CMOS single-chip 8-bit EPROM microcontroller

87C451

FEATURES

- User-programmable microcontroller
- 80C51-based architecture
- 68-Pin QFP package
  - Six 8-bit ports and one 4-bit port
- Port 6 features:
  - 8 data pins
  - 4 control pins
  - Direct MPU bus interface
  - Parallel printer interface
- On the microcontroller
  - 4K × 8 EPROM
  - 128 × 8 RAM
  - Two 16-bit counter/timers
  - Two external interrupts
- External memory addressing capability:
  - 64K ROM and 64K RAM
- Low power consumption:
  - Normal operation: less than 24mA at 5V, 12MHz
  - Idle mode
  - Power-down mode

DESCRIPTION

The Philips 87C451 is an I/O expanded, single-chip microcontroller fabricated with Philips high-density CMOS technology. Philips epitaxial substrate minimizes latch-up sensitivity.

The 87C451 has 4K of EPROM on chip as program memory and is otherwise identical to the 83C451.

The 87C451 is a functional extension of the 87C51 microcontroller with three additional I/O ports and four I/O control lines. Four control lines associated with port 6 facilitate high-speed asynchronous I/O functions.

The 87C451 includes a 4K × 8 EPROM; a 128 × 8 RAM; 64 I/O lines; two 16-bit timer/counters; a five source, two priority level, nested interrupt structure; a serial I/O port for either a full-duplex UART, I/O expansion, or multiprocessor communications; and on-chip oscillator and clock circuits.

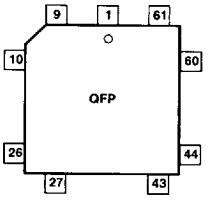
The 87C451 has two software selectable modes of reduced activity for further power reduction; idle mode and power-down mode. Idle mode freezes the CPU while allowing the RAM, timers, serial port, and interrupt system to continue functioning. Power-down mode freezes the oscillator, causing all other chip functions to be inoperative while maintaining the RAM contents.

ORDERING INFORMATION

DESCRIPTION	ORDER CODE	PKG DESIGNATION*
68-Pin J Bend QFP with Quartz Window	87C451/BMA	GQCC1-J68
68-Pin J Bend QFP w/out Quartz Window	87C451/BMA OT[1]	GQCC1-J68

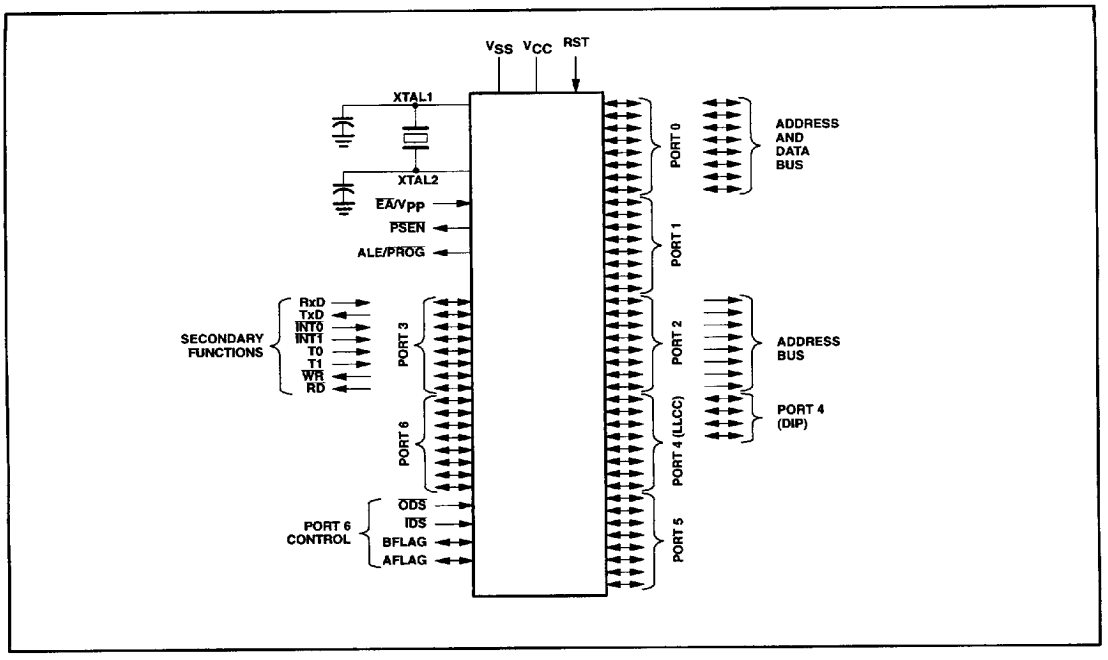
* MIL-STD 1835 or Appendix A of 1995 Military Data Handbook

PIN CONFIGURATION

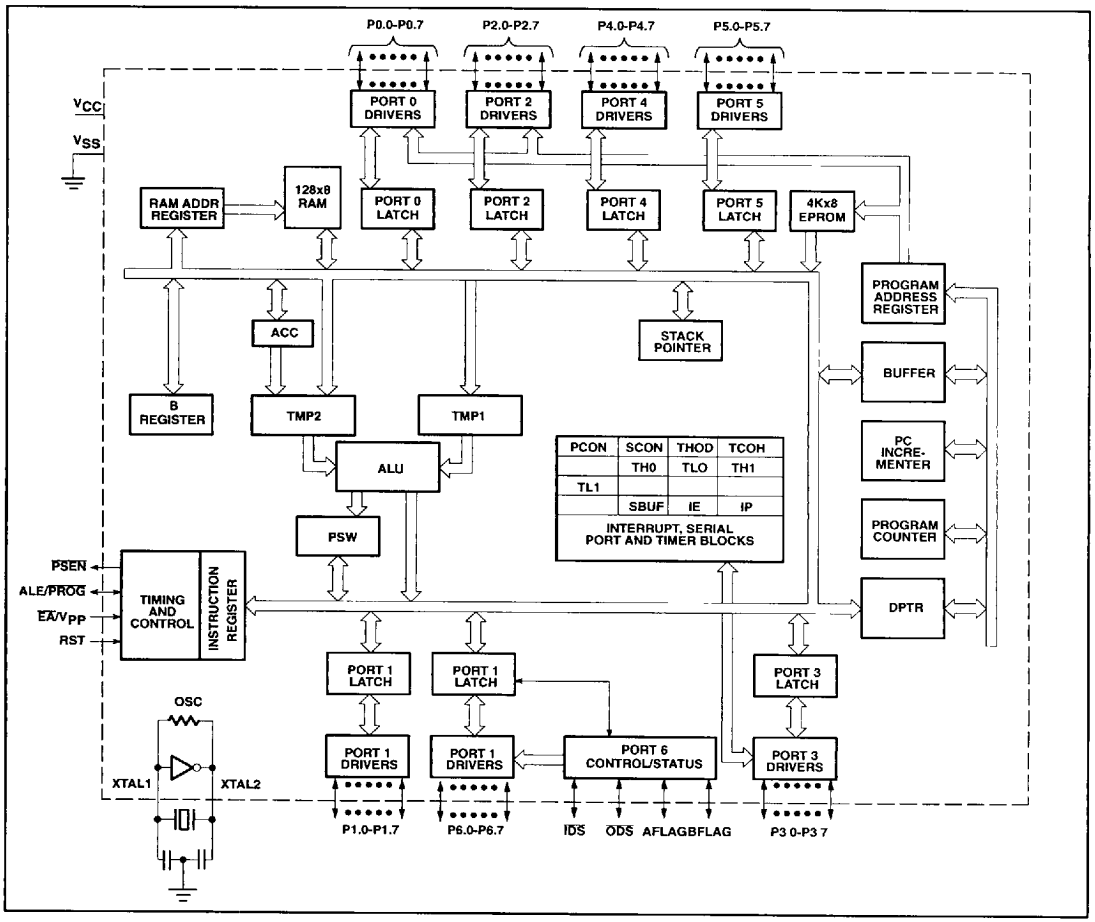


Pin	Function	Pin	Function
1	P5 0/ADC0	35	XTAL1
2	V_{DD}	36	V_{SS}
3	STADC	37	V_{SS}
4	$\overline{PWM0}$	38	NC
5	$\overline{PWM1}$	39	P2 0/A08
6	$\overline{EW}$	40	P2 1/A09
7	P4 0/CMSR0	41	P2 2/A10
8	P4 1/CMRS1	42	P2 3/A11
9	P4 2CMSR2	43	P2 4/A12
10	P4 3/CMSR3	44	P2 5/A13
11	P4 4/CMSR4	45	P2 6/A14
12	P4 5/CMSR5	45	P2 7/A15
13	P4 6/CMT0	47	$\overline{PSEN}$
14	P4 7/CMT1	48	ALE/$\overline{PROG}$
15	RST	49	$\overline{EA}$/V_{PP}
16	P1 0/CT0I	50	P0 7/AD7
17	P1 1/CT1I	51	P0 6/AD6
18	P1 2/CT2I	52	P0 5/AD5
19	P1 3/CT3I	53	P0 4/AD4
20	P1 4/T2	54	P0 3/AD3
21	P1 5/RT2	55	P0 2/AD2
22	P1 6/SCL	56	P0 1/AD1
23	P1.7/SDA	57	P0 0/AD0
24	P3 0/RxD	58	AVref-
25	P3 1TxD	59	AVref+
26	P3 2/$\overline{INT0}$	60	AV_{SS}
27	P3 3/$\overline{INT1}$	61	AV_{DD}
28	P3 4/T0	62	P5 7/ADC7
29	P3 5/T1	63	P5 6/ADC6
30	P3 6/$\overline{WR}$	64	P5 5/ADC5
31	P3 7/$\overline{RD}$	65	P5 4/ADC4
32	NC	66	P5 3/ADC3
33	NC	67	P5.2/ADC2
34	XTAL2	68	P5 1/ADC1

LOGIC SYMBOL



BLOCK DIAGRAM



PIN DESCRIPTION

MNEMONIC	PIN NO	TYPE	NAME AND FUNCTION
V_{SS}	50		**Ground:** 0V reference
V_{CC}	18		**Power Supply:** +5V.
P0.0-P0.7	17-10	I/O	**Port 0:** An 8-bit open-drain, bidirectional I/O port. Port 0 is also the multiplexed low-order address and data bus during accesses to external memory, and outputs instruction bytes during program verification. External pull-ups are required during program verification. Port 0 can sink/source eight LSTTL inputs.
P1.0-P1.7	23-30	I/O	**Port 1:** An 8-bit bidirectional I/O port with internal pull-ups. Port 1 receives the low-order address bytes during program verification. In the 87C451, port 1 can sink/source three LSTTL inputs, and drive CMOS inputs without external pull-ups.
P2.0-P2.7	2-9	I/O	**Port 2:** An 8-bit bidirectional I/O port with internal pull-ups. Port 2 emits the high-order address bytes during accesses to external memory and receives the high-order address bit and control signals during program verification in the 87C451. Port 2 can sink/source three LSTTL inputs and drive CMOS inputs without external pull-ups.
P3.0-P3.7	32-39	I/O	**Port 3:** An 8-bit bidirectional I/O port with internal pull-ups. Port 3 can sink/source three LSTTL inputs and drive CMOS inputs without external pull-ups. Port 3 also serves the 87C451 special functions listed below:
	32	I	RxD (P3.0): Serial input port
	33	O	TxD (P3.1): Serial output port
	34	I	$\overline{INT0}$ (P3.2): External interrupt 0
	35	I	$\overline{INT1}$ (P3.3): External interrupt 1
	36	I	T0 (P3.4): Timer 0 external input
	37	I	T1 (P3.5): Timer 1 external input
	38	O	$\overline{WR}$ (P3.6): External data memory write strobe
	39	O	$\overline{RD}$ (P3.7): External data memory read strobe
P4.0-P4.3	22-19	I/O	**Port 4:** A 4-bit bidirectional port with internal pull-ups. Port 4 can sink/source three LSTTL inputs and drive CMOS inputs without external pull-ups.
P5.0-P5.7	40-47	I/O	**Port 5:** An 8-bit I/O port with internal pull-ups. Port 5 can sink/source three LSTTL inputs and drive CMOS inputs without external pull-ups.
P6.0-P6.7	55-62	I/O	**Port 6:** A specialized 8-bit bidirectional I/O port with internal pull-ups. This special port can sink/source three LSTTL inputs and drive CMOS inputs without external pull-ups. Port 6 can be used in a strobed or non-strobed mode of operation, and in conjunction with four control pins that serve the functions listed below.
			Port 6 Control Lines:
$\overline{ODS}$	51	I	$\overline{ODS}$: Output data strobe
$\overline{IDS}$	52	I	$\overline{IDS}$: Input data strobe
BFLAG	53	I/O	BFLAG: A bidirectional I/O pin with internal pull-ups
AFLAG	54	I/O	A FLAG: A bidirectional I/O pin with internal pull-ups
RST	31	I	**RESET:** A High level on this pin for two machine cycles while the oscillator is running resets the device. An internal pull-down resistor permits power-on reset using only a capacitor connected to the V_{CC}
ALE/$\overline{PROG}$	64	I/O	**Address Latch Enable Program Pulse:** An output for latching the Low byte of the address during accesses to external memory. ALE is activated at a constant rate of 1/6 the oscillator frequency except during an external data memory access, at which time one ALE is skipped. ALE can sink/source eight LSTTL inputs and drive CMOS inputs without an external pull-up. This pin is also the program pulse input during EPROM programming.
$\overline{PSEN}$	63	O	**Program Store Enable:** This output is the read strobe to external program memory. $\overline{PSEN}$ is activated twice each machine cycle during fetches from external program memory; however, when executing out of external program memory, two activations of $\overline{PSEN}$ are skipped during each access to external data memory. $\overline{PSEN}$ is not activated during fetches from internal program memory. $\overline{PSEN}$ can sink/source eight LSTTL inputs and drive CMOS inputs without an external pull-up.
$\overline{EA}$/V_{PP}	1	I	**Instruction Execution Control/Programming Supply Voltage:** When $\overline{EA}$ is held High, the CPU executes out of internal program memory, unless the program counter exceeds OFFFH. When $\overline{EA}$ is held Low, the CPU executes out of external program memory. $\overline{EA}$ must never be allowed to float. This pin also receives the 12.75V programming supply voltage (V_{PP}) during EPROM programming.
XTAL1	49	I	**Crystal 1:** An input to the inverting amplifier that forms the oscillator This input receives the external oscillator when an external oscillator is used.
XTAL2	48	O	**Crystal 2:** Output of the inverting amplifier that forms the oscillator This pin should be floated when an external oscillator is used.

ABSOLUTE MAXIMUM RATINGS[2]

SYMBOL	PARAMETER	RATING	UNIT
T_A	Operating ambient temperature range	-55 to +125	°C
T_{STG}	Storage temperature range	-65 to +150	°C
	Voltage from V_{CC} to V_{SS}[3]	-0 5 to +6 5	V
	Voltage from any pin to V_{SS} (except V_{PP})3	-0.5 to V_{CC} +0 5	V
	Voltage on V_{PP}	-0.5 to 13 0	V
P_D	Power dissipation	200	mW

DC ELECTRICAL CHARACTERISTICS

$-55°C \le T_{amb} \le +125°C$, $4\ 5V \le V_{CC} \le 5\ 5V$, $V_{SS} = 0V$

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS		UNIT
			MIN	MAX	
V_{IL}	Input Low voltage, except $\overline{EA}$		-0 5	0.2 V_{CC} - 0.25	V
V_{IL1}	Input Low voltage, $\overline{EA}$			0 2 V_{CC} - 0 45	V
V_{IH}	Input High voltage, except XTAL1, RST		0 2 V_{CC} +1 1	V_{CC} + 0 5	V
V_{IH1}	Input High voltage, XTAL1, RST		0 7 V_{CC} +0 2	V_{CC} + 05	V
V_{OL}	Output Low voltage, ports 1,2,3,4,5,6, AFLAG, BFLAG	I_{OL} = 1.6mA[4]		0 45	V
V_{OL1}	Output Low voltage, port 0, ALE, $\overline{PSEN}$	I_{OL} = 3.2mA[4]		0.45	V
V_{OH}	Output High voltage, ports 1,2,3,4,5,6, AFLAG, BFLAG	I_{OH} = -60µA, V_{CC} = 5V ± 10% I_{OH} = -25µA I_{OH} = -10µA	2 4 0 75V_{CC} 0 9V_{CC}		V V V
V_{OH1}	Output High voltage, port 0 in external bus mode, ALE, $\overline{PSEN}$	I_{OH} = -400µA, V_{CC} = 5V ± 10% I_{OH} = -150µA I_{OH} = -40µA[5]	2 4 0 75V_{CC} 0.9V_{CC}		V V V
I_{IL}	Logical 0 input current, ports 1,2,3,4,5,6, AFLAG, BFLAG	V_{IN} = 0 45V		-75	µA
I_{TL}	Logical 1 to 0 transition current, ports 1,2,3,4,5,6, AFLAG, BFLAG	V_{IN} = 2V		-750	µA
I_{LI}	Input leakage, current port 0, $\overline{EA}$, $\overline{IDS}$, $\overline{ODS}$	$0\ 45V \le V_{IN} \le V_{CC}$		±10	µA
R_{RST}	Reset pulldown resistor		50	150	kΩ
C_{IO}[7]	Pin capacitance	Test freq = 1MHz, T_A = 25°C		10	pF
I_{PD}[6]	Power-down current	V_{CC} = 2V to 6V		75	µA

MAXIMUM I_{CC} (mA)

Frequency/V_{CC}	OPERATING[8]			IDLE[9]			UNITS
	4.5V	5V[11]	5.5V	4.5V	5V[11]	5.5V	
3.5MHz[11]	8	10	12	2 5	3	3 5	mA
12MHz	20	25	30	5 0	5 5	6 0	mA

AC ELECTRICAL CHARACTERISTICS

$-55°C \leq T_{amb} \leq +125°C$, $V_{CC} = 5V \pm 10\%$, $V_{SS} = 0V$, load capacitance for port 0, ALE, and $\overline{PSEN}$ = 100pF, load capacitance for all other outputs = 80 pF[10]

SYMBOL	PARAMETER	12MHz CLOCK		VARIABLE CLOCK ($f = 1/t_{CLCL}$)		UNIT
		MIN	MAX	MIN	MAX	
$1/t_{CLCL}$				3.5	12	MHz
t_{LHLL}	ALE pulse width	112		$2t_{CLCL}$ -55		ns
t_{AVLL}	Address valid to ALE Low	13		t_{CLCL} -70		ns
t_{LLAX}	Address hold after ALE Low	33		t_{CLCL} -50		ns
t_{LLIV}	ALE Low to valid instr in		218		$4t_{CLCL}$ -115	ns
t_{LLPL}	ALE Low to $\overline{PSEN}$ Low	28		t_{CLCL} -55		ns
t_{PLPH}	$\overline{PSEN}$ pulse width	190		$3t_{CLCL}$ -60		ns
t_{PLIV}	$\overline{PSEN}$ Low to valid instr in		130		$3t_{CLCL}$ -120	ns
t_{PXIX}	Input instr hold after $\overline{PSEN}$	0		0		ns
t_{PXIZ}	Input instr float after $\overline{PSEN}$		58		t_{CLCL} -25	ns
t_{AVIV}	Address to valid instr in		297		$5t_{CLCL}$ -120	ns
t_{PLAZ}	$\overline{PSEN}$ Low to address float		25		25	ns
t_{RLRH}	$\overline{RD}$ pulse width	400		$6t_{CLCL}$ -100		ns
t_{WLWH}	$\overline{WR}$ pulse width	400		$6t_{CLCL}$ -100		ns
t_{RLDV}	$\overline{RD}$ Low to valid data in		232		$5t_{CLCL}$ -185	ns
t_{RHDX}	Data hold after $\overline{RD}$	0		0		ns
t_{RHDZ}	Data float after $\overline{RD}$		82		$2t_{CLCL}$ -85	ns
t_{LLDV}	ALE Low to valid data in		496		$8t_{CLCL}$ -170	ns
t_{AVDV}	Address to valid data in		565		$9t_{CLCL}$ -185	ns
t_{LLWL}	ALE Low to $\overline{RD}$ or $\overline{WR}$ Low	185	315	$3t_{CLCL}$ -65	$3t_{CLCL}$ +65	ns
t_{QVWX}	Data valid to $\overline{WR}$ transition	8		t_{CLCL} -75		ns
t_{WHQX}	Data hold after $\overline{WR}$	18		t_{CLCL} -65		ns
t_{RLAZ}	$\overline{RD}$ Low to address float		0		0	ns
t_{WHLH}	$\overline{RD}$ or $\overline{WR}$ High to ALE High	18	148	t_{CLCL} -65	t_{CLCL} +65	ns
Port 6 input (input rise and fall times ≤ 5ns)						
t_{ILIH}	$\overline{IDS}$ width	270		$3t_{CLCL}$ +20		ns
t_{DVIH}	Data setup to $\overline{IDS}$ High	0		0		ns
t_{IHDX}	Data hold after $\overline{IDS}$	30		30		ns
t_{FLIL}	$\overline{PE}$ to $\overline{IDS}$	25		25		ns
t_{IVFV}	$\overline{IDS}$ to BFLAG (IBF) delay		130		130	ns
Port 6 ouput						
t_{OLOH}	$\overline{ODS}$ width	270		$3t_{CLCL}$ +20		ns
t_{FVDV}	SEL to data out delay		85		85	ns
t_{OLDV}	$\overline{ODS}$ to data out delay		80		80	ns
t_{OHDZ}	$\overline{ODS}$ to data float delay		35		35	ns
t_{OVFV}	$\overline{ODS}$ to AFLAG (OBF) delay		100		100	ns
t_{FLDV}	$\overline{PE}$ to data out delay		120		120	ns
t_{OHFH}	$\overline{ODS}$ High to AFLAG (SEL) delay	100		100		ns

NOTES:

1. Erase characteristics do not apply for one time programming (OT).
2. Stress above those listed under Absolute Maximum Rating may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or at any conditions other than those described in the AC and DC Electrical Characteristics section of this specification is not implied.
3. This product includes circuitry specifically designed for the protection on its internal devices from damaging effects of excessive static charge. Nonetheless it is suggested that conventional precautions be taken to avoid applying voltages greater than the rated maximum.
4. Capacitive loading on ports 0 and 2 can cause spurious noise to be superimposed on the V_{OLS} of ALE and ports 1 and 3. The noise is caused by external bus capacitance discharging into the port 0 and port 2 pins when these pins make 1-to-0 transitions during bus operations. In the worst cases it could be desirable to qualify ALE with a Schmitt trigger, or use an address latch with a Schmitt trigger STROBE input.
5. Capacitive loading on ports 0 and 2 can cause the V_{OH} on ALE and $\overline{PSEN}$ to momentarily fall before the $0.9V_{CC}$ specification when the address bits are stabilizing.
6. Power-down I_{CC} is measured with all output pins disconnected; $\overline{EA}$ = port 0 = V_{CC}, XTAL2 = N.C.; RST = V_{SS}.
7. C_{IO} is tested initially and after any design or process changes which may affect capacitance.
8. I_{CC} is measured with all output pins disconnected; XTAL1 driven with t_{CLCH}, t_{CHCL} = 5ns, $V_{IL} = V_{SS}$+ 0.5V, $V_{IH} = V_{CC}$-0.5V; XTAL1 = N.C.; XTAL2 = $\overline{EA}$ = RST = Port 0 = V_{CC}. I_{CC} will be slightly higher if a crystal oscillator is used.

NOTES: (Continued)

9 Idle I_{CC} is measured with all output pins disconnected; XTAL1 driven with t_{CLCH}, t_{CHCL} = 5ns, V_{IL} = V_{SS}+ 0 5V, V_{IH} = V_{CC}-0 5V, XTAL = N.C.; port 0 = V_{CC}, $\overline{EA}$ = RST = V_{SS}

10. Parameters are valid over operating temperature range unless otherwise specified.

11. Guaranteed but not tested to the limits specified.

PORTS 4 and 5

Ports 4 and 5 are bidirectional I/O ports with internal pull-ups Port 4 is a 4-bit port Port 4 and port 5 pins, with ones written to them, are pulled High by the internal pull-ups, and in that state can be used as inputs Ports 4 and 5 are addressed at the special function register addresses shown in Table 1.

PORT 6

Port 6 is a special 8-bit bidirectional I/O port with internal pull-ups. (See Figure 1) This port can be used as a standard I/O port, or in strobed modes of operation in conjunction with four special control lines $\overline{ODS}$, $\overline{IDS}$, AFLAG, and BFLAG Port 6 operating modes are controlled by the port 6 Control Status Register (CSR) Port 6 and the CSR are addressed at the special function register addresses shown in Table 1 The following four control pins are used in conjunction with port 6.

$\overline{ODS}$: Output data strobe input for port 6 $\overline{ODS}$ can be programmed to control the port 6 output drivers and the Output Buffer Full Flag (OBF), or to clear only the OBF flag bit in the CSR (output-always mode) $\overline{ODS}$ is Active-Low for output driver control. The OBF flag can be programmed to be cleared on the negative or positive edge of $\overline{ODS}$.

$\overline{IDS}$ Input data strobe input for port 6 $\overline{IDS}$ is used to control the port 6 input latch and Input Buffer Full Flag (IBF) bit in the CSR. The input data latch can be programmed to be transparent when the $\overline{IDS}$ is Low and latched on the positive transition of $\overline{IDS}$, or to latch only on the positive transition of $\overline{IDS}$ Correspondingly, the IBF flag is set on the negative or positive transition of $\overline{IDS}$

AFLAG: A bidirectional I/O pin. AFLAG can be programmed to be an output set High or Low under program control, or to output the state of the output buffer full flag AFLAG can also be programmed to be an input which selects whether the contents of the output buffer, or the contents of the port 6 control status register will be output on port 6 This feature grants complete port 6 status to external devices

BFLAG: A bidirectional I/O pin BFLAG can be programmed to be an output, set High or Low under program control, or to output the state of the input buffer full flag. BFLAG can also be programmed to input an enable signal for port 6. When BFLAG is used as an enable input, port 6 output drivers are in the High impedance state, and the input latch does not respond to the $\overline{IDS}$ strobe when BFLAG is High Both features are enabled when BFLAG is Low This feature facilitates the use of the 87C451 in bused multiprocessor systems.

CONTROL STATUS REGISTER

The Control Status Register (CSR) establishes the mode of operation for port 6 and indicates the current status of the port 6 I/O registers All control status register bits can be read and written by the CPU, except bits 0 and 1, which are read only Reset writes ones to bits 2 through 7, and writes zeros to bits 0 and 1

CSR.0 — Input Buffer Full Flag (IBF) (Read only)
The IBF bit is set to a logic 1 when port 6 data is loaded into the input buffer under control of $\overline{IDS}$ This can occur on the negative or positive edge of $\overline{IDS}$, as determined by CSR 2 IBF is cleared when the CPU reads the input buffer register

CSR.1 — Output Buffer Full Flag (OBF) (Read only)
The OBF flag is set to a logic 1 when the CPU writes to the port 6 output data buffer. OBF is cleared by the positive or negative edge of $\overline{ODS}$, as determined by CSR.3.

CSR.2 — IDS Mode Select (IDSM)
When CSR 2 = 0, a Low-to-High transition on the $\overline{IDS}$ pin sets the IBF flag. The port 6 input buffer is loaded on the $\overline{IDS}$ positive edge When CSR.2 = 1, a High-to-Low transition on the $\overline{IDS}$ pin sets the IBF flag. The port 6 input buffer is transparent when $\overline{IDS}$ is Low, and latched when $\overline{IDS}$ is High.

CSR.3 — Output Buffer Full Flag Clear Mode (OBFC)
When CSR 3 = 1, the positive edge of the $\overline{ODS}$ input clears the OBF flag. When CSR 3 = 0, the negative edge of the $\overline{ODS}$ input clears the OBF flag

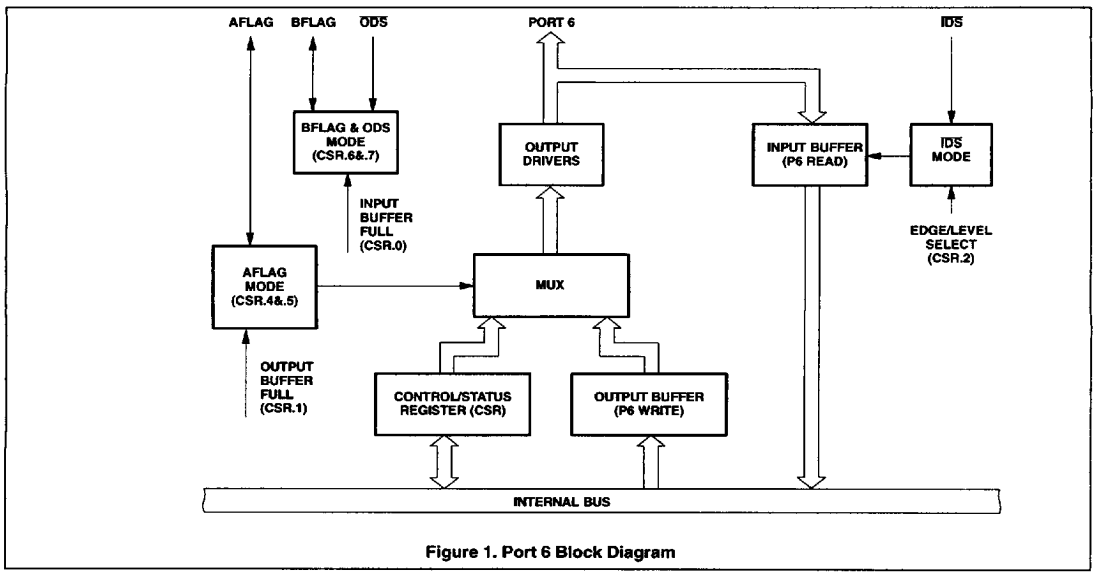


Figure 1. Port 6 Block Diagram

CSR.4, CSR.5 — AFLAG Mode Select (MA0, MA1)
Bits 4 and 5 select the mode of operation for the AFLAG pin, as follows:

MA1	MA0	AFLAG Function
0	0	Logic 0 output
0	1	Logic 1 output
1	0	OBF flag output (CSR.1)
1	1	Select (SEL) input mode

The select (SEL) input mode is used to determine whether the port 6 data register or the control status register is output on port 6. When the select feature is enabled, the AFLAG input controls the source of port 6 output data. A logic 0 on AFLAG input selects the port 6 data register, and a logic 1 on AFLAG input selects the control status register.

CSR.6, CSR.7 — BFLAG Mode Select (MB0, MB1)
Bits 6 and 7 select the mode of operation for the BFLAG pin, as follows:

MB1	MB0	BFLAG Function
0	0	Logic 0 output
0	1	Logic 1 output
1	0	IBF flag output (CSR.0)
1	1	Port enable ($\overline{PE}$)

In the port enable mode, $\overline{IDS}$ and $\overline{ODS}$ inputs are disabled when BFLAG input is High. When the BFLAG input is Low, the port is enabled for I/O.

CONTROL STATUS REGISTER

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
(CSR)	MB1	MB0	MA1	MA0	OBFC	IDSM	OBF	IBF
	BFLAG mode select		AFLAG mode select		Output buffer flag clear mode	Input data strobe mode	Output buffer full flag	Input buffer full flag
	0/0 = Logic 0 output* 0/1 = Logic 1 output* 1/0 = IBF output 1/1 = $\overline{PE}$ input (0 = Select) (1 = disable I/O)		0/0 = Logic 0 output 0/1 = Logic 1 output 1/0 = OBF output* 1/1 = SEL input (0 = Data) (1 = Control/status)		0 = Negative edge of $\overline{ODS}$ 1 = Positive edge of $\overline{ODS}$	0 = Positive edge of $\overline{IDS}$ 1 = Low level of $\overline{IDS}$	0 = Output data buffer empty 1 = Output data buffer full	0 = Input data buffer empty 1 = input data buffer full

* Output-always mode: MB1 = 0, MA1 = 1, and MA0 = 0. In this mode port 6 is always enabled for output. $\overline{ODS}$ only clears the OBF flag.

SPECIAL FUNCTION REGISTER ADDRESSES

Special function register adresses for the 87C451 are identical to those of the 80C451, except for the additional registers listed in Table 1

Table 1. Special Function Register Addresses

REGISTER ADDRESS			BIT ADDRESS							
Name	Symbol	Address	MSB							LSB
Port 4	P4	C0	C7	C6	C5	C4	C3	C2	C1	C0
Port 5	P5	C8	CF	CE	CD	CC	CB	CA	C9	C8
Port 6 data	P6	D8	DF	DE	DD	DC	DB	DA	D9	D8
Port 6 control status	CSR	E8	EF	EE	ED	EC	EB	EA	E9	E8

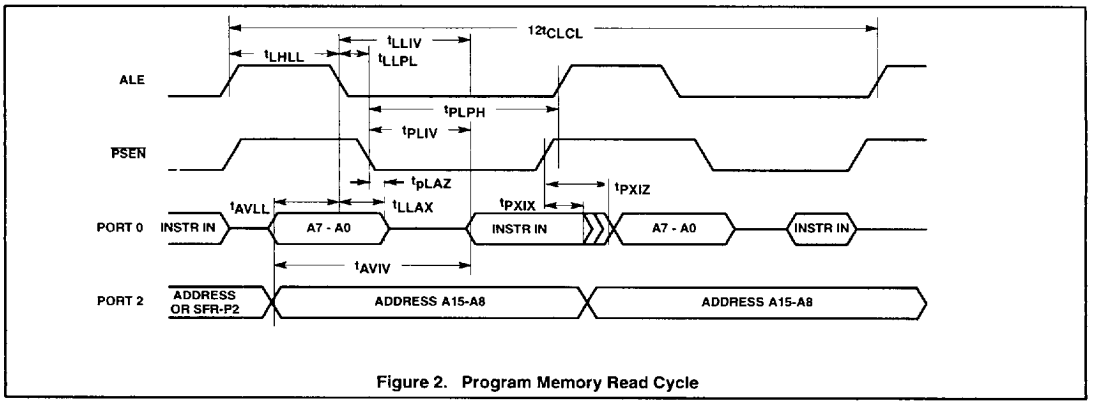


Figure 2. Program Memory Read Cycle

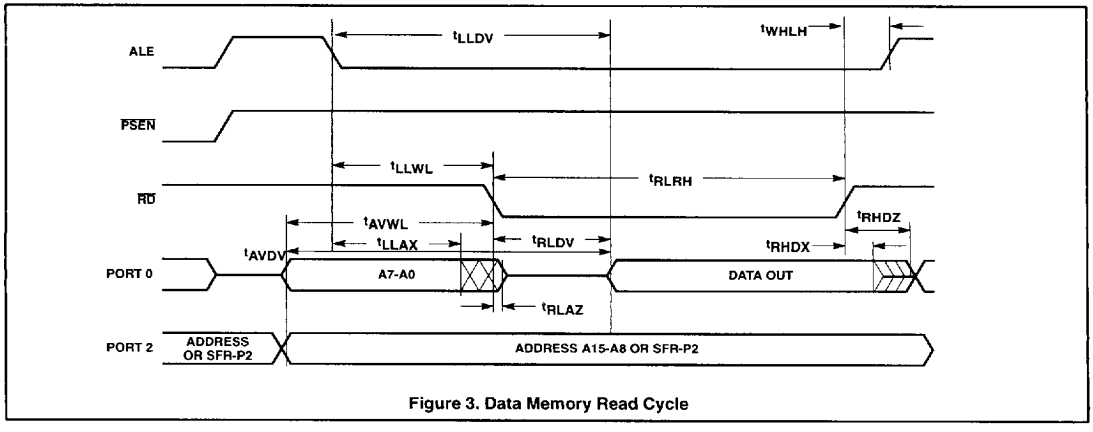


Figure 3. Data Memory Read Cycle

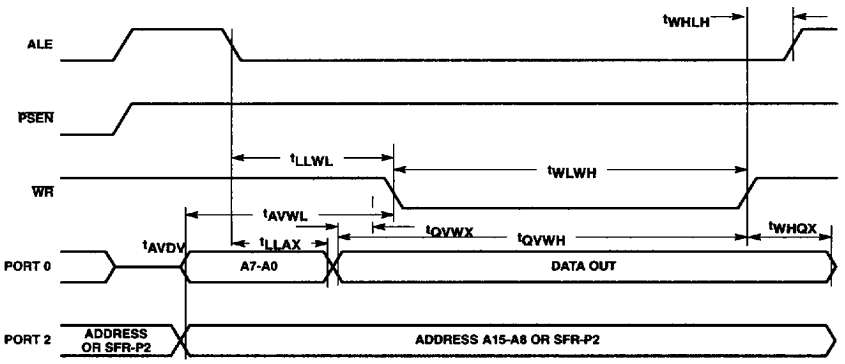


Figure 4. Data Memory Write Cycle

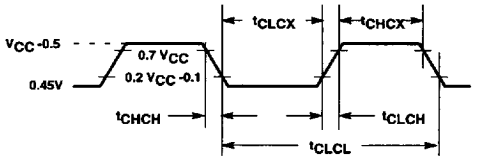
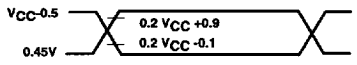


Figure 5. External Clock Drive Waveform



NOTE:
AC inputs during testing are driven at V_{CC}-0 5V for a logic "1" and 0 45 for a logic "0". Timing measurements are made at V_{IHMIN} for a logic "1" and V_{ILMAX} for a logic "0"

Figure 6. AC Testing Input, Output Waveforms

NOTE:
For timing purposes a port pin is no longer floating when a 100mV change from load voltage occurs, and begins to float when a 100mV change from the loaded V_{OH}/V_{OL} level occurs. $I_{OL}/I_{OH} \geq \pm 20$mA.

Figure 7. Float Waveforms

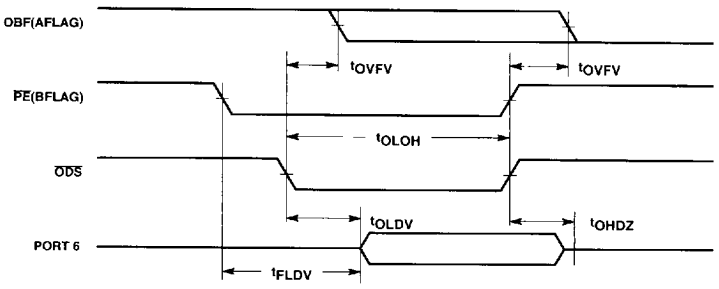


Figure 8. Port 6. Output Waveforms

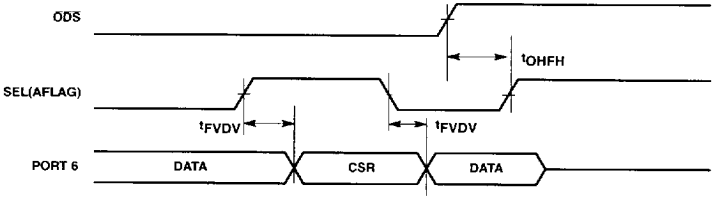


Figure 9. Port 6 Select Mode Waveforms

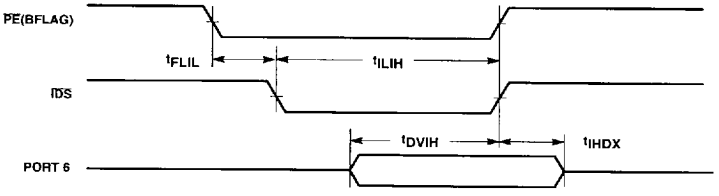


Figure 10. Port 6 Input Waveforms

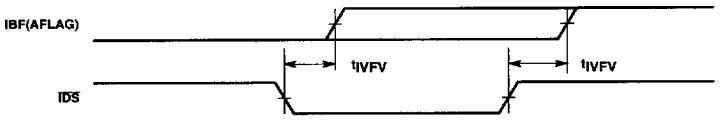
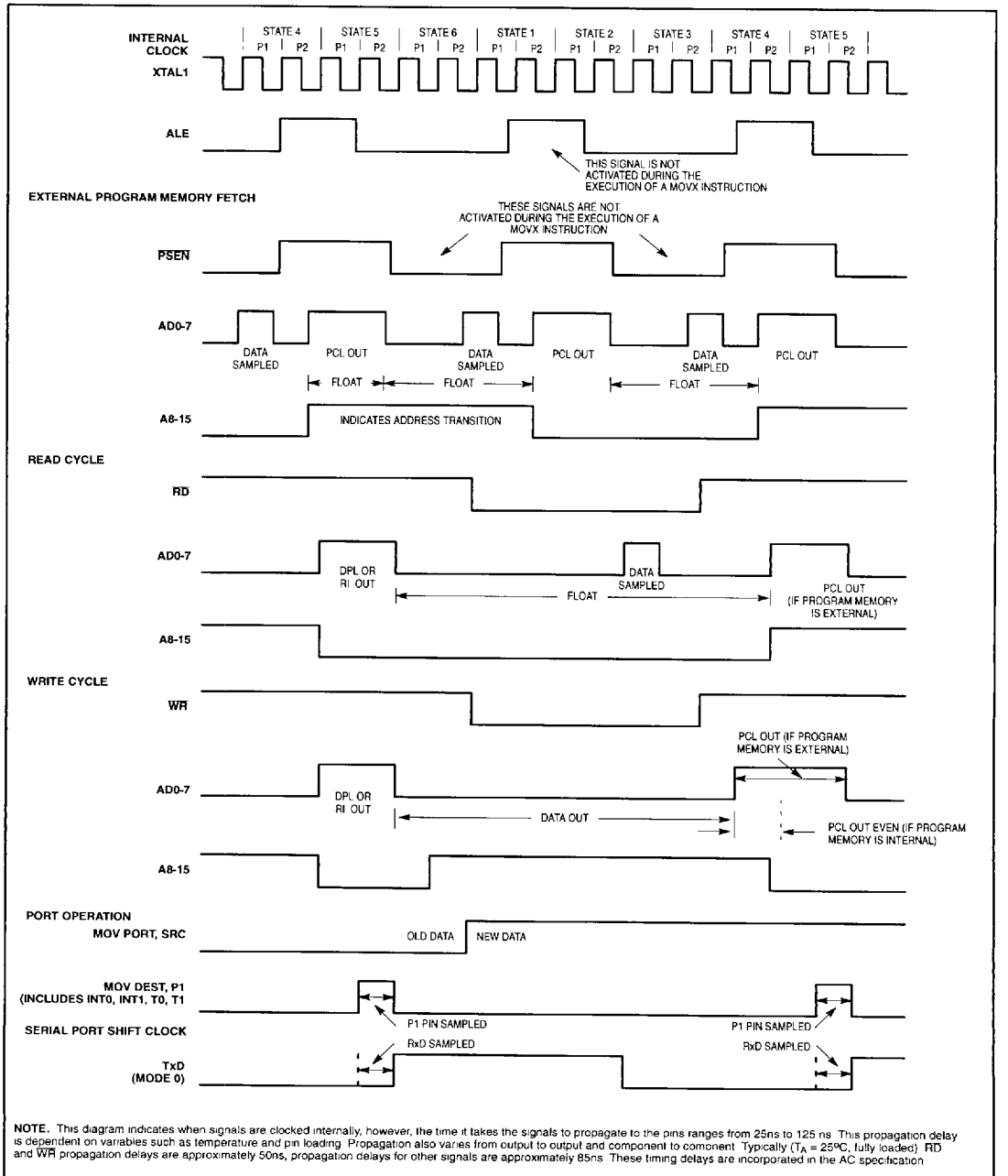


Figure 11. IBF Flag Output Waveforms



NOTE. This diagram indicates when signals are clocked internally, however, the time it takes the signals to propagate to the pins ranges from 25ns to 125 ns. This propagation delay is dependent on variables such as temperature and pin loading. Propagation also varies from output to output and component to component. Typically (T_A = 25°C, fully loaded) RD and $\overline{WR}$ propagation delays are approximately 50ns, propagation delays for other signals are approximately 85ns. These timing delays are incorporated in the AC specification.

Figure 12. Timing Waveforms

EPROM CHARACTERISTICS

The 87C451 is programmed by a modified quick-pulse programming ™algorithm. It differs from older methods in the value used for V_{PP} (programming supply voltage) and in the width and number of the ALE/$\overline{PROG}$ pulses.

The 87C451 contains two signature bytes that can be read and used by an EPROM programming system to identify the device. The signature bytes identify the device as an 87C451 manufactured by Philips.

Table 2 shows the logic levels for reading the signature byte, and for programming the program memory, the Encryption Table, and the lock bits. The circuits configuration and waveforms for quick-pulse programming are shown in Figures 13 and 14. Figure 15 shows the circuit configuration for normal program memory verification.

QUICK-PULSE PROGRAMMING™

The setup for microcontroller quick-pulse programming is shown in Figure 13. Note that the 87C451 is running with a 4 to 6MHz oscillator. The reason the oscillator needs to be running is that the device is executing internal address and program data transfers.

The address of the EPROM location to be programmed is applied to ports 1 and 2, as shown in Figure 13. The code byte to be programmed into that location is applied to port 0. RST, $\overline{PSEN}$ and pins of port 2 and 3 specified in Table 2 are held at the "Program Code Data" levels indicated in Table 2. The ALE/$\overline{PROG}$ is pulsed Low 25 times as shown in Figure 14.

To program the Encryption Table, repeat the 25-pulse programming sequence for addresses 0 through 1FH, using the "Pgm Encryption Table" levels. Do not forget that after the Encryption Table is programmed, verify cycles will produce only encrypted data.

To program the lock bits, repeat the 25-pulse programming sequence using the "Pgm Lock Bit" levels. After one lock bit is programmed, further programming of the code memory and Encryption Table is disabled. However, the other lock bit can still be programmed.

Note that the $\overline{EA}$/V_{PP} pin must not be allowed to go above the maximum specified V_{PP} level for any amount of time. Even a narrow glitch above that voltage level can cause permanent damage to the device. The V_{PP} source should be well regulated and free of glitches and overshoot.

Program Verification

If Lock Bit 2 has not been programmed, the on-chip program memory can be read out for program verification. The address of the program memory locations to be read is applied to ports 1 and 2 as shown in Figure 15. The other pins are held at the "Verify Code Data" levels indicated in Table 2. The contents of the addressed location will be emitted on port 0. External pull-ups are required on port 0 for this operation.

If the Encryption Table has been programmed, the data presented at port 0 will be the Exclusive-NOR of the program byte with one of the encryption bytes. The user will have to know the Encryption Table contents in order to correctly decode the verification data. The Encryption Table itself cannot be read out.

Reading the Signature Bytes

The signature bytes are read by the same procedure as a normal verification of locations 030H and 031H, except that P3.6 and P3.7 need to be pulled to a logic Low. The values are:

(030H) = 89H indicates manufactured by Philips

(031H) = 57H indicates 87C451

Program/Verify Algorithms

Any algorithm in agreement with the conditions listed in Table 2, and which satisfies the timing specifications, is suitable.

Erasure Characteristics

Erasure of the EPROM begins to occur when the chip is exposed to light with wavelengths shorter than approximately 4,000Å. Since sunlight and fluorescent lighting have wavelengths in this range, exposure to these light sources over an extended time (about 1 week in sunlight, or 3 years in room level fluorescent lighting) could cause inadvertent erasure. If an application subjects the device to this type of exposure, it is suggested that an opaque label be placed over the window.

The recommended erasure procedure is exposure to ultraviolet light (at 2537 Å) to an integrated dose of at least 15W-sec/cm^2. Exposing the EPROM to an ultraviolet lamp of 12,000µW/cm^2 rating for 20 to 39 minutes, at a distance of about 1 inch, should be sufficient.

Erasure leaves the array in all 1s state.

For elevated temperature or environments where solvents are being used, apply kapton tape fluorglas (part number 2345-5) or equivalent.

Table 2. EPROM Programming Modes

MODE	RST	PSEN	ALE/PROG	EA/V_{PP}	P2.7	P2.6	P3.7	P3.6
Read Signature	1	0	1	1	0	0	0	0
Program Code Data	1	0	0*	V_{PP}	1	0	1	1
Verify Code Data	1	0	1	1	0	0	1	1
Pgm Encryption Table	1	0	0*	V_{PP}	1	0	1	0
Pgm Lock Bit 1	1	0	0*	V_{PP}	1	1	1	1
Pgm Lock Bit 2	1	0	0*	V_{PP}	1	1	0	0

NOTES:
"1" = Valid High for that pin.
"0" = Valid Low for that pin.
V_{PP} = 12.75V ± 0.25V.
V_{CC} = 5V ± 10% during programming and verification.
* ALE/$\overline{PROG}$ receives 25 programming pulses while V_{PP} is held at 12.75V. Each programming pulse is Low for 100µs (± 10µs) and High for a minimum of 10µs.

™ Quick-pulse programming is a phrase trademark of Intel Corp.

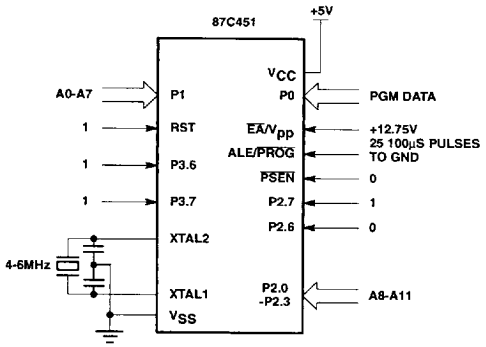


Figure 13. Programming Configuration

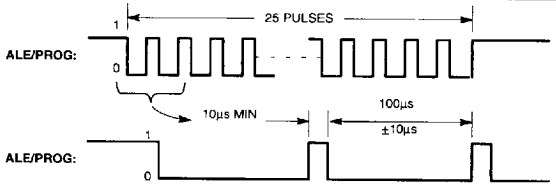


Figure 14. PROG Waveforms

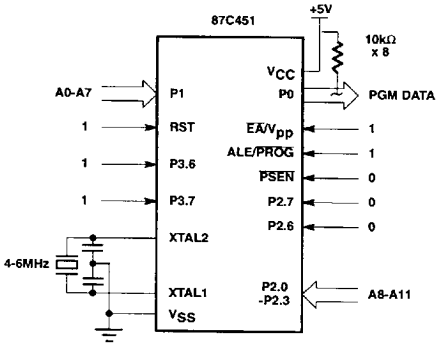
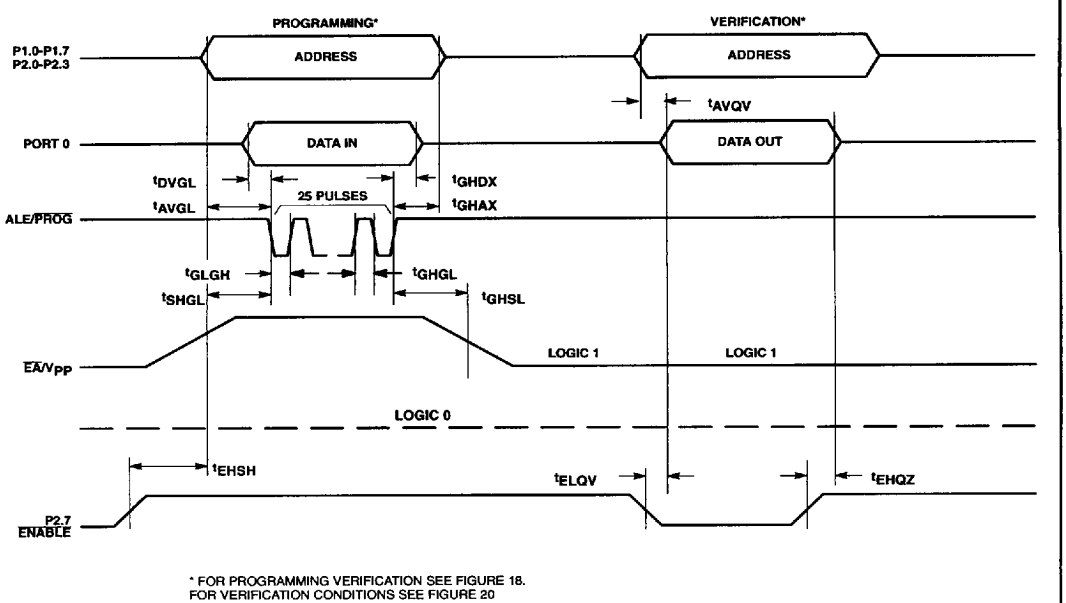


Figure 15. Program Verification

EPROM PROGRAMMING AND VERIFICATION CHARACTERISTICS

T_{amb} = 21°C to 27°C, V_{CC} = 5V ± 10%, V_{SS} = 0V

SYMBOL	PARAMETER	LIMITS		UNIT
		Min	Max	
V_{PP}	Programming supply voltage	12.5	13.0	V
I_{PP}	Programming supply current		50	mA
$1/t_{CLCL}$	Oscillator frequency	4	6	MHz
t_{AVGL}	Address setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHAX}	Address hold after $\overline{PROG}$	$48t_{CLCL}$		
t_{DVGL}	Data setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHDX}	Data hold after $\overline{PROG}$	$48t_{CLCL}$		
t_{EHSH}	P2.7 ($\overline{ENABLE}$) High to V_{PP}	$48t_{CLCL}$		
t_{SHGL}	V_{PP} setup to $\overline{PROG}$ Low	10		µs
t_{GHSL}	V_{PP} hold after $\overline{PROG}$	10		µs
t_{GLGH}	$\overline{PROG}$ width	90	110	µs
t_{AVQV}	Address to data valid		$48t_{CLCL}$	
t_{ELQV}	$\overline{ENABLE}$ Low to data valid		$48t_{CLCL}$	
t_{EHQZ}	Data float after $\overline{ENABLE}$	0	$48t_{CLCL}$	
t_{GHGL}	$\overline{PROG}$ High to $\overline{PROG}$ Low	10		µs



* FOR PROGRAMMING VERIFICATION SEE FIGURE 18.
FOR VERIFICATION CONDITIONS SEE FIGURE 20

Figure 16. EPROM Programming and Verification Waveforms

Table 3. Instruction Set

MNEMONIC		DESCRIPTION	BYTE	CYCLES
Arithmetic operations				
ADD	A,Rn	Add register to accumulator	1	1
ADD	A,direct	Add direct byte to accumulator	2	1
ADD	A,@Ri	Add indirect RAM to accumulator	1	1
ADD	A,R#data	Add immediate data to accumulator	2	1
ADDC	A,Rn	Add register to accumulator with carry	1	1
ADDC	A,direct	Add direct byte to A with carry flag	2	1
ADDC	A,@Ri	Add indirect RAM to A with carry flag	1	1
ADDC	A,#data	Add immediate data to A with carry flag	2	1
SUBB	A,Rn	Subtract register from A with borrow	1	1
SUBB	A,direct	Subtract direct byte from A with borrow	2	1
SUBB	A,@Ri	Subtract indirect RAM from A w/borrow	1	1
SUBB	A,#data	Subtract immed. data from A w/borrow	2	1
INC	A	Increment accumulator	1	1
INC	Rn	Increment register	1	1
INC	direct	Increment direct byte	2	1
INC	@Ri	Increment indirect RAM	1	1
DEC	A	Decrement accumulator	1	1
DEC	Rn	Decrement register	1	1
DEC	direct	Decrement direct byte	2	1
DEC	@Ri	Decrement indirect RAM	1	1
INC	DPTR	Increment data pointer	1	2
MUL	AB	Multiply A & B	1	4
DIV	AB	Divide A by B	1	4
DA	A	Decimal adjust accumulator	1	1
Logical operations				
ANL	A,Rn	AND register to accumulator	1	1
ANL	A,direct	AND direct byte to accumulator	2	1
ANL	A,@Ri	AND indirect RAM to accumulator	1	1
ANL	A,#data	AND immediate data to accumulator	2	1
ANL	direct,A	AND accumulator to direct byte	2	1
ANL	direct,#data	AND immediate data to direct byte	3	2
ORL	A,Rn	OR register to accumulator	1	1
ORL	A,direct	OR direct byte to accumulator	2	1
ORL	A,@Ri	OR indirect RAM to accumulator	1	1
ORL	A,#data	OR immediate data to accumulator	2	1
ORL	direct,A	OR accumulator to direct byte	2	1
ORL	direct,#data	OR immediate data to direct byte	3	2
XRL	A,Rn	Exclusive-OR register to accumulator	1	1
XRL	A,direct	Exclusive-OR direct byte to accumulator	2	1
XRL	A,@Ri	Exclusive-OR indirect RAM to A	1	1
XRL	A,#data	Exclusive-OR immediate data to A	2	1
XRL	direct,A	Exclusive-OR accumulator to direct byte	2	1
XRL	direct,#data	Exclusive-OR immediate data to direct	3	2
CLR	A	Clear accumulator	1	1
CPL	A	Complement accumulator	1	1
RL	A	Rotate accumulator left	1	1
RLC	A	Rotate A left through the carry flag	1	1
RR	A	Rotate accumulator right	1	1
RRC	A	Rotate A right through carry flag	1	1
SWAP	A	Swap nibbles within the accumulator	1	1
Data transfer				
MOV	A,Rn	Move register to accumulator	1	1
MOV	A,direct	Move direct byte to accumulator	2	1
MOV	A,@Ri	Move indirect RAM to accumulator	1	1
MOV	A,#data	Move immediate data to accumulator	2	1
MOV	Rn,A	Move accumulator to register	1	1
MOV	Rn,direct	Move direct byte to register	2	2
MOV	Rn,#data	Move immediate data to register	2	1
MOV	direct,A	Move accumulator to direct byte	2	1
MOV	direct,Rn	Move register to direct byte	2	2
MOV	direct,direct	Move direct byte to direct	3	2
MOV	direct,@Ri	Move indirect RAM to direct byte	2	2
MOV	direct,#data	Move immediate data to direct byte	3	2
MOV	@Ri,A	Move accumulator to indirect RAM	1	1
MOV	@Ri,direct	Move direct byte to indirect RAM	2	2

Table 3. Instruction Set (Continued)

MNEMONIC		DESCRIPTION	BYTE	CYCLES
Data transfer (continued)				
MOV	@Ri,#data	Move immediate data to indirect RAM	2	1
MOV	DPTR,#data16	Load data pointer with a 16-bit constant	3	2
MOVC	A,@A + DPTR	Move code byte relative to DPTR to A	1	2
MOVC	A,@A + PC	Move code byte relative to PC to A	1	2
MOVX	A,@Ri	Move external RAM (8-bit addr) to A	1	2
MOVX	A,@DPTR	Move external RAM (16-bit addr) to A	1	2
MOVX	@Ri,A	Move A to external RAM (8-bit addr)	1	2
MOVX	@DPTR,A	Move A to external RAM (16-bit addr)	1	2
PUSH	direct	Push direct byte onto stack	2	2
POP	direct	Pop direct byte from stack	2	2
XCH	A,Rn	Exchange register with accumulator	1	1
XCH	A,direct	Exchange direct byte with accumulator	2	1
XCH	A,@Ri	Exchange indirect RAM with A	1	1
XCHD	A,#Ri	Exchange low-order digit ind. RAM w/A	1	1
Boolean variable manipulation				
CLR	C	Clear carry flag	1	1
CLR	bit	Clear direct bit	2	1
SETB	C	Set carry flag	1	1
SETB	bit	Set direct bit	2	1
CPL	C	Complement carry flag	1	1
CPL	bit	Complement direct bit	2	1
ANL	C,bit	AND direct bit to carry flag	2	2
ANL	C,/bit	AND complement of direct bit to carry	2	2
ORL	C,bit	OR direct bit to carry flag	2	2
ORL	C,/bit	OR complement of direct bit to carry	2	2
MOV	C,bit	Move direct bit to carry flag	2	1
MOV	bit,C	Move carry flag to direct bit	2	2
Program and machine control				
ACALL	addr11	Absolute subroutine call	2	2
LCALL	addr16	Long subroutine call	3	2
RET		Return from subroutine	1	2
RETI		Return from interrupt	1	2
AJMP	addr11	Absolute jump	2	2
LJMP	addr16	Long jump	3	2
SJMP	rel	Short jump (relative addr)	2	2
JMP	@A + DPTR	Jump indirect relative to the DPTR	1	2
JZ	rel	Jump if accumulator is zero	2	2
JNZ	rel	Jump if accumulator is not zero	2	2
JC	rel	Jump if carry flag is set	2	2
JNC	rel	Jump if no carry flag	2	2
JB	bit,rel	Jump if direct bit set	3	2
JNB	bit,rel	Jump if direct bit not set	3	2
JBC	bit,rel	Jump if direct bit is set & clear bit	3	2
CJNE	A,direct,rel	Compare direct to A & jump if not equal	3	2
CJNE	A,#data,rel	Comp. immed. to A & jump if not equal	3	2
CJNE	Rn,#data,rel	Comp. immed. to reg. & jump if not equal	3	2
CJNE	@Ri,#data,rel	Comp. immed. to ind. & jump if not equal	3	2
DJNZ	Rn,rel	Decrement register & jump if not zero	2	2
DJNZ	direct,rel	Decrement direct & jump if not zero	3	2
NOP		No operation	1	1

Notes on data addressing modes:

Rn -Working register R0-R7
direct -128 internal RAM locations, any I/O port, control or status register
@Ri -Indirect internal RAM location addressed by register R0 or R1
#data -8-bit constant included in instruction
#data16 -16-bit constant included as bytes 2 & 3 of instruction
bit -128 software flags, any I/O pin, control or status bit

Notes on program addressing modes:

addr16 -Destination address for LCALL & LJMP may be anywhere within the 64-kilobyte program memory address space.
addr11 -Destination address for ACALL & AJMP will be within the same 2-kilobyte page of program memory as the first byte of the following instruction.
rel -SJMP and all conditional jumps include an 8-bit offset byte. Range is + 127 - 128 bytes relative to first byte of the following instruction.

Table 4. Instruction Opcodes in Hexadecimal Order

HEX CODE	NUMBER OF BYTES	MNEMONIC	OPERANDS
00	1	NOP	
01	2	AJMP	code addr
02	3	LJMP	code addr
03	1	RR	A
04	1	INC	A
05	2	INC	data addr
06	1	INC	@R0
07	1	INC	@R1
08	1	INC	R0
09	1	INC	R1
0A	1	INC	R2
0B	1	INC	R3
0C	1	INC	R4
0D	1	INC	R5
0E	1	INC	R6
0F	1	INC	R7
10	3	JBC	bit addr, code addr
11	2	ACALL	code addr
12	3	LCALL	code addr
13	1	RRC	A
14	1	DEC	A
15	2	DEC	data addr
16	1	DEC	@R0
17	1	DEC	@R1
18	1	DEC	R0
19	1	DEC	R1
1A	1	DEC	R2
1B	1	DEC	R3
1C	1	DEC	R4
1D	1	DEC	R5
1E	1	DEC	R6
1F	1	DEC	R7
20	3	JB	bit addr, code addr
21	2	AJMP	code addr
22	1	RET	
23	1	RL	A
24	2	ADD	A,#data
25	2	ADD	A,data addr
26	1	ADD	A,@R0
27	1	ADD	A,@R1
28	1	ADD	A,R0
29	1	ADD	A,R1
2A	1	ADD	A,R2
2B	1	ADD	A,R3
2C	1	ADD	A,R4
2D	1	ADD	A,R5
2E	1	ADD	A,R6
2F	1	ADD	A,R7
30	3	JNB	bit addr, code addr
31	2	ACALL	code addr
32	1	RETI	
33	1	RLC	A
34	2	ADDC	A,#data
35	2	ADDC	A,data addr
36	1	ADDC	A,@R0
37	1	ADDC	A,@R1
38	1	ADDC	A,R0
39	1	ADDC	A,R1
3A	1	ADDC	A,R2,
3B	1	ADDC	A,R3
3C	1	ADDC	A,R4
3D	1	ADDC	A,R5
3E	1	ADDC	A,R6
3F	1	ADDC	A,R7
40	2	JC	code addr
41	2	AJMP	code addr
42	2	ORL	data addr,A
43	3	ORL	data addr,#data
44	2	ORL	A,#data
45	2	ORL	A,data addr
46	1	ORL	A,@R0
47	1	ORL	A,@R1
48	1	ORL	A,R0
49	1	ORL	A,R1
4A	1	ORL	A,R2
4B	1	ORL	A,R3
4C	1	ORL	A,R4
4D	1	ORL	A,R5
4E	1	ORL	A,R6
4F	1	ORL	A,R7
50	2	JNC	code addr
51	2	ACALL	code addr
52	2	ANL	data addr,A
53	3	ANL	data addr,#data
54	2	ANL	A,#data
55	2	ANL	A,data addr
56	1	ANL	A,@R0
57	1	ANL	A,@R1
58	1	ANL	A,R0
59	1	ANL	A,R1
5A	1	ANL	A,R2
5B	1	ANL	A,R3
5C	1	ANL	A,R4
5D	1	ANL	A,R5
5E	1	ANL	A,R6
5F	1	ANL	A,R7
60	2	JZ	code addr
61	2	AJMP	code addr
62	2	XRL	data addr,A
63	3	XRL	data addr,#data
64	2	XRL	A,#data
65	2	XRL	A,data addr
66	1	XRL	A,@R0
67	1	XRL	A,@R1
68	1	XRL	A,R0
69	1	XRL	A,R1
6A	1	XRL	A,R2
6B	1	XRL	A,R3
6C	1	XRL	A,R4
6D	1	XRL	A,R5
6E	1	XRL	A,R6
6F	1	XRL	A,R7
70	2	JNZ	code addr
71	2	ACALL	code addr
72	2	ORL	C,bit addr
73	1	JMP	@A + DPTR
74	2	MOV	A,#data
75	3	MOV	data addr,#data
76	2	MOV	@R0,#data
77	2	MOV	@R1,#data
78	2	MOV	R0,#data
79	2	MOV	R1,#data
7A	2	MOV	R2,#data
7B	2	MOV	R3,#data
7C	2	MOV	R4,#data
7D	2	MOV	R5,#data
7E	2	MOV	R6,#data
7F	2	MOV	R7,#data

Table 4. Instruction Opcodes in Hexadecimal Order (Continued)

HEX CODE	NUMBER OF BYTES	MNEMONIC	OPERANDS
80	2	SJMP	code addr
81	2	AJMP	code addr
82	2	ANL	C,bit addr
83	1	MOVC	A,@A + PC
84	1	DIV	AB
85	3	MOV	data addr,data addr
86	2	MOV	data addr,@R0
87	2	MOV	data addr,@R1
88	2	MOV	data addr,R0
89	2	MOV	data addr,R1
8A	2	MOV	data addr,R2
8B	2	MOV	data addr,R3
8C	2	MOV	data addr,R4
8D	2	MOV	data addr,R5
8E	2	MOV	data addr,R6
8F	2	MOV	data addr,R7
90	3	MOV	DPTR,#data
91	2	ACALL	code addr
92	2	MOV	bit addr,C
93	1	MOVC	A,@A + DPTR
94	2	SUBB	A,#data
95	2	SUBB	A,data addr
96	1	SUBB	A,@R0
97	1	SUBB	A,@R1
98	1	SUBB	A,R0
99	1	SUBB	A,R1
9A	1	SUBB	A,R2
9B	1	SUBB	A,R3
9C	1	SUBB	A,R4
9D	1	SUBB	A,R5
9E	1	SUBB	A,R6
9F	1	SUBB	A,R7
A0	2	ORL	C,/bit addr
A1	2	AJMP	code addr
A2	2	MOV	C,bit addr
A3	1	INC	DPTR
A4	1	MUL	AB
A5		reserved	
A6	2	MOV	@R0,data addr
A7	2	MOV	@R1,data addr
A8	2	MOV	R0,data addr
A9	2	MOV	R1,data addr
AA	2	MOV	R2,data addr
AB	2	MOV	R3,data addr
AC	2	MOV	R4,data addr
AD	2	MOV	R5,data addr
AE	2	MOV	R6,data addr
AF	2	MOV	R7,data addr
B0	2	ANL	C,/bit addr
B1	2	ACALL	code addr
B2	2	CPL	bit addr
B3	1	CPL	C
B4	3	CJNE	A,#data,code addr
B5	3	CJNE	A,data addr,code addr
B6	3	CJNE	@R0,#data,code addr
B7	3	CJNE	@R1,#data,code addr
B8	3	CJNE	R0,#data,code addr
B9	3	CJNE	R1,#data,code addr
BA	3	CJNE	R2,#data,code addr
BB	3	CJNE	R3,#data,code addr
BC	3	CJNE	R4,#data,code addr
BD	3	CJNE	R5#data,code addr
BE	3	CJNE	R6,#data,code addr
BF	3	CJNE	R7,#data,code addr

HEX CODE	NUMBER OF BYTES	MNEMONIC	OPERANDS
C0	2	PUSH	data addr
C1	2	AJMP	code addr
C2	2	CLR	bit addr
C3	1	CLR	C
C4	1	SWAP	A
C5	2	XCH	A,data addr
C6	1	XCH	A,@R0
C7	1	XCH	A,@R1
C8	1	XCH	A,R0
C9	1	XCH	A,R1
CA	1	XCH	A,R2
CB	1	XCH	A,R3
CC	1	XCH	A,R4
CD	1	XCH	A,R5
CE	1	XCH	A,R6
CF	1	XCH	A,R7
D0	2	POP	data addr
D1	2	ACALL	code addr
D2	2	SETB	bit addr
D3	1	SETB	C
D4	1	DA	A
D5	3	DJNZ	data addr,code addr
D6	1	XCHD	A,@R0
D7	1	XCHD	A,@R1
D8	2	DJNZ	R0,code addr
D9	2	DJNZ	R1,code addr
DA	2	DJNZ	R2,code addr
DB	2	DJNZ	R3,code addr
DC	2	DJNZ	R4,code addr
DD	2	DJNZ	R5,code addr
DE	2	DJNZ	R6,code addr
DF	2	DJNZ	R7,code addr
E0	1	MOVX	A,@ DPTR
E1	2	AJMP	code addr
E2	1	MOVX	A,@R0
E3	1	MOVX	A,@R1
E4	1	CLR	A
E5	2	MOV	A,.data addr
E6	1	MOV	A,@R0
E7	1	MOV	A,@R1
E8	1	MOV	A,R0
E9	1	MOV	A,R1
EA	1	MOV	A,R2
EB	1	MOV	A,R3
EC	1	MOV	A,R4
ED	1	MOV	A,R5
EE	1	MOV	A,R6
EF	1	MOV	A,R7
F0	1	MOVX	@ DPTR,A
F1	2	ACALL	code addr
F2	1	MOVX	@R0,A
F3	1	MOVX	@R1,A
F4	1	CPL	A
F5	2	MOV	data addr,A
F6	1	MOV	@R0,A
F7	1	MOV	@R1,A
F8	1	MOV	R0,A
F9	1	MOV	R1,A
FA	1	MOV	R2,A
FB	1	MOV	R3,A
FC	1	MOV	R4,A
FD	1	MOV	R5,A
FE	1	MOV	R6,A
FF	1	MOV	R7,A