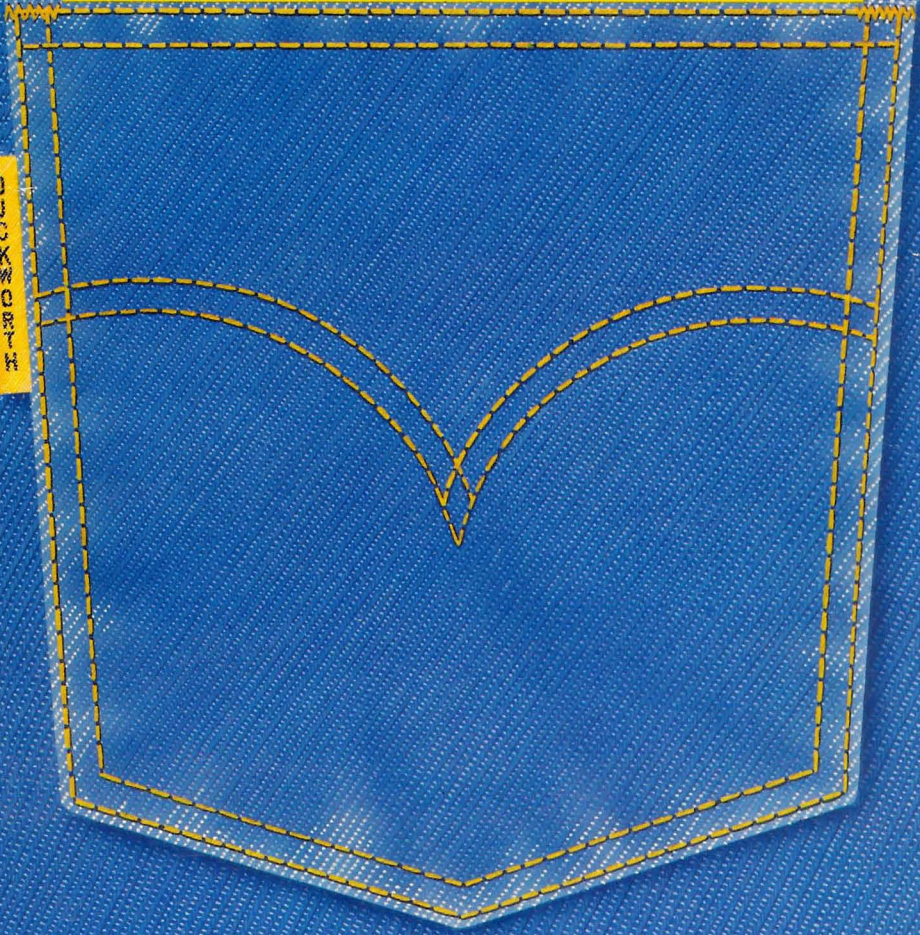
A Pocket Handbook for the COMMODORE 64



Peter Gerrard & Danny Doyle

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Peter Gerrard
&
Danny Doyle

Duckworth

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Contents

Preface

This book is a collection of relevant facts and figures about your Commodore 64 computer.

As well as including full memory maps, microprocessor instruction set, computer glossary, interface tables, disk formats, Basic commands, input/output tables, memory architecture, and much more, this conveniently sized book tells you, at a glance, any important fact you need to know when programming and using your computer.

We've tried to include as much relevant material as possible in as small a space as possible. As a result, the majority of this book is simply facts and figures: one day we might write a book with words in it!

We'd like to thank Jim Butterfield (without whom...) for getting the whole Commodore scene rolling in his own inimitable style, anyone who's given us any help, advice and information in compiling this book, the New Inn in Gawcott for providing excellent pints of Marston ales in times of stress, and finally our wives, Penny and Beryl, for putting up with us.

P.G. and D.D.

ASCII tables

Standard ASCII characters (7-bit code)

LSD	MSD	0 000	1 001	2 010	3 011	4 100	5 101	6 110	7 111
0	0000	NUL	DLE	SP	0	@	P	–	p
1	0001	SOH	DC1	!	1	A	Q	a	q
2	0010	STX	DC2	"	2	B	R	b	r
3	0011	ETX	DC3	£	3	C	S	c	s
4	0100	EOT	DC4	$	4	D	T	d	t
5	0101	ENQ	NAK	%	5	E	U	e	u
6	0110	ACK	SYN	&	6	F	V	f	v
7	0111	BEL	ETB	'	7	G	W	g	w
8	1000	BS	CAN	(	8	H	X	h	x
9	1001	HT	EM	)	9	I	Y	i	y
A	1010	LF	SUB	*	:	J	Z	j	z
B	1011	VT	ESC	+	;	K	[	k	
C	1100	FF	FS	,	<	L		l	
D	1101	CR	GS	–	=	M		m	
E	1110	SO	RS	.	>	N		n	
F	1111	SI	US	/	?	O		o	DEL

The ASCII symbols.

NUL – Null
SOH – Start of Heading
STX – Start of Text
ETX – End of Text
EOT – End of Transmission
ENQ – Enquiry
ACK – Acknowledge
BEL – Bell (audible alert)
BS – Backspace
HT – Horizontal Tabulation
LF – Line Feed
VT – Vertical Tabulation
FF – Form Feed
CR – Carriage Return
SO – Shift Out
SI – Shift In

DLE – Data Link Escape
DC – Device Control
NAK – Negative Acknowledge
SYN – Synchronous Idle
ETB – End of Transmission Block
CAN – Cancel
EM – End of Medium
SUB – Substitute
ESC – Escape
FS – File Separator
GS – Group Separator
RS – Record Separator
US – Unit Separator
SP – Space (Blank)
DEL – Delete

Keyboard CNTL Sequences.

NUL - CNTL 1
SOH - CNTL A
STX - CNTL B
ETX - CNTL C
EOT - CNTL D
ENQ - CNTL E
ACK - CNTL F
BEL - CNTL G
BS - CNTL H/BS
HT - CNTL I/TAB
LF - CNTL J/LF
VT - CNTL K
FF - CNTL L
CR - CNTL M/CR
SO - CNTL N

DLE - CNTL P
DC1/2/3/4 - CNTL Q/R/S/T
NAK - CNTL U
SYN - CNTL V
ETB - CNTL W
CAN - CNTL X
EM - CNTL Y
SUB - CNTL Z
ESC - ESC
FS - CNTL BACKSLASH
GS - CNTL]
RS - CNTL =
US - CNTL -
SP - Space
SI - CNTL O

Basic keywords

BASIC Commands

Command	Format
ABS	ABS(<expression>)
AND	<expression> AND <expression>
ASC	ASC(<string>)
ATN	ATN(<number>)
CHR$	CHR$(<number>)
CLOSE	CLOSE <file number>
CLR	CLR
CMD	CMD <file number> [,string]
CONT	CONT
COS	COS(<number>)
DATA	DATA <list of constants>
DEF FN	DEF FN<name>(<variable>) = <expression>
DIM	DIM <variable>(<subscripts>)[, <variable>(<subscripts>)...]
END	END
EXP	EXP(<number>)
FN	FN<number>(<number>)
FOR	FOR <variable> = <start> TO <limit> [STEP <increment>
FRE	FRE(<dummy>)
GET	GET <variable list>
GET£	GET£ <file number>,<variable list>
GOSUB	GOSUB <line number>
GOTO	GOTO <line number>
IF	IF <expression> THEN <line number> IF <expression> GOTO <line number> IF <expression> THEN <statement>
INPUT	INPUT ["<prompt>"]; <variable list>
INPUT£	INPUT£<file number>,<variable list>
INT	INT(<numeric>)
LEFT$	LEFT$(<string>,<integer>)
LEN	LEN(<string>)
LET	LET <variable> = <expression>
LIST	LIST [[<first-line>]-[<last-line>]]
LOAD	LOAD ["<file-name>"][,<device>]
LOG	LOG(<numeric>)
MID$	MID$(<string>,<numeric-1>[,<numeric-2>])
NEW	NEW
NEXT	NEXT [<counter>][,<counter>]...
NOT	NOT <expression>
ON	ON <variable> GOTO/GOSUB <line-number> [,<line-number>]...
OPEN	OPEN <file-number>,[<device>][,<address>] [,"<file-name>[,<type>][,<mode>]"]
OR	<operand> OR <operand>
PEEK	PEEK(<numeric>)
POKE	POKE <location>,<value>

```
POS         POS(<dummy>)
PRINT       PRINT [<variable>][<,/]<variable>]...
PRINT£      PRINT£ <file-number> [,<variable> ]
                   [<,/;> <variable>]...
READ        READ <variable> [,<variable>]...
REM         REM [<remark>]
RESTORE     RESTORE
RETURN      RETURN
RIGHT$      RIGHT$(<string>,<numeric>)
RND         RND(<numeric>)
RUN         RUN [line number]
SAVE        SAVE ["<file-name>"][,<device-number>]
                 [,<address>]
SGN         SGN (<numeric>)
SIN         SIN(<numeric>)
SPC         SPC(<numeric>)
SQR         SQR(<NUMERIC>)
STATUS      ST
STOP        STOP
STR$        STR$(<numeric>)
SYS         SYS <memory location>
TAB         TAB(<numeric>)
TAN         TAN(<numeric>)
TIME        TI
TIME$       TI$
USR         USR(<numeric>)
VAL         VAL(<string>)
VERIFY      VERIFY
WAIT        WAIT <location>,<mask-1>[,<mask-2>]
```

```
[] indicates optional.
<> indicates mandatory.
() indicates brackets required.
```

OUT OF MEMORY There is no more RAM available for program or variables. This may also occur when too many FOR loops have been nested, or when there are too many GOSUBs in effect.

OVERFLOW The result of a computation is larger than the largest number allowed, which is 1.70141884E+38.

REDIM'D ARRAY An array may only be DIMensioned once. If an array variable is used before that array is DIM'd, an automatic DIM operation is performed on that array setting the number of elements to ten, and any subsequent DIMs will cause this error.

REDO FROM START Character data was typed in during an INPUT statement when numeric data was expected. Just re-type the entry so that it is correct, and the program will continue by itself.

RETURN WITHOUT GOSUB A RETURN statement was encountered, and no GOSUB command has been issued.

STRING TOO LONG A string can contain up to 255 characters.

?SYNTAX ERROR A statement is unrecognizable by the Commodore 64. A missing or extra parenthesis, misspelled keywords, etc.

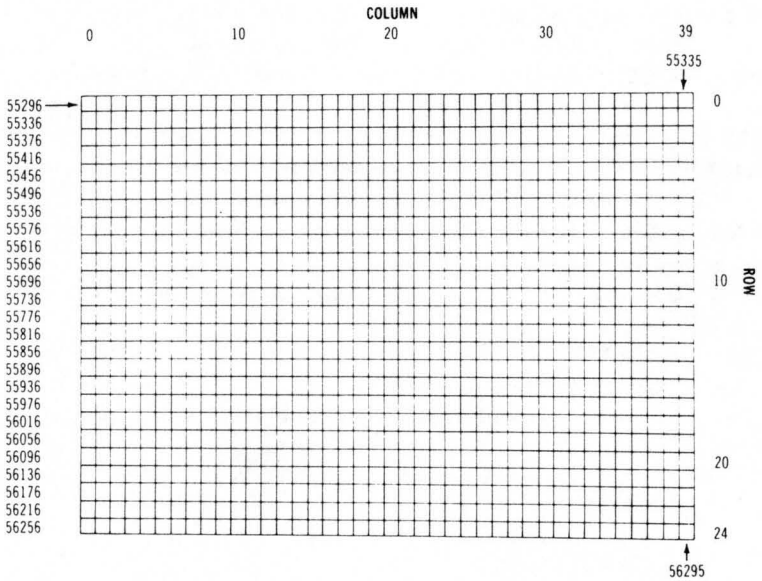
TYPE MISMATCH This error occurs when a number is used in place of a string, or vice-versa.

UNDEF'D FUNCTION A user defined function was referenced, but it has never been defined using the DEF FN statement.

UNDEF'D STATEMENT An attempt was made to GOTO or GOSUB or RUN a line number that doesn't exist.

VERIFY The program on tape or disk does not match the program currently in memory.

Colour memory



ARITHMETIC OPERATORS

SYMBOL	EXAMPLE	PURPOSE
=	10 X = Y	ASSIGNS VALUE TO VARIABLE.
/	10 X = Y / Z	DIVISION.
*	10 X = Y * Z	MULTIPLICATION.
+	10 X = Y + Z	ADDITION.
-	10 X = Y - Z	SUBTRACTION.
=	10 IF X = Y THEN	TEST FOR EQUALITY.
<>	10 IF X <> Y THEN	TEST FOR INEQUALITY.
<	10 IF X < Y THEN	TEST FOR LESS THAN.
>	10 IF X > Y THEN	TEST FOR GREATER THAN.
<=	10 IF X <= Y THEN	TEST FOR LESS THAN OR EQUAL TO.
>=	10 IF X >= Y THEN	TEST FOR GREATER THAN OR EQUAL TO
AND	10 IF X AND Y THEN	LOGICAL AND.
OR	10 IF X OR Y THEN	LOGICAL OR.
NOT	10 IF NOT X THEN	LOGICAL NEGATION.
[]	10 PRINT X[]Y	EXPONENTIATION.

ARITHMETIC FUNCTIONS

FUNCTION	EXAMPLE	DESCRIPTION
ABS	10 Z = ABS(X)	RETURNS MAGNITUDE OF ARGUMENT IRRESPECTIVE OF SIGN.
ATN	10 Z = ATN(X)	RETURNS ARCTANGENT OF ARGUMENT. Z GIVEN I RADIANS.
COS	10 Z = COS(X)	RETURNS COSINE OF ARGUMENT. X MUST BE IN RADIANS.
EXP	10 Z = EXP(X)	RETURNS MATHEMATICAL CONSTANT 'E' RAISED TO POWER OF X.
INT	10 Z = INT(X)	RETURNS INTEGER PART OF X.
LOG	10 Z = LOG(X)	RETURNS NATURAL LOG OF ARGUMENT. X MUST BE GREATER OR EQUAL TO 0.
RND	10 Z = RND(X)	RETURNS RANDOM NUMBER BETWEEN ZERO AND ONE.
SGN	10 Z = SGN(X)	RETURNS MATHEMATICAL SIGN OF ARGUMENT.
SQR	10 Z = SQR(X)	RETURNS SQUARE ROOT OF ARGUMENT.
TAN	10 Z = TAN(X)	RETURNS TANGENT OF ARGUMENT. X MUST BE IN RADIANS.

Basic error messages

BAD DATA String data was received from an open file, but the program was expecting numeric data.

BAD SUBSCRIPT The program was trying to reference an element of an array whose number is outside of the range specified in the DIM statement.

CAN'T CONTINUE The CONT command will not work, either because the program was never RUN, there has been an error, or a line has been edited.

DEVICE NOT PRESENT The required I/O device was not available for an OPEN, CLOSE, CMD, PRINT#, INPUT#, or GET#.

DIVISION BY ZERO Division by zero is a mathematical oddity and not allowed.

EXTRA IGNORED Too many items of data were typed in response to an INPUT statement. Only the first few items were accepted.

FILE NOT FOUND If you were looking for a file on tape, and END-OF-TAPE marker was found. If you were looking on disk, no file with that name exists.

FILE NOT OPEN The file specified in a CLOSE, CMD, PRINT#, INPUT#, or GET#, must first be OPENed.

FILE OPEN An attempt was made to open a file using the number of an already open file.

FORMULA TOO COMPLEX The string expression being evaluated should be split into at least two parts for the system to work with.

ILLEGAL DIRECT The INPUT statement can only be used within a program, and not in direct mode.

ILLEGAL QUANTITY A number used as the argument of a function or statement is out of the allowable range.

LOAD There is a problem with the program on tape.

NEXT WITHOUT FOR This is caused by either incorrectly nesting loops or having a variable name in a NEXT statement that doesn't correspond with one in a FOR statement.

NOT INPUT FILE An attempt was made to INPUT or GET data from a file which was specified to be for output only.

NOT OUTPUT FILE An attempt was made to PRINT data to a file which was specified as input only.

OUT OF DATA A READ statement was executed but there is no data left unREAD in a DATA statement.

Conversion tables

Code Conversion Table

Dec	Oct	Hex	6502 Instruction	Poke 1	Poke 2	CHR$	Asc	Token	Binary
0	000	00	BRK	@	@		NUL		0000 0000
1	001	01	ORA (Ind,X)	A	a		SOH		0000 0001
2	002	02	-	B	b		STX		0000 0010
3	003	03	-	C	c		ETX		0000 0011
4	004	04	-	D	d		EOT		0000 0100
5	005	05	ORA 0-Page	E	e		ENQ		0000 0101
6	006	06	ASL 0-Page	F	f		ACK		0000 0110
7	007	07	-	G	g		BEL		0000 0111
8	010	08	PHP	H	h		BS		0000 1000
9	011	09	ORA Immediate	I	i		HT		0000 1001
10	012	0A	ASL Accum.	J	j		LF		0000 1010
11	013	0B	-	K	k		VT		0000 1011
12	014	0C	-	L	l		FF		0000 1100
13	015	0D	ORA Absolute	M	m		CR		0000 1101
14	016	0E	ASL Absolute	N	n		SO		0000 1110
15	017	0F	-	O	o		SI		0000 1111
16	020	10	BPL	P	p		DLE		0001 0000
17	021	11	ORA (Ind),Y	Q	q	CRSR DN	DC1		0001 0001
18	022	12	-	R	r	RVS ON	DC2		0001 0010
19	023	13	-	S	s	HOME	DC3		0001 0011
20	024	14	-	T	t	DEL	DC4		0001 0100
21	025	15	ORA 0-Page,X	U	u		NAK		0001 0101
22	026	16	ASL 0-Page,X	V	v		SYN		0001 0110
23	027	17	-	W	w		ETB		0001 0111
24	030	18	CLC	X	x		CAN		0001 1000
25	031	19	ORA Abs,Y	Y	y		EM		0001 1001
26	032	1A	-	Z	z		SUB		0001 1010
27	033	1B	-	[	[		ESC		0001 1011
28	034	1C	-				FS		0001 1100
29	035	1D	ORA Abs,X	]	]		GS		0001 1101
30	036	1E	ASL Abs,X				RS		0001 1110
31	037	1F	-				US		0001 1111

Code Conversion Table

Dec	Oct	Hex	6502 Instruction	Poke U	Poke L	CHR$ U	CHR$ L	Std Asc	Token	Binary
32	040	20	JSR	SPC	SPC	SPC	SPC	SPC		0010 0000
33	041	21	AND (Ind,X)							0010 0001
34	042	22	-	"	"	"	"	"		0010 0010
35	043	23	-	£	£	£	£	£		0010 0011
36	044	24	BIT 0-Page	$	$	$	$	$		0010 0100
37	045	25	AND 0-Page	%	%	%	%	%		0010 0101
38	046	26	ROL 0-Page	&	&	&	&	&		0010 0110
39	047	27	-	'	'	'	'	'		0010 0111
40	050	28	PLP	(	(	(	(	(		0010 1000
41	051	29	AND Immediate	)	)	)	)	)		0010 1001
42	052	2A	ROL Accum.	*	*	*	*	*		0010 1010
43	053	2B	-	+	+	+	+	+		0010 1011
44	054	2C	BIT Absolute	,	,	,	,	,		0010 1100
45	055	2D	AND Absolute	-	-	-	-	-		0010 1101
46	056	2E	ROL Absolute	.	.	.	.	.		0010 1110
47	057	2F	-	/	/	/	/	/		0010 1111
48	060	30	BMI	0	0	0	0	0		0011 0000
49	061	31	AND (Ind),Y	1	1	1	1	1		0011 0001
50	062	32	-	2	2	2	2	2		0011 0010
51	063	33	-	3	3	3	3	3		0011 0011
52	064	34	-	4	4	4	4	4		0011 0100
53	065	35	AND 0-Page,X	5	5	5	5	5		0011 0101
54	066	36	ROL 0-Page,X	6	6	6	6	6		0011 0110
55	067	37	-	7	7	7	7	7		0011 0111
56	070	38	SEC	8	8	8	8	8		0011 1000
57	071	39	AND Abs,Y	9	9	9	9	9		0011 1001
58	072	3A	-	:	:	:	:	:		0011 1010
59	073	3B	-	;	;	;	;	;		0011 1011
60	074	3C	-	<	<	<	<	<		0011 1100
61	075	3D	AND Abs,X	=	=	=	=	=		0011 1101
62	076	3E	ROL Abs,X	>	>	>	>	>		0011 1110
63	077	3F	-	?	?	?	?	?		0011 1111

Code Conversion Table

Dec	Oct	Hex	6502 Instruction	Poke U	Poke L	CHR$ U	CHR$ L	Std Asc	Token	Binary
64	100	40	RTI			@	@	@		0100 0000
65	101	41	EOR (Ind,X)		A	A	a	A		0100 0001
66	102	42	-		B	B	b	B		0100 0010
67	103	43	-		C	C	c	C		0100 0011
68	104	44	-		D	D	d	D		0100 0100
69	105	45	EOR 0-Page		E	E	e	E		0100 0101
70	106	46	LSR 0-Page		F	F	f	F		0100 0110
71	107	47	-		G	G	g	G		0100 0111
72	110	48	PHA		H	H	h	H		0100 1000
73	111	49	EOR Immediate		I	I	i	I		0100 1001
74	112	4A	LSR Accum.		J	J	j	J		0100 1010
75	113	4B	-		K	K	k	K		0100 1011
76	114	4C	JMP Absolute		L	L	l	L		0100 1100
77	115	4D	EOR Absolute		M	M	m	M		0100 1101
78	116	4E	LSR Absolute		N	N	n	N		0100 1110
79	117	4F	-		O	O	o	O		0100 1111
80	120	50	BVC		P	P	p	P		0101 0000
81	121	51	EOR (Ind),Y		Q	Q	q	Q		0101 0001
82	122	52	-		R	R	r	R		0101 0010
83	123	53	-		S	S	s	S		0101 0011
84	124	54	-		T	T	t	T		0101 0100
85	125	55	EOR 0-Page,X		U	U	u	U		0101 0101
86	126	56	LSR 0-Page,X		V	V	v	V		0101 0110
87	127	57	-		W	W	w	W		0101 0111
88	130	58	CLI		X	X	x	X		0101 1000
89	131	59	EOR Abs,Y		Y	Y	y	Y		0101 1001
90	132	5A	-		Z	Z	z	Z		0101 1010
91	133	5B	-			[	[	[		0101 1011
92	134	5C	-							0101 1100
93	135	5D	EOR Abs,X			]	]	]		0101 1101
94	136	5E	LSR Abs,X							0101 1110
95	137	5F	-							0101 1111

Code Conversion Table

Dec	Oct	Hex	6502 Instruction	Poke 1	Poke 2	CHR$	Asc	Token	Binary
96	140	60	RTS				-		0110 0000
97	141	61	ADC (Ind,X)				a		0110 0001
98	142	62	-				b		0110 0010
99	143	63	-				c		0110 0011
100	144	64	-				d		0110 0100
101	145	65	ADC 0-Page				e		0110 0101
102	146	66	ROR 0-page				f		0110 0110
103	147	67	-				g		0110 0111
104	150	68	PLA				h		0110 1000
105	151	69	ADC Immediate				i		0110 1001
106	152	6A	ROR Accum.				j		0110 1010
107	153	6B	-				k		0110 1011
108	154	6C	JMP Indirect				l		0110 1100
109	155	6D	ADC Absolute				m		0110 1101
110	156	6E	ROR Absolute				n		0110 1110
111	157	6F	-				o		0110 1111
112	160	70	BVS				p		0111 0000
113	161	71	ADC (Ind),Y				q		0111 0001
114	162	72	-				r		0111 0010
115	163	73	-				s		0111 0011
116	164	74	-				t		0111 0100
117	165	75	ADC 0-Page,X				u		0111 0101
118	166	76	ROR 0-Page,X				v		0111 0110
119	167	77	-				w		0111 0111
120	170	78	SEI				x		0111 1000
121	171	79	ADC Abs,Y				y		0111 1001
122	172	7A	-				z		0111 1010
123	173	7B	-				?		0111 1011
124	174	7C	-				?		0111 1100
125	175	7D	ADC Abs,X				?		0111 1101
126	176	7E	ROR Abs,X				?		0111 1110
127	177	7F	-				DEL		0111 1111

Code Conversion Table

Dec	Oct	Hex	6502 Instruction	Poke 1	Poke 2	CHR$	Asc	Token	Binary
128	200	80	-					END	1000 0000
129	201	81	STA (Ind,X)					FOR	1000 0001
130	202	82	-					NEXT	1000 0010
131	203	83	-					DATA	1000 0011
132	204	84	STY 0-Page					INPUT£	1000 0100
133	205	85	STA 0-Page					INPUT	1000 0101
134	206	86	STX 0-Page					DIM	1000 0110
135	207	87	-					READ	1000 0111
136	210	88	DEY					LET	1000 1000
137	211	89	-					GOTO	1000 1001
138	212	8A	TXA					RUN	1000 1010
139	213	8B	-					IF	1000 1011
140	214	8C	STY Absolute					RESTORE	1000 1100
141	215	8D	STA Absolute					GOSUB	1000 1101
142	216	8E	STX Absolute					RETURN	1000 1110
143	217	8F	-					REM	1000 1111
144	220	90	BCC					STOP	1001 0000
145	221	91	STA (Ind),Y					ON	1001 0001
146	222	92	-					WAIT	1001 0010
147	223	93	-					LOAD	1001 0011
148	224	94	STY 0-Page,X					SAVE	1001 0100
149	225	95	STA 0-Page,X					VERIFY	1001 0101
150	226	96	STX 0-Page,Y					DEF	1001 0110
151	227	97	-					POKE	1001 0111
152	230	98	TYA					PRINT£	1001 1000
153	231	99	STA Abs,Y					PRINT	1001 1001
154	232	9A	TXS					CONT	1001 1010
155	233	9B	-					LIST	1001 1011
156	234	9C	-					CLR	1001 1100
157	235	9D	STA Abs,X					CMD	1001 1101
158	236	9E	-					SYS	1001 1110
159	237	9F	-					OPEN	1001 1111
160	240	A0	LDY Immediate					CLOSE	1010 0000
161	241	A1	LDA (Ind,X)					GET	1010 0001
162	242	A2	LDX Immediate					NEW	1010 0010
163	243	A3	-					TAB(	1010 0011
164	244	A4	LDY 0-Page					TO	1010 0100
165	245	A5	LDA 0-Page					FN	1010 0101
166	246	A6	LDX 0-Page					SPC(	1010 0110
167	247	A7	-					THEN	1010 0111
168	250	A8	TAY					NOT	1010 1000
169	251	A9	LDA Immediate					STEP	1010 1001
170	252	AA	TAX					+	1010 1010
171	253	AB	-					-	1010 1011
172	254	AC	LDY Absolute					*	1010 1100
173	255	AD	LDA Absolute					/	1010 1101
174	256	AE	LDX Absolute						1010 1110
175	257	AF	-					AND	1010 1111
176	260	B0	BCS					OR	1011 0000
177	261	B1	LDA (Ind),Y					>	1011 0001
178	262	B2	-					=	1011 0010
179	263	B3	-					<	1011 0011
180	264	B4	LDY 0-Page,X					SGN	1011 0100
181	265	B5	LDA 0-Page,X					INT	1011 0101
182	266	B6	LDX 0-Page,Y					ABS	1011 0110
183	267	B7	-					USR	1011 0111
184	270	B8	CLV					FRE	1011 1000
185	271	B9	LDA Abs,Y					POS	1011 1001
186	272	BA	TSX					SQR	1011 1010
187	273	BB	-					RND	1011 1011
188	274	BC	LDY Abs,X					LOG	1011 1100
189	275	BD	LDA Abs,X					EXP	1011 1101
190	276	BE	LDX Abs,Y					COS	1011 1110
191	277	BF	-					SIN	1011 1111
192	300	C0	CPY Immediate					TAN	1100 0000
193	301	C1	CMP (Ind,X)					ATN	1100 0001
194	302	C2	-					PEEK	1100 0010
195	303	C3	-					LEN	1100 0011
196	304	C4	CPY 0-Page					STR$	1100 0100
197	305	C5	CMP 0-Page					VAL	1100 0101
198	306	C6	DEC 0-Page					ASC	1100 0110
199	307	C7	-					CHR$	1100 0111
200	310	C8	INY					LEFT$	1100 1000
201	311	C9	CMP Immediate					RIGHT$	1100 1001
202	312	CA	DEX					MID$	1100 1010
203	313	CB	-						1100 1011

Code Conversion Table

Dec	Oct	Hex	6502 Instruction	Poke 1	Poke 2	CHR$	Asc	Token	Binary
204	314	CC	CPY Absolute						1100 1100
205	315	CD	CMP Absolute						1100 1101
206	316	CE	DEC Absolute						1100 1110
207	317	CF	-						1100 1111
208	320	D0	BNE						1101 0000
209	321	D1	CMP (Ind),Y						1101 0001
210	322	D2	-						1101 0010
211	323	D3	-						1101 0011
212	324	D4	-						1101 0100
213	325	D5	CMP 0-Page,X						1101 0101
214	326	D6	DEC 0-Page,X						1101 0110
215	327	D7	-						1101 0111
216	330	D8	CLD						1101 1000
217	331	D9	CMP Abs,Y						1101 1001
218	332	DA	-						1101 1010
219	333	DB	-						1101 1011
220	334	DC	-						1101 1100
221	335	DD	CMP Abs,X						1101 1101
222	336	DE	DEC Abs,X						1101 1110
223	337	DF	-						1101 1111
224	340	E0	CPX Immediate						1110 0000
225	341	E1	SBC (Ind,X)						1110 0001
226	342	E2	-						1110 0010
227	343	E3	-						1110 0011
228	344	E4	CPX 0-Page						1110 0100
229	345	E5	SBX 0-Page						1110 0101
230	346	E6	INC 0-Page						1110 0110
231	347	E7	-						1110 0111
232	350	E8	INX						1110 1000
233	351	E9	SBC Immediate						1110 1001
234	352	EA	NOP						1110 1010
235	353	EB	-						1110 1011
236	354	EC	CPX Absolute						1110 1100
237	355	ED	SBC Absolute						1110 1101
238	356	EE	INC Absolute						1110 1110
239	357	EF	-						1110 1111
240	360	F0	BEQ						1111 0000
241	361	F1	SBC (Ind),Y						1111 0001
242	362	F2	-						1111 0010
243	363	F3	-						1111 0011
244	364	F4	-						1111 0100
245	365	F5	SBC 0-Page,X						1111 0101
246	366	F6	INC 0-Page,X						1111 0110
247	367	F7	-						1111 0111
248	370	F8	SED						1111 1000
249	371	F9	SBC Abs,Y						1111 1001
250	372	FA	-						1111 1010
251	373	FB	-						1111 1011
252	374	FC	-						1111 1100
253	375	FD	SBC Abs,X						1111 1101
254	376	FE	INC Abs,X						1111 1110
255	377	FF	-						1111 1111

Disk commands

DISKETTE COMMAND SUMMARY BASIC 4.0

```
APPEND £<file number>,"<name>":,D<x>;:ON U<y>;
        Append data to the end of a sequential
        file.

BACKUP D<x> TO D<y> :ON U<z>;
        Duplicate entire contents of one disk
        onto another.

CATALOG/DIRECTORY :D<x>;:ON U<y>;
        Display disk directory on screen.

COLLECT :D<x>;:ON U<y>;
        Release space allocated to improperly
        closed files.

CONCAT :D<x>,;"<name1>" TO :D<y>,;"name2>":ON U<z>;
        Concatenate sequential files.

COPY :D<x>,;"<name1>" TO :D<y>,;"<name2>": ON U<z>;
        Make a copy of a file within a disk unit.

DCLOSE :£<1>; :ON U<x>;
        Close disk files.

DLOAD "<name>":,D<x>; :ON U<y>;
        Load BASIC program file from disk.

DOPEN £<1>,"<name>":,L<y>;:,D<x>; :ON U<z>; :,W;
        Declare a sequential or random access
        file for read or write.

DSAVE "<name>":,D<x>; :ON U<y>;
        Save a BASIC program file to disk.

HEADER "<disk name>",D<x>:,I<zz>; :ON U<y>;
        To format a blank disk or clear an old
        disk.

RECORD £<logical file>,<record>:,<byte>;
        Used before GET£,INPUT£ or PRINT£ to
        position record pointer in a random
        access file.

RENAME :D<x>.;"<old name>" TO "<new name>" :ON U<y>]
        Change the name of a disk file.

SCRATCH "<name>":,Dx; :ON U<y>;
        Delete a disk file.
```

DISKETTE COMMAND SUMMARY BASIC 2.0

(APPEND) Not available.

(BACKUP) PRINT£15,"D<y> = x"

(CATALOG/ LOAD "$D<x>:?...name:*;:=P/S;;
DIRECTORY)

(COLLECT) PRINT£15,"VD<x>"

(CONCAT) PRINT£15,"CD<y>:<name3>=D<y>:<name2>,D<x>:
<name1>"

(COPY) PRINT£15,"CD<y>:<name2>=D<x>:<name1>"

(DCLOSE) CLOSE <file number>

(DLOAD) LOAD "D<x>:<filename>:*;"

(DOPEN) OPEN <file number>,;<device>;:,<address>;
:."<filename>:,<type>;:,<mode>;";

(DSAVE) SAVE :"<filename>";:,<device>;

(HEADER) PRINT£15,"ND<x>:filename,I<zz>"

(RECORD) Not available.

(RENAME) PRINT£15,"RD<x>:<name2>=<name1>"

(SCRATCH) PRINT£15,"SD<x>:<filename>:*;/*"

Disk error messages

DOS ERROR MESSAGES

OK (00 00 00)

No errors encountered.

FILES SCRATCHED (00 £ Files 00)

Files scratched.

BLOCK HEADER NOT FOUND (20 T S)

Disk controller is unable to locate the header of the requested data block. Caused by an illegal sector number, or the header has been destroyed.

NO SYNC CHARACTER (21 T S)

Disk controller is unable to detect a sync mark on the desired track. Caused by misalignment of the read/write head or no diskette is present. Can also indicate a hardware failure.

DATA BLOCK NOT PRESENT (22 T S)

Disk controller has been requested to read or verify a data block which was not properly written. This error message occurs in conjunction with the BLOCK COMMANDS and indicates an illegal track and/or sector request.

CHECKSUM ERROR IN DATA BLOCK (23 T S)

This error message indicates that there is an error in one or more of the data bytes. The data has been read into the DOS memory, but the checksum over the data is in error. This message may also indicate grounding problems.

BYTE DECODING ERROR (24 T S)

The data or header has been read into the DOS memory, but a hardware error has been created due to an invalid bit pattern in the data byte. This message may also indicate grounding problems.

CHECKSUM ERROR IN HEADER (27 T S)

Disk controller has detected an error in the header of the requested data block. The block has not been read into the DOS memory. This message may also indicate grounding problems.

WRITE-VERIFY ERROR (25 T S)

This message is generated if the controller detects a mis-match between the written data and the data in the DOS memory.

WRITE PROTECT ON (26 T S)

This message is generated when the controller has been requested to write a data block while the write protect switch is depressed. Typically, this is caused by using a diskette with a write protect tab over the notch.

LONG DATA BLOCK (28 T S)

The controller attempts to detect the sync mark of the next header after writing a data block. If the sync mark does not appear within a pre-determined time, the error message is generated. The error message is caused by a bad diskette format (the data extends into the next block), or by a hardware failure.

DISK ID MIS-MATCH (29 T S)

This message is generated when the controller has been requested to access a diskette which has not been initialised. This error can also occur if a diskette has a bad header.

GENERAL SYNTAX (30 00 00)

The DOS cannot interpret the command sent to the command channel. Typically, this is caused by an illegal number of file names, or patterns are illegally used. For example, two file names may appear on the left side of the COPY command.

INVALID COMMAND (31 00 00)

The DOS does not recognise the command. The command must start in the first position.

LONG LINE (32 00 00)

The command sent is longer than forty characters.

INVALID FILE NAME (33 00 00)

Pattern matching is invalidly used in the OPEN, or SAVE command.

NO FILE GIVEN (34 00 00)

The file name was left out of the command, or the DOS does not recognise it as such. Typically, a quotation mark (") or colon (:) has been left out of the command.

INVALID DOS COMMAND (39 00 00)

An unrecognisable DOS command was received.

RECORD NOT PRESENT (50 00 00)

An INPUT£ or GET£ statement selected a record beyond the current end of file. This is an error if you are attempting to read a record; it is not necessarily an error if you are positioning to the end of the file in order to add new records to an old file.

OVERFLOW IN RECORD (51 T S)

A PRINT£ statement attempted to write more than the allowed number of characters to a relative file. The terminating carriage return is counted as one character when computing record length.

FILE TOO LARGE (52 T S)

The current record position will result in disk overflow on the next write-to-disk operation.

WRITE FILE OPEN (60 00 00)

This message is generated when a write file that has not been closed is being opened for reading.

FILE NOT OPEN (61 00 00)

This message is generated when a file is being accessed that has not been opened in the DOS. Sometimes, in this case, a message is not

generated; the request is simply ignored.

FILE NOT FOUND (62 00 00)

The requested file does not exist on the indicated drive.

FILE EXISTS (63 00 00)

The file name of the file being created already exists on the diskette.

FILE TYPE MIS-MATCH (64 00 00)

The file type does not match the file type in the directory entry for the requested file.

NO BLOCK (65 T S)

This message occurs in conjunction with the B-A command. It indicates that the block to be allocated has been previously allocated. The parameters indicate the next higher in number available track and sector. If the parameters are zero, then all blocks higher in number are in use.

ILLEGAL TRACK & SECTOR (66 T S)

An attempt has been made to access a sector that does not physically exist. The track and/or sector number specified is out of the allowed range for the current diskette. Unless you are using random access files, you should never see this error code.

ILLEGAL SYSTEM TRACK & SECTOR (67 T S)

When accessing program or data files, an attempt has been made to access a sector that is reserved for use by the DOS.

NO CHANNEL (70 00 00)

The requested channel is not available, or all channels are in use. A maximum of five sequential files may be opened at one time to the DOS. Direct access channels may have six open files.

DIR (71 00 00)

The BAM does not match the internal count. There is a problem in the BAM allocation or the BAM has

been over-written in DOS memory. To correct this problem re-initialise the diskette to restore the BAM in memory. Some active files may be terminated by the corrective action.

DISK FULL (72 00 00)

Either the blocks on the diskette are used, or the directory is at its limit (152 entries).

DOS MIS-MATCH (73 00 00)

Data written to a diskette using any one version of DOS may be read using any other version of DOS. However, you must write to a diskette using the same DOS version with which the diskette was initialised. Error 73 is reported if you attempt to write to a diskette using a different version of DOS from the one which created and initialised the diskette.

DRIVE NOT READY (74 00 00)

An attempt has been made to access the 8050 diskette unit with the selective drive.

STRUCTURE OF INDIVIDUAL DIRECTORY ENTRIES.

BYTE	DEFINITION
0	File flag OR'ed with $80 0 = DELETED 1 = SEQ 2 = PRG 3 = REL
1-2	First data block track and sector.
3-18	Reserved for file name.
19-20	Track and sector of first side sector block (REL files only).
21	Record size for REL files.
22-25	Not used.
26-27	Track and sector of replacement file using '@' operations.
28-29	Number of blocks in file.

STANDARD FILE FORMATS.

BYTE	DEFINITION
0-1	Track and sector of next seqential block.
2-255	Reserved for file storage.

STRUCTURE OF BAM ENTRY.

BYTE	DEFINITION
0	Number of available sectors.
1	Bit map for sectors 00-07.
2	Bit map for sectors 08-15.
3	Bit map for sectors 16-23.
4	8050 only: Bit map for sectors for 24-31.

RELATIVE FILES ONLY.
Side sector blocks.

BYTE	DEFINITION
0-1	Track and sector of next side sector block.
2	Side sector number.
3	Record length.
4-5	Track and sector of first side sector.
6-7	Track and sector of second side sector.
8-9	Track and sector of third side sector.
10-11	Track and sector of fourth side sector.
12-13	Track and sector of fifth side sector.
14-15	Track and sector of sixth side sector.
16-255	Track and sector pointers to data blocks.

8050 BAM FORMAT.
Track 38, Sector 00.

BYTE	CONTENTS	DEFINITION
0-1	38,3	Track and sector of second BAM block.
2	67	Indicates 8050.
3	0	NULL flag.
4	1	Lowest track number in this BAM block.
5	51	Highest track number plus 1 in this BAM block.
6	-	Number of unused blocks on track 1.
7-10	-	Bit map of available blocks on track 1.
11-255	-	5 bytes each for BAM of tracks 2-50.

8050 BAM FORMAT.
Track 38, Sector 03.

BYTE	CONTENTS	DEFINITION
0-1	39,1	Track and sector of first directory block.
2	67	Indicates 8050.
3	0	NULL flag.
4	51	Lowest track number.
5	78	Highest track number plus 1.
6	-	Number of unused block on track 51.
7-10	-	Bit map of available blocks on track 51.
11-140	-	5 bytes each for BAM of tracks 52-77.
144-255	-	Not used.

COMMON DIRECTORY FORMAT
For 2040/3040/4040/1540/1541: Track 18, Sector 01.
For 8050: Track 39, Sector 01

BYTE	DEFINITION
0-1	Track and sector of next directory block.
2-31	File entry £1.
34-63	File entry £2.
66-95	File entry £3.
98-127	File entry £4.
130-159	File entry £5.
162-191	File entry £6.
194-223	File entry £7.
226-255	File entry £8.

2040/3040 BAM & HEADER.
Track 18, Sector 00.

BYTE	CONTENTS	DEFINITION
0-1	18,1	Track and sector of first directory block.
2	1	Indicates DOS 1.
3	0	NULL flag.
4-143	-	The BAM bit map of available blocks for tracks 1-35.
144-161	-	Reserved for disk name.
162-163	-	Reserved for disk ID.
164-170	160	Shifted SPACES.
171-255	0	Not used.

4040/1540/1541 BAM & HEADER.
Track 18, Sector 00

BYTE	CONTENTS	DEFINITION
0-1	18,1	Track and sector of first directory block.
?2	65	Indicates 4040/1540/1541
3	0	NULL byte.
4-143	-	BAM bit map of available blocks for tracks 1-35.
144-161	-	Reserved for disk name.
162-163	-	Reserved for disk ID.
164	160	Shifted SPACE.
165-166	50,65	Indicates DOS version (2A) and format.
166-170	160	Shifted SPACES.
171-255	0	Not used.

8050 DIRECTORY HEADER.
Track 39, Sector 00.

BYTE	CONTENTS	DEFINITION
0-1	38,0	Track and sector of first BAM block.
2	67	Indicates 8050.
3	0	NULL flag.
4-5	0	Not used.
6-21	-	Indicates disk name.
22-23	160	Shifted SPACES.
24-25	-	Indicates disk ID.
26	160	Shifted SPACE.
27-28	50,67	Indicates DOS version (2C) and format.
29-32	160	Shifted SPACES.
33-255	0	Not used.

Extramon listing

```
100 PRINT"TINY PEEKER/POKER"
110 X$="*":INPUTX$:IFX$="*"THENEND
120 GOSUB500
130 IF E GOTO280
140 A=V
150 IFJ>LEN(X$)GOTO300
160 FORI=0TO7
170 P=J:GOSUB550
180 C(I)=V
190 IF E GOTO 280
200 NEXTI
210 T=0
220 FORI=0TO7
230 POKE A+I,C(I)
240 T=T+C(I)
250 NEXT I
260 PRINT"CHECKSUM=";T
270 GOTO110
280 PRINTMID$(X$,1,J);"??":GOTO110
300 T=0
310 FORI=0TO7
320 V=PEEK(A+I)
330 T=T+V
340 V=V/16
350 PRINT " ";
360 FORJ=1TO2
370 V%=V
380 V=(V-V%)*16
390 IFV%>9THENV%=V%+7
400 PRINTCHR$(V%+48);
410 NEXT J
420 NEXT I
430 PRINT "/";T
440 GOTO110
500 P=1
510 L=4
520 GOTO600
550 P=J
560 L=2
600 E=0
610 V=0
620 FORJ=P TO LEN(X$)
630 X=ASC(MID$(X$,J))
640 IFX=32 THEN NEXT J
650 IFJ>LEN(X$)THEN790
660 P=J
670 FORJ=PTOLEN(X$)
680 X=ASC(MID$(X$,J))
```

```
690 IF X<>32 THEN NEXT J
700 IF J-P<>L THEN 790
710 FORK=PTOJ-1
720 X=ASC(MID$(X$,K))
730 IF X<58 THENX=X-48
740 IF X>64 THEN X=X-55
750 IF X<0 OR X>15 THEN790
760 V=V*16+X
770 NEXT K
780 RETURN
790 E=-1
800 RETURN
```

```
0800 00 1A 04 64 00 99 22 93
0808 12 1D 1D 1D 1D 53 55 50
0810 45 52 20 36 34 2D 4D 4F
0818 4E 00 31 04 6E 00 99 22
0820 11 20 20 20 20 20 20 20
0828 20 20 20 20 20 20 20 20
0830 00 4B 04 78 00 99 22 11
0838 20 2E 2E 4A 49 4D 20 42
0840 55 54 54 45 52 46 49 45
0848 4C 44 00 66 04 82 00 9E
0850 28 C2 28 34 33 29 AA 32
0858 35 36 AC C2 28 34 34 29
0860 AA 31 32 37 29 00 00 00
0868 AA AA AA AA AA AA AA AA
0870 AA AA AA AA AA AA AA AA
0878 AA AA AA AA AA AA AA AA

0880 A5 2D 85 22 A5 2E 85 23
0888 A5 37 85 24 A5 38 85 25
0890 A0 00 A5 22 D0 02 C6 23
0898 C6 22 B1 22 D0 3C A5 22
08A0 D0 02 C6 23 C6 22 B1 22
08A8 F0 21 85 26 A5 22 D0 02
08B0 C6 23 C6 22 B1 22 18 65
08B8 24 AA A5 26 65 25 48 A5
08C0 37 D0 02 C6 38 C6 37 68
08C8 91 37 8A 48 A5 37 D0 02
08D0 C6 38 C6 37 68 91 37 18
08D8 90 B6 C9 4F D0 ED A5 37
08E0 85 33 A5 38 85 34 6C 37
08E8 00 4F 4F 4F 4F AD E6 FF
08F0 00 8D 16 03 AD E7 FF 00
08F8 8D 17 03 A9 80 20 90 FF

0900 00 00 D8 68 8D 3E 02 68
0908 8D 3D 02 68 8D 3C 02 68
0910 8D 3B 02 68 AA 68 A8 38
0918 8A E9 02 8D 3A 02 98 E9
0920 00 00 8D 39 02 BA 8E 3F
0928 02 20 57 FD 00 A2 42 A9
0930 2A 20 57 FA 00 A9 52 D0
0938 34 E6 C1 D0 06 E6 C2 D0
0940 02 E6 26 60 20 CF FF C9
0948 0D D0 F8 68 68 A9 90 20
0950 D2 FF A9 00 00 85 26 A2
0958 0D A9 2E 20 57 FA 00 A9
0960 05 20 D2 FF 20 3E F8 00
0968 C9 2E F0 F9 C9 20 F0 F5
0970 A2 0E DD B7 FF 00 D0 0C
0978 8A 0A AA BD C7 FF 00 48

0980 BD C6 FF 00 48 60 CA 10
0988 EC 4C ED FA 00 A5 C1 8D
0990 3A 02 A5 C2 8D 39 02 60
0998 A9 08 85 1D A0 00 00 20
09A0 54 FD 00 B1 C1 20 48 FA
09A8 00 20 33 F8 00 C6 1D D0
09B0 F1 60 20 88 FA 00 90 0B
09B8 A2 00 00 81 C1 C1 C1 F0
09C0 03 4C ED FA 00 20 33 F8
09C8 00 C6 1D 60 A9 3B 85 C1
09D0 A9 02 85 C2 A9 05 60 98
09D8 48 20 57 FD 00 68 A2 2E
09E0 4C 57 FA 00 A9 90 20 D2
09E8 FF A2 00 00 BD EA FF 00
09F0 20 D2 FF E8 E0 16 D0 F5
09F8 A0 3B 20 C2 F8 00 AD 39

0A00 02 20 48 FA 00 AD 3A 02
0A08 20 48 FA 00 20 B7 F8 00
0A10 20 8D F8 00 F0 5C 20 3E
0A18 F8 00 20 79 FA 00 90 33
0A20 20 69 FA 00 20 3E F8 00
0A28 20 79 FA 00 90 28 20 69
0A30 FA 00 A9 90 20 D2 FF 20
0A38 E1 FF F0 3C A6 26 D0 38
0A40 A5 C3 C5 C1 A5 C4 E5 C2
0A48 90 2E A0 3A 20 C2 F8 00
0A50 20 41 FA 00 20 8B F8 00
0A58 F0 E0 4C ED FA 00 20 79
0A60 FA 00 90 03 20 8D F8 00
0A68 20 B7 F8 00 D0 07 20 79
0A70 FA 00 90 EB A9 08 85 1D
0A78 20 3E F8 00 20 A1 F8 00

0A80 D0 F8 4C 47 F8 00 20 CF
0A88 FF C9 0D F0 0C C9 20 D0
0A90 D1 20 79 FA 00 90 03 20
0A98 80 F8 00 A9 90 20 D2 FF
0AA0 AE 3F 02 9A 78 AD 39 02
0AA8 48 AD 3A 02 48 AD 3B 02
0AB0 48 AD 3C 02 AE 3D 02 AC
0AB8 3E 02 40 A9 90 20 D2 FF
0AC0 AE 3F 02 9A 6C 02 A0 A0
0AC8 01 84 BA 84 B9 88 84 B7
0AD0 84 90 84 93 A9 40 85 BB
0AD8 A9 02 85 BC 20 CF FF C9
0AE0 20 F0 F9 C9 0D F0 38 C9
0AE8 22 D0 14 20 CF FF C9 22
0AF0 F0 10 C9 0D F0 29 91 BB
0AF8 E6 B7 C8 C0 10 D0 EC 4C

0B00 ED FA 00 20 CF FF C9 0D
0B08 F0 16 C9 2C D0 DC 20 88
0B10 FA 00 29 0F F0 E9 C9 03
0B18 F0 E5 85 BA 20 CF FF C9
0B20 0D 60 6C 30 03 6C 32 03
0B28 20 96 F9 00 D0 D4 A9 90
0B30 20 D2 FF A9 00 00 20 EF
0B38 F9 00 A5 90 29 10 D0 C4
0B40 4C 47 F8 00 20 96 F9 00
0B48 C9 2C D0 BA 20 79 FA 00
0B50 20 69 FA 00 20 CF FF C9
0B58 2C D0 AD 20 79 FA 00 A5
0B60 C1 85 AE A5 C2 85 AF 20
0B68 69 FA 00 20 CF FF C9 0D
0B70 D0 98 A9 90 20 D2 FF 20
0B78 F2 F9 00 4C 47 F8 00 A5

0B80 C2 20 48 FA 00 A5 C1 48
0B88 4A 4A 4A 4A 20 60 FA 00
0B90 AA 68 29 0F 20 60 FA 00
0B98 48 8A 20 D2 FF 68 4C D2
0BA0 FF 09 30 C9 3A 90 02 69
0BA8 06 60 A2 02 B5 C0 48 B5
0BB0 C2 95 C0 68 95 C2 CA D0
0BB8 F3 60 20 88 FA 00 90 02
0BC0 85 C2 20 88 FA 00 90 02
0BC8 85 C1 60 A9 00 00 85 2A
0BD0 20 3E F8 00 C9 20 D0 09
0BD8 20 3E F8 00 C9 20 D0 0E
0BE0 18 60 20 AF FA 00 0A 0A
0BE8 0A 0A 85 2A 20 3E F8 00
0BF0 20 AF FA 00 05 2A 38 60
0BF8 C9 3A 90 02 69 08 29 0F

0C00 60 A2 02 2C A2 00 00 B4
0C08 C1 D0 08 B4 C2 D0 02 E6
0C10 26 D6 C2 D6 C1 60 20 3E
0C18 F8 00 C9 20 F0 F9 60 A9
0C20 00 00 8D 00 00 01 20 CC
0C28 FA 00 20 8F FA 00 20 7C
0C30 FA 00 90 09 60 20 3E F8
0C38 00 20 79 FA 00 B0 DE AE
0C40 3F 02 9A A9 90 20 D2 FF
0C48 A9 3F 20 D2 FF 4C 47 F8
0C50 00 20 54 FD 00 CA D0 FA
0C58 60 E6 C3 D0 02 E6 C4 60
0C60 A2 02 B5 C0 48 B5 27 95
0C68 C0 68 95 27 CA D0 F3 60
0C70 A5 C3 A4 C4 38 E9 02 B0
0C78 0E 88 90 0B A5 28 A4 29

0C80 4C 33 FB 00 A5 C3 A4 C4
0C88 38 E5 C1 85 1E 98 E5 C2
0C90 A8 85 1E 60 20 D4 FA 00
0C98 20 69 FA 00 20 E5 FA 00
0CA0 20 0C FB 00 20 E5 FA 00
0CA8 20 2F FB 00 20 69 FA 00
0CB0 90 15 A6 26 D0 64 20 28
0CB8 FB 00 90 5F A1 C1 81 C3
0CC0 20 05 FB 00 20 33 F8 00
0CC8 D0 EB 20 28 FB 00 18 A5
0CD0 1E 65 C3 85 C3 98 65 C4
0CD8 85 C4 20 0C FB 00 A6 26
0CE0 D0 3D A1 C1 81 C3 20 28
0CE8 FB 00 B0 34 20 B8 FA 00
0CF0 20 BB FA 00 4C 7D FB 00
0CF8 20 D4 FA 00 20 69 FA 00

0D00 20 E5 FA 00 20 69 FA 00
0D08 20 3E F8 00 20 88 FA 00
0D10 90 14 85 1D A6 26 D0 11
0D18 20 2F FB 00 90 0C A5 1D
0D20 81 C1 20 33 F8 00 D0 EE
0D28 4C ED FA 00 4C 47 F8 00
0D30 20 D4 FA 00 20 69 FA 00
0D38 20 E5 FA 00 20 69 FA 00
0D40 20 3E F8 00 A2 00 00 20
0D48 3E F8 00 C9 27 D0 14 20
0D50 3E F8 00 9D 10 02 E8 20
0D58 CF FF C9 0D F0 22 E0 20
0D60 D0 F1 F0 1C 8E 00 00 01
0D68 20 8F FA 00 90 C6 9D 10
0D70 02 E8 20 CF FF C9 0D F0
0D78 09 20 88 FA 00 90 B6 E0

0D80 20 D0 EC 86 1C A9 90 20
0D88 D2 FF 20 57 FD 00 A2 00
0D90 00 A0 00 00 B1 C1 D0 10
0D98 02 D0 0C C8 E8 E4 1C D0
0DA0 F3 20 41 FA 00 20 54 FD
0DA8 00 20 33 F8 00 A6 26 D0
0DB0 8D 20 2F FB 00 B0 DD 4C
0DB8 47 F8 00 20 D4 FA 00 85
0DC0 20 A5 C2 85 21 A2 00 00
0DC8 86 28 A9 93 20 D2 FF A9
0DD0 90 20 D2 FF A9 16 85 1D
0DD8 20 6A FC 00 20 CA FC 00
0DE0 85 C1 84 C2 C6 1D D0 F2
0DE8 A9 91 20 D2 FF 4C 47 F8
0DF0 00 A0 2C 20 C2 F8 00 20
0DF8 54 FD 00 20 41 FA 00 20
```

```
0E00 54 FD 00 A2 00 00 A1 C1   1000 00 BD 2A FF 00 20 B9 FE
0E08 20 D9 FC 00 48 20 1F FD   1008 00 D0 B5 CA D0 D1 F6 0A
0E10 00 68 20 35 FD 00 A2 06   1010 20 B8 FE 00 D0 AB 20 B8
0E18 E0 03 D0 12 A4 1F F0 0E   1018 FE 00 D0 A6 A5 28 C5 1D
0E20 A5 2A C9 E8 B1 C1 B0 1C   1020 D0 A0 20 69 FA 00 A4 1F
0E28 20 C2 FC 00 88 D0 F2 06   1028 F0 28 A5 29 C9 9D D0 1A
0E30 2A 90 0E BD 2A FF 00 20   1030 20 1C FB 00 90 0A 98 D0
0E38 A5 FD 00 BD 30 FF 00 F0   1038 04 A5 1E 10 0A 4C ED FA
0E40 03 20 A5 FD 00 CA D0 D5   1040 00 C8 D0 FA A5 1E 10 F6
0E48 60 20 CD FC 00 AA E8 D0   1048 A4 1F D0 03 B9 C2 00 00
0E50 01 C8 98 20 C2 FC 00 8A   1050 91 C1 88 D0 F8 A5 26 91
0E58 86 1C 20 48 FA 00 A6 1C   1058 C1 20 CA FC 00 85 C1 84
0E60 60 A5 1F 38 A4 C2 AA 10   1060 C2 A9 90 20 D2 FF A0 41
0E68 01 88 65 C1 90 01 C8 60   1068 20 C2 F8 00 20 54 FD 00
0E70 A8 4A 90 0B 4A B0 17 C9   1070 20 41 FA 00 20 54 FD 00
0E78 22 F0 13 29 07 09 80 4A   1078 A9 05 20 D2 FF 4C B0 FD

0E80 AA BD D9 FE 00 B0 04 4A   1080 00 A8 20 BF FE 00 D0 11
0E88 4A 4A 4A 29 0F D0 04 A0   1088 98 F0 0E 86 1C A6 1D DD
0E90 80 A9 00 00 AA BD 1D FF   1090 10 02 08 E8 86 1D A6 1C
0E98 00 85 2A 29 03 85 1F 98   1098 28 60 C9 30 90 03 C9 47
0EA0 29 8F AA 98 A0 03 E0 8A   10A0 60 38 60 40 02 45 03 D0
0EA8 F0 0B 4A 90 08 4A 4A 09   10A8 08 40 09 30 22 45 33 D0
0EB0 20 88 D0 FA C8 88 D0 F2   10B0 08 40 09 40 02 45 33 D0
0EB8 60 B1 C1 20 C2 FC 00 A2   10B8 08 40 09 40 02 45 B3 D0
0EC0 01 20 FE FA 00 C4 1F C8   10C0 08 40 09 00 00 22 44 33
0EC8 90 F1 A2 03 C0 04 90 F2   10C8 D0 8C 44 00 00 11 22 44
0ED0 60 A8 B9 37 FF 00 85 28   10D0 33 D0 8C 44 9A 10 22 44
0ED8 B9 77 FF 00 85 29 A9 00   10D8 33 D0 08 40 09 10 22 44
0EE0 00 A0 05 06 29 26 28 2A   10E0 33 D0 08 40 09 62 13 78
0EE8 88 D0 F8 69 3F 20 D2 FF   10E8 A9 00 00 21 81 82 00 00
0EF0 CA D0 EC A9 20 2C A9 0D   10F0 00 00 59 4D 91 92 86 4A
0EF8 4C D2 FF 20 D4 FA 00 20   10F8 85 9D 2C 29 2C 23 28 24

0F00 69 FA 00 20 E5 FA 00 20   1100 59 00 00 58 24 24 00 00
0F08 69 FA 00 A2 00 00 86 28   1108 1C 8A 1C 23 5D 8B 1B A1
0F10 A9 90 20 D2 FF 20 57 FD   1110 9D 8A 1D 23 9D 8B 1D A1
0F18 00 20 72 FC 00 20 CA FC   1118 00 00 29 19 AE 69 A8 19
0F20 00 85 C1 84 C2 20 E1 FF   1120 23 24 53 1B 23 24 53 19
0F28 F0 05 20 2F FB 00 B0 E9   1128 A1 00 00 1A 5B 5B A5 69
0F30 4C 47 F8 00 20 D4 FA 00   1130 24 24 AE AE A8 AD 29 00
0F38 A9 03 85 1D 20 3E F8 00   1138 00 7C 00 00 15 9C 6D 9C
0F40 20 A1 F8 00 D0 F8 A5 20   1140 A5 69 29 53 84 13 34 11
0F48 85 C1 A5 21 85 C2 4C 46   1148 A5 69 23 A0 D8 62 5A 48
0F50 FC 00 C5 28 F0 03 20 D2   1150 26 62 94 88 54 44 C8 54
0F58 FF 60 20 D4 FA 00 20 69   1158 68 44 E8 94 00 00 B4 08
0F60 FA 00 8E 11 02 A2 03 20   1160 84 74 B4 28 6E 74 F4 CC
0F68 CC FA 00 48 CA D0 F9 A2   1168 4A 72 F2 A4 8A 00 00 AA
0F70 03 68 38 E9 3F A0 05 4A   1170 A2 A2 74 74 74 72 44 68
0F78 6E 11 02 6E 10 02 88 D0   1178 B2 32 B2 00 00 22 00 00

0F80 F6 CA D0 ED A2 02 20 CF   1180 1A 1A 26 26 72 72 88 C8
0F88 FF C9 0D F0 1E C9 20 F0   1188 C4 CA 26 48 44 44 A2 C8
0F90 F5 20 D0 FE 00 B0 0F 20   1190 3A 3B 52 4D 47 58 4C 53
0F98 9C FA 00 A4 C1 84 C2 85   1198 54 46 48 44 50 2C 41 42
0FA0 C1 A9 30 9D 10 02 E8 9D   11A0 F9 00 35 F9 00 CC F8 00
0FA8 10 02 E8 D0 DB 86 28 A2   11A8 F7 F8 00 56 F9 00 89 F9
0FB0 00 00 86 26 F0 04 E6 26   11B0 00 F4 F9 00 0C FA 00 3E
0FB8 F0 75 A2 00 00 86 1D A5   11B8 FB 00 92 FB 00 C0 FB 00
0FC0 26 20 D9 FC 00 A6 2A 86   11C0 38 FC 00 5B FD 00 8A FD
0FC8 29 AA BC 37 FF 00 BD 77   11C8 00 AC FD 00 46 F8 00 FF
0FD0 FF 00 20 B9 FE 00 D0 E3   11D0 F7 00 ED F7 00 0D 20 20
0FD8 A2 06 E0 03 D0 19 A4 1F   11D8 20 50 43 20 20 53 52 20
0FE0 F0 15 A5 2A C9 E8 A9 30   11E0 41 43 20 58 52 20 59 52
0FE8 B0 21 20 BF FE 00 D0 CC   11E8 20 53 50 AA AA AA AA AA
0FF0 20 C1 FE 00 D0 C7 88 D0
0FF8 EB 06 2A 90 0B BC 30 FF
```

Entering Extramon : Commodore 64 version

Use the program Tiny Peeker/Poker as follows.

Type POKE 8192,0:POKE44,32 (return)

Enter and run the peeker/poker program.

In response to the program prompts, type in the data as given in the following tables. When you've finished, type POKE44,8:POKE45,232:POKE46,17:CLR.

Save Extramon with a normal SAVE before attempting to run it.

Then type NEW. and use the following checksum program to enable you to identify and locate any errors:

```
100 REM EXTRAMON64 CHECKSUM PROGRAM
110 DATA10170,13676,15404,14997,15136,16221,16696
115 DATA12816,16228,14554
120 DATA14677,15039,14551,15104,15522,16414,15914
125 DATA8958,11945:S=2048
130 FORB=1TO19:READX:FORI=1TOS:N=PEEK(I):Y=Y+N
140 NEXTI:IFY<>XTHEN?"ERROR IN BLOCK "B:GOTO160
150 PRINT"BLOCK "B" CORRECT"
160 S=I:Y=0:NEXTB:REM CHECK LAST BLOCK BY HAND
```

This program must be run after the first set of POKEs, and before the second set.

If errors are found, type NEW (you won't lose Extramon!), re-load Tiny Peeker/Poker, enter block of memory again, type NEW, re-load checksum program, run it, if errors found type NEW and re-load Tiny Peeker/Poker, and so on until no errors remain. Then, issue last set of POKEs and SAVE Extramon!

Extramon Instruction Set

This will be given in the form COMMAND, followed by the syntax.

1) Simple Assembler
```
.A 2000 LDA£12
```
start assembly at 2000 hex.

2) Disassembler
```
.D 2000
```
disassemble hex from 2000 onwards.

3) Printing Disassembler
```
.P 2000,2040
```
engage printer beforehand with OPEN4,4:CMD4.

4) Fill memory
```
.F 1000 1100 FF
```
fill memory from 1000 to 1100 hex with the byte FF.

5) Go run
```
.G 1000
```
go to hex 1000 and executre program there.

6) Hunt memory
```
.H C000 D000 'READ
```
look from C000 to D000 for the ASCII string READ.

7) Load
```
.L "FRED",08
```

8) Memory display
```
.M 0800 0820
```
display memory from hex 0800 to 0820.

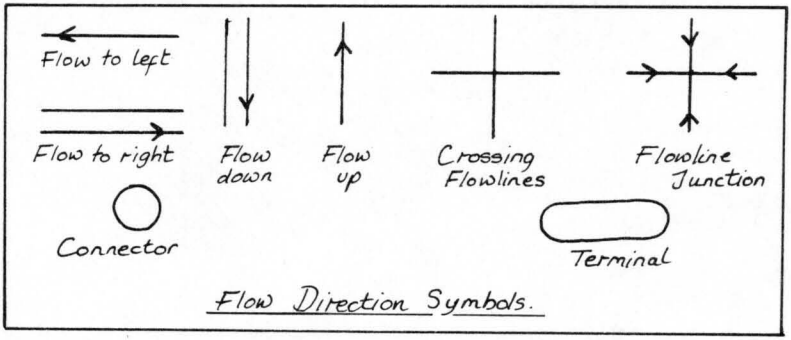
9) Register display
```
.R
```
displays register values when Extramon was entered.

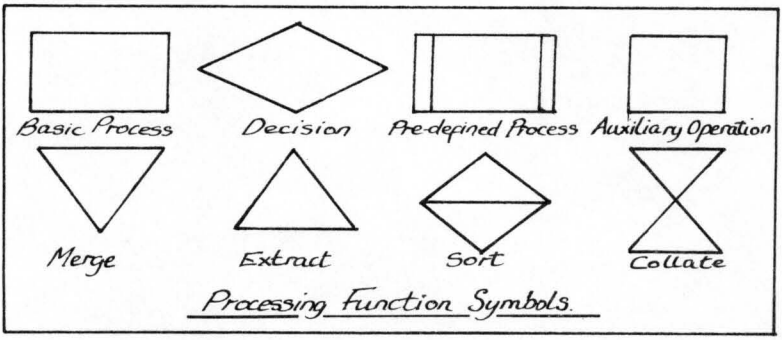
10) Save
```
.S "0:FRED",08,0800,0820
```
save memory from hex 0800 to 0820 onto device 08 drive 1, and call that portion of memory FRED.

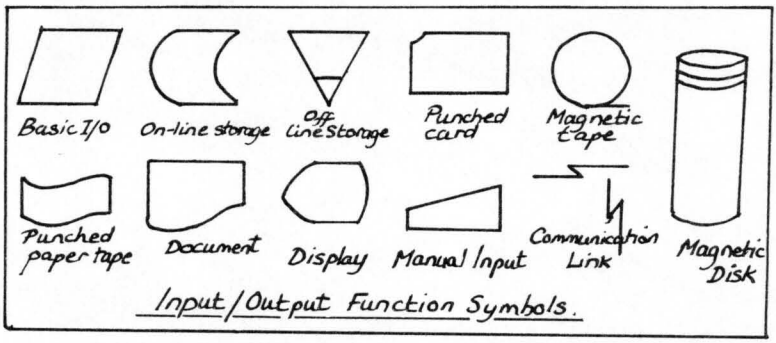
11) Transfer memory
.T 1000 1100 5000
transfer memory in the range hex 1000 to 1100 and start storing it at hex 5000 onwards.

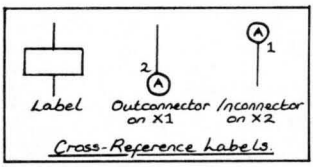
12) Exit to Basic
.Q
return to Basic ready mode. Perform a CLR before doing anything.

Flow charting

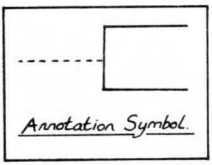








Cross-Reference Labels.


Annotation Symbol.

Hex/Dec convertor

Decimal & Hexadecimal Conversions

HEXADECIMAL COLUMNS

6		5		4		3		2		1	
HEX	DEC	HEX	DEC	HEX	DEC	HEX	DEC	HEX	DEC	HEX	DEC
0	0	0	0	0	0	0	0	0	0	0	0
1	1,048,576	1	65,536	1	4,096	1	256	1	16	1	1
2	2,097,152	2	131,072	2	8,192	2	512	2	32	2	2
3	3,145,728	3	196,608	3	12,288	3	768	3	48	3	3
4	4,194,304	4	262,144	4	16,384	4	1,024	4	64	4	4
5	5,242,880	5	327,680	5	20,480	5	1,280	5	80	5	5
6	6,291,456	6	393,216	6	24,576	6	1,536	6	96	6	6
7	7,340,032	7	458,752	7	28,672	7	1,792	7	112	7	7
8	8,388,608	8	524,288	8	32,768	8	2,048	8	128	8	8
9	9,437,184	9	589,824	9	36,864	9	2,304	9	144	9	9
A	10,485,760	A	655,360	A	40,960	A	2,560	A	160	A	10
B	11,534,336	B	720,897	B	45,056	B	2,816	B	176	B	11
C	12,582,912	C	786,432	C	49,152	C	3,072	C	192	C	12
D	13,631,488	D	851,968	D	53,248	D	3,328	D	208	D	13
E	14,680,064	E	917,504	E	57,344	E	3,584	E	224	E	14
F	15,728,640	F	983,040	F	61,440	F	3,840	F	240	F	15

Notes.

To convert from hexadecimal to decimal, first find the corresponding column position for each hexadecimal digit. Make a note of the decimal equivalents, then add the noted values together to obtain the converted decimal value.

To convert from decimal to hexadecimal, find the largest decimal value in the table that will fit into the number to be converted. Next make a note of the hex equivalent and column position. Calculate the decimal remainder, and repeat the process on this and any subsequent remainders.

Hyperbolic functions

FUNCTION	BASIC EQUIVALENT
SECANT	SEC(X)=1/COS(X)
COSECANT	CSC(X)=1/SIN(X)
COTANGENT	COT(X)=1/TAN(X)
INVERSE SINE	ARCSIN(X)=ATN(X/SQR(−X*X+1))
INVERSE COSINE	ARCCOS(X)=−ATN(X/SQR (−X*X +1)) +π/2
INVERSE SECANT	ARCSEC(X)=ATN(X/SQR(X*X−1))
INVERSE COSECANT	ARCCSC(X)=ATN(X/SQR(X*X−1)) +(SGN(X)−1*π/2
INVERSE COTANGENT	ARCOT(X)=ATN(X)+π/2
HYPERBOLIC SINE	SINH(X)=(EXP(X)−EXP(−X))/2
HYPERBOLIC COSINE	COSH(X)=(EXP(X)+EXP(−X))/2
HYPERBOLIC TANGENT	TANH(X)=EXP(−X)/(EXP(x)+EXP (−X))*2+1
HYPERBOLIC SECANT	SECH(X)=2/(EXP(X)+EXP(−X))
HYPERBOLIC COSECANT	CSCH(X)=2/(EXP(X)−EXP(−X))
HYPERBOLIC COTANGENT	COTH(X)=EXP(−X)/(EXP(X) −EXP(−X))*2+1
INVERSE HYPERBOLIC SINE	ARCSINH(X)=LOG(X+SQR(X*X+1))
INVERSE HYPERBOLIC COSINE	ARCCOSH(X)=LOG(X+SQR(X*X−1))
INVERSE HYPERBOLIC TANGENT	ARCTANH(X)=LOG((1+X)/(1−X))/2
INVERSE HYPERBOLIC SECANT	ARCSECH(X)=LOG((SQR (−X*X+1)+1/X)
INVERSE HYPERBOLIC COSECANT	ARCCSCH(X)=LOG((SGN(X)*SQR (X*X+1/x)
INVERSE HYPERBOLIC COTAN-GENT	ARCCOTH(X)=LOG((X+1)/(x−1))/2

Memory maps

0000		0	Chip directional register
0001		1	Chip I/O; memory & tape control
0003	-0004	3-4	Float-Fixed vector
0005	-0006	5-6	Fixed-Float vector
0007		7	Search character
0008		8	Scan-quotes flag
0009		9	TAB column save
000A		10	0 = LOAD, 1 = VERIFY
000B		11	Input buffer pointer/# subscrpt
000C		12	Default DIM flag
000D		13	Type: FF = string, 00 = numeric
000E		14	Type: 80 = integer, 00 = floating point
000F		15	DATA scan/LIST quote/memry flag
0010		16	Subscript/FNx flag
0011		17	0 = INPUT;$40 = GET;$98 = READ
0012		18	ATN sign/Comparison eval flag
0013		19	Current I/O prompt flag
0014	-0015	20-21	Integer value
0016		22	Pointer: temporary string stack
0017	-0018	23-24	Last temp string vector
0019	-0021	25-33	Stack for temporary strings
0022	-0025	34-37	Utility pointer area
0026	-002A	38-42	Product area for multiplication
002B	-002C	43-44	Pointer: Start-of-Basic
002D	-002E	45-46	Pointer: Start-of-Variables
002F	-0030	47-48	Pointer: Start-of-Arrays
0031	-0032	49-50	Pointer: End-of-Arrays
0033	-0034	51-52	Pointer: String-storage(moving down)
0035	-0036	53-54	Utility string pointer
0037	-0038	55-56	Pointer: Limit-of-memory
0039	-003A	57-58	Current Basic line number
003B	-003C	59-60	Previous Basic line number
003D	-003E	61-62	Pointer: Basic statement for CONT
003F	-0040	63-64	Current DATA line number
0041	-0042	65-66	Current DATA address
0043	-0044	67-68	Input vector
0045	-0046	69-70	Current variable name
0047	-0048	71-72	Current variable address
0049	-004A	73-74	Variable pointer for FOR/NEXT
004B	-004C	75-76	Y-save; op-save; Basic pointer save
004D		77	Comparison symbol accumulator
004E	-0053	78-83	Misc work area, pointers, etc
0054	-0056	84-86	Jump vector for functions
0057	-0060	87-96	Misc numeric work area
0061		97	Accum#1: Exponent
0062	-0065	98-101	Accum#1: Mantissa
0066		102	Accum#1: Sign
0067		103	Series evaluation constant pointer
0068		104	Accum#1 hi-order (overflow)
0069	-006E	105-110	Accum#2: Exponent, etc.
006F		111	Sign comparison, Acc#1 vs #2

0070	112	Accum#1 lo-order (rounding)
0071 -0072	113-114	Cassette buff len/Series pointer
0073 -008A	115-138	CHRGET subroutine; get Basic char
007A -007B	122-123	Basic pointer (within subrtn)
008B -008F	139-143	RND seed value
0090	144	Status word ST
0091	145	Keyswitch PIA: STOP and RVS flags
0092	146	Timing constant for tape
0093	147	Load = 0, Verify = 1
0094	148	Serial output: deferred char flag
0095	149	Serial deferred character
0096	150	Tape EOT received
0097	151	Register save
0098	152	How many open files
0099	153	Input device, normally 0
009A	154	Output CMD device, normally 3
009B	155	Tape character parity
009C	156	Byte-received flag
009D	157	Direct = $80/RUN = 0 output control
009E	158	Tp Pass 1 error log/char buffer
009F	159	Tp Pass 2 err log corrected
00A0 -00A2	160-162	Jiffy Clock HML
00A3	163	Serial bit count/EOI flag
00A4	164	Cycle count
00A5	165	Countdown,tape write/bit count
00A6	166	Tape buffer pointer
00A7	167	Tp Wrt ldr count/Rd pass/inbit
00A8	168	Tp Wrt new byte/Rd error/inbit cnt
00A9	169	Wrt start bit/Rd bit err/stbit
00AA	170	Tp Scan;Cnt;Ld;End/byte assy
00AB	171	Wr lead length/Rd checksum/parity
00AC -00AD	172-173	Pointer: tape bufr, scrolling
00AE -00AF	174-175	Tape end adds/End of program
00B0 -00B1	176-177	Tape timing constants
00B2 -00B3	178-179	Pntr: start of tape buffer
00B4	180	1 = Tp timer enabled; bit count
00B5	181	Tp EOT/RS232 next bit to send
00B6	182	Read character error/outbyte buf
00B7	183	# characters in file name
00B8	184	Current logical file
00B9	185	Current secndy address
00BA	186	Current device
00BB -00BC	187-188	Pointer to file name
00BD	189	Wr shift word/Rd input char
00BE	190	# blocks remaining to Wr/Rd
00BF	191	Serial word buffer
00C0	192	Tape motor interlock
00C1 -00C2	193-194	I/O start address
00C3 -00C4	195-196	Kernel setup pointer
00C5	197	Last key pressed
00C6	198	# chars in keybd buffer
00C7	199	Screen reverse flag
00C8	200	End-of-line for input pointer
00C9 -00CA	201-202	Input cursor log (row, column)
00CB	203	Which key: 64 if no key

00CC		204	0 = flash cursor
00CD		205	Cursor timing countdown
00CE		206	Character under cursor
00CF		207	Cursor in blink phase
00D0		208	Input from screen/from keyboard
00D1	-00D2	209-210	Pointer to screen line
00D3		211	Position of cursor on above line
00D4		212	0 = direct cursor, else programmed
00D5		213	Current screen line length
00D6		214	Row where curosr lives
00D7		215	Last inkey/checksum/buffer
00D8		216	# of INSERTs outstanding
00D9	-00F2	217-242	Screen line link table
00F3	-00F4	243-244	Screen color pointer
00F5	-00F6	245-246	Keyboard pointer
00F7	-00F8	247-248	RS-232 Rcv pntr
00F9	-00FA	249-250	RS-232 Tx pntr
00FF	-010A	256-266	Floating to ASCII work area
0100	-013E	256-318	Tape error log
0100	-01FF	256-511	Processor stack area
0200	-0258	512-600	Basic input buffer
0259	-0262	601-610	Logical file table
0263	-026C	611-620	Device # table
026D	-0276	621-630	Sec Adds table
0277	-0280	631-640	Keybd buffer
0281	-0282	641-642	Start of Basic Memory
0283	-0284	643-644	Top of Basic Memory
0285		645	Serial bus timeout flag
0286		646	Current color code
0287		647	Color under cursor
0288		648	Screen memory page
0289		649	Max size of keybd buffer
028A		650	Repeat all keys
028B		651	Repeat speed counter
028C		652	Repeat delay counter
028D		653	Keyboard Shift/Control flag
028E		654	Last shift pattern
028F	-0290	655-656	Keyboard table setup pointer
0291		657	Keyboard shift mode
0292		658	0 = scroll enable
0293		659	RS-232 control reg
0294		660	RS-232 command reg
0295	-0296	661-662	Bit timing
0297		663	RS-232 status
0298		664	# bits to send
0299	-029A	665	RS-232 speed/code
029B		667	RS232 receive pointer
029C		668	RS232 input pointer
029D		669	RS232 transmit pointer
029E		670	RS232 output pointer
029F	-02A0	671-672	IRQ save during tape I/O
02A1		673	CIA 2 (NMI) Interrupt Control
02A2		674	CIA 1 Timer A control log
02A3		675	CIA 1 Interrupt Log
02A4		676	CIA 1 Timer A enabled flag

02A5		677	Screen row marker	
02C0	-02FE	704-766	(Sprite 11)	
0300	-0301	768-769	Error message link	
0302	-0303	770-771	Basic warm start link	
0304	-0305	772-773	Crunch Basic tokens link	
0306	-0307	774-775	Print tokens link	
0308	-0309	776-777	Start new Basic code link	
030A	-030B	778-779	Get arithmetic element link	
030C		780	SYS A-reg save	
030D		781	SYS X-reg save	
030E		782	SYS Y-reg save	
030F		783	SYS status reg save	
0310	-0312	784-785	USR function jump	(B248)
0314	-0315	788-789	Hardware interrupt vector	(EA31)
0316	-0317	790-791	Break interrupt vector	(FE66)
0318	-0319	792-793	NMI interrupt vector	(FE47)
031A	-031B	794-795	OPEN vector	(F34A)
031C	-031D	796-797	CLOSE vector	(F291)
031E	-031F	798-799	Set-input vector	(F20E)
0320	-0321	800-801	Set-output vector	(F250)
0322	-0323	802-803	Restore I/O vector	(F333)
0324	-0325	804-805	INPUT vector	(F157)
0326	-0327	806-807	Output vector	(F1CA)
0328	-0329	808-809	Test-STOP vector	(F6ED)
032A	-032B	810-811	GET vector	(F13E)
032C	-032D	812-813	Abort I/O vector	(F32F)
032E	-032F	814-815	Warm start vector	(FE66)
0330	-0331	816-817	LOAD link	(F4A5)
0332	-0333	818-819	SAVE link	(F5ED)
033C	-03FB	828-1019	Cassette buffer	
0340	-037E	832-894	(Sprite 13)	
0380	-03BE	896-958	(Sprite 14)	
03C0	-03FE	960-1022	(Sprite 15)	
0400	-07FF	1024-2047	Screen memory	
0800	-9FFF	2048-40959	Basic RAM memory	
8000	-9FFF	32768-40959	Alternate: ROM plug-in area	
A000	-BFFF	40960-49151	ROM: Basic	
A000	-BFFF	49060-59151	Alternate: RAM	
C000	-CFFF	49152-53247	RAM memory, including alternate	
D000	-D02E	53248-53294	Video Chip (6566)	
D400	-D41C	54272-54300	Sound Chip (6581 SID)	
D800	-DBFF	55296-56319	Color nybble memory	
DC00	-DC0F	56320-56335	Interface chip 1, IRQ (6526 CIA)	
DD00	-DD0F	56576-56591	Interface chip 2, NMI (6526 CIA)	
D000	-DFFF	53248-53294	Alternate: Character set	
E000	-FFFF	57344-65535	ROM: Operating System	
E000	-FFFF	57344-65535	Alternate: RAM	
FF81	-FFF5	65409-65525	Jump Table, Including:	
	FFC6		- Set Input channel	
	FFC9		- Set Output channel	
	FFCC		- Restore default I/O channels	
	FFCF		- INPUT	
	FFD2		- PRINT	
	FFE1		- Test Stop key	
	FFE4		- GET	

A000; ROM control vectors
A00C; Keyword action vectors
A052; Function vectors
A080; Operator vectors
A09E; Keywords
A19E; Error messages
A328; Error message vectors
A365; Misc messages
A38A; Scan stack for FOR/GOSUB
A3B8; Move memory
A3FB; Check stack depth
A408; Check memory space
A435; 'out of memory'
A437; Error routine
A469; BREAK entry
A474; 'ready.'
A480; Ready for Basic
A49C; Handle new line
A533; Re–chain lines
A560; Receive input line
A579; Crunch tokens
A613; Find Basic line
A642; Perform [NEW]
A65E; Perform [CLR]
A68E; Back up text pointer
A69C; Perform [LIST]
A742; Perform [FOR]
A7ED; Execute statement
A81D; Perform [RESTORE]
A82C; Break
A82F; Perform [STOP]
A831; Perform [END]
A857; Perform [CONT]
A871; Perform [RUN]
A883; Perform [GOSUB]
A8A0; Perform [GOTO]
A8D2; Perform [RETURN]
A8F8; Perform [DATA]
A906; Scan for next statement
A928; Perform [IF]
A93B; Perform [REM]
A94B; Perform [ON]
A96B; Get fixed point number
A9A5; Perform [LET]
AA80; Perform [PRINT#]
AA86; Perform [CMD]
AAA0; Perform [PRINT]
AB1E; Print string from (y.a)
AB3B; Print format character
AB4D; Bad input routine
AB7B; Perform [GET]
ABA5; Perform [INPUT#]
ABBF; Perform [INPUT]
ABF9; Prompt & input
AC06; Perform [READ]
ACFC; Input error messages
AD1E; Perform [NEXT]
AD78; Type match check
AD9E; Evaluate expression
AEA8; Constant – pi
AEF1; Evaluate within brackets
AEF7; ')'
AEFF; comma..
AF08; Syntax error
AF14; Check range
AF28; Search for variable
AFA7; Setup FN reference
AFE6; Perform [OR]
AFE9; Perform [AND]
B016; Compare
B081; Perform [DIM]
B08B; Locate variable
B113; Check alphabetic
B11D; Create variable
B194; Array pointer subrtine
B1A5; Value 32768
B1B2; Float–fixed
B1D1; Set up array
B245; 'bad subscript'
B248; 'illegal quantity'
B34C; Compute array size
B37D; Perform [FRE]
B391; Fix–float
B39E; Perform [POS]
B3A6; Check direct
B3B3; Perform [DEF]
B3E1; Check fn syntax
B3F4; Perform [FN]
B465; Perform [STR$]
B475; Calculate string vector
B487; Set up string
B4F4; Make room for string
B526; Garbage collection
B5BD; Check salvageability
B606; Collect string
B63D; Concatenate
B67A; Build string to memory
B6A3; Discard unwanted string
B6DB; Clean descriptor stack
B6EC; Perform [CHR$]
B700; Perform [LEFT$]
B72C; Perform [RIGHT$]
B737; Perform [MID$]
B761; Pull string parameters
B77C; Perform [LEN]
B782; Exit string–mode
B78B; Perform [ASC]
B79B; Input byte paramter
B7AD; Perform [VAL]
B7EB; Parameters for POKE/WAIT
B7F7; Float–fixed
B80D; Perform [PEEK]
B824; Perform [POKE]
B82D; Perform [WAIT]

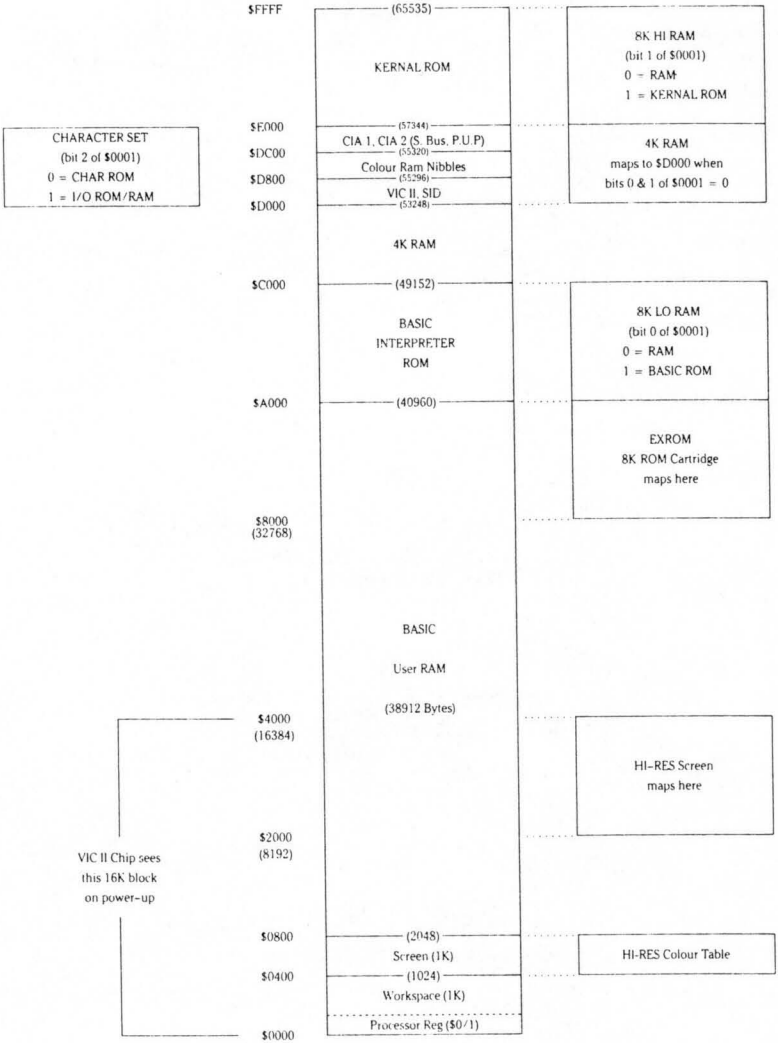
B849; Add 0.5
B850; Subtract-from
B853; Perform [subtract]
B86A; Perform [add]
B947; Complement FAC#1
B97E; 'overflow'
B983; Multiply by zero byte
B9EA; Perform [LOG]
BA2B; Perform [multiply]
BA59; Multiply-a-bit
BA8C; Memory to FAC#2
BAB7; Adjust FAC#1/#2
BAD4; Underflow/overflow
BAE2; Multiply by 10
BAF9; +10 in floating pt
BAFE; Divide by 10
BB12; Perform [divide]
BBA2; Memory to FAC#1
BBC7; FAC#1 to memory
BBFC; FAC#2 to FAC#1
BC0C; FAC#1 to FAC#2
BC1B; Round FAC#1
BC2B; Get sign
BC39; Perform [SGN]
BC58; Perform [ABS]
BC5B; Compare FAC#1 to mem
BC9B; Float-fixed
BCCC; Perform [int]
BCF3; String to FAC
BD7E; Get ascii digit
BDC2; Print 'IN..'
BDCD; Print line number
BDDD; Float to ascii
BF16; Decimal constants
BF3A; TI constants
BF71; Perform [SQR]
BF7B; Perform [power]
BFB4; Perform [negative]
BFED; Perform [EXP]
E043; Series eval 1
E059; Series eval 2
E097; Perform [RND]
E0f9; ?? breakpoints ??
E12A; Perform [SYS]
E156; Perform [SAVE]
E165; Perform [VERIFY]
E168; Perform [LOAD]
E1BE; Perform [OPEN]
E1C7; Perform [CLOSE]
E1D4; Parameters for LOAD/SAVE
E206; Check default parameters
E20E; Check for comma
E219; Parameters for open/close
E264; Perform [COS]
E26B; Perform [SIN]
E2B4; Perform [TAN]
E30E; Perform [ATN]
E37B; Warm restart

E394; Initialize
E3A2; CHRGET for zero page
E3BF; Initialize Basic
E447; Vectors for $300
E453; Initialize vectors
E45F; Power-up message
E500; Get I/O address
E505; Get screen size
E50A; Put/get row/column
E518; Initialize I/O
E544; Clear screen
E566; Home cursor
E56C; Set screen pointers
E5A0; Set I/O defaults
E5B4; Input from keyboard
E632; Input from screen
E684; Quote test
E691; Setup screen print
E6B6; Advance cursor
E6ED; Retreat cursor
E701; Back into previous line
E716; Output to screen
E87C; Go to next line
E891; Perform <return>
E8A1; Check line decrement
E8B3; Check line increment
E8CB; Set color code
E8DA; Color code table
E8EA; Scroll screen
E965; Open space on screen
E9C8; Move a screen line
E9E0; Synchronize color transfer
E9F0; Set start-of-line
E9FF; Clear screen line
EA13; Print to screen
EA24; Synchronize color pointer
EA31; Interrupt - clock etc
EA87; Read keyboard
EB79; Keyboard select vectors
EB81; Keyboard 1 - unshifted
EBC2; Keyboard 2 - shifted
EC03; Keyboard 3 - 'comm'
EC44; Graphics/text contrl
EC4F; Set graphics/text mode
EC78; Keyboard 4
ECB9; Video chip setup
ECE7; Shift/run equivalent
ECF0; Screen ln address low
ED09; Send 'talk'
ED0C; Send 'listen'
ED40; Send to serial bus
EDB2; Serial timeout
EDB9; Send listen SA
EDBE; Clear ATN
EDC7; Send talk SA
EDCC; Wait for clock
EDDD; Send serial deferred
EDEF; Send 'untalk'

EDFE; Send 'unlisten'
EE13; Receive from serial bus
EE85; Serial clock on
EE8E; Serial clock off
EE97; Serial output '1'
EEA0; Serial output '0'
EEA9; Get serial in & clock
EEB3; Delay 1 ms
EEBB; RS-232 send
EF06; Send new RS-232 byte
EF2E; No-DSR error
EF31; No-CTS error
EF3B; Disable timer
EF4A; Compute bit count
EF59; RS232 receive
EF7E; Setup to receive
EFC5; Receive parity error
EFCA; Receive overflow
EFCD; Receive break
EFD0; Framing error
EFE1; Submit to RS232
F00D; No-DSR error
F017; Send to RS232 buffer
F04D; Input from RS232
F086; Get from RS232
F0A4; Check serial bus idle
F0BD; Messages
F12B; Print if direct
F13E; Get..
F14E; ..from RS232
F157; Input
F199; Get.. tape/serial/rs232
F1CA; Output..
F1DD; ..to tape
F20E; Set input device
F250; Set output device
F291; Close file
F30F; Find file
F31F; Set file values
F32F; Abort all files
F333; Restore default I/O
F34A; Do file open
F3D5; Send SA
F409; Open RS232
F49E; Load program
F5AF; 'searching'
F5C1; Print filename
F5D2; 'loading/verifying'
F5DD; Save program
F68F; Print 'saving'
F69B; Bump clock
F6BC; Log PIA key reading
F6DD; Get time
F6E4; Set time
F6ED; Check stop key
F6FB; Output error messages
F72D; Find any tape headr
F76A; Write tape header
F7D0; Get buffer address
F7D7; Set buffer start/end pointers
F7EA; Find specific header
F80D; Bump tape pointer
F817; 'press play..'
F82E; Check tape status
F838; 'press record..'
F841; Initiate tape read
F864; Initiate tape write
F875; Common tape code
F8D0; Check tape stop
F8E2; Set read timing
F92C; Read tape bits
FA60; Store tape chars
FB8E; Reset pointer
FB97; New character setup
FBA6; Send transition to tape
FBC8; Write data to tape
FBCD; IRQ entry point
FC57; Write tape leader
FC93; Restore normal IRQ
FCB8; Set IRQ vector
FCCA; Kill tape motor
FCD1; Check r/w pointer
FCDB; Bump r/w pointer
FCE2; Power reset entry
FD02; Check 8-rom
FD10; 8-rom mask
FD15; Kernal reset
FD1A; Kernal move
FD30; Vectors
FD50; Initialize system constnts
FD9B; IRQ vectors
FDA3; Initialize I/O
FDDD; Enable timer
FDF9; Save filename data
FE00; Save file details
FE07; Get status
FE18; Flag status
FE1C; Set status
FE21; Set timeout
FE25; Read/set top of memory
FE27; Read top of memory
FE2D; Set top of memory
FE34; Read/set bottom of memory
FE43; NMI entry
FE66; Warm start
FEB6; Reset IRQ & exit
FEBC; Interrupt exit
FEC2; RS-232 timing table
FED6; NMI RS-232 in
FF07; NMI RS-232 out
FF43; Fake IRQ
FF48; IRQ entry
FF81; Jumbo jump table
FFFA; Hardware vectors

Memory architecture

Commodore-64 Architecture Map



Processor I/O Port (6510)

$0000	IN	IN	OUT	IN	OUT	OUT	OUT	OUT	DDR 0
$0001			Tape Motor	Tape Sense	Tape Write	D-ROM Switch	EF RAM Switch	AB RAM Switch	PR 1

SID (6581)

Voice 1	Voice 2	Voice 3		Voice 1	Voice 2	Voice 3
$D400	$D407	$D40E	Frequency L	54272	54279	54286
$D401	$D408	$D40F	Frequency H	54273	54280	54287
$D402	$D409	$D410	Pulse Width L	54274	54281	54288
$D403	$D40A	$D411	0 0 0 0 H	54275	54282	54289
$D404	$D40B	$D412	Voice Type: NSE PUL SAW TRI Key	54276	54283	54290
$D405	$D40C	$D413	Attack Time 2ms - 8ms / Decay Time 6ms - 24 sec	54277	54284	54291
$D406	$D40D	$D414	Sustain Level / Release Time 6ms - 24 sec	54278	54285	54292

Voices (write only)

$D415	0 0 0 0 0 L	54293
$D416	Filter Frequency H	54294
$D417	Resonance / Filter Voices: Ext V3 V2 V1	54295
$D418	Passband: V3 off HI BP LO / Master Volume	54296

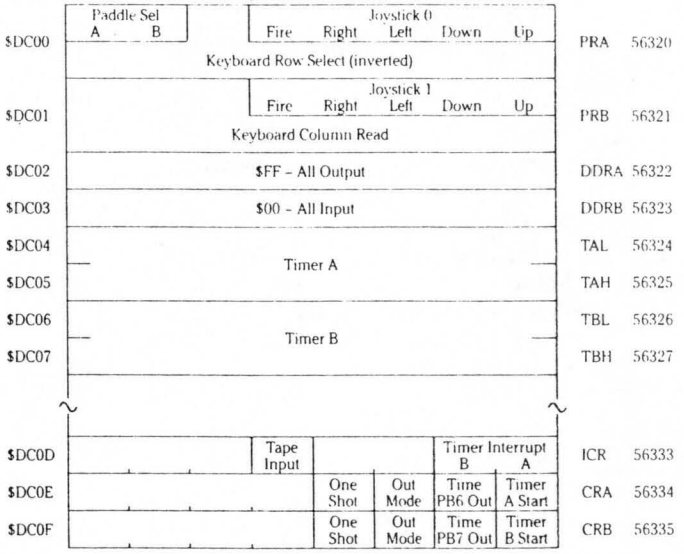
Filter & Volume (write only)

$D419	Paddle X (A/D #1)	54297
$D41A	Paddle Y (A/D #2)	54298
$D41B	Noise 3 (random)	54299
$D41C	Envelope 3	54300

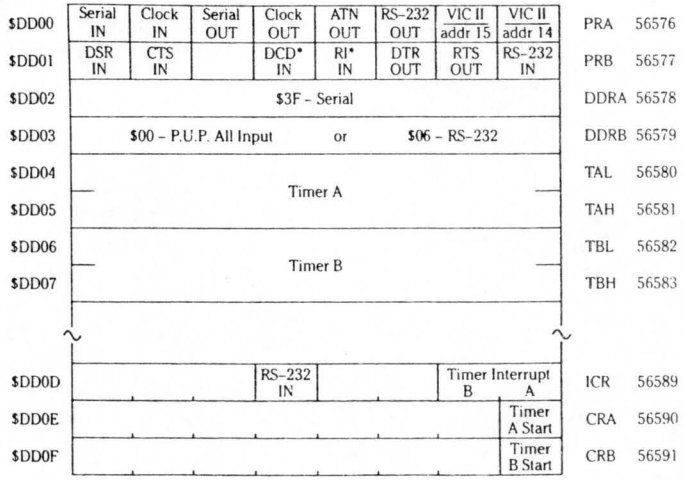
Sense (read only)

Note: Special Voice Features
(TEST, RING MOD, SYNC)
are omitted from the above diagram.

CIA 1 (IRQ) (6526)



CIA 2 (NMI) (6526)



* Connected but not used by O.S.

M/C instruction set

The following notation applies to this summary:

A	Accumulator
X, Y	Index registers
M	Memory
P	Processor status register
S	Stack Pointer
√	Change
–	No change
+	Add
∧	Logical AND
−	Subtract
V	Logical Exclusive-OR
→, ←	Transfer to
∀	Logical (inclusive) OR
PC	Program counter
PCH	Program counter high
PCL	Program counter low
#dd	8-bit immediate data value (2 hexadecimal digits)
aa	8-bit zero page address (2 hexadecimal digits)
aaaa	16-bit absolute address (4 hexadecimal digits)
↑	Transfer from stack (Pull)
↓	Transfer onto stack (Push)

ADC

Add to Accumulator with Carry

Operation: A + M + C → A, C

N Z C I D V
✓ ✓ ✓ – – ✓

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	ADC	#dd	69	2	2
Zero Page	ADC	aa	65	2	3
Zero Page, X	ADC	aa,X	75	2	4
Absolute	ADC	aaaa	6D	3	4
Absolute, X	ADC	aaaa,X	7D	3	4*
Absolute, Y	ADC	aaaa,Y	79	3	4*
(Indirect, X)	ADC	(aa,X)	61	2	6
(Indirect), Y	ADC	(aa),Y	71	2	5*

*Add 1 if page boundary is crossed.

AND

AND Memory with Accumulator

Logical AND to the accumulator
Operation: A ∧ M → A

N Z C I D V
✓ ✓ – – – –

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	AND	#dd	29	2	2
Zero Page	AND	aa	25	2	3
Zero Page, X	AND	aa,X	35	2	4
Absolute	AND	aaaa	2D	3	4
Absolute, X	AND	aaaa,X	3D	3	4*
Absolute, Y	AND	aaaa,Y	39	3	4*
(Indirect, X)	AND	(aa,X)	21	2	6
(Indirect), Y	AND	(aa),Y	31	2	5*

*Add 1 if page boundary is crossed.

ASL

Accumulator Shift Left

Operation: C ← 7 6 5 4 3 2 1 0 ← 0

N Z C I D V
√ √ √ – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Accumulator	ASL A	0A	1	2
Zero Page	ASL aa	06	2	5
Zero Page, X	ASL aa,X	16	2	6
Absolute	ASL aaaa	0E	3	6
Absolute, X	ASL aaaa,X	1E	3	7

BCC

Branch on Carry Clear

Operation: Branch on C = 0

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BCC aa	90	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to different page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BCC aaaa), and convert it to a relative address.

BCS

Branch on Carry Set

Operation: Branch on C = 1

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BCS aa	B0	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to next page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BCS aaaa), and convert it to a relative address.

BEQ

Branch on Result Equal to Zero

Operation: Branch on $Z = 1$

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BEQ aa	F0	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to next page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BEQ aaaa), and convert it to a relative address.

BIT

Test Bits in Memory with Accumulator

Operation: A M, $M_7 \rightarrow N$, $M_6 \rightarrow V$
Bit 6 and 7 are transferred to the Status Register. If the result of A M is zero then $Z = 1$, otherwise $Z = 0$

N Z C I D V
M_7 ✓ – – – M_6

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Zero Page	BIT aa	24	2	3
Absolute	BIT aaaa	2C	3	4

BMI

Branch on Result Minus

Operation: Branch on $N = 1$

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BMI aa	30	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to different page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BMI aaaa), and convert it to a relative address.

BNE

Branch on Result Not Equal to Zero

Operation: Branch on Z = 0

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BNE aa	D0	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to different page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BNE aaaa), and convert it to a relative address.

BPL

Branch on Result Plus

Operation: Branch on N = 0

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BPL aa	10	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to different page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BPL aaaa), and convert it to a relative address.

BRK

Force Break

Operation: Forced Interrupt PC + 2 ↓ P ↓

B N Z C I D V
1 – – – 1 – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	BRK	00	1	7

BVC

Branch on Overflow Clear

Operation: Branch on V = 0

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BVC aa	50	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to different page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BVC aaaa), and convert it to a relative address.

BVS

Branch on Overflow Set

Operation: Branch on V = 1

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Relative	BVS aa	70	2	2*

*Add 1 if branch occurs to same page.
Add 2 if branch occurs to different page.
Note: AIM 65 will accept an absolute address as the operand (instruction format BVS aaaa), and convert it to a relative address.

CLC

Clear Carry Flag

Operation: 0 → C

N Z C I D V
– – 0 – – –

Addressing Mode	Assembly Language Form	OP CODE	No Bytes	No. Cycles
Implied	CLC	18	1	2

CLD

Clear Decimal Mode

Operation: 0 → D

N Z C I D V
– – – – 0 –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	CLD	D8	1	2

CLI

Clear Interrupt Disable Bit

Operation: 0 → I

N Z C I D V
– – – 0 – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	CLI	58	1	2

CLV

Clear Overflow Flag

Operation: 0 → V

N Z C I D V
– – – – – 0

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	CLV	B8	1	2

CMP

Compare Memory and Accumulator

Operation: A — M

N Z C I D V
√ √ √ — — —

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	CMP	#dd	C9	2	2
Zero Page	CMP	aa	C5	2	3
Zero Page, X	CMP	aa,X	D5	2	4
Absolute	CMP	aaaa	CD	3	4
Absolute, X	CMP	aaaa,X	DD	3	4*
Absolute, Y	CMP	aaaa,Y	D9	3	4*
(Indirect, X)	CMP	(aa,X)	C1	2	6
(Indirect), Y	CMP	(aa),Y	D1	2	5*

*Add 1 if page boundary is crossed.

CPX

Compare Memory and Index X

Operation: X — M

N Z C I D V
√ √ √ — — —

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	CPX	#dd	E0	2	2
Zero Page	CPX	aa	E4	2	3
Absolute	CPX	aaaa	EC	3	4

CPY

Compare Memory and Index Y

Operation: Y — M

N Z C I D V
√ √ √ — — —

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	CPY	#dd	C0	2	2
Zero Page	CPY	aa	C4	2	3
Absolute	CPY	aaaa	CC	3	4

DEC

Decrement Memory by One

Operation: M − 1 → M

N Z C I D V
√ √ − − − −

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Zero Page	DEC aa	C6	2	5
Zero Page, X	DEC aa,X	D6	2	6
Absolute	DEC aaaa	CE	3	6
Absolute, X	DEC aaaa,X	DE	3	7

DEX

Decrement Index X by One

Operation: X − 1 → X

N Z C I D V
√ √ − − − −

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	DEX	CA	1	2

DEY

Decrement Index Y by One

Operation: Y − 1 → Y

N Z C I D V
√ √ − − − −

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	DEY	88	1	2

EOR

Exclusive-OR Memory with Accumulator

Operation: A V M → A

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	EOR	#dd	49	2	2
Zero Page	EOR	aa	45	2	3
Zero Page, X	EOR	aa,X	55	2	4
Absolute	EOR	aaaa	4D	3	4
Absolute, X	EOR	aaaa,X	5D	3	4*
Absolute, Y	EOR	aaaa,Y	59	3	4*
(Indirect, X)	EOR	(aa,X)	41	2	6
(Indirect), Y	EOR	(aa),Y	51	2	5*

*Add 1 if page boundary is crossed.

INC

Increment Memory by One

Operation: M + 1 → M

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Zero Page	INC	aa	E6	2	5
Zero Page, X	INC	aa,X	F6	2	6
Absolute	INC	aaaa	EE	3	6
Absolute, X	INC	aaaa,X	FE	3	7

INX

Increment Index X by One

Operation: X + 1 → X

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	INX	E8	1	2

INY

Increment Index Y by One

Operation: Y + 1 → Y

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form	OP Code	No. Bytes	No. Cycles
Implied	INY	C8	1	2

JMP

Jump

Operation: (PC + 1) → PCL
(PC + 2) → PCH

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Absolute	JMP aaaa	4C	3	3
Indirect	JMP (aaaa)	6C	3	5

JSR

Jump to Subroutine

Operation: PC + 2↓, (PC + 1) → PCL
(PC + 2) → PCH

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Absolute	JSR aaaa	20	3	6

LDA

Load Accumulator with Memory

Operation: M → A

N Z C I D V
✓ ✓ – – – –

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	LDA	#dd	A9	2	2
Zero Page	LDA	aa	A5	2	3
Zero Page, X	LDA	aa,X	B5	2	4
Absolute	LDA	aaaa	AD	3	4
Absolute, X	LDA	aaaa,X	BD	3	4*
Absolute, Y	LDA	aaaa,Y	B9	3	4*
(Indirect, X)	LDA	(aa,X)	A1	2	6
(Indirect), Y	LDA	(aa),Y	B1	2	5*

*Add 1 if page boundary is crossed.

LDX

Load Index X with Memory

Operation: M → X

N Z C I D V
✓ ✓ – – – –

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	LDX	#dd	A2	2	2
Zero Page	LDX	aa	A6	2	3
Zero Page, Y	LDX	aa,Y	B6	2	4
Absolute	LDX	aaaa	AE	3	4
Absolute, Y	LDX	aaaa,Y	BE	3	4*

*Add 1 when page boundary is crossed.

LDY

Load Index Y with Memory

Operation: M → Y

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Immediate	LDY #dd	A0	2	2
Zero Page	LDY aa	A4	2	3
Zero Page, X	LDY aea,X	B4	2	4
Absolute	LDY aaaa	AC	3	4
Absolute, X	LDY aaaa,X	BC	3	4*

*Add 1 when page boundary is crossed.

LSR

Local Shift Right

Operation: 0 → [7|6|5|4|3|2|1|0] → C

N Z C I D V
0 √ √ – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Accumulator	LSR A	4A	1	2
Zero Page	LSR aa	46	2	5
Zero Page, X	LSR aa,X	56	2	6
Absolute	LSR aaaa	4E	3	6
Absolute, X	LSR aaaa,X	5E	3	7

NOP

No Operation

Operation: No Operation (2 cycles)

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	NOP	EA	1	2

ORA

OR Memory with Accumulator

Operation: A V M → A

N Z C I D V
✓ ✓ – – – –

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	ORA	#dd	09	2	2
Zero Page	ORA	aa	05	2	3
Zero Page, X	ORA	aa,X	15	2	4
Absolute	ORA	aaaa	0D	3	4
Absolute, X	ORA	aaaa,X	1D	3	4*
Absolute, Y	ORA	aaaa,Y	19	3	4*
(Indirect, X)	ORA	(aa,X)	01	2	6
(Indirect), Y	ORA	(aa),Y	11	2	5*

*Add 1 on page crossing.

PHA

Push Accumulator on Stack

Operation: A ↓

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	PHA	48	1	3

PHP

Push Processor Status on Stack

Operation: P↓

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	PHP	08	1	3

PLA

Pull Accumulator from Stack

Operation: A ↑

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	PLA	68	1	4

PLP

Pull Processor Status from Stack

Operation: P ↑

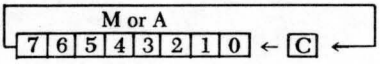
N Z C I D V
From Stack

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	PLP	28	1	4

ROL

Rotate Left

Operation:

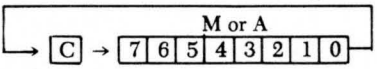


N Z C I D V
√ √ √ – – –

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Accumulator	ROL	A	2A	1	2
Zero Page	ROL	aa	26	2	5
Zero Page, X	ROL	aa,X	36	2	6
Absolute	ROL	aaaa	2E	3	6
Absolute, X	ROL	aaaa,X	3E	3	7

ROR

Rotate Right

Operation: 

N Z C I D V
✓ ✓ ✓ – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Accumulator	ROR A	6A	1	2
Zero Page	ROR aa	66	2	5
Zero Page, X	ROR aa,X	76	2	6
Absolute	ROR aaaa	6E	3	6
Absolute, X	ROR aaaa,X	7E	3	7

RTI

Return from Interrupt

Operation: P↑ PC↑

N Z C I D V
From Stack

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	RTI	40	1	6

RTS

Return from Subroutine

Operation: PC↑, PC + 1 → PC

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	RTS	60	1	6

SBC

Subtract from Accumulator with Carry

Operation: $A - M - \overline{C} \rightarrow A$

Note: $\overline{C}$ = Borrow

N Z C I D V
√ √ √ – – √

Addressing Mode	Assembly Language Form		OP CODE	No. Bytes	No. Cycles
Immediate	SBC	#dd	E9	2	2
Zero Page	SBC	aa	E5	2	3
Zero Page, X	SBC	aa,X	F5	2	4
Absolute	SBC	aaaa	ED	3	4
Absolute, X	SBC	aaaa,X	FD	3	4*
Absolute, Y	SBC	aaaa,Y	F9	3	4*
(Indirect, X)	SBC	(aa,X)	E1	2	6
(Indirect), Y	SBC	(aa),Y	F1	2	5*

*Add 1 when page boundary is crossed.

SEC

Set Carry Flag

Operation: $1 \rightarrow C$

N Z C I D V
– – 1 – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	SEC	38	1	2

SED

Set Decimal Mode

Operation: $1 \rightarrow D$

N Z C I D V
– – – – 1 –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	SED	F8	1	2

SEI

Set Interrupt Disable Status

Operation: $1 \rightarrow I$

N Z C I D V
– – – 1 – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	SEI	78	1	2

STA

Store Accumulator in Memory

Operation: $A \rightarrow M$

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Zero Page	STA aa	85	2	3
Zero Page, X	STA aa,X	95	2	4
Absolute	STA aaaa	8D	3	4
Absolute, X	STA aaaa,X	9D	3	5
Absolute, Y	STA aaaa,Y	99	3	5
(Indirect, X)	STA (aa,X)	81	2	6
(Indirect), Y	STA (aa),Y	91	2	6

STX

Store Index X in Memory

Operation: $X \rightarrow M$

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Zero Page	STX aa	86	2	3
Zero Page, Y	STX aa,Y	96	2	4
Absolute	STX aaaa	8E	3	4

STY

Store Index Y in Memory

Operation: Y → M

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Zero Page	STY aa	84	2	3
Zero Page, X	STY aa,X	94	2	4
Absolute	STY aaaa	8C	3	4

TAX

Transfer Accumulator to Index X

Operation: A → X

N Z C I D V
✓ ✓ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	TAX	AA	1	2

TAY

Transfer Accumulator to Index Y

Operation: A → Y

N Z C I D V
✓ ✓ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	TAY	A8	1	2

TSX

Transfer Stack Pointer to Index X

Operation: S → X

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	TSX	BA	1	2

TXA

Transfer Index X to Accumulator

Operation: X → A

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	TXA	8A	1	2

TXS

Transfer Index X to Stack Pointer

Operation: X → S

N Z C I D V
– – – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	TXS	9A	1	2

TYA

Transfer Index Y to Accumulator

Operation: Y → A

N Z C I D V
√ √ – – – –

Addressing Mode	Assembly Language Form	OP CODE	No. Bytes	No. Cycles
Implied	TYA	98	1	2

M/C mnemonics

6502 INSTRUCTION REPERTOIRE

MNEMONIC	FUNCTION
ADC	Add memory to accumulator with carry.
AND	AND memory with accumulator.
ASL	Shift left 1 bit.
BCC	Branch on carry clear.
BCS	Branch on carry set.
BEQ	Branch on 0.
BIT	Test bits in memory with accumulator.
BMI	Branch on result negative.
BNE	Branch on result <> 0.
BPL	Branch on result positive.
BRK	Force break.
BVC	Branch on overflow clear.
BVS	Branch on overflow set.
CLC	Clear carry flag.
CLD	Clear decimal mode.
CLI	Clear interrupt disable.
CLV	Clear overflow flag.
CMP	Compare memory with accumulator.
CPX	Compare memory with X register.
CPY	Compare memory with Y register.
DEC	Decrement memory.
DEX	Decrement X register.
DEY	decrement Y register.
EOR	Exclusive OR memory with accumulator.
INC	Increment memory.
INX	Increment X register.
INY	Increment Y register.
JMP	Jump to specified location.
JSR	Jump to subroutine.
LDA	Load accumulator.
LDX	Load X register.
LDY	Load Y register.
LSR	Shift right 1 bit.
NOP	No operation.
ORA	OR memory with accumulator.
PHA	Push accumulator onto stack.
PHP	Push processor status onto stack.
PLA	Pull accumulator from stack.
PLP	Pull processor status from stack.

ROL	Rotate left 1 bit.
ROR	Rotate right 1 bit.
RTI	Return from interrupt.
RTS	Return from subroutine.
SBC	Subtract memory with borrow from accumulator.
SEC	Set carry flag.
SED	Set decimal mode.
SEI	Set interrupt disable.
STA	Store accumulator.
STX	Store X register.
STY	Store Y register.
TAX	Transfer accumulator to X register.
TAY	Transfer accumulator to Y register.
TSX	Transfer stack pointer to X register.
TXA	Transfer X register to accumulator.
TXS	Transfer X register to stack pointer.
TYA	Transfer Y register to accumulator.

Powers tables

Powers of 2

N 2	N
256	8
512	9
1,024	10
2,048	11
4,096	12
8,192	13
16,384	14
32,768	15
65,536	16
131,072	17
262,144	18
524,288	19
1,048,576	20
2,097,152	21
4,194,304	22
8,388,608	23
16,777,216	24

Powers of 16

N 16	N
1	0
16	1
256	2
4,096	3
65,536	4
1,048,576	5
16,777,216	6
268,435,456	7
4,294,967,296	8
68,719,476,736	9
1,099,511,627,776	10
17,592,186,044,416	11
281,474,976,710,656	12
4,503,599,627,370,496	13
72,057,594,037,927,936	14
1,152,921,504,606,846,976	15

Cartridge slot

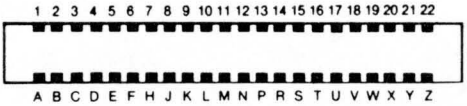
Cartridge Expansion Slot

Pin	Type
22	GND
21	CD0
20	CD1
19	CD2
18	CD3
17	CD4
16	CD5
15	CD6
14	CD7
13	$\overline{\text{DMA}}$
12	BA

Pin	Type
11	$\overline{\text{ROML}}$
10	I/O2
9	$\overline{\text{EXROM}}$
8	$\overline{\text{GAME}}$
7	I/O1
6	Dot Clock
5	R/$\overline{\text{W}}$
4	$\overline{\text{IRQ}}$
3	+ 5V
2	+ 5V
1	GND

Pin	Type
Z	GND
Y	CA0
X	CA1
W	CA2
V	CA3
U	CA4
T	CA5
S	CA6
R	CA7
P	CA8
N	CA9

Pin	Type
M	CA10
L	CA11
K	CA12
J	CA13
H	CA14
F	CA15
E	$\overline{\text{S02}}$
D	$\overline{\text{NMI}}$
C	$\overline{\text{RESET}}$
B	$\overline{\text{ROMH}}$
A	GND

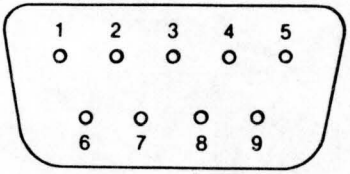


Joystick slot

1) Game I/O
2) Cartridge Slot
3) Audio/Video
4) Serial I/O (Disk/Printer)
5) Modulator Output
6) Cassette
7) User Port

Control Port 1

Pin	Type	Note
1	JOYA0	
2	JOYA1	
3	JOYA2	
4	JOYA3	
5	POT AY	
6	BUTTON A/LP	
7	+5V	MAX. 100mA
8	GND	
9	POT AX	



Control Port 2

Pin	Type	Note
1	JOYB0	
2	JOYB1	
3	JOYB2	
4	JOYB3	
5	POT BY	
6	BUTTON B	
7	+5V	MAX. 100mA
8	GND	
9	POT BX	

RS232 standards

EIA RS232-C (CCITT V24)

Notes

Transmission is serial (asynchronous).
MARK = binary 1 = OFF = -3 to -25 volts.
SPACE = binary 0 = ON = +3 to +25 volts.
25-pin "D" type connector.
Data Control Equipment (DCE) has female connector.
Data Terminal Equipment (DTE) has male connector.
Open circuit drive voltage cannot exceed 25 volts.
Terminator resistance 3-7K ohms.
50 foot maximum DCE, DTE separation.
2500 pico farad max conductor capacitance.

PIN	NAME	DIRECTION	CIRCUIT CCITT	CIRCUIT EIA	FUNCTION
01	FG	-	101	AA	Frame Ground.
02	TD	To DCE	103	BA	Transmitted Data.
03	RD	To DTE	104	BB	Received Data.
04	RTS	To DCE	105	CA	Request To Send.
05	CTS	To DTE	106	CB	Clear To Send.
06	DSR	To DTE	107	CC	Data Set Ready.
07	SG	-	102	AB	Signal Ground.
08	DCD	To DTE	109	CF	Data Carrier Detect.
09		To DTE			Positive DC Test Voltage.
10		To DTE			Negative DC Test Voltage.
11	QM	To DTE	Bell 208A		Equaliser Mode.
12	(S)DCD	To DTE	122	SCF	Secondary Data Carrier Detect.
13	(S)CTS	To DTE	121	SCB	Secondary Clear To Send.
14	(S)TD	To DCE	118	SBA	Secondary Transmitted Data.
	NS	To DCE	Bell 208A		New Synch.
15	TC	To DTE	114	DB	Transmitter Clock.
16	(S)RD	To DTE	119	SBB	Secondary Received Data.
	DCT	To DTE	Bell 208A		Divided Clock Transmitter.
17	RC	To DTE	115	DD	Receiver Clock.
18	DCR	To DTE	Bell 208A		Divided Clock Receiver.
19	(S)RTS	To DCE	120	SCA	Secondary Request to Send.
20	DTR	To DCE	108.2	CD	Data Terminal Ready.
21	SQ	To DTE	110	CG	Signal Quality Detect.
22	RI	To DTE	125	CE	Ring Indicator.
23		To DCE	111	CH	Data Rate Selector.
		To DTE	112	CI	Data Rate Selector.
24	TC	To DCE	113	DA	EXT Transmitter Clock.
25		To DCE	Bell 113B		Busy.

Circuit 102 - Signal Ground or Common Return

This conductor establishes the signal common return for interchange circuits.

Circuit 103 - Transmitted Data

The data signals originated by the DTE, to be transmitted via the data channel to one or more remote data stations, are transferred on this circuit to DCE.

Circuit 104 - Received Data

The data signals generated by the DCE, in response to data channel line signals received from a remote data station, are transferred on this circuit to the DTE.

Circuit 105 - Request to Send

Controls the data channel transmit function of the DCE.

Circuit 106 - Ready for Sending

Indicates whether the DCE is conditioned to transmit data on the data channel.

Circuit 107 - Data Set Ready

Indicates whether the DCE is ready to operate.

Circuit 108/1 - Connect Data Set to Line

Controls switching of the signal-conversion or similar equipment to or from the line.

Circuit 108/2 - Data Terminal Ready

Controls switching of the signal-conversion or similar equipment to or from the line.

Circuit 109 - Carrier Detect

Indicates whether the received data channel line signal is within appropriate limits, as specified by the relevant recommendation for DCE.

Circuit 110 - Data Signal Quality Detector

Indicates whether there is a reasonable probability of an

error in the data received on the data channel.

Circuit 111 - Data Signalling Rate Selector

Used to select one or two data signalling rates of a dual-rate synchronous DCE, or to select one of the two ranges of data signalling rates of a dual-range synchronous DCE.

Circuit 112 - Data Signalling Rate Selector

Used to select one of the two data signalling rates or ranges of rates in the DTE to coincide with the data signalling rate or range of rates in use in a dual-rate synchronous or dual-range asynchronous DCE.

Circuit 113 - Transmitter Signal Element Timing

Provides the DCE with signal element timing information.

Circuit 114 - Transmitter Signal Element Timing

Provides the DTE with signal element timing information.

Circuit 115 - Receiver Signal Element Timing

Provides the DTE with signal element timing information.

Circuit 116 - Select Standby

Used to select the normal or standby facilities such as signal convertors and communication channels.

Circuit 117 - Standby Indicator

Indicates whether the DCE is conditioned in its standby mode with the pre-determined facilities replaced by their reserves.

Circuit 118 - Transmitted Backward Channel Data

Equivalent to circuit 103, except that it is used for data received on the backward channel.

Circuit 120 - Transmit Backward Channel Line Signal

Equivalent to circuit 105, except that it is used to control the backward channel transmit function of the DCE.

Circuit 121 - Backward Channel Ready

Equivalent to circuit 106, except that it is used to

indicate whether the DCE is conditioned to transmit data on the backward channel.

Circuit 122 - Supervisory Carrier Detect

Equivalent to circuit 109, except that it is used to indicate whether the received backward channel line signal is within appropriate limits.

Circuit 123 - Backward Channel Signal Quality Detector

Equivalent to circuit 110, except that it is used to indicate the signal quality of the received backward channel line signal.

Circuit 124 - Select Frequency Groups

Used to select the desired frequency groups available on the DCE.

Circuit 125 - Calling Indicator

Indicates whether a calling signal is being received by the DCE.

Circuit 126 - Select Transmit Frequency

Used to select the required transmit frequency of the DCE.

Circuit 127 - Select Receive Frequency

Used to select the required receive frequency of the DCE.

Circuit 128 - Receiver Signal Element Timing

Provides the DCE with signal element timing information.

Circuit 129 - Request to Receive

Used to control the receive function of the DCE.

Circuit 130 - Transmit Backward Tone

Controls the transmission of a backward channel tone.

Circuit 131 - Received Character Timing

Provides the DTE with character timing information.

Circuit 132 - Return to Non-Data Mode

Used to restore the non-data mode provided with the DCE, without releasing the line connection to the remote station.

Circuit 133 - Ready for Receiving

Controls the transfer of data on circuit 104, indicating whether the DTE is capable of accepting a given amount of data, specified in the appropriate recommendation for intermediate equipment, for example, error control equipment.

Circuit 134 - Received Data Present

Used to separate information messages from supervisory messages, transferred on circuit 104.

Circuit 191 - Transmitted Voice Answer

Signals generated by a voice answer unit in the DTE are transferred on this circuit to the DCE.

Circuit 192 - Received Voice Answer

Received voice signals, generated by a voice answering unit at the remote data terminal, are transferred on this circuit to the DTE.

Other CCITT "V" Interfaces

V10

Electrical characteristics for unbalanced double-current interchange circuits for general use with integrated circuit equipment in the field of data communications.

V11

Electrical characteristics for balanced double-current interchange circuits for general use with integrated circuit equipment in the field of data communications.

V15

Use of acoustic coupling for data transmission.

V16

Medical analogue data transmission modems.

V19

Modems for parallel data transmission using telephone signalling frequencies.

V20

Parallel data transmission modems standardised for universal use in the general switch telephone network.

V21

200-baud modem standardised for use in the general switched telephone network.

V22

Defines the procedures and standards for 1200 baud full duplex communications over the public switched network.

V23

600/1200-baud modem standardised for use in the general switched telephone network.

V24

List of definitions for interchange circuits between data terminal equipment and data circuit terminating equipment.

V25

Automatic calling and/or answering equipment on the general switched telephone network, including disabling of echo-suppressors on manually established calls.

V26

2400 bits per second modem standardised for use on 4-wire leased telephone-type circuits.

V26 (alternative)

2400/1200 bits per second modem standardised for use in the general switched telephone network.

V27

4800 bits per second modems with manual equaliser standardised for use on leased telephone-type circuits.

V27 (alternative 1)

4800 bits per second modems with automatic equaliser

standardised for use on leased telephone-type circuits.

V27 (alternative 2)

4800/2400 bits per second modems standardised for use in the general switched telephone network.

V28

Electrical characteristics for unbalanced double-current interchange circuits.

V29

9600 bits per second modems standardised for use in leased telephone circuits.

V31

Electrical characteristics for single current interchange circuits controlled by contact closure.

V35

Data transmission at 48 kilobits per second using 60-108 KHz group band circuits.

V36

Modems for synchronous transmission using 60-108 KHz group band circuits.

Centronics standards

CENTRONICS PARALLEL INTERFACE

Notes

Busy is set if:

1) Data is being received.
2) Printer is printing.
3) Printer is offline.
4) An error condition is present.

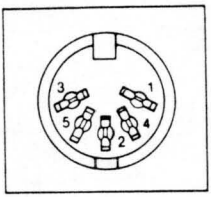
On pins 02-09 a high level represents binary ONE, a low level represents binary ZERO. All printable characters (i.e. codes having a ONE in DATA 6 or DATA 7) are stored in the printer buffer. Control characters (i.e. codes ZERO in both DATA 6 and DATA 7) are used to specify special control functions. These codes are not stored in the buffer except when they specify a print command and are preceded by at least one printable character in that line.

PIN	CODE	FUNCTION
01	STROBE	Read Data Pulse.
02	DATA 1	Data lines.
03	DATA 2	ditto.
04	DATA 3	ditto.
05	DATA 4	ditto.
06	DATA 5	ditto.
07	DATA 6	ditto.
08	DATA 7	ditto.
09	DATA 8	ditto.
10	ACKNLG	Data Received and Ready for More.
11	BUSY	Not Ready for Data.
12	PE	SET high when Out-of-Paper.
13	+5V	
14	AUTO FEED	Switch Set gives extra line-feed.
15	NC	No Connection.
16	GND LOGIC	Logic Ground.
17	GND CASE	Chassis Ground.
18	NC	No Connection.
19-30	GND	Signal Grounds.
31	INT	Reset and Buffer Clear.
32	ERROR	See Notes on BUSY.
33	GND	Signal Ground.
34	NC	No Connection.
35	+5V	
36	SLCT IN	Optional DC1/DC3.

Other output

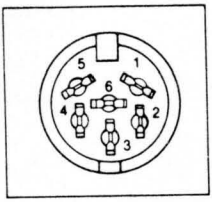
Audio/Video

Pin	Type	Note
1	LUMINANCE	
2	GND	
3	AUDIO OUT	
4	VIDEO OUT	
5	AUDIO IN	



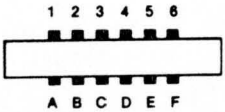
Serial I/O

Pin	Type
1	SERIAL $\overline{\text{SRQIN}}$
2	GND
3	SERIAL ATN IN/OUT
4	SERIAL CLK IN/OUT
5	SERIAL DATA IN/OUT
6	$\overline{\text{RESET}}$



Cassette

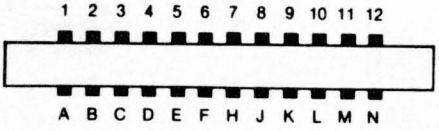
Pin	Type
A-1	GND
B-2	+5V
C-3	CASSETTE MOTOR
D-4	CASSETTE READ
E-5	CASSETTE WRITE
F-6	CASSETTE SENSE



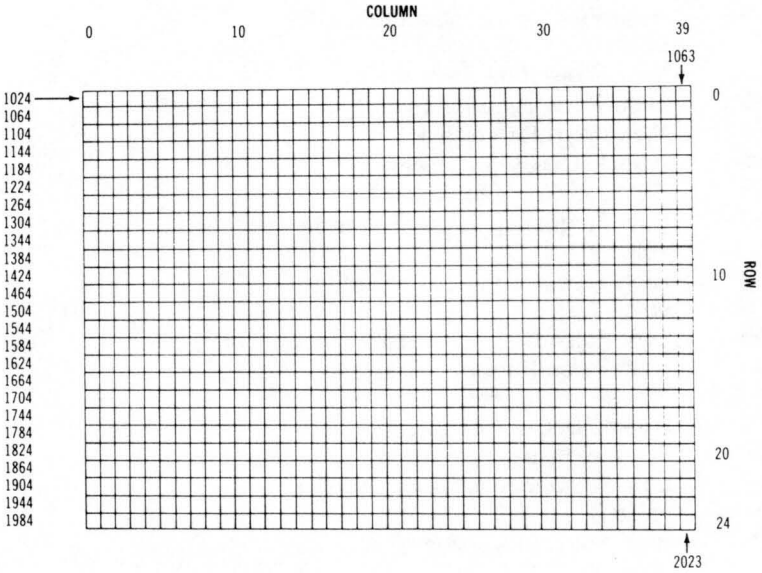
User I/O

Pin	Type	Note
1	GND	
2	+5V	MAX. 100 mA
3	$\overline{\text{RESET}}$	
4	CNT1	
5	SP1	
6	CNT2	
7	SP2	
8	$\overline{\text{PC2}}$	
9	SER. ATN IN	
10	9 VAC	MAX. 100 mA
11	9 VAC	MAX. 100 mA
12	GND	

Pin	Type	Note
A	GND	
B	$\overline{\text{FLAG2}}$	
C	PB0	
D	PB1	
E	PB2	
F	PB3	
H	PB4	
J	PB5	
K	PB6	
L	PB7	
M	PA2	
N	GND	



Screen memory



Sound chip registers

Byte	Description
00	Low Frequency value of note for voice 1
01	High Frequency value of note for voice 1
02	Low Pulse Rate for voice 1
03	High Pulse Rate for voice 1
04	Waveform for voice 1
05	Attack/Decay for voice 1
06	Sustain/Relese for voice 1
07	Low Frequency value of note for voice 2
08	High Frequency value of note for voice 2
09	Low Pulse Rate for voice 2
10	High Pulse Rate for voice 2
11	Waveform for voice 2
12	Attack/Decay for voice 2
13	Sustain/Release for voice 2
14	Low Frequency value of note for voice 3
15	High Frequency value of note for voice 3
16	Low Pulse Rate for voice 3
17	High Pulse Rate for voice 3
18	Waveform for voice 3
19	Attack/Decay for voice 3
20	Sustain/Release for voice 3
21	High Frequency Cut-Off
22	Low Frequency Cut-Off
23	Turn on filtering
24	Set volume for all three voices Plus select filter type
25	Access To Output of envelope generator of voice 3
27	Digitised output from voice 3
28	Digitised output from envelope generator 3

Musical notes values

Note	Note–Octave	Hi Freq	Low Freq
0	C–0	1	18
1	C#–0	1	35
2	D–0	1	52
3	D#–0	1	70
4	E–0	1	90
5	F–0	1	110
6	F#–0	1	132
7	G–0	1	155
8	G#–0	1	179
9	A–0	1	205
10	A#–0	1	233
11	B–0	2	6
12	C–1	2	37
13	C#–1	2	69
14	D–1	2	104
15	D#–1	2	140
16	E–1	2	179
17	F–1	2	220
18	F#–1	3	8
19	G–1	3	54
20	G#–1	3	103
21	A–1	3	155
22	A#–1	3	210
23	B–1	4	12
24	C–2	4	73
25	C#–2	4	139
26	D–2	4	208
27	D#–2	5	25
28	E–2	5	103
29	F–2	5	185
30	F#–2	6	16
31	G–2	6	108
32	G#–2	6	206
33	A–2	7	53
34	A#–2	7	163
35	B–2	8	23
36	C–3	8	147
37	C#–3	9	21
38	D–3	9	159
39	D#–3	10	60
40	E–3	10	205
41	F–3	11	114
42	F#–3	12	32
43	G–3	12	216

Note	Note–Octave	Hi Freq	Low Freq
44	G#–3	13	156
45	A–3	14	107
46	A#–3	15	70
47	B–3	16	47
48	C–4	17	37
49	C#–4	18	42
50	D–4	19	63
51	D#–4	20	100
52	E–4	21	154
53	F–4	22	227
54	F#–4	24	63
55	G–4	25	177
56	G#–4	27	56
57	A–4	28	214
58	A#–4	30	141
59	B–4	32	94
60	C–5	34	75
61	C#–5	36	85
62	D–5	38	126
63	D#–5	40	200
64	E–5	43	52
65	F–5	45	198
66	F#–5	48	127
67	G–5	51	97
68	G#–5	54	111
69	A–5	57	172
70	A#–5	61	126
71	B–5	64	188
72	C–6	68	149
73	C#–6	72	169
74	D–6	76	252
75	D#–6	81	161
76	E–6	86	105
77	F6	91	140
78	F#–6	96	254
79	G–6	102	194
80	G#–6	108	223
81	A–6	115	88
82	A#–6	122	52
83	B–6	129	120
84	C–7	137	43
85	C#–7	145	83
86	D–7	153	247
87	D#–7	163	31
88	E–7	172	210
89	F–7	183	25
90	F#–7	193	252
91	G–7	205	133
92	G#–7	217	189
93	A–7	230	176
94	A#–7	244	103

Sprite memory diagram

Address (53248+)	Description
00	X position of sprite 0
01	Y position of sprite 0
02-15	Ditto for sprites 1 through 7
16	Most Significant Bit of X position
17	Most Significant Bit of Y position
18	Raster Register
19	X position of Light Pen
20	Y position of Light Pen
21	Turn Sprite On
23	Expand Sprite in Y direction
24	Memory Pointers
25	Interrupt Register
26	Enable Interrupt
27	Sprite Data Priority
28	Multi-colour Sprites!
29	Expand Sprite in X direction
30	Sprite to Sprite collision
31	Sprite Data collision
32	Exterior colour
33	Background Colour 0
34	,, ,, 1
35	,, ,, 2
36	,, ,, 3
37	Sprite multi-colour 0
38	Sprite multi-colour 1
39	Colour for sprite 0
40-46	Ditto for sprites 1 through 7

Index

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