



HACKENSACK, NJ

6502 (65XX)

MICROPROCESSOR INSTANT REFERENCE CARD

MICRO[®]
CHART

Hex to Instruction Conversion

LSD →

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0-	BRK n	ORA (n,X)				ORA n	ASL n		PHP	ORA #n	ASL A			ORA nn	ASL nn	
1-	BPL n	ORA (n),Y				ORA n,X	ASL n,X		CLC	ORA nn,Y				ORA nn,X	ASL nn,X	
2-	JSR nn	AND (n,X)			BIT n	AND n	ROL n		PLP	AND #n	ROL A		BIT nn	AND nn	ROL nn	
3-	BMI n	AND (n),Y				AND n,X	ROL n,X		SEC	AND nn,Y				AND nn,X	ROL nn,X	
4-	RTI	EOR (n,X)				EOR n	LSR n		PHA	EOR #n	LSR A		JMP nn	EOR nn	LSR nn	
5-	BVC n	EOR (n),Y				EOR n,X	LSR n,X		CLI	EOR nn,Y				EOR nn,X	LSR nn,X	
6-	RTS	ADC (n,X)				ADC n	ROR n		PLA	ADC #n	ROR A		JMP (nn)	ADC nn	ROR nn	
7-	BVS n	ADC (n),Y				ADC n,X	ROR n,X		SEI	ADC nn,Y				ADC nn,X	ROR nn,X	
8-		STA (n,X)			STY n	STA n	STX n		DEY		TXA		STY nn	STA nn	STX nn	
9-	BCC n	STA (n),Y			STY n,X	STA n,X	STX n,Y		TYA	STA nn,Y	TXS			STA nn,X		
A-	LDY #n	LDA (n,X)	LDX #n		LDY n	LDA n	LDX n		TAY	LDA #n	TAX		LDY nn	LDA nn	LDX nn	
B-	BCS n	LDA (n),Y			LDY n,X	LDA n,X	LDX n,Y		CLV	LDA nn,Y	TSX		LDY nn,X	LDA nn,X	LDX nn,Y	
C-	CPY #n	CMP (n,X)			CPY n	CMP n	DEC n		INY	CMP #n	DEX		CPY nn	CMP nn	DEC nn	
D-	BNE n	CMP (n),Y				CMP n,X	DEC n,X		CLD	CMP nn,Y				CMP nn,X	DEC nn,X	
E-	CPX #n	SBC (n,X)			CPX n	SBC n	INC n		INX	SBC #n	NOP		CPX nn	SBC nn	INC nn	
F-	BEQ n	SBC (n),Y				SBC n,X	INC n,X		SED	SBC nn,Y				SBC nn,X	INC nn,X	

Memory Map

ZERO PAGE	0000
	00FF
DATA & STACK*	0100
	01FF
	0200
RAM I/O ROM	
NMI VECTOR	FFF9
RES VECTOR	FFFA&B
I/O VECTOR	FFFC&D
	FFFE&F

*In systems with < 512 bytes of RAM the hardware can ignore signal AB8, moving stack into page zero.

Status Flags

MSB	LSB
NV	B D I Z C

N = negative result
V = overflow
B = BRK instruction
D = decimal mode
I = IRQ disable
Z = zero result
C = carry/borrow

Note: above is true when flag = 1.

Overflow normally signifies signed arithmetic result is out of range.

When D=1, only ADC and SBC use decimal (BCD) arithmetic.

Interrupts

IRQ is low level sensitive.
NMI is falling edge sensitive.
Reset sets I=1.
Interrupts are processed by:
1. Push PC of unexecuted instruction.
2. Push P.
3. I=1.
4. Jump via appropriate vector.

Effect on Flags

	NV	B	D	I	Z	C
ADC	NV	-	-	-	Z	C
AND	N	-	-	-	Z	-
ASL	N	-	-	-	Z	C
BIT	NV	-	-	-	Z	-
BRK	-	-	-	1	-	-
CLC	-	-	-	-	-	0
CLD	-	-	-	-	0	-
CLI	-	-	-	-	0	-
CLV	-	0	-	-	-	-
CMP	N	-	-	-	Z	C
CPX	N	-	-	-	Z	C
CPY	N	-	-	-	Z	C
DEC	N	-	-	-	Z	-
DEX	N	-	-	-	Z	-
DEY	N	-	-	-	Z	-
EOR	N	-	-	-	Z	-
INC	N	-	-	-	Z	-
INX	N	-	-	-	Z	-
INY	N	-	-	-	Z	-
LDA	N	-	-	-	Z	-
LDX	N	-	-	-	Z	-
LDY	N	-	-	-	Z	-
LSR	0	-	-	-	Z	C
ORA	N	-	-	-	Z	-
PLA	N	-	-	-	Z	-
PLP	NV	-	B	D	I	Z
ROL	N	-	-	-	Z	C
ROR	N	-	-	-	Z	C
RTI	NV	-	B	D	I	Z
SBC	NV	-	-	-	Z	C
SEC	-	-	-	-	1	-
SED	-	-	-	-	1	-
SEI	-	-	-	-	1	-
TAX	N	-	-	-	Z	-
TAY	N	-	-	-	Z	-
TSX	N	-	-	-	Z	-
TXA	N	-	-	-	Z	-
TYA	N	-	-	-	Z	-

- ① If in decimal mode Z flag is invalid.
② N = data bit 7
Z = AND result
③ C = borrow

Note: unlisted instructions have no effect on flags.

Addressing Modes

Note: Full 2 byte addresses in code, stack, and data areas are stored low byte followed by high byte. Thus, in hex, JMP \$1234 is: 4C 34 12.

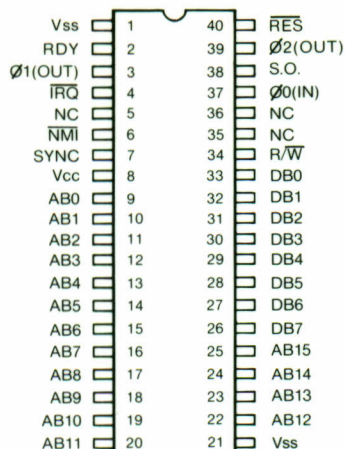
FORM	ADDRESSING	DESCRIPTION
nn	Absolute	Location nn holds data.
nn,X	Absolute X	Location nn+X holds data.
nn,Y	Absolute Y	Location nn+Y holds data.
A	Accumulator	Accumulator holds data.
#n	Immediate	n is data.
(n,X)	Ind X	Location n+X and next of page 0 hold address of data.**
(n),Y	Ind Y	Address of data is Y + address held by location n and next of page 0.**
(nn)	Indirect	Location nn and next hold address to jump to.**
n	Relative	Address to jump to is n + address of next instruction, with n treated as a signed number.
n	Zero Page	Location n of page 0 holds data.
n,X	Zero Page X	Location n+X of page 0 holds data.
n,Y	Zero Page Y	Location n+Y of page 0 holds data.

*n+X is computed discarding any carry.
**2 bytes must not cross page boundary.

ASCII Character Set

MSD	0	1	2	3	4	5	6	7
LSD	000	001	010	011	100	101	110	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	

6502 Pins



Hex and Decimal Conversion

LSD →	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
3	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
4	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
5	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
6	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
7	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
8	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143
9	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159
A	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175
B	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191
C	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207
D	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223
E	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239
F	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255

Miscellaneous

S points to next free byte of stack.

Stack push decrements S.

In pushing PC, high byte is pushed first.

Pre 67/66 chips have no ROR instruction.

65XX is a totally software compatible family.

This card is based on specifications from MOS Technology, Inc.

Abbreviations

B = number of Bytes
C = number of Cycles, also Carry.
n = 1 byte quantity
nn = 2 byte quantity
IRQ = Interrupt ReQuest
NMI = Non Maskable Interrupt
RES = REset
XOR = eXclusive OR
(00=0 01=1 10=2 11=3)

A,P,S,X,Y,PC=see "Registers"
N,V,B,D,I,Z,C = see "Status Flags"
#\$(%)(); = see "Assembler Symbols"

Registers

A	ACCUMULATOR
Y	Y INDEX REG
X	X INDEX REG
PC	PROGRAM COUNTER
S	STACK PNTR
P	FLAGS

A, Y, X, S, P = 1 byte.
Only PC is 2 bytes.

Unsigned Comparisons

example: CMP #n	
A < n	BCC YES
A = n	BEQ YES
A > n	BCC NO
A ≥ n	BNE YES
A ≠ n	BCS YES
A ≤ n	BNE YES
A < n	BCC YES
A = n	BEQ YES

YES represents label for code to be executed if condition is true. For > & ≤, test requires both instructions.

Internally, A-n is computed to determine N,Z,C flags.



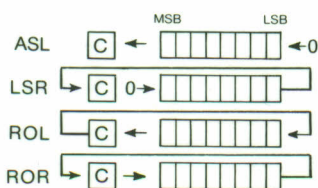
INSTRUCTION SET

	INSTRUCTION	OP	C	B	DESCRIPTION	ADDRESSING		INSTRUCTION	OP	C	B	DESCRIPTION	ADDRESSING
A	ADC #n	69	2	2	Add with carry to A	Immediate	L	LDA #n	A9	2	2	Load A	Immediate
	ADC nn	6D	4	3	Add with carry to A	Absolute		LDA nn	AD	4	3	Load A	Absolute
	ADC n	65	3	2	Add with carry to A	Zero Page		LDA n	A5	3	2	Load A	Zero Page
	ADC (n,X)	61	6	2	Add with carry to A	Ind X		LDA (n,X)	A1	6	2	Load A	Ind X
	ADC (n),Y	71	5+	2	Add with carry to A	Ind Y		LDA (n),Y	B1	5+	2	Load A	Ind Y
	ADC n,X	75	4	2	Add with carry to A	Zero Page X		LDA n,X	B5	4	2	Load A	Zero Page X
	ADC nn,X	7D	4+	3	Add with carry to A	Absolute X		LDA nn,X	BD	4+	3	Load A	Absolute X
	ADC nn,Y	79	4+	3	Add with carry to A	Absolute Y		LDA nn,Y	B9	4+	3	Load A	Absolute Y
	AND #n	29	2	2	AND to A	Immediate		LDX #n	A2	2	2	Load X	Immediate
	AND nn	2D	4	3	AND to A	Absolute		LDX nn	AE	4	3	Load X	Absolute
B	AND n	25	3	2	AND to A	Zero Page	N	LDX n	A6	3	2	Load X	Zero Page
	AND (n,X)	21	6	2	AND to A	Ind X		LDX nn,Y	BE	4+	3	Load X	Absolute Y
	AND (n),Y	31	5+	2	AND to A	Ind Y		LDX n,Y	B6	4	2	Load X	Zero Page Y
	AND n,X	35	4	2	AND to A	Zero Page X		LDY #n	A0	2	2	Load Y	Immediate
	AND nn,X	3D	4+	3	AND to A	Absolute X		LDY nn	AC	4	3	Load Y	Absolute
	AND nn,Y	39	4+	3	AND to A	Absolute Y		LDY n	A4	3	2	Load Y	Zero Page
	ASL nn	0E	6	3	Arithmetic shift left	Absolute		LDY n,X	B4	4	2	Load Y	Zero Page X
	ASL n	06	5	2	Arithmetic shift left	Zero Page		LDY nn,X	BC	4+	3	Load Y	Absolute X
	ASL A	0A	2	1	Arithmetic shift left	Accumulator	O	LSR nn	4E	6	3	Logical shift right	Absolute
	ASL n,X	16	6	2	Arithmetic shift left	Zero Page X		LSR n	48	5	2	Logical shift right	Zero Page
	ASL nn,X	1E	7	3	Arithmetic shift left	Absolute X		LSR A	4A	2	1	Logical shift right	Accumulator
C	BCC n	90	2+	2	Branch if carry clear (C=0)	Relative		LSR n,X	56	6	2	Logical shift right	Zero Page X
	BCS n	B0	2+	2	Branch if carry set (C=1)	Relative		LSR nn,X	5E	7	3	Logical shift right	Absolute X
	BEQ n	F0	2+	2	Branch if equal (Z=1)	Relative	P	NOP	EA	2	1	No operation	None
	BNE n	D0	2+	2	Branch if not equal (Z=0)	Relative		ORA #n	09	2	2	OR to A	Immediate
	BMI n	30	2+	2	Branch if minus (N=1)	Relative		ORA nn	0D	4	3	OR to A	Absolute
	BPL n	10	2+	2	Branch if plus (N=0)	Relative		ORA n	05	3	2	OR to A	Zero Page
	BVC n	50	2+	2	Branch if ovfl clear (V=0)	Relative		ORA (n,X)	01	6	2	OR to A	Ind X
	BVS n	70	2+	2	Branch if ovfl set (V=1)	Relative		ORA (n),Y	11	5+	2	OR to A	Ind Y
	BIT nn	2C	4	3	AND with A (A unchanged)	Absolute		ORA n,X	15	4	2	OR to A	Zero Page X
	BIT n	24	3	2	AND with A (A unchanged)	Zero Page		ORA nn,X	1D	4+	3	OR to A	Absolute X
	BRK	00	7	1	Break (force interrupt)	None		ORA nn,Y	19	4+	3	OR to A	Absolute Y
	CLC	18	2	1	Clear carry	None	R	PHA	48	3	1	Push A onto stack	None
D	CLD	D8	2	1	Clear decimal mode	None		PHP	08	3	1	Push P onto stack	None
	CLI	58	2	1	Clear IRQ disable	None		PLA	68	4	1	Pull (pop) A from stack	None
	CLV	B8	2	1	Clear overflow	None		PLP	28	4	1	Pull (pop) P from stack	None
	CMP #n	C9	2	2	Compare with A	Immediate		ROL nn	2E	6	3	Rotate left through carry	Absolute
	CMP nn	CD	4	3	Compare with A	Absolute		ROL n	26	5	2	Rotate left through carry	Zero Page
	CMP n	C5	3	2	Compare with A	Zero Page		ROL A	2A	2	1	Rotate left through carry	Accumulator
	CMP (n,X)	C1	6	2	Compare with A	Ind X		ROL n,X	36	6	2	Rotate left through carry	Zero Page X
	CMP (n),Y	D1	5+	2	Compare with A	Ind Y		ROL nn,X	3E	7	3	Rotate left through carry	Absolute X
	CMP n,X	D5	4	2	Compare with A	Zero Page X		ROR nn	6E	6	3	Rotate right through carry	Absolute
	CMP nn,X	DD	4+	3	Compare with A	Absolute X	S	ROR n	66	5	2	Rotate right through carry	Zero Page
E	CMP nn,Y	D9	4+	3	Compare with A	Absolute Y		ROR A	6A	2	1	Rotate right through carry	Accumulator
	CPX #n	E0	2	2	Compare with X	Immediate		ROR n,X	76	6	2	Rotate right through carry	Zero Page X
	CPX nn	EC	4	3	Compare with X	Absolute		ROR nn,X	7E	7	3	Rotate right through carry	Absolute X
	CPX n	E4	3	2	Compare with X	Zero Page		RTI	40	6	1	Return from interrupt	None
	CPY #n	C0	2	2	Compare with Y	Immediate		RTS	60	6	1	Return from subroutine	None
	CPY nn	CC	4	3	Compare with Y	Absolute		SBC #n	E9	2	2	Subtract with borrow from A	Immediate
	CPY n	C4	3	2	Compare with Y	Zero Page		SBC nn	ED	4	3	Subtract with borrow from A	Absolute
	DEC nn	CE	6	3	Decrement by one	Absolute		SBC n	E5	3	2	Subtract with borrow from A	Zero Page
	DEC n	C6	5	2	Decrement by one	Zero Page		SBC (n,X)	E1	6	2	Subtract with borrow from A	Ind X
	DEC n,X	D6	6	2	Decrement by one	Zero Page X		SBC (n),Y	F1	5+	2	Subtract with borrow from A	Ind Y
F	DEC nn,X	DE	7	3	Decrement by one	Absolute X		SBC n,X	F5	4	2	Subtract with borrow from A	Zero Page X
	DEX	CA	2	1	Decrement X by one	None	T	SBC nn,X	FD	4+	3	Subtract with borrow from A	Absolute X
	DEY	B8	2	1	Decrement Y by one	None		SBC nn,Y	F9	4+	3	Subtract with borrow from A	Absolute Y
	EOR #n	49	2	2	XOR to A	Immediate		SEC	38	2	1	Set carry	None
	EOR nn	4D	4	3	XOR to A	Absolute		SED	F8	2	1	Set decimal mode	None
	EOR n	45	3	2	XOR to A	Zero Page		SEI	78	2	1	Set IRQ disable	None
	EOR (n,X)	41	6	2	XOR to A	Ind X		STA nn	8D	4	3	Store A	Absolute
	EOR (n),Y	51	5+	2	XOR to A	Ind Y		STA n	85	3	2	Store A	Zero Page
	EOR n,X	55	4	2	XOR to A	Zero Page X		STA (n,X)	81	6	2	Store A	Ind X
	EOR nn,X	5D	4+	3	XOR to A	Absolute X		STA (n),Y	91	6	2	Store A	Ind Y
	EOR nn,Y	59	4+	3	XOR to A	Absolute Y		STA n,X	95	4	2	Store A	Zero Page X
I	INC nn	EE	6	3	Increment by one	Absolute	J	STA nn,X	9D	5	3	Store A	Absolute X
	INC n	E6	5	2	Increment by one	Zero Page		STA nn,Y	99	5	3	Store A	Absolute Y
	INC n,X	F6	6	2	Increment by one	Zero Page X		STX nn	8E	4	3	Store X	Absolute
	INC nn,X	FE	7	3	Increment by one	Absolute X		STX n	86	3	2	Store X	Zero Page
	INX	E8	2	1	Increment X by one	None		STX n,Y	96	4	2	Store X	Zero Page Y
	INY	C8	2	1	Increment Y by one	None		STY nn	8C	4	3	Store Y	Absolute
	JMP nn	4C	3	3	Jump to new location	Absolute		STY n	84	3	2	Store Y	Zero Page
	JMP (nn)	6C	5	3	Jump to new location	Indirect		STY n,X	94	4	2	Store Y	Zero Page X
	JSR nn	20	6	3	Jump to subroutine	Absolute		TAX	AA	2	1	Transfer A to X	None
								TAY	AB	2	1	Transfer A to Y	None

Instruction Notes

ADC	A+DATA+C→A
BRK	Ignore I flag, Set B=1 Push return address+1 Jump to IRQ vector
JSR	Push return address-1 Jump absolute
RTI	Pop P, Pop PC
RTS	Pop PC, Increment PC
SBC	A-DATA-C→A

Shift Instructions



Added Cycle Time

A (+) in the (C) column for branch instructions means:
Add 0 if branch not taken.
Add 1 if taken within page.
Add 2 if taken across pages.

A (+) in the (C) column for other instructions means:
Add 1 if indexing across page boundary.

Assembler Symbols

- . Assembler directive
- # Immediate addressing
- \$ Hex number prefix
- @ Octal number prefix
- % Binary number prefix
- ' ASCII character prefix
- () Indirect addressing
- ; In col 1 for comment

Intentionally Blank