

HD6805W1

MCU (Microcomputer Unit)

The HD6805W1 is an 8-bit microcomputer unit (MCU) which contains a CPU, on-chip clock, ROM, RAM, standby RAM, an A/D Converter, I/O and two timers. It is a member of the HD6805 family which is designed for user who needs an economical microcomputer with proven capabilities of the HD6800-based instruction set.

The following are some of the hardware and software highlights of the MCU.

■ HARDWARE FEATURES

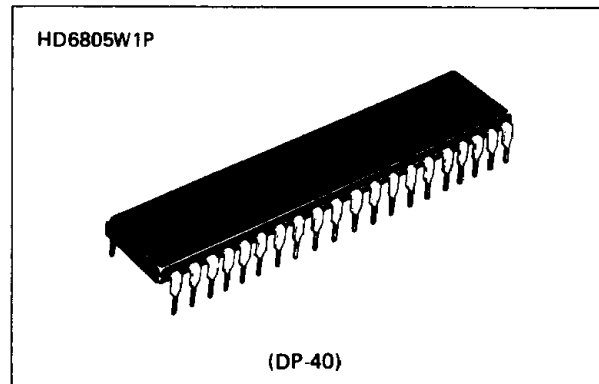
- 8-Bit Architecture
- 96 Bytes of RAM
(8 bytes are standby RAM functions)
- Memory Mapped I/O
- 3848 Bytes of User ROM
- Internal 8-Bit Timer (Timer 1) with 7-Bit Prescaler
- Internal 8-Bit Programmable Timer (Timer 2)
- Interrupts – 2 External and 4 Timers
- 23 TTL/CMOS compatible I/O Lines; 8 Lines Directly Drive LEDs.
- On-Chip 8-Bit, 4-Channel A/D Converter
- On-Chip Clock Circuit
- Self-Check Mode
- Master Reset
- Low Voltage Inhibit
- Easy for System Development and Debugging
- 5 Vdc Single Supply

■ SOFTWARE FEATURES

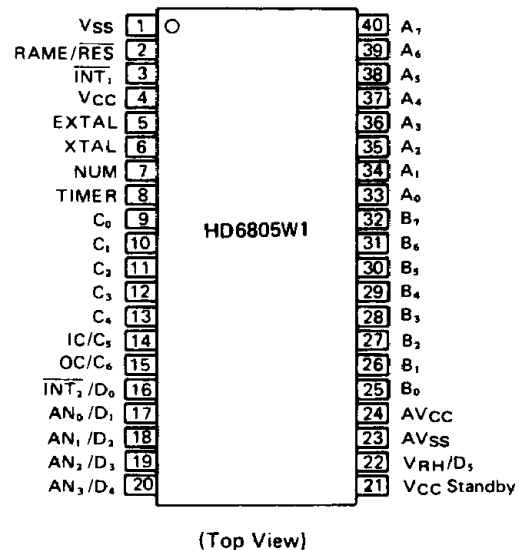
- Similar to HD6800
- Byte Efficient Instruction Set
- Easy to Program
- True Bit Manipulation
- Bit Test and Branch Instructions
- Versatile Interrupt Function
- Powerful Indexed Addressing for Tables
- Full Set of Conditional Branches
- Memory Usable as Registers/Flags
- Single Instruction Memory Examine/Change
- 10 Powerful Addressing Modes
- All Addressing Modes Apply to ROM, RAM and I/O
- Compatible with MC6805P2, HD6805S1 and HD6805V1

■ PROGRAM DEVELOPMENT SUPPORT TOOLS

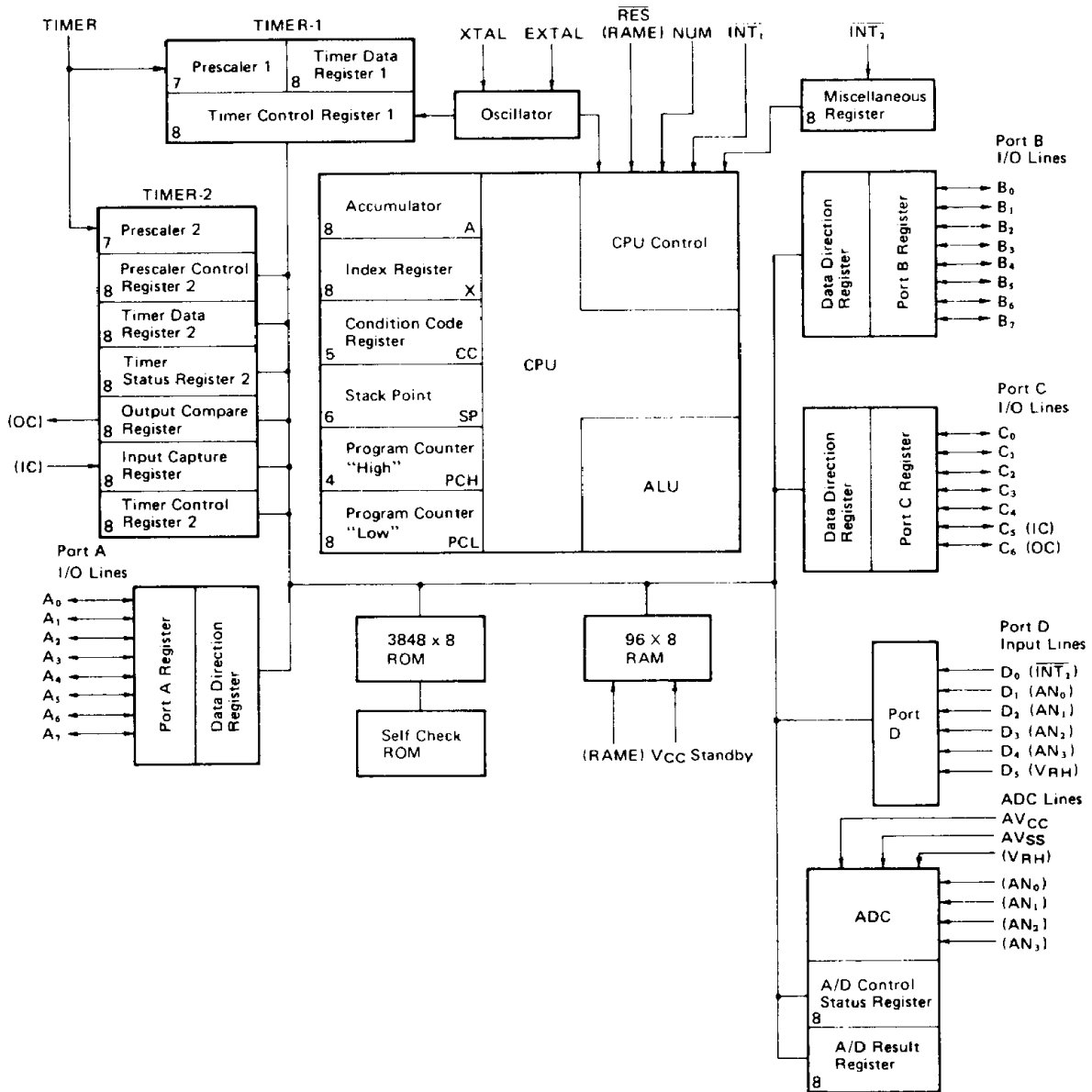
- Cross assembler software for use with IBM PCs and compatibles
- In circuit emulator for use with IBM PCs and compatibles



■ PIN ARRANGEMENT



■ BLOCK DIAGRAM



(NOTE) The contents of () items can be changed by software.

HD6805W1

■ ABSOLUTE MAXIMUM RATINGS

Item	Symbol	Value	Unit
Supply Voltage	V_{CC}	-0.3 ~ +7.0	V
Input Voltage (EXCEPT TIMER)	V_{in}	-0.3 ~ +7.0	V
Input Voltage (TIMER)		-0.3 ~ +12.0	V
Operating Temperature	T_{opr}	0 ~ +70	°C
Storage Temperature	T_{stg}	-55 ~ +150	°C

(NOTE) This device has an input protection circuit for high quiescent voltage and field, however, be careful not to impress a high input voltage than the insulation maximum value to the high input impedance circuit. To insure normal operation, the following are recommended for V_{in} and V_{out} :
 $V_{SS} \leq (V_{in} \text{ or } V_{out}) \leq V_{CC}$

■ ELECTRICAL CHARACTERISTICS

● DC CHARACTERISTICS ($V_{CC} = 5.25V \pm 0.5V$, $V_{SS} = GND$, $T_a = 0 \sim +70^\circ C$, unless otherwise noted.)

Item	Symbol	Test Condition	min	typ	max	Unit	
Input "High" Voltage	RES	V_{in}	4.0	—	V_{CC}	V	
	INT ₁ , INT ₂		3.0	—	V_{CC}	V	
	All Others		2.0	—	V_{CC}	V	
Input "High" Voltage (Timer)	Timer Mode		2.0	—	V_{CC}	V	
	Self-Check Mode		9.0	—	11.0	V	
Input "Low" Voltage	RES		V_{iL}	-0.3	—	0.8	V
	INT ₁ , INT ₂	-0.3		—	0.8	V	
	EXTAL(Crystal Mode)	-0.3		—	0.6	V	
	All Others	-0.3		—	0.8	V	
Power Dissipation	P_D		—	—	750	mW	
Low Voltage Recover	LVR		—	—	4.75	V	
Low Voltage Inhibit	LVI		—	4.0	—	V	
Input Leak Current	TIMER	I_{iL}	$V_{in}=0.4V \sim V_{CC}$	-20	—	20	μA
	INT ₁ , INT ₂			-50	—	50	μA
	EXTAL(Crystal Mode)			-1200	—	0	μA
Standby Voltage	Nonoperation Mode	V_{SBB}	4.0	—	V_{CC}	V	
	Operation Mode	V_{SB}	4.75	—	V_{CC}		
Standby Current	Nonoperation Mode	I_{SBB}	$V_{SBB}=4.0V$		—	3	mA

● AC CHARACTERISTICS ($V_{CC} = 5.25V \pm 0.5V$, $V_{SS} = GND$, $T_a = 0 \sim +70^\circ C$, unless otherwise noted.)

Item	Symbol	Test Condition	min	typ	max	Unit
Clock Frequency	f_{cl}		0.4	—	4.0	MHz
Cycle Time	t_{cyc}		1.0	—	10	μs
Oscillation Frequency (External Resistor Mode)	f_{EXT}	$R_{CP}=15.0k\Omega \pm 1\%$	—	3.4	—	MHz
INT ₁ Pulse Width	t_{iWL}		$t_{cyc}^+ / 250$	—	—	ns
RES Pulse Width	t_{rWL}		$t_{cyc}^+ / 250$	—	—	ns
TIMER Pulse Width	t_{TWL}		$t_{cyc}^+ / 250$	—	—	ns
Oscillation Start-up Time (Crystal Mode)	t_{osc}	$C_L=22pF \pm 20\%$ $R_S=60\Omega \text{ max.}$	—	—	100	ms
Delay Time Reset	t_{RHL}	External Cap. = 2.2 μF	100	—	—	ms
Input Capacitance	XTAL, V_{RH}/D_s	$V_{in}=0V$	—	—	35	pF
	All Others		—	—	10	pF



● PORT ELECTRICAL CHARACTERISTICS ($V_{CC} = 5.25V \pm 0.5V$, $V_{SS} = GND$, $T_a = 0 \sim +70^\circ C$, unless otherwise noted.)

Item	Symbol	Test Condition	min	typ	max	Unit	
Output "High" Voltage	Port A	V_{OH}	$I_{OH} = -10 \mu A$	3.5	—	—	V
			$I_{OH} = -100 \mu A$	2.4	—	—	V
			$I_{OH} = -200 \mu A$	2.4	—	—	V
	Port B		$I_{OH} = -1 \text{ mA}$	1.5	—	—	V
			$I_{OH} = -100 \mu A$	2.4	—	—	V
Output "Low" Voltage	Ports A and C	V_{OL}	$I_{OL} = 1.6 \text{ mA}$	—	—	0.5	V
	Port B		$I_{OL} = 3.2 \text{ mA}$	—	—	0.5	V
			$I_{OL} = 10 \text{ mA}$	—	—	1.0	V
Input "High" Voltage	Ports A, B, C and D	V_{IH}		2.0	—	V_{CC}	V
Input "Low" Voltage			V_{IL}		-0.3	—	0.8
Input Leak Current	Port A	I_{IL}	$V_{in} = 0.8V$	-500	—	—	μA
			$V_{in} = 2V$	-300	—	—	μA
	Ports B, C and D		$V_{in} = 0.4V \sim V_{CC}$	-20	—	20	μA

● A/D CONVERTER ELECTRICAL CHARACTERISTICS ($V_{CC} = 5.25V \pm 0.5V$, $V_{SS} = AV_{SS} = GND$, $T_a = 0 \sim +70^\circ C$, unless otherwise noted.)

Item	Symbol	Test Condition	min	typ	max	Unit
Analog Power Supply Voltage	AV_{CC}		4.75	5.25	5.75	V
Analog Input Voltage	AV_{in}		0	—	V_{RH}	V
Reference Voltage	V_{RH}	$4.75V \leq V_{CC} \leq 5.25V$	4.0	—	V_{CC}	V
		$5.25V < V_{CC} \leq 5.75V$	4.0	—	5.25	V
Analog Multiplexer Input Capacitance			—	—	7.5	pF
Resolution Power			—	8	—	Bit
Conversion Time		at 4MHz	76	76	76	t_{cyc}
Input Channels			4	4	4	Channel
Absolute Accuracy		$T_a = 25^\circ C$	—	—	± 1.5	LSB

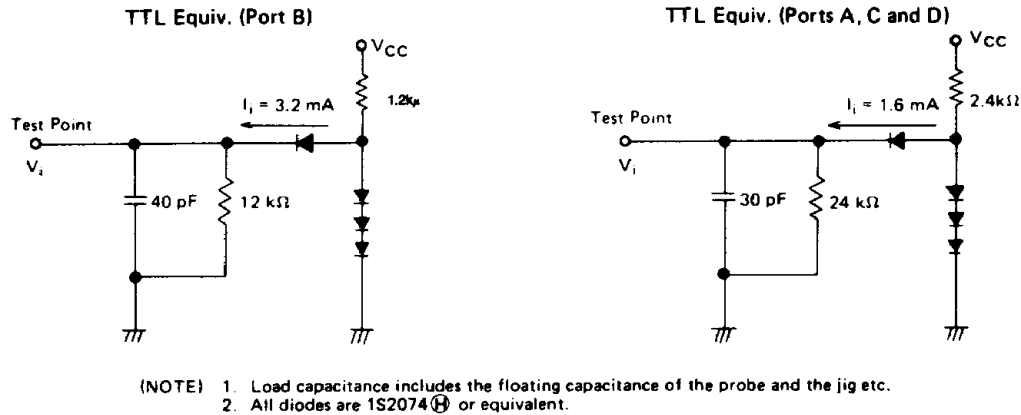


Figure 1 Bus Timing Test Loads

• **SIGNAL DESCRIPTION**

The input and output signals for the MCU, shown in PIN ARRANGEMENT, are described in the following paragraphs.

• **V_{CC} and V_{SS}**

Voltage is supplied to the MCU using these two pins. V_{CC} is 5.25V ±0.5V. V_{SS} is the ground connection.

• **INT₁/INT₂**

This pin provides the capability for asynchronously applying an external interrupt to the MCU. Refer to INTERRUPTS for additional information.

• **XTAL and EXTAL**

These pins provide connections for the on-chip clock circuit. A crystal (AT cut, 4 MHz maximum), a resistor or an external signal can be connected to these pins to provide a system clock with various stability/cost tradeoffs. Refer to INTERNAL OSCILLATOR OPTIONS for recommendations about these inputs.

• **TIMER**

This pin allows an external input to be used to count for the internal timer circuitry. Refer to TIMER 1 and TIMER 2 for additional information about the timer circuitry. When this pin isn't used, it must be grounded.

• **RES**

This pin allows resetting of the MCU at times other than the automatic resetting capability already in the MCU. Refer to RESETS for additional information.

• **NUM**

This pin is not for user application and should be connected to V_{SS}.

• **I/O Lines (A₀ ~ A₇, B₀ ~ B₇, C₀ ~ C₆)**

There 23 lines are arranged into three ports (A, B and C). All lines are programmable as either inputs or outputs under software control of the Data Direction Register (DDR). Refer to INPUT/OUTPUT for additional information.

• **Input Lines (D₀ ~ D₅)**

These are TTL compatible input lines, in location S003. These also allow analog inputs to be used for an A/D converter and interrupt. Refer to INPUT and A/D converter for addition-

al information.

• **V_{CC} Standby**

V_{CC} Standby provides power to the standby portion of the RAM and the STBY PWR and RAME bits of the RAM Control Register. Voltage requirements depend on whether the MCU is in a powerup or powerdown state. In the powerup state, the power supply should provide V_{CC} and must reach V_{SB} before RES reaches 4.0V. During powerdown, V_{CC} standby must remain above V_{SB}(min) to sustain the standby RAM and STBY PWR bit. While in powerdown operation, the standby current will not exceed I_{SB}.

It is typical to power both V_{CC} and V_{CC} Standby from the same source during normal operation. A diode must be used between them to prevent supplying power to V_{CC} during powerdown operation shown Figure 2.

To sustain the standby RAM during powerdown, the following software or hardware are needed.

(1) **Software**

When clearing the RAM Enable bit (RAME) which is bit 6 of the RAM Control Register at location S001F, the RAM is disabled.

V_{CC} Standby must remain above V_{SB}(min).

(2) **Hardware**

When RAME pin is "Low" before powerdown, the RAM is disabled. V_{CC} Standby must remain above V_{SB}(min).

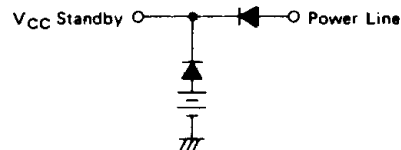


Figure 2 Battery Backup for V_{CC} Standby

• **RAME**

This pin is used for the external control of the RAM. When it is "Low" before powerdown, the RAM is disabled. If V_{CC} Standby remains above V_{SB}(min), the standby RAM is sustained.

- AV_{CC}**
 This pin is used for the power supply of the A/D converter. When high accuracy is required, a different power source from V_{CC} should be impressed. Connect to V_{CC} for all other cases. AV_{SS} corresponds to AV_{CC} as a GND terminal.
- AN₀ ~ AN₃**
 These pins allow analog inputs to be used for an A/D converter. These inputs are switched by the internal multiplexer and selected by bit 0 and 1 of the A/D Control Status Register (ADCSR: \$00E).
- V_{RH} and AV_{SS}**
 The input terminal reference voltage for the A/D converter is "High" (V_{RH}) or "Low" (AV_{SS}). AV_{SS} is fixed at 0V.
- Input Capture (IC)**
 This pin is used for input of Timer 2 control, in this case, Port C₄ should be configured as input. Refer to TIMER 2 for more details.
- Output Compare (OC)**
 This pin is used for output of Timer 2 when the Output

Compare Register is matched with the Timer Data Register 2. In this case, Port C₄ should be configured as an output. Refer to TIMER 2 for more details.

■ MEMORY

The MCU memory is configured as shown in Figure 3. During the interrupt processing, the contents of the CPU registers are pushed onto the stack in the order shown in Figure 4. Since the stack pointer decrements during pushes, the low order byte (PCL) of the program counter is stacked first; then the high order three bits (PCH) are stacked. This ensures that the program counter is loaded correctly as the stack pointer increments when it pulls data from the stack. A subroutine call will cause only the program counter (PCH, PCL) contents to be pushed onto the stack.

Caution: — Self Test ROM Address Area
 Self test ROM locations can not be used for a user program. If the user's program is in this location, it will be removed when manufacturing mask for production.

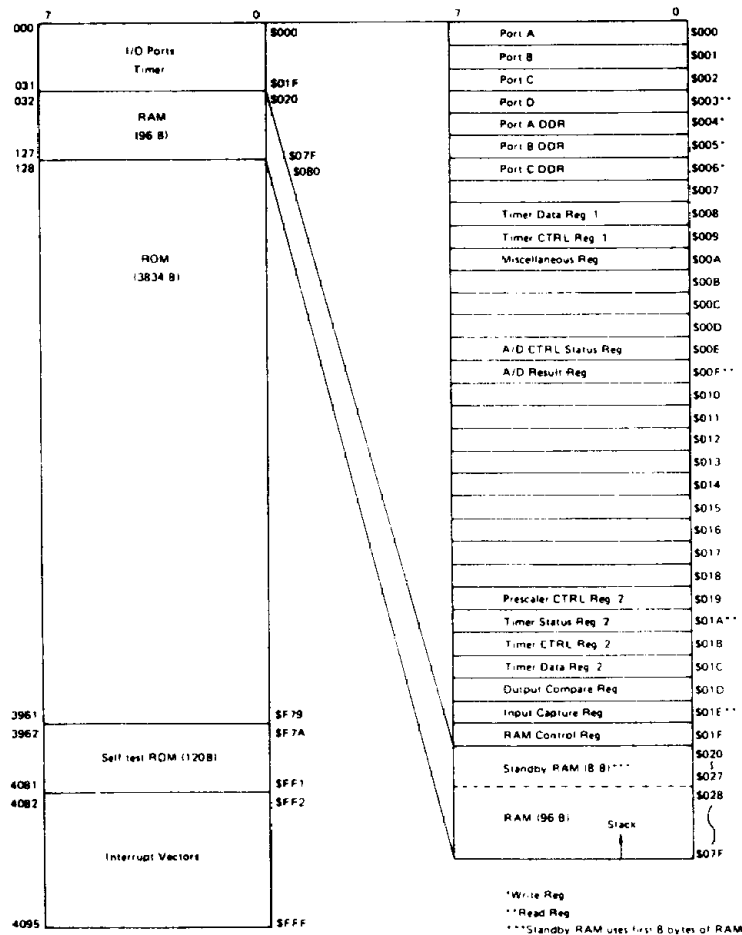


Figure 3 MCU Memory Structure

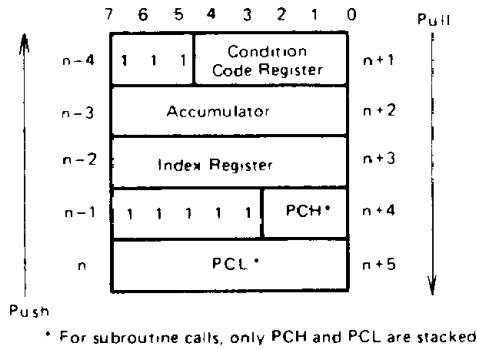


Figure 4 Interrupt Stacking Order

REGISTERS

The CPU has five registers available to the programmer, as shown in Figure 5 and explained below.

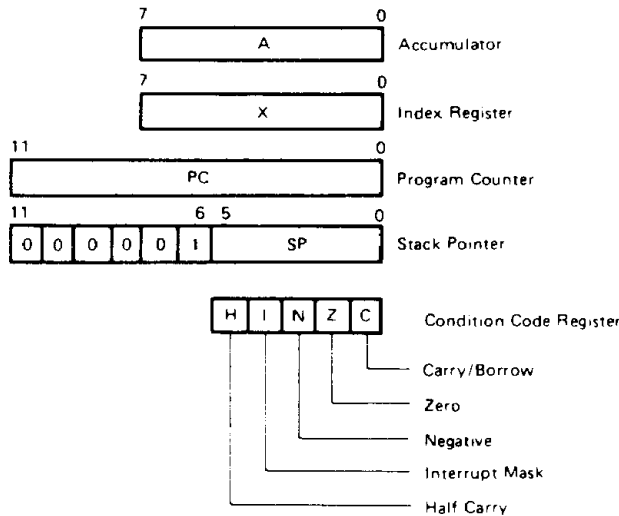


Figure 5 Programming Model

Accumulator (A)

The accumulator is a general purpose 8-bit register used to hold operands and results of arithmetic calculations or data manipulations.

Index Register (X)

The index register is an 8-bit register used for the indexed addressing mode and contains an 8-bit address that may be added to an offset value to create an effective address. The index register can also be used for limited calculations or data manipulations when using read/modify/write instructions. When not required by a code sequence being executed, the index register can be used as a temporary storage area.

Program Counter (PC)

The program counter is a 12-bit register that contains the address of the next instruction to be executed

Stack Pointer (SP)

The stack pointer is a 12-bit register that contains the address of the next free location on the stack. Initially, the stack pointer is set to location \$07F and is decremented as data is being pushed onto the stack and incremented while data is being pulled from the stack. The six most significant bits of the stack pointer are permanently set to 000001. During an MCU reset or reset stack pointer (RSP) instruction, the stack pointer is set to location \$07F. Subroutines and interrupts may be nested down to location \$041 which allows the programmer to use up to 31 levels of subroutine calls.

Condition Code Register (CC)

The condition code register is a 5-bit register in which each bit is used to indicate or flag the results of the instruction just executed. These bits can be individually tested by a program and specific action taken as a result of their state. Each individual condition code register bit is explained below.

Half Carry (H)

The half carry bit is used during arithmetic operations (ADD or ADC) to indicate that a carry occurred between bits 3 and 4.

Interrupt (I)

This bit is set to mask everything. If an interrupt occurs while this bit is set, it is latched and will be processed as soon as the interrupt bit is reset.

Negative (N)

The negative bit is used to indicate that the result of the last arithmetic, logical or data manipulation was negative (bit 7 in a result equal to a logical one).

Zero (Z)

Zero is used to indicate that the result of the last arithmetic, logical or data manipulation was zero.

Carry/Borrow (C)

Carry/borrow is used to indicate that a carry or borrow out of the arithmetic logic unit (ALU) occurred during the last arithmetic operation. This bit is also affected during bit test and branch instructions, shifts and rotates.

TIMER 1

The MCU timer circuitry is shown in Figure 6. The 8-bit counter, Timer Data Register 1 (TDR1), is loaded under program control and counts down toward zero as soon as the clock input is applied. When the TDR1 reaches zero, the timer interrupt request bit (bit 7) in the Timer Control Register 1 (TCR1) is set. The CPU responds to this interrupt by saving the present CPU state in the stack, fetching the timer 1 interrupt vector from locations \$FF8 and \$FF9 and executing the interrupt routine. The timer 1 interrupt can be masked by setting the timer interrupt mask bit (bit 6) in the TCR1. The interrupt bit (I bit) in the Condition Code Register also prevents a timer 1 interrupt from being processed.

The clock input to the timer 1 can be from an external source applied to the TIMER input pin or it can be the internal ϕ_2 signal. When ϕ_2 is used as the source, it can be gated by an input applied to the TIMER input pin allowing the user to easily perform pulse-width measurements. When the TIMER input pin doesn't control the ϕ_2 signal, connect the TIMER input pin to V_{CC} . The timer 1 continues to count past zero, falling through to \$FF from zero and then continuing the

count. Thus, the counter (TDR1) can be read at any time by reading the TDR1. This allows a program to determine the length of time since a timer interrupt has occurred and not disturb the counting process.

At power-up or reset, the prescaler and the counter (TDR1) are initialized with all logical ones; the timer 1 interrupt request

bit (bit 7) is cleared and the timer 1 interrupt mask bit (bit 6) is set. In order to release the timer 1 interrupt, bit 7 of the TCR1 must be cleared by software.

(NOTE) If the MCU Timer 1 and Timer 2 are not used, the TIMER input pin must be grounded.

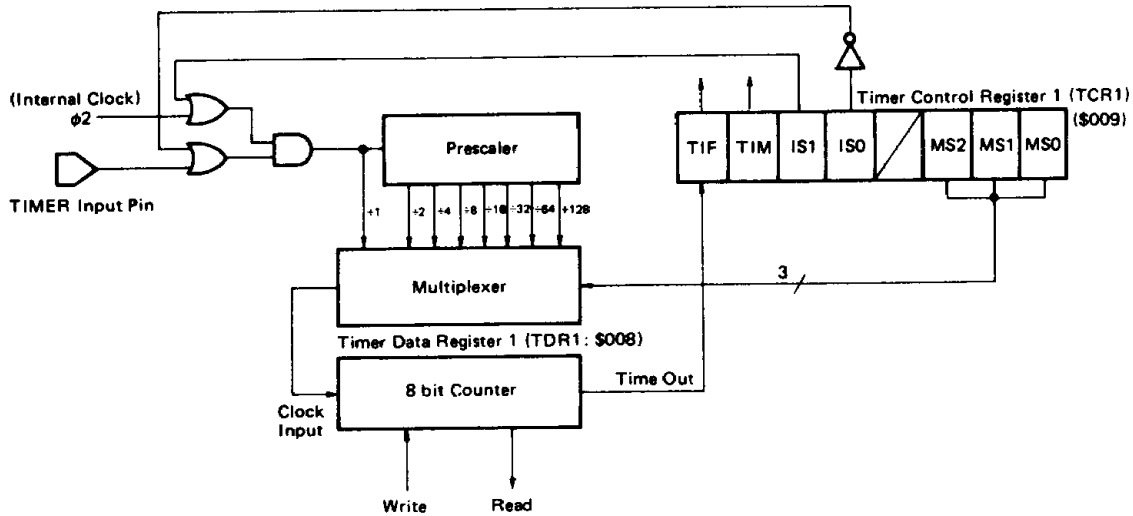
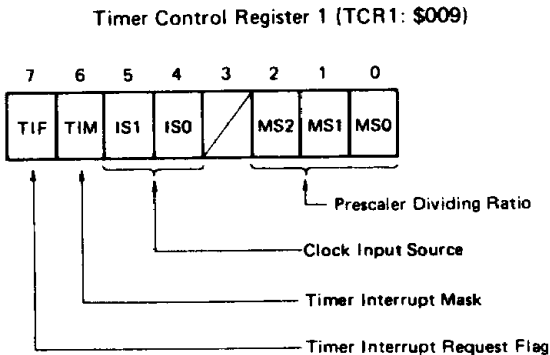


Figure 6 Timer Clock

• **Timer Control Register 1 (TCR1: \$009)**

The Timer Control Register 1 (TCR1) can control selection of clock input source and prescaler dividing ratio and timer interrupt.

interrupt at "0" and masks at "1". Timer 1 interrupt causes Timer 1 interrupt request bit (TIF) to be set. TIF must be cleared by software.



As shown in Table 1, the selection of the clock input source is ISO and IS1 in the TCR1 (bit 4 and bit 5) and 3 kinds of input are selectable. At reset, internal clock φ₂ controlled by the TIMER input (bit 4=1, bit5=0) is selected.

The prescaler dividing ratio is selected by MS0, MS1, and MS2 in the TCR1 (bit 0, bit 1, bit 2) as shown in Table 2. The dividing ratio is selectable from eight ways (÷1, ÷2, ÷4, ÷8, ÷16, ÷32, ÷64, ÷128). At reset, ÷1 mode is selected. The prescaler is initialized by writing in the TDR1.

Timer 1 interrupt mask bit (TIM) allows the Timer 1 into

Table 1 Selection of Clock Input Source

TCR1		Clock Input Source
Bit 5	Bit 4	
0	0	Internal Clock φ ₂ *
0	1	φ ₂ Controlled by TIMER Input
1	0	
1	1	Event Input From TIMER

* The TIMER input pin must be tied to V_{CC} for uncontrolled φ₂ clock input.

Table 2 Selection of Prescaler Dividing Ratio

TCR1			Prescaler Dividing Ratio
Bit 2	Bit 1	Bit 0	
0	0	0	÷ 1
0	0	1	÷ 2
0	1	0	÷ 4
0	1	1	÷ 8
1	0	0	÷ 16
1	0	1	÷ 32
1	1	0	÷ 64
1	1	1	÷ 128

TIMER 2

The HD6805W1 includes an 8-bit programmable timer (Timer 2) which can not only measure the input waveform but also generate the output waveform. The pulse width for both input and output waveform can be varied from several micro-seconds to several seconds.

(NOTE) If the MCU Timer 1 and Timer 2 are not used, the **TIMER** input pin must be grounded.

Timer 2 hardware consists of the followings.

- an 8-bit control register 2
- an 8-bit status register 2
- an 8-bit timer data register 2
- an 8-bit output compare register
- an 8-bit input capture register
- a 5-bit prescaler control register 2
- a 7-bit prescaler 2

A block diagram of the timer 2 is shown in Figure 7.

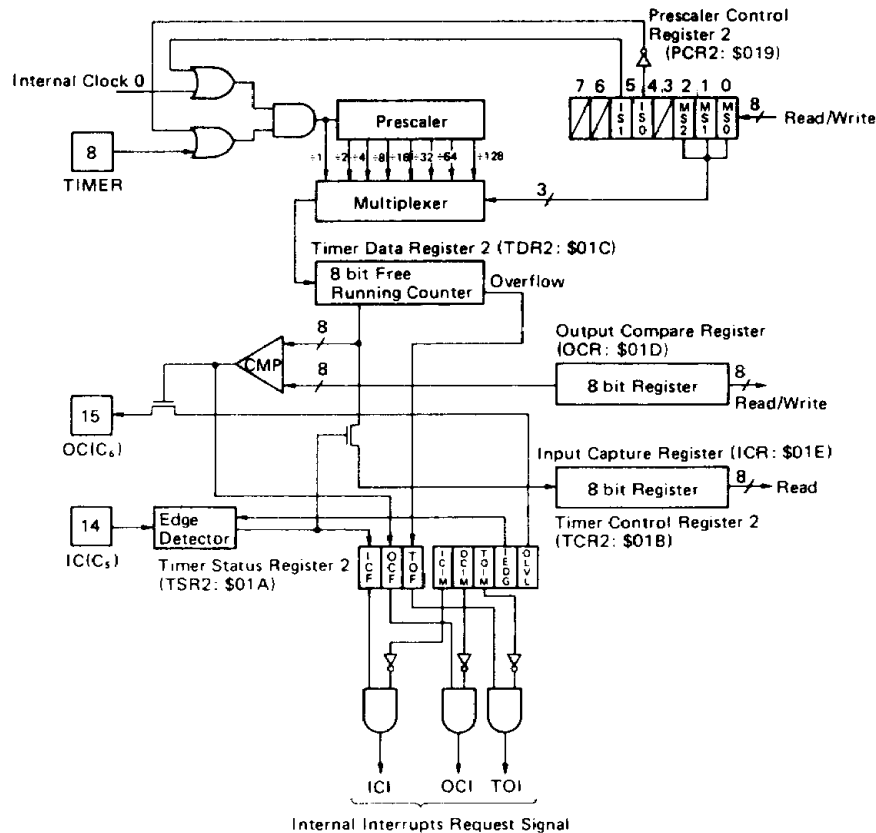


Figure 7 Block Diagram of Timer 2

Timer Data Register 2 (TDR2: \$01C)

The main part of the Timer 2 is the 8-bit Timer Data Register 2 (TDR2) as free-running counter, which is driven by internal clock ϕ_2 or the **TIMER** input and increments the value. The values in the counter is always readable by software.

The Timer Data Register 2 is Read/Write register and is cleared at reset.

Output Compare Register (OCR: \$01D)

The Output Compare Register (OCR) is an 8-bit Read/Write register used to control an output waveform. The contents of this register are always compared with those of the TDR2. When these two contents conform to each other, the flag (OCF) in the Timer Status Register 2 (TCR 2) is set and the value of the output level bit (OLVL) in the TCR2 is transferred to Port C₆ (OC).

If Port C₆'s Data Direction Register (DDR) is "1" (output), this value will appear at Port C₆ (OC). Then the values of OCF and OLVL can be changed for the next compare. The OCR is set to SFF at reset.

Input Capture Register (ICR: \$01E)

The Input Capture Register (ICR) is an 8-bit Read-only register used to store the value of the TDR2 when Port C₅ (IC) input transition occurs as defined by the input edge bit (IEDG) of the TCR2.

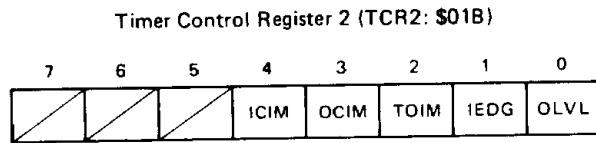
In order to apply Port C₅ (IC) input to the edge detect circuit, the DDR of Port C₅ should be cleared ("0").*

To ensure an input capture under all condition, Port C₅ (IC) input pulse width should be 2 Enable-cycles at least.

*The edge detect circuit always senses Port C₅ (IC) even if the DDR is set with Port C₅ output.

● **Timer Control Register 2 (TCR2: \$01B)**

The Timer Control Register 2 (TCR2) consists of an 8-bit register of which all bits can be read and written.



Bit 0 OLVL Output Level

This bit will appear at Port C₆ when the value in the TDR2 equals the value in the OCR, if the DDR of Port C₆ is set. It is cleared by reset.

Bit 1 IEDG Input Edge

This bit determines which level transition of Port C₅ (IC input) will trigger a data store to ICR from the TDR2. When this function is used, it is necessary to clear DDR of Port C₅. When IEDG = 0, the negative edge triggers ("High" to "Low" transition). When IEDG = 1, the positive edge triggers ("Low" to "High" transition). It is cleared by reset.

Bit 2 TOIM Timer Overflow Interrupt Mask

When this bit is cleared, internal interrupt (TOI) is enabled by TOF interrupt but when set, interrupt is inhibited.

Bit 3 OCIM Output Compare Interrupt Mask

When this bit is cleared, internal interrupt (OCI) by OCF interrupt occurs. When set, interrupt is inhibited.

Bit 4 ICIM Input Capture Interrupt Mask

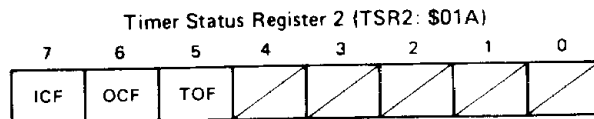
When this bit is cleared, internal interrupt (ICI) by ICF interrupt occurs. When set, interrupt is inhibited.

● **Timer Status Register 2 (TSR2: \$01A)**

The Timer Status Register 2 (TSR2) is an 8-bit read-only register which indicates that:

- (1) A proper level transition has been detected on the input pin with a subsequent transfer of the TDR2 value to the ICR (ICF).
- (2) A match has been found between the TDR2 and the OCR (OCF).
- (3) The TDR2 is zero (TOF).

Each of the event can generate 3 kinds of internal interrupt request and is controlled by an individual inhibit bits in the TCR2. If the I bit in the Condition Code Register is cleared, priority vectors are generated in response to clearing each interrupt mask bit. Each bit is described below.



Bit 5 TOF Timer Overflow Flag

This read-only bit is set when the TDR2 contains \$00. It is cleared by reading the TSR2 followed by reading of the TDR2.

Bit 6 OCF Output Compare Flag

This read-only bit is set when a match is found between the OCR and the TDR2. It is cleared by reading the TSR2 and then writing to the OCR.

Bit 7 ICF Input Capture Flag

This read-only bit is set to indicate a proper level transition and cleared by reading the TSR2 and then reading the TCR2.

CAUTION

The flag of the TSR2 will be occasionally cleared when manipulating or testing the TSR2 by Read/Modify/Write instruction shown in Table 3. Don't use these instructions for read/write/test operation of the TSR2 flags.

Table 3

		Bit Manipulation		Read/Modify/Write
		Test & Branch	Set/Clear	DIR
High →	0	0	1	3
	0	BRSET 0	BSET 0	NEG
Low	1	BRCLR 0	BCLR 0	—
	2	BRSET 1	BSET 1	—
	3	BRCLR 1	BCLR 1	COM
	4	BRSET 2	BSET 2	LSR
	5	BRCLR 2	BCLR 2	—
	6	BRSET 3	BSET 3	ROR
	7	BRCLR 3	BCLR 3	ASR
	8	BRSET 4	BSET 4	LSL/ASL
	9	BRCLR 4	BCLR 4	ROL
	A	BRSET 5	BSET 5	DEC
	B	BRCLR 5	BCLR 5	—
	C	BRSET 6	BSET 6	INC
	D	BRCLR 6	BCLR 6	TST
	E	BRSET 7	BSET 7	—
	F	BRCLR 7	BCLR 7	CLR
			3/10	2/7

(Note) 1. Undefined opcodes are marked with "—".
 2. The number at the bottom of each column denote the number of bytes and cycles required.

User can write into port C₆ by software.

Accordingly, after port C₆ has output by hardware and is immediately write into by software, simultaneous cyclic pulse control with a short width is easy.

● **Prescaler Control Register 2 (PCR2: \$019)**

The selection of clock input source and prescaler dividing ratio are performed by the Prescaler Control Register 2 (PCR2).

The selection of clock input source is performed in three different ways by bit 4 and bit 5 of the PCR2, as shown in Table 3. At reset, internal clock ϕ_2 controlled by the TIMER input (bit 4 = 1, bit 5 = 0) is selected.

The prescaler dividing ratio is selected by three bits in the PCR2 (bits 0, 1, 2), as shown in Table 4. The dividing ratio can be selected in 8 ways ($\div 1, \div 2, \div 4, \div 8, \div 16, \div 32, \div 64, \div 128$). At reset, $\div 1$ (bit 0 = bit 1 = bit 2 = 0) is selected.

When writing into the PCR2, or when writing into the TDR2,

HD6805W1

prescaler is initialized to \$FF.

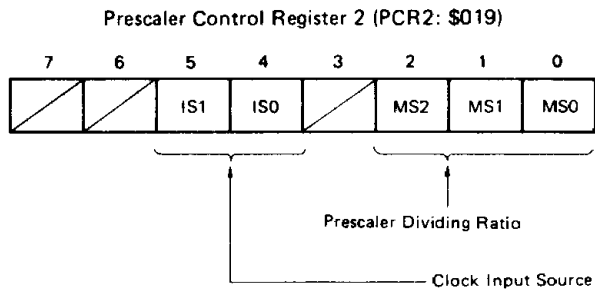


Table 4 Selection of Clock Input Source

PCR2		Clock Input Source
Bit 5	Bit 4	
0	0	Internal Clock ϕ_2 *
0	1	ϕ_2 Controlled by TIMER Input
1	0	Event Input from TIMER
1	1	Event Input from TIMER

* The TIMER input pin must be tied to V_{CC} for uncontrolled ϕ_2 clock input.

Table 5 Selection of Prescaler Dividing Ratio

PCR2			Prescaler Dividing Ratio
Bit 2	Bit 1	Bit 0	
0	0	0	$\div 1$
0	0	1	$\div 2$
0	1	0	$\div 4$
0	1	1	$\div 8$
1	0	0	$\div 16$
1	0	1	$\div 32$
1	1	0	$\div 64$
1	1	1	$\div 128$

SELF CHECK

The MCU self check easily determines whether the LSI functions normally or not. When the MCU is connected as shown in Fig. 8, the outputs of port C₃ (LED) flicker in normal operation. ROM, RAM, TIMER 1, INT₁, Interrupt. I/O of Port A, B and C are checked by this capability.

RESETS

The MCU can be reset three ways; by initial power-up, by the external reset input (RES) and by an optional internal low voltage detect circuit, see Figure 9. All the I/O ports are initialized to input mode (DDRs are cleared) during reset.

During power-up, a minimum 100 milliseconds is needed before allowing the RES input to go "High". This time allows the internal crystal oscillator to stabilize. Connecting a capacitor to the RES input, as shown in Figure 10, typically provides sufficient delay.

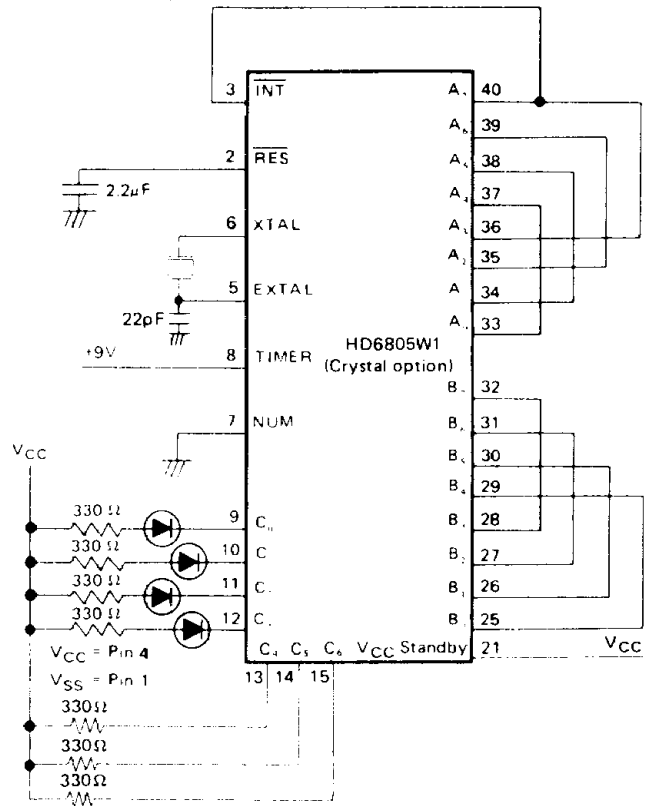


Figure 8 Self Check Connections

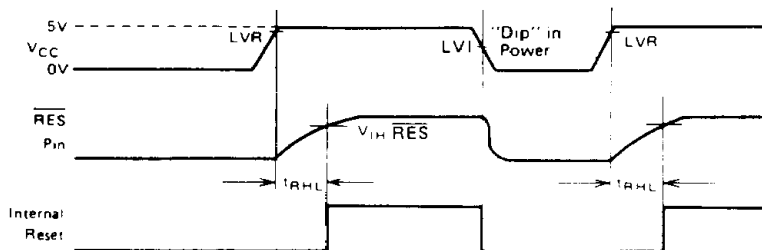


Figure 9 Power Up and Reset Timing

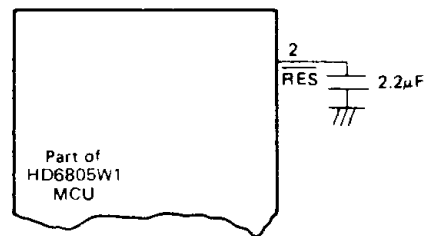


Figure 10 Power Up Reset Delay Circuit

INTERNAL OSCILLATOR OPTIONS

The internal oscillator circuit is designed to require a minimum of external components. A crystal (AT cut, 4 MHz max), a resistor, a jumper wire or an external signal may be used to generate a system clock with various stability/cost tradeoffs. A manufacturing mask option is required to select either the

crystal oscillator or the RC oscillator circuit. Four different connection methods are shown in Figure 11. Crystal specifications are given in Figure 12. A resistor selection graph is shown in Figure 13. EXTAL may be driven with a duty cycle of 50% with XTAL connected to ground.

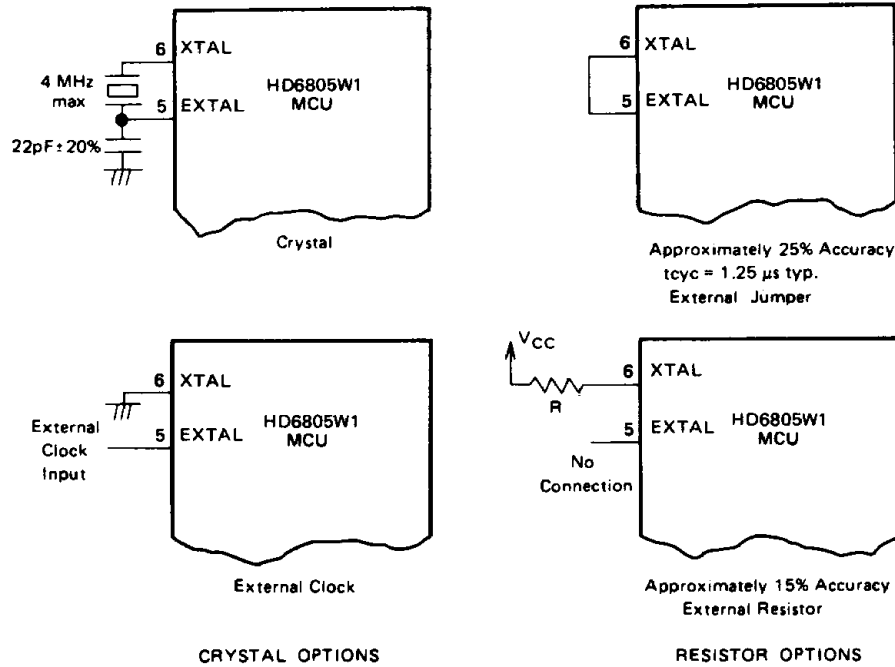
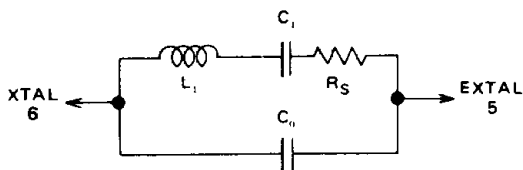


Figure 11 Internal Oscillator Options



AT - Cut Parallel Resonance Crystal
 $C_0 = 7 \text{ pF max.}$
 $f = 4 \text{ MHz } (C_1 = 22\text{pF} \pm 20\%)$
 $R_S = 60 \Omega \text{ max.}$

Figure 12 Crystal Parameters

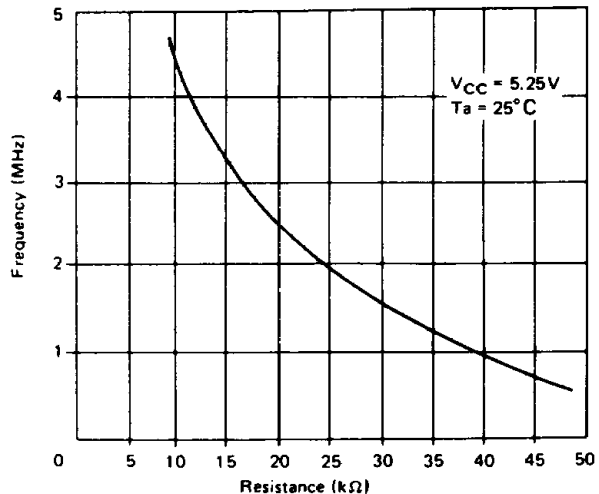


Figure 13 Typical Resistor Selection Graph

■ INTERRUPTS

The MCU can be interrupted in seven different ways: through external interrupt input pin (\overline{INT}_1 and \overline{INT}_2), internal timer interrupt request (Timer 1, ICI, OCI and OFI) and a software interrupt instruction (SWI). \overline{INT}_2 and Timer 1 are generated by the same vector address. When interrupt occurs, processing of the program is suspended, the present CPU state is pushed onto the stack in the order shown in Figure 4. The interrupt mask bit (I) of the Condition Code Register is set and the external routine priority address is achieved from the special external vector address. After that, the external interrupt routine is executed. Stacking the CPU registers, setting the I bit, and vector fetching requires 11 cycles. The interrupt service routines normally end with a return from interrupt (RTI) instruction which allows the CPU to resume processing of the program prior to the interrupt. The priority interrupts are shown in Table 6 with the vector address that contains the starting address of the appropriate interrupt routine. The interrupt sequence is shown as a flowchart in Figure 14.

Table 6 Interrupt Priorities

Interrupt	Priority	Vector Address
RES	1	\$FFE, \$FFF
SWI	2	\$FFC, \$FFD
\overline{INT}_1	3	\$FFA, \$FFB
TIMER ₁ / \overline{INT}_2	4	\$FF8, \$FF9
ICI	5	\$FF6, \$FF7
OCI	6	\$FF4, \$FF5
OFI	7	\$FF2, \$FF3

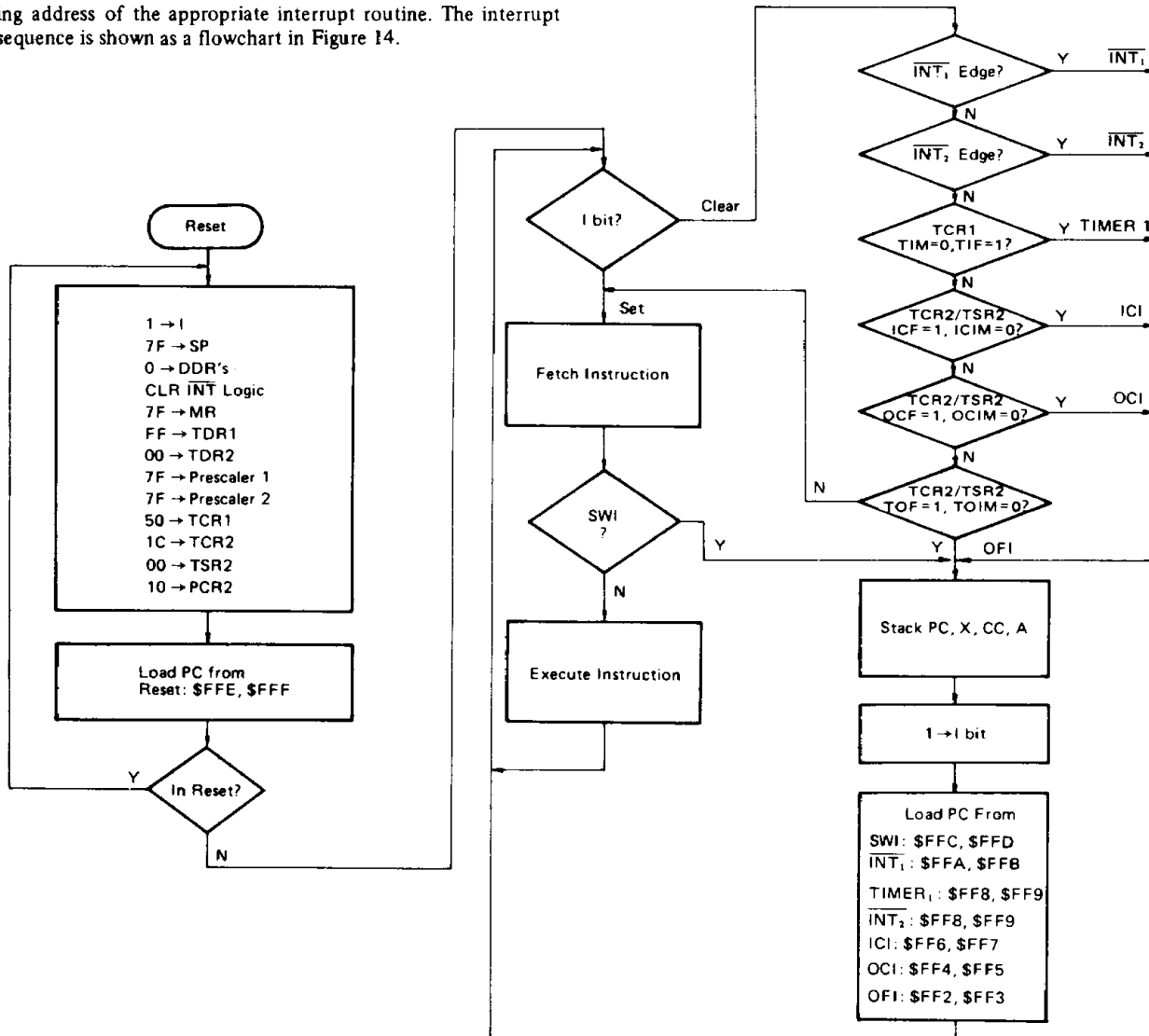


Figure 14 Interrupt Flowchart

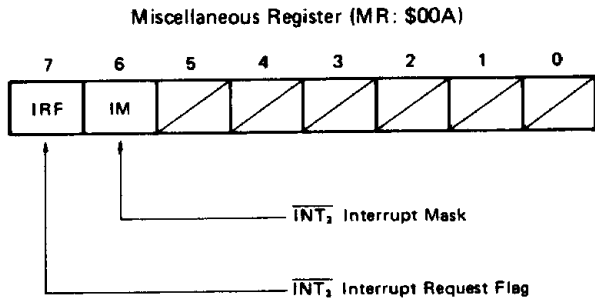


• **Miscellaneous Register (MR: \$00A)**

The vector address generated by the external interrupt (\overline{INT}_2) is the same as that of TIMER1 as shown in Table 6. The Miscellaneous Register (MR) controls the \overline{INT}_2 interrupt.

Bit 7 (IRF) of the MR is used as an \overline{INT}_2 interrupt request flag. \overline{INT}_2 interrupt occurs at the \overline{INT}_2 negative edge, and IRF is set. \overline{INT}_2 interrupt or not can be proved by checking IRF by software in the interrupt routine of the vector address (\$FF8, \$FF9). IRF should be reset by software (BCLR instruction).

Bit 6 (IM) of the MR is an \overline{INT}_2 interrupt mask bit. When IM is set, \overline{INT}_2 interrupt is disabled. \overline{INT}_2 interrupt is also disabled by bit (I) of the Condition Code Register (CC) like other interrupts.



IRF is available for both read and write. However, IRF is not writable by software. Therefore, \overline{INT}_2 interrupt cannot be requested by software. At reset, IRF is cleared and IM is set.

■ **INPUT/OUTPUT**

There are 23 input/output pins. All pins (port A, B, and C) are programmable as either inputs or outputs under software

control of the corresponding Data Direction Register (DDR). The port I/O programming is accomplished by writing the corresponding bit in the port DDR to a logic "1" for output or a logic "0" for input. On reset, all the DDRs are initialized to a logic "0" state to put the ports in the input mode. The port output registers are not initialized on reset but may be written to before setting the DDR bits to avoid undefined levels. When programmed as outputs, the latched output data is readable as input data, regardless of the logic levels at the output pin due to output loading; see Figure 15. When port B is programmed for outputs, it is capable of sinking 10 mA and sourcing 1 mA on each pin.

All input/output lines are TTL compatible as both inputs and outputs. Ports B and C are CMOS compatible as inputs. Port A is CMOS compatible as outputs. Figure 16 provides some examples of port connections.

Port C5 and C6 are also used for Timer 2.

When Port C5 is used as Timer 2 Input Capture (IC), Port C5's DDR should be cleared (Port C5 as input) and bit 4 (ICIM) in the Timer Control Register 2 (TCR2) should be cleared too. The Input Capture Register (ICR) stores the TDR2 when a Port C5 input transition occurs as defined by bit 1 (IDEG) of the TCR2.

When Port C6 is used as Timer 2 Output Compare (OC), Port C6's DDR should be set (Port C6 as output). When the Output Compare Register (OCR) matches the TDR2, bit 0 (OLVL) in the TCR2 is set and OLVL will appear at Port C6. Port C6 is writable by software. But the writing by software is unavailable when a match between the TDR2 and the OCR is found at the same time.

■ **INPUT**

Port D is usable as either TTL compatible inputs or a 4-channel input for an A/D converter. Figure 17 shows port D logic configuration.

The Port D register at location \$003 stores TTL compatible inputs. When using as analog inputs for an A/D converter, refer to A/D CONVERTER. D0 can be used as the \overline{INT}_2 interrupt input pin.

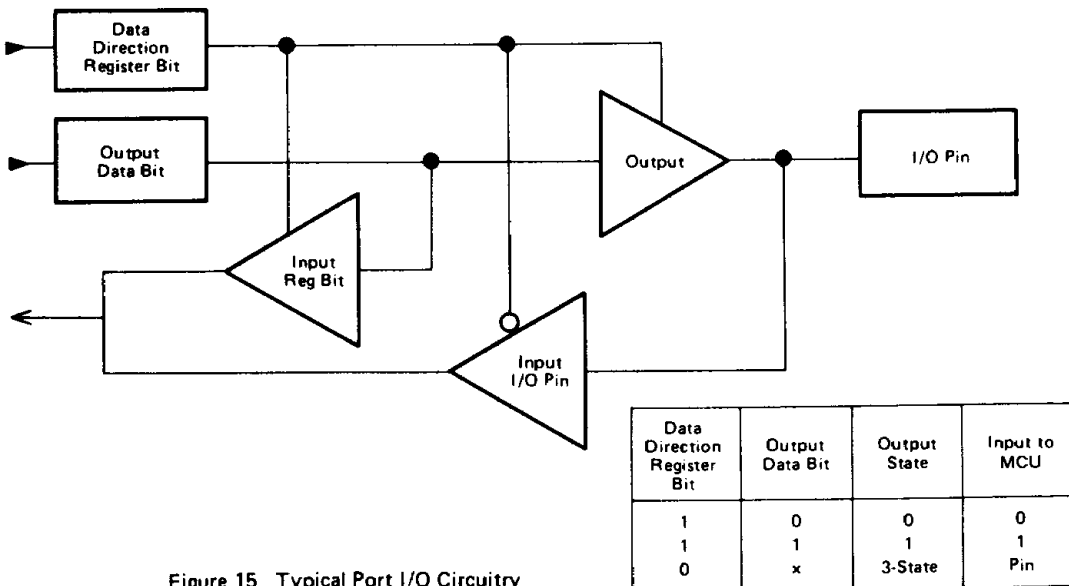


Figure 15 Typical Port I/O Circuitry

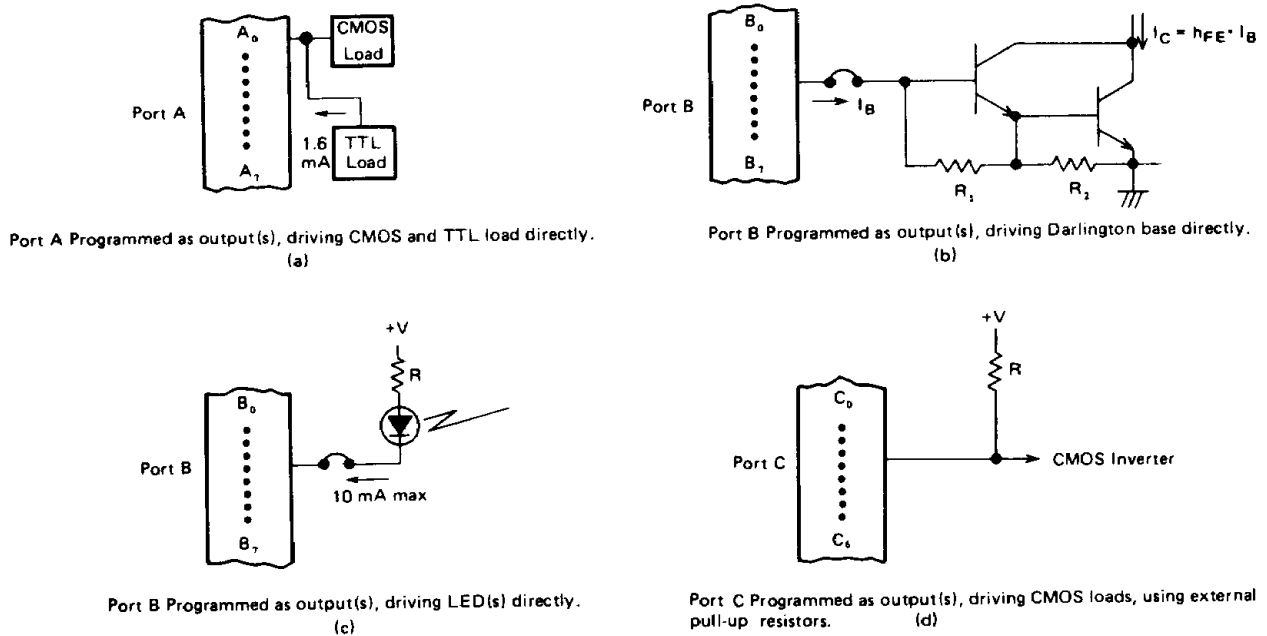


Figure 16 Typical Port Connections

■ A/D CONVERTER

The HD6805W1 has an internal 8-bit A/D converter. The A/D converter, shown in Figure 18, includes 4 analog inputs (AN₀ to AN₃), the Result Register (ADRR) and the Control Status Register (ADCSR).

to 5V. The resolution is 8-bit (256 divisions) with a conversion time of 76 μs at 1 MHz. Analog conversion starts selecting analog inputs by bit 0 and bit 1 of the ADCSR analog input. Since the CPU is not required during conversion, other user programs can be executed.

● Analog Input (AN₀ to AN₃)

Analog inputs AN₀ to AN₃ accept analog voltages of 0V

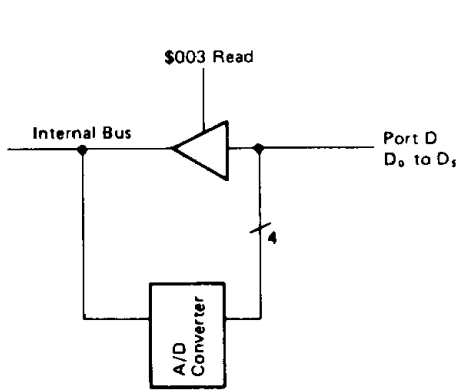


Figure 17 Port D

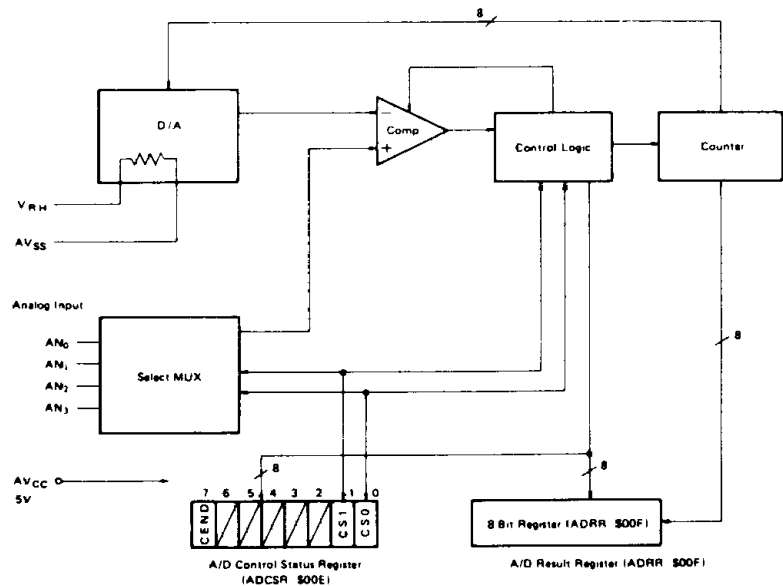


Figure 18 A/D Converter Block Diagram

CAUTION

The MCU has circuitry to protect the inputs against damage due to high static voltages or electric field; however, the design of the input circuitry for the A/D converter, AN₀ ~ AN₃, V_{RH} and AV_{CC}, does not offer the same level of protection. Precautions should be taken to avoid applications of any voltage higher than maximum-rated voltage or handled in any environment producing high-static voltages.

Table 7 Analog Input Selection

ADCSR		Analog Input Signal
Bit 1	Bit 0	
0	0	AN ₀
0	1	AN ₁
1	0	AN ₂
1	1	AN ₃

• **A/D Control Status Register (ADCSR: \$00E)**

The Control Status Register (ADCSR) is used to select an analog input pin and confirm A/D conversion termination. An analog input pin is selected by bit 0 and bit 1 as shown in Table 7.

A/D conversion begins when the data is written into bit 0 and bit 1 of the ADCSR. When A/D conversion ends, bit 7 (CEND) is set. Bit 7 is reset after the ADRR is read. Even if bit 7 is set, A/D conversion execution still continues. To end the A/D conversion, the A/D Result Register (ADRR) stores the most current value. During A/D conversion execution, new data is written into the ADCSR selecting the input channel and the A/D conversion execution at that time is suspended. CEND is reset and new A/D conversion begins.

• **A/D Result Register (ADRR: \$00F)**

When the A/D conversion ends, the result is set in the A/D Result Register (\$00F). When CEND of the ADCSR is set, converted result is obtained by reading the ADRR. Furthermore, CEND is cleared.

■ **STANDBY RAM**

The portion from \$020 to \$027 of the RAM can be used for the standby RAM.

When using the standby RAM, V_{CC} Standby should remain above V_{SBB} (min) during powerdown. Consequently, power is provided only to the standby RAM and STBY PWR bit of the RAM Control Register. 8 byte RAM is sustained with small power dissipation. The RAM including the standby RAM is controlled by the RAM Control Register (RCR) or RAME pin.

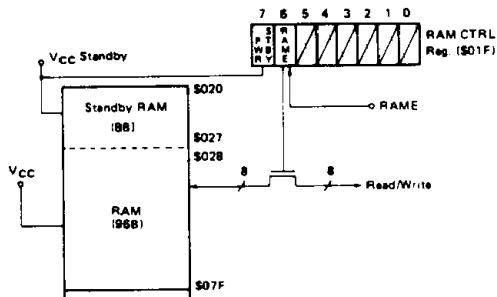
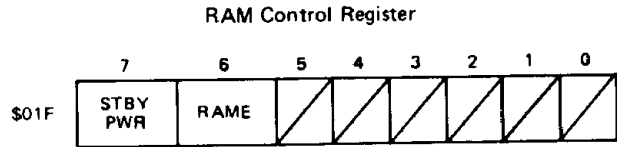


Figure 19 Standby RAM

• **RAM Control Register (RCR: \$01F)**

This register at location \$01F gives the status information about the RAM. When RAM Enable bit (RAME) is "0", the RAM is disabled. When V_{CC} Standby is greater than V_{SBB}, Standby Power bit (STBY PWR) is set and the standby RAM is sustained during powerdown.



Bit 6 RAM Enable

RAME bit is set or cleared by either software or hardware. When the MCU is reset, RAME bit is set and the RAM is enabled. If RAME bit is cleared, the user can neither read nor write the RAM.

When the RAM is disabled (logic "0"), the RAM address is invalid.

Bit 7 Standby Power

STBY PWR bit is cleared whenever V_{CC} standby decreases below V_{SBB} (min). This bit is a read/write status bit that the user can read. When this bit is set, it indicates that the standby power is applied and data in the standby RAM is valid. This bit is set by software and not affected by reset.

• **RAME Signal**

RAME bit in the RCR can be cleared when RAME pin goes "Low" by hardware (RAM is disabled). To make standby mode by hardware, set RAME pin "Low" during V_{CC} Standby remains above V_{SBB} (min) and powerdown sequence should be as shown in Fig. 20.

When RAME pin gets "Low" in the powerup state, RAME bit of the RCR is cleared and the RAM is disabled. During powerdown, RAME bit is sustained by V_{CC} Standby. When RAME pin gets "High" in the powerup state, RAME bit of the RCR is set and the RAM is enabled.

RAME pin can be used to control the RAM externally without software.

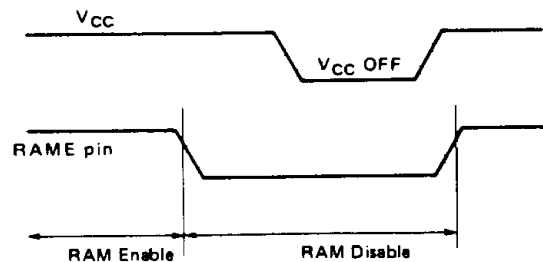


Figure 20 RAM Control Signal (RAME)

■ **BIT MANIPULATION**

The MCU has the ability to set or clear any single RAM or input/output port (except the data direction registers) with a single instruction (BSET and BCLR). Any bit in the page zero read only memory can be tested by using the BRSET and

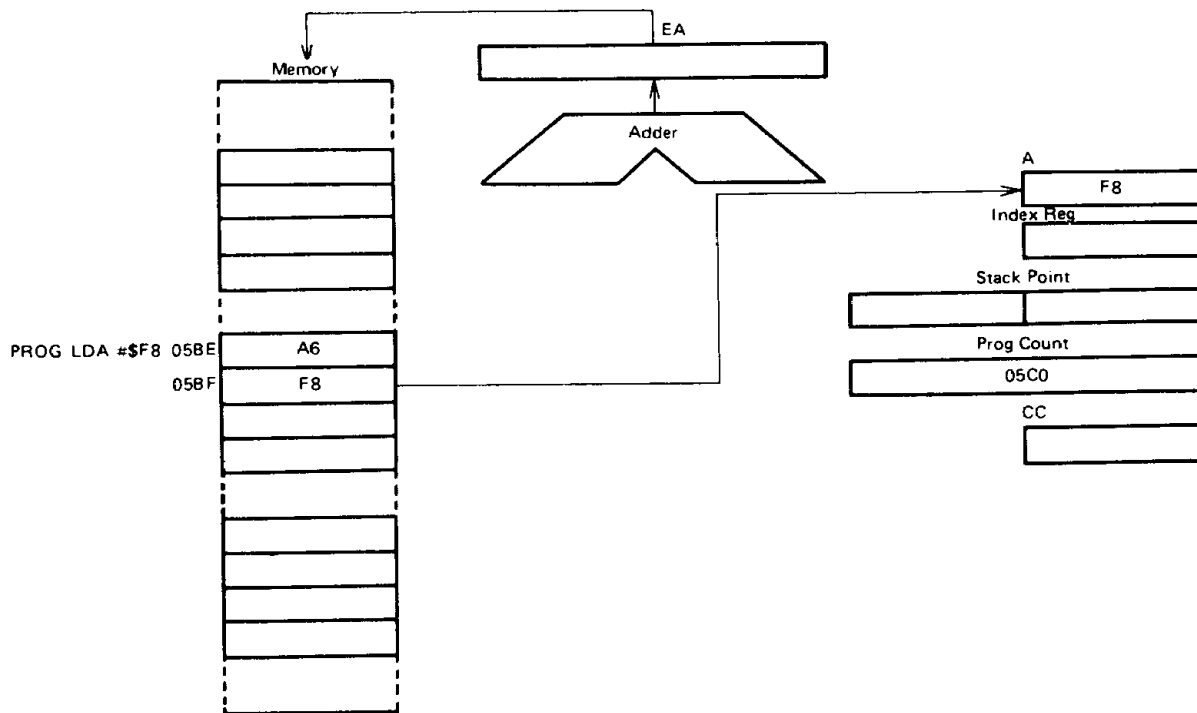


Figure 22 Immediate Addressing Example

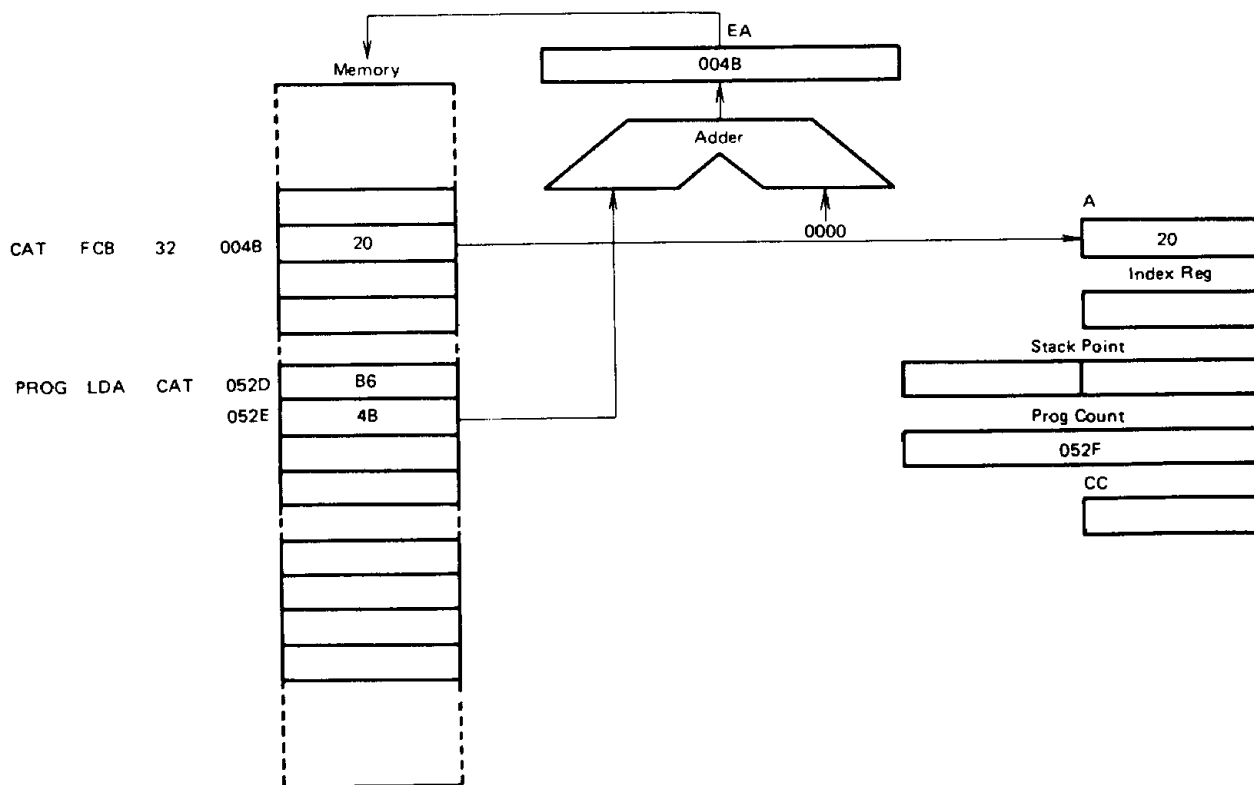


Figure 23 Direct Addressing Example

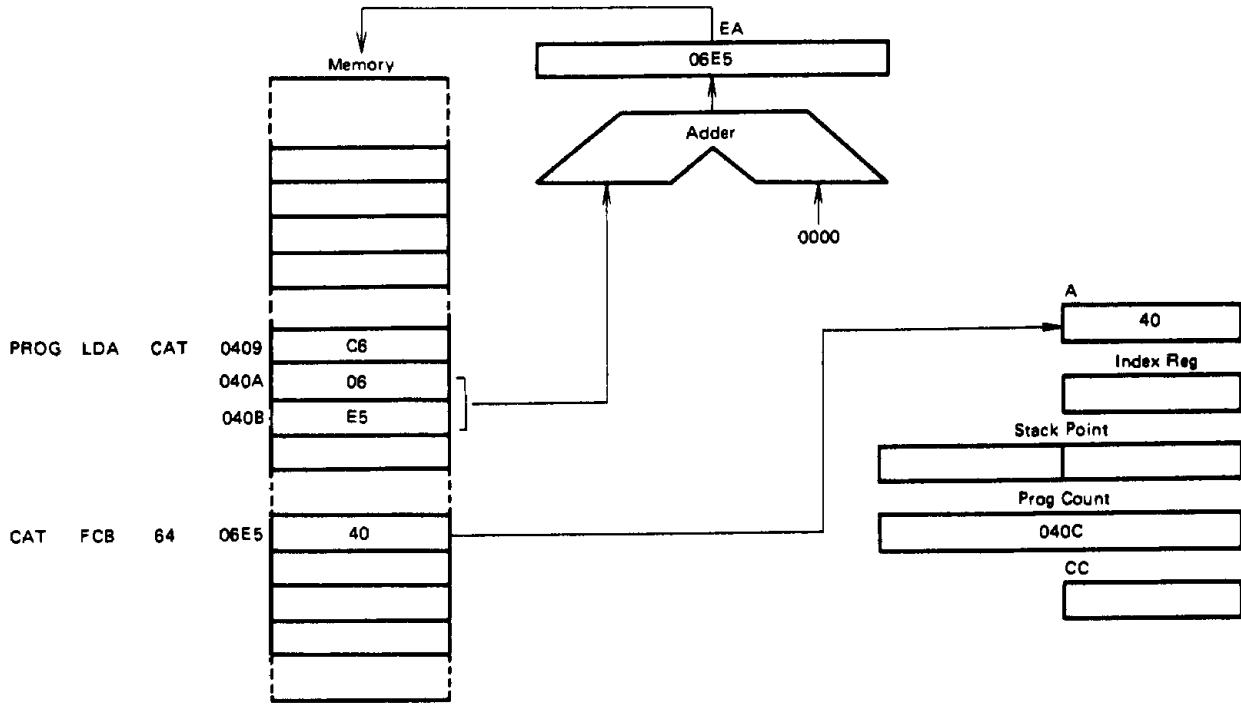


Figure 24 Extended Addressing Example

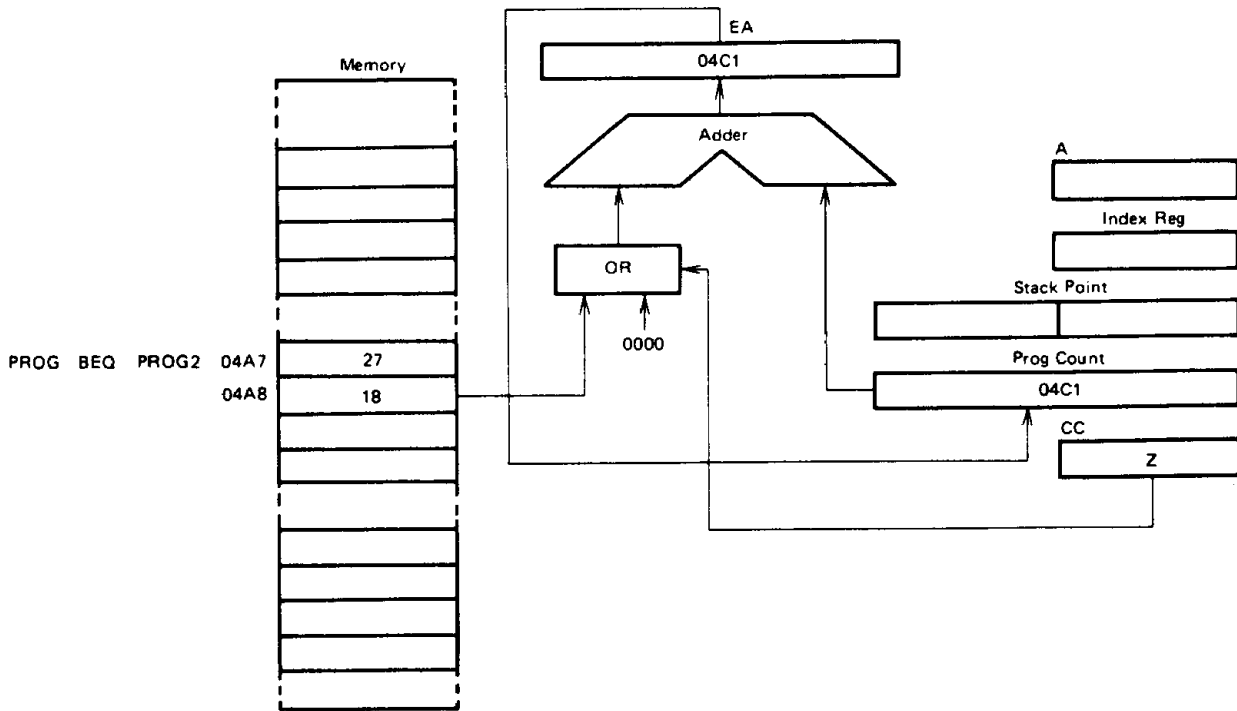


Figure 25 Relative Addressing Example

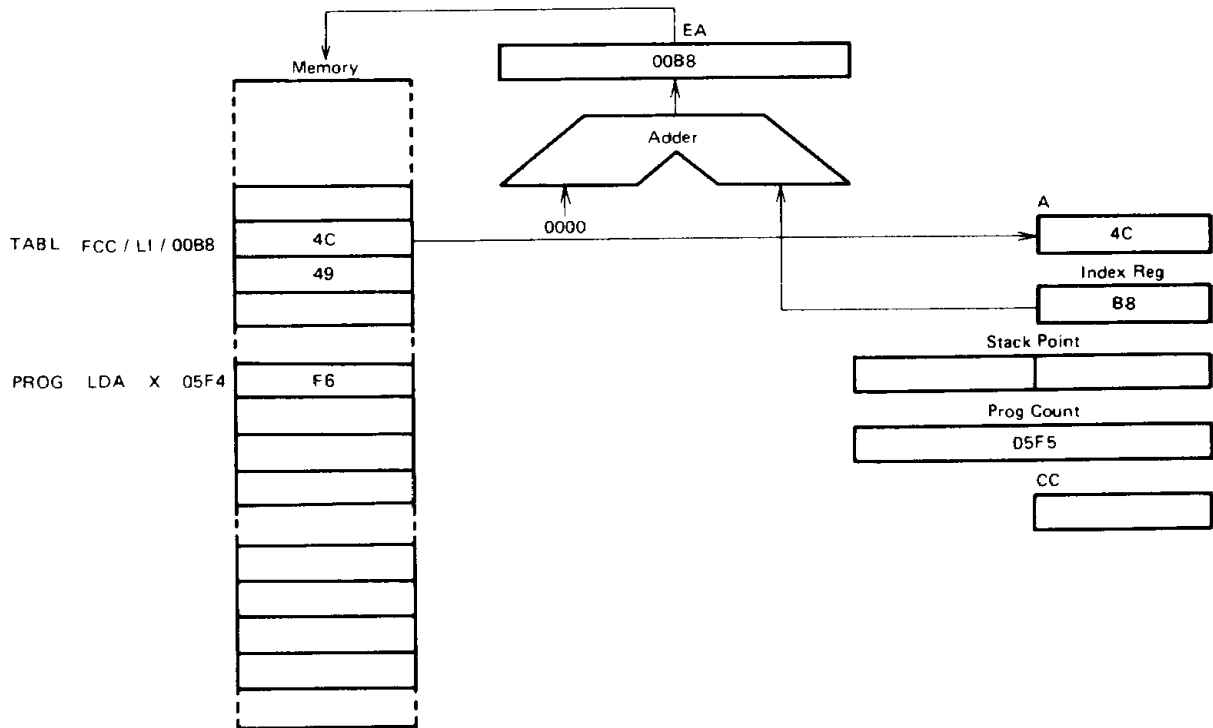


Figure 26 Indexed (No Offset) Addressing Example

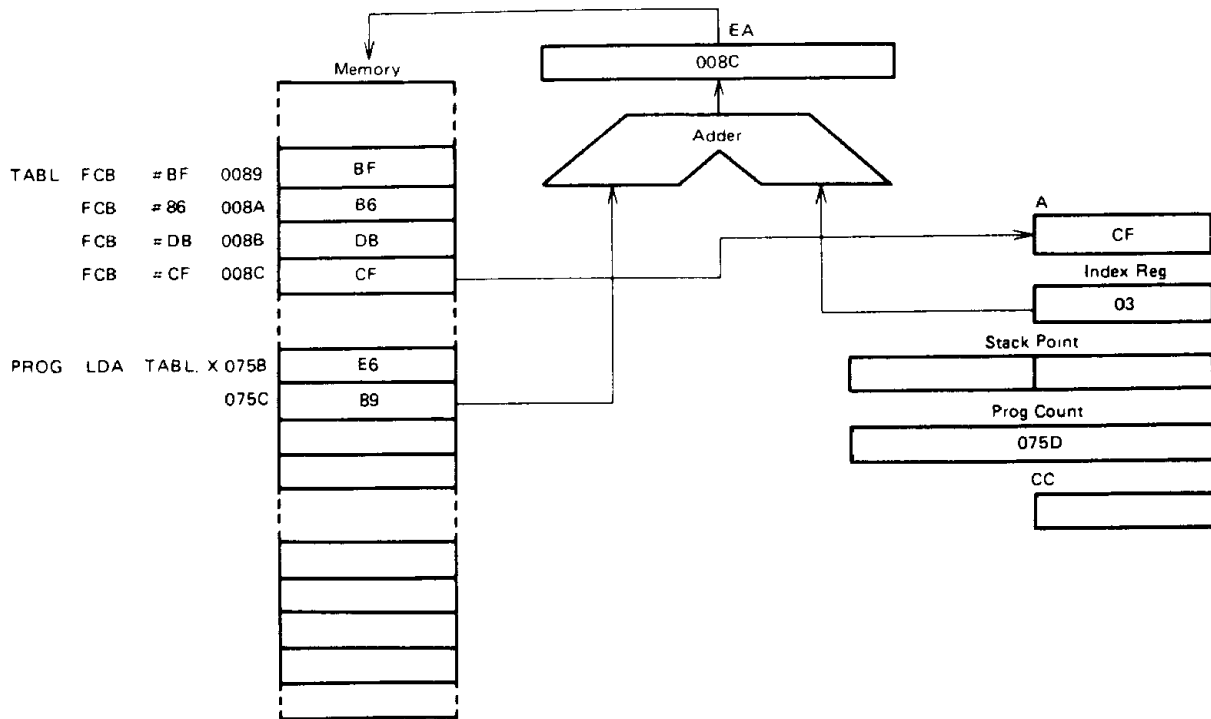


Figure 27 Indexed (8-Bit Offset) Addressing Example

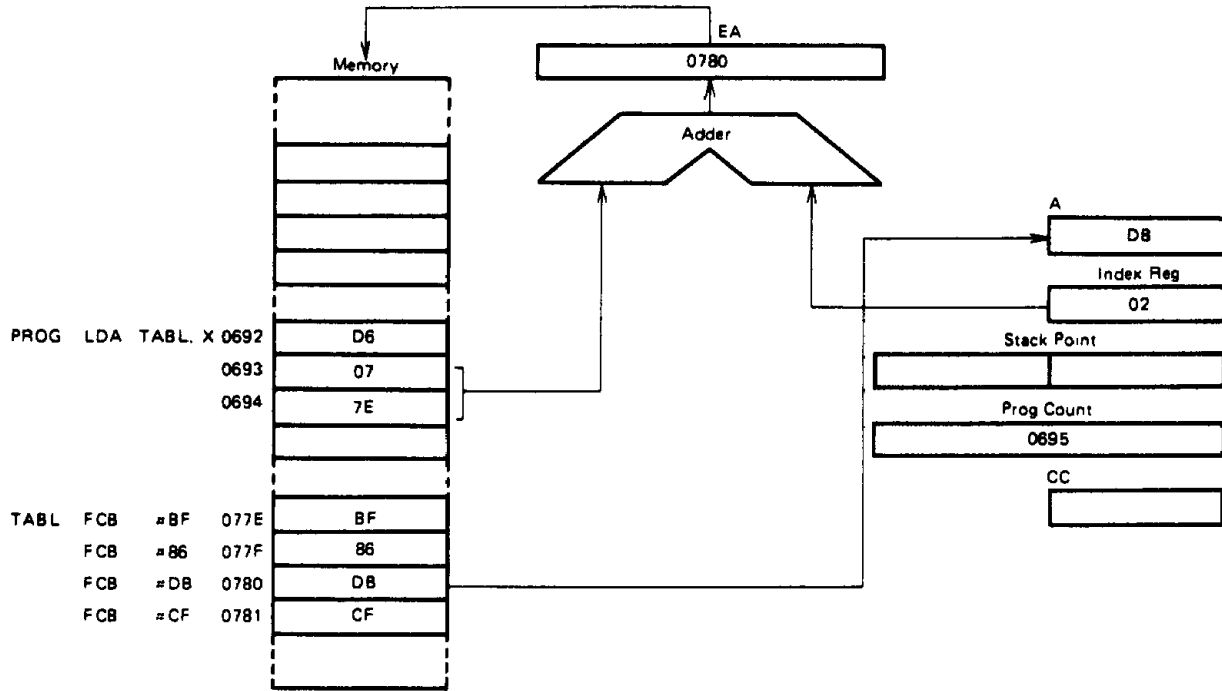


Figure 28 Indexed (16-Bit Offset) Addressing Example

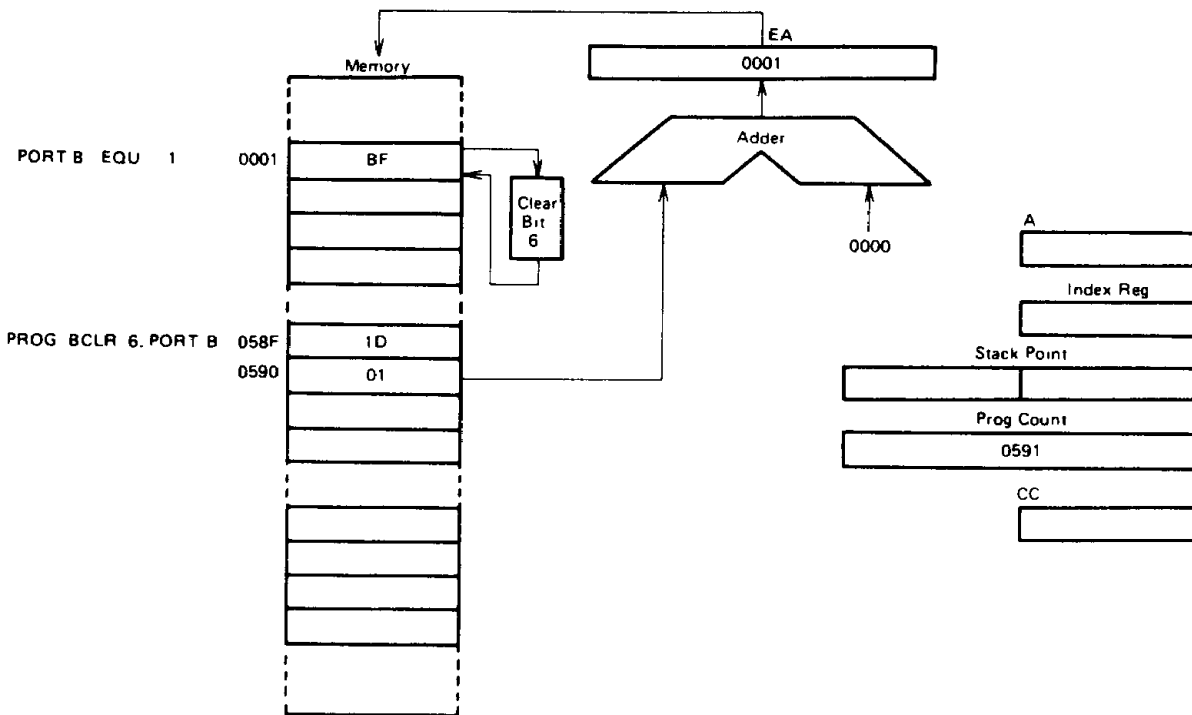


Figure 29 Bit Set/Clear Addressing Example

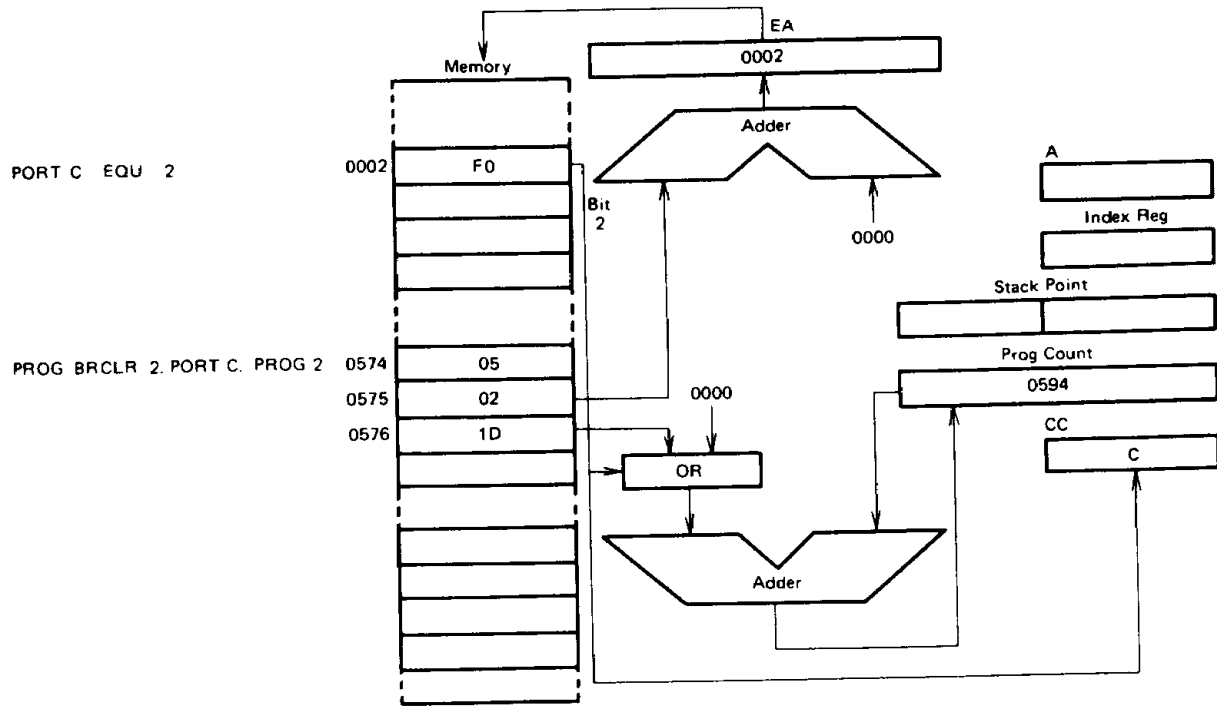


Figure 30 Bit Test and Branch Addressing Example

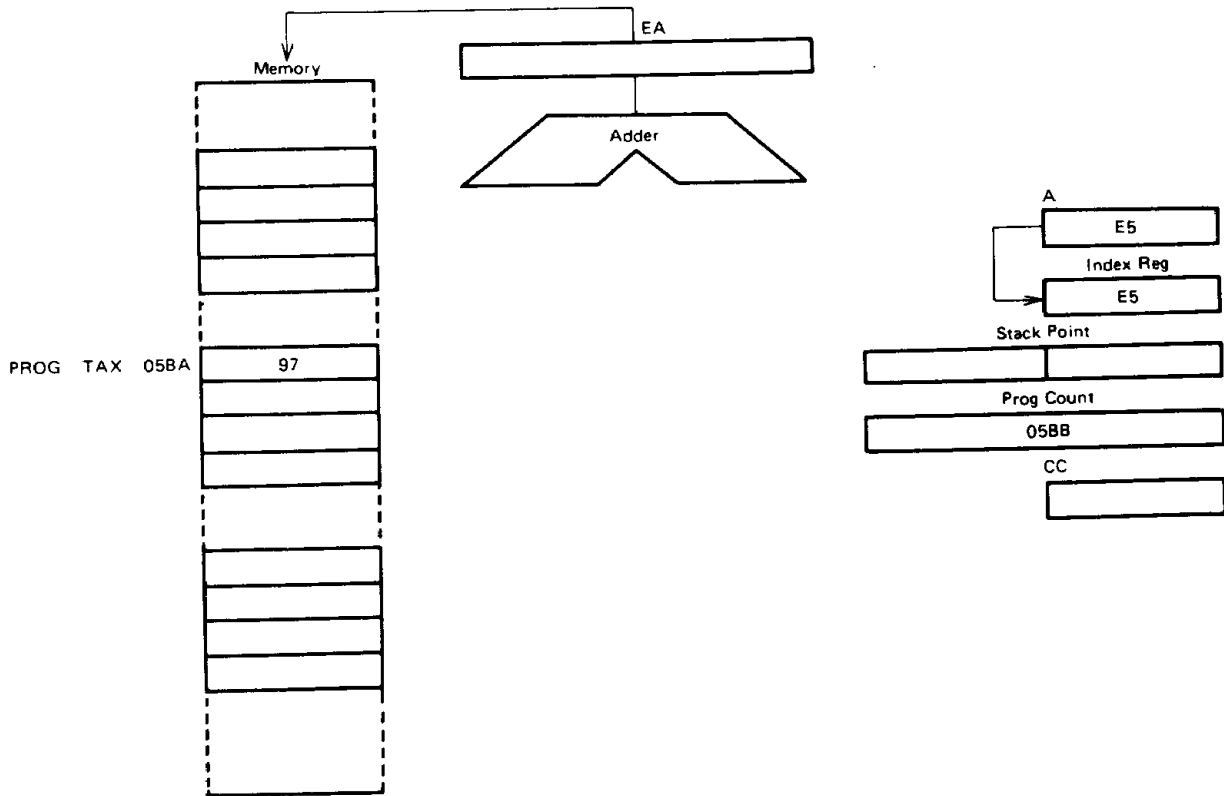


Figure 31 Implied Addressing Example

■ INSTRUCTION SET

The MCU has a set of 59 basic instructions. These instructions can be divided into five different types; register/memory, read/modify/write, branch, bit manipulation and control. Each instruction is briefly explained below. All of the instructions within a given type are presented in individual tables.

● Register/Memory Instructions

Most of these instructions use two operands. One operand is either the accumulator or the index register. The other operand is obtained from memory by using one of the addressing modes. The jump unconditional (JMP) and jump to subroutine (JSR) instructions have no register operand. Refer to Table 8.

● Read/Modify/Write Instructions

These instructions read a memory location or a register, modify or test its contents and write the modified value back to the memory or register. The TST instruction for test of negative or zero is an exception to the read/modify/write instructions since it does not perform the write. Refer to Table 9.

● Branch Instructions

The branch instructions cause a branch from a program when a certain condition is met. Refer to Table 10.

● Bit Manipulation Instructions

These instructions are used on any bit in the first 256 bytes of the memory. One group either sets or clears. The other group performs the bit test and branch operations. Refer to Table 11.

● Control Instructions

The control instructions control the MCU operations during program execution. Refer to Table 12.

● Alphabetical Listing

The complete instruction set is given in alphabetical order in Table 13.

● Opcode Map

Table 14 is an opcode map for the instructions used on the MCU.

Table 8 Register/Memory Instructions

Function	Mnemonic	Addressing Modes																	
		Immediate			Direct			Extended			Indexed (No Offset)			Indexed (8-Bit Offset)			Indexed (16-Bit Offset)		
		Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles
Load A from Memory	LDA	A6	2	2	B6	2	4	C6	3	5	F6	1	4	E6	2	5	D6	3	6
Load X from Memory	LDX	AE	2	2	BE	2	4	CE	3	5	FE	1	4	EE	2	5	DE	3	6
Store A in Memory	STA	-	-	-	B7	2	5	C7	3	6	F7	1	5	E7	2	6	D7	3	7
Store X in Memory	STX	-	-	-	BF	2	5	CF	3	6	FF	1	5	EF	2	6	DF	3	7
Add Memory to A	ADD	AB	2	2	BB	2	4	CB	3	5	FB	1	4	EB	2	5	DB	3	6
Add Memory and Carry to A	ADC	A9	2	2	B9	2	4	C9	3	5	F9	1	4	E9	2	5	D9	3	6
Subtract Memory	SUB	A0	2	2	B0	2	4	C0	3	5	F0	1	4	E0	2	5	D0	3	6
Subtract Memory from A with Borrow	SBC	A2	2	2	B2	2	4	C2	3	5	F2	1	4	E2	2	5	D2	3	6
AND Memory to A	AND	A4	2	2	B4	2	4	C4	3	5	F4	1	4	E4	2	5	D4	3	6
OR Memory with A	ORA	AA	2	2	BA	2	4	CA	3	5	FA	1	4	EA	2	5	DA	3	6
Exclusive OR Memory with A	EOR	A8	2	2	B8	2	4	C8	3	5	F8	1	4	E8	2	5	D8	3	6
Arithmetic Compare A with Memory	CMP	A1	2	2	B1	2	4	C1	3	5	F1	1	4	E1	2	5	D1	3	6
Arithmetic Compare X with Memory	CPX	A3	2	2	B3	2	4	C3	3	5	F3	1	4	E3	2	5	D3	3	6
Bit Test Memory with A (Logical Compare)	BIT	A5	2	2	B5	2	4	C5	3	5	F5	1	4	E5	2	5	D5	3	6
Jump Unconditional	JMP	-	-	-	BC	2	3	CC	3	4	FC	1	3	EC	2	4	DC	3	5
Jump to Subroutine	JSR	-	-	-	BD	2	7	CD	3	8	FD	1	7	ED	2	8	DD	3	9

Symbols:
Op : Operation Abbreviation
: Instruction Statement

Table 9 Read/Modify/Write Instructions

Function	Mnemonic	Addressing Modes														
		Implied (A)			Implied (X)			Direct			Indexed (No Offset)			Indexed (8 Bit Offset)		
		Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles
Increment	INC	4C	1	4	5C	1	4	3C	2	6	7C	1	6	6C	2	7
Decrement	DEC	4A	1	4	5A	1	4	3A	2	6	7A	1	6	6A	2	7
Clear	CLR	4F	1	4	5F	1	4	3F	2	6	7F	1	6	6F	2	7
Complement	COM	43	1	4	53	1	4	33	2	6	73	1	6	63	2	7
Negate (2's Complement)	NEG	40	1	4	50	1	4	30	2	6	70	1	6	60	2	7
Rotate Left Thru Carry	ROL	49	1	4	59	1	4	39	2	6	79	1	6	69	2	7
Rotate Right Thru Carry	ROR	46	1	4	56	1	4	36	2	6	76	1	6	66	2	7
Logical Shift Left	LSL	48	1	4	58	1	4	38	2	6	78	1	6	68	2	7
Logical Shift Right	LSR	44	1	4	54	1	4	34	2	6	74	1	6	64	2	7
Arithmetic Shift Right	ASR	47	1	4	57	1	4	37	2	6	77	1	6	67	2	7
Arithmetic Shift Left	ASL	48	1	4	58	1	4	38	2	6	78	1	6	68	2	7
Test for Negative or Zero	TST	4D	1	4	5D	1	4	3D	2	6	7D	1	6	6D	2	7

Symbols:
Op : Operation Abbreviation
: Instruction Statement

Table 10 Branch Instructions

Function	Mnemonic	Relative Addressing Mode		
		Op Code	# Bytes	# Cycles
Branch Always	BRA	20	2	4
Branch Never	BRN	21	2	4
Branch IF Higher	BHI	22	2	4
Branch IF Lower or Same	BLS	23	2	4
Branch IF Carry Clear	BCC	24	2	4
(Branch IF Higher or Same)	(BHS)	24	2	4
Branch IF Carry Set	BCS	25	2	4
(Branch IF Lower)	(BLO)	25	2	4
Branch IF Not Equal	BNE	26	2	4
Branch IF Equal	BEQ	27	2	4
Branch IF Half Carry Clear	BHCC	28	2	4
Branch IF Half Carry Set	BHCS	29	2	4
Branch IF Plus	BPL	2A	2	4
Branch IF Minus	BMI	2B	2	4
Branch IF Interrupt Mask Bit is Clear	BMC	2C	2	4
Branch IF Interrupt Mask Bit is Set	BMS	2D	2	4
Branch IF Interrupt Line is Low	BIL	2E	2	4
Branch IF Interrupt Line is High	BIH	2F	2	4
Branch to Subroutine	BSR	AD	2	8

Symbols: Op: Operation Abbreviation #: Instruction Statement

Table 11 Bit Manipulation Instructions

Function	Mnemonic	Addressing Modes					
		Bit Set/Clear			Bit Test and Branch		
		Op Code	# Bytes	# Cycles	Op Code	# Bytes	# Cycles
Branch IF Bit n is set	BRSET n (n=0 7)	—	—	—	2·n	3	10
Branch IF Bit n is clear	BRCLR n (n=0 7)	—	—	—	01+2·n	3	10
Set Bit n	BSET n (n=0 7)	10+2·n	2	7	—	—	—
Clear bit n	BCLR n (n=0 7)	11+2·n	2	7	—	—	—

Symbols: Op: Operation Abbreviation #: Instruction Statement

Table 12 Control Instructions

Function	Mnemonic	Implied		
		Op Code	# Bytes	# Cycles
Transfer A to X	TAX	97	1	2
Transfer X to A	TXA	9F	1	2
Set Carry Bit	SEC	99	1	2
Clear Carry Bit	CLC	98	1	2
Set Interrupt Mask Bit	SEI	9B	1	2
Clear Interrupt Mask Bit	CLI	9A	1	2
Software Interrupt	SWI	83	1	11
Return from Subroutine	RTS	81	1	6
Return from Interrupt	RTI	80	1	9
Reset Stack Pointer	RSP	9C	1	2
No-Operation	NOP	9D	1	2

Symbols: Op: Operation Abbreviation #: Instruction Statement



Table 13 Instruction Set

Mnemonic	Addressing Modes										Condition Code				
	Implied	Immediate	Direct	Extended	Relative	Indexed (No Offset)	Indexed (8 Bits)	Indexed (16 Bits)	Bit Set/Clear	Bit Test & Branch	H	I	N	Z	C
ADC		x	x	x		x	x	x			^	•	^	^	^
ADD		x	x	x		x	x	x			^	•	^	^	^
AND		x	x	x		x	x	x			•	•	^	^	•
ASL	x		x			x	x				•	•	^	^	^
ASR	x		x			x	x				•	•	^	^	^
BCC					x						•	•	•	•	•
BCLR									x		•	•	•	•	•
BCS					x						•	•	•	•	•
BEQ					x						•	•	•	•	•
BHCC					x						•	•	•	•	•
BHCS					x						•	•	•	•	•
BHI					x						•	•	•	•	•
BHS					x						•	•	•	•	•
BIH					x						•	•	•	•	•
BIL					x						•	•	•	•	•
BIT		x	x	x		x	x	x			•	•	^	^	•
BLO					x						•	•	•	•	•
BLS					x						•	•	•	•	•
BMC					x						•	•	•	•	•
BMI					x						•	•	•	•	•
BMS					x						•	•	•	•	•
BNE					x						•	•	•	•	•
BPL					x						•	•	•	•	•
BRA					x						•	•	•	•	•
BRN					x						•	•	•	•	•
BRCLR										x	•	•	•	•	^
BRSET										x	•	•	•	•	^
BSET									x		•	•	•	•	•
BSR					x						•	•	•	•	•
CLC	x										•	•	•	•	0
CLI	x										•	0	•	•	•
CLR	x		x			x	x				•	•	0	1	•
CMP		x	x	x		x	x	x			•	•	^	^	^
COM	x		x			x	x				•	•	^	^	1
CPX		x	x	x		x	x	x			•	•	^	^	^
DEC	x		x			x	x				•	•	^	^	•
EOR		x	x	x		x	x	x			•	•	^	^	•
INC	x		x			x	x				•	•	^	^	•
JMP			x	x		x	x	x			•	•	•	•	•
JSR			x	x		x	x	x			•	•	•	•	•
LDA		x	x	x		x	x	x			•	•	^	^	•
LDX		x	x	x		x	x	x			•	•	^	^	•

Condition Code Symbols:
H Half Carry (From Bit 3)
I Interrupt Mask
N Negative (Sign Bit)
Z Zero

C Carry Borrow
^ Test and Set if True, Cleared Otherwise
• Not Affected

(to be continued)



Table 13 Instruction Set

Mnemonic	Addressing Modes										Condition Code				
	Implied	Immediate	Direct	Extended	Relative	Indexed (No Offset)	Indexed (8 Bits)	Indexed (16 Bits)	Bit Set/Clear	Bit Test & Branch	H	I	N	Z	C
LSL	x		x			x	x				●	●	^	^	^
LSR	x		x			x	x				●	●	0	^	^
NEQ	x		x			x	x				●	●	●	●	●
NOP	x										●	●	●	●	●
ORA		x	x	x		x	x	x			●	●	^	^	●
ROL	x		x			x	x				●	●	^	^	^
ROR	x		x			x	x				●	●	●	●	●
RSP	x										?	?	?	?	?
RTI	x										●	●	●	●	●
RTS	x										●	●	^	^	^
SBC		x	x	x		x	x	x			●	●	●	●	1
SEC	x										●	1	●	●	●
SEI	x										●	1	●	●	●
STA			x	x		x	x	x			●	●	^	^	●
STX			x	x		x	x	x			●	●	^	^	●
SUB		x	x	x		x	x	x			●	●	^	^	^
SWI	x										●	1	●	●	●
TAX	x										●	●	●	●	●
TST	x		x			x	x				●	●	^	^	●
TXA	x										●	●	●	●	●

Condition Code Symbols:

H Half Carry (From Bit 3)
 I Interrupt Mask
 N Negative (Sign Bit)
 Z Zero

C Carry/Borrow
 ^ Test and Set if True, Cleared Otherwise
 ● Not Affected
 ? Load CC Register From Stack

Table 14 Opcode Map

Test & Branch	Bit Manipulation		Brnch	Read/Modify/Write				Control		Register/Memory							--HIGH	
	Set/Clear	Rel		DIR	A	X	X1	X0	IMP	IMP	IMM	DIR	EXT	X2	X1	X0		
0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F			
0	BRSET0	BSET0	BRA	NEQ				RTI*	--	SUB							0	
1	BRCLR0	BCLR0	BRN	--				RTS*	--	CMP							1	
2	BRSET1	BSET1	BHI	--				--	--	SBC							2	
3	BRCLR1	BCLR1	BLS	COM				SWI*	--	CPX							3 L	
4	BRSET2	BSET2	BCC	LSR				--	--	AND							4 D	
5	BRCLR2	BCLR2	BCS	--				--	--	BIT							5 W	
6	BRSET3	BSET3	BNE	ROR				--	--	LDA							6	
7	BRCLR3	BCLR3	BEQ	ASR				--	TAX	--	STA(+1)							7
8	BRSET4	BSET4	BHCC	LSL/ASL				--	CLC	--	EOR							8
9	BRCLR4	BCLR4	BHCS	ROL				--	SEC	--	ADC							9
A	BRSET5	BSET5	BPL	DEC				--	CLI	--	ORA							A
B	BRCLR5	BCLR5	BMI	--				--	SEI	--	ADD							B
C	BRSET6	BSET6	BMC	INC				--	RSP	--	JMPI(-1)							C
D	BRCLR6	BCLR6	BMS	TST				--	NOP	BSR*	JSR(+3)							D
E	BRSET7	BSET7	BIL	--				--	--	--	LDX							E
F	BRCLR7	BCLR7	BIH	CLR				--	TXA	--	STX(+1)							F
	3/10	2/7	2/4	2/6	1/4	1/4	2/7	1/6	1/*	1/2	2/2	2/4	3/5	3/6	2/5	1/4		

(NOTE) 1. Undefined opcodes are marked with "--".
 2. The number at the bottom of each column denote the number of bytes and the number of cycles required (Bytes/Cycles).
 Mnemonics followed by a "*" require a different number of cycles as follows:
 RTI 9
 RTS 6
 SWI 11
 BSR 8
 3. () indicate that the number in parenthesis must be added to the cycle count for that instruction.

