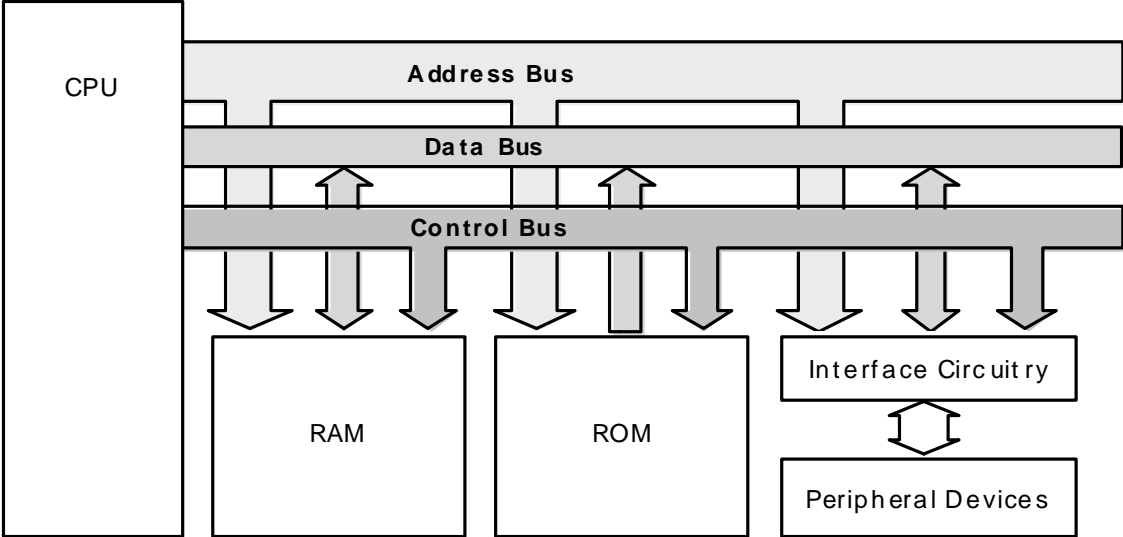
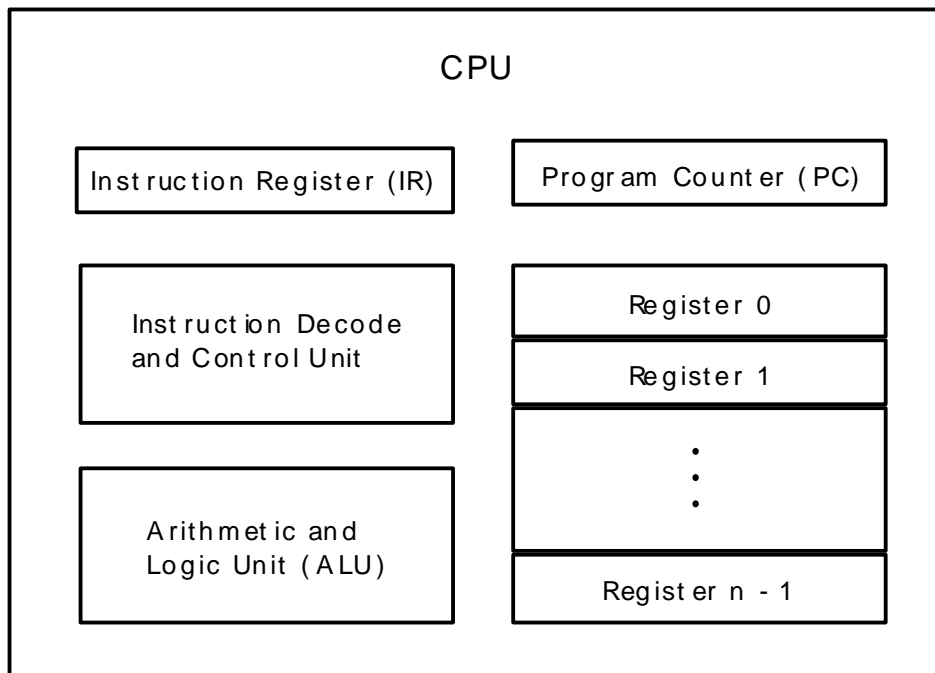


# Microcomputer Block Diagram



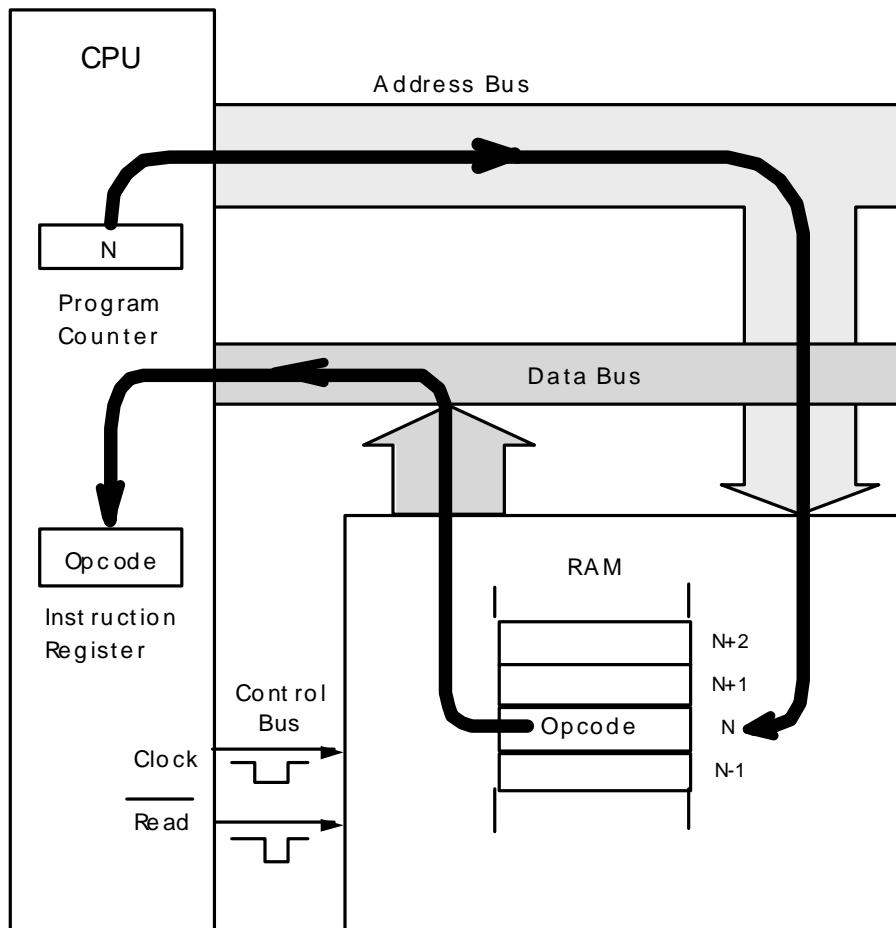
F1-1

# CPU Functional Units



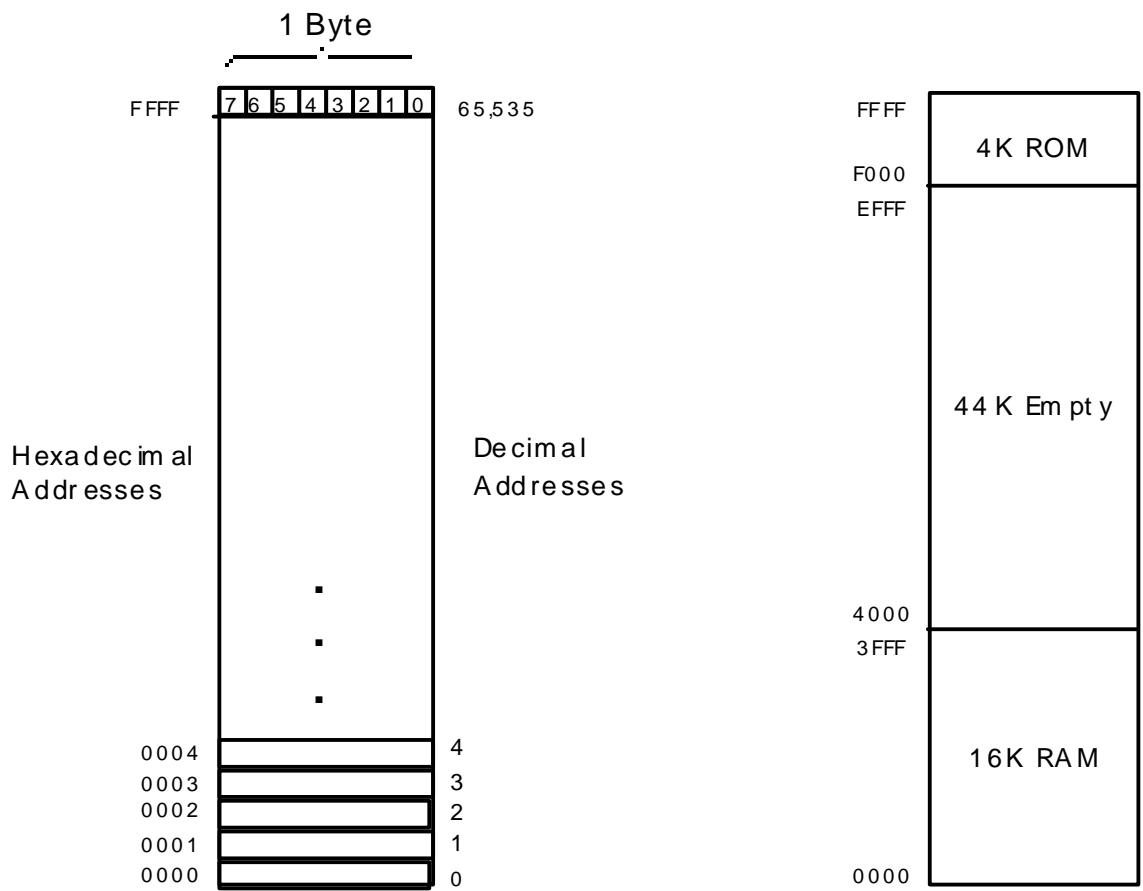
F1-2

# Opcode Fetch



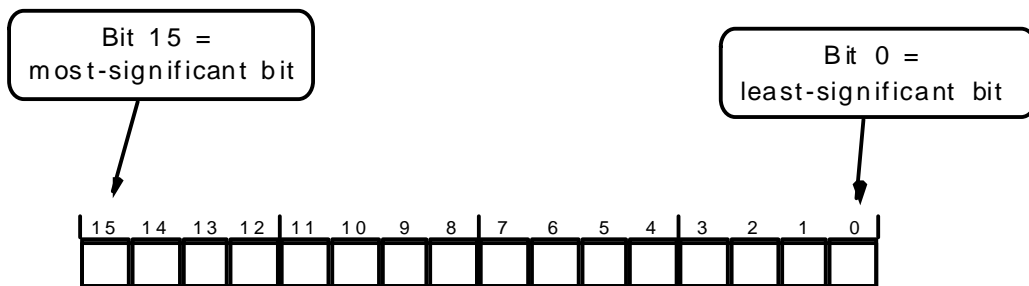
F1-3

# Memory Maps

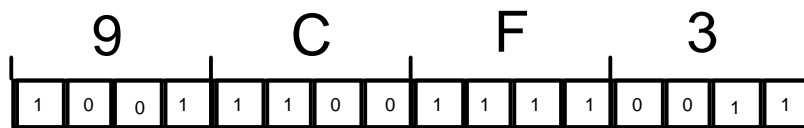


F1-6/7

# 16-Bit Addresses



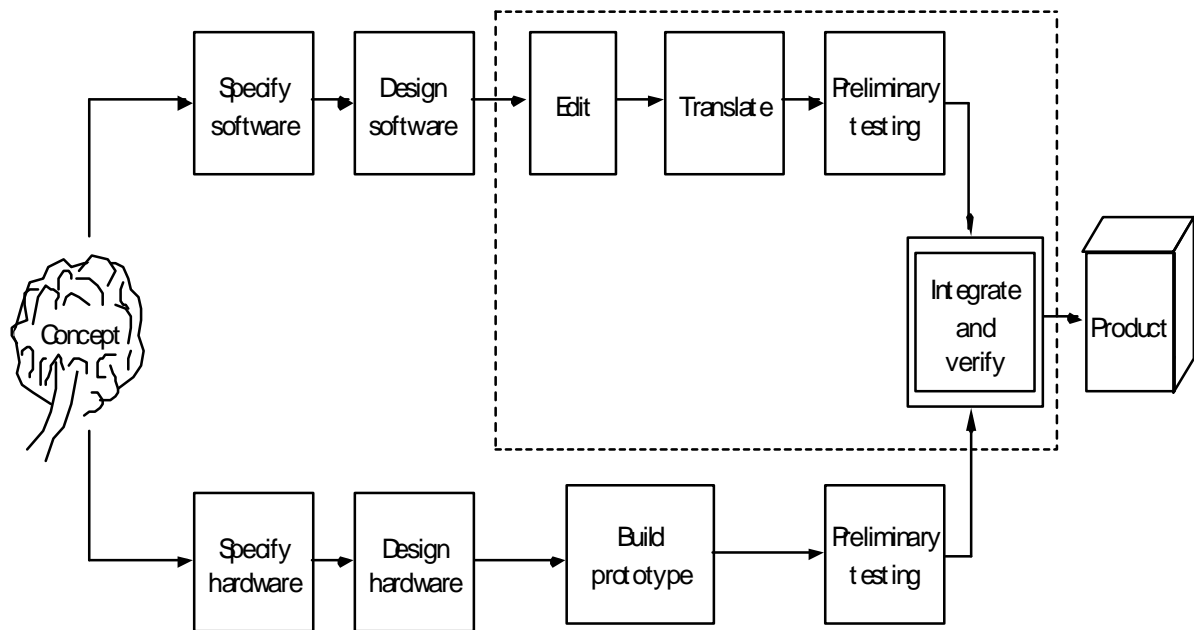
(a)



(b)

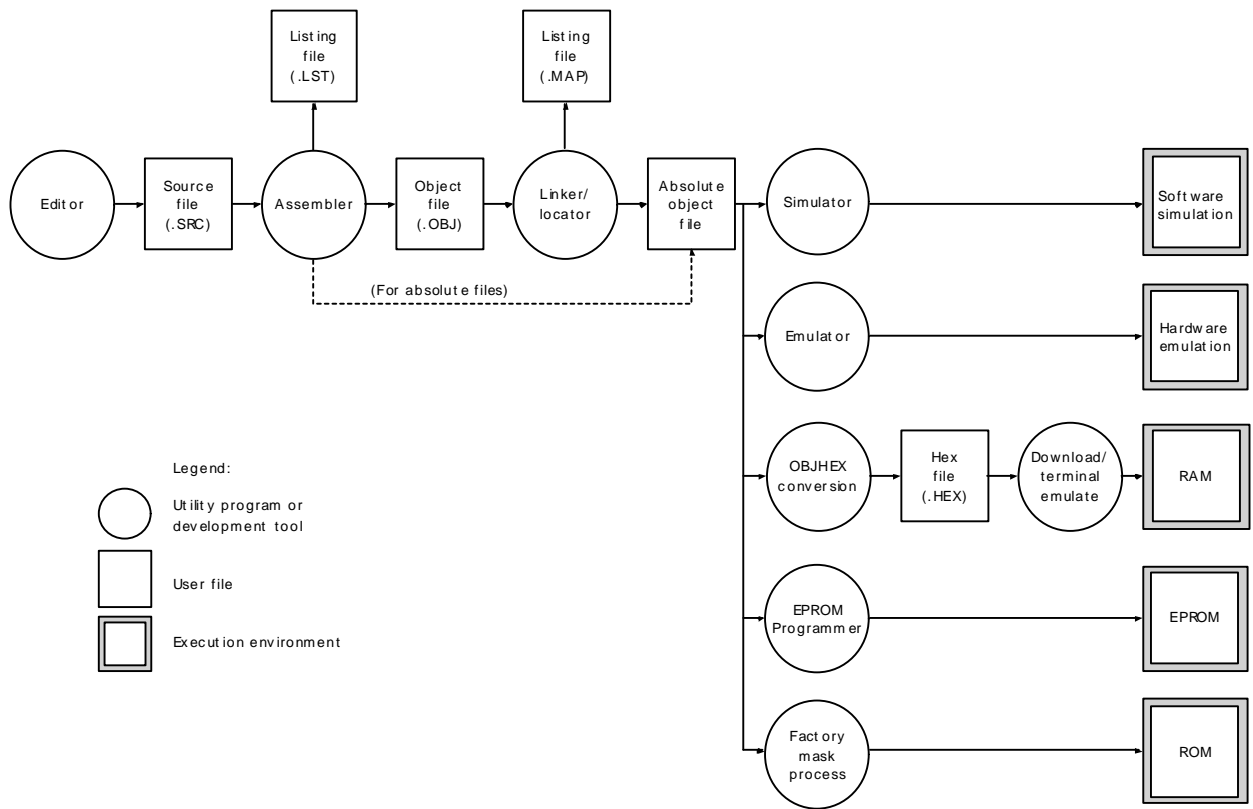
F1-8

# The Development Cycle



1-11

# Steps in the Development Cycle

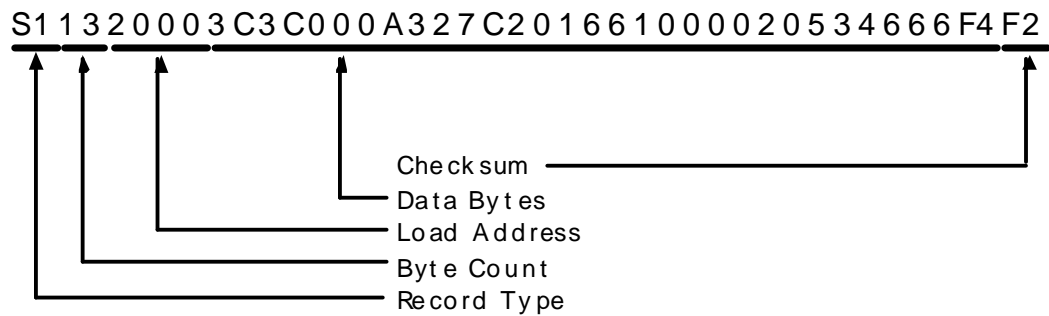


# Motorola S-records

```

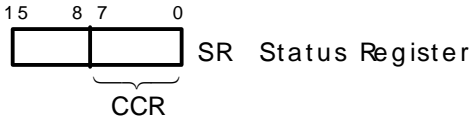
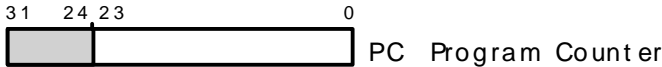
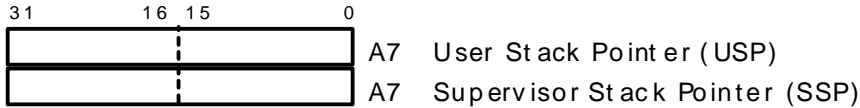
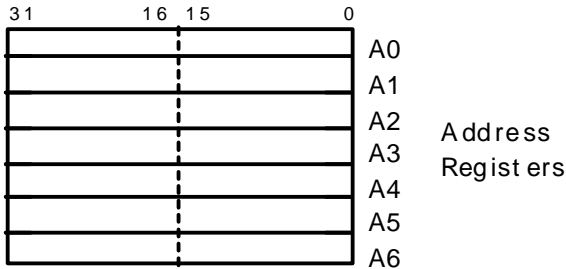
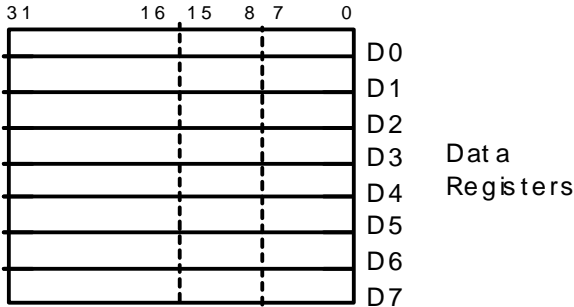
S00900006D796E616D656F
S11320003C3C000A327C201661000020534666F4F2
S11320101E3C00E44E4E53636F7474204D61634B59
S10C2020656E7A6965200D0A0061
S113202A1E3C00F81019670000064E4E60F64E7505
S9030000FC
    
```

(a)

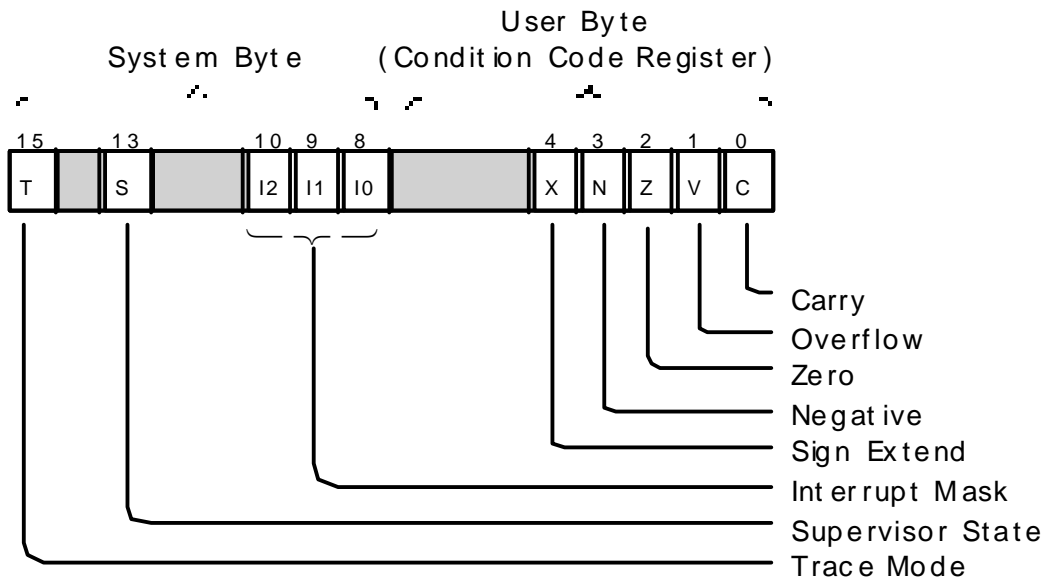


(b)

# 68000 Programmer's Model

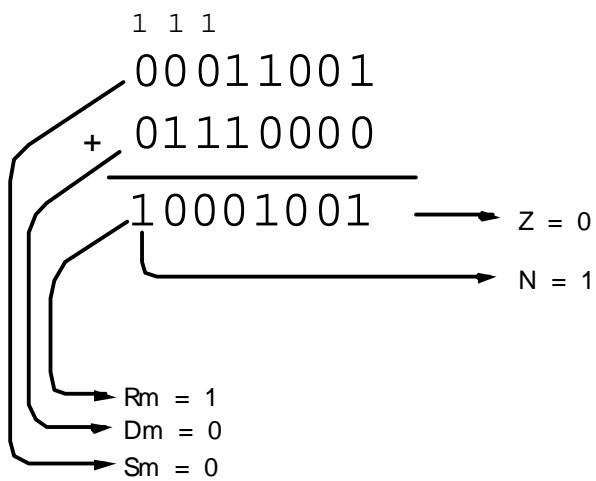


# 68000 Status Register



F2-4

# Condition Code Computation



$$\begin{aligned}
 C &= S_m \cdot D_m + \overline{R_m} \cdot D_m + S_m \cdot \overline{R_m} \\
 &= 0 \cdot 0 + 0 \cdot 0 + 0 \cdot 0 \\
 &= 0
 \end{aligned}$$

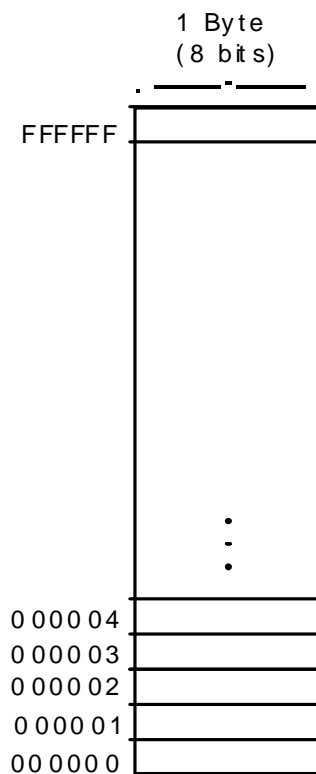
$$\begin{aligned}
 V &= S_m \cdot D_m \cdot \overline{R_m} + \overline{S_m} \cdot \overline{D_m} \cdot R_m \\
 &= 0 \cdot 0 \cdot 0 + 1 \cdot 1 \cdot 1 \\
 &= 1
 \end{aligned}$$

$$X = C = 0$$

F2-5

# 68000 Memory Map

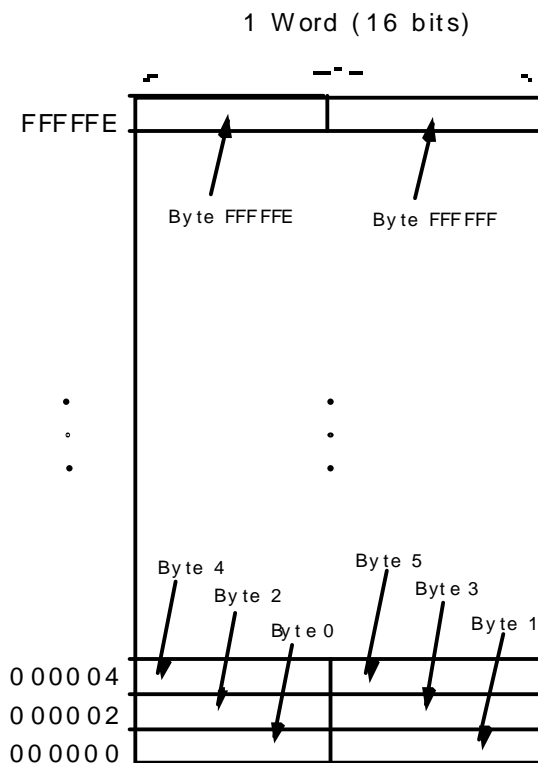
## -- Byte View --



F2-7

# 68000 Memory Map

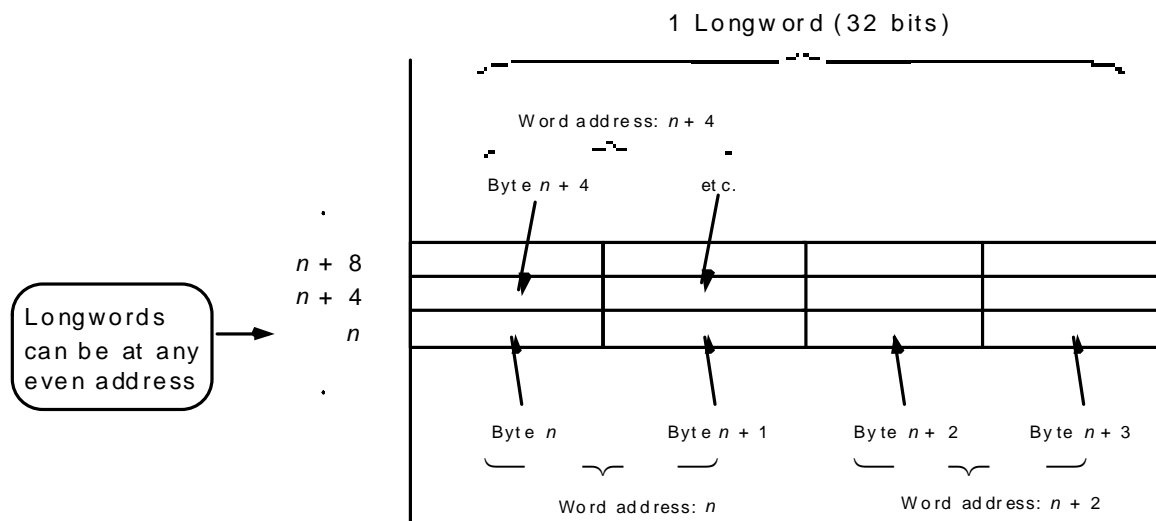
## -- Word View --



Note:  
*Even* bytes correspond to *upper* bytes on the external data bus. *Odd* bytes correspond to *lower* bytes on the external data bus.

# 68000 Memory Map

## -- Longword View --



F2-9

# 68000 Addressing Modes

Mode	Assembler Syntax	Effective Address Generation
Data Register Direct	Dn	EA = Dn
Address Register Direct	An	EA = An
Absolute Short	xxx.W or <xxx	EA = (next word)
Absolute Long	xxx.L or >xxx	EA = (next two words)
Register Indirect	(An)	EA = (An)
Postincrement Register Indirect	(An)+	EA = (An), An ` An + N
Predecrement Register Indirect	-(An)	An ` An - N, EA = (An)
Register Indirect with Offset	d16(An)	EA = (An) + d16
Register Indirect with Index & Offset	d8(An,Xn)	EA = (An) + (Xn) + d8
PC Relative with Offset	d16(PC)	EA = (PC) + d16
PC Relative with Index and Offset	d8(PC,Xn)	EA = (PC) + (Xn) + d8
Immediate	#data	DATA = next word(s)
Implied Register	CCR, SR, USP, SSP, PC	EA = CCR, SR, USP, SSP, PC

*Notes:*

EA = effective address  
 An = address register  
 Dn = data register  
 Xn = address or data register used as index register  
 CCR = condition code register  
 SR = status register  
 USP = user stack pointer  
 SSP = supervisor stack pointer

PC = program counter  
 ( ) = contents of  
 d8 = 8-bit offset (displacement)  
 d16 = 16-bit offset (displacement)  
 N = 1 for byte, 2 for word, 4 for longword. (If An is the stack pointer and the operand size is byte, N = 2 to keep the stack pointer on a word boundary.)  
 ` = is replaced by

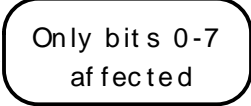
T2-1

# Data Register Direct

Instruction: MOVE.B D0,D3

	Register	Contents
Before:	D0	10204FFF
	D3	1034F88A
After:	D0	10204FFF
	D3	1034F8FF

Only bits 0-7  
affected



F2-10

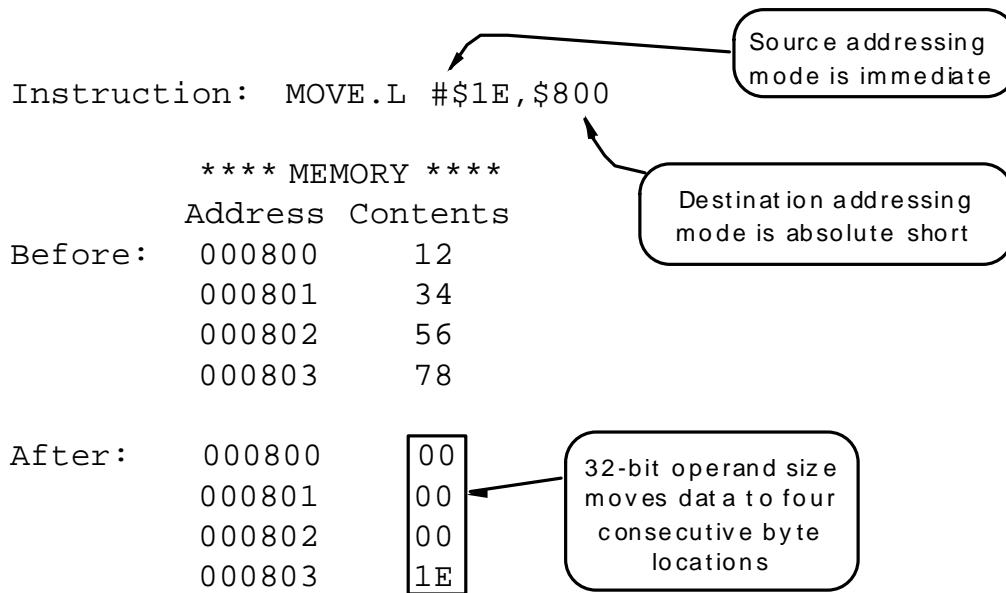
# Address Register Direct

Instruction: MOVEA.L A3,A0

	Register	Contents	
Before:	A0	00200000	Move to address register
	A3	0004F88A	
After:	A0	0004F88A	32 bits are moved
	A3	0004F88A	

F2-11

# Absolute Short



F2-13

# Absolute Long

Instruction: MOVE.B #\$1E,\$8F000

\*\*\*\* MEMORY \*\*\*\*

Address Contents

Before: 08F000 FF

After: 08F000 1E

Destination addressing mode is absolute long

Operand size is byte

F2-14

# Register Indirect

Instruction: MOVE.L D0,(A0)

A0 contains the address of the destination

\*\*\*\* MEMORY \*\*\*\*

	Address	Contents	Registers
Before:	001000	55	A0 00001000
	001001	02	D0 1043834F
	001002	3F	
	001003	00	

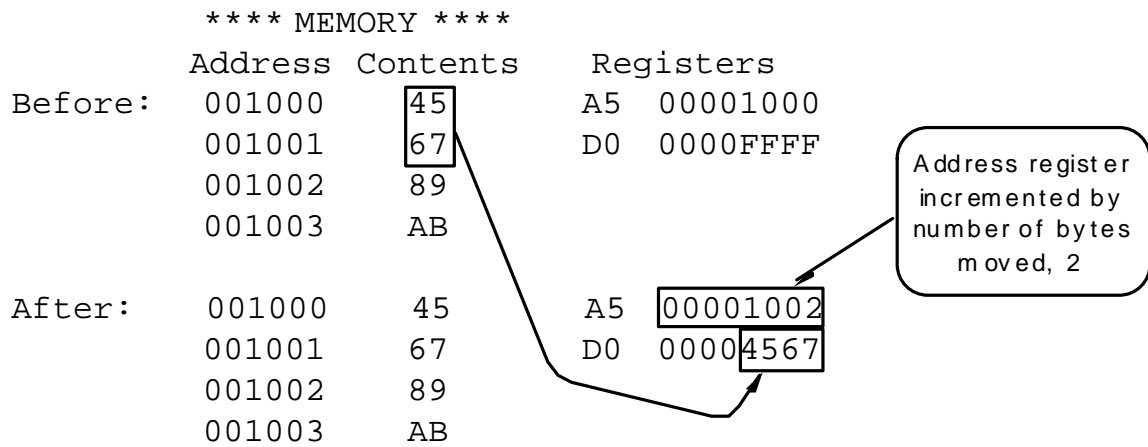
After:	001000	10	A0 00001000
	001001	43	D0 1043834F
	001002	83	
	001003	4F	

A0 does not change

A long word is written to address \$001000

# Postincrement Address Register Indirect

Instruction: MOVE.W (A5)+,D0



F2-18

# Predecrement Address Register Indirect

Instruction: MOVE.W D0,-(A7)

\*\*\*\* MEMORY \*\*\*\*

	Address	Contents	Registers
Before:	001000	10	A7 00001002
	001001	12	D0 00000143
	001002	83	
	001003	47	
After:	001000	01	A7 00001000
	001001	43	D0 00000143
	001002	83	
	001003	47	

Address register decremented by number of bytes moved, 2

F2-19

# Register Indirect With Offset

Instruction: MOVE.W 6(A0),D0

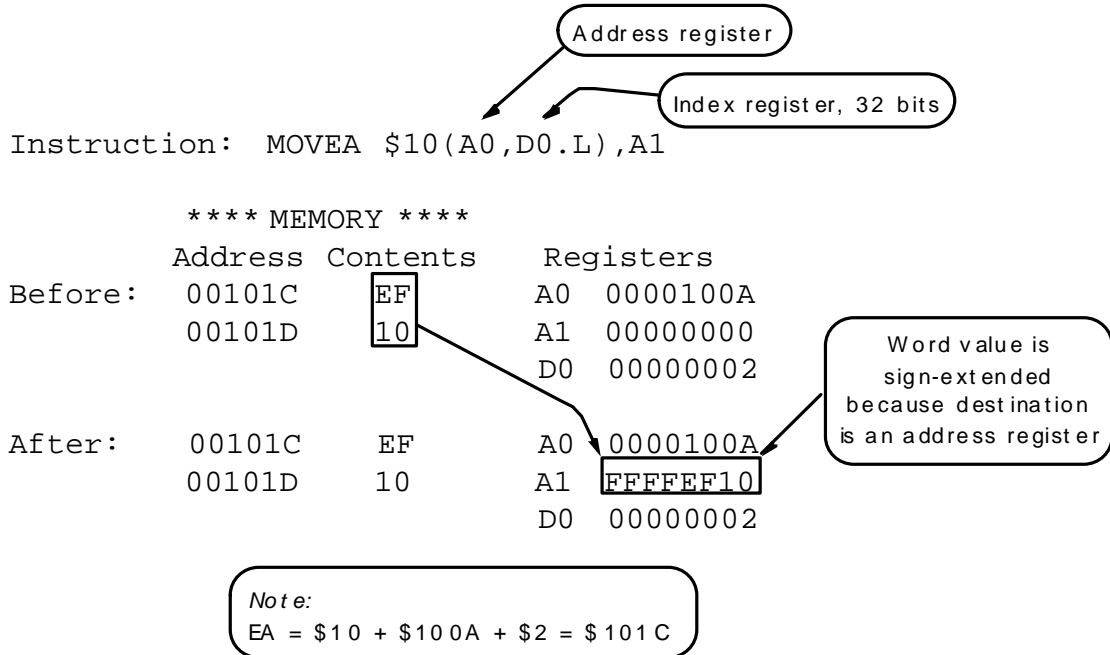
Effective address is  
6 plus value in A0

\*\*\*\* MEMORY \*\*\*\*

	Address	Contents	Registers
Before:	001026	07	A0 00001020
	001027	BF	D0 00000000
After:	001026	07	A0 00001020
	001027	BF	D0 000007BF

Address register  
does not change

# Register Indirect With Index and Offset



# PC-Relative With Offset

Instruction: MOVE.W \$1020(PC),D5

\*\*\*\* MEMORY \*\*\*\*

	Address	Contents	Registers
Before:	001020	AB	PC 00001000
	001021	CD	D5 12345678
After:	001020	AB	PC 00001004
	001021	CD	D5 1234ABCD

Instruction is two words long, so PC is incremented by four

F2-23

# PC-Relative With Index and Offset

Instruction: MOVE.W \$1020(PC,D0.W),D5

		**** MEMORY ****		Registers	
	Address	Contents			
Before:	001026	FE	PC	00001000	
	001027	DC	D0	ABCD0006	
			D5	12345678	
After:	001026	FE	PC	00001004	
	001027	DC	D0	ABCD0006	
			D5	1234FEDC	

Only low-order  
16 bits of D0 used  
as index

F2-26

# Immediate

Instruction: MOVE.L # $\$1FFFF$ ,D0

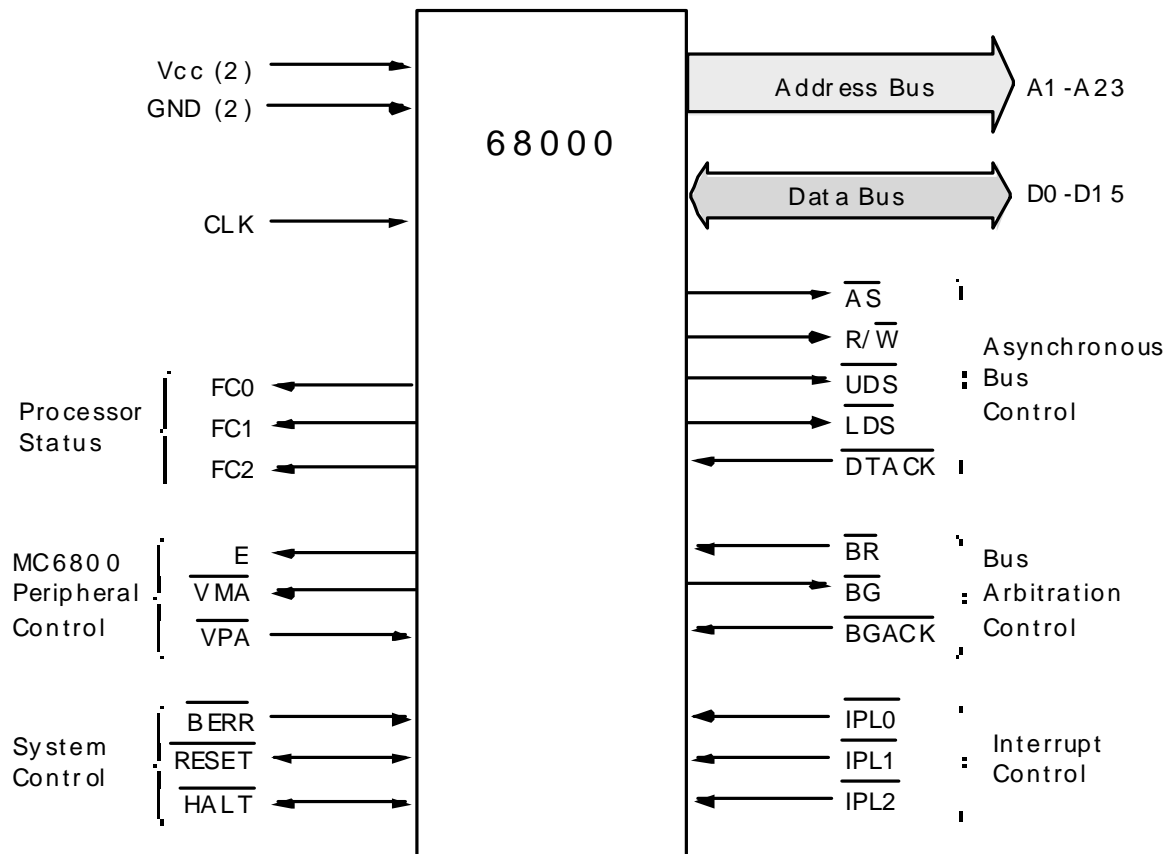
Immediate data follow

	Register	Contents
Before:	D0	12345678
After:	D0	0001FFFF

*Base:*  
\$ = hexadecimal  
@ = octal  
% = binary  
& (or nothing) = decimal  
'AB' = ASCII characters

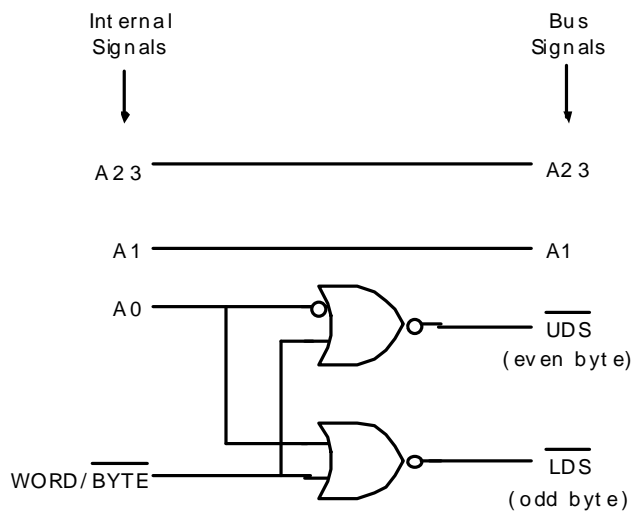
F2-28

# 68000 Signals



F2-33

# Upper Data Strobe and Lower Data Strobe



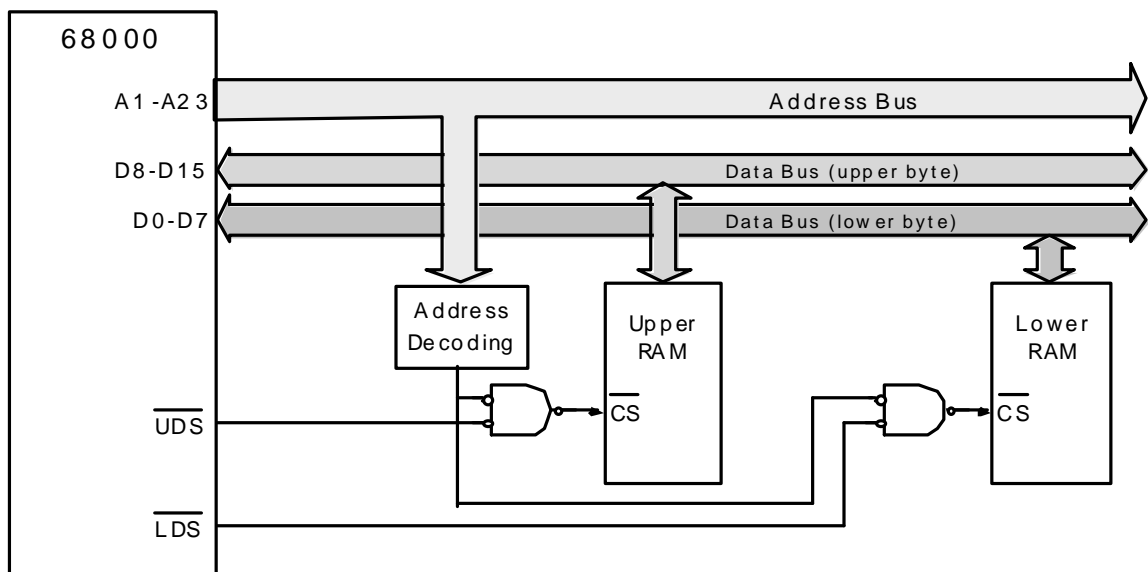
(a)

WORD/ BYTE	A0	$\overline{\text{UDS}}$	$\overline{\text{LDS}}$
1	X	0	0
0	0	0	1
0	1	1	0

(b)

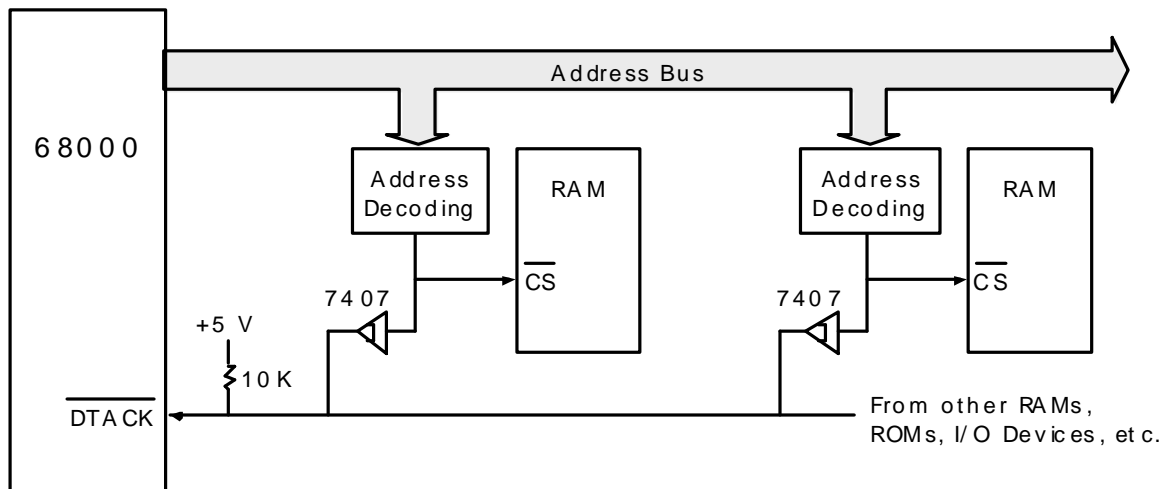
F2-34

# Decoding with -UDS and -LDS



F2-36

# Generation of -DTACK



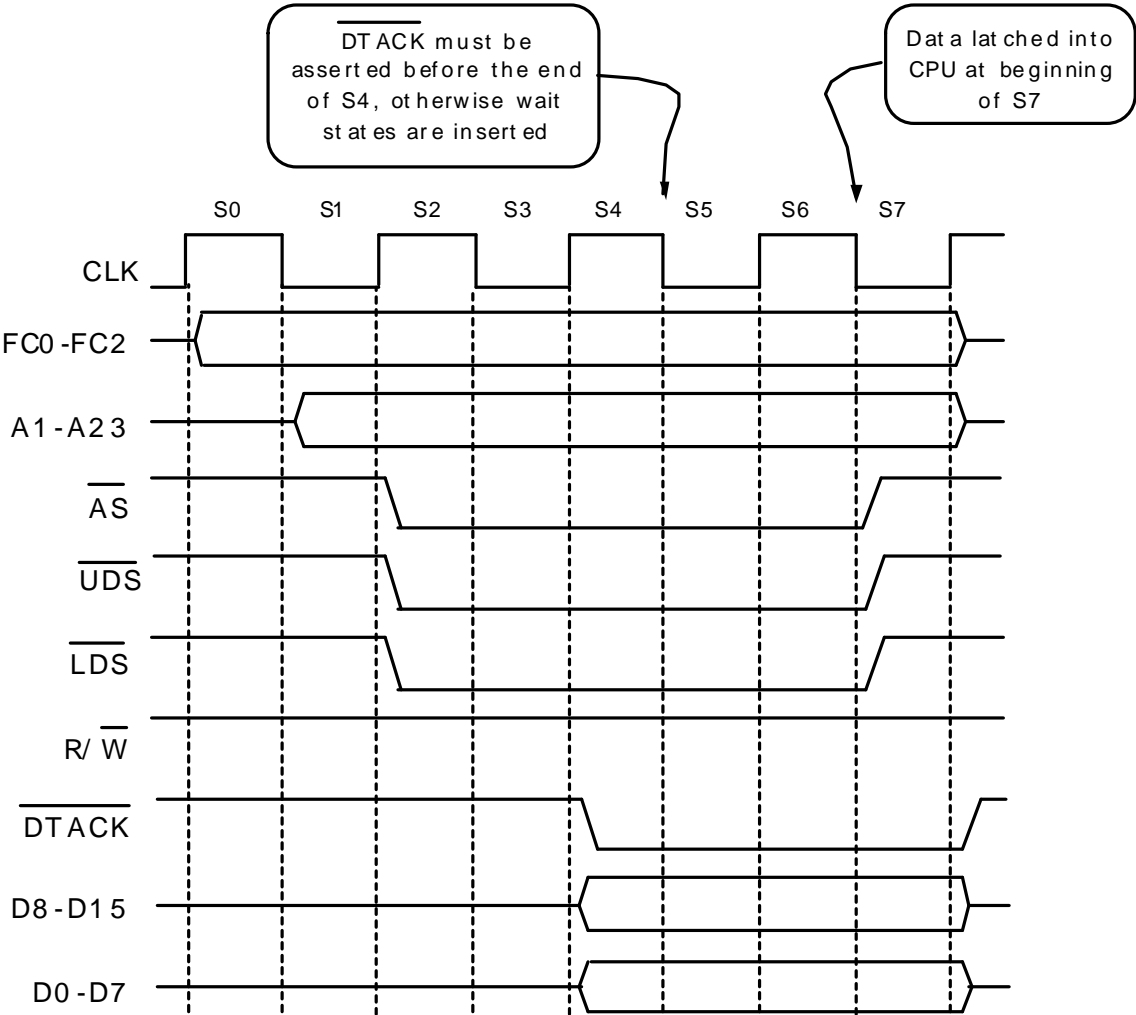
F2-36

# Function Code Outputs

Function Code			Address Space Type
FC2	FC1	FC0	
0	0	0	(Undefined, reserved)
0	0	1	User Data
0	1	0	User Program
0	1	1	(Undefined, reserved)
1	0	0	(Undefined, reserved)
1	0	1	Supervisor Data
1	1	0	Supervisor Program
1	1	1	CPU Space (Interrupt Acknowledge)

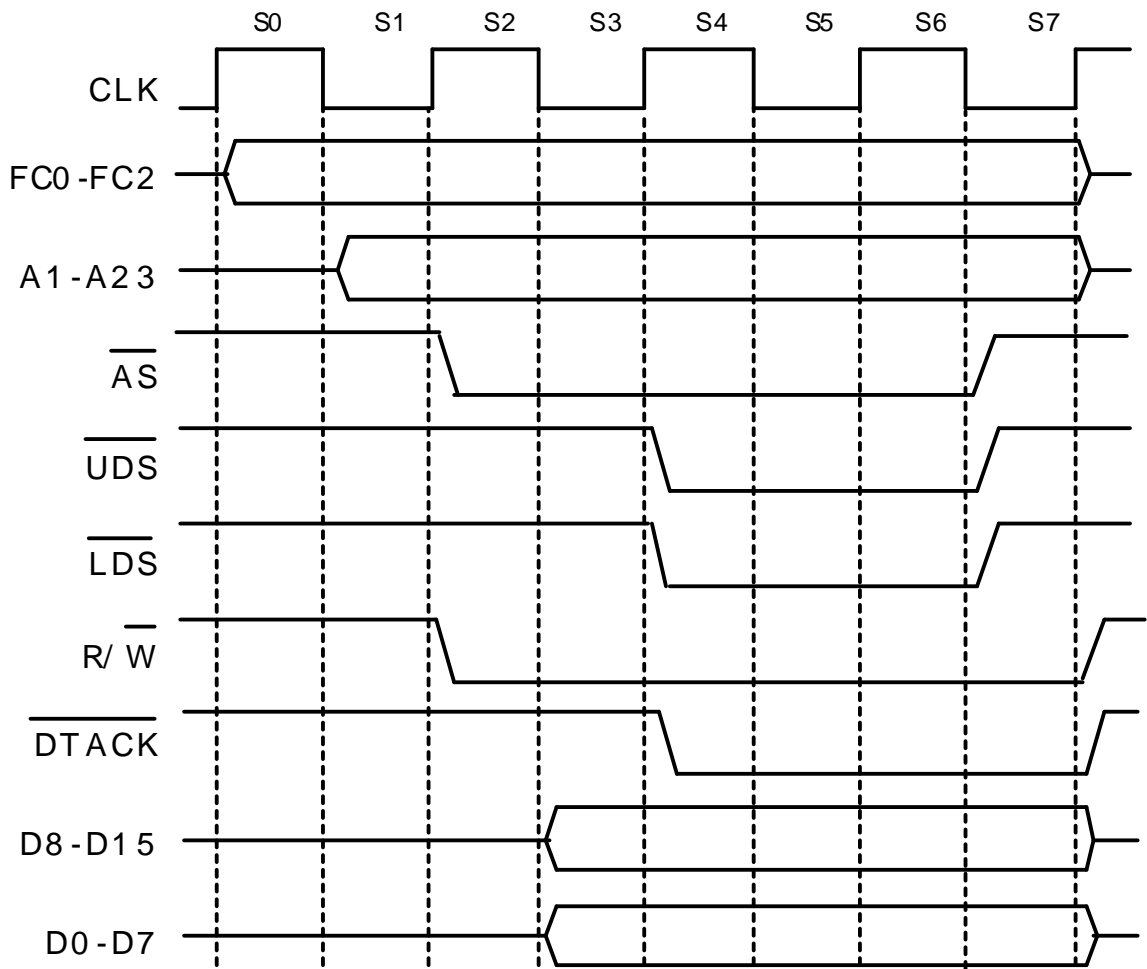
T2-3

# Read Cycle Timing



F2-39

# Write Cycle Timing



F2-40

# Data Movement Instructions

<b>Instruction</b>	<b>Operation</b>
EXG	Exchange registers
LEA	Load effective address
LINK	Link and allocate stack
MOVE	Move source to destination
MOVEA	Move source to address register
MOVEM	Move multiple registers
MOVEP	Move to peripheral
MOVEQ	Move short data to destination
PEA	Push effective address
UNLK	Unlink stack

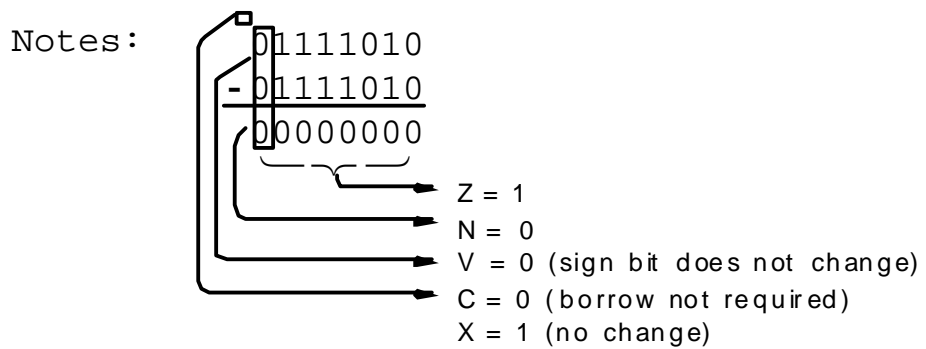
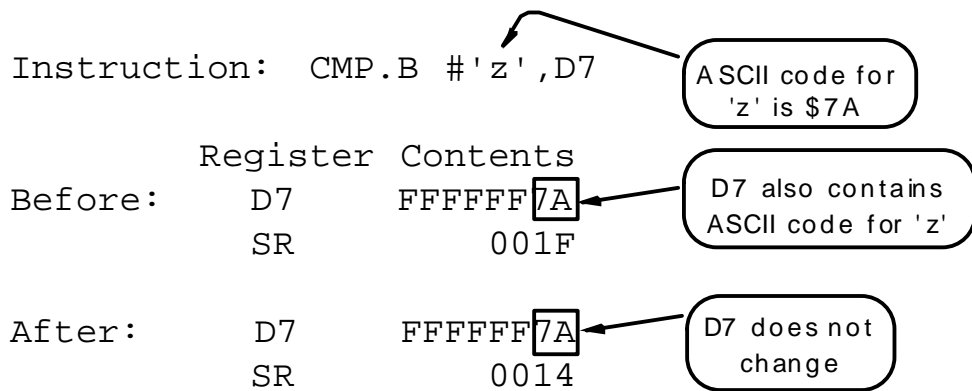
T3-3

# Integer Arithmetic Instructions

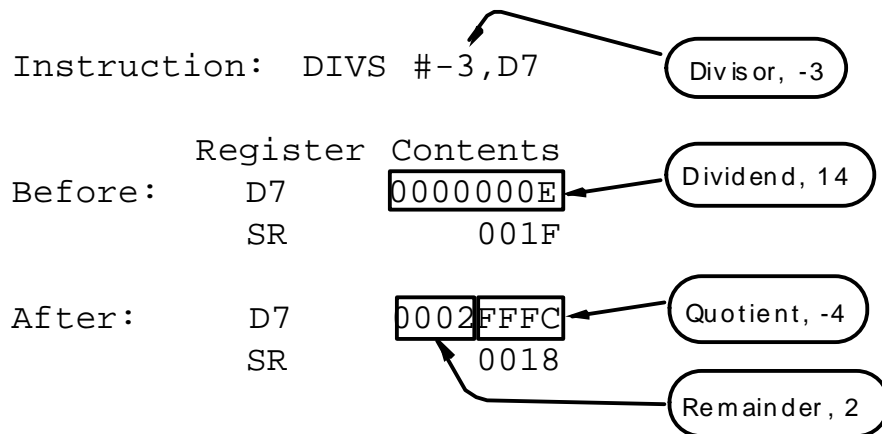
Instruction	Operation
ADD	Add source to destination
ADDA	Add source to address register
ADDI	Add immediate data to destination
ADDQ	Add short data to destination
ADDX	Add with extend bit to destination
CLR	Clear operand
CMP	Compare source to destination
CMPA	Compare source to address register
CMPM	Compare memory
DIVS	Signed divide
DIVU	Unsigned divide
EXT	Sign extend
EXTB	Sign extend byte
MULS	Signed multiply
MULU	Unsigned multiply
NEG	Negate
NEGX	Negate with extend
SUB	Subtract source from destination
SUBA	Subtract source from address register
SUBI	Subtract immediate from destination
SUBQ	Subtract short from destination
SUBX	Subtract with extend bit from destination

T3-4

# CMP Example



# DIVS Example



Notes:  $14 / -3 = -4$  with a remainder of 2

F3-8

# Boolean Instructions

Instruction	Operation
AND	AND source to destination
ANDI	AND immediate data to destination
EOR	Exclusive OR source to destination
EORI	Exclusive OR immediate data to destination
NOT	Complement destination
OR	OR source to destination
ORI	OR immediate data to destination
Scc	Test condition codes and set operand
TST	Test operand and set condition codes

T3-5

# EOR Example

Instruction: EOR.L D6,(A4)+

\*\*\*\* MEMORY \*\*\*\*

	Address	Contents	Registers
Before:	003100	AB	A4 00003100
	003101	CD	D6 12345678
	003102	EF	SR 0000
	003103	10	
After:	003100	B9	A4 00003104
	003101	F9	D0 12345678
	003102	B9	SR 0008
	003103	68	

Annotations:  
 - Source operand: D6 (12345678)  
 - Destination operand: Memory address 003102 (EF)  
 - A4 incremented by four: A4 (00003104)

Notes:

	ABCDEF10
⊕	12345678
<hr/>	
	B9F9B968

Z = 0  
 N = 1  
 V = C = 0 (always)  
 X = not affected (assume 0)

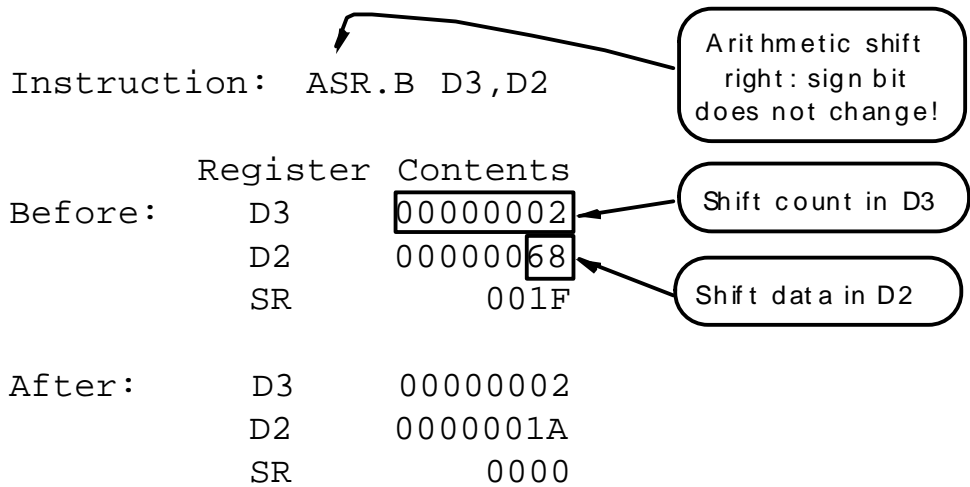
F3-10

# Shift and Rotate Instructions

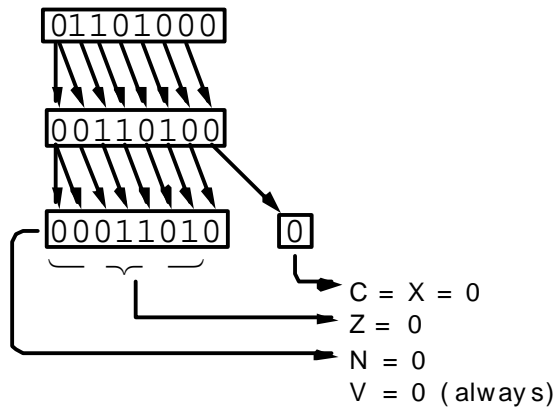
Instruction	Operation	Bit Movement
ASL	Arithmetic shift left	
ASR	Arithmetic shift right	
LSL	Logical shift left	
LSR	Logical shift right	
ROL	Rotate left	
ROR	Rotate right	
ROXL	Rotate left with extend bit	
ROXR	Rotate right with extend bit	
SWAP	Swap words of a longword	

T3-6

# ASR Example



Notes:



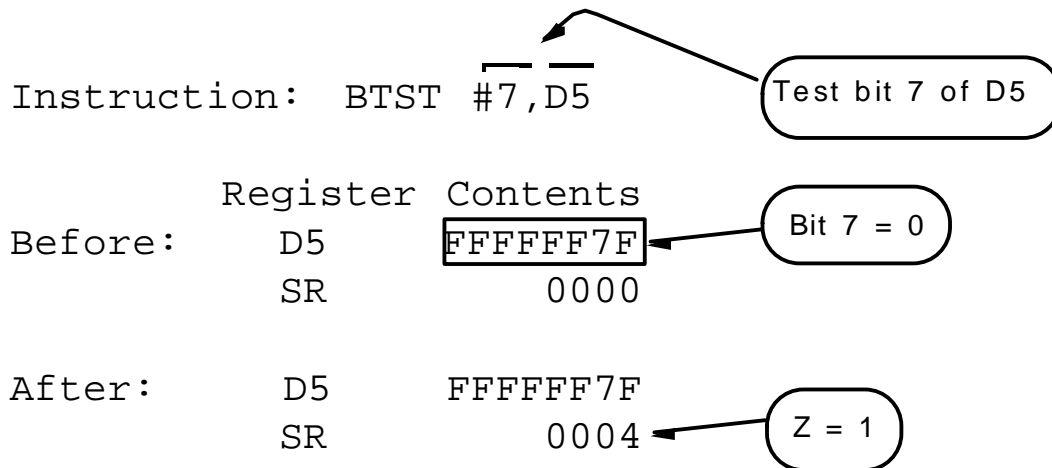
F3-11

# Bit Manipulation Instructions

<b>Instruction</b>	<b>Operation</b>
BCHG	Change bit
BCLR	Clear bit
BSET	Set bit
BTST	Test bit

T3-7

# BTST Example



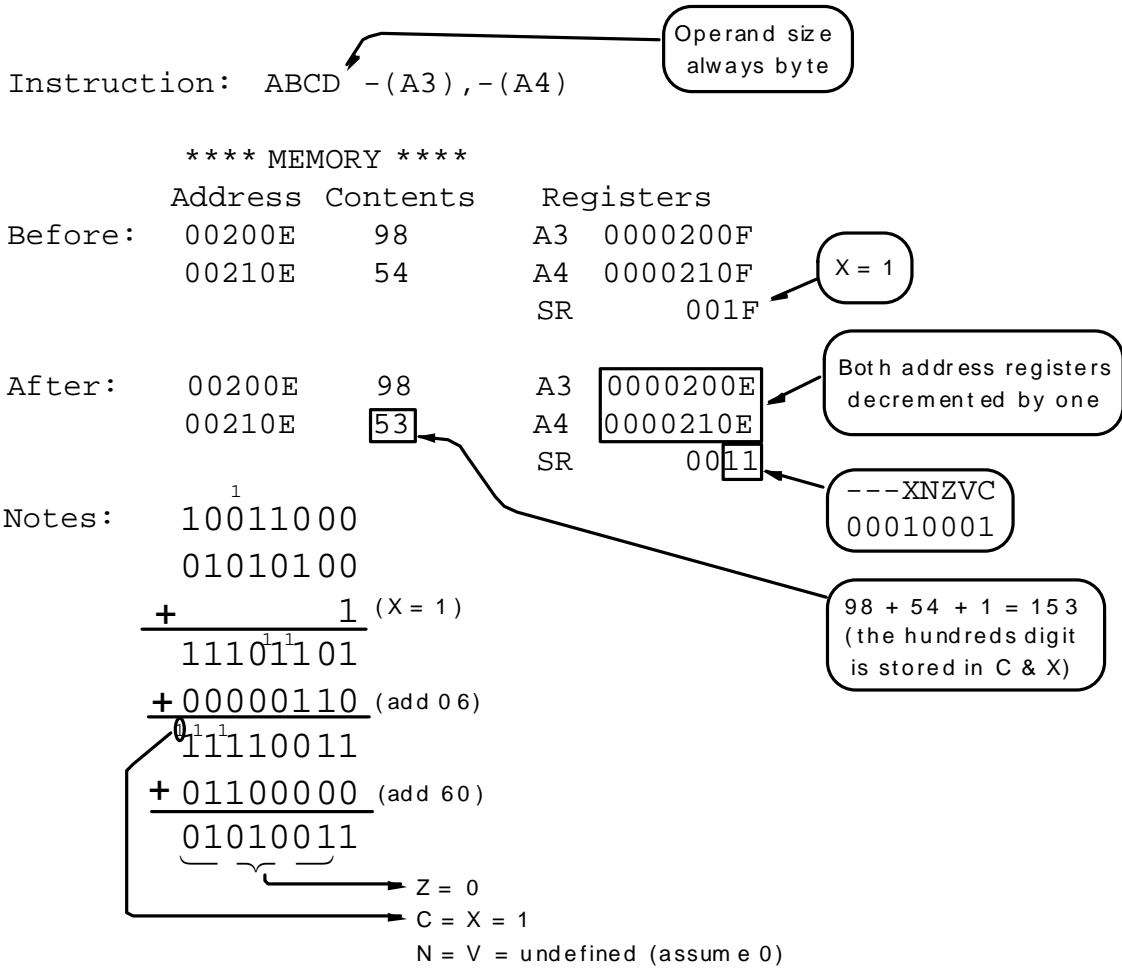
F3-12

# Binary-Coded Decimal Instructions

Instruction	Operation
ABCD	Add source to destination
NBCD	Negate destination
SBCD	Subtract source from destination

T3-8

# ABCD Example



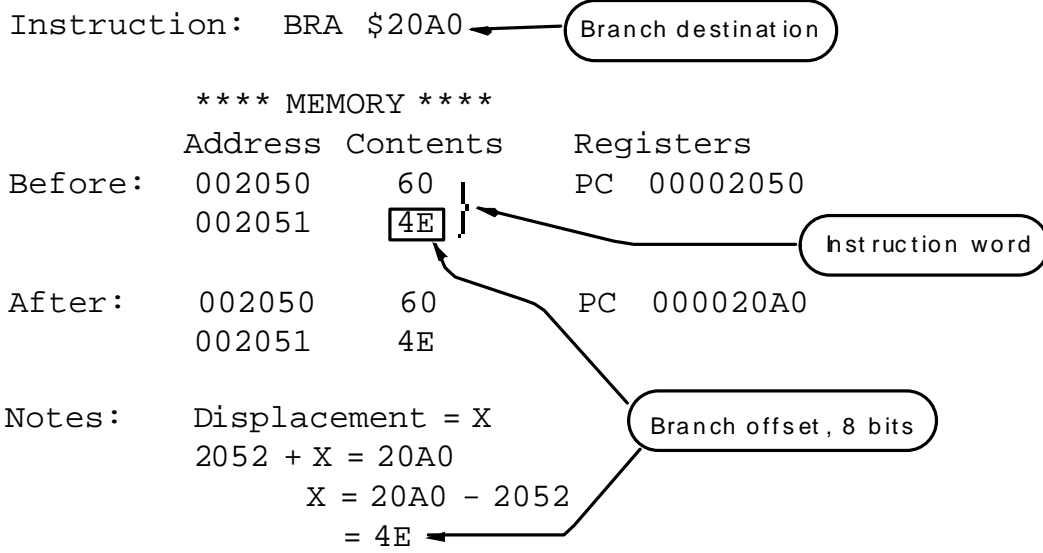
# Program Flow Instructions

Instruction	Operation
Bcc	Branch conditionally
BRA	Branch always
BSR	Branch to subroutine
DBcc	Test, decrement, and branch
JMP	Jump to address
JSR	Jump to subroutine
NOP	No operation
RTE <sup>†</sup>	Return and deallocate stack
RTR	Return and restore condition codes
RTS	Return from subroutine

<sup>†</sup>privileged instruction

T3-9

# BRA Example



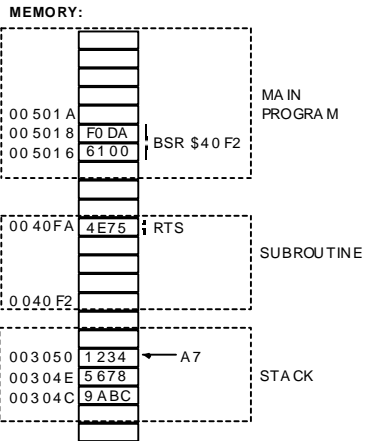
F3-15

# BSR/RTS Example

BSR \$40F2

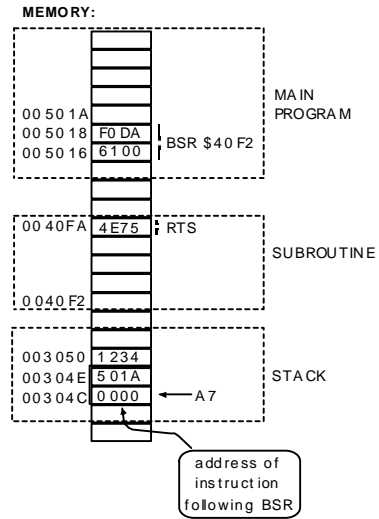
BEFORE

REGISTERS:  
PC 005016  
A7 0003050



AFTER

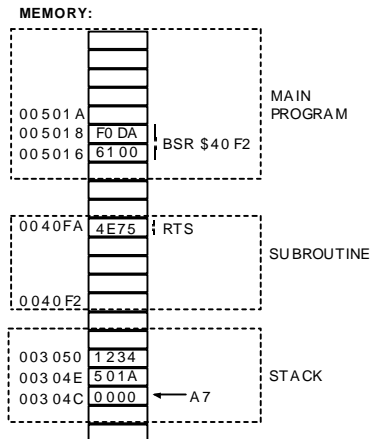
REGISTERS:  
PC 0040F2  
A7 000304C



RTS

BEFORE

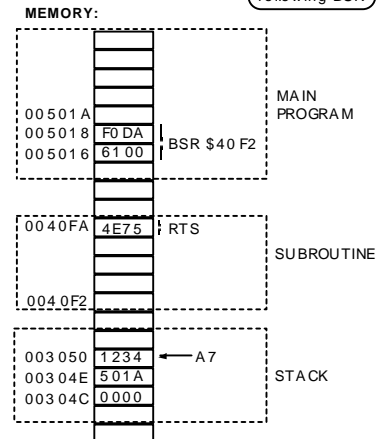
REGISTERS:  
PC 0040FA  
A7 000304C



AFTER

REGISTERS:  
PC 00501A  
A7 0003050

return to instruction following BSR



# System Control Instructions

Instruction	Operation
ANDI++	AND immediate to status register/condition code register
CHK	Trap on upper out-of-bounds operand
EORI++	Exclusive OR immediate to status register/condition code register
ILLEGAL	Illegal instruction trap
MOVE++	Move to/from status register/condition code register
ORI++	OR immediate to status register/condition code register
RESET+	Assert RESET line
STOP+	Stop processor
TAS	Test and set operand
TRAP	Trap unconditionally
TRAPV	Trap on overflow

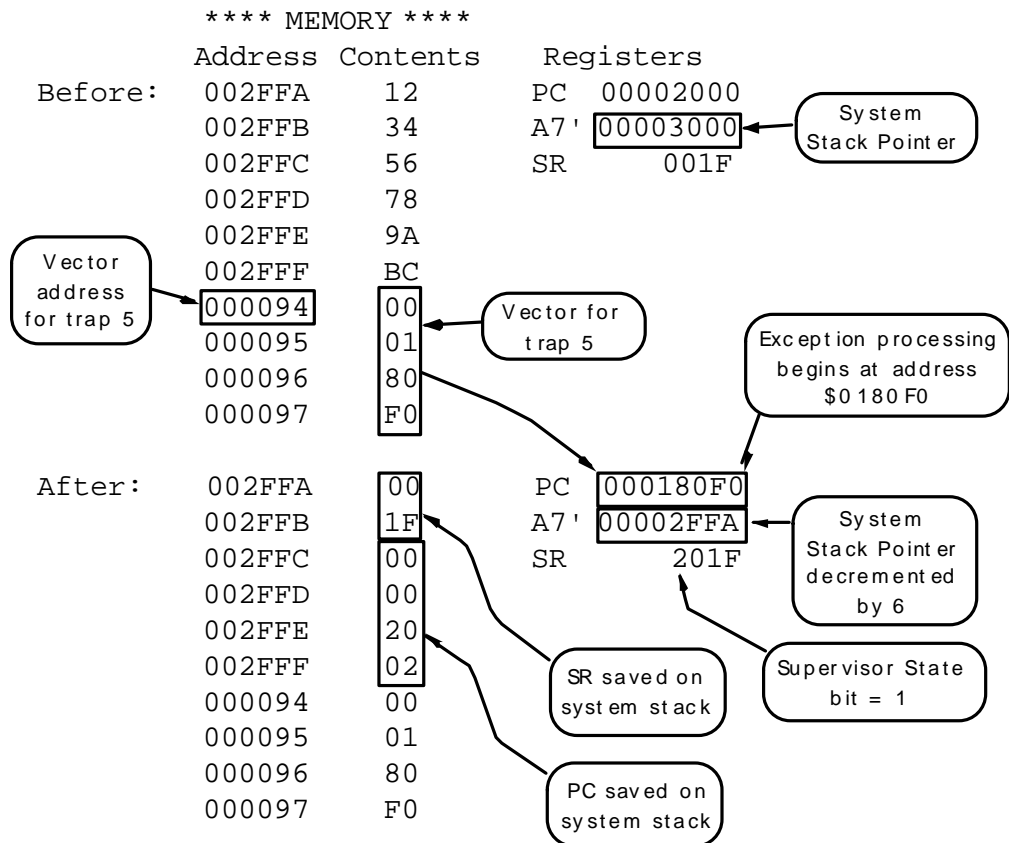
+privileged instruction

++privileged instruction if SR specified

T3-10

# TRAP Example

Instruction: TRAP #5



Notes: Vector read from address  $\$80 + (5 \times 4) = \$94$

# 68000 Instruction Format

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Operation Word (1st word specifies operation and addressing modes)															
Immediate Operand (if any, one or two words)															
Source Effective Address Extension (if any, one or two words)															
Destination Effective Address Extension (if any, one or two words)															

F3-19

# Effective Address Encoding

Addressing Mode	Mode Bits	Register Bits
Data Register Direct	000	register number
Address Register Direct	001	register number
Address Register Indirect	010	register number
Address Register Indirect with Postincrement	011	register number
Address Register Indirect with Predecrement	100	register number
Address Register Indirect with Displacement†	101	register number
Address Register Indirect with Index*	110	register number
Absolute Short†	111	000
Absolute Long††	111	001
Program Counter with Displacement†	111	010
Program Counter with Index*	111	011
Immediate or Status Register†††	111	100

† One extension word required

†† Two extension words required

††† For Immediate addressing, one or two extension words required depending on the size of the operation

\* One extension word required; see Table C-4 for the encoding

T3-11

# 68000 Condition Code Encoding

Mnemonic	Condition	Encoding	Test
T†	true	0000	1
F†	false	0001	0
HI	high	0010	$\bar{C} \cdot \bar{Z}$
LS	low or same	0011	$C + Z$
CC(HS)	carry clear	0100	$\bar{C}$
CS(LO)	carry set	0101	C
NE	not equal	0110	$\bar{Z}$
EQ	equal	0111	Z
VCT†	overflow clear	1000	$\bar{V}$
VST†	overflow set	1001	V
PL	plus	1010	$\bar{N}$
MI	minus	1011	N
GE††	greater or equal	1100	$N \cdot V + \bar{N} \cdot \bar{V}$
LT††	less than	1101	$N \cdot \bar{V} + \bar{N} \cdot V$
GT††	greater than	1110	$N \cdot V \cdot \bar{Z} + \bar{N} \cdot \bar{V} \cdot \bar{Z}$
LE††	less or equal	1111	$Z + N \cdot \bar{V} + \bar{N} \cdot V$

† Not available for Bcc instruction

†† Twos complement arithmetic

• = Boolean AND

+ = Boolean OR

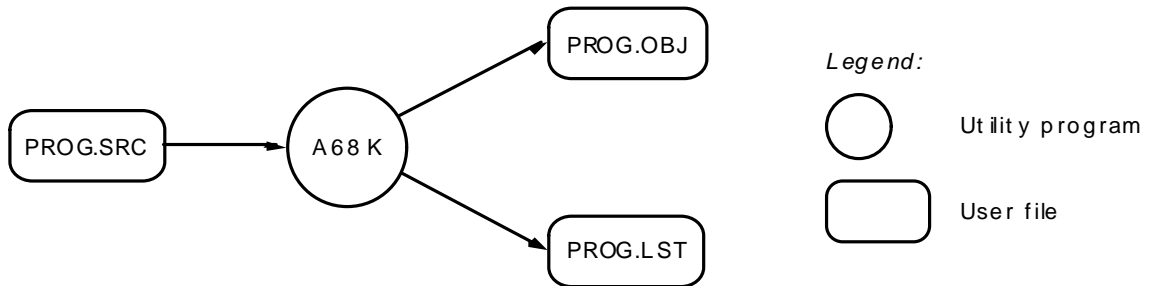
T3-12

# Opcode Map

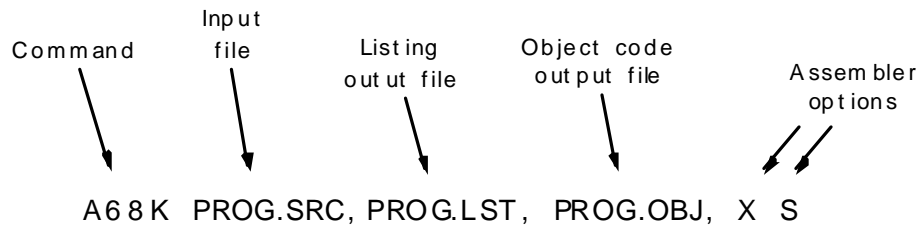
<b>Bits 15 through 12</b>	<b>Operation</b>
0000	Bit Manipulation/MOVEP/Immediate
0001	Move Byte
0010	Move Long
0011	Move Word
0100	Miscellaneous
0101	ADDQ/SUBQ/ScC/DBcc
0110	Bcc/BSR
0111	MOVEQ
1000	OR/DIV/SBCD
1001	SUB/SUBX
1010	(Unassigned)
1011	CMP/EOR
1100	AND/MUL/ABCD/EXG
1101	ADD/ADDX
1110	Shift/Rotate
1111	(Unassigned)

T3-13

# Assembler Operation



(a)



F4-1

# Assembler Files

Label field	Mnemonic field	Operand field	Com ment field (empty)
	ORG	\$1000	
PROG	LEA	\$800,A0	
	MOVE.B	#50,D0	
	CLR.W	D7	
LOOP	ADD.W	(A0)+,D7	
	SUBQ.B	#1,D0	
	BRA	*	
	END		

Source file

(a)

Line number	Address	Contents	Source file
1	00001000		ORG \$1000
2	00001000	41F80800 PROG	LEA \$800,A0
3	00001004	103C0032	MOVE.B #50,D0
4	00001008	4247	CLR.W D7
5	0000100A	DE58 LOOP	ADD.W (A0)+,D7
6	0000100C	5300	SUBQ.B #1,D0
7	0000100E	60FE	BRA *
8	00001010		END

Listing file

(b)

## Listing Examples

```

1 00001000          ORG      $1000
2 00001000 6006          BRA      *+8          ;"*" location counter
3 00001002 60FE          BRA      *          ;branch to itself
4 00001004 6000FFFE  HERE  BRA      HERE          ;branch to itself
5 00001008 181B          MOVE.B  (A3)+,D4      ;indirect addressing
6 00000064          COUNT EQU      100          ;equate symbol to value
7 0000100A 3A3C0064      MOVE.W  #COUNT,D5      ;symbol as immed. data
8 0000100E 3A3C0064      MOVE.W  #100,D5          ;decimal
9 00001012 3A3C0064      MOVE.W  #$64,D5          ;hexadecimal
10 00001016 3A3C0064      MOVE.W  #144Q,D5         ;octal (A68K format)
11 0000101A 3A3C0064      MOVE.W  #%01100100,D5    ;binary
12 0000101E 3E3CFFFB      MOVE.W  #-5,D7          ;negative number, decimal
13 00001022 3E3CFFFB      MOVE.W  #$FFFB,D7       ;negative number, decimal
14 00001026 3A390000      MOVE   $F000,D5        ;data address
    0000102A F000
15 0000F000          PORT  EQU      $F000          ;equate symbol as address
16 0000102C 3A390000      MOVE   PORT,D5         ;data address (symbol)
    00001030 F000
17 00001032 4E71          BACK  NOP          ;code address (NOP =
18 00001034 4E71          NOP          ; no operation)
19 00001036 67FA          BEQ   BACK
20 00001038          END

```

F4-4

# Assemble-Time Operators

Operator†	Function	Precedence	Type
-	Unary minus	1	Unary
.NOT.	Logical NOT	1	Unary
.LOW.	Low byte	1	Unary
.HIGH.	High byte	1	Unary
.LWRD.	Low word	1	Unary
.HWRD.	High word	1	Unary
*	Multiplication	3	Binary
/	Division	3	Binary
+	Addition	4	Binary
-	Subtraction	4	Binary
.MOD.	Modulo	3	Binary
.SHR.	Logical shift right	3	Binary
.SHL.	Logical shift left	3	Binary
.AND.	Logical AND	5	Binary
.OR.	Logical OR	6	Binary
.XOR.	Logical XOR	6	Binary
.EQ.	Equal††	7	Binary
.NE.	Not Equal††	7	Binary
.GE.	Greater or equal††	7	Binary
.LE.	Less or equal††	7	Binary
.GT.	Greater than††	7	Binary
.LT.	Less than††	7	Binary
.UGT.	Unsigned greater than††	7	Binary
.ULT.	Unsigned less than††	7	Binary

†Operators apply to A68K. Different assemblers may support different operators.

††Relational operators return 1s (true) or 0s (false).

T4-1

## Examples of Assemble-Time Operators

```
1 00000064          COUNT      EQU      100
2 00002000          ORG        $2000
3 00002000 3A3CFFFF  MOVE     #-1,D5
4 00002004 3A3C0009  MOVE     #4+50/10,D5
5 00002008 3A3C0001  MOVE     #25.mod.6,D5
6 0000200C 3A3C0400  MOVE     #$8000.shr.5,D5
7 00002010 3A3C0040  MOVE     #$45&$F0,D5
8 00002014 3A3C0041  MOVE     #.high.'AB',D5
9 00002018 3A3CFFFF  MOVE     #5.gt.4,D5
10 0000201C 3A3C0032  MOVE     #COUNT/2,D5
11 00002020          END
```

F4-5

# Assembler Directives

Directive	Operation	Syntax
ORG	set program origin	ORG value
EQU	equate value to symbol	symbol EQU value
END	end of source program	END label
DC	define data constant	[label] DC number[,number][...]
DS	define RAM storage	[label] DS count
RSEG	begin relocatable segment	RSEG name
EXTERN	define external symbol	EXTERN symbol[,symbol][...]
PUBLIC	define public symbol	PUBLIC symbol[,symbol][...]

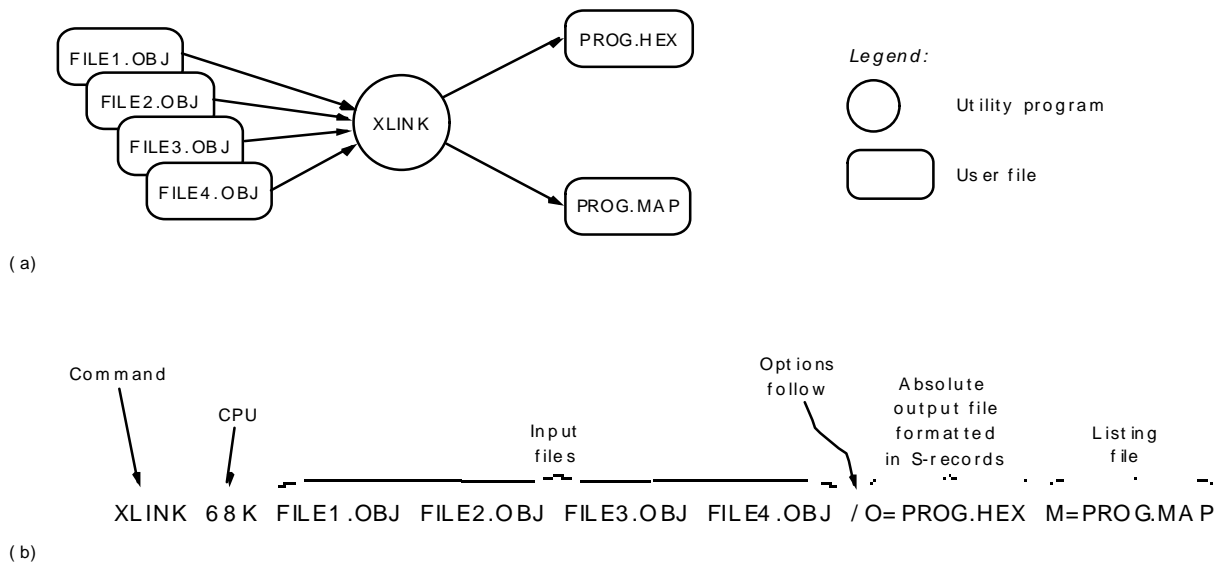
T4-2

# Listing Examples

	Address	Contents	*****	CH4-6.SRC	*****
1	00001000			ORG \$1000	
2	00001000	1A3C0064	START	MOVE.B #100,D5	
3	00000064		COUNT	EQU 100	
4	00002000			ORG \$2000	
5	00002000	1A3C0064	HERE	MOVE.B #COUNT,D5	
6	0000000D		CR	EQU \$0D	define a symbol
7	00003000			ORG \$3000	set origin
8	00003000	0005FFFF	NUM	DC 5,-1	word size default
9	00003004	05FF	MORE	DC.B 5,-1	byte size constants
10	00003006	4A4F484E	NAME	DC.B 'JOHN'	ASCII string
11	0000300A	0D00		DC.B CR,0	CR is a symbol
12	00004001			ORG \$4001	
13	00004002	000F	VALUE	DC 15	decimal constant
14	00005000			ORG \$5000	
15	00005000	6100		DC.W 'a'	
16	00000050		LENGTH	EQU 80	
17	00006000			ORG \$6000	
18	00006000		BUFFER	DS.B LENGTH	
19	00006050		TEMP	DS.B 1	
20	00007000			ORG \$7000	
21	00007000	7250		MOVE.L #LENGTH,D1	use R1 as counter
22	00007002	327C6000		MOVEA #BUFFER,A1	A1 points to buff
23	00007006	12FC0000	LOOP	MOVE.B #0,(A1)+	clear location
24	0000700A	5301		SUBQ.B #1,D1	done?
25	0000700C	66F8		BNE LOOP	no: clear again
26	00000000			RSEG EPROM	
27	00000000	1A3C002C	BEGIN	MOVE.B #44,D5	
28	00000004			END	

F4-8

# Linker Operation



F4-10

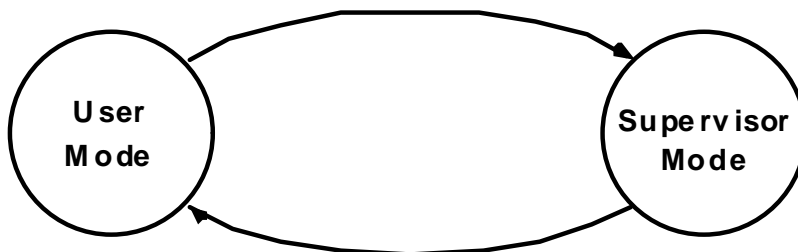
## User Mode vs. Supervisor Mode

Feature	User Mode	Supervisor Mode
Entered by	Clearing S-bit in SR	Exception processing
FC2 =	0	1
Active stack pointer	USP	SSP
Other stacks using	A0 - A6	USP, A0-A6
SR access Read: Write:	Entire SR CCR bits only	Entire SR Entire SR
Instructions available	All except  AND #data,SR EOR #data,SR MOVE <ea>,SR MOVE USP,An MOVE An,USP OR #data,SR RESET RTE STOP	All

T6-1

# Changing Between User Mode and Supervisor Mode

Transition may occur only  
during exception processing

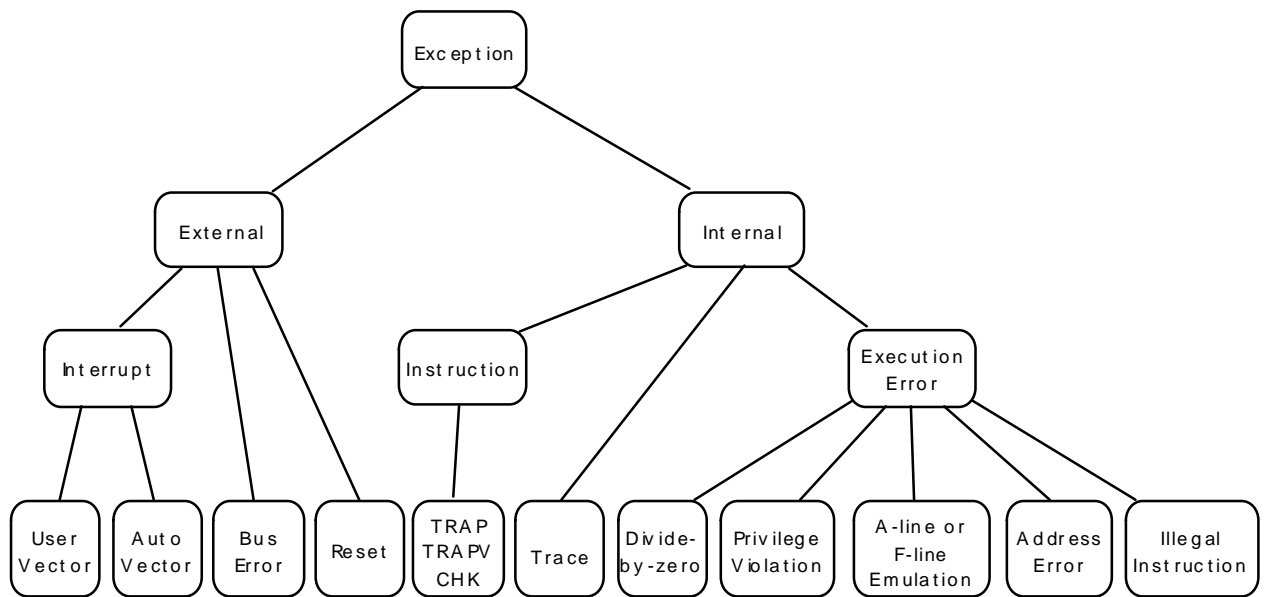


Transition may occur  
through four instructions:

MOVE to SR  
ANDI to SR  
EOR to SR  
RTE

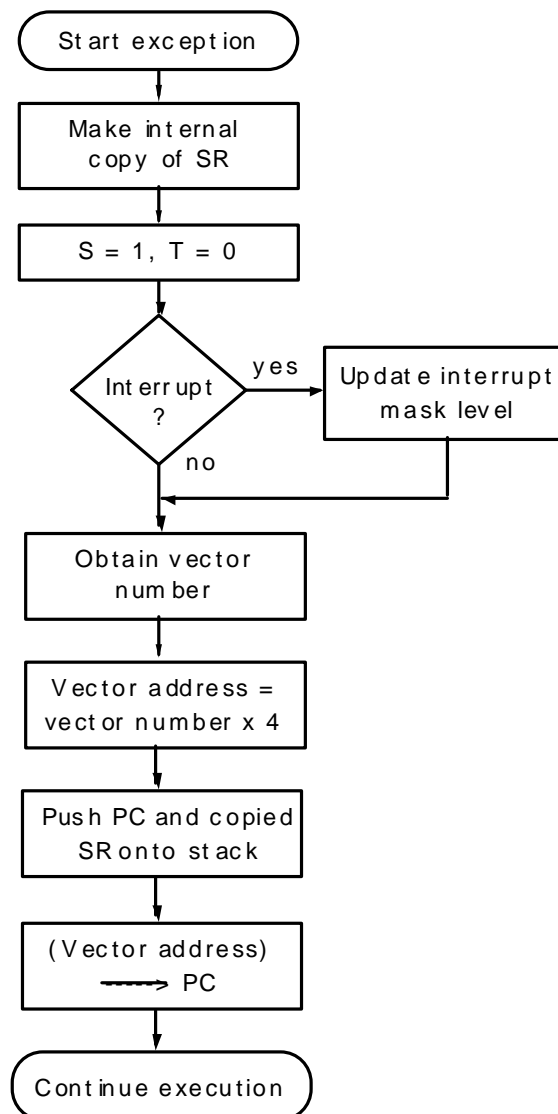
F6-1

# Exception Tree



F6-2

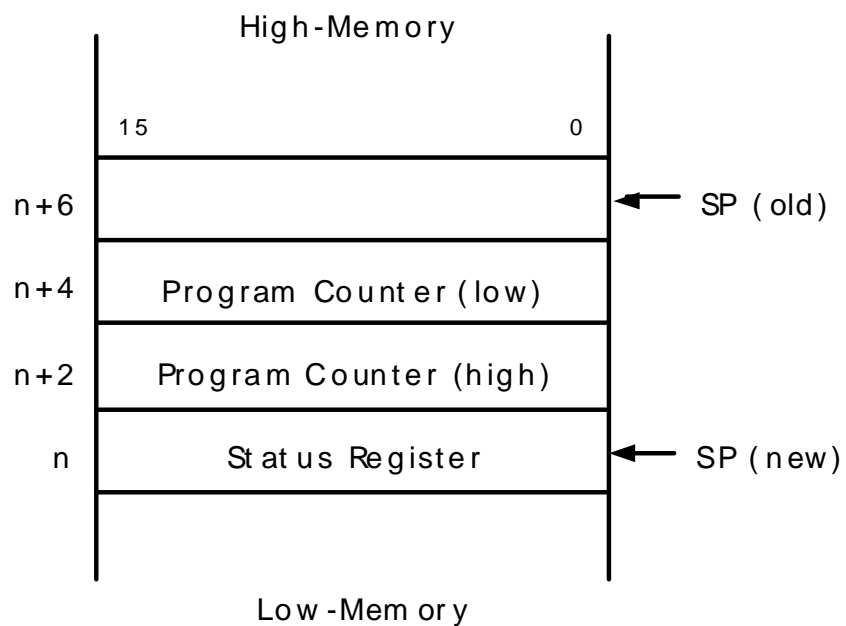
# Exception Processing Sequence



F6-3

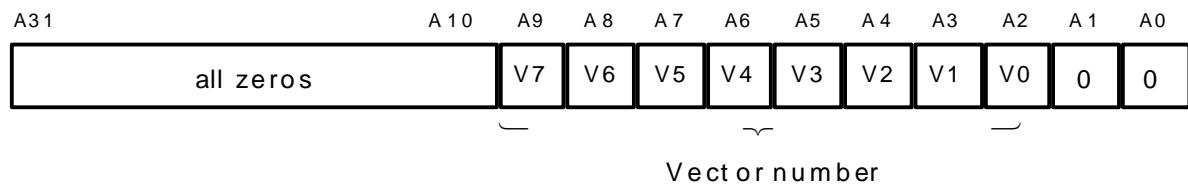
# Stack Frame for Exceptions

(except bus error and address error)



F6-4

# Exception Vector Address



F6-5

# Reset and Exception Vector Assignments

Vector Number	Hexadecimal Address	Assignment
0	000	Reset SSP <sup>†</sup>
–	004	Reset PC <sup>†</sup>
2	008	Bus Error
3	00C	Address Error
4	010	Illegal instruction
5	014	Divide-by-zero
6	018	CHK instruction
7	01C	TRAPV instruction
8	020	Privilege violation
9	024	Trace
10	028	Line 1010 emulator
11	02C	Line 1111 emulator
12	030	(reserved)
13	034	(reserved)
14	038	Format error (68010)
15	03C	Uninitialized interrupt vector
16-23	040-05C	(reserved)
24	060	Spurious interrupt <sup>††</sup>
25	064	Level 1 interrupt autovector
26	068	Level 2 interrupt autovector
27	06C	Level 3 interrupt autovector
28	070	Level 4 interrupt autovector
29	074	Level 5 interrupt autovector
30	078	Level 6 interrupt autovector
31	07C	Level 7 interrupt autovector
32-47	080-0BC	TRAP instruction vectors <sup>†††</sup>
48-63	0C0-0FC	(reserved)
64-255	100-3FC	User interrupt vectors

<sup>†</sup> The reset vector is four words and resides in the supervisor program (SP) space. All other vectors reside in the supervisor data (SD) space.

<sup>††</sup> The spurious interrupt vector is taken when there is a bus error during an interrupt acknowledge cycle.

<sup>†††</sup> Trap #n uses vector number 32 + n. See Table 6-5.

## Exception Grouping and Priority

Group	Exception	Processing
0	Reset Address Error Bus Error	Exception processing begins within two CPU cycles
1	Trace Interrupt Illegal Instruction Privilege Violation	Exception processing begins before the next instruction
2	TRAP, TRAPV CHK Zero Divide	Exception processing begins by normal instruction execution

T6-3

## Traps vs. Subroutines

<b>Features</b>	<b>Traps</b>	<b>Subroutines</b>
Initiated from	user mode or supervisor mode	user mode or supervisor mode
Routine executes in	supervisor mode	user mode or supervisor mode
Registers saved	PC and SR	PC
Registers saved on	system stack	user stack or system stack
Routine ends with	RTE	RTS
Privilege state after is	user mode or supervisor mode	user mode or supervisor mode

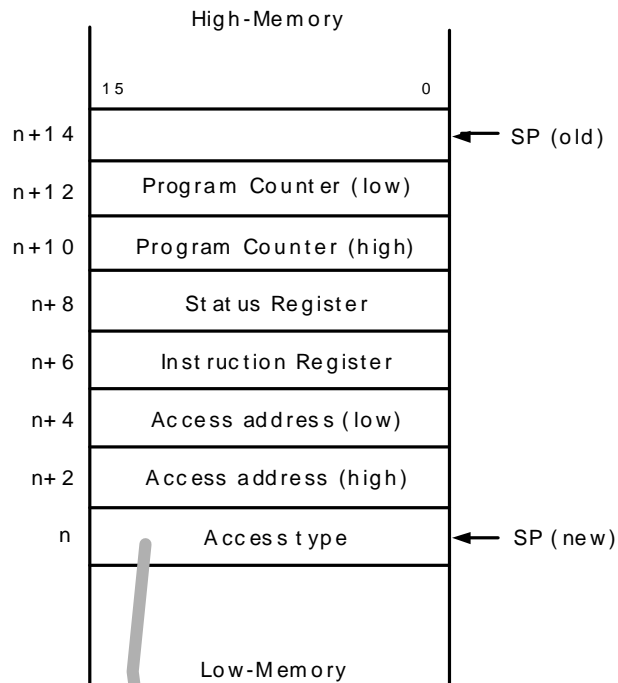
T6-4

# Vector Assignments for TRAP Instructions

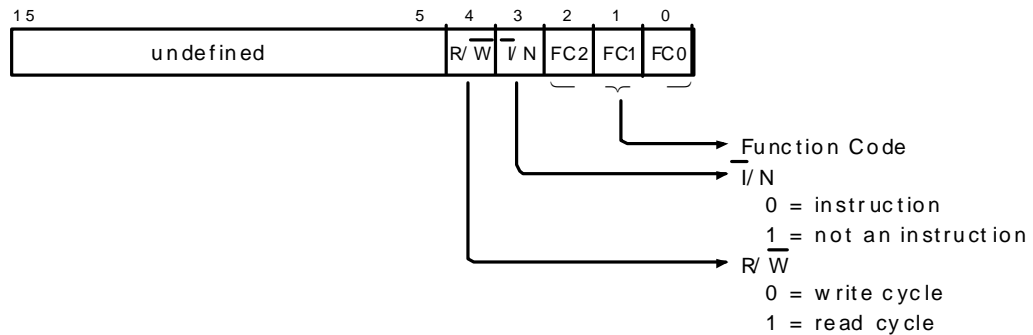
Instruction	Vector Number	Vector Address
TRAP #0	32	\$000080
TRAP #1	33	\$000084
TRAP #2	34	\$000088
TRAP #3	35	\$00008C
TRAP #4	36	\$000090
TRAP #5	37	\$000094
TRAP #6	38	\$000098
TRAP #7	39	\$00009C
TRAP #8	40	\$0000A0
TRAP #9	41	\$0000A4
TRAP #10	42	\$0000A8
TRAP #11	43	\$0000AC
TRAP #12	44	\$0000B0
TRAP #13	45	\$0000B4
TRAP #14	46	\$0000B8
TRAP #15	47	\$0000BC

T6-5

# Stack Frame for Bus Error and Address Error



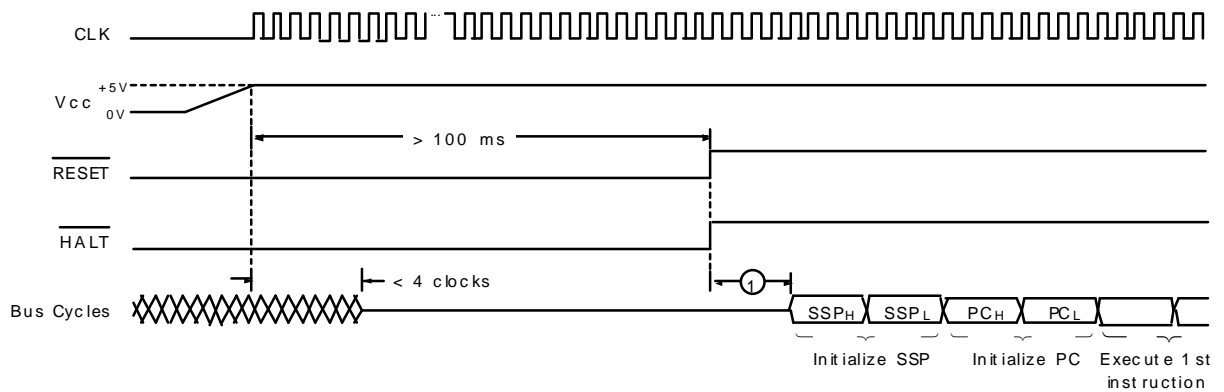
(a)



(b)



# Power-on Reset Timing



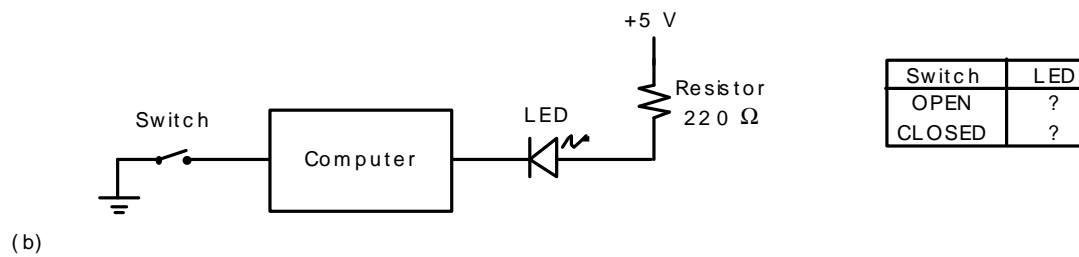
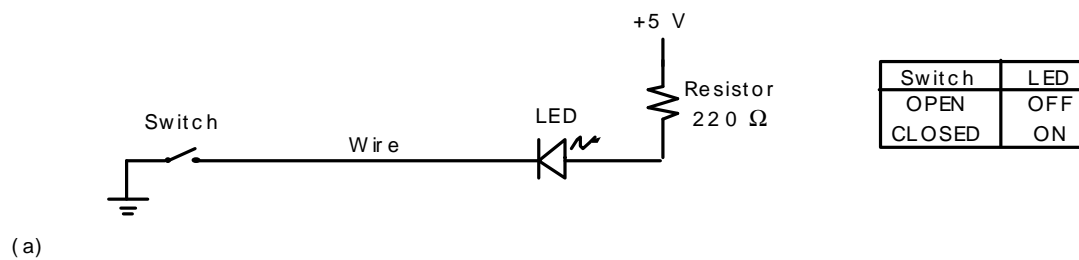
Legend:

- ① Internal start-up time
- XXXX Bus state unknown

- ⎓ All control signals inactive. Data bus in read mode
- ▭ Bus cycle (memory read or memory write)

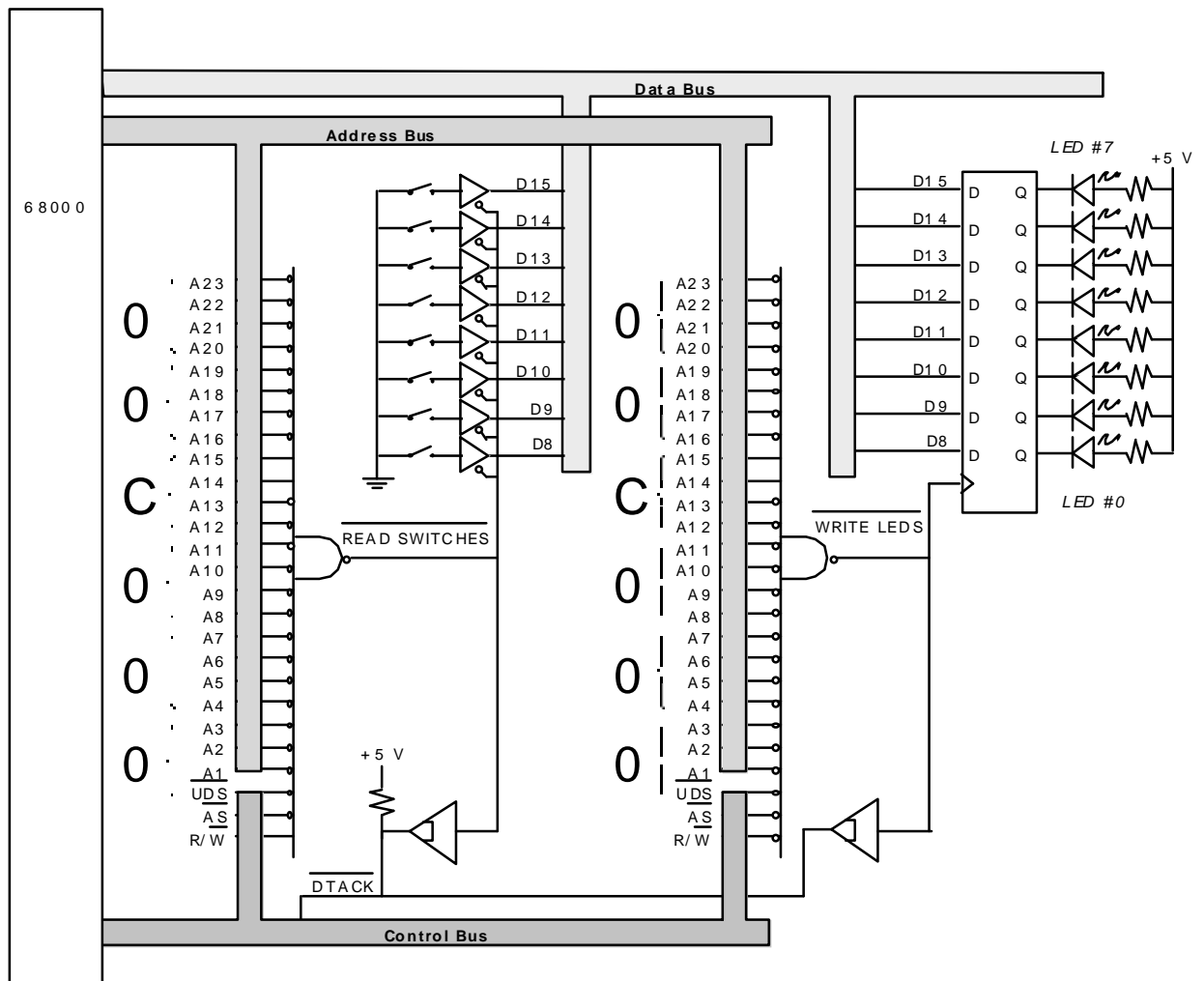
F6-7

# A Switch as an Input Device and an LED as an Output Device



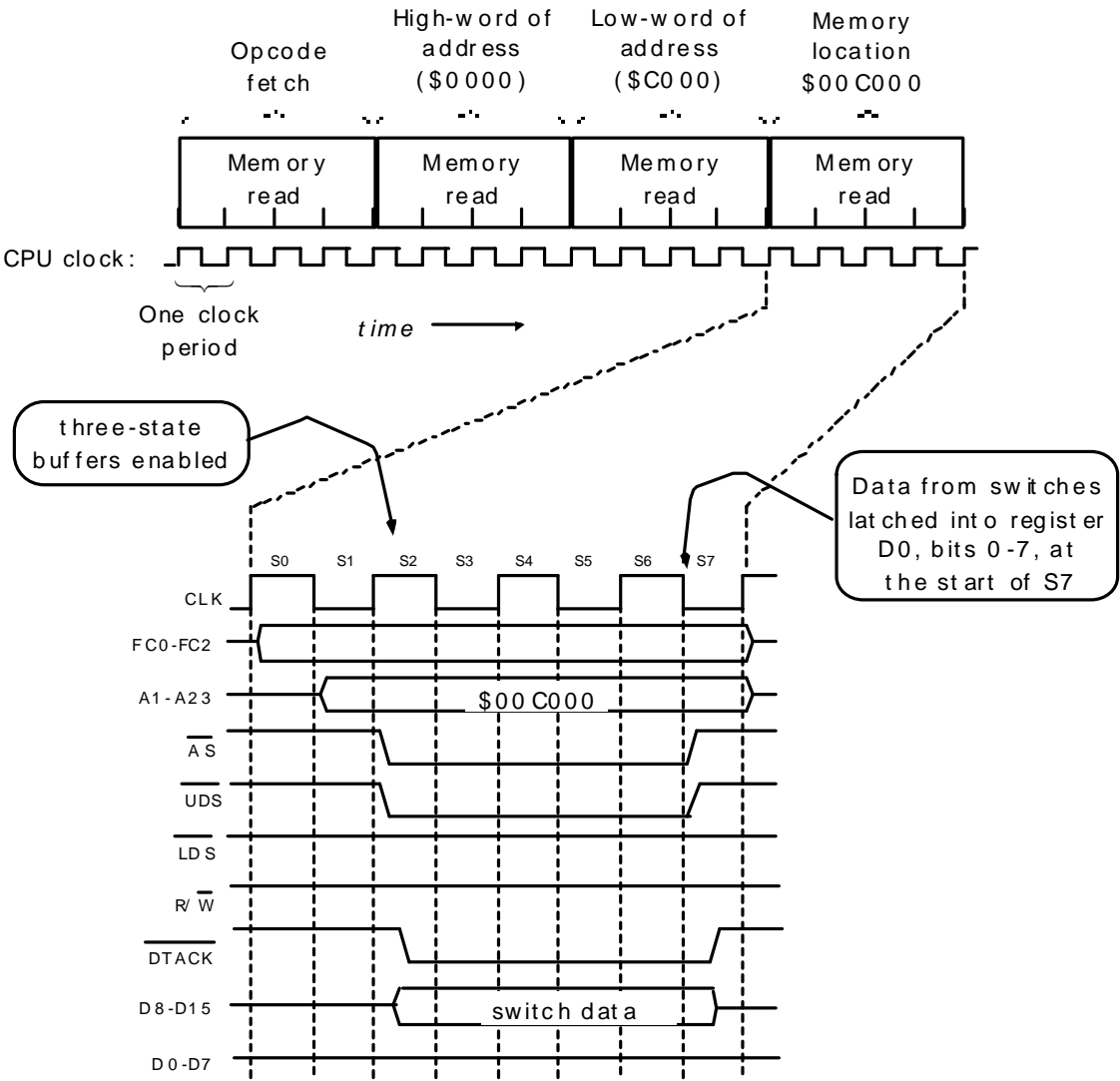
F7-1

# Interface to Switches and LEDs (conceptual)

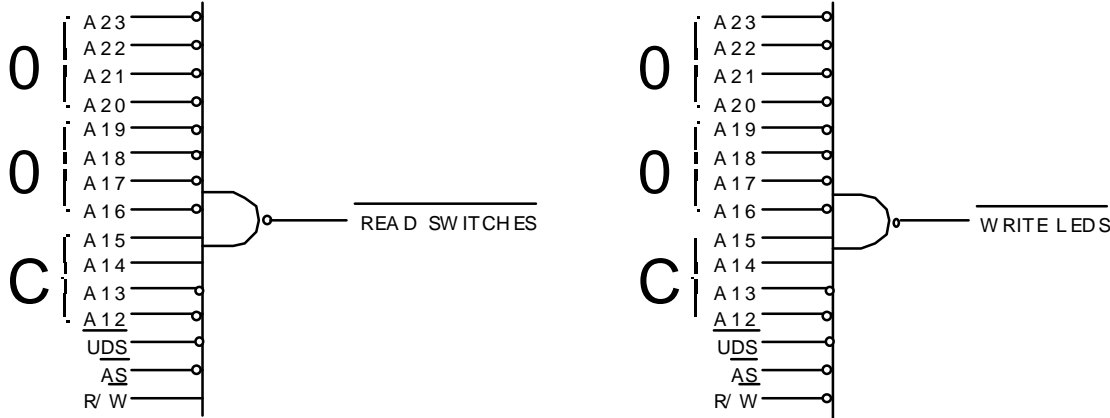


F7-2

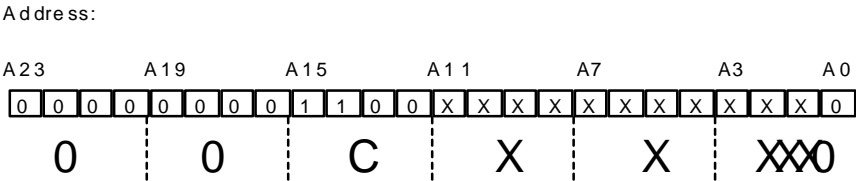
# Timing for MOVE.B \$00C000,D0



# Example of Partial Decoding



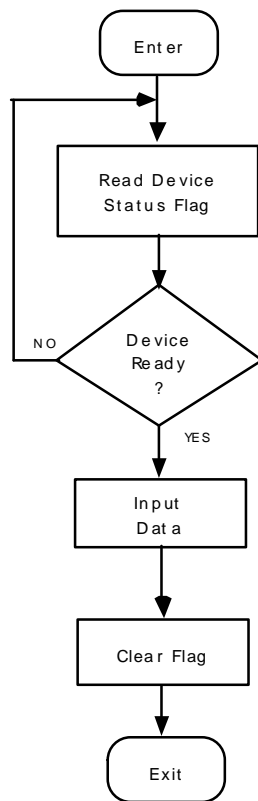
(a)



(b)

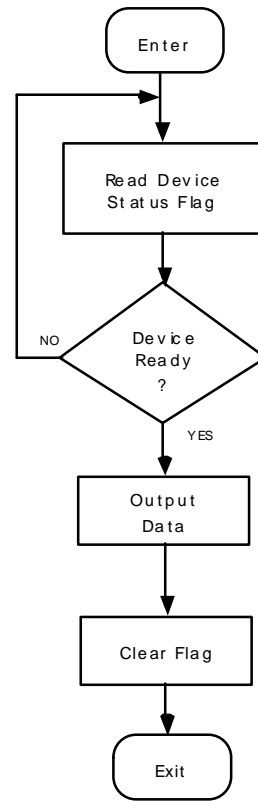
# Flowcharts for Program-Conditional I/O

Input Flowchart :



(a)

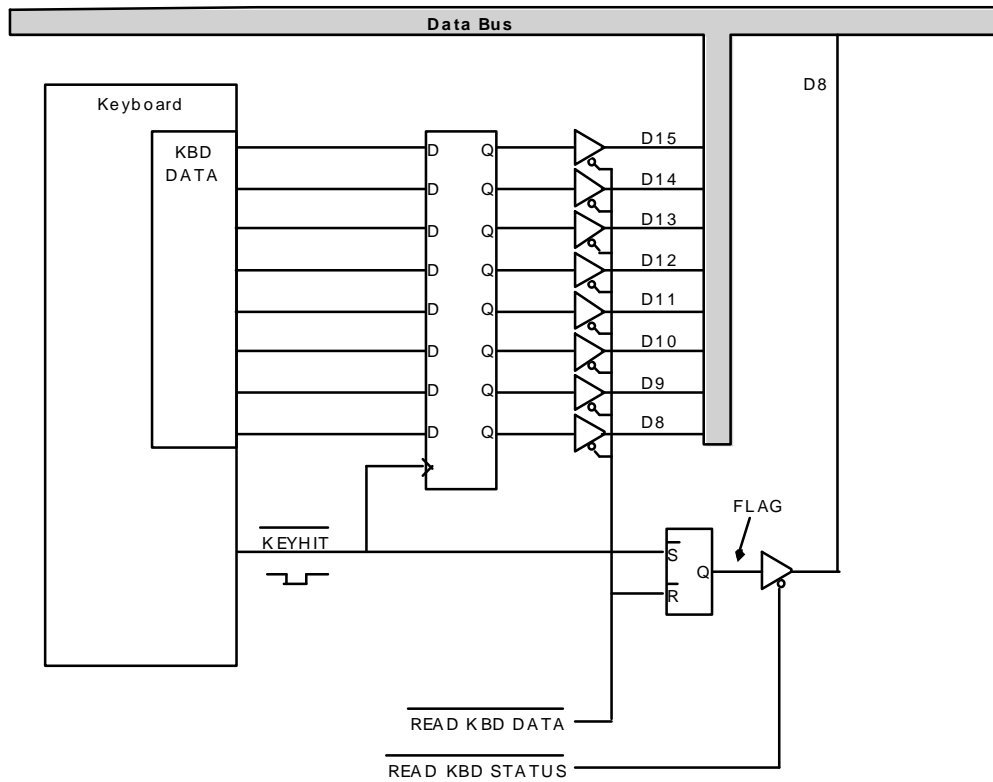
Output Flowchart:



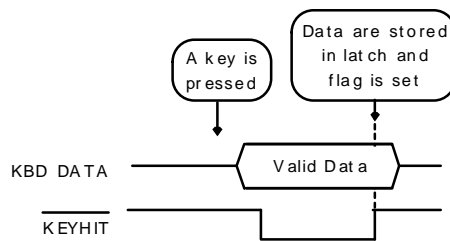
(b)

F7-7

# Keyboard Interface



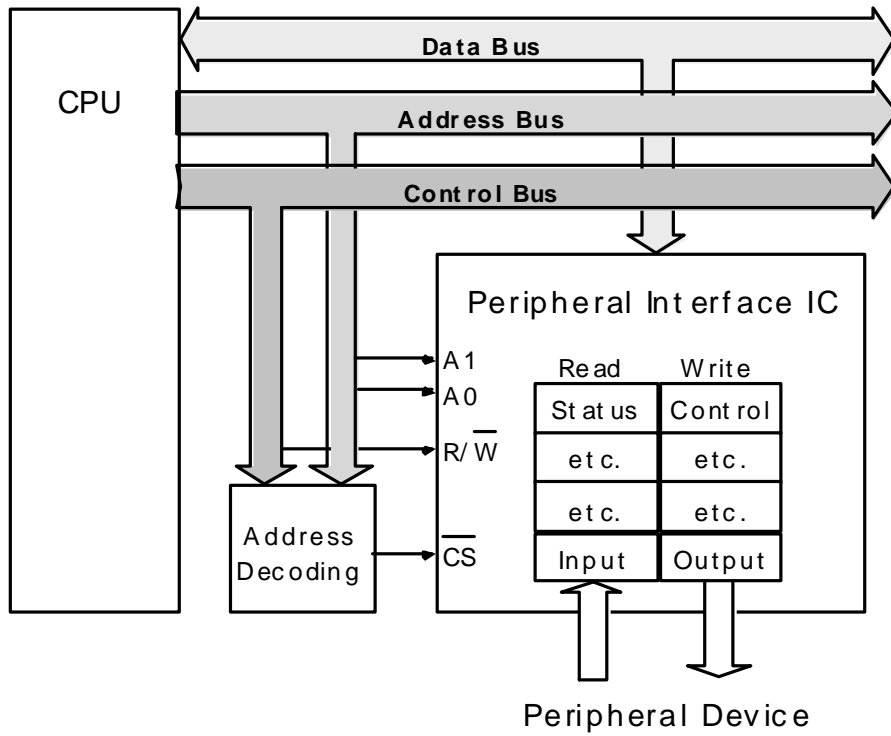
(a)



(b)

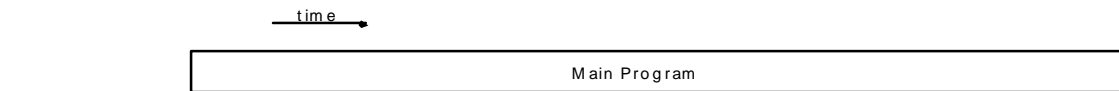
F7-6

# Interface Using a Peripheral Interface IC

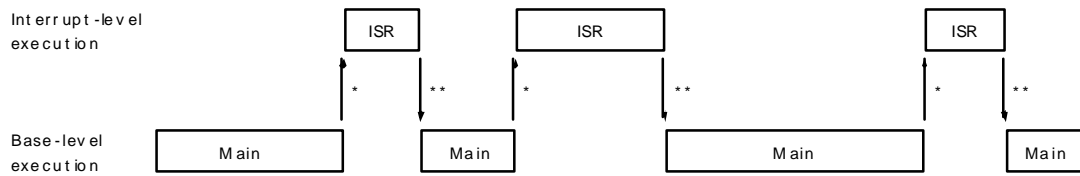


F7-9

# Program Execution Without Interrupts or With Interrupts



(a)



\* Interrupt  
\*\* Return from interrupt instruction

(b)

F7-11

## Interrupt Priority Conditions on - IPL2, -IPL1, and -IPL0

Signal			Interrupt	Condition	Maskable	Priority
$\overline{\text{IP2}}$	$\overline{\text{IP1}}$	$\overline{\text{IP0}}$				
1	1	1	0	No interrupt	-	-
1	1	0	1	Interrupt	Yes	Lowest
1	0	1	2	Interrupt	Yes	(etc.)
1	0	0	3	Interrupt	Yes	(etc.)
0	1	1	4	Interrupt	Yes	(etc.)
0	1	0	5	Interrupt	Yes	(etc.)
0	0	1	6	Interrupt	Yes	(etc.)
0	0	0	7	Interrupt	No	Highest

T7-3

## Autovectors for Automatic IACK Cycles

Interrupt	Vector Address (Autovector)
0	-
1	\$000064
2	\$000068
3	\$00006C
4	\$000070
5	\$000074
6	\$000078
7	\$00007C

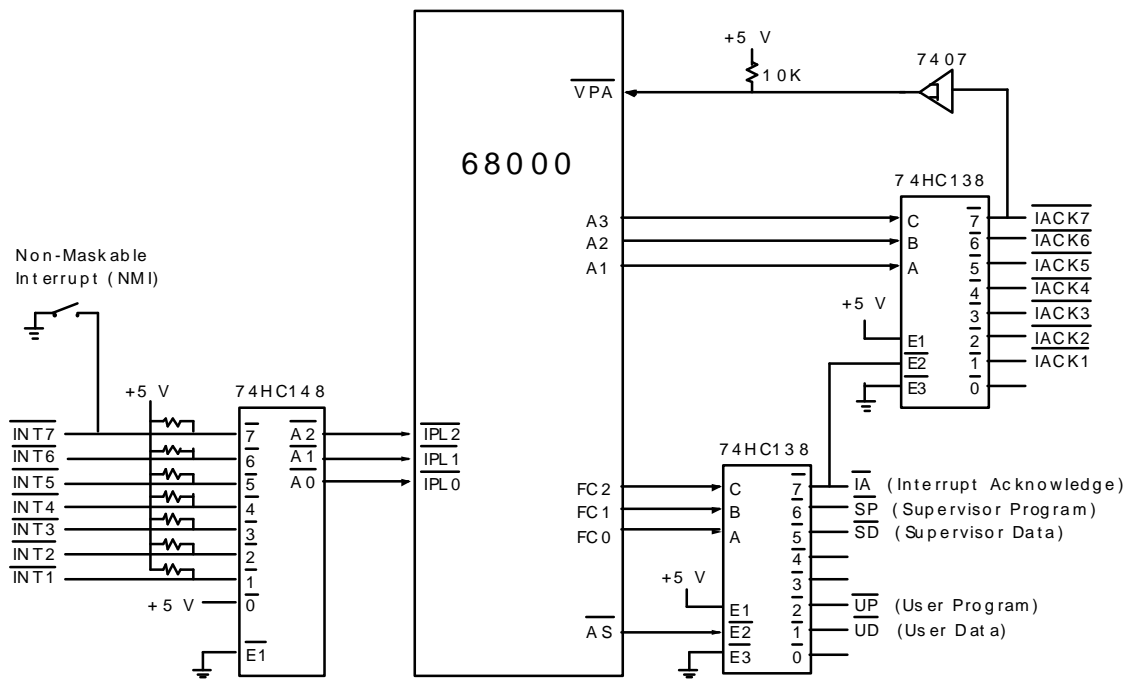
T7-4

## Vector Addresses for User IACK Cycles

Vector Number	Vector Address
0	\$000000
1	\$000004
2	\$000008
etc.	etc.
255	\$0003FC

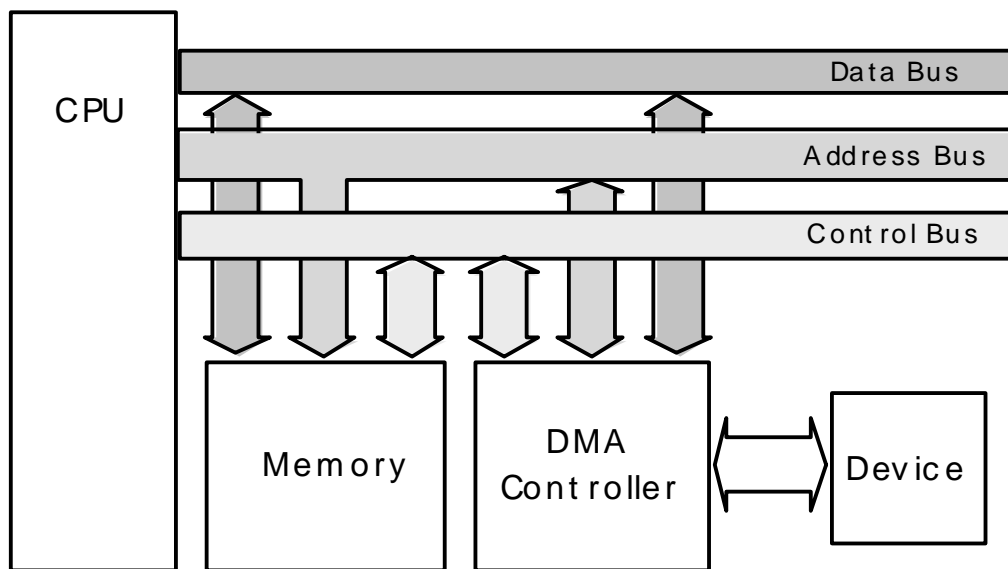
T7-5

# Interrupt Circuitry



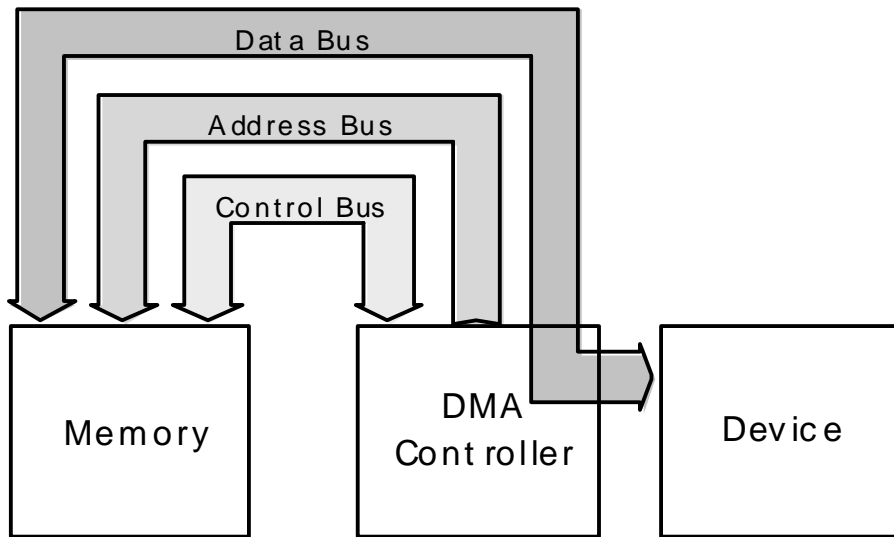
F7-12

# Bus Connections for DMA Interface



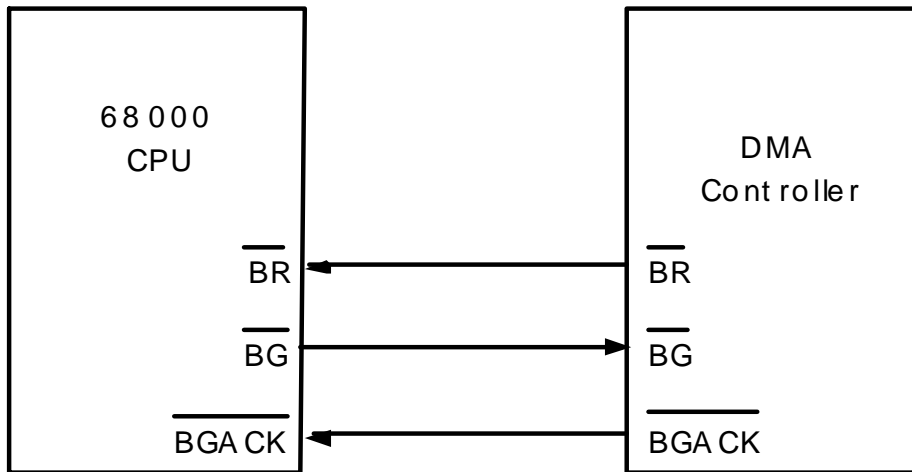
F7-13

# Device-to-Memory Transfer Using DMA



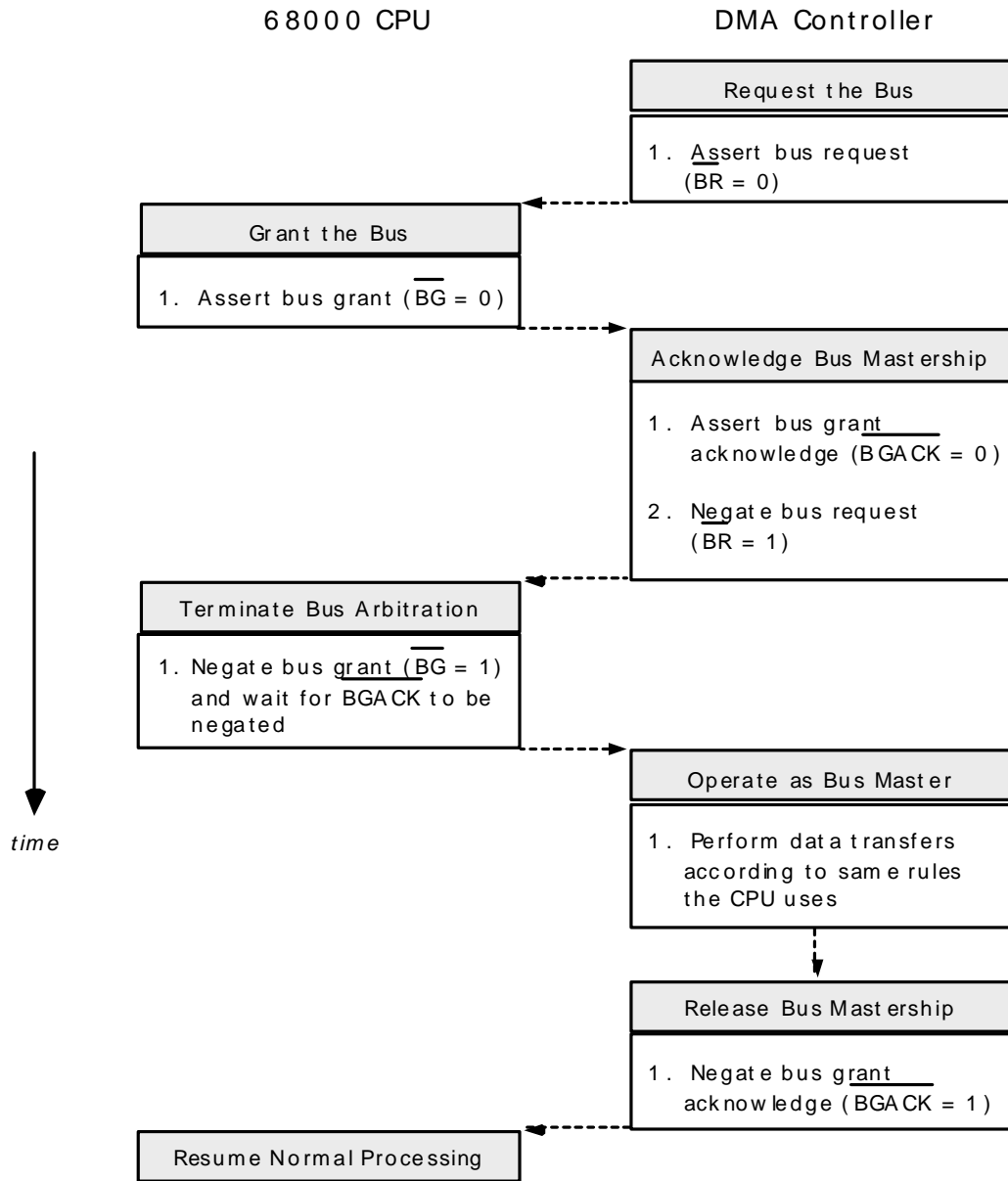
F7-14

# 68000 Bus Arbitration Control Signals

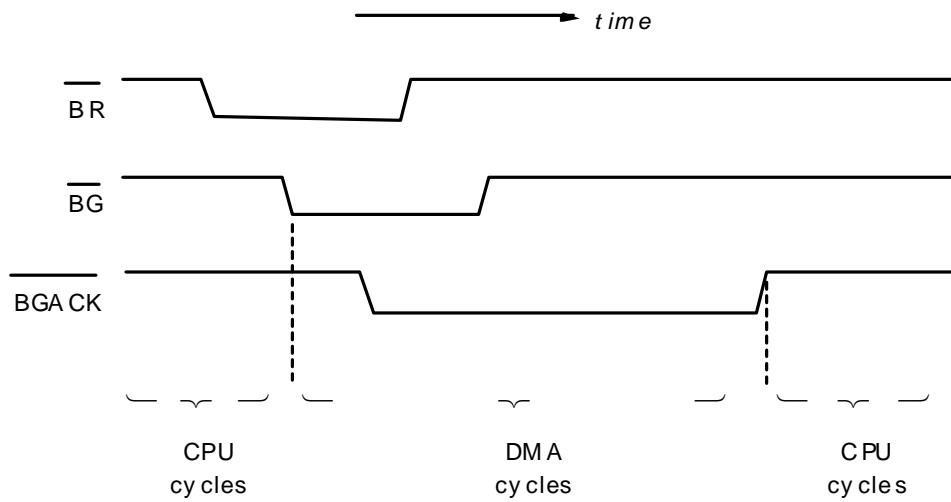


F7-15

# Bus Arbitration

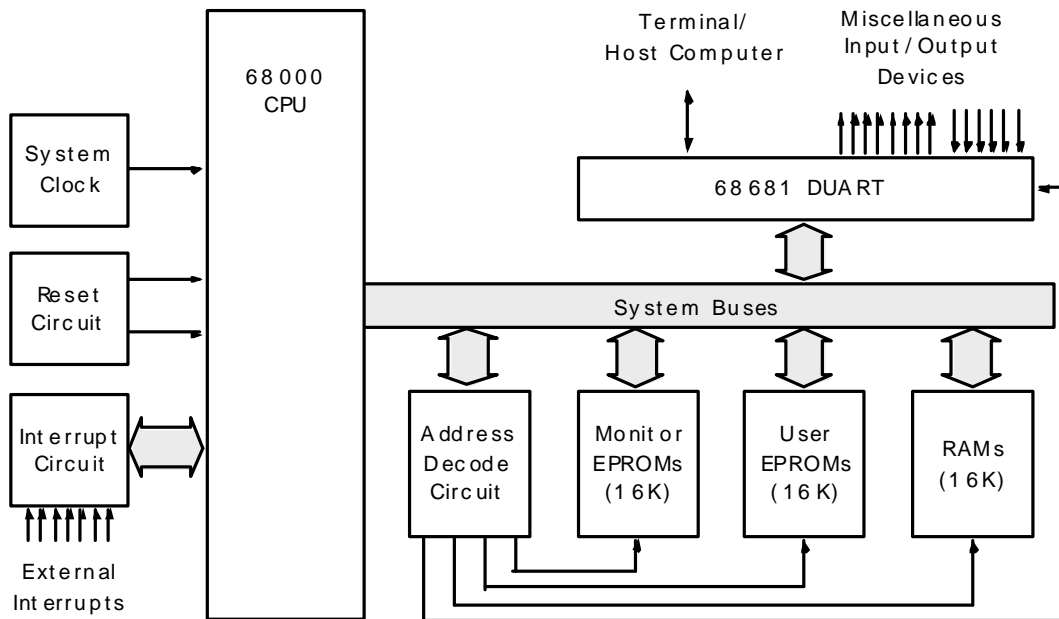


# Timing for Bus Arbitration



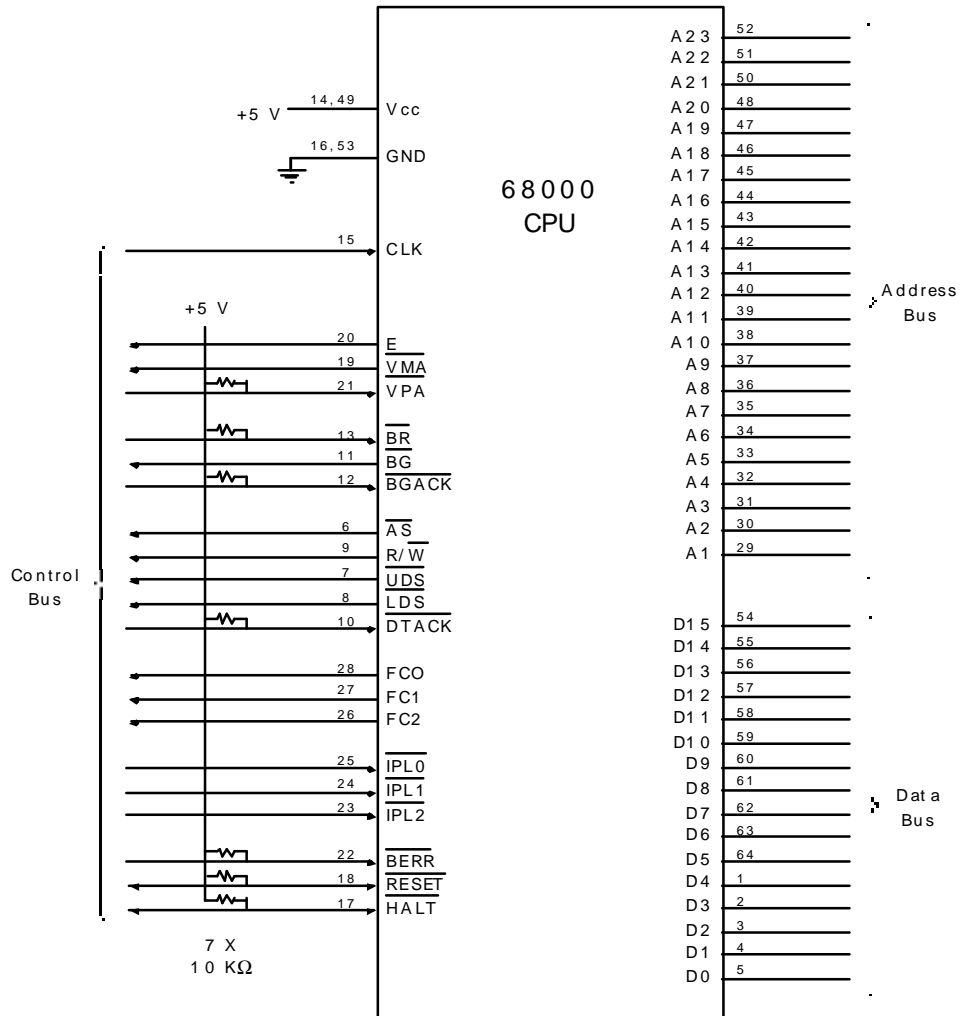
F7-17

# Block Diagram of the 68KMB



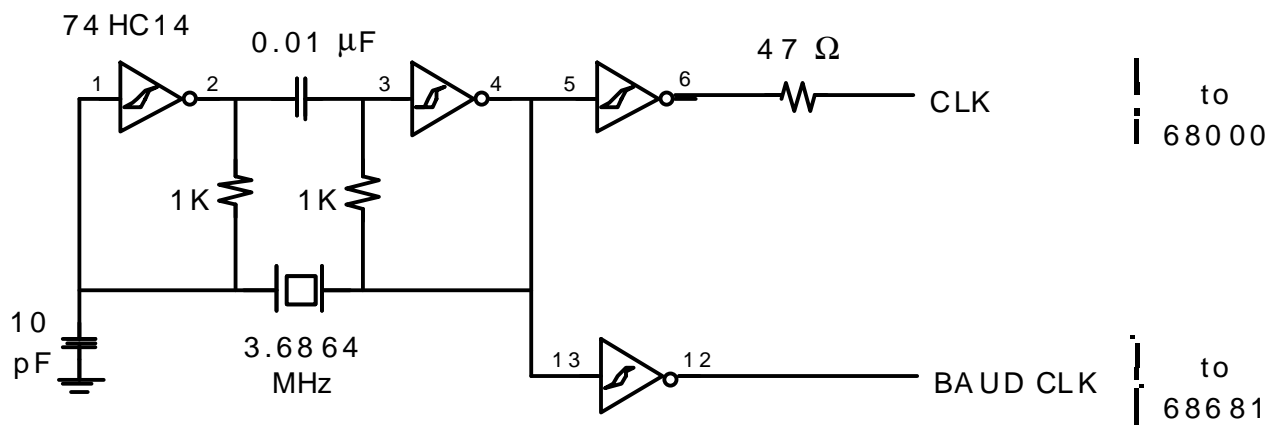
F8-3

# 68000 CPU



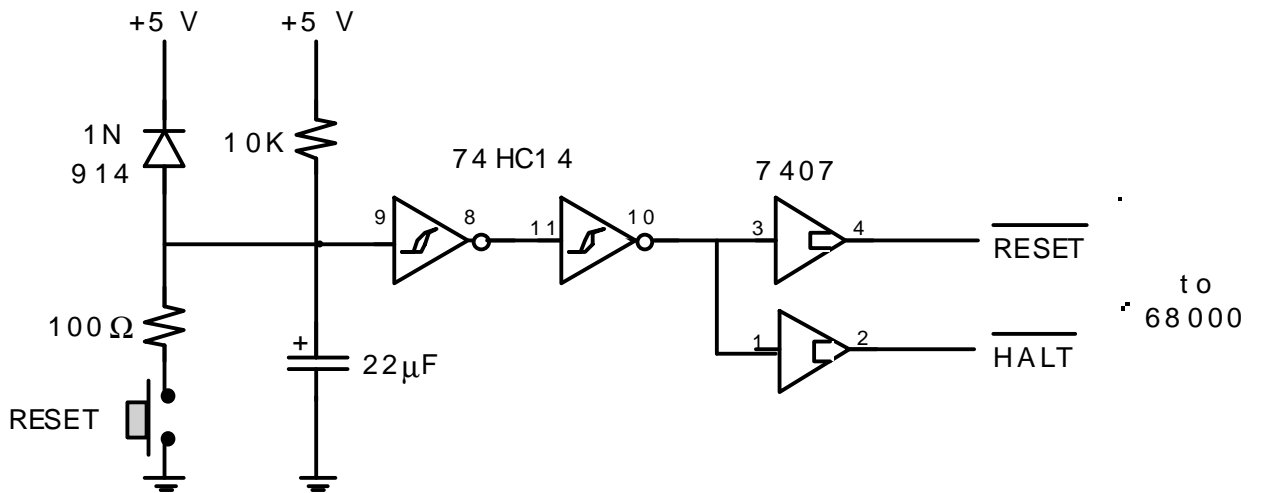
F8-4

# 68KMB Clock Circuit



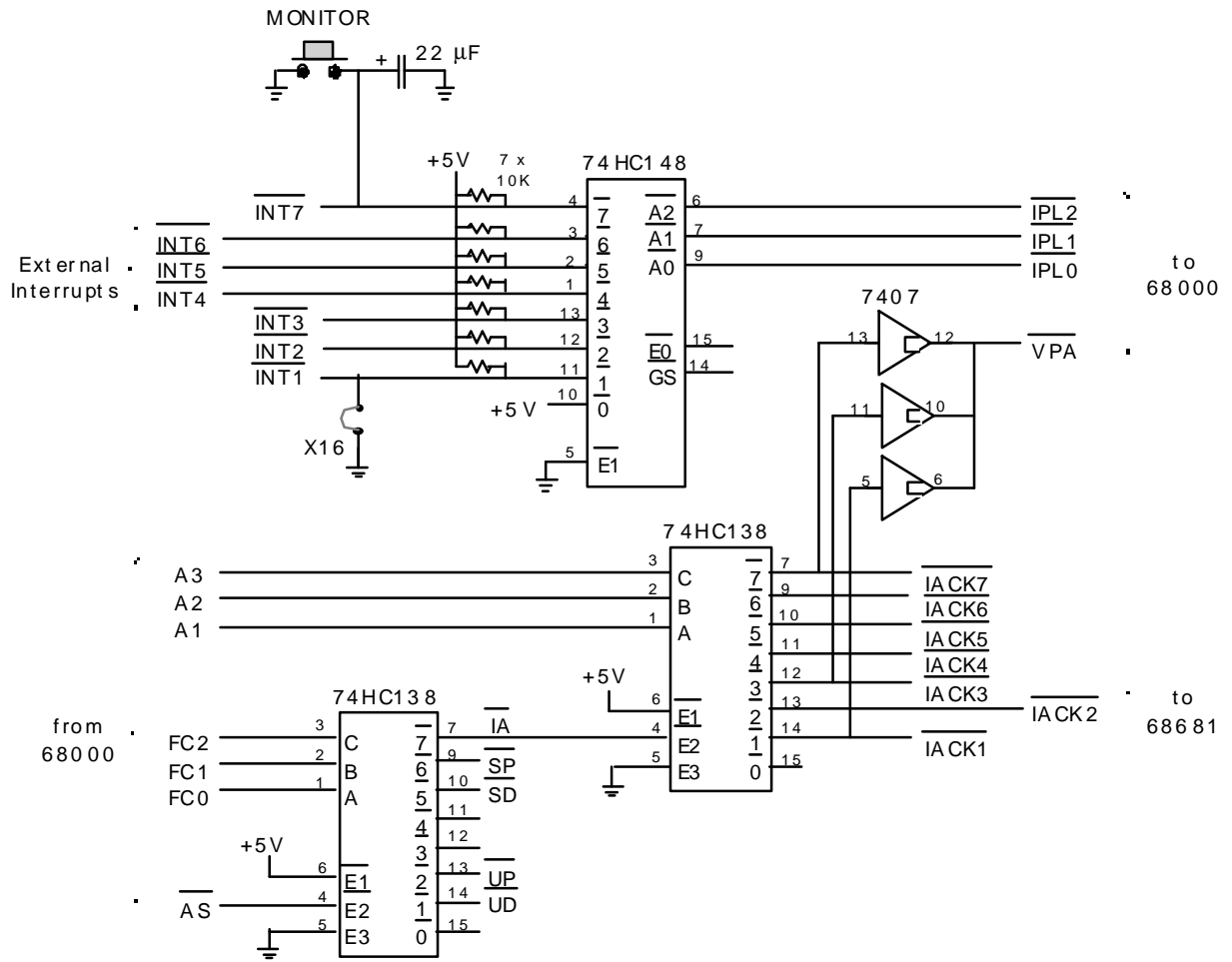
F8-6

# 68KMB Reset Circuit



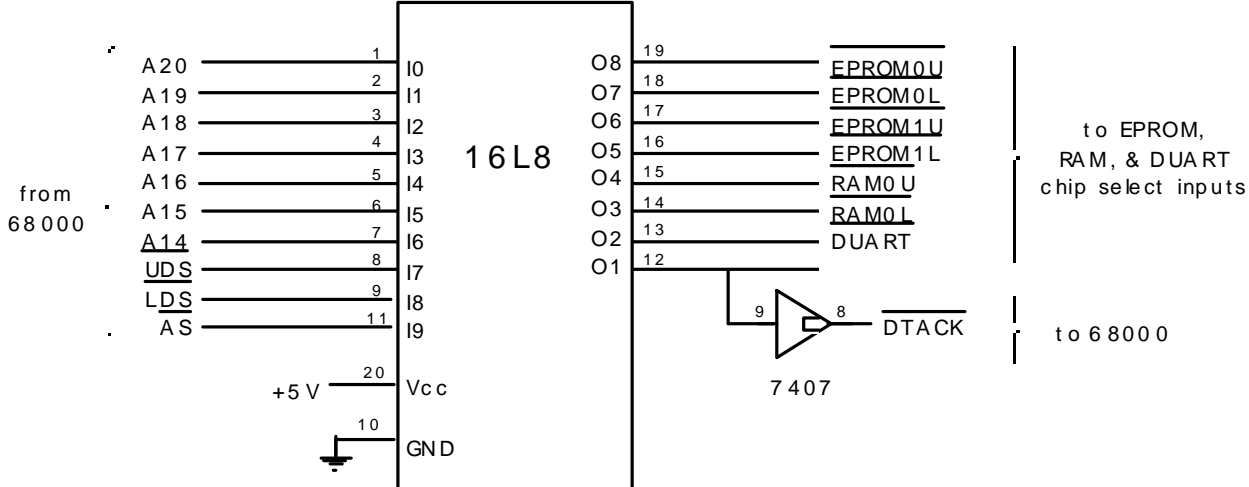
F8-7

# 68KMB Interrupt Circuit



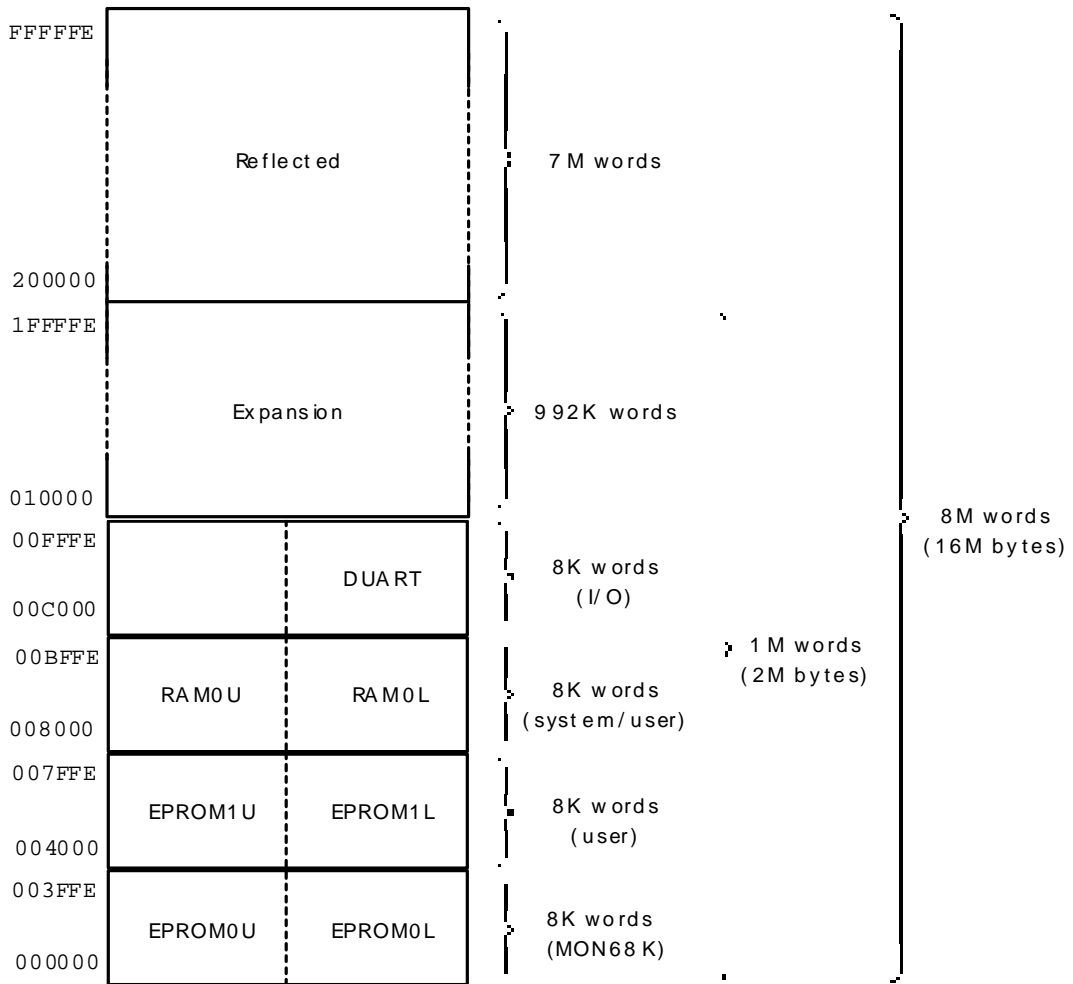
F8-8

# 68KMB Address Decoding

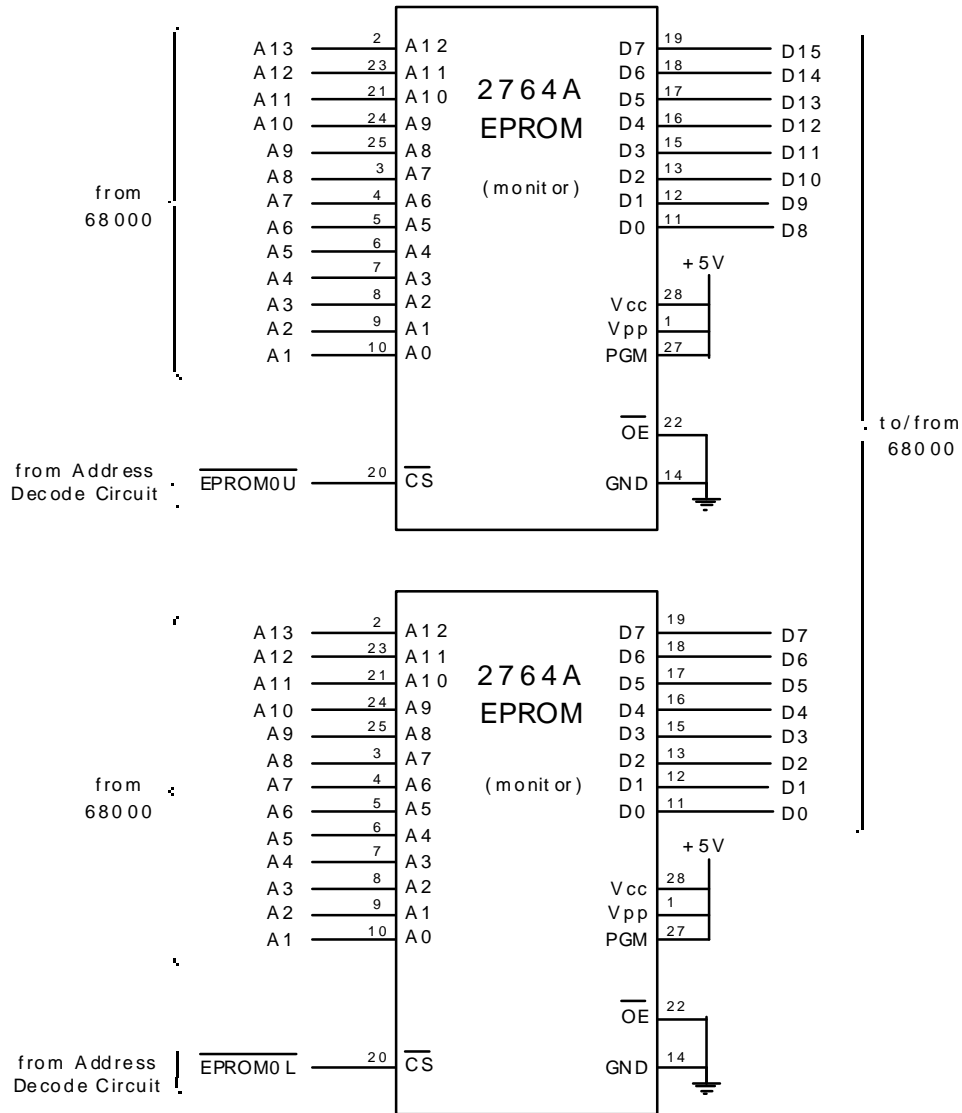


F8-9

# 68KMB Memory Map

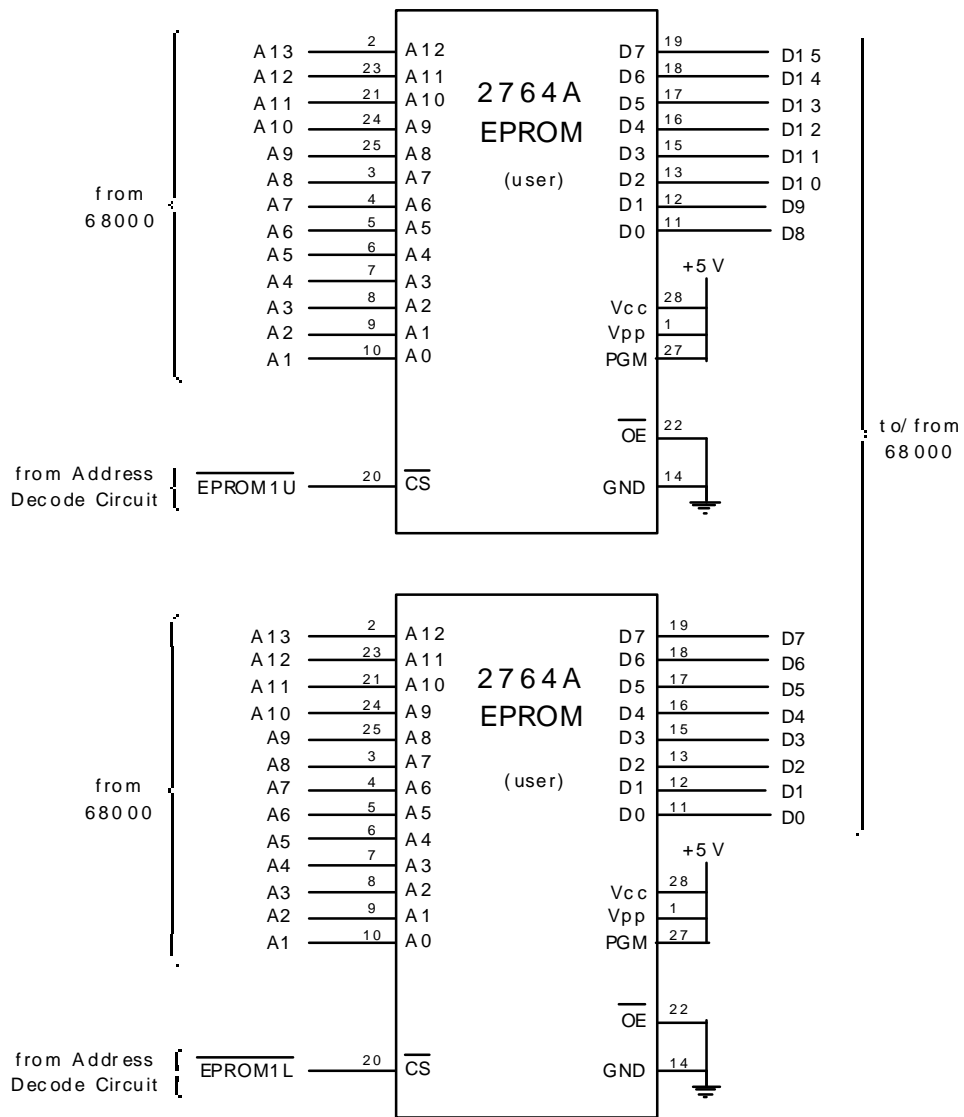


# Monitor EPROMs

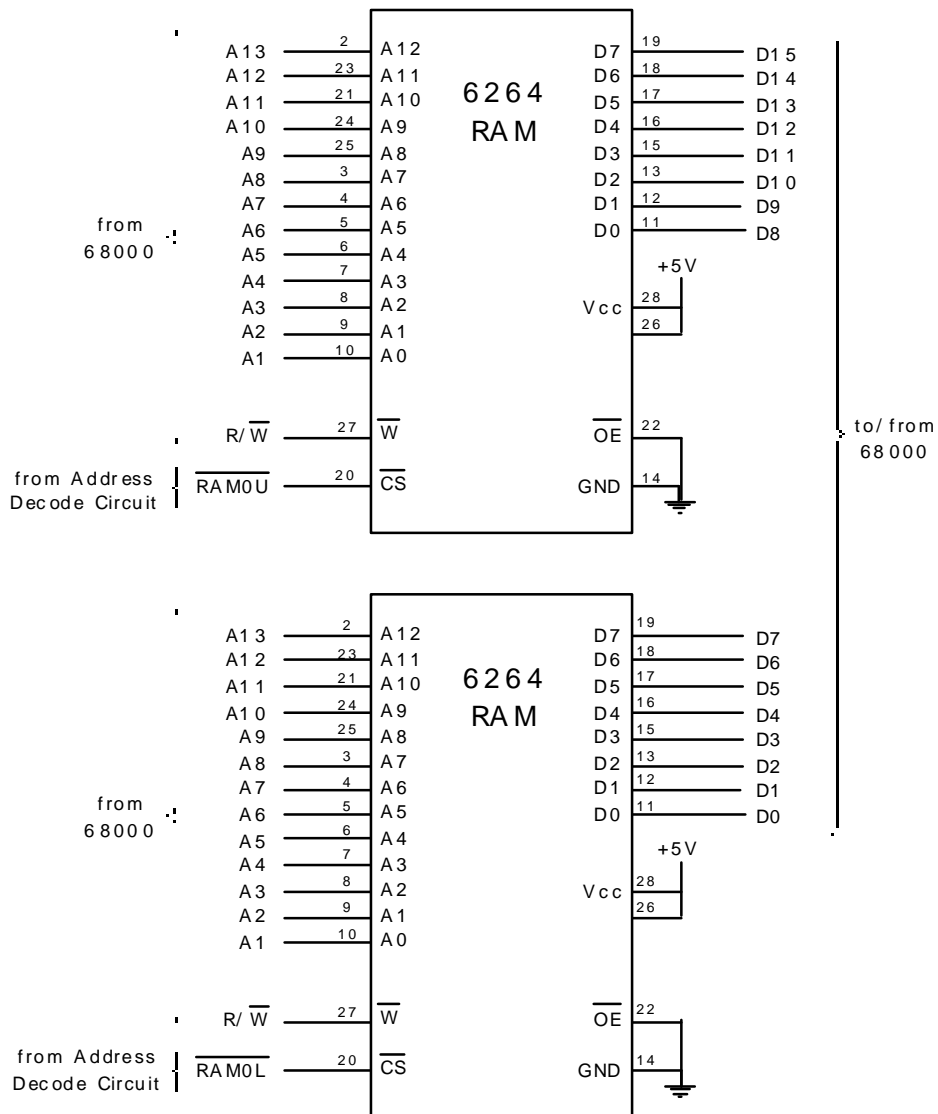


F8-12

# User EPROMs

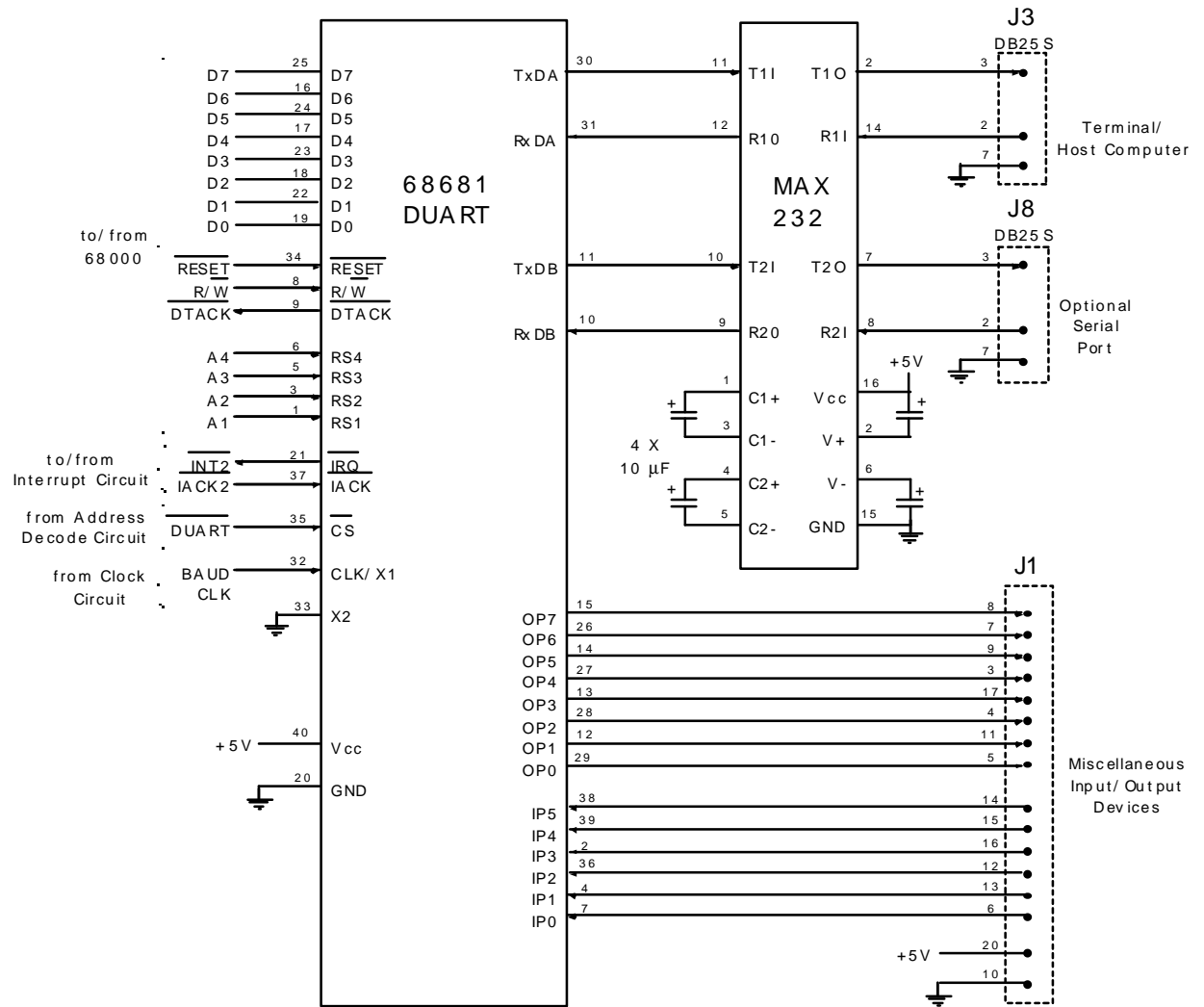


# System/User RAM



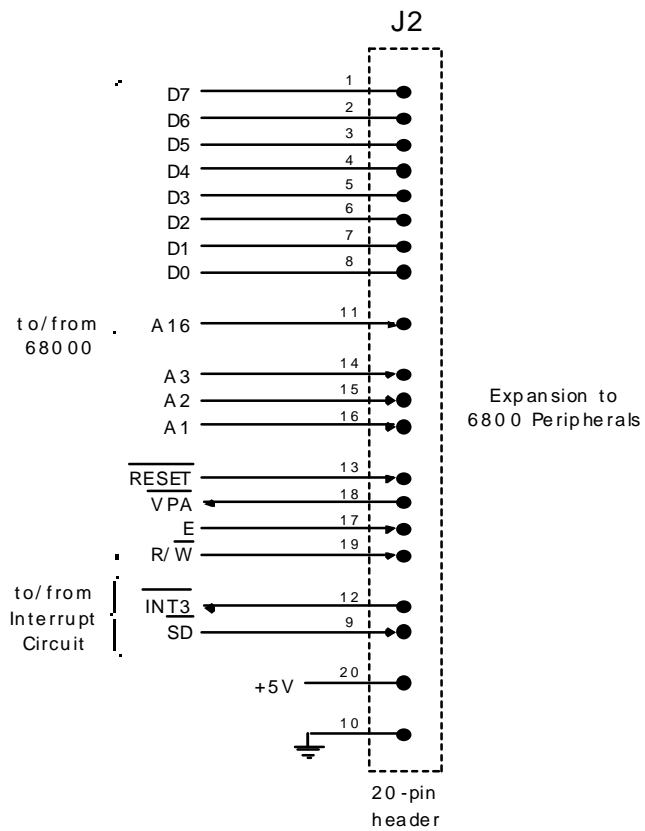
F8-14

# 68681 DUART



F8-15

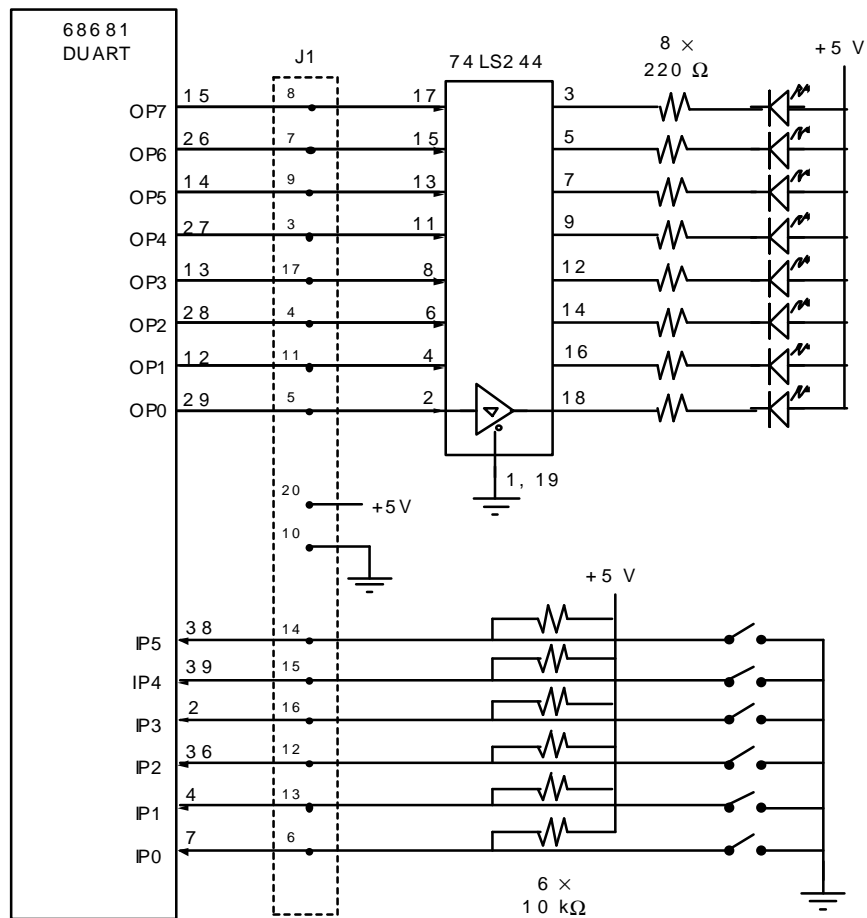
# Expansion to 6800 Peripherals



F8-16

# 68681 Interface to LEDs and Switches

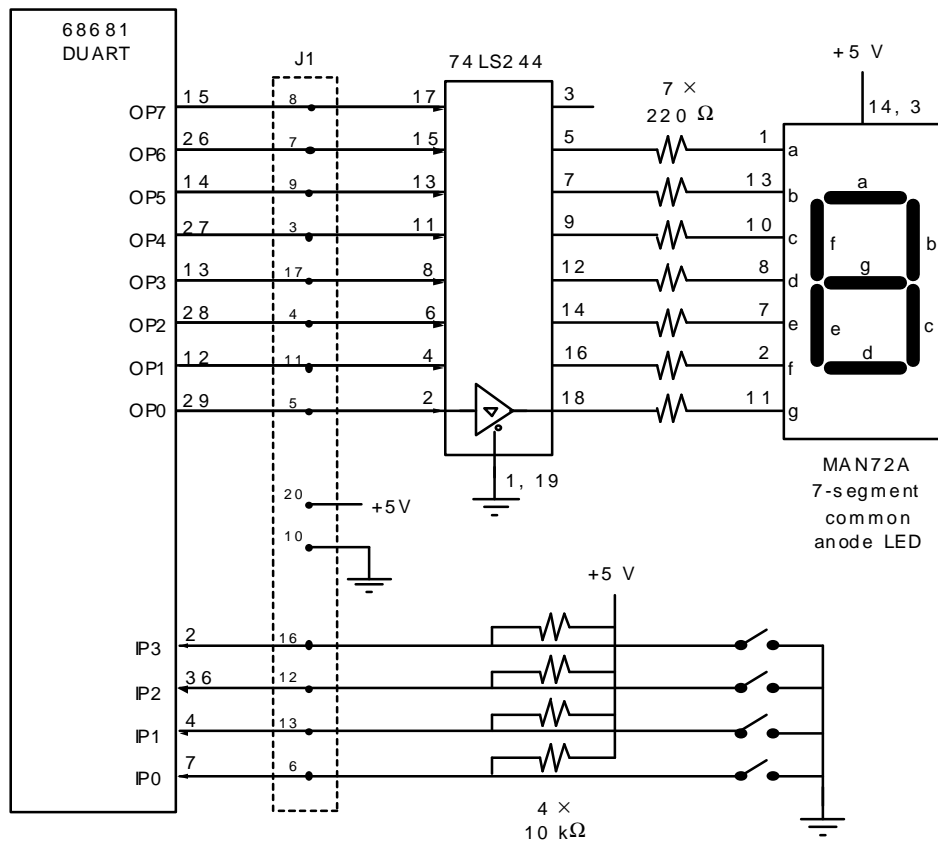
## (I/O Board #1)



F9-3

# Interface to Switches and 7-Segment LED

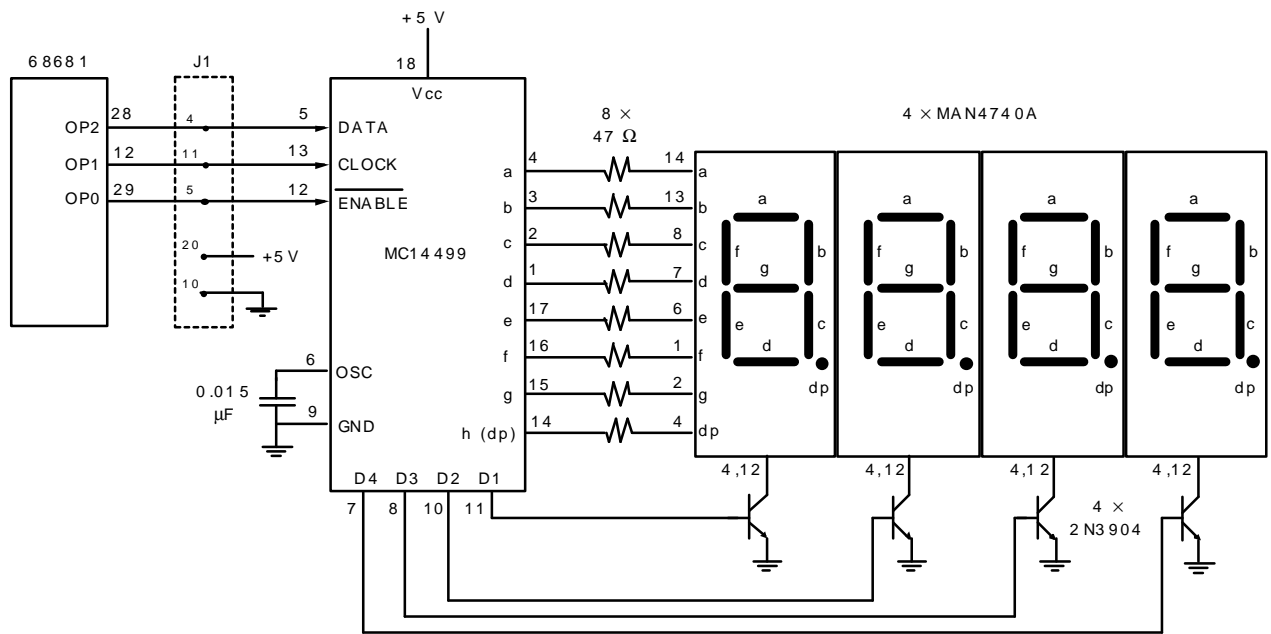
## (I/O Board #2)



F9-4

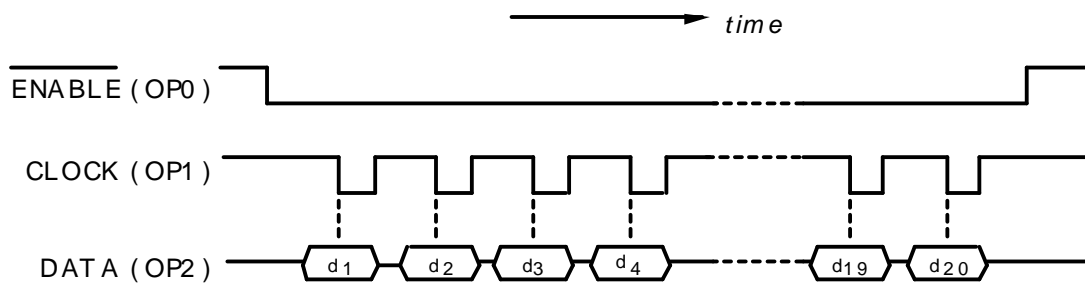
# 4-Digit 7-Segment Display

## (I/O Board #3)



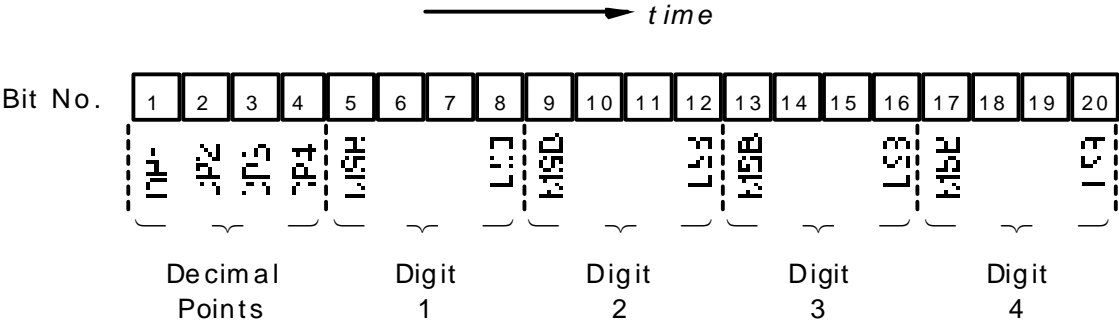
F9-6

# MC14499 Timing



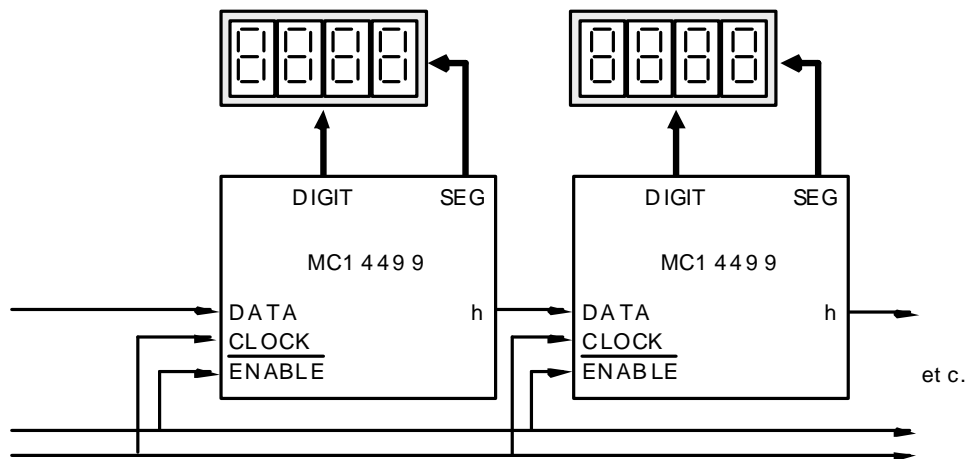
F9-7

# MC14499 Digit and Bit Sequence



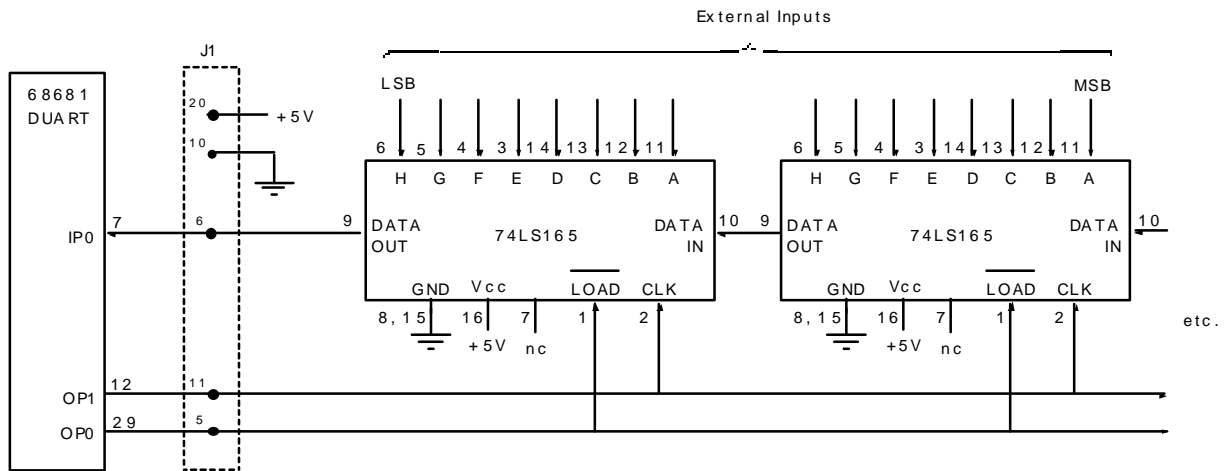
F9-8

# 8-Digit 7-Segment Display (I/O Board #4)



F9-9

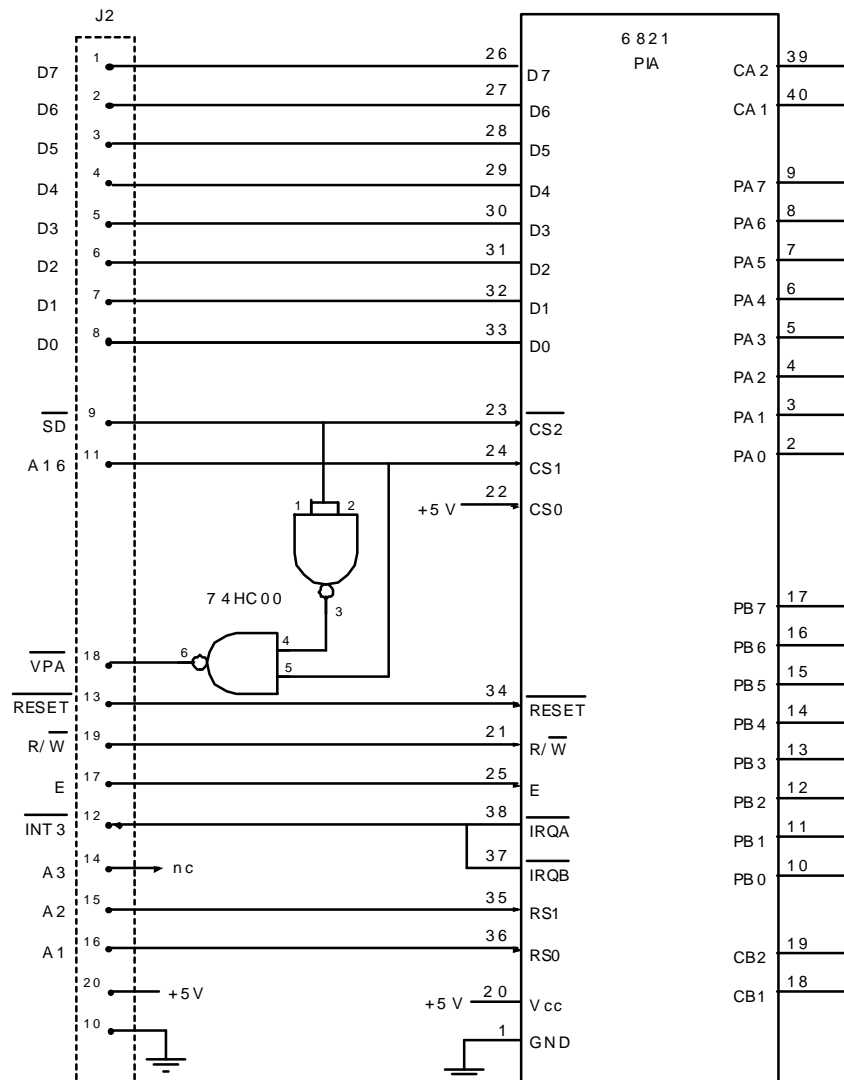
# 68681 Input Expansion Using 74LS165s



F9-10

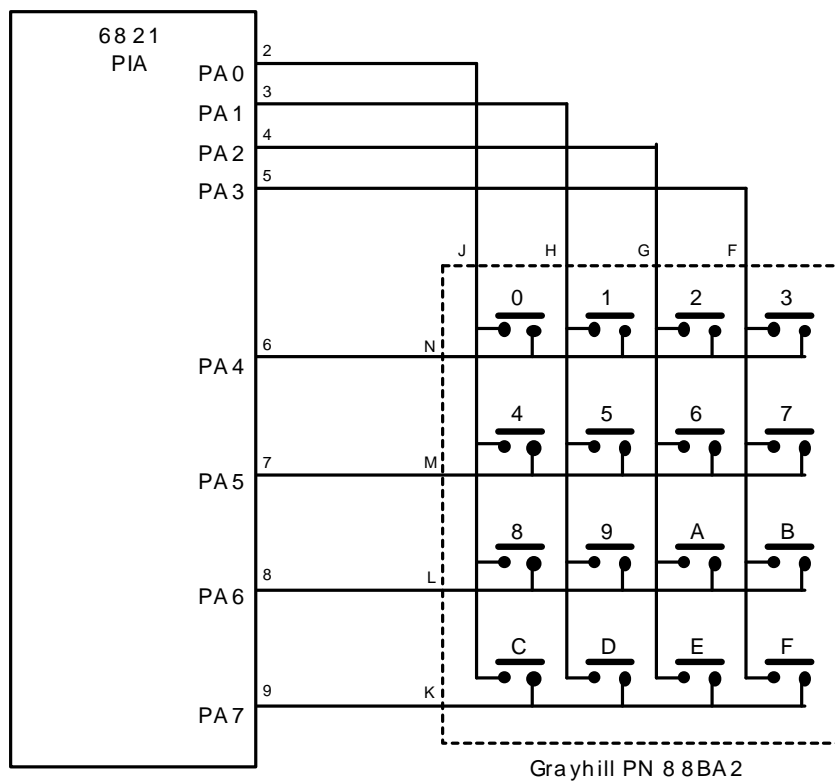
# 6821 Interface to the 68000

## (I/O Boards #5 & #6)



F9-11

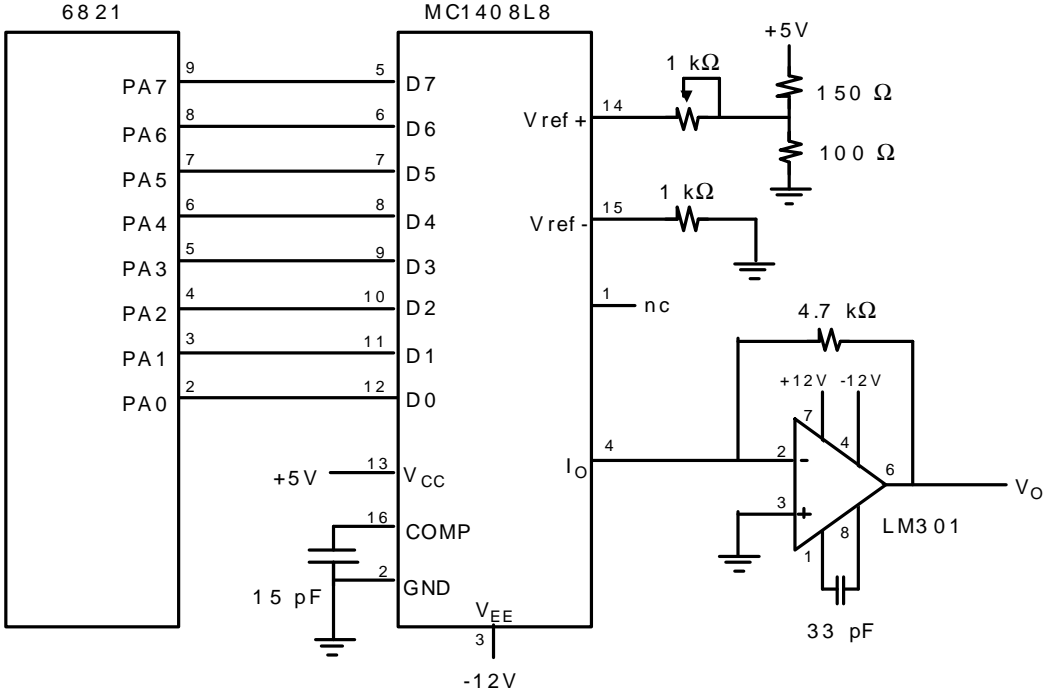
# Keypad Interface to the 6821 (I/O Board #5)



F9-12

# Output to a MC1408L8 DAC

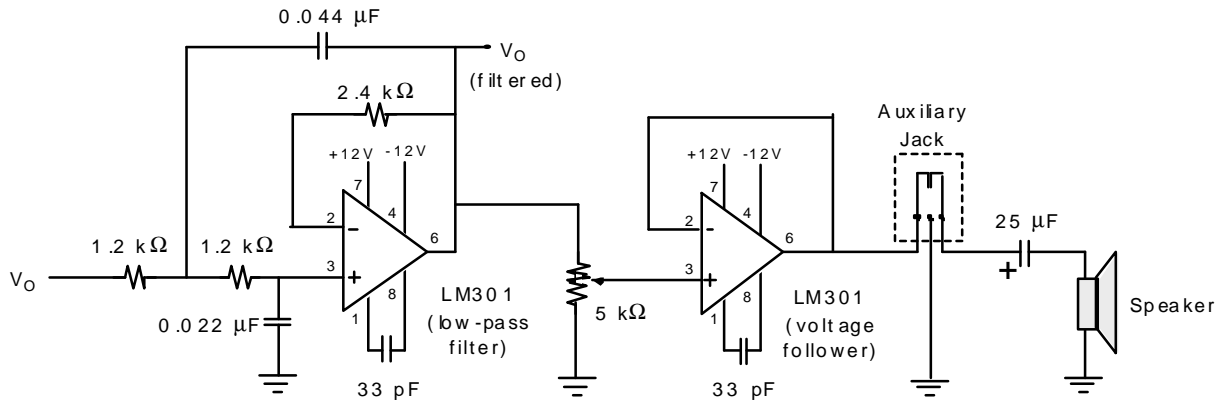
## (I/O Board #6, 1 of 4)



F9-13

# Low-Pass Filter and Audio Output

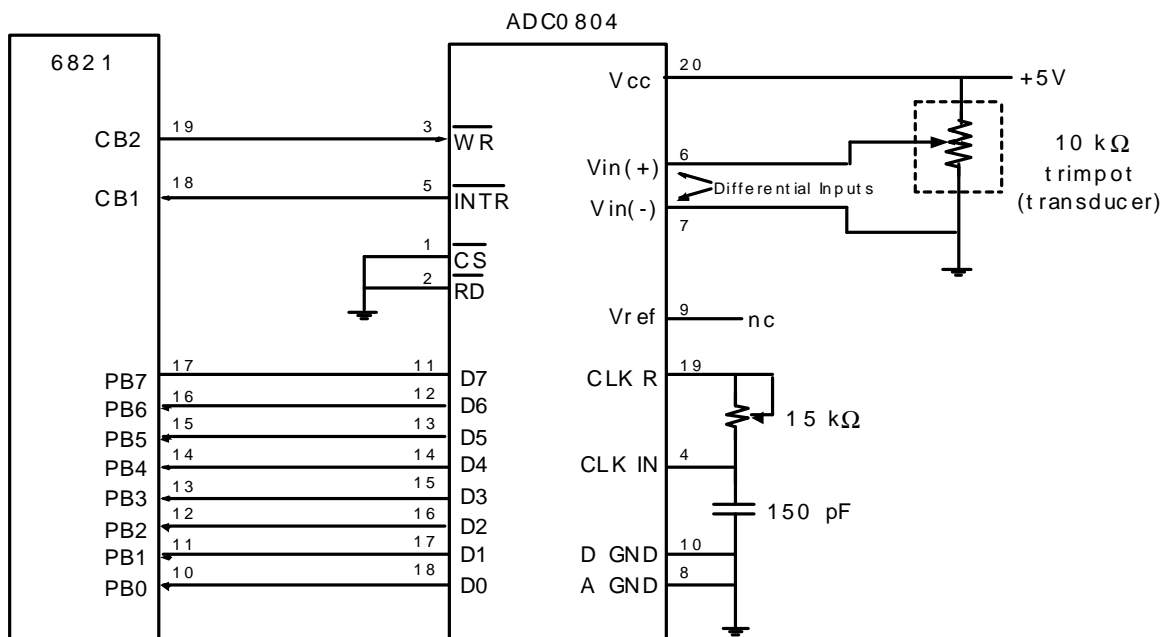
## (I/O Board #6, 2 of 4)



F9-15

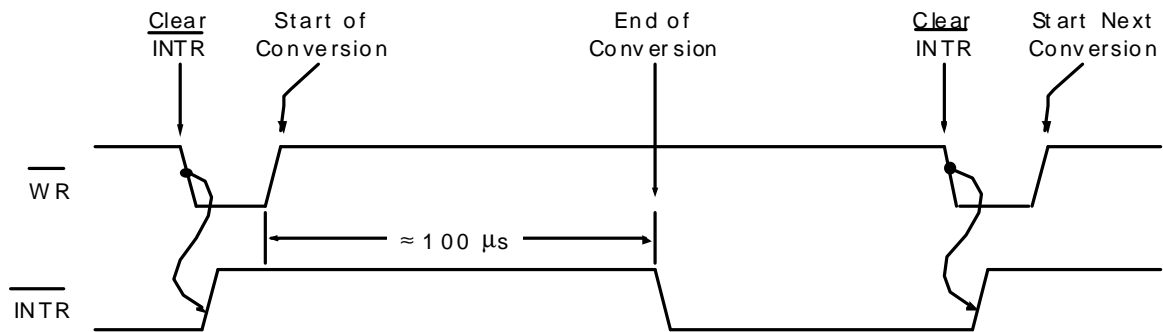
# Interface to ADC0804 Analog-to-Digital Converter

(I/O Board #6, 3 of 4)



F9-16

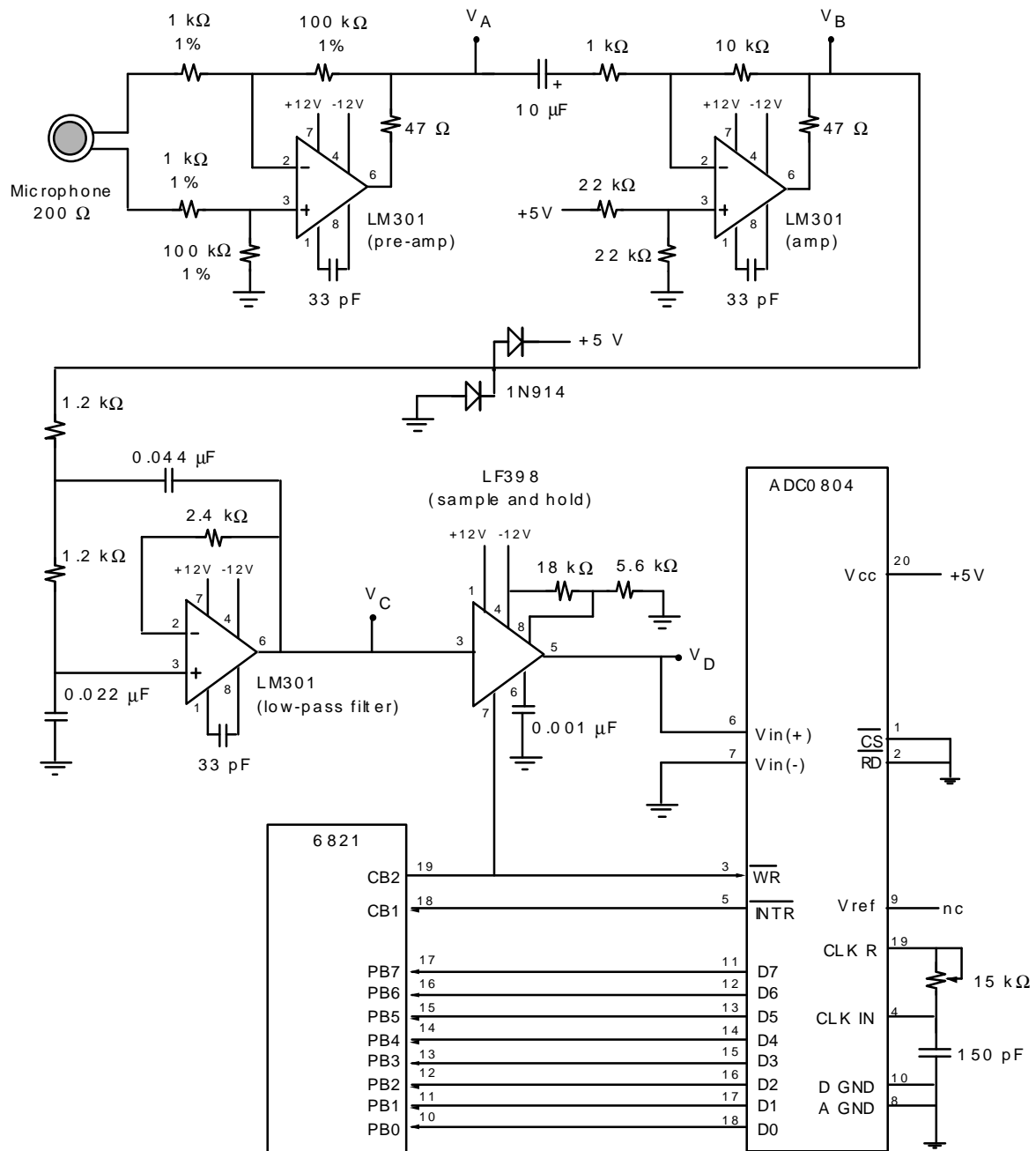
# Timing for ADC0804 Conversions



F9-17

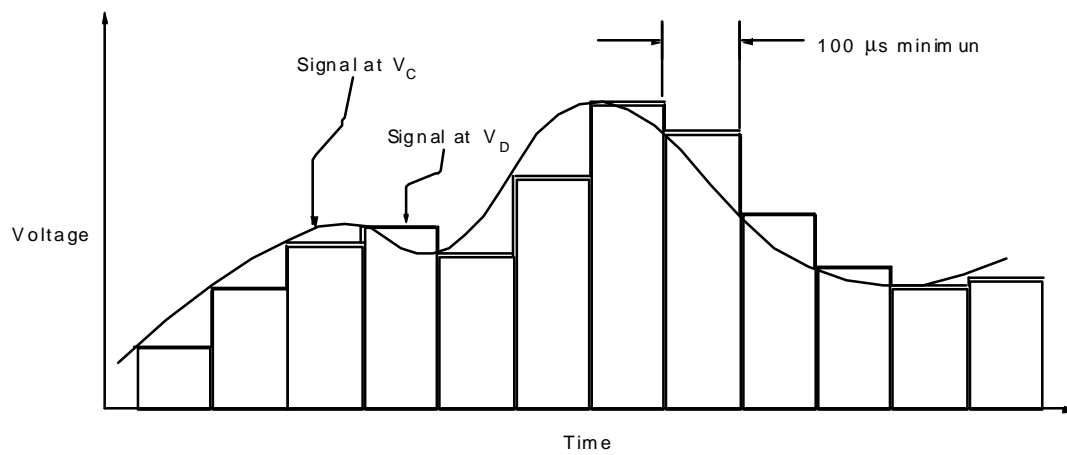
# Microphone Input to the ADC0804

## (I/O Board #6, 4 of 4)





# Sample-and-Hold Waveforms



F9-20

## 68000-Family Features

	<b>48-pin 68008</b>	<b>52-pin 68008</b>	<b>68000</b>	<b>68010</b>	<b>68020</b>	<b>68030</b>	<b>68040</b>
Data Bus (bits)	8	8	16	16	32	32	32
Address Bus (bits)	20	22	24	24	32	32	32
Data Cache (bytes)	–	–	–	–	–	256	4096
Instruction Cache (bytes)	–	–	–	–	256	256	4096
On-Chip Memory Management	No	No	No	No	No	Yes	Yes
On-Chip Floating- Point Unit	No	No	No	No	No	No	Yes

T10-1

## Comparison of Five Recent Microprocessors<sup>†</sup>

	<b>68040</b>	<b>80486</b>	<b>PowerPC</b>	<b>Pentium</b>	<b>Alpha 21064</b>
Company	Motorola	Intel	IBM/Motorola	Intel	DEC
Introduced	1989	6/91	4/93	3/93	2/92
Architecture	CISC	CISC	RISC	CISC	RISC
Width (bits)	32	32	32	32	64
Registers (general/FP)	16/8	8/8	32/32	8/8	32/32
Multiprocessing Support?	No	No	Yes	Yes	Yes
Device Size (mm)	10.8 x 11.7	not available	11 x 11	17.2 x 17.2	15.3 x 12.7
Transistors (millions)	1.2	1.2	2.8	3.1	1.68
Clock (MHz)	25	50	80	66	200
SPECint 92 <sup>††</sup>	21	27.9	85	67.4	130
SPECfp 92 <sup>††</sup>	15	13.1	105	63.6	184
Peak Power (Watts)	6	5	9.1	16	30
Price (\$US/1000 units)	\$233	\$432	\$557	\$898	\$505

<sup>†</sup> Source: *IEEE Spectrum*, December 1993, p. 21

<sup>††</sup> Integer and floating-point performance benchmarks

T10-10