize and the selected mode).

Example

Key sequence	Description
142 **VIEWH**	The number in the X register (142) is changed into its hexadecimal equivalent and this is viewed (in this case 8E).

Further Hints

ALPHA data in X generates the error message "ALPHA DATA". If the decimal number in the X register is not representable in the current wordsize or sign mode, the error message "DATA ERROR X" will be indicated. For numbers whose hex representation has less digits than the current wordsize is set for, leading zeros are placed in the most significant digits.

Related Function

ARCLH, PMTH

ARCLH

ARCLH appends the hexadecimal equivalent of the number in the X register to the contents of the ALPHA register.

Input

X register	:	Decimal number in the allowed value range (dependent on the current wordsize and the selected complement mode).

Example

Key sequence	Description
UNS	switches on the Uunsigned mode
CLX WSIZE	set the wordsize to 8 bits
"ABC"	Input of the text "ABC" into the ALPHA register
ARCLH	appends two hexadecimal numbers to the ALPHA register; in this case 00, i.e., the ALPHA register now contains ABC00".
55 **ARCLH**	The number hex 37 is appended to the ALPHA register

Further Hints

For ALPHA data in X, the error message "ALPHA DATA" will show. If the decimal number in the X register is not representable in the current wordsize and the sign mode, the error message "DATA ERROR X" will be shown.

Related Functions

VIEWH, PMTH

XTOAH

The function **XTOAH** appends one or more characters with the value of the X register to the contents of the ALPHA register.

Input

X register	:	Value of the characters to be appended (depends on the current wordsize and sign mode)

Example

Key sequence	Description
CLA 10 **WSIZE**	The ALPHA register is erased and a wordsize of 10 bits is set.
340 **XTOAH**	340 equals 154_h. Therefore the following characters are appended to ALPHA, the man character (hex byte 01) and "T" (Byte hex 54).

Further Hints

With ALPHA data in X the error message "ALPHA DATA" is generated. If the decimal number in the X register is not representable in the current wordsize and sign mode, the error message "DATA ERROR X" will be indicated.

Related Function

XTOA (function in the Extended Functions module)

Logical Operations

AND

The function **AND** combines X and Y using the logical AND function, i.e. in the result all bits that were set in both binary numbers at the same time are set, all other bits are cleared (set to zero). The stack is pushed down and the old X value is placed in LASTX (Binarily this would mean for example: 1011 and 0111 is equal to 0011.)

Input

Y register	:	Operand 1
X register	:	Operand 2

Example

Key sequence	Display	Description
4 **WSIZE**	4.0000	selecting wordsize 4 bits
3 **ENTER** 1 **AND**	1.0000	0011 and 0001 equals 0001
7 **ENTER** 8 **AND**	0.0000	0111 and 1000 equals 0000
7 **ENTER** 15 **AND**	7.0000	0111 and 1111 equals 0111

Further Hints

Using ALPHA data, the error message "ALPHA DATA" be encountered. If the decimal number in the X or Y register is not representable in the current wordsize and sign mode, the error message "DATA ERROR X" or "DATA ERROR Y" will be indicated.

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Related Functions

OR, XOR, NOT

OR

The function **OR** combines X and Y with the logical **OR** function, i.e., all bits that were set in both individual binary numbers before the execution of this function, are set in the result. The stack is pushed down and the old X value is put down in the LASTX register. (Binarily this would mean for example: 1011 **OR** 0111 equals 1111.)

Input

Y register : Operand 1
X register : Operand 2

Examples

Key sequence	Display	Description
4 **WSIZE**	4.0000	sets wordsize of 4 bits.
3 **ENTER** 1 **OR**	3.0000	0011 or 0001 equals 0011
7 **ENTER** 8 **OR**	15.0000	0111 or 1000 equals 1111
7 **ENTER** 15 **OR**	15.0000	0111 or 1111 equals 1111

Further Hints

Using ALPHA data the error message "ALPHA DATA" will be generated. If the decimal number in the X or Y register is not representable in the current wordsize or sign mode, the error message "DATA ERROR X" or "DATA ERROR Y" will be shown.

Related Functions

AND, XOR, NOT

XOR

The function **XOR** connects X and Y with the logical EXCLUSIVE OR function, i.e. all bits that were set in only one of the two original binary numbers are set in the result. If a bit is set if both of the operands or, is clear in both of the operands then it will be cleared in the final result. The stack is lowered and the old X value is placed in LASTX. (Binarily this would mean for example: 1011 exclusive or 0111 equals 1100.)

Input

Y register	:	Operand 1
X register	:	Operand 2

Examples

Key sequence	Display	Description
4 **WSIZE**	4.0000	sets the wordsize 4 bits
3 **ENTER** 1 **XOR**	2.0000	0011 exclusive or 0001 equals 0010
7 **ENTER** 8 **XOR**	15.0000	0111 exclusive or 1000 equals 1111
7 **ENTER** 15 **XOR**	8.0000	0111 exclusive or 1111 equals 1000

Further Hints

Using ALPHA data, the error message "ALPHA DATA" is generated. If the decimal number in the X or Y register is not representable in the current wordsize or sign mode, the error message "DATA ERROR X", or "DATA ERROR Y" is displayed.

Related Functions

AND, OR, NOT

NOT

The function **NOT** inverts all bits of the number in the X register. The old X value is placed in the LASTX register. (binarily this would mean for example: NOT 1011 equals 0100.)

Input

X register : Decimal number

Examples

Key sequence	Display	Description
4 **WSIZE**	4.0000	sets wordsize 4 bits
3 **NOT**	12.0000	not 0011 equals 1100
7 **NOT**	8.0000	not 0111 equals 1000
15 **NOT**	0.0000	not 1111 equals 0000

Further Hints

Using ALPHA data, the error message "ALPHA DATA" will display. If the decimal number in the X register is not representable in the current wordsize and sign mode, the error message "DATA ERROR X" is displayed. In the 1's Complement mode executing the function **NOT** would carry with it a change of sign (+ to - or - to +).

Related Functions

AND, OR, NOT

Functions for the Manipulation of Individual Bits

S<

The function S< shifts the bits of the X register by one bit (one binary place) to the left. The bit that was pushed out is stored in the carry bit (Flag 0). If, before shifting, the very left bit was set, Flag 0 is set, if it was cleared, Flag 0 will be cleared as well. While shifting the bits the value 0 is always pushed in from the right.

Input

X register	:	decimal number which is binarily representable in the selected wordsize and the set sign mode.

Example

Key sequence	Display	Description
4 WSIZE	4.0000	setting the wordsize on 4 bits
UNS 1	1.0000	selecting of the Unsigned mode
S<	2.0000	0001 becomes 0010, Flag 0 is cleared
S<	4.0000	0010 becomes 0100, Flag 0 is cleared
S<	8.0000	0100 becomes 1000, Flag 0 is cleared and stays cleared
S<	0.0000	1000 becomes 0000, Flag 0 is set
S<	0.0000	0000 stays 0000, Flag 0 is clear

Further Hints

S< is equivalent to, in the Unsigned mode and the 2's Complement a multiplication by 2. In the 1's Complement the shift to the left in a positive number range also equals a multiplication by 2, whereas in a negative number range it would be equal to a multiplication by 2 and then a subtraction of 1. Using ALPHA data, the error message "ALPHA DATA" will be displayed. If the decimal number in the X register is not representable in the current wordsize and sign mode the error message "DATA ERROR X" is generated.

Related Functions

S>, R<, R>

S>

The function S> shifts the binary equivalent of the X register by one bit (one binary place) to the right. The pushed out bit is stored in the carry bit, i. e. in Flag 0. If, before moving, the very right bit was set, Flag 0 is set, whereas if it was cleared, Flag 0 will be cleared as well. When shifting the bits the value 0 is always pushed in from the left.

Input

X register: Decimal number that is binarily representable in the selected wordsize and the set sign mode.

Example

Key sequence	Display	Description
4 WSIZE	4.0000	set wordsize on 4 bits
UNS 8	8.0000	selection of unsigned mode
S>	4.0000	1000 becomes 0100, Flag 0 is cleared
S>	2.0000	0100 becomes 0010, Flag 0 is cleared
S>	1.0000	0010 becomes 0001, Flag 0 is cleared
S>	0.0000	0001 becomes 0000, Flag 0 is set
S>	0.0000	0000 stays 0000, Flag 0 is cleared

Further Hints

For ALPHA data, the error message "ALPHA DATA" shows. If the decimal number in the X register is not representable in the current wordsize and sign mode, the error message "DATA ERROR X" will be shown.

Related Functions

S<, R<, R>

R<

The function **R<** rotates on a binary representation of the X register by one bit (one binary place) to the left. The pushed out bit is stored in the carry bit, in Flag 0 and then pushed in again from the right. If, before rotating, the very left bit was set, Flag 0 is set, if it was cleared, Flag 0 will be cleared as well.

Input

X register : decimal number that is representable in the selected wordsize and set sign mode.

Example

Key sequence	Display	Description
4 WSIZE	4.0000	set wordsize on 4 bits
UNS 1	1.0000	selecting Unsigned mode
R<	2.0000	0001 becomes 0010, Flag 0 is cleared
R<	4.0000	0010 becomes 0100, Flag 0 is cleared
R<	8.0000	0100 becomes 1000, Flag 0 is cleared
R<	1.0000	1000 becomes 0001, Flag 0 is set
R<	2.0000	0001 becomes 0010, Flag 0 is cleared

Further Hints

With ALPHA data in X, the error message "ALPHA DATA" is displayed. If the decimal number in the X register is not rep resentable in the current wordsize and sign mode, the error message "DATA ERROR X" will be generated.

Related Functions

S<, S>, R>

R>

The function **R>** rotates the binary equivalent of the X register by one bit (one binary place) to the right. The pushed out bit is stored in the carry bit (Flag 0) and then pushed in again from the left. If, before rotating, the very right bit was set, flag 0 is set, if it was zeroed flag 0 will be cleared.

Input

X register : decimal number that is binarily representable in the selected wordsize and set sign mode.

Example

Key sequence	Display	Description
4 WSIZE	4.0000	set wordsize 4 bits
UNS 8	8.0000	select Unsigned mode
R>	4.0000	1000 becomes 0100, Flag 0 is cleared
R>	2.0000	0100 becomes 0010, Flag 0 is cleared
R>	1.0000	0010 becomes 0001, Flag 0 is cleared
R>	8.0000	0001 becomes 1000, Flag 0 is set
R>	4.0000	1000 becomes 0100, Flag 0 is cleared

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Further Hints

For ALPHA data, the error message "ALPHA DATA" is displayed. If the decimal number in the X register is not representable in the current wordsize and sign mode, the error message "DATA ERROR X" will be shown.

Related Functions

S<, S>, R<

bS?

The function **bS?** makes it possible to check if binary digits in the X register are set or clear. The decimal number is changed to its binary representation and then the specified bit is checked. This questioning is similar to the checking of a single flag, after the number in X was transferred to flags 0-7 with **X<>F** (**X<>F** is contained in the extended functions module, or the HP-41CX). This roundabout way through the flags is not necessary in the bit manipulation functions of the CCD-Module. The answer to **bS?** is "YES", if bit *bb* as specified in the X register is set, it is "NO", if the bit is cleared. A stack drop follows, the old X value is written into the LASTX register.

Input

X register	:	*bb* (decimal number; 0 <= *bb* <= current wordsize - 1)
Y register	:	decimal number that is binarily representable in the selected wordsize and the set sign mode.

Examples

Key sequence	Display	Description
4 **WSIZE UNS**	4.0000	setting of wordsize 4 bits and Unsigned mode
7 **ENTER** 0 **bS?**	YES	Bit 0 of the binary number 0111 or 7 is set.
CLX	7.0000	erasing of indication YES
7 **ENTER** 3 **bS?**	NO	The third bit of the binary number 0111 or 7 is not set.

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Further Hints

With ALPHA data in X, the error message "ALPHA DATA" displays. If the decimal number in the Y register is not representable in the current wordsize and the sign mode, the error message "DATA ERROR Y" is generated. The error message "DATA ERROR X" comes up if the given bit *bb* lies beyond the allowed value range. The numbering of the bits takes place from right to left, the rightmost bit is 0 bit. The highest bit number that can be given is always one smaller than the current wordsize (using wordsize 8 bits 0-7 can be given, thus all 8 bits of the binary number). During a program run the next step is executed, if the given bit is set, if it is cleared the next step is skipped.

Related Functions

bC?, Sb, Cb

bC?

The function **bC?** allows us to check if a bit of the binary representation in the Y register is cleared. The number of the bit to be checked is in X. The answer is "YES" if the corresponding bit in the X register, bit *bb*, is cleared, it is "NO" if the bit is set. A stack drop follows, the old X value is written into the LASTX register.

Input

X register	: *bb* (decimal number; 0 <= *bb* <= current wordsize - 1)
Y register	: decimal number which is binarily representable in the selected wordsize and the set sign mode.

Examples

Key sequence	Display	Description
4 **WSIZE UNS**	4.0000	setting of wordsize 4 bits and Unsigned mode.
7 **ENTER** 0 **bC?**	NO	bit 0 of the binary number 0111_b or 7 is not cleared.
CLX	7.0000	clearing of displayed "NO"
7 **ENTER** 3 **bC?**	YES	bit 3 of the binary number 0111_b or 7 is cleared.

– HEX FNS

Further Hints

For ALPHA data, the error message "ALPHA DATA" is generated. If the decimal number in the Y register is not representable in the current wordsize and sign mode, the error message "DATA ERROR Y" will be shown. The error message "DATA ERROR X" displays, if the given bit *bb* lies beyond the allowed value range. The numbering of the bits takes place from right to left, the rightmost bit is the 0 bit. The highest bit number that can be in X is always smaller than the current wordsize by one (using wordsize 8, bit 0-7 can be given, thus all 8 bits of the binary number). In a running program the next program step is executed, if the given bit is cleared, if it is set, the next step is skipped.

Related Functions

bS?, Sb, Cb

Cb

The function **Cb** allows us to clear the a bit of the binary equivalent of the decimal number in Y. The specified bit number is in the X register. A stack drop follows, the old X value is written into the LASTX register.

Input

X register	:	*bb* (decimal number; 0 <= *bb* <= current wordsize - 1)
Y register	:	decimal number which is binarily representable in the selected wordsize and the set sign mode.

Examples

Key sequence	Display	Description
4 **WSIZE UNS**	4.0000	setting of wordsize 4 bits and Unsigned mode
7 **ENTER** 0 **Cb**	6.0000	bit 0 of the binary number bin 0111 was cleared i.e. 0111 became 0110
7 **ENTER** 3 **Cb**	7.0000	bit 3 of the binary number bin 0111 was not changed, since it is already cleared

– HEX FNS

Further Hints

With ALPHA data in X, the error message "ALPHA DATA" will be shown. If the decimal number in the Y register is not representable in the current wordsize and sign mode, the error message "DATA ERROR Y" will be displayed. The error message "DATA ERROR X" is generated if bit *bb* lies beyond the allowed value range. The numbering of the bits takes place from right to left, the rightmost bit is always bit 0. The highest bit number that can be given is always one smaller than the current wordsize (using wordsize 8 bits 0-7 can be given, thus all 8 bits of the binary number).

Related Functions

bC?, bS?, Sb

Sb

The function **Sb** enables us to set any bit of the binary number representation of the decimal number in Y. The number in the X register in the given bit *bb* of the number in the Y register that is to be set. A stack drop follows, the old X value is written into the LASTX register.

Input

X register	:	*bb* (decimal number; 0 <= *bb* <= current wordsize - 1)
Y register	:	decimal number which is binarily representable in the selected wordsize and the set sign mode.

Examples

Key sequence	Display	Description
4 **WSIZE UNS**	4.0000	setting of wordsize 4 bits and Unsigned mode.
7 **ENTER** 0 **Sb**	6.0000	bit 0 of the binary number 0111_b was not changed, since it was already set.
7 **ENTER** 3 **Sb**	15.0000	bit 3 of the binary number 0111_b was set, 0111 became 1111.

– HEX FNS

Further Hints

With ALPHA data in X, the error message "ALPHA DATA" will show. If the decimal number in the Y register is not representable in the current wordsize and sign mode, the error message "DATA ERROR Y" displays. The error message "DATA ERROR X" is shown, if the given bit *bb* lies beyond the allowed value range. The numbering of the bits takes place from right to left, the rightmost bit is always the 0 bit. The highest bit number that can be given is always one smaller than the current wordsize (using a wordsize of 8, bits 0-7 can be specified, thus all 8 bits of the binary number).

Related Functions

bC?, bS?, Cb

Program Examples

Following you will find two helpful programs that will help you to better understand the CCD-Module binary functions.

Determination of the Set Wordsize

Using the following programs the current wordsize can be calculated:

```
01*LBL "W?"
02 CLX
03 UNS
04 NOT
05 LN1+X
06 4
07 LN
08 /
09 ST+ X
10 END
```

– HEX FNS

Clearing of Flag 55

If the printer is plugged in, usually the printer existence flag (flag 55) will be set. In program sections during which no printer is necessary, it is sometimes sensible to clear flag 55, since programs with flag 55 cleared will run faster. The clearing of this flag can be done with the following program:

```
01*LBL "CF55"
02 14
03 PEEKB
04 0
05 Cb
06 POKEB
07 END
```

When executing a printer function or a flag 55 question instruction with the printer plugged in, flag 55 will automatically be set or if the program stops runing.

Chapter 6

Input/Output Functions

Contents Chapter 6

Input/Output functions

In and Output Functions

The functions in this chapter are meant to aid the user in the dialog-oriented programming of the HP-41. These functions give many possibilities for formated input and output. With this kind of help the user can concentrate fully on the actual solution to the problem, without having to worry about the input and output. In particular, the CCD-Module makes output to HP-IL devices like the Thinkjet printer or Video interface, much easier than ever before. Furthermore the CCD-Module functions help save RAM memory that is needed for other uses, if such functions were written in normal USER-code. Also, the execution time of the programs can be greatly cut down by using the CCD-Module functions.

Input Functions

INPT

The function **INPT** is a universal data input function. With its help data blocks can be filled very comfortably. This function may be replaced by the following USER-code program:

```
01*LBL 05
02 TONE 0
```

03*LBL "INP" 04 " ⊢: "	A colon and a space are added to the contents of **ALPHA**
05 RCL IND 00 06 ARCL X	The contents of the register specified by control register R00 are recalled to X and appended to the contents of **ALPHA**
07 PROMPT	The contents of **ALPHA** are displayed and execution is halted; the HP-41 expects numerical input
08 CLA- 09 ABSP	The original contents of **ALPHA** are cleared, i.e., from the leftmost

10 ABSP 11 1 12 X<>Y 13 X<NN? 14 GTO 05 15 2 16 X<>Y 17 X>NN? 18 GTO 05	character up to and including the colon for comparison; if then number in X lies outside this range (the limits are specified in R01 and R02), execution returns to the beginning of the routine (note that the conditionals **X<NN?** and **X>NN?** are HP-41 CX functions)
19 STO IND 00 20 ISG 00 21 END	The value lies within the previously established limits; the contents of the register specified in R00 are overwritten by the contents of X; finally (line 20) the control number in R00 is incremented

PLNG "INP"
44 BYTES

As can be clearly seen, using the function **INPT** saves a lot of complex programming, which would otherwise use up a great amount of program memory. Actually this function consists of two different partial functions. When first executing the function only the first function part is executed. In the above shown USER program this corresponds to the code up to line 07 **PROMPT**. Then the function **INPT** executes **BST**, so that the program pointer points to **INPT**. In order for the function to know which part of the function to execute, namely the second part, the CCD-Module input flag is set (Bit 5 of byte 4 in Reg. 13).

Now the user is asked to commence with data input, and after pushing the R/S key the second part of the **INPT** function is executed. This part compares the input value with the input.

boundaries of registers 01 and 02 and stores it, corresponding to the control number in register 00. If no new value was given, the old one is used, but only if it lies within the input boundaries. After this the control number *iii.fffcc* in the register 00 is incremented by the value *cc* and the next program line is skipped, if: *iii>fff* (also see **ISG** in the HP-41 users handbook).

Input

R000: control number *iii.fffcc*
R001: possible minimum input value
R002: possible maximum input value

Examples

During a chemical experiment 10 different pH values were measured. These are to be put in data registers 10-19 for evaluation by a program that might look like this:

01*LBL "PHI NPT"	
02 10.019	The control number *iii,fffcc* is entered
03 STO 00	and stored in R00
04 CLX	The minimum permitted input (min = 0) is
05 STO 01	stored in R01
06 14	The maximum allowed input (max = 14) is
07 STO 02	stored in R02
08 "PH"	
09*LBL 01	This loop accomplishes input of the 10
10 INPT	data points
11 GTO 01	
12 BEEP	Execution is completed
13 END	

PLNG "PHINPT"
34 BYTES

Further Hints

The function **INPT**, like all prompt functions of the CCD-Module, executes **BST** once during the execution in the program. If **BST** is executed at the end of a program, this would take a long time when using large programs. Therefore it is advisable to put all prompt functions of the CCD-Module at the beginning of the concerned program (possibly in a subprogram), or shortly behind a global label. Furthermore the function **INPT**, as well as the function **PMTA**, sets the input flag of the CCD-Module (bit 5 of Reg. byte 13.4). This means that if the function **INPT** was broken off incorrectly (the only right keys are **R/S** and **ON**), the flag is still set, so that when executing the function only the second part is executed. To be sure that the input flag is erased at a certain place in the program, it is best to insert the following program lines before the **INPT** instruction:

13.4 These instructions erase the CCD-Module input flag.
1
POKEB

If only the second part of the function **INPT** is to be executed, the number 1 should be substituted by the number 33.

Related Functions

ISG, PMTA

PMTA

The function **PMTA** gives the possibility of a comfortable ALPHA input. Like the function **INPT** this function consists of two parts. If **PMTA** is executed in a running program, the program run will be interrupted and the program pointer will be set back by one program line to the function **PMTA**. Now the CCD-Module input flag (bit 5 of byte 4 in reg. 13) is set, the ALPHA register is switched and a prompt sign is placed into the display (ALPHA is switched on!). Using **R/S** and **ON** the function can be terminated, without the loss of the original ALPHA contents. If a different key is pushed, all of the previous contents of the ALPHA register are erased, which has no influence on the indication. If the depressed key is a letter key, the ALPHA register will be overwritten with the corresponding letter and this will be appended to the display. After pushing the key **R/S, PMTA** is executed for the second time. The function recognizes this by the fact that the input flag of the CCD- module is still set. Now this flag is erased, ALPHA is turned off and flag 23 is set, if there was any input into ALPHA.

Input

none

Example

The following subprogram clearly shows the effect of the function **PMTA**. In this program the user is asked for his name.

```
01*LBL "NAM
         E"
02*LBL 01          Beginning of the function loop
03 CF 23           The ALPHA input flag is cleared
04 "NAME: "
05 PMTA            The HP-41 requests the input of a name
06 FC? 23          Has the name been supplied?
07 GTO 01          If not, return to LBL 01 and ask again
08 END             The name has been input and execution is
                   finished
```

Further Hints

If, during execution of the function **PMTA** the ALPHA register is empty, the string "TEXT: " is indicated. Like all prompt functions of the CCD-Module, the function **PMTA** executes **BST** once during the execution of the program. If **BST** is executed at the end of a program, this will take quite a long time when using large programs. Therefore it is advisable to put all prompt functions of the CCD-Module at the beginning of the program (possibly in a sub program), or shortly behind a global label. **PMTA** also employs the input flag of the CCD-Module (see **INPT**).

Related Functions

INPT, PMTH, PMTK, PROMPT

PMTH

The function **PMTH** is the input function of the CCD-Module for hexadecimal numbers. If **PMTH** is executed using the from the keyboard, the user is asked to enter a hexadecimal number, corresponding to the set wordsize.(See *binary functions*) Now the keys 0-9 and A-F are active. If a hexadecimal number is input which is larger than the set wordsize, the function will begin anew and again asks for the input. If the input is correct, the stack is lifted and the number, after having been changed to a decimal number, is written into the X register. If the function is executed in a running program, the ALPHA register is placed in the left of the display and the program run is interrupted. After input of the last hex digit the program execution is automatically continued.

Input

The amount of the hexdigits to be given in is dependent on the set wordsize.

Example

The following program changes a hexadecimal number into an octal number and vice versa. Asking for the input of the corresponding numbers happens automatically.

01*LBL "H-O"	Change from HEX to OKT
	Setting of wordsize to 16 bit. The
02 16	greatest HEX number therefore is FFFF
03 WSIZE	which is 177777 octal.
04 UNS	Setting of Unsigned mode
05 "HEX"	Using "HEX" in ALPHA the function **PMTH**
06 PMTH	asks for HEX input.
07 OCT	The decimal number is changed into an
08 "OCT: "	octal number and as an integer number is
09 ARCLI	now appended to the ALPHA string "OCT:".
10 PROMPT	Now the octal result is shown.

11*LBL "O-H"	changing OCT to HEX
12 "OKT _"	Using string "OCT_" it is asked for the input of an octal number.
13 PROMPT	
14 DEC	Which is changed into its decimal equivalent. The hexadecimal representa-
15 "HEX "	
16 ARCLH	tion of this number is now appended to the ALPHA string "HEX".
17 PROMPT	Now the hexadecimal result is shown.
18 END	END!

PLNG "H-O"
55 BYTES

Further Hints

Like all prompt functions of the CCD-Module, the function **PMTH** executes **BST** once during the execution of the program. If **BST** is executed at the end of a program, it will take quite a long time when using large programs. Therefore it is advisable to put all prompt functions of the CCD-Module at the beginning of the program (possibly in a sub program) or shortly after a global label.

Related Function

ARCLH

PMTK

The function **PMTK** makes it possible to use a menu function for the HP-41. The ALPHA register is displayed and program execution is interrupted. Now the calculator is waiting for the user to press a key. For this there are four different possibilities:

1) The **ON** key turns off the calculator. The program pointer is still set to the function **PMTK**, so that when starting the program at this place the function is executed again.
2) A wrong key is pressed. The calculator answers this with a short sound (only when flag 26 is set).
3) A correct key is pressed. Correct meaning, its ALPHA character is in the display. Additionally, extra texan be placed in the ALPHA register, which has no influence on the menu control. This text must be placed into the ALPHA register, and it is then followed by at least one space and then correct ALPHA character. The function **PMTK** will distinguish between the extra informative text and the correct characters by use of the space, which separates the two text groups from each other. If a key, whose ALPHA character is displayed is pressed, the digit value of the character is written into the X register (the leftmost character being a value of 1). The stack is lifted. This number, being key dependent, can now be used for program ramification. The ALPHA register is erased, except for the commentary text and one empty space.
4) If the ALPHA register is empty, "KEY?" is displayed and the key code (also see **ASN** and **GETKEY** from the extended functions module) of the next key that is pressed will be entered into the X register. The stack is lifted.

Input

ALPHA register: commentary text and correct key signs, separated by at least one empty space or empty ALPHA register.

Example

We want to explain the menu control with a simple example. Controlled by different keys, we want the HP-41 to execute **BEEP** 1-4 times.

01*LBL "KEY"	
02 "1234"	The correct keys are entered into the ALPHA register.
03 PMTK	Using **PMTK** "1:2:3:4" is displayed and the calculator is expecting a key to be pressed.
04 GTO IND X	Depending on the digit value, which in this case corresponds to the ALPHA character we now go to to LBL 1-4.
05*LBL 04	
06 BEEP	
07*LBL 02	
08 BEEP	
09*LBL 02	
10 BEEP	
11*LBL 01	
12 BEEP	
13 END	

In the following example an application is shown, where the commentary text shall be also be displayed. The user is asked if the given data is supposed to be stored on tape or not.

01*LBL "?>C AS"	
02 "->TAPE? YN"	Commentary text and the correct characters (Y and N) are entered into the ALPHA register.
03 PMTK	Using **PMTK** the display will show: "->TAPE? Y:N" with Y for yes and N for NO. The two characters are spearated by a colon.
04 X<>Y	The control number for the function **WRTRX** is exchanged with the value 1 or 2, which was produced by the function **PMTK**
05 GTO IND Y	Depending on whether Y or N was pushed, we now go to the corresponding label 01 or 02.
06*LBL 01	
07 WRTRX	Write to tape.
08*LBL 02	LBL 02 no operation.
09 END	Ready!

If the ALPHA register is empty, the function **PMTK** works as follows:

Key sequence	Display	Commentary
CLA **PMTK**	KEY?‘	asking for a key to be pressed
SHIFT	31.0000	The key code of the SHIFT key (row 3, column 1 on the keys) is entered into the X register.

Further Hints

If a wrong key is pushed, it can be corrected by pressing it until "NULL" appears in the display. If the ALPHA register is empty, the key code of the key that was pressed, is displayed. If a comma, period or colon are to be one of the characters directly behind the space, at least two empty spaces are needed.

Following extra characters are useful as well:

Character code decimal	Key
005	**R/S**
007, 008	**SST**
012	**USER, PRGM, ALPHA**
014	**SHIFT**

Like all prompt functions of the CCD-Module, **PMTK** executes **BST** once during the execution of the program. If **BST** is executed at the end of a program, it may take quite a long while when using large programs. Therefore it is advisable to put all prompt functions of the CCD-module at the beginning of the program (perhaps in a sub program), or shortly behind a global label.

Related Functions

PMTA, PMTH, GETKEY

Output Functions

Functions for Printer Output

ACAXY

With **ACAXY** (accumulate ALPHA and X by Y) it is possible to transfer text and numbers in the X register to the printer buffer. The contents of ALPHA are justified to the left and the contents of the X register to the right. If flag 20 is set, all of the spaces between the text and the X value are substituted by dots. If text and X value together need more space than the given printer width, the printer width is doubled until there is enough space for an interval. If the ALPHA register is empty, only the X value is transferred (to the right). In FIX/ENG mode the X value is transferred in **ENG** format with a letter instead of an exponent. After executing the function the X value is stored into the LAST X register and the stack drops. **ACAXY** works only with the plug in printer, or with an HP-IL module.

Input

X register	:	Number which is to be transferred in format to the right.
Y register	:	Printer width (number between 0 and 99)
ALPHA register	:	Text to be printed to the left.

Examples

Example 1

The following line is to be printed with a 24 character printer.

Width: 200.00 meters

In the program mode the following program steps are necessary:

```
01*LBL "PR"
02 "WIDTH"
03 18
04 RCL 00
05 ACAXY
06 "METER"
07 ACA
08 PRBUF
09 END
```

Example 2

The register contents of the registers 1-9 are to be printed in table format using a 24 character printer:

Register Contents

R01=	200.00
R02=	15.00
R03=	16.20
R04=	150.00
R05=	20.50
R06=	12.20
R07=	150.00
R08=	18.80
R09=	42.32

Print with TAB Program

```
200.00   15.00   16.20
150.00   20.50   12.20
159.00   18.80   42.32
```

Program Listing

```
01*LBL "TAB"
02 CLA
03 1.009
04 8

05*LBL 01
06 RCL IND
        Y
07 ACAXY
08 ISG Y
09 GTO 01
10 PRBUF
11 END
```

Further Hints

If printer width in the Y register is equal to 0, the standard printer width of 24 characters is assumed. If negative printer widths occur, the absolute value is chosen.

A table of the internationally standardized characters for the exponent is found by looking at the function **ARCLE.**

Related Function

PRAXY

PRAXY

PRAXY (print ALPHA and X by Y) makes it possible to print text and number in the X register formated on the carriage width in Y. The contents of ALPHA are printed to the left and the contents of X to the right, depending on the width of the printing field specified in Y. This interval is automatically filled with empty spaces. If flag 20 is set, all spaces between text and X value are substituted by dots. If text and X value together need more space than the given printer width, the printer width is doubled until there is enough space for an interval. If the ALPHA register is empty, only the X value is printed (to the right). In FIX/ENG mode the X value is printed in **ENG** format with a letter instead of an exponent. After executing the function, the X value is stored into the LASTX register and the stack drops. **PRAXY** only works with the plug in printer, or with the HP-IL module plugged in.

Input

X register	:	Value to be printed formatted to the right
Y register	:	Printer width (number between 0 and 99)
ALPHA register	:	Text to be printed to the left

Example

The following line is to be printed using a 40 character printer:

```
NUMBER OF ITEMS...................... 120
```

In the program mode the following program steps are necessary:

```
01*LBL "PR 3"
02 FIX 0
03 "NUMBER OF
         ITEMS"
04 SF 20
05 40
06 120
07 PRAXY
08 END
```

Further Hints

If the printer width in the Y register is equal to 0, the standard printer width of 24 signs is assumed. If negative printer widths should occur, the absolute value is selected.

A table with the internationally standardized characters for exponents can be found by looking at the function **ARCLE**.

Related Function

ACAXY

– I/O FNS

ACLX

ACLX (accumulate line by X) transfers *aa* characters with the character code *bbb* into the printer buffer. *aa.bbb* is specified in X. This function makes it possible to output a line of the specified character, this quite fast and saves program memory. **ACLX** works only with the plug in printer, or with the HP-IL module.

Input

X register: *aa.bbb*

Example

A number column is to be underlined on the right and the printer stripe is to be limited by two lines, using a 24 character printer:

Print

```
✚✚✚✚✚✚✚✚✚✚✚✚✚
       200.00
       ------
*************
```

Program Listing

```
01*LBL "PR1"
02 SF 12
03 CLX
04 ACLX
05 RCL 00
06 ACX
07 ADV
08 6.045
09 ACLX
10 ADV
11 .042
12 ACLX
13 ADV
14 END
```

Further Hints

If the value *aa* in the X register is equal to 0, the standard printer width of 24 characters is assumed. If negative values should occur, the absolute value is used.

Related Function

PRL

PRL

The function **PRL** (print line) prints a line of 24 (or 12, if flag 12 is set) "-" characters. If any characters were present in the printer buffer, these are printed first, followed by a line feed and then the dashes.

Input

none

Example

The following program clearly shows the effect of **PRL**.

Print

```
                   TEST1
------------------------
TEST2
------------
```

Program Listing

```
01*LBL "PR4"
02 CF 12
03 "TEST1"
04 ACA
05 PRL
06 SF 12
07 "TEST2"
08 ACA
09 PRL
10 END
```


Further Hints

To reach underlinings of any length the function **ACLX** must be employed. **PRL** is only meant for the 24 character printers made by Hewlett-Packard.

Related Function

ACLX

Display of Hexadecimal Number Values

VIEWH

The function **VIEWH** (view hex) displays the hexadecimal equivalent of the X value (depends on the set word size and the set mode, see **-HEX FNS**, otherwise error message "DATA ERROR X" is displayed.")

Input

X register :	Decimal number in the allowed value range (dependent on the set wordsize and the selected mode).

Example

Key sequence	Description
142 **VIEWH**	The number from the X register is changed into its hexadecimal equivalent and displayed (8E).

Further Hints

ALPHA data in the X register calls forth the error message "ALPHA DATA", values that are too great cause the error message "DATA ERROR X".

Related Function

ARCLH

Setting FIX/ENG Mode

F/E

The function **F/E** sets the so called Fix/Eng mode. Flag 40 and 41 are set. The calculator now displays all numbers as in the **FIX** format. If the number is so large, that it has to be expressed with exponents (>9,999,999,999), it is displayed in the **ENG** format. The number of digits after the decimal point. This **F/E** mode is looked upon as an indicator for a special printer type by the functions **ACAXY** and **PRAXY** (see **ACAXY** and **PRAXY**).

Input

none

Example

Number representation in the different modes (for example with two digits after the decimal point):

FIX		**ENG**		**F/E**	
0,00		0,00	00	0,00	
1500,00		1,50	03	1500,00	
89.456,25		89,5	03	89.456,25	
9.999.999.999		10,0	09	9.999.999.999	
1,00	11	100,	09	100,	09
1,59	52	15,9	51	15,9	51
-7,95	53	-795,	51	-795,	51

Further Hints

The **F/E** mode stays active as long as no other mode (**FIX, ENG** or **SCI**) is selected. If the number of digits after the comma in the **F/E** mode is to be changed, it is first changed with the function **FIX**. Afterwards the Fix/Eng mode has to be switched on with **F/E**.

Related Functions

FIX, SCI, ENG, ACAXY, PRAXY

ALPHA Functions

Functions for Manipulating of the ALPHA Register

ABSP

The function **ABSP** (ALPHA backspace) erases the rightmost character in the ALPHA register.

Input

none

Example

If the text "ABCDEFG" is in the ALPHA register, the function **ABSP** erases the right character (in this case "G") and only "ABCDEF" is left in the ALPHA register.

Further Hints

The function **ABSP** works just as well if the last byte on the right in the ALPHA register has the value 00.

Related Function

CLA-

CLA-

The function **CLA-** erases the ALPHA register from the right, until it finds a letter followed by an empty space to the right. The space belonging to this letter is not erased.

Input

none

Example

If ALPHA displays for example "KEY 123", after execution of the function **CLA-** the ALPHA register will display "KEY ". The character string "123" has been erased!

Further Hints

If the ALPHA register is empty or contains only empty spaces or letters, the whole ALPHA register will be erased.

Related Functions

CLA, ABSP

XTOAH

The function **XTOAH** (X to ALPHA hex) appends (depending on the set wordsize) one or more characters to the ALPHA register. These characters correspond to the hexadecimal equivalent of the X register.

Input

X register: value of the character(s) to be appended

Example

Key sequence	Description
CLA 10 **WSIZE**	The ALPHA register is erased and a wordsize of 10 bits is set.
340 **VIEWH**	The value 340 is hexadecimally displayed as '154.
XTOAH	The characters '01 and '54 ("man" and "T") are appended to the ALPHA register.

Further Hints

Assuming a wordsize of 8 bits the function **XTOAH** works exactly like the function **XTOA** in the Extended Functions module.

Related Function

XTOA (Extended Functions module)

ARCLE

The function **ARCLE** (ALPHA recall engineering) works similar to the function already present in the HP-41 **ARCL X** (with **ENG** format), but substitutes the exponent with a letter, corresponding to the internationally standardized SI characters (see table).

Input

X register : Number to be appended to the ALPHA register.

Example

A number with an SI units is supposed to be inserted into the text and then printed on an 80 character printer:

Program

```
01*LBL "PR2"
02 "THE "
03 ACA
04 "STREET
  LENGTH "
05 ACA
06 "IS "
07 RCL 00
08 ARCLE
09 " ⊢m."
10 ACA
11 PRBUF
12 END
```

R00= 15,000.00

Print

```
THE STREET LENGTH IS 15.00 km.
```

Table of the Internationally Standardized SI Characters

Factor	Prefix Name	Prefix Symbol
10^{18}	Exa	E
10^{15}	Peta	P
10^{12}	Tera	T
10^{9}	Giga	G
10^{6}	Mega	M
10^{3}	Kilo	k
10^{-3}	Milli	m
10^{-6}	Micro	u (instead of μ)
10^{-9}	Nano	n
10^{-12}	Pico	p
10^{-15}	Femto	f
10^{-18}	Atto	a

Further Hints

If the exponent of the number in the X register is smaller than 10^{-78} or greater than 10^{78}, this number is, as in **ARCL X**, appended to the ALPHA register with its exponent.

Related Functions

ARCLH, ARCLI

ARCLH

ARCLH (ALPHA recall hex) appends the hexadecimal representation of the number in the X register to the contents of the ALPHA register. This representation is dependent on the selected wordsize and the set complement mode (see *binary functions*). Only characters between 0 and 9 and A to F are appended to the ALPHA register. If the wordsize is unchanged, the number of appended characters is always the same. Depending on the wordsize it may be between 1 and 8 characters.

Input

X register: decimal representation of a hex number

Example

A hexadecimal number is to be appended to a present text in ALPHA:

CLX WSIZE	Setting wordsize on 8 bits
"VALUE"	The text "VALUE" is written into the ALPHA register.
PMTH 8E	The hexadecimal number 8E is decimally entered into the X register as value 142.
ARCLH	The value 142 is appended to the ALPHA register as hexadecimal number 8E. Display shows: "VALUE 8E".

Further Hints

To avoid mistakes made when using this function, it is advisable to read the chapter *binary functions* first.

Related Functions

VIEWH, PMTH, XTOAH, ARCLE, ARCLI, ARCL X

ARCLI

The function **ARCLI** (ALPHA recall integer) makes it possible to append only the integer part of a number to the ALPHA register, without changing the display format of the calculator.

Input

none

Example

ALPHA says for example "COLUMN", the value in the X register is 15.002. After executing the function **ARCLI**, The ALPHA register displays "COLUMN 15".

Further Hints

none

Related Functions

ARCL X, ARCLE, ARCLH

Chapter 7

Functions for Advanced Programming

Contents Chapter 7

Functions for Advanced Programming

Functions for Advanced Programming

The 17 functions of this block form the basis for advanced programming techniques, many of which were previously possible only with a great amount of effort, if at all. The following chapter explains each function and demonstrates possible applications example programs. To be able to fully understand this chapter it is important to know about the HP-41 register structure and addressing. These are explained in detail in chapter 1 '*Internal Design of the HP-41*'.

PLNG

The function **PLNG** prompts for the input of the program name (global label), In the same way as the function **CLP** does. Execute the function and press **ALPHA** *name of the label* **ALPHA**. The length of the program in bytes is displayed. No status registers are changed, meaning that the program pointer is unaltered, as are the X register and all the stack registers. As in the function **CLP** the input sequence **PLNG ALPHA ALPHA** will display the program length for the current program, which is the one the program pointer is set to.

Input

The program name.

Example

If the program "CDE" is present in the calculator, the key sequence **PLNG ALPHA** *CDE* **ALPHA** will display the message " 60 Bytes". If a printer in TRACE or NORM mode is plugged into the calculator, the number of bytes is printed.

Further Hints

PLNG is not normally programmable although the byte sequence (162, 220) may be entered into a program line. When executed this would normally display the error message "NONEXISTENT". However, if register Q contains a program name backwards the program will stop and display the length of that program in bytes. If register Q is clear then the current program length is displayed, and also program execution is not interrupted.

Related Function

PPLNG

PPLNG

PPLNG (Programmable Program Length) is the programmable version of **PLNG**. The name of the program is expected in the ALPHA register, or any global label whithin the program. The result is pushed into the X register, lifting the rest of the stack.

Input

ALPHA register: program name

Example

The program lines
"CDE"
PPLNG

puts the value 60 into the X register, if the program "CDE" is in main memory.

Further Hints

If the ALPHA register is clear, **PPLNG** shows the length of the current program. When executing **PPLNG** from the keyboard the program pointer is unchanged. After execution in a program the pointer is moved to the next line to be executed, as would be expected, rather than branching to the program whose length has been calculated.

Related Function

PLNG

PHD

The function **PHD** (program head) gives the absolute address of the first byte of a program. Like **PPLNG**, a global label is expected in the ALPHA register. If the ALPHA register is clear the absolute address of the current program is returned. The absolute address of the program head is written into the X register. The format of the address is such that it can be immediately used by **PEEKB**, **POKEB**, **X>PC** or **X>RTN**.

Input

ALPHA register: program name

Example

Assuming SIZE 000, the key sequence **ALPHA** *name of the first program in CAT 1* **ALPHA PHD** will return 511.6 in X (on an HP-41 CV or CX).

Further Hints

It should be noted that the absolute address of a program line can change for many reasons and with it the result of **PHD**. The address changes when the **SIZE** is changed, often during packing, and all program lines following an inserted program line, including programs further down the catalog chain.

Related Function

PC>X

Functions for Calculation of Absolute Addresses

The calculation functions for absolute addresses are **A+**, **A+B**, **A-**, **A-A**. These work for the entire memory range of the HP-41, which is from 0.0 to 1023.6. The digits before the decimal point are the absolute register address *aaa* and the digits after the decimal point are the absolute byte address *c* within the given register. Values in the X or Y register, that do not correspond to the given range will cause the error message "DATA ERROR X" or "DATA ERROR Y". The digits following the first digit after the decimal point are not used for absolute addresses by the calculation functions, they do not call forth any error messages.

A+

This function increments the absolute address *aaa.c* specified in the X register by one byte. The result is entered into X, the original value of X before execution of A+ is placed in the LAST X register.

Input

X register: *aaa.c*

Examples

192.0 **A+** results in 192.1
192.6 **A+** results in 193.0

Further Hints

The function **A+** does not check if the absolute address it calculates actually exists.

Related Functions

A+B, A-, A-A

A+B

This function adds the absolute address *aaa.c* contained in the Y register to a number (*n* bytes) specified in X. If the X register contains a negative number, a subtraction will be made corresponding to this. As in a "normal" calculating function, for example **+**, the stack registers are pushed down: The result of the calculation "address plus bytes" is placed in the X register, the amount of the added bytes (original value of the X register) is put into the LAST X register.

Input

X register: *nnnn*
Y register: *aaa.c*

Examples

412 **ENTER** 70 **CHS A+B** results in 402
192 **ENTER** 2239 **A+B** results in 511.6
(= entire main memory range of the HP-41 CV or CX.)

Further Hints

The function **A+B** works independent of the fact that the absolute address actually exists, for the entire calculating range of 0,0 to 1023,6. The greatest correct input for the X register (amount of the bytes that are to be added) is 7167 (or -7167).

Related Functions

A+, A-, A-A

A-

This function decrements the absolute address *aaa.c* specified in X, by one byte. The result is entered into X, the original value of the X register, before execution of A-, is placed into the LAST X register.

Input

X register: *aaa.c*

Example

192.1 A- results in 192.0
193.0 A- results in 192.6

Further Hints

The function A- works independent of the fact if the absolute address really exists, for the entire calculating range of 0.0 to 1023.6.

Related Functions

A+, A+B, A-A

A-A

This function calculates the difference between an absolute address *aaa.c* in the Y register and an absolute address *ddd.e* in the X register. The result in bytes is entered into X. As in a "normal" subtraction, the stack registers are pushed down; the absolute address, which the X register contained before the execution of A-A is entered into LAST X. If, before the execution of A-A, the value in the Y register was greater than the value in the X register, the result will become negative.

Input

X register: *ddd.e*
Y register: *aaa.c*

Example

511.6 **ENTER** 192 **A-A** results in 2239
402 **ENTER** 412 **A-A** results in -70

Further Hints

The function **A-A** works independent of the fact if the absolute addresses actually exist, for the entire calculating range of 0.0 to 1023.6.

Related Functions

A+, A+B, A-

DCD

The function **DCD** (decode) decodes the value in X and appends the hexadecimally decoded representation to the ALPHA register. This function is especially useful for the analysis of non normalized numbers.

Input

X register: value to be decoded

Example

CLA RCL b DCD ALPHA

Result for example 000000000060F7, this means: The register b did not contain a return address, the program pointer was positioned to 247.5 (according to **PC>X**).

Further Hints

In the result representation of **DCD**, two hexadecimal numerals correspond to one byte, therefore the representation always has 14 digits and every single byte is definitely identifiable.

The return function of **DCD** would be "CDE" (code). The following program codes a hexadecimal representation from the ALPHA register and writes the result into the X and the M register (visible as text):

```
01♦LBL "CDE
           "

02 CLX
03 WSIZE
04 6,5
05 SF 22

06♦LBL 00
07 5
08 PEEKB
09 ABSP
10 X<>Y
11 RDN
12 57
13 -
14 X>0?
15 2
16 X<=0?
17 9
18 +
19 X<0?
20 CLX
21 FS?C 22
22 GTO 00
23 16
24 *
25 +
26 POKEB
27 SF 22
28 CLX
29 5.5
30 X<>Y
31 A-
32 X≠Y?
33 GTO 00
34 RCL [
35 END

 PLNG "CDE"
   60 BYTES
```

Functions for Manipulating the Program Pointer

The group of functions that make manipulations of the pointer and the return addresses possible, will be explained next. The functions **PC<>RTN, PC>X, X>PC, X>RTN, and XR>RTN** allow program manipulation of the program counter and the return stack. This is available for the entire memory range, the status registers and especially to the extended memory of the extended functions module and X memory modules. Additionally, **XR>RTN** allows a program to jump into any section of code in a plug in software module.

PC>X

The function **PC>X** (program counter to X) reads the absolute address of the program pointer out of the status register b and writes it into the X register. Since the value is a decimal number it can be stored in a data register. This function makes it possible to calculate any kind of byte distances very easily. It is, for example, possible to recognize if the jumping range of a two byte **GTO** is long enough for the required jump.

Input

none

Example

We want to calculate the leap length, to find out if a two byte **GTO** will suffice for this distance. This calculation could be done with the following steps:

Go to the program line after **GTO NN**, **PRGM** off, **PC>X**. Then go to **LBL NN**; **PC>X**, **A-A**.

If the displayed value is smaller than 112, a two-byte-**GTO** will be able to hold the jump distance when the jump is to be compiled. In case the result was negative (in the program **LBL NN** is in front of **GTO NN**), it is necessary before to go to the first **PC>X** on the program line which is before **GTO NN**, to exactly calculate the leap distance.

Further Hints

none

Related Functions

PHD, X>PC

X>PC

This function (X to program counter) sets the pointer to the absolute address *aaa.c* given in the X register. Every existent absolute address may be given, not only in the "normal" program memory range. **X>PC** is meant especially for reaching a certain place in a program where the absolute address of the program pointer was beforehand determined by PC>X. If this method is employed in the program memory range, the amount of the data registers may not be changed in the meantime, since otherwise the absolute addresses of the program would change.

Input

X register: *aaa.c*

Example

01 PC>X
02 TONE
03 X>PC

This is a neverending program routine and corresponds to the program sequence **RCL b, TONE N, STO b**, except the address returned by **PC>X** can be, contrary to the value from **RCL b**, stored in a data register, and the value for **X>PC** can be a simple decimal number without causing any problems, whereas the value for STO b must be encoded before it may be stored away.

Further Hints

X>PC is especially useful for directly reaching all of the extended memory of the extended functions or X memory module. The absolute address of the first byte in the extended functions module is 191.6. Here the header of the first file starts. Each file has two header registers and then starts with its actual contents. The absolute addresses are, like in the program memory, descending.

Example

CAT'4 displays:
KA K004 (Keyfile 4 register)
CLK K000 (Keyfile 0 register)
ALM B006 (Bufferfile 6 registers)
K? P007 (Program file 7 registers)

99.0000 (free registers in the extended functions module)

(The explanations to the file types **K** and **B** are given in the function block *X/F memory functions*; the program for the production of the file "CLK" with 0 registers can be found there as well.)

Now we want to directly execute the program "K?" in the file "K?" with the function **X>PC**. For this the absolute address of the program start in the program file must be calculated:

First byte in the extended functions module	:	191.6
minus two header registers of "KA" results in	:	189.6
minus four register files "KA" results in	:	185.6
minus two header registers of "CLK" results in	:	183.6
minus zero registers of "CLK" results in	:	183.6
minus two header registers of "ALM" results in	:	181.6
minus six registers of "ALM" results in	:	175.6
minus two header registers of "K?" results in	:	**173.6**

This is the absolute address of the first byte of the program "K?" as a program file in the extended functions module. With 173.6 in the X register and **X>PC** in this case, we get directly into the program "K?" and can execute it immediately. If the program is not to be executed starting from the first program line, the absolute address of each program line can be determined (for example go through program with **SST** and then read the program pointer with **PC>X**).

Related Functions

PC>X, PHD

X>RTN

The function **X>RTN** (X to return stack) sets the first return address to the absolute address *aaa.c* specified in X.

Input

X register: *aaa.c*

Further Hints

Like in **X>PC**, this function can display all actually existing absolute addresses (not only the ones in the program memory). At the next **RTN** or **END** the pointer is set to the given address. Each one of the used return addresses can be stored; this enables us to construct a practically unlimited return stack. Since ramification only occurs at **RTN** or **END**, all stack registers may be set up as necessary.

Related Functions

PC<>RTN, XR>RTN

PC<>RTN

This function (program counter exchange return address) exchanges the present value of the pointer with the present value of the first return address. The function **PC<>RTN** may therefore only be executed, if there is at least one return address present (otherwise "DATA ERROR").

Input

none

Example

The function sequence

Program A
rrr.b
X>RTN
PC<>RTN
Program B

has the following function:

First *program A* is executed, then the absolute address *rrr.b* is stored as the first return address, and **PC<>RTN** exchanges the pointer with this first return address. Thus the program execution is continued from the absolute address *rrr.b* (for example in the Extended Functions module!), until **RTN** or **END** is reached. Now the *program B* is executed, since **PC<>RTN** stored the program pointer at the start of *program B* as the first return address.

Further Hints

The function **PC<>RTN** makes it possible to program a subroutine call for any absolute address. A subroutine call and a return from the Extended Functions module are also made possible.

Related Functions

X>RTN, XR>RTN

XR>RTN

This functions allows the subroutine call or a jump into the program with an XROM number *kk.ll* of a software module at any program line *nnn* (not only where there is a label!). Therefore this function makes it possible to evade the **PROMPT** functions in some modules or to use only parts of programs as subroutines.

Input

X register:	program line number *nnn*
Y register:	XROM number *kk.ll*

Example

The program "T1" in the PPC ROM starts with program line 140, contains first 13 synthetic tones, then an **RTN**. It has the XROM number 10,47. Usually only XROM "T1" is able to execute all 13 tones together. The function **XR>RTN** now allows us to execute only part of program "T1". The sequence 10.47 **ENTER** 150 **XR>RTN** for example, only executes four tones (lines 150-153).

Further Hints

If a return into the main program is desired, **PC<>RTN** needs to be used after **XR>RTN**.

Related Functions

PC<>RTN, X>RTN

PEEK and POKE Functions

The functions for the pointer manipulation offer a variety of new programming techniques which could only be hinted at in the previous paragraph. For example it is even possible to run programs below the **.END.**, these programs are not listed in **CAT'1** and usually not immediately discovered. To be able to program there, the functions **PEEKB**, **POKEB**, **PEEKR** and **POKER**, which are talked about in this section, are needed. These functions allow every conceivable byte manipulation in the entire memory range of the calculator. This opens up more and more possibilities as will be shown in several programs.

PEEKB

This function reads the decimal value of the byte, whose absolute address *aaa.c* is displayed in the X register. The result is placed in X and the stack is lifted. The LAST X register is not changed. The absolute address of a byte is to be entered in the format *aaa.c*, in the course of which *aaa* is the absolute register address and *c* is the byte position within the register *aaa*.

Input

X register: *aaa.c*

Examples

If there are any User key assignments (from **CAT 2** or **CAT 3**) the byte 192,6 has the value 240. Using **PEEKB** it can be determined how many key assignment registers are occupied, since byte 6 of any key assignment register is 240. Therfore first 192,6 has to be tested, then 193,6 etc., until a value different from 240 results.

Program Example "A?"

Program "A?" determines how many registers all in all are occupied with key assignments and I/O buffers (alarm registers, buffers of the CCD Module or other buffers). The correct result can only be obtained if there is at least one free register after the .END.. If there is no unoccupied register, programming will not be easy. If only the amount of the occupied key assignment registers is to be calculated, the program lines from 15-21 need to be deleted.

```
01♦LBL "A?"
02 191.6
03 R↑
04 240

05♦LBL 00
06 R↑
07 R↑
08 ISG X
09 PEEKB
10 R↑
11 X=Y?
12 GTO 00
13 R↑
14 R↑
15 -.1
16♦LBL 01
17 +
18 PEEKB
19 X≠0?
20 GTO 01
21 CLX
22 192
23 -
24 INT
25 END

  PLNG "A?"
   47 BYTES
```

Another Program Example for PEEKB:

"VB" (VIEW BYTES)

The program "VB" makes it possible to clearly identify text lines in programs or to decode status registers in decimal or hexadecimal form. If the output is desired to be in hexadecimal format, line 11 is to be substituted by **ARCLH**, and **CLX, WSIZE** should be executed before starting the program to set the wordsize to 8 bits.

The program "VB" displays any amount of bytes in the ALPHA register in the following format:

absolute byte address - - - decimal value of the byte

The program can be used to display any byte in the memory range of the calculator (except the ALPHA register, since the program changes the ALPHA as well as the stack registers).

Input would be:

Number of desired bytes, **ENTER**, absolute address of the first byte. If a program is to be completely decoded, the following function sequence is possible:

Enter program name in ALPHA, then **PPLNG, PHD**, XEQ"VB".

```
01◆LBL "VB"
02◆LBL 00
03 " "
04 RCL d
05 FIX 1
06 ARCL Y
07 STO d
08 RDN
09 "⊢___"
10 PEEKB
11 ARCLI
12 AVIEW
13 RDN
14 A-
15 DSE Y
16 GTO 00
17 CLST
18 CLD
19 END

        PLNG "VB"
         40 BYTES
```

The output of the program "VB" itself is, for example, is as follows (in the course of which the given absolute addresses are displayed differently, depending on where in memory "VB" resides):

```
280,1___198
280,0___0
279,6___243
279,5___0
279,4___86
```

One more useful program using PEEKB: "GE"

This program sets the pointer on the first line of the last program in main memory, thus to the program which contains **.END.** as its last program line. This makes its function identical to its namesake program in the PPC ROM, only much shorter and without synthetics. Therefore the last program is reached quickly (even if it does not have a global label!), without having to run through the entire **CAT 1**.

In lines 02 to 13 the absolute address of the **.END.** is decoded out of the bytes 13.0 and 13.1 (register c). Two **A+**'s result in the absolute address of the start of **.END.** ; this address becomes the first return address and after **CLST END** executes the jump to the **.END.**, which stops the program run. Now if we switch to the PRGM mode, line 01 of the last program can be seen. (If **GTO..** was executed before, this last program contains only the **.END.**)

```
01♦LBL "GE"
02 13
03 PEEKB
04 X<>Y
05 A+
06 PEEKB
07 16
08 MOD
09 LASTX
10 X↑2
11 *
12 R↑
13 +
14 A+
15 A+
16 X>RTN
17 CLST
18 END

PLNG "GE"
 33 BYTES
```

Further Hints

none

Related Functions

PEEKR, POKEB, POKER

PEEKR

This function can be compared to the **RCL** function. However, it is now possible to read the contents of any register, without normalization, into the X register. This removes one of the main problems of synthetic programming. The address of the register to be read is entered as absolute address *aaa* into X. As when using an **RCL IND X**, the stack registers are changed.

Input

X register: *aaa*

Example

Program Example for PEEKR: "VR" (VIEW REGISTER)

The program "VR" shows any number of register contents in hexadecimally decoded format or prints the results. The absolute address is shown as well.

Input would be:
Absolute address of the first desired register as the part before the decimal point, and the last desired register as the number after the decimal point. 192.205 for example displays registers 192 to 205. The program "VR" was principally written for the decoding of the key assignment registers or buffer registers, therefore the registers are treated in ascending order. Line 05 appends three spaces to the ALPHA register. The program "VR" is only possible in this simple format, because **PEEKR** can not be normalized and simply decoded with **DCD**. Lines 09 to 11 were inserted so that the program will run faster when the printer is being used (no scrolling).

```
01♦LBL "VR"
02♦LBL 00
03 CLA
04 ARCLI
05 "├   "
06 PEEKR
07 DCD
08 RDN
09 SF 25
10 PRA
11 FC?C 25
12 AVIEW
13 ISG X
14 GTO 00
15 END

  PLNG "VR"
   34 BYTES
```

Further Hints

PEEKR works for every existing register address from 0 to 1023, if we want to use data (relative) register addresses with **PEEKR**, the absolute addresses of the data registers must be calculated.

Related Functions

PEEKB, POKEB, POKER

POKEB

This function writes over the byte, whose absolute address *aaa.c* is specified in Y, with the value *bbb* specified in X. **POKEB** works for the entire memory area of the calculator. The stack registers remain unchanged, as long as they are not specified by the absolute address in Y.

Input

X register: *bbb*
Y register: *aaa.c*

Examples

As the first program example we want to show a program for the production of synthetic tones and for the measuring of the tone duration, which changes itself depending on the input value. Thus we are talking about a "self programming" program.

```
01◆LBL "TD"
02 " "
03 ARCLI
04 "⊢___"
05 PC>X
06 11
07 CHS
08 A+B
09 X<>Y
10 POKEB
11 TIME
12 TONE X
13 TIME
14 X<>Y
15 HMS-
16 7 E-6
17 -
18  E4
19 *
20 RCL d
21 FIX 2
22 ARCL Y
23 STO d
24 R↑
25 R↑
26 AVIEW
27 END

  PLNG "TD"
   55 BYTES
```


The Program "TD" (Tone Duration)

The program "TD" executes every tone in the range of 0 to 127, by changing the second byte of the function in line 12. If, for example, the program is started with 120 in the X register, line 12 is changed into **TONE P.**; this change is brought about by the function **POKEB**, which is in line 10! The rest of the program consists of the time measuring with the help of the function **TIME** of the TIME module. If the principle of **POKEB**, as represented here, is to be used without the time measuring with the TIME module, the program is to be shortened accordingly:

```
01♦LBL "T"
02 PC>X
03 -8
04 A+B
05 X<>Y
06 POKEB
07 TONE X
08 END
```

Any **TONE** function may be entered into the program at line 07. Before executing "TD" or "T", the program memory must be packed, to exclude any possibility of an error.

A program using the functions **PEEKB** and **POKEB** is "TLC". It serves the function of switching, enabling and disabling the lower case mode of the CCD Module. If ALPHA mode is on and USER mode is off, it is possible to enter any ALPHA characters. This special function can be deactivated or activated again with the program "TLC". The corresponding coding takes place in register c (13) byte 4. Inputs are not necessary for "TLC".

```
01♦LBL "TLC
       "
02 13,4
03 PEEKB
04 128
05 XOR
06 POKEB
07 CLST
08 END

 PLNG "TLC"
   24 BYTES
```

```
01♦LBL "TLC
       "
02 13,4
03 PEEKB
04 128
05 X<Y?
06 CHS
07 +
08 POKEB
09 CLST
10 END

 PLNG "TLC"
   25 BYTES
```

```
01♦LBL "TLC
       "
02 13,4
03 PEEKB
04 X<>F
05 FC?C 07
06 SF 07
07 X<>F
08 POKEB
09 CLST
10 END

 PLNG "TLC"
   27 BYTES
```

As can be seen when looking at the program example, there are several different possibilities to switch a bit around.

Another especially useful program using **PEEKR**, **PEEKB** and **POKEB** is "CHK". It corrects the checksum of a program file in the Extended Functions module. If an uncompiled program (not all GTO's and XEQ's were executed before the storing into the extended functions module) is directly executed in the extended functions module, it will not be possible to get the program back into main memory using **GETP** or **GETSUB**. If this is attempted it will call forth the error message "CHKSUM ERR". Now only the program "CHK" has to be executed with the name of the program file in the ALPHA register, and the checksum is corrected. The program file must be completely in the Extended Functions module! The program "CHK" may also be used for programs,which are completely inside an X memory module.

Now line 03 should be changed to 751 or 1007, depending in which port the X memory module has been plugged. Line 04 appends six spaces to the ALPHA register.

```
01♦LBL "CHK
             "
02 RCLPTA
03 191
04 "├
             "
05 7
06 AROT
07 RCL [

08♦LBL 00
09 R↑
10 R↑
11 PEEKR
12 DSE Y
13 R↑
14 X≠Y?
15 GTO 00
16 CLX
17 STO \
18 RDN
19♦LBL 01
20 RDN
21 A-
22 PEEKB
23 ST+ T
24 DSE Z
25 GTO 01
26 RDN
27 A-
28 RCL Z
29 256
30 MOD
31 POKEB
32 END

 PLNG "CHK"
   66 BYTES
```

Further Hints

Since **POKEB** can change any byte, this function should only be employed if the calculation function is clear. Otherwise it may draw forth unwanted changes in programs, data registers, status register etc. or "MEMORY LOST".

Related Functions

PEEKB, PEEKR, POKER

POKER

This function writes over the absolute register, whose address *aaa* is specified in the Y register, with the contents of the X register. **POKER** works for the entire exisiting register range of the calculator. The stack registers remain unchanged, as long as they are not specified by the absolute address in the Y register.

Input

X register: value to be stored
Y register: *aaa*

Examples

Program Example for POKER: Program "CB" (Clear Buffer)

The function of the program "CB" corresponds to the program "CK" from the PPC ROM. I erases the entire I/O buffer area. All registers starting with the register with the absolute address 192 up to the register directly under the **.END.** are erased. This erases all I/O buffers and all key assignments from **CAT 2** or **CAT 3** . In CAT'6 it is necessary to erase the key assignment bit to each key with the key C (assignments appear as **ABS**). All key assignments bits can be erased at once using 15 **ENTER CLX POKER** and 10 **ENTER CLX POKER**; but this also causes all key assignments of the global labels to become ineffective. The actual purpose of the program "CB" is to erase garbage that has been placed in the I/O buffer area.


```
01♦LBL "CB"
02 13
03 PEEKB
04 X<>Y
05 A+
06 PEEKB
07 16
08 MOD
09 LASTX
10 X↑2
11 *
12 R↑
13 +
14 DSE X
15  E3
16 /
17 193
18 +
19 DSE X
20 CLST
21 .

22♦LBL 00
23 POKER
24 ISG Y
25 GTO 00
26 END

   PLNG "CB"
    46 BYTES
```

The program "CB" calculates the absolute address of the register, in which the **.END.** is stored. Afterwards this address is decreased by one in line 14. If there are some free registers present in the calculator (**RTN**, **PRGM** on: displays 00REG NN), these registers can be hidden by storing a number into the register directly under the **.END.** Thus "CB" is only run until line 14 (incl.) and then the input: **ENTER**, **POKER** follows. Now the HP-41 does not show any free registers. This faulty state can be neutralized by executing program "CB".

Every unwanted register within the free registers can be erased with "CB". The program can also be modified in such a way that a certain number of key assignment registers and buffer registers is preserved; for this the number of the registers to be preserved has to be subtracted from 193 and the result has to be inserted in line 17 of the program "CB". Corresponding to this, the programs "A?" and "CB" can be combined.

Further Hints

Since **POKER** can change any register, this function should only be employed if the calculating structure is clear. Otherwise it may result in unwanted changes in programs, data registers, status registers, etc. or "MEMORY LOST".

Related Functions

PEEKB, PEEKR, POKEB

The entire function block of the -**ADV FNS** offers a great number of new possibilities for advanced programming of the HP-41. A further example for this is the program "ST". It serves to find all synthetic text lines of a program decodes them and then prints them. After the prompt "PRGM?" a global label of the program to be checked has to be entered and started with **R/S**. **SIZE 020** is needed. The program "ST" does not contain any synthetic text lines, but does contain three synthetic three byte **GTO** functions:

line 031 **GTO** 13
line 121 **GTO** 08
line 142 **GTO** 08

The Program "ST" (Synthetic Text Lines)

```
01♦LBL "ST"
02 CLST
03 WSIZE
04 STO 01
05 "PRGM? "
06 PMTA
07 PRA
08 PHD
09 STO 00
10 CF 22
11 GTO 08

12♦LBL 01
13 RCL 00
14 A-
15 STO 00
16 LASTX
17 PEEKB
18 RTN

19♦LBL 02
20 XEQ 01
21♦LBL 03
22 XEQ 01
23 GTO 08

24♦LBL 04
25 XEQ 01

26♦LBL 05
27 XEQ 01
28 240
29 -
30 X<0?
31 GTO 13
32 STO 03

33♦LBL 06
34 XEQ 01
35 DSE 03
36 GTO 06
37 GTO 08
```



```
38♦LBL 07
39 FS? 22
40 GTO 09
41 SF 22

42♦LBL 08
43 ISG 01
44 CLX
45 CF 21
46 VIEW 01

47♦LBL 09
48 XEQ 01
49 STO 04
50 X=0?
51 CF 22
52 X=0?
53 GTO 09
54 16
55 X>Y?
56 GTO 08
57 13
58 +
59 X>Y?
60 GTO 07
61 CF 22
62 2
63 +
64 X>Y?
65 GTO 05
66 113
67 +
68 X>Y?
69 GTO 08
70 48
71 +
72 X>Y?
73 GTO 03
74 14
75 +
76 X=Y?
77 GTO 03
78 1
79 +
80 X=Y?
81 GTO 03
82 X>Y?
83 GTO 04
84 33
85 +
86 X>Y?
87 GTO 02
88 -
89 X=0?
90 SF 21
91 4
92 +
93  E3
94 /
95 5
96 +
97 STO 02
98 1
99 -
100 STO 03
101 FS? 21
102 GTO 11

103♦LBL 10
104 XEQ 01
105 127
106 X=Y?
107 GTO 11
108 32
109 -
110 X<Y?
111 SF 21
112 X<> L
113 X>Y?
114 SF 21
```

```
115♦LBL 11
116 RDN
117 STO IND
          02
118 ISG 02
119 GTO 10
120 FC? 21
121 GTO 08
122 CLA
123 RCL 01
124  E2
125 X>Y?
126 "0"
127 SQRT
128 X>Y?
129 "⊢0"
130 X<>Y
131 ARCLI
132 "⊢:"
133♦LBL 12
134 RCL IND
          03
135 ARCLH
136 "⊢ "
137 ACA
138 CLA
139 ISG 03
140 GTO 12
141 PRBUF
142 GTO 08

143♦LBL 13
144 SF 21
145 ADV
146 BEEP
147 END

   PLNG "ST"
   251 BYTES
```

Barcodes of Programs in Main Memory
with the CCD-Module and ThinkJet Printer

The program "PBC" makes it possible to print bar codes of any program directly out of the RAM of the HP-41. For this the extended functions module, the ThinkJet printer (with IL module) and the CCD-module are required.

Program Use:

1. Find the printer and select with CAT'0 and set back. (Key **ENTER** and key C in CAT'0)
2. **SIZE 019** is necessary.
3. A global label of the program, of which the bar codes are to be printed is entered into ALPHA. If the ALPHA register is empty, the program "PBC" prints its own bar codes.
4. Start the program "PBC".

```
01♦LBL "PBC
           "
02 PHD
03 CLRG
04 STO 00
05 1
06 PPLNG
07 STO 02
08 -
09 A+B
10 PEEKB
11 SF 23
12 6
13 bS?
14 CF 23
15 9.018
16 STO 03
17 SF 21
18 PRA
19 "Æ*r784S
           "
20 ACA
21 "µ"
22 23
23 CRFLAS

24♦LBL 00
25 RCL 00
26 A-
27 X<> 00
28 PEEKB
29 STO IND
          03
30 ST+ 06
31 DSE 01
32 GTO 01
33 143
34 -
35 X<=0?
36 97
37 64
38 -
39 X<=0?
40 34
41 32
42 -
43 X<=0?
44 3
45 STO 01
46 STO 04

47♦LBL 01
48 ISG 03
49 X<0?
50 GTO 02
51 DSE 02
52 GTO 00

53♦LBL 02
54 RCL 05
55 16
56 MOD
57 LASTX
58 FC? 23
59 ST+ X
60 +
61 ST+ 06
62 STO 07
63 ISG 05
64 CLX
65 RCL 04
66 RCL 01
67 DSE X
68 -
69 RCL 08
70 +
71 STO 08
72 RCL 06
73 +
74 255
```



```
 75 MOD
 76 X=0?
 77 LASTX
 78 STO 06
 79 RCL 03
 80 INT
 81 DSE X
 82  E3
 83 /
 84 9
 85 +
 86 STO 03
 87 3
 88 -
 89 CLA
 90 RCL 05
 91 CHS
 92 ARCLI
 93 "⊢-"
 94 PRA
 95 "ρρ"
 96 SF 22

 97♦LBL 03
 98 X<>Y
 99 RCL IND
            X
100 7
101 CHS

102♦LBL 04
103 bC?
104 XEQ 07
105 LASTX
106 bS?
107 XEQ 08
108 LASTX
109 ISG X
110 GTO 04
111 APPCHR
112 CLA
113 RDN
114 ISG Y
115 GTO 03
116 XEQ 08
117 XEQ 07
118 APPCHR
119 26

120♦LBL 05
121 RCLPT
122  E3
123 *
124 "Æ*b"
125 ARCLI
126 "⊢W"
127 ACA
128 CLX
129 SEEKPT

130♦LBL 06
131 GETREC
132 OUTA
133 FS? 17
134 GTO 06
135 X<>Y
136 DSE X
137 GTO 05
138 6
139 "Æ*b1W♦"
140 GTO 10

141♦LBL 07
142 FS? 22
143 "⊢ρ"
144 FC? 22
145 "⊢↓"
146 RTN
```



```
147♦LBL 08
148 FC?C 22
149 GTO 09
150 "├├"
151 RTN

152♦LBL 09
 153 "├↓"
154 SF 22
155 RTN

156♦LBL 10
157 ACA
158 DSE X
159 GTO 10
160 "μ"
161 CLFL
162 RCL 05
163 18
164 MOD
165 X=0?
166 OUTA
167 16
168 RCL 01
169 DSE X
170 *
171 STO 08
172 DSE 02
173 GTO 00
174 PURFL
175 "Æ*rB"
176 OUTA
177 BEEP
178 END

   PLNG "PBC"
    319 BYTES
```

Program Description:

The program uses two routines from the bar code program of Winfried Maschke, as was published in PRISMA 10/11-1982 and in the PPC Calculator Journal V9N4P45. The bar codes are, corresponding to the status of the program of which they are printed, produced in normal and privately protected format. To be sure that the graphic capacity of the ThinkJet printer can never be exceded only ten program bytes (+ three control bytes) are printed in one row. The program contains eleven synthetic text lines:

Line	Decimal values	Description
019	247,027,042,114 055,056,052,083	Escape sequence for the graphic mode.
021	241,012	File name
095	242,112,112	Start bits 0 0
124	243,027,042,098	Escape sequence for the number of the graphic bytes together with lines 125,126
139	246,027,042,098, 049,087,000	Escape sequence for a graphic feed
143	242,127,112	Graphic byte for 0 bit
145	242,127,007	Graphic byte for 0 bit
150	242,127,127	Graphic byte for 1 bit
153	243,127,007,240	Graphic bytes for 1 bit
160	241,012	File name and paper feed
175	244,027,042,114,066	Escape sequence for end of graphic mode

The decimal byte values of the program of which the bar codes are to be printed, are read out of the program memory with **PEEKB** (line 28) and stored in the data registers 9 to 18 (line 29). Register 00 contains the absolute byte address of the byte to be worked on next. The number of program bytes is stored in data register 02; this register is used as a counter (lines 51 and 172). If ten byte values are stored, the values for three control bytes are calculated (lines54 to 78); these are stored in data registers 06, 07, and 08; registers 05 contains the respective row number.

For each single bit of the bar code row a graphic byte is stored into a text file, starting with line 95. Line 95 contains the two bits for the two start bits; all other bits are formed in the labels 07,08 or 09 for each bit of the read program. Each byte of the program gives us 8 to 12 graphic bytes. To reach the desired height of the bar code rows, the entire graphic information of a row is sent to the printer 26 times (Label 05 and Label 06). The height of these bars can be changed using the control number in line 119. Lines 156 to 159 in connection with the escape sequence from line 139 cause a line feed to the next bar code row. This control number (6) is in line 138 and can be changed as well.

The program prints a row of immediately readable bar codes in first quality in about 3 1/2 minutes. If the graphic bytes were not stored in a text file, a program with the same function, such as "PBC" would be possible without the Extended Functions module,but in this case the printing of a bar code row would take about 35 minutes! After 18 bar code rows have been printed on one page, the program automatically executes a form feed (lines 162 to 166); control number for this in line 163. This way the program automatically prints bar codes for programs of any length using endless paper. If single pages are used, a new paper has to be put in by hand after the paper output and the blue key "TOF" has to be used. (For this paper change the program does not have to be stopped.)

Flags 17, 22 and 23 are used. The program can be stopped at any time; it can also be executed using **SST**. If the calculator is to be turned off during the program run (for example for a battery change), the state of the flags 17, 22 and 23 has to be asked about beforehand. This state must be reconstructed when starting anew. The stack registers and the ALPHA register, the data registers used by the program (0 to 18) and **SIZE** may obviously not be changed either, if the program is to be executed successfully. If the program is to be broken off, the printer must be cleared (by **CAT‘0**) and the text file should be erased.

If you own an Extended Functions module of the B revision, you should, after the program ends, define a working file (because of **PURFL** in line 174). The program contains a Long Form **GTO** (208,000,000) in line 173.

Program (319 bytes) and text by Gerhard Kruse.

Chapter 8

XF/Memory Functions

– XF/M FNS

Contents Chapter 8

XF/Memory Functions

The Extended Functions/Memory Functions block

These functions expand the capability and utility of the Extended Functions module. Therefore they can only be employed in connection with this module or an HP-41CX. Otherwise the error message "NO XF/M" will occur.

SAVEB

Saves the I/O buffer with the ID number *aa* in the buffer file specified in alpha, *aa* is specified in X. If the ALPHA register is empty, the current file is used. The function **SAVEB** allows us to construct as many files as wanted (with different names) of the same buffer ID number (for a description of the various buffers ID's in use see **B?**).

Input

X register	:	*aa*
ALPHA register	:	file name

Example

The present alarm data are to be stored as a file with the name "ALM".

Input: **ALPHA** *ALM* **ALPHA** 10 **SAVEB.**

These inputs cause the bufferfile "ALM" to be constructed and the data in this buffer is saved. The original buffer is preserved in memory. The alarm data may be erased by using 10 **CLB**, this will free the registers.

Further Hints

A buffer file with the file type **B** is displayed in using **CAT'4** with the CCD Module in the calculator. The CCD module distinguishes between different buffer files, since it is not visible in **CAT'4**; this means, a buffer file which contains alarm data for the TIME module can not be written over by a buffer file with a different ID number.

Related Functions

GETB, SAVEK, GETK

GETB

This function puts the buffer data from the buffer file back into the I/O buffer. The file name is in the ALPHA register, if the ALPHA register is empty, the current file is employed. If an I/O buffer which corresponds to the buffer file to be retrieved already exists, this I/O buffer is erased before using the file data to construct a new buffer.

Input

ALPHA register: file name

Example

Program for I/O Buffers: "BS?" (Buffer Size)

The program "BS?" is to be started with the desired buffer ID number in the X register. It then calculates how many registers the corresponding buffer occupies. If the number given in X does not correspond to an existing buffer the function **SF 99** in line 04 shall cause the error message "NONEXISTENT". The program works perfectly independent of how many different buffers exist. Also any amount (or none) of key assignment registers may be occupied. The ID number of the buffer which is constructed by the CCD Module itself, is 5. Therefore 5 XEQ **"BS?"** indicates how many registers this buffer occupies.

```
01♦LBL  "BS?
            "
02 B?
03 X=0?
04 SF 99
05 17
06 *
07 191.6
08 R↑
09 240

10♦LBL 00
11 R↑
12 R↑
13 ISG X
14 PEEKB
15 R↑
16 X=Y?
17 GTO 00
18 X<> T
19 X=Y?
20 GTO 02

21♦LBL 01
22 XEQ 02
23 +
24 A+
25 PEEKB
26 RCL Z
27 X≠Y?
28 GTO 01

29♦LBL 02
30 RCL Z
31 A-
32 PEEKB
33 END

 PLNG "BS?"
   64 BYTES
```

Further Hints

If the calculator is switched on without the module that created the I/O buffer, the management system of the HP-41 automatically erases that I/O buffer. But the functions **SAVEB** and **GETB** work independent of the fact if the module belonging to the treated buffer is plugged in or not.

The function **CLFL** should not be executed for buffer files; for erasing the files, **PURFL** should be used.

Related Functions

SAVEB, SAVEK, GETK, MRGK

SAVEK

This function stores all key assignments of functions from **CAT 2** and **CAT 3** as a keyfile in extended memory.

The use is analoguous to **SAVEP**. The file name must be specified in the ALPHA register. If the ALPHA register is empty, the current file is employed.

Input

The existing key assignments from **CAT 2** and **CAT 3** are to be stored in a keyfile with the name "KEYS". For this the following steps are necessary:

ALPHA "KEYS" ALPHA SAVEK

Further Hints

A keyfile is displayed in **CAT'4** with the display **K.** The key assignments are preserved unchanged.

Related Functions

GETK, MRGK, GETB, SAVEB

GETK

This function erases all key assignments of functions from **CAT 2** and **CAT 3**, and then activates the stored key assignments in the specified key file. The file name is in the ALPHA register. If the ALPHA register is empty, the current file is used.

Input

ALPHA register: file name

Example

A Program for GETK: "CLK" (Constructing of a CLEAR KEY FILE)

The program "CLK" constructs a file which is displayed as "CLK K000" in **CAT'4**, it consists only of header registers. This file erases all key assignments of functions from **CAT 2** and **CAT 3**. (**CLKEYS** would erase all key assignments of global labels as well.) This program does not require any input. It can only be used if there are at least two free registers in the extended functions portion of extended memory. Otherwise the program will stop in line 10 displaying "NONEXISTENT" or at line 17 displaying "DATA ERROR".

The program "CLK" contains two synthetic text lines:

line 03: F7, FF, FF, FF, FF, FF, FF, FF
line 30: F0 (NOP).

line 18 contains the file name "CLK" and four spaces; meaning the ALPHA register has the length 7!

Immediately after "MEMORY LOST" or after the extended function module was plugged in anew, it is necessary to execute **CAT'4** once, before the program "CLK" can be used.

A register with seven hex FF bytes (dec 255) is stored as a limit below the last employed register in the extended memory. First, the program "CLK" searches for this border (lines 02 to 13). Now this border register is written over with the file name "CLK" (lines 18 to 20), and the register immediately below gets the criterion as keyfile (lines 22 to 28). The register directly below is now marked as a new border register (lines 29 to 32). Now **GETK**, with the help of the produced keyfile, erases all key assignments of functions from **CAT 2** and **CAT 3**.

```
01♦LBL "CLK"
02 192
03 ""
04 RCL [
05 ENTER↑

06♦LBL 00
07 R↑
08 R↑
09 DSE X
10 PEEKR
11 R↑
12 X≠Y?
13 GTO 00
14 66
15 R↑
16 X<=Y?
17 ASIN
18 "CLK"
19 RCL [
20 POKER
21 DSE Y
22 CLX
23 POKER
24 CLX
25 .6
26 +
27 96
28 POKEB
29 DSE Y
30 ""
31 X<> T
32 POKER
33 CLST
34 GETK
35 END

 PLNG "CLK"
   75 BYTES
```

Further Hints

Key assignments of programs are only erased if a different assignment is put on the corresponding key by the fetched keyfile.

Related Functions

SAVEK, MRGK, SAVEB, GETB

MRGK

This function activates the key assignments stored in the employed keyfile. Existing key assignments are only erased if the same key is occupied by a key in the keyfile. Other existing assignments remain unchanged.

Input

ALPHA register: file name

Example

Since the function **GETK** erases all exisitng key assignments from **CAT 2** and **CAT 3**, the functions **SAVEK** and **GETK** give a simple and quick possibility to pack the key assignment registers.

The key sequence for this is:

Put any name into ALPHA, **SAVEK, GETK, PURFL.** If you possess an Extended Functions module of the revision B, **CAT'4** or **EMDIR** should be executed following this, to secure the files in extended memory.

The following program packs the key assignment registers only by use of the functions **PEEKB** and **POKEB.** The program needs no input and can be stopped at any time or executed with **SST.** But if the function **POKEB** has been reached once, the program must run through until the end, since otherwise there will be chaos or double storages in the assignment registers. The program "PK" requires **SIZE 002**. All buffers remain untouched.

```
01♦LBL "PK"
02 192
03 STO 00
04 STO 01

05♦LBL 00
06 RCL 00
07 ,6
08 +
09 PEEKB
10 240
11 X≠Y?
12 GTO 01
13 RCL 00
14 PEEKB
15 X≠0?
16 XEQ 02
17 RCL 00
18 ,3
19 +
20 PEEKB
21 X≠0?
22 XEQ 02
23 ISG 00
24 CLX
25 GTO 00

26♦LBL 01
27 RCL 00
28 RCL 01
29 X=Y?
30 GTO 05
31 0
32 POKEB
33 X<>Y
34 A+
35 X<>Y
36 POKEB
37 X<>Y
38 A+
39 XEQ 03
40 GTO 01

41♦LBL 02
42 RCL 01
43 XEQ 04
44 XEQ 04

45♦LBL 03
46 X<>Y
47 POKEB
48 X<>Y
49 ENTER↑
50 FRC
51 +
52 ENTER↑
53 FRC
54 4
55 /
56 -
57 STO 01
58 RTN

59♦LBL 04
60 X<>Y
61 POKEB
62 RCL Z
63 A+
64 PEEKB
65 R↑
66 A+
67 RTN

68♦LBL 05
69 CLST
70 SEED
71 END

PLNG "PK"
113 BYTES
```


Further Hints

none

Related Functions

SAVEK, GETK, SAVEB, GETB

SORTFL

This function sorts the registers of a data file. The file name is specified in ALPHA. If the ALPHA register is empty, the current file is employed. Numeric as well as ALPHA data is sorted. The stack registers are not changed. After executing **SORTFL**, the first data register of the file now contains the smallest value of the specified data file.

Input

ALPHA register: file name

Further Hints

Contrary to the function **SORT**, descending sorting is not possible!

Related Function

SORT

At the end of this function block we will show just one more program which solves an often occuring problem quite easily:

Storing a Text File on Magnetic Cards

The program "WF/RF", which only contains one synthetic step, can be used for any extended memory file type, but was actually only written for text files (ASCII files). Line 18 appends six spaces to the ALPHA register. The second header register of the file must reside in the the Extended Functions module (absolute address 69 to 190).

The program "WF" (Write File) transfers all registers of the file to data registers. For this the number of data registers is set to the number of file registers (**FLSIZE**, **PSIZE**). Therefore this program can only be used for files which can be wholly saved into data registers (plus existing free registers). Nevertheless, files up to a size of over 300 registers can be processed in an HP-41 CV or HP-41 CX!

Program use:

The file name is specified in ALPHA. Now "WF" must be executed, to store the file on magnetic cards. At the input prompting "RDY 01 OF NN" it is imperative to slide in one (several) magnet card(s) or to start the program again using **R/S** twice. Otherwise the file type, which was temporarily changed, will not be changed back to the original file type.

Before being able to read back the file content from the magnetic cards using the program "RF" (Read File), the desired file must be constructed with the right file type and in sufficient length. Now the file name must again be placed in the ALPHA register and "RF" must be executed. After the input prompting "CARD" it is imperative to slide in one (several) magnet card(s) or to start the program again using **R/S** twice (see above).

The program can also just be used to transfer the file to data registers or vice versa. For this the functions **WDTA** and **RDTA** must be deleted. Now it is possible to enlarge a textfile without having to input the contents again. For this application one would excute "WF" and then destroy the file in extended memory and resize it larger, and then execute "RF".

The program "WF/RF" can be used for **all** file types. Naturally, using it on program files is senseless. If the program is used for buffer files, the buffer file where the data will be saved must be of the same type as the buffer saved in the data registers. To avoid problems, the size should be the same as well. If all these restrictions are followed, there should be no problem storing all kinds of buffers on magnetic cards using "WF" and "RF".

```
01♦LBL "WF"
02 XEQ 00
03 GETR
04 WDTA
05 POKEB
06 RTN

07♦LBL "RF"
08 XEQ 00
09 RDTA
10 SAVER
11 POKEB
12 RTN

13♦LBL 00
14 RCLPTA
15 FLSIZE
16 PSIZE
17 191.6
18 "├
                    "
19 7
20 AROT
21 RCL [
22 CLA
23♦LBL 01
24 R↑
25 R↑
26 PEEKR
27 DSE Y
28 CLX
29 R↑
30 X≠Y?
31 GTO 01
32 RCL Z
33 PEEKB
34 X<>Y
35 32
36 POKEB
37 CLX
38 SEEKPT
39 X<> Z
40 TONE 8
41 END

   PLNG "WF"
    89 BYTES
```

Chapter 9

Bar Codes

Contents Chapter 9

Bar Codes

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3 (9-12)

4 (12-17)

5 (18-19)

INP

1 (1-4)

2 (4-11)

3 (12-19)

4 (20-26)

INV

1 (1-5)

2 (6-13)

3 (13-20)

4 (21-29)

5 (30-41)

6 (42-49)

7 (50-60)

8 (60-68)

9 (69-78)

10 (78-85)

11 (85-94)

12 (95-103)

13 (104-112)

14 (112-118)

15 (118-125)

16 (125-135)

17 (136-143)

18 (144-150)

19 (151-156)

PBC

1 (1-6)

2 (6-14)

3 (14-19)

4 (19-23)

5 (23-30)

6 (31-38)

7 (38-48)

8 (49-57)

9 (57-65)

10 (66-76)

11 (76-86)

12 (87-96)

13 (96-104)

14 (105-111)

15 (111-118)

16 (118-124)

17 (125-130)

18 (131-138)

Bar Codes

19 (138-142)

20 (143-149)

21 (150-155)

22 (156-163)

23 (163-171)

24 (172-177)

25 (177-183)

PHINPT

1 (1-2)

2 (2-9)

3 (10-14)

PK

1 (1-6)

2 (7-14)

3 (14-22)

4 (22-30)

5 (31-39)

6 (39-45)

7 (46-57)

8 (58-66)

9 (66-77)

10 (77)

PR1

1 (1-5)

2 (6-11)

3 (11-15)

PR4

1 (1-3)

2 (3-7)

3 (7-11)

ST

1 (1-5)

2 (5-10)

3 (11-20)

4 (20-26)

5 (27-33)

6 (34-40)

7 (40-48)

8 (48-56)

9 (56-65)

10 (65-73)

11 (73-82)

12 (83-90)

13 (91-101)

14 (102-108)

15 (108-117)

16 (117-124)

17 (124-132)

18 (132-138)

19 (139-145)

20 (146-147)

TD

1 (1-4)

2 (4-11)

3 (11-18)

4 (18-26)

5 (27-28)

TLC

1 (1-3)

2 (4-8)

TLC1

1 (1-3)

2 (4-10)

TLC2

1 (1-3)

2 (4-10)

3 (10)

VB

1 (1-5)

2 (6-11)

3 (11-20)

4 (21)

VR

1 (1-5)

2 (5-11)

3 (12-16)

W?

1 (1-6)

2 (7-11)

WF

1 (1-4)

2 (5-9)

3 (9-16)

4 (17-18)

5 (19-27)

6 (28-36)

7 (36-43)

Bar Codes

BAR - CODES CCD - ROM

B?	CAS	CLB	RNDM	SAS	SEED	SORT
>C+	>R+	?IJ	?IJA	C<>C	C>+	C>-
CMAXAB	CNRM	CSUM	DIM	FNRM	IJ=	IJ=A
M+	M-	M*	M*M	M/	MAX	MAXAB
MDIM	MIN	MOVE	PIV	R-PR	R-QR	R<>R
R>+	R>-	R>R?	RMAXAB	RNRM	RSUM	SUM
SUMAB	SWAP	YC+C				
1CMP	2CMP	AND	bC?	bS?	Cb	NOT
OR	R<	R>	S<	S>	Sb	UNS
WSIZE	XOR					
-I/O FNS	ABSP	ACAXY	ACLX	ARCLE	ARCLH	ARCLI
CLA-	F/E	INPT	PMTA	PMTH	PMTK	PRAXY
PRL	VIEWH	XTOAH				
-ADV FNS	A+	A+B	A-	A-A	DCD	PC<>RTN
PC>X	PEEKB	PEEKR	PHD	PLNG	POKEB	POKER
PPLNG	X>PC	X>RTN	XR>RTN	-XF/M FNS	GETB	GETK
MRGK	SAVEB	SAVEK	SORTFL			

Chapter 10

Function Index

Function Index

The following **CAT 2** function list of the CCD-Module shows the XROM numbers, byte combinations and the stack requirements of all CCD-Module functions.

Sign Description:
- \- The stack is not changed
- ↑ The stack is lifted; a result value is entered in X.
- ↓ Stack drop.
- L The original X value is entered into the LASTX register.

-W&W CCD A

FCN-NAME	XROM-#	BYTES	STACK	Page
-W&W CCD A	09.00	162=064		
B?	09.01	162=065	–	3.05
CAS	09.02	162=066	–	3.09
CLB	09.03	162=067	–	3.07
RNDM	09.04	162=068	↑	3.10
SAS	09.05	162=069	–	3.08
SEED	09.06	162=070	–	3.12
SORT	09.07	162=071	–	3.13

-ARR FNS

FCN-NAME	XROM-#	BYTES	STACK	Page
-ARR FNS	09.08	162=072		
>C+	09.09	162=073	–	4.19
>R+	09.10	162=074	–	4.21
?IJ	09.11	162=075	↑	4.14
?IJA	09.12	162=076	↑	4.15
C<>C	09.13	162=077	–	4.31
C>+	09.14	162=078	↑	4.23
C>-	09.15	162=079	↑	4.25

Function Index

FCN-NAME	XROM-#	BYTES	STACK	Page
CMAXAB	09.16	162=080	↑	4.43
CNRM	09.17	162=081	↑	4.54
CSUM	09.18	162=082	–	4.52
DIM	09.19	162=083	↑	4.13
FNRM	09.20	162=084	↑	4.56
IJ=	09.21	162=085	–	4.16
IJ=A	09.22	162=086	–	4.17
M+	09.23	162=087	–	4.57
M-	09.24	162=088	–	4.59
M*	09.25	162=089	–	4.61
M*M	09.26	162=090	–	4.65
M/	09.27	162=091	–	4.63
MAX	09.28	162=092	↑	4.39
MAXAB	09.29	162=093	↑	4.41
MDIM	09.30	162=094	–	4.09
MIN	09.31	162=095	–	4.45
MOVE	09.32	162=096	–	4.35
PIV	09.33	162=097	↑	4.46
R-PR	09.34	162=098	–	4.73
R-QR	09.35	162=099	–	4.69
R<>R	09.36	162=100	–	4.33
R>+	09.37	162=101	↑	4.27
R>-	09.38	162=102	↑	4.29
R>R?	09.39	162=103	–	4.47
RMAXAB	09.40	162=104	↑	4.44
RNRM	09.41	162=105	↑	4.55
RSUM	09.42	162=106	–	4.53
SUM	09.43	162=107	↑	4.49
SUMAB	09.44	162=108	↑	4.51
SWAP	09.45	162=109	–	4.37
YC+C	09.46	162=110	–	4.67

-HEX FNS

-HEX FNS	09.47	162=111		
1CMP	09.48	162=112	L	5.19
2CMP	09.49	162=113	↓L	5.20
AND	09.50	162=114	↓L	5.27

FCN-NAME	XROM-#	BYTES	STACK	Page
A+	11.18	162=210	L	7.09
A+B	11.19	162=211	↓L	7.11
A-	11.20	162=212	L	7.12
A-A	11.21	162=213	↓L	7.13
DCD	11.22	162=214	–	7.14
PC<>RTN	11.23	162=215	–	7.21
PC>X	11.24	162=216	↑	7.16
PEEKB	11.25	162=217	↑	7.24
PEEKR	11.26	162=218	↑	7.29
PHD	11.27	162=219	↑	7.08
PLNG	11.28	162=220	↑	7.05
POKEB	11.29	162=221	–	7.31
POKER	11.30	162=222	–	7.35
PPLNG	11.31	162=223	↑	7.07
X>PC	11.32	162=224	–	7.18
X>RTN	11.33	162=225	–	7.20
XR>RTN	11.34	162=226	–	7.23

-XF/M FNS

-XF/M FNS	11.35	162=227		
GETB	11.36	162=228	–	8.07
GETK	11.37	162=229	–	8.10
MRGK	11.38	162=230	–	8.12
SAVEB	11.39	162=231	–	8.05
SAVEK	11.40	162=232	–	8.09
SORTFL	11.41	162=233	–	8.15

FCN-NAME	XROM-#	BYTES	STACK	Page
A+	11.18	162:210	L	7.09
A+B	11.19	162:211	↓L	7.11
A-	11.20	162:212	L	7.12
A-A	11.21	162:213	↓L	7.13
DCD	11.22	162:214	–	7.14
PC<>RTN	11.23	162:215	–	7.21
PC>X	11.24	162:216	↑	7.16
PEEKB	11.25	162:217	↑	7.24
PEEKR	11.26	162:218	↑	7.29
PHD	11.27	162:219	↑	7.08
PLNG	11.28	162:220	↑	7.05
POKEB	11.29	162:221	–	7.31
POKER	11.30	162:222	–	7.35
PPLNG	11.31	162:223	↑	7.07
X>PC	11.32	162:224	–	7.18
X>RTN	11.33	162:225	–	7.20
XR>RTN	11.34	162:226	–	7.23

-XF/M FNS

-XF/M FNS	11.35	162:227		
GETB	11.36	162:228	–	8.07
GETK	11.37	162:229	–	8.10
MRGK	11.38	162:230	–	8.12
SAVEB	11.39	162:231	–	8.05
SAVEK	11.40	162:232	–	8.09
SORTFL	11.41	162:233	–	8.15

Chapter 11

Compatibility

Compatibility

Once you have plugged the CCD-Module into your calculator, it may happen, as described below, that some functions do work as described. To avoid this, please check if any of the points mentioned below apply to you:

1) Your calculator has an old operating system. The operating system extensions are only possible, if the module can, after every press of a key, take control of the calculator for a short while. This is only possible with the newer operating system of the HP-41. Therefore, if you possess an older HP-41 (i.e., the serial number is smaller than 2035...), it may be possible that some CCD-Module operating system extensions will not work. If this is the case you can:

    a) simulate some functions, by plugging the CCD-Module into Port 1 and reading the barcodes for "ASN", "CAT" and "XEQ" (see barcodes).

ASN

1 (1-3)

2 (4-11)

3 (11-19)

4 (20)

CAT

1 (1-4)

2 (4-7)

XEQ

1 (1-4)

2 (4-7)

b) Suppose a barcode reader is plugged in, press a key, if "Prompt" is displayed. Through this the CCD-Module takes control and the extended function is put to use.
c) Exchange your operating system against the usual costs at any HP service center

For incompatibilities with possibly newly developed HP-41 models no liability is taken. The CCD-Module works with all HP-41 models built until January 1985.

2) You work the CCD-Module together with the HP-IL development module. If you would like to use an HP-development module in conjunction with the CCD-Module, make sure that the CCD-Module is before the HP-IL development module. If this is not the case, some of the CCD-Module operating system extensions may not work. If the modules are plugged in the order explained above, there is nothing to worry about.

3) Using the CCD-Module in connection with the ZENROM. When employing the ZENROM, there is an incompatibility in the small letter mode, since the ZENROM is able to produce small letters as well. This can only be avoided by switching off the small letter mode of the CCD-Module (see program "TLC").

4) Using the CCD-Module in conjunction with a module of the same XROM number. Once you have plugged in the CCD-Module, further modules with the XROM numbers 9 or 11 may not be plugged in anymore.

Up until now these are the following:

- Home management module
- Real estate module
- PANAME module

Chapter 12

Literature

Literary Hints

If you are interested in knowing more about synthetic or optimized programming of your HP-41, we recommend the following books:

1) Synthetic Programming on the HP-41C
   Author: W. C. Wickes

2) HP-41 Synthetic programming made easy
   Author: K. Jarrett

3) Optimales Programmieren mit dem HP-41
   Author: Gerhard Kruse

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