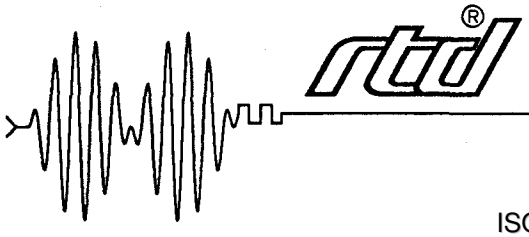
AD1000 User's Manual



Real Time Devices, Inc.

"Accessing the Analog World"™

ISO9001 and AS9100 Certified

AD1000
User's Manual

REAL TIME DEVICES, INC.
820 North University Drive
Post Office Box 906
State College, Pennsylvania 16804
Phone: (814) 234-8087
FAX: (814) 234-5218

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INTRODUCTION

The AD1000 medium speed multichannel analog input board turns your IBM PC/XT/AT or compatible computer into a high-performance data acquisition and control system. Installed within a single short or full-size expansion slot in the computer, the AD1000 board features:

- Eight single-ended analog input channels,
- 12-bit, 20 microsecond A/D converter,
- 25 kHz maximum throughput,
- ±5 volt analog input range,
- Three independent 8-MHz timer/counters,
- 24 TTL/CMOS-compatible 8255-based digital I/O lines (16 at the I/O connector and 8 at on-board pads).

The following paragraphs briefly describe the major functions of the board. More detailed discussions of board functions are included in Chapter 3, *Hardware Description*, and Chapter 4, *Board Operation and Programming*. The board setup is described in Chapter 1, *Board Settings*.

Analog-to-Digital Conversion

The analog-to-digital (A/D) circuitry receives up to eight single-ended analog inputs and converts these inputs into 12-bit digital data words which can then be read and/or transferred to PC memory.

The input voltage range is -5 to +5 volts, with overvoltage protection to ±35 volts. A/D conversions are performed by an industry standard 12-bit successive approximation converter. This high-performance converter and the high-speed sample-and-hold amplifier preceding it make sure that dynamic input voltages are accurately digitized. The resolution of a 12-bit conversion is 2.4414 millivolts and themaximum throughput is 25 kHz.

The converted data is read and/or transferred to PC memory, one byte at a time, through the PC data bus.

8254 Timer/Counter

An 8254 programmable interval timer contains three 16-bit, 8-MHz timer/counters to support a wide range of timing and counting functions. The clock, gate and output pins for each of the three timer/counters are available at the I/O connector.

Digital I/O

The AD1000 has 24 TTL/CMOS-compatible digital I/O lines which can be directly interfaced with external devices or signals to sense switch closures, trigger digital events, or activate solid-state relays. The lines are provided by the on-board 8255 programmable peripheral interface (PPI) chip. Sixteen of the lines are brought out to the I/O connector and eight are available at a set of on-board pads.

What Comes With Your Board

You receive the following items in your AD1000 package:

- AD1000 interface board
- Software and diagnostics diskette with example programs in BASIC, Turbo Pascal, and Turbo C; source code
- User's manual

If any item is missing or damaged, please call Real Time Devices' Customer Service Department at (814) 234-8087. If you require service outside the U.S., contact your local distributor.

Board Accessories

In addition to the items included in your AD1000 package, Real Time Devices offers a full line of software and hardware accessories. Call your local distributor or our main office for more information about these accessories and for help in choosing the best items to support your board's application.

Application Software and Drivers

Our custom application software packages provide excellent data acquisition and analysis support. Use SIGNAL*MATH for integrated data acquisition and sophisticated digital signal processing and analysis, or ATLANTIS for real-time monitoring and data acquisition. rtdLinx and rtdLinx/NB drivers provide full-featured high level interfaces between the AD1000 and custom or third party software, including Labtech Notebook, Notebook/XE, and LT/Control. rtdLinx source code is available for a one-time fee. Our Pascal and C Programmer's Toolkit provides routines with documented source code for custom programming.

Hardware Accessories

Hardware accessories for the AD1000 include the TB40 terminal board and XB40 prototype/terminal board for prototype development and easy signal access, EX-XT and EX-AT extender boards for simplified testing and debugging of prototype circuitry, and the XP40 single wire flat ribbon cable for external interfacing. The AD1000 can be interfaced to RTD's 50-pin channel expansion and signal conditioning boards by using a Discrete Wire Kit.

Using This Manual

This manual is intended to help you install your new board and get it running quickly, while also providing enough detail about the board and its functions so that you can enjoy maximum use of its features even in the most complex applications. We assume that you already have an understanding of data acquisition principles and that you can customize the example software or write your own applications programs.

When You Need Help

This manual and the example programs in the software package included with your board provide enough information to properly use all of the board's features. If you have any problems installing or using this board, contact our Technical Support Department, (814) 234-8087, during regular business hours, eastern standard time or eastern daylight time, or send a FAX requesting assistance to (814) 234-5218. When sending a FAX request, please include your company's name and address, your name, your telephone number, and a brief description of the problem.

CHAPTER 1

BOARD SETTINGS

The AD1000 board has jumper settings you can change if necessary for your application. The board is factory-configured as listed on the table and shown in the diagram at the beginning of this chapter. Should you need to change these settings, use these easy-to-follow instructions before you install the board in your computer.

Factory-Configured Jumper Settings

Table 1-1 lists the factory settings of the user-configurable jumpers on the AD1000 board. Figure 1-1 shows the board layout and the locations of the factory-set jumpers. The following paragraphs explain how to change the factory settings. Pay special attention to the setting of P6, the base address header connector, to avoid address contention when you first use your board in your system.

Table 1-1 — Factory Settings

Jumper	Function Controlled	Factory Setting
P2	Connects the A/D end-of-convert signal to an interrupt channel	Disabled (not connected)
P3	Connects one of the 8254 timer/counter outputs to an interrupt channel	Disabled (not connected)
P4	Connects an external interrupt or an interrupt generated by the PPI (INTRA) to an interrupt channel	Disabled (not connected)
P5	Configures the 8254 timer/counters	All timer/counters are cascaded (see diagram for P5)
P6	Sets the base address	300 hex (768 decimal)
P8	Connects the A/D end-of-convert signal so that it can be monitored through the PPI at PA7, PB7, or PC7	Monitored through PB7
P9	8255 Port B pads available for soldering connections	No connections

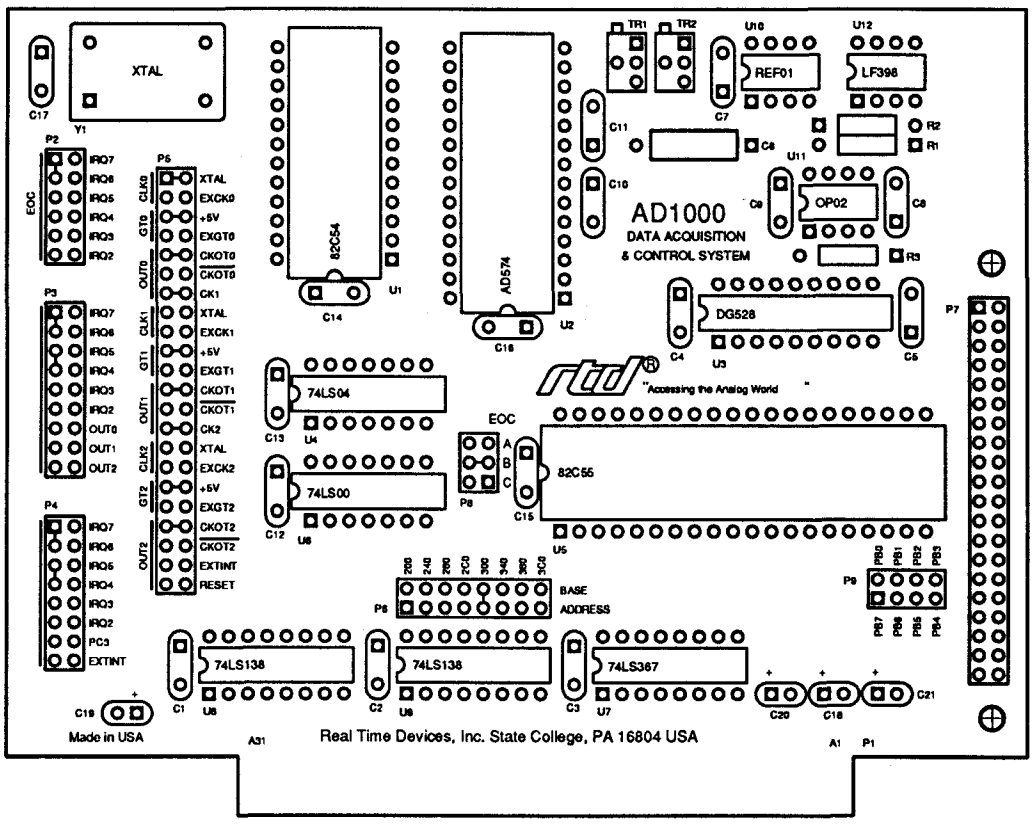


Fig. 1-1 — Board Layout Showing Factory-Configured Settings

P2, P3, and P4 — Interrupts

Header connectors P2, P3, and P4 let you connect various on-board and external signals to the computer's interrupt channels. Interrupts can be generated by the A/D converter's end-of-convert signal, by any one of the three timer/counter outputs, and by the 8255 programmable peripheral interface or from an external interrupt source brought onto the board through the I/O connector.

Before trying to use interrupts, you must be familiar with the procedure for initializing the interrupt vectors and the PC's interrupt controller, and setting up the interrupt handling routines. These procedures are beyond the scope of this manual, but must be understood to effectively use interrupts in your computer system. Chapter 4 provides an overview on using interrupts.

Also, be careful to avoid contention with other devices that may use interrupts in your computer when you choose your interrupt channel. Each interrupt source activated must be assigned to an unused interrupt channel. Use the table inside the back cover of this manual to record the interrupt channel you have selected.

It is also very important to note that the board interrupt source is a TTL totem-pole (push/pull) type output; it is **not** open-collector. Therefore, **do not** connect this interrupt to any other interrupt output!

• P2 — A/D End-of-Convert (EOC) Interrupt (Factory Setting: Disabled)

Header connector P2, shown in Figure 1-2, lets you connect the A/D converter's end-of-convert (EOC) signal to any of the computer's interrupt channels, IRQ2 (highest priority channel) through IRQ7 (lowest priority channel). The jumper is stored vertically across the top two leftmost pins, as shown in Figure 1-2a. By placing this jumper horizontally across the pins of one of the IRQ channels, the EOC signal can be used to generate interrupts. Figure 1-2b shows the EOC connected to IRQ3. The EOC goes high when a conversion is completed; therefore, an interrupt will occur when the EOC line transitions from low (converting) to high (not converting).

Fig. 1-2a: Factory setting (disabled)

Fig. 1-2b: EOC connected to IRQ3

Fig. 1-2 — End-of-Convert Interrupt Channel Selection Jumper, P2

• P3 — 8254 Timer/Counter Output Interrupt (Factory Setting: Disabled)

Header connector P3, shown in Figure 1-3, is used to jumper one of the three 8254 timer/counter outputs, OUT0, OUT1, or OUT2, to one of the computer's interrupt channels, IRQ2 (highest priority channel) through IRQ7 (lowest priority channel). The top six pairs of pins on this header connector are used to select the IRQ channel, and the bottom three pairs of pins are used to select the desired 8254 output. The two jumpers stored vertically across the top four pairs of pins, as shown in Figure 1-3a, must be installed to connect an 8254 output to an interrupt channel. Place one jumper horizontally across the pins of the selected timer/counter output (one of the bottom three pairs of pins). Then place the second jumper across the pins of the selected interrupt channel (one of the top six pairs of pins). Figure 1-3b shows an example.

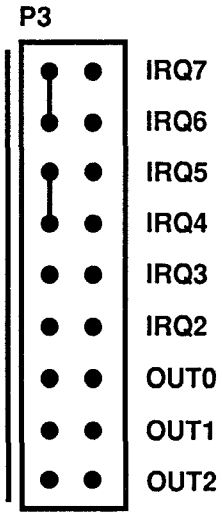


Fig. 1-3a: Factory settings (disabled)

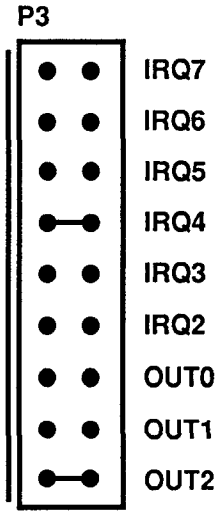


Fig. 1-3b: OUT2 connected to IRQ4

Fig. 1-3 — 8254 Timer/Counter Output Interrupt Jumpers, P3

• P4 — EXTINT and PPI PC3 Interrupts (Factory Setting: Disabled)

Header connector P4, shown in Figure 1-4, lets you connect an external signal, EXTINT, or the 8255 PPI's PC3 (INTRA) signal to one of the computer's interrupt channels, IRQ2 (highest priority channel) through IRQ7 (lowest priority channel). EXTINT is routed onto the board through external I/O connector P7. PC3 is generated when the 8255 PPI is being operated in mode 1 or mode 2, as explained in the data sheet in Appendix C. To connect one of these two signals to an interrupt channel, the two stored jumpers, shown in Figure 1-4a, must be installed across the appropriate pairs of pins. Place one jumper horizontally across the pins of the signal chosen and place the second jumper horizontally across the pins of the selected IRQ channel. Figure 1-4b shows the PC3 connected to IRQ7.

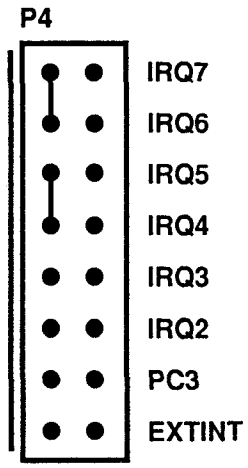


Fig. 1-4a: Factory settings (disabled)

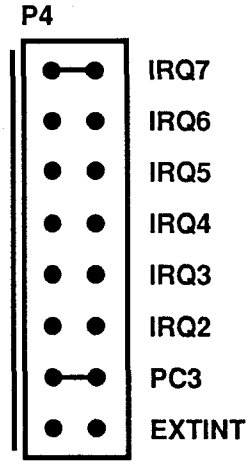


Fig. 1-4b: PC3 connected to IRQ7

Fig. 1-4 — EXTINT and PC3 Interrupt Jumpers, P4

P5 — 8254 Timer/Counter I/O Header Connector (Factory Settings: As Shown in Figure 1-5)

Header connector P5, shown in Figure 1-5, configures the 8254 programmable interval timer's clock and gate sources and output connections. Also included on P5 are pins to route an external interrupt (EXTINT) from and the computer's RESET signal to external I/O connector P7. Figure 1-5 shows the factory settings. All three timer/counters are cascaded. These are the settings used by SIGNAL*MATH and ATLANTIS acquisition and analysis software (see Appendixes D and E).

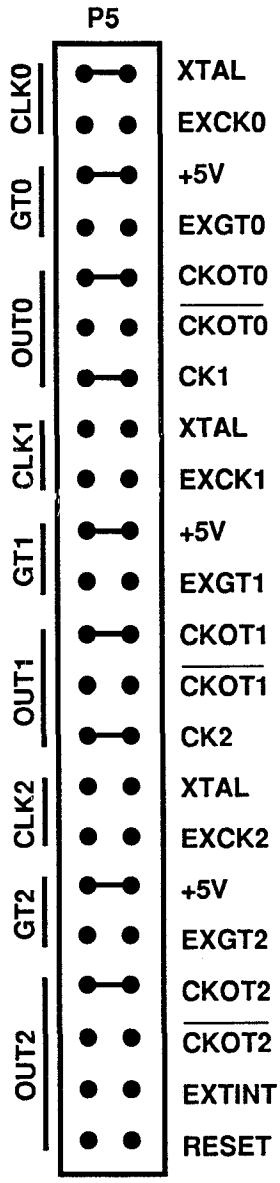


Fig. 1-5 — 8254 Programmable Interval Timer Jumpers, P5

The 8254 provides three independent 16-bit, 8 MHz timer/counters for timing and counting functions such as frequency measurement, event counting, and interrupts. Each timer/counter has two inputs, clock (CK) in and gate (GT) in, and one output, timer/counter OUT. Figure 1-6 shows a block diagram of the 8254 and P5 circuitry.

Starting from the top of P5, the first three groups of pins on the left side are labeled CLK0, GT0, and OUT0, the three I/O signals for timer/counter 0. The signals on the right side for timer/counter 0 are labeled XTAL, EXCK0, +5V, EXGT0, CKOT0, $\overline{\text{CKOT0}}$ (this signal has a bar over top of the signal name on the board because it is the inverse of the CKOT0 signal), and CK1 (the output which cascades timer/counter 0 to timer/counter 1). The groups of signals for timer/counters 1 and 2 are identical to timer/counter 0, except that OUT2 can be connected to EXTINT, an external signal, or RESET, the computer's reset signal. The following paragraphs describe these signals. An "x" is used in place of 0, 1, or 2 in the signal names whenever the application can be applied to any or all of the three timer/counters.

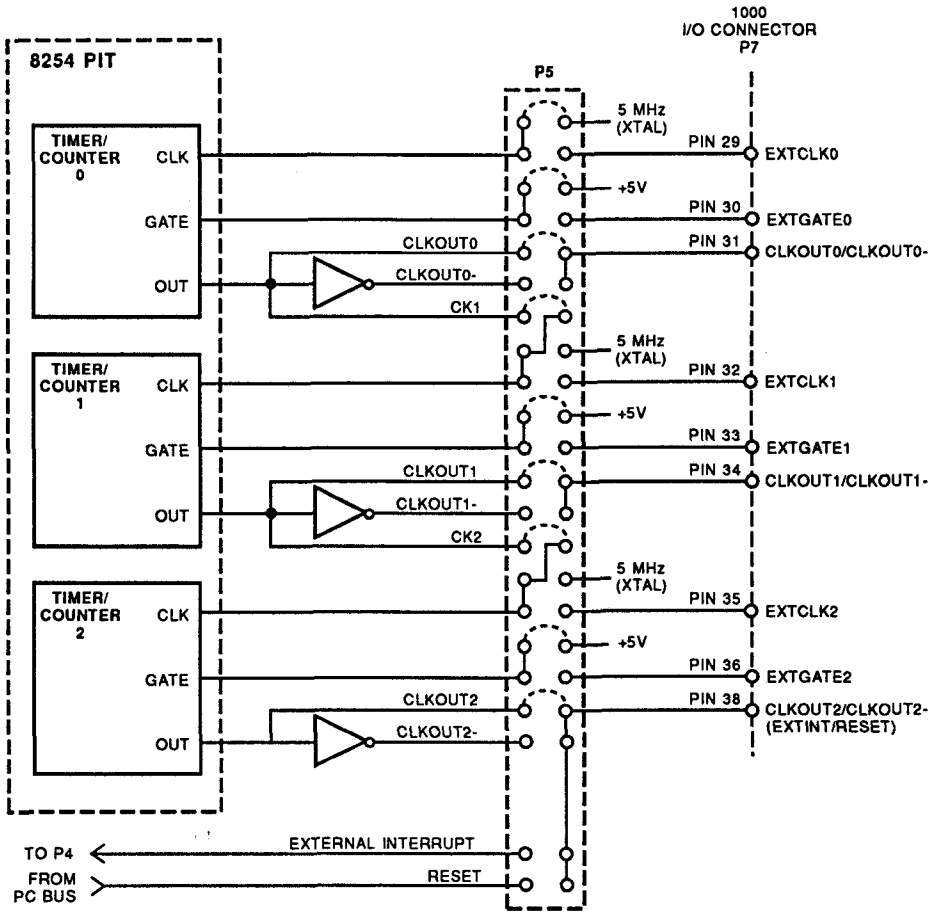


Fig. 1-6 — 8254 and P5 Circuitry

• Counter Inputs (Connect Only ONE at a Time):

XTAL — This input to all three timer/counter circuits is from the 5 MHz crystal oscillator, labeled Y1, located in the upper left corner of the board. Installing a jumper horizontally across the pair of pins connects the 5 MHz clock to the timer/counter clock input. If required by your application, the XTAL frequency can be changed by installing a different crystal oscillator at Y1. Note, however, that the maximum frequency at which the timer/counters will operate is 8 MHz.

EXCKx — This input allows an external clock to control the timing of the corresponding timer/counter. This pin can be horizontally jumpered to the CKx input on the right side of the connector, in place of the XTAL source. The EXCKx signals are brought onto the board through external I/O connector P7 (see Appendix B).

CKx — This input connects the output of one timer/counter to the clock input of the next timer/counter. CKx is provided for timer/counters 1 and 2 only, and is connected to the output of the previous timer/counter (timer/counter 0 or 1) by placing a jumper horizontally between the pins. These connections are used to cascade the timer/counters for longer time delays than are supported by a single 16-bit timer/counter.

• Gate Inputs (Connect Only ONE at a Time):

+5V — This input, if connected to the GTx input by installing a jumper horizontally across the two pins, places the timer/counter in an enabled state at all times.

EXGTx — This input can be horizontally jumpered to the GTx input on the right side of the connector to provide an external gate. The EXGTx signals are brought onto the board through external I/O connector P7 (see Appendix B).

• **Counter Outputs (Connect Only ONE at a Time):**

CKOTx — This output can be horizontally jumpered to the corresponding OUT pin on the right side of the connector so that the timer/counter's output signal can be routed to external I/O connector P7 (see Appendix B). The CKOTx signals are available at P7.

$\overline{\text{CKOTx}}$ — This output can be horizontally jumpered to the corresponding OUT pin on the right side of the connector to provide the inverse of the timer/counter output signal to external I/O connector P7 (see Appendix B). The $\overline{\text{CKOTx}}$ signals are available at P7.

EXTINT and RESET (timer/counter 2 only) — These two pairs of pins at the bottom of the header let you connect an external interrupt signal to one of the PC's interrupt channels, or bring the PC bus reset signal out to the external I/O connector, P7. Both signals are routed through the same P7 I/O pin that carries the CKOT2 and $\overline{\text{CKOT2}}$ signals, pin 38. CKOT2, $\overline{\text{CKOT2}}$, EXINT, and RESET are all internally connected on header P5. Only one of these four pairs of pins can be jumpered at a time. The jumpered signal is available at P7-38. For example, when the external interrupt is connected to P7-38, the jumper is installed across the EXTINT pins on P5 (see Figure 1-6). This routes the EXTINT signal through P5 to header connector P4 where it can be jumpered to a PC interrupt channel.

P6 — Base Address (Factory Setting: 300 hex (768 decimal))

One of the most common causes of failure when you are first trying your board is address contention. Some of your computer's I/O space is already occupied by internal I/O and other peripherals. When the AD1000 board attempts to use I/O address locations already used by another device, contention results and the board does not work.

To avoid this problem, the AD1000 has a header connector, P6, which lets you select any one of eight starting addresses in the computer's I/O. Should the factory setting of 300 hex (768 decimal) be unsuitable for your system, you can select a different base address. These addresses are, from left to right on P6:

Hexadecimal	Decimal
200	512
240	576
280	640
2C0	704
300	768
340	832
380	896
3C0	960

To change the base address setting, remove the jumper from the fifth pair of pins (300 hex) and, using Figure 1-7 as a guide, install it in the desired location. Record the new base address setting on the table inside the back cover of this manual.

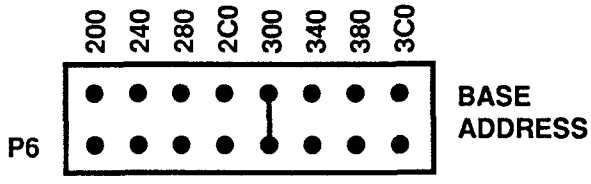


Fig. 1-7 — Base Address Jumper, P6

P8 — End-of-Convert Monitor (Factory Setting: 8255 PPI Port B, Bit 7)

The A/D converter's end-of-convert (EOC) signal can be used to monitor the status of A/D conversions. Header connector P8, shown in Figure 1-8, lets you choose one of three digital lines from the PPI through which to monitor the EOC: Port A, bit 7 (PA7); Port B, bit 7 (PB7); and Port C, bit 7 (PC7). One of these three lines is selected by installing a jumper horizontally across the appropriate pair of pins. The selected digital line must be configured as a Mode 0 input (see Chapter 4).

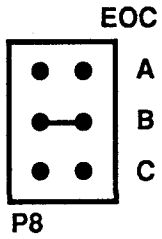


Fig. 1-8 — End-of-Convert Jumper, P8

CHAPTER 2

BOARD INSTALLATION

The AD1000 board is easy to install in your IBM PC/XT/AT or compatible computer. It can be placed in any slot, short or full-size. This chapter tells you step-by-step how to install and connect the board.

After you have installed the board and made all of your connections, you can turn your system on and run the RTDDIAG board diagnostics program included on your example software disk to verify that your board is working.

Board Installation

Keep the board in its antistatic bag until you are ready to install it in your computer. When removing it from the bag, hold the board at the edges and do not touch the components or connectors.

Before installing the board in your computer, check the jumper settings. Chapter 1 reviews the factory settings and how to change them. If you need to change any settings, refer to the appropriate instructions in Chapter 1. Note that incompatible jumper settings can result in unpredictable board operation and erratic response.

To install the board:

1. Turn OFF the power to your computer.
2. Remove the top cover of the computer housing (refer to your owner's manual if you do not already know how to do this).
3. Select any unused short or full-size expansion slot and remove the slot bracket.
4. Touch the metal housing of the computer to discharge any static buildup and then remove the board from its antistatic bag.
5. Holding the board by its edges, orient it so that its card edge (bus) connector lines up with the expansion slot connector in the bottom of the selected expansion slot.
6. After carefully positioning the board in the expansion slot so that the card edge connector is resting on the computer's bus connector, gently and evenly press down on the board until it is secured in the slot.

   NOTE: Do not force the board into the slot. If the board does not slide into place, remove it and try again. Wiggling the board or exerting too much pressure can result in damage to the board or to the computer.
7. After the board is installed, secure the slot bracket back into place and put the cover back on your computer. The board is now ready to be connected via the external I/O connector at the rear panel of your computer.

External I/O Connections

Figure 2-1 shows the AD1000's P7 I/O connector pinout. Refer to this diagram as you make your I/O connections.

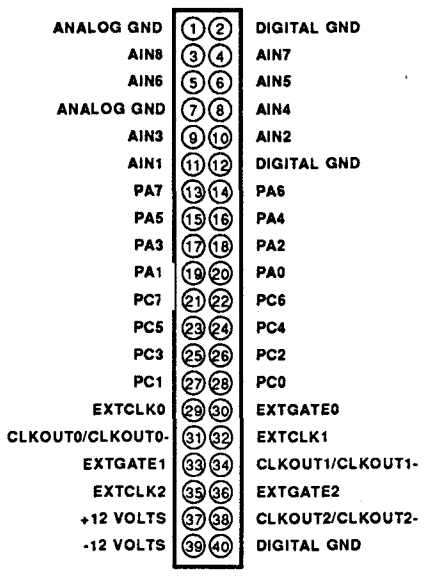


Fig. 2-1 — P7 I/O Connector Pin Assignments

Connecting the Analog Inputs

Connect the high side of each analog input to one of the analog input channels, AIN1 through AIN8, and connect the low side to any one of the two ANALOG GND signals (P4-1 or 7). Figure 2-2 shows how these connections are made.

NOTE: It is good practice to connect all unused channels to ANALOG GND, as shown with channel 8 in the diagram below. Failure to do so may affect the accuracy of your conversion results.

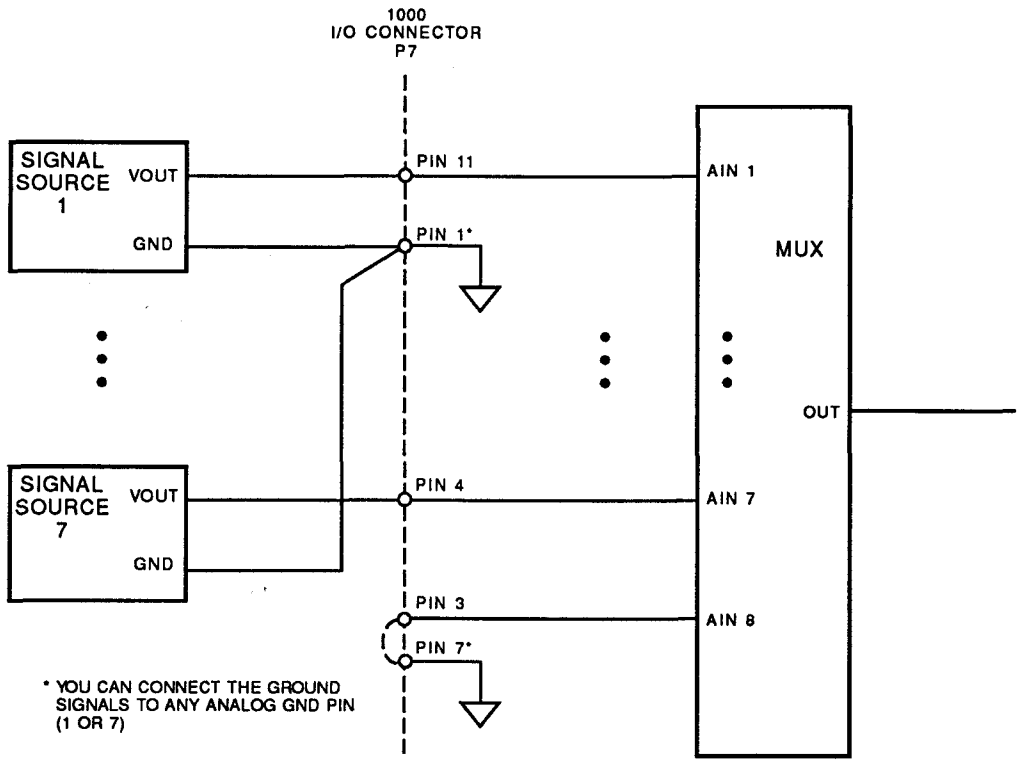


Fig. 2-2 — Analog Input Connection

Connecting the Timer/Counters and Digital I/O

For all of these connections, the high side of an external signal source or destination device is connected to the appropriate signal pin on the I/O connector, and the low side is connected to any DIGITAL GND.

Running the RTDDIAG Diagnostics Program

Now that your board is ready to use, you will want to try it out. An easy-to-use diagnostics program, RTDDIAG, is included with your example software to help you verify your board's operation. You can also use this program to make sure that your current base address setting does not contend with another device.

CHAPTER 3

HARDWARE DESCRIPTION

This chapter describes the features of the AD1000 hardware. The major circuits are the A/D converter, the 8254 timer/counters, and the 8255 programmable peripheral interface which provides the digital I/O lines. Board interrupts are also described in this chapter.

The AD1000 board has three major circuits, the A/D converter, the timer/counters, and the programmable peripheral interface (PPI) which provides the digital I/O lines. Figure 3-1 shows the block diagram of the board. This chapter describes hardware which makes up the major circuits. It also discusses interrupts.

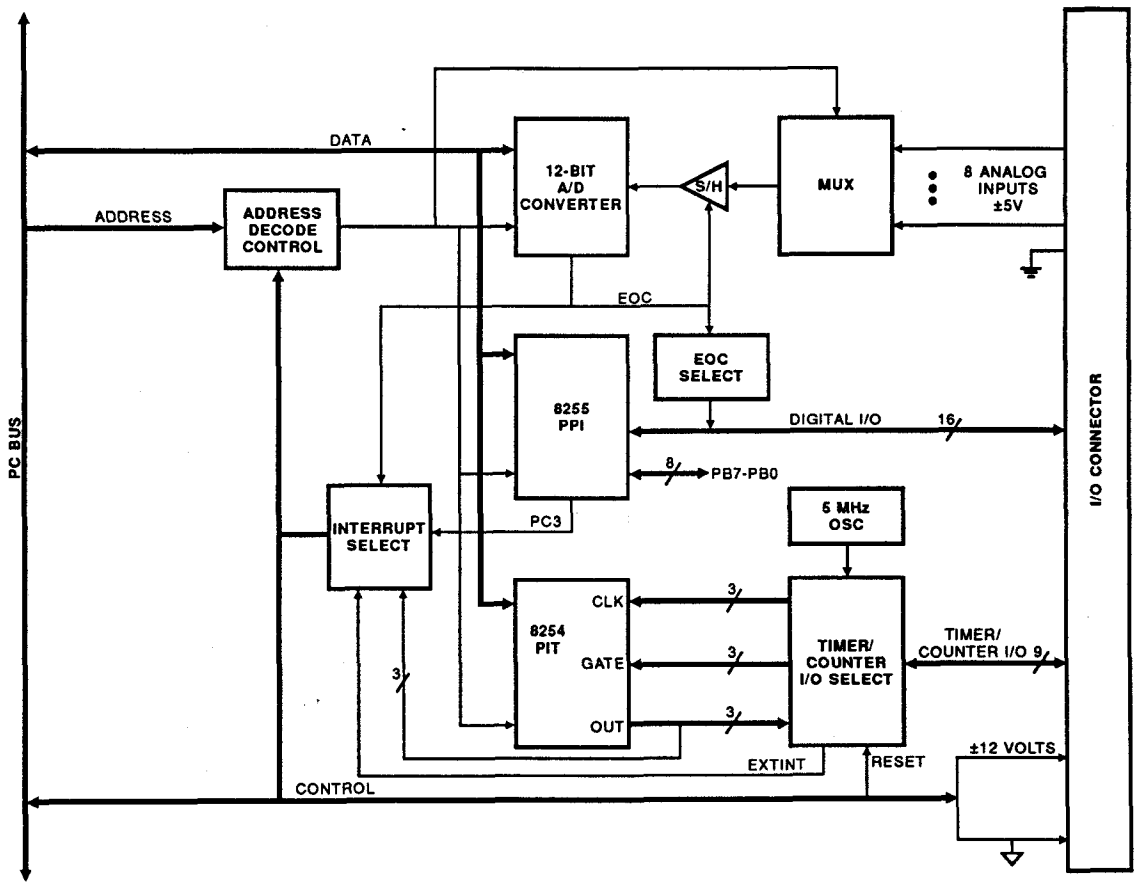


Fig. 3-1 — AD1000 Block Diagram

A/D Conversion Circuitry

The AD1000 board performs analog-to-digital conversions on up to eight analog input channels. The following paragraphs describe the A/D circuitry.

Analog Inputs

Eight single-ended analog input channels are available on the AD1000 board. The analog input range is -5 to +5 volts, with ±35 Vdc overvoltage protection. The channels are connected to a sample-and-hold amplifier through an eight-channel multiplexer. The active channel is selected through software by writing to the desired channel's I/O port, as described in Chapter 4.

The S/H amplifier captures and holds the input signal at a constant level while the conversion is performed, ensuring that dynamic analog signals are accurately digitized. This capacitive circuit quickly charges to a level corresponding to the input voltage being sampled and holds the charge for the duration of the conversion. The AD1000 uses a .01 µF low dielectric capacitor with a maximum acquisition time of 20 microseconds.

A/D Converter

The industry standard HI574 A/D converter performs conversions at a rate of up to 50 kHz, or one conversion every 20 microseconds. This conversion time is added to the S/H amplifier's acquisition time of 20 microseconds to

give a board maximum throughput rate of 25 kHz. The A/D output is a 12-bit data word which is output in two 8-bit bytes. Note that 8-bit conversions can be performed when speed is more critical than resolution. Because the converted data is contained in a single 8-bit byte, 8-bit conversions take about 13 microseconds, increasing the maximum board throughput to about 30 kHz.

Timer/Counters

An 8254 programmable interval timer provides three 16-bit, 8 MHz timer/counters to support a wide range of timing and counting functions. These timer/counters can be cascaded or used individually for many applications, including triggering an A/D conversion at a specified time.

Each timer/counter has two inputs, CK in and GT in, and one output, timer/counter OUT. The sources or destinations of the timer/counter I/O can be selected using jumpers on header connector P5 (see Chapter 1). The timer/counters can be programmed as binary or BCD down counters by writing the appropriate data to the command word, as described in Chapter 4. The command word also lets you set up the mode of operation. The six programmable modes are:

Mode 0	Event Counter (Interrupt on Terminal Count)
Mode 1	Hardware-Retriggerable One-Shot
Mode 2	Rate Generator
Mode 3	Square Wave Mode
Mode 4	Software-Triggered Strobe
Mode 5	Hardware Triggered Strobe (Retriggerable)

These modes are detailed in the 8254 Data Sheet, reprinted from Intel in Appendix C.

Digital I/O, Programmable Peripheral Interface

The 8255 programmable peripheral interface (PPI) is used for digital I/O functions. This high-performance TTL/CMOS compatible chip has 24 digital I/O lines divided into two groups of 12 lines each:

Group A — Port A (8 lines) and Port C Upper (4 lines);
Group B — Port B (8 lines) and Port C Lower (4 lines).

Sixteen lines, Port A, Port C Lower, and Port C Upper, are brought out to the I/O connector. Port B's eight lines are available at the P9 pads on the board. You can use these ports in one of these three PPI operating modes:

Mode 0 — Basic input/output. Lets you use simple input and output operation for a port. Data is written to or read from the specified port.

Mode 1 — Strobed input/output. Lets you transfer I/O data from Port A or Port B in conjunction with strobes or handshaking signals.

Mode 2 — Strobed bidirectional input/output. Lets you communicate bidirectionally with an external device through Port A. Handshaking is similar to Mode 1.

These modes are detailed in the 8255 Data Sheet, reprinted from Intel in Appendix C.

Interrupts

The AD1000 has four jumper-selectable interrupt sources: end-of-convert, 8254 timer/counter outputs, PC3 (INTRA) from the 8255 PPI, and an external interrupt brought onto the board through P7. The end-of-convert signal can be used to interrupt the computer when an A/D conversion is completed. The 8254 timer/counter interrupts can be used to generate various end-of-count interrupts. The 8255 PC3 interrupt can be generated when PPI Port A is operated in mode 1 or mode 2, as explained on the 8255 data sheet, Appendix C. The external interrupt can be used to generate interrupts at any desired interval. We recommend that you have an understanding of how to use interrupts in your system before you connect an interrupt to an IRQ channel. Chapter 4 provides a more detailed discussion about interrupts.

CHAPTER 4

BOARD OPERATION AND PROGRAMMING

This chapter shows you how to program and use your AD1000 board. It provides a complete description of the I/O map, a detailed description of programming operations, and a flow diagram to aid you in programming. The example programs provided on the disk in your board package are listed at the end of this chapter. These programs, written in Turbo C, Turbo Pascal, and BASIC, include source code to simplify your applications programming.

Defining the I/O Map

The I/O map for the AD1000 is shown in Table 4-1. As shown, the board occupies 20 I/O port locations. The base address (designated as BA) can be selected by changing the jumper on header connector P6, as described in Chapter 1, *Board Settings*. The following sections describe the register contents of each address used in the I/O map.

Table 4-1 — AD1000 I/O Map

Register Description	Read Function	Write Function	Address * (Decimal)
Channel 1 (AIN1) Select	Reserved	Activate channel 1	BA + 0
Channel 2 (AIN2) Select	Reserved	Activate channel 2	BA + 1
Channel 3 (AIN3) Select	Reserved	Activate channel 3	BA + 2
Channel 4 (AIN4) Select	Reserved	Activate channel 4	BA + 3
Channel 5 (AIN5) Select	Reserved	Activate channel 5	BA + 4
Channel 6 (AIN6) Select	Reserved	Activate channel 6	BA + 5
Channel 7 (AIN7) Select	Reserved	Activate channel 7	BA + 6
Channel 8 (AIN8) Select	Reserved	Activate channel 8	BA + 7
Start 12-Bit Conversion/ Read Data	Read A/D converted data, MSB	Start 12-bit A/D conversion	BA + 8
Start 8-Bit Conversion/ Read Data	Read A/D converted data, LSB	Start 8-bit A/D conversion	BA + 9
Reserved			BA + 10
Reserved			BA + 11
PPI Port A	Read PA0-PA7 digital I/O	Program PA0-PA7 digital I/O	BA + 12
PPI Port B	Read PB0-PB7 digital I/O	Program PB0-PB7 digital I/O	BA + 13
PPI Port C	Read PC0-PC7 digital I/O	Program PC0-PC7 digital I/O	BA + 14
PPI Control Word	Reserved	Program PPI configuration	BA + 15
8254 Timer/Counter 0	Read TC0 count value	Load TC0 count register	BA + 16
8254 Timer/Counter 1	Read TC1 count value	Load TC1 count register	BA + 17
8254 Timer/Counter 2	Read TC2 count value	Load TC2 count register	BA + 18
8254 Control Word	Reserved	Program control register	BA + 19
* BA = Base Address			

BA + 0: Channel 1 (AIN1) Select (Write Only)

Writing to this address selects analog input channel 1 (AIN1). The data written is irrelevant. After you select channel 1, it remains active until you select another channel or power down.

BA + 1: Channel 2 (AIN2) Select (Write Only)

Writing to this address selects analog input channel 2 (AIN2). The data written is irrelevant. After you select channel 2, it remains active until you select another channel or power down.

BA + 2: Channel 3 (AIN3) Select (Write Only)

Writing to this address selects analog input channel 3 (AIN3). The data written is irrelevant. After you select channel 3, it remains active until you select another channel or power down.

BA + 3: Channel 4 (AIN4) Select (Write Only)

Writing to this address selects analog input channel 4 (AIN4). The data written is irrelevant. After you select channel 4, it remains active until you select another channel or power down.

BA + 4: Channel 5 (AIN5) Select (Write Only)

Writing to this address selects analog input channel 5 (AIN5). The data written is irrelevant. After you select channel 5, it remains active until you select another channel or power down.

BA + 5: Channel 6 (AIN6) Select (Write Only)

Writing to this address selects analog input channel 6 (AIN6). The data written is irrelevant. After you select channel 6, it remains active until you select another channel or power down.

BA + 6: Channel 7 (AIN7) Select (Write Only)

Writing to this address selects analog input channel 7 (AIN7). The data written is irrelevant. After you select channel 7, it remains active until you select another channel or power down.

BA + 7: Channel 8 (AIN8) Select (Write Only)

Writing to this address selects analog input channel 8 (AIN8). The data written is irrelevant. After you select channel 8, it remains active until you select another channel or power down.

BA + 8: Start 12-Bit Conversion/Read MSB Data (Read/Write)

Writing to this address starts a 12-bit A/D conversion (the data written is irrelevant). A read provides the MSB (8 most significant bits) of the 12-bit A/D conversion, as defined below. The converted data is left-justified. When you are performing 8-bit conversions, only the MSB must be read.

MSB	D7	D6	D5	D4	D3	D2	D1	D0
12-Bit:	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4
8-Bit:	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

BA + 9: Start 8-Bit Conversion/Read LSB Data (Read/Write)

Writing to this address starts an 8-bit A/D conversion (the data written is irrelevant). A read provides the LSB (4 least significant bits) of the 12-bit A/D conversion, as defined below. The converted data is left-justified.

LSB	D7	D6	D5	D4	D3	D2	D1	D0
	Bit 3	Bit 2	Bit 1	Bit 0	X	X	X	X

BA + 10: Reserved

BA + 11: Reserved

BA + 12: PPI Port A — Digital I/O (Read/Write)

Transfers the 8-bit Port A digital input and digital output data between the board and an external device. A read transfers data from the external device, through P7, and into PPI Port A; a write transfers the written data from Port A through P7 to an external device.

BA + 13: PPI Port B — Digital I/O (Read/Write)

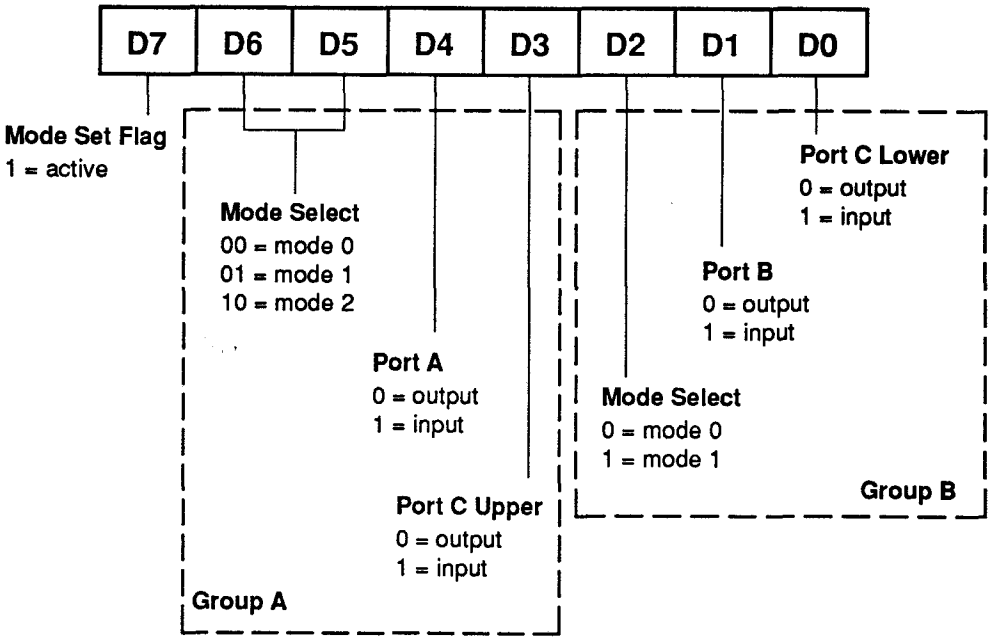
Transfers the 8-bit Port B digital input and digital output data between the board and an external device. A read transfers data from the external device, to the on-board pads at P9, and into PPI Port B; a write transfers the written data from Port B through the on-board pads at P9 to an external device.

BA + 14: PPI Port C — Digital I/O (Read/Write)

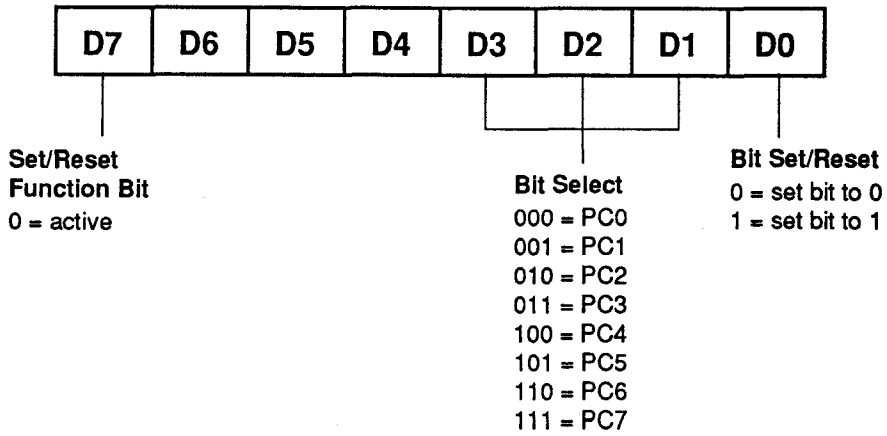
Transfers the two 4-bit Port C digital input and digital output data groups (Port C Upper and Port C Lower) between the board and an external device. A read transfers data from the external device, through P7, and into PPI Port C; a write transfers the written data from Port C through P7 to an external device.

BA + 15: 8255 PPI Control Word (Write Only)

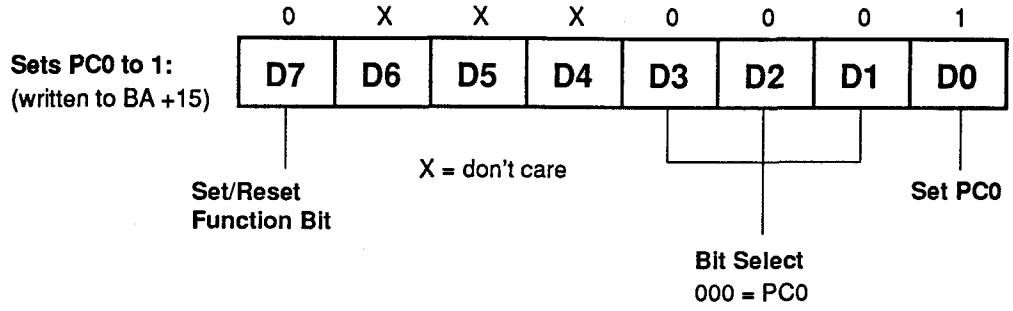
When bit 7 of this word is set to 1, a write programs the PPI configuration. When you want to monitor the end-of-convert signal through P8, bit 7 of PPI Port A, B, or C, the PPI must be programmed so that the port used is a Mode 0 input port.



When bit 7 of the control word is set to 0, a write can be used to individually program the Port C lines.



For example, if you want to set Port C bit 0 to 1, you would set up the control word so that bit 7 is 0; bits 1, 2, and 3 are 0 (this selects PC0); and bit 0 is 1 (this sets PC0 to 1). The control word is set up like this:



BA + 16: 8254 Timer/Counter 0 (Read/Write)

A read shows the count in the counter, and a write loads the counter with a new value. Counting begins as soon as the count is loaded.

BA + 17: 8254 Timer/Counter 1 (Read/Write)

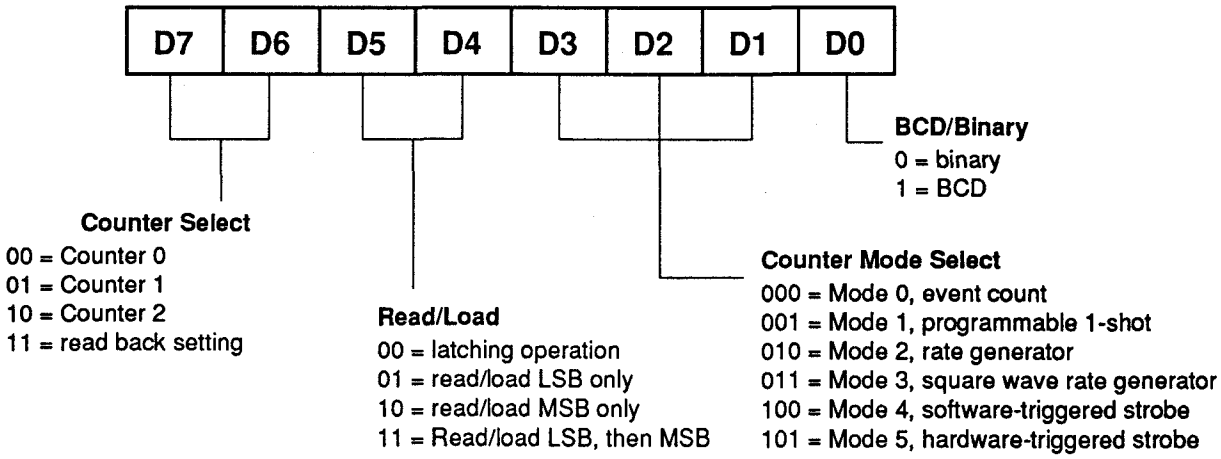
A read shows the count in the counter, and a write loads the counter with a new value. Counting begins as soon as the count is loaded.

BA + 18: 8254 Timer/Counter 2 (Read/Write)

A read shows the count in the counter, and a write loads the counter with a new value. Counting begins as soon as the count is loaded.

BA + 19: 8254 Timer/Counter Control Word (Write Only)

Accesses the 8254 control register to directly control the three timer/counters.



Programming the AD1000

This section gives you some general information about programming and the AD1000 board, and then walks you through the major AD1000 programming functions. These descriptions will help you as you use the example programs included with the board and the programming flow diagram at the end of this chapter. All of the program descriptions in this section use decimal values unless otherwise specified.

The AD1000 is programmed by writing to and reading from the correct I/O port locations on the board. These I/O ports were defined in the previous section. Most high-level languages such as BASIC, Pascal, C, and C++, and of course assembly language, make it very easy to read/write these ports. The table below shows you how to read from and write to I/O ports using some popular programming languages.

Language	Read	Write
BASIC	Data = INP(Address)	OUT Address, Data
Turbo C	Data = inportb(Address)	outportb(Address, Data)
Turbo Pascal	Data := Port[Address]	Port[Address] := Data

Assembly	mov dx, Address
	in al, dx
		mov dx, Address
		mov al, Data
		out dx, al

In addition to being able to read/write the I/O ports on the AD1000, you must be able to perform a variety of operations that you might not normally use in your programming. The table below shows you some of the operators discussed in this section, with an example of how each is used with Pascal, C, and BASIC. Note that the modulus operator is used to retrieve the least significant byte (LSB) of a two-byte word, and the integer division operator is used to retrieve the most significant byte (MSB).

Language	Modulus	Integer Division	AND	OR
C	% a = b % c	/ a = b / c	& a = b & c	| a = b | c
Pascal	MOD a := b MOD c	DIV a := b DIV c	AND a := b AND c	OR a := b OR c
BASIC	MOD a = b MOD c	\ (backslash) a = b \ c	AND a = b AND c	OR a = b OR c

Many compilers have functions that can read/write either 8 or 16 bits from/to an I/O port. For example, Turbo Pascal uses **Port** for 8-bit port operations and **PortW** for 16 bits, Turbo C uses **inportb** for an 8-bit read of a port and **inport** for a 16-bit read. **Be sure to use only 8-bit operations with the AD1000!**

Now that you know some of the language basics, we are ready to look at the programming steps for the AD1000 board functions.

A/D Conversions

The following paragraphs walk you through the programming steps for performing A/D conversions. You can follow these steps on the flow diagram at the end of this chapter and in our example programs included with the board. In this discussion, BA refers to the base address.

• Initializing the AD1000

Before operating the AD1000, you may have to initialize the 8255 PPI and 8254 timer/counter. The PPI must be programmed so that the digital I/O lines are set up as inputs or outputs, Mode 0, 1, or 2 operation, depending on your application. For example, if you want to monitor the end-of-convert signal through Port B, bit 7, you must set up Port B as a Mode 0 input. This is done by writing the following control word to BA + 15 (X = don't care):

1	X	X	X	X	0	1	X
D7	D6	D5	D4	D3	D2	D1	D0

If we replace the Xs (don't care) with zeros, the command in BASIC is:

```
OUT (BA + 15), 130
```

The 8254 timer/counter must be programmed to define the desired mode of operation if you are using any of the OUT signals as an interrupt or when using the 8254 for timing or counting operations. The 8254 is initialized by writing the control word at BA + 19. Failure to initialize the 8254 when an output is connected to an interrupt channel may cause erratic system operation.

• Selecting a Channel

To select a conversion channel, you must simply write to the address port of the desired channel, as shown in Table 4-1. The data written is irrelevant. Note that when the system is first powered up, all channels are disabled. After you program a channel, it remains active until you select another channel.

• Starting an A/D Conversion

A/D conversions are started by writing a START CONVERT command to the appropriate I/O port. For 12-bit conversions, Port BA + 8 is used. For 8-bit conversions, Port BA + 9 is used. A START CONVERT command must be written for each A/D conversion. The data written is irrelevant. Figure 4-1 shows the timing diagram for A/D conversions.

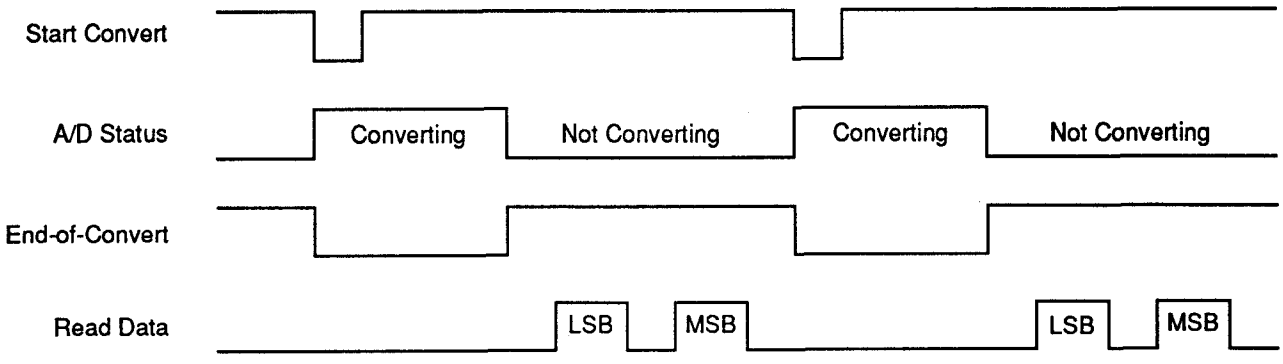


Fig. 4-1 — A/D Conversion Timing Diagram

• **Monitoring Conversion Status**

The A/D conversion status can be monitored through the end-of-convert (EOC) signal. This signal, the inverse of the STATUS signal output by the A/D converter, is low when a conversion is in progress and goes high when the conversion is completed. This low-to-high transition can be monitored through any one of three PPI digital I/O lines, PA7, PB7, or PC7, or through an interrupt line.

• **Reading the Converted Data**

The general algorithm for taking an A/D reading is:

1. Start a 12-bit conversion by writing to BA + 8:

```
out base_address+8,0
```

(Note that the value you send is not important. The act of writing to this I/O location is the key to starting a conversion.)

2. Delay at least 20 microseconds, monitor PPI port A, B, or C, bit 7 for a transition, or use an interrupt to ensure that the conversion is completed.

3. Read the least significant byte of the converted data from BA + 9:

```
lsb% = inp(base_address% +9)
```

4. Read the most significant byte of the converted data from BA + 8:

```
msb% = inp(base_address% +8)
```

5. Combine them into the 12-bit result by shifting the four LSB bits to the right. The MSB must also be weighted correctly:

```
result% = (msb% * 16) + (lsb%/16)
```

For a 12-bit conversion, the A/D data read is left justified in a 16-bit word, with the least significant four bits equal to zero. Because of this, the two bytes of A/D data read must be scaled to obtain a valid A/D reading. Once it is calculated, the reading can be correlated to a voltage value by subtracting 2048 to scale it and then multiplying by 2.4414 millivolts.

For example, if the A/D reading is 1024, the analog input voltage is calculated as follows:

```
(1024 - 2048) bits * 2.4414 mV/bit = -2.49999 volts.
```

Note that 8-bit A/D conversions can also be performed by writing to I/O location BA + 9 to start a conversion. While an 8-bit conversion has a lower resolution, it is performed much more rapidly, in about 13 microseconds. A 12-bit conversion takes about 20 microseconds.

The key digital codes and their input voltage values are given for 12-bit and 8-bit conversions in the following two tables.

12- bit A/D Bipolar Code Table	
Input Voltage	**Output Code**
+4.9976 volts	MSB 1111 1111 1111 LSB
+2.500 volts	1100 0000 0000
0 volts	1000 0000 0000
-2.500 volts	0100 0000 0000
-5.000 volts	0000 0000 0000
1 LSB = 2.44 millivolts	

8-bit A/D Bipolar Code Table	
Input Voltage	**Output Code**
+4.9609 volts	MSB 1111 1111 LSB
+2.500 volts	1100 0000
0 volts	1000 0000
-2.500 volts	0100 0000
-5.000 volts	0000 0000
1 LSB = 39.063 millivolts	

Interrupts

- What Is an Interrupt?

An interrupt is an event that causes the processor in your computer to temporarily halt its current process and execute another routine. Upon completion of the new routine, control is returned to the original routine at the point where its execution was interrupted.

Interrupts are very handy for dealing with asynchronous events (events that occur at less than regular intervals). Keyboard activity is a good example; your computer cannot predict when you might press a key and it would be a waste of processor time for it to do nothing while waiting for a keystroke to occur. Thus, the interrupt scheme is used and the processor proceeds with other tasks. Then, when a keystroke does occur, the keyboard 'interrupts' the processor, and the processor gets the keyboard data, places it in memory, and then returns to what it was doing before it was interrupted. Other common devices that use interrupts are modems, disk drives, and mice.

Your AD1000 board can interrupt the processor when a variety of conditions are met, such as conversion completed, timer countdown finished, and others. By using these interrupts, you can write software that effectively deals with real world events.

- Interrupt Request Lines

To allow different peripheral devices to generate interrupts on the same computer, the PC bus has eight different interrupt request (IRQ) lines. A transition from low to high on one of these lines generates an interrupt request which is handled by the PC's interrupt controller. The interrupt controller checks to see if interrupts are to be acknowledged from that IRQ and, if another interrupt is already in progress, it decides if the new request should supersede the one in progress or if it has to wait until the one in progress is done. This prioritizing allows an interrupt to be interrupted if the second request has a higher priority. The priority level is based on the number of the IRQ; IRQ0 has the highest priority, IRQ1 is second-highest, and so on through IRQ7, which has the lowest. Many of the IRQs are used by the standard system resources. IRQ0 is used by the system timer, IRQ1 is used by the keyboard, IRQ3 by COM2, IRQ4 by COM1, and IRQ6 by the disk drives. Therefore, it is important for you to know which IRQ lines are available in your system for use by the AD1000 board.

- 8259 Programmable Interrupt Controller

The chip responsible for handling interrupt requests in the PC is the 8259 Programmable Interrupt Controller. To use interrupts, you will need to know how to read and set the 8259's interrupt mask register (IMR) and how to send the end-of-interrupt (EOI) command to the 8259.

- Interrupt Mask Register (IMR)

Each bit in the interrupt mask register (IMR) contains the mask status of an IRQ line; bit 0 is for IRQ0, bit 1 is for IRQ1, and so on. If a bit is **set** (equal to 1), then the corresponding IRQ is masked and it will not generate an interrupt. If a bit is **clear** (equal to 0), then the corresponding IRQ is unmasked and can generate interrupts. The IMR is programmed through port 21H.

IRQ7	IRQ6	IRQ5	IRQ4	IRQ3	IRQ2	IRQ1	IRQ0

I/O Port 21H

For all bits:
0 = IRQ unmasked (enabled)
1 = IRQ masked (disabled)

- End-of-Interrupt (EOI) Command

After an interrupt service routine is completed, the 8259 interrupt controller must be notified. This is done by writing the value 20H to I/O port 20H.

- What Exactly Happens When an Interrupt Occurs?

Understanding the sequence of events when an interrupt is triggered is necessary to properly write software interrupt handlers. When an interrupt request line is driven high by a peripheral device (such as the AD1000), the

interrupt controller checks to see if interrupts are enabled for that IRQ, and then checks to see if other interrupts are active or requested and determines which interrupt has priority. The interrupt controller then interrupts the processor. The current code segment (CS), instruction pointer (IP), and flags are pushed on the stack for storage, and a new CS and IP are loaded from a table that exists in the lowest 1024 bytes of memory. This table is referred to as the interrupt vector table and each entry is called an interrupt vector. Once the new CS and IP are loaded from the interrupt vector table, the processor begins executing the code located at CS:IP. When the interrupt routine is completed, the CS, IP, and flags that were pushed on the stack when the interrupt occurred are now popped from the stack and execution resumes from the point where it was interrupted.

- Using Interrupts in Your Programs

Adding interrupts to your software is not as difficult as it may seem, and what they add in terms of performance is often worth the effort. Note, however, that although it is not that hard to use interrupts, the smallest mistake will often lead to a system hang that requires a reboot. This can be both frustrating and time-consuming. But, after a few tries, you'll get the bugs worked out and enjoy the benefits of properly executed interrupts.

- Special Considerations for AD1000 Interrupt Programming

Two special considerations must be taken into account when using interrupts on the AD1000. First, you must be very careful to make sure that the 8259 programmable interrupt controller is properly configured to ignore interrupts on the selected channel immediately after power-up. This is necessary because the 8254 timer/counter must first be initialized to define the desired mode(s) of operation. Before the 8254 is initialized, its modes, counts, and outputs are all undefined. If system interrupts are not disabled, the counter outputs may cause erratic behavior.

To use the 8255 PPI's PC3 interrupt, you must enable the interrupt by writing a "1" to the INTE mask bit in the PPI control word. This operation is fully described in the 8255 data sheet included in Appendix C. Note that the INTE mask is always disabled at power-up or reset and whenever the PPI modes are changed.

- Writing an Interrupt Service Routine (ISR)

The first step in adding interrupts to your software is to write the interrupt service routine (ISR). This is the routine that will automatically be executed each time an interrupt request occurs on the specified IRQ. An ISR is different than standard routines that you write. First, on entrance, the processor registers should be pushed onto the stack **BEFORE** you do anything else. Second, just before exiting your ISR, you must write an end-of-interrupt (EOI) command to the 8259 interrupt controller. Finally, when exiting the ISR, in addition to popping all the registers you pushed on entrance, you must use the IRET instruction and **not** a plain RET. The IRET automatically pops the flags, CS, and IP that were pushed when the interrupt was called.

If you find yourself intimidated by interrupt programming, take heart. Most Pascal and C compilers allow you to identify a procedure (function) as an interrupt type and will automatically add these instructions to your ISR, with one important exception: most compilers **do not** automatically add the end-of-interrupt command to the procedure; you must do this yourself. Other than this and the few exceptions discussed below, you can write your ISR just like any other routine. It can call other functions and procedures in your program and it can access global data. If you are writing your first ISR, we recommend that you stick to the basics; just something that will convince you that it works, such as incrementing a global variable.

NOTE: If you are writing an ISR using assembly language, you are responsible for pushing and popping registers and using IRET instead of RET.

There are a few cautions you must consider when writing your ISR. The most important is, **do not use any DOS functions or routines that call DOS functions from within an ISR.** DOS is **not** reentrant; that is, a DOS function cannot call itself. In typical programming, this will not happen because of the way DOS is written. But what about when using interrupts? Then, you could have a situation such as this in your program. If DOS function X is being executed when an interrupt occurs and the interrupt routine makes a call to DOS function X, then function X is essentially being called while it is already active. Such a reentrancy attempt spells disaster because DOS functions are not written to support it. This is a complex concept and you do not need to understand it. Just make sure that you do not call any DOS functions from within your ISR. The one wrinkle is that, unfortunately, it is not obvious which library routines included with your compiler use DOS functions. A rule of thumb is that routines

which write to the screen, or check the status of or read the keyboard, and any disk I/O routines use DOS and should be avoided in your ISR.

The same problem of reentrancy exists for many floating point emulators as well, meaning you may have to avoid floating point (real) math in your ISR.

Note that the problem of reentrancy exists, no matter what programming language you are using. Even if you are writing your ISR in assembly language, DOS and many floating point emulators are not reentrant. Of course, there are ways around this problem, such as those which involve checking to see if any DOS functions are currently active when your ISR is called, but such solutions are well beyond the scope of this discussion.

The second major concern when writing your ISR is to make it as short as possible in terms of execution time. Spending long periods of time in your ISR may mean that other important interrupts are being ignored. Also, if you spend too long in your ISR, it may be called again before you have completed handling the first run. This often leads to a hang that requires a reboot.

Your ISR should have this structure:

- Push any processor registers used in your ISR. Most C and Pascal interrupt routines automatically do this for you.
- Put the body of your routine here.
- Issue the EOI command to the 8259 interrupt controller by writing 20H to port 20H.
- Pop all registers pushed on entrance. Most C and Pascal interrupt routines automatically do this for you.

The following C and Pascal examples show what the shell of your ISR should be like:

In C:

```
void interrupt ISR(void)
{
   /* Your code goes here. Do not use any DOS functions! */
   outportb(0x20, 0x20);            /* Send EOI command to 8259 */
}
```

In Pascal:

```
Procedure ISR; Interrupt;
begin
   { Your code goes here. Do not use any DOS functions! }
   Port[$20] := $20;                { Send EOI command to 8259 }
end;
```

- Saving the Startup Interrupt Mask Register (IMR) and Interrupt Vector

The next step after writing the ISR is to save the startup state of the interrupt mask register and the interrupt vector that you will be using. The IMR is located at I/O port 21H. The interrupt vector you will be using is located in the interrupt vector table which is simply an array of 256-bit (4-byte) pointers and is located in the first 1024 bytes of memory (Segment = 0, Offset = 0). You can read this value directly, but it is a better practice to use DOS function 35H (get interrupt vector). Most C and Pascal compilers provide a library routine for reading the value of a vector. The vectors for the hardware interrupts are vectors 8 through 15, where IRQ0 uses vector 8, IRQ1 uses vector 9, and so on. Thus, if the AD1000 will be using IRQ3, you should save the value of interrupt vector 11.

Before you install your ISR, temporarily mask out the IRQ you will be using. This prevents the IRQ from requesting an interrupt while you are installing and initializing your ISR. To mask the IRQ, read in the current IMR at I/O port 21H and set the bit that corresponds to your IRQ (remember, setting a bit disables interrupts on that IRQ while clearing a bit enables them). The IMR is arranged so that bit 0 is for IRQ0, bit 1 is for IRQ1, and so on. See the paragraph entitled *Interrupt Mask Register (IMR)* earlier in this chapter for help in determining your IRQ's bit. After setting the bit, write the new value to I/O port 21H.

With the startup IMR saved and the interrupts on your IRQ temporarily disabled, you can assign the interrupt vector to point to your ISR. Again, you can overwrite the appropriate entry in the vector table with a direct memory write, but this is a bad practice. Instead, use either DOS function 25H (set interrupt vector) or, if your compiler provides it, the library routine for setting an interrupt vector. Remember that vector 8 is for IRQ0, vector 9 is for IRQ1, and so on.

If you need to program the source of your interrupts, do that next. For example, if you are using the programmable interval timer to generate interrupts, you must program it to run in the proper mode and at the proper rate.

Finally, clear the bit in the IMR for the IRQ you are using. This enables interrupts on the IRQ.

– Restoring the Startup IMR and Interrupt Vector

Before exiting your program, you must restore the interrupt mask register and interrupt vectors to the state they were in when your program started. To restore the IMR, write the value that was saved when your program started to I/O port 21H. Restore the interrupt vector that was saved at startup with either DOS function 35H (get interrupt vector), or use the library routine supplied with your compiler. Performing these two steps will guarantee that the interrupt status of your computer is the same after running your program as it was before your program started running.

- Common Interrupt Mistakes

- Remember that hardware interrupts are numbered 8 through 15, even though the corresponding IRQs are numbered 0 through 7.
- One of the most common mistakes when writing an ISR is forgetting to issue the EOI command to the 8259 interrupt controller before exiting the ISR.

Timer/Counters

The 8254 programmable interval timer provides three 16-bit, 8-MHz timer/counters for timing and counting functions such as frequency measurement, event counting, and interrupts. Figure 4-2 shows the timer/counter circuitry.

Each timer/counter has two inputs, CK in and GT in, and one output, timer/counter OUT. They can be programmed as binary or BCD down counters by writing the appropriate data to the command word, as described in the I/O map section at the beginning of this chapter.

One of two clock sources, the on-board 5-MHz crystal or the external clock, can be jumpered as the clock input to each timer/counter. Or, the output from the previous timer/counter can be used to clock the next timer/counter to cascade multiple counters. Two gate sources are available for enabling the timer/counters: a +5 volt source and an external gate source. The outputs are available at the P7 I/O connector and interrupt header connector P3.

The timer/counters can be programmed to operate in one of six modes, depending on your application. The following paragraphs briefly describe each mode.

Mode 0, Event Counter (Interrupt on Terminal Count). This mode is typically used for event counting. While the timer/counter counts down, the output is low, and when the count is complete, it goes high. The output stays high until a new Mode 0 control word is written to the timer/counter.

Mode 1, Hardware-Retriggerable One-Shot. The output is initially high and goes low on the clock pulse following a trigger to begin the one-shot pulse. The output remains low until the count reaches 0, and then goes high and remains high until the clock pulse after the next trigger.

Mode 2, Rate Generator. This mode functions like a divide-by-N counter and is typically used to generate a real-time clock interrupt. The output is initially high, and when the count decrements to 1, the output goes low for one clock pulse. The output then goes high again, the timer/counter reloads the initial count, and the process is repeated. This sequence continues indefinitely.

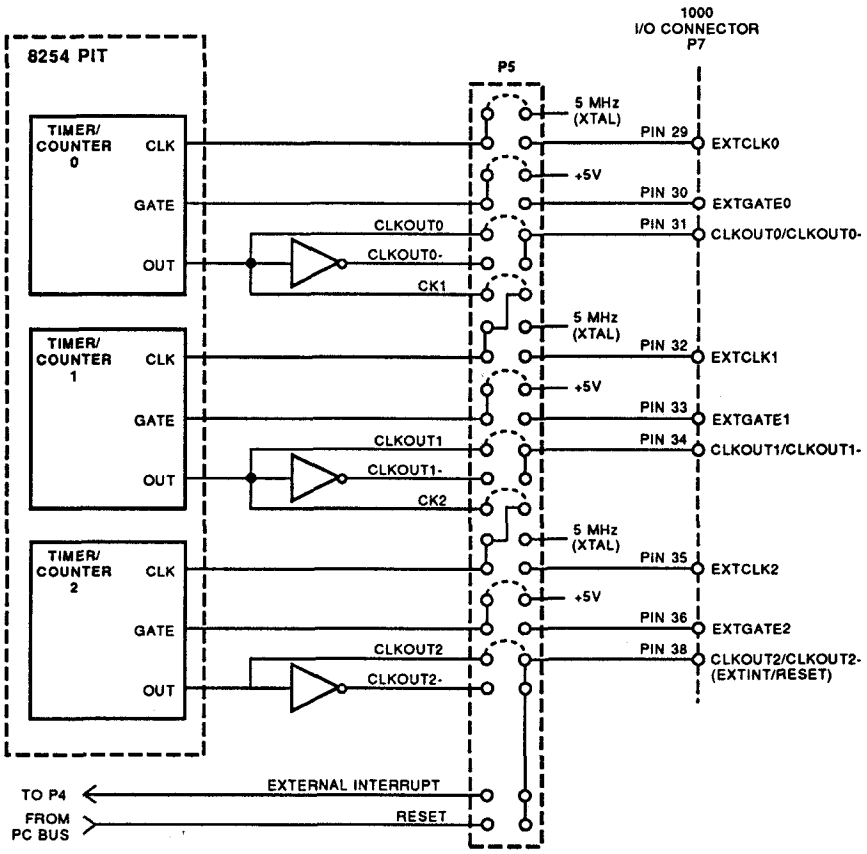


Fig. 4-2 — 8254 Timer/Counter Circuitry

Mode 3, Square Wave Mode. Similar to Mode 2 except for the duty cycle output, this mode is typically used for baud rate generation. The output is initially high, and when the count decrements to one-half its initial count, the output goes low for the remainder of the count. The timer/counter reloads and the output goes high again. This process repeats indefinitely.

Mode 4, Software-Triggered Strobe. The output is initially high. When the initial count expires, the output goes low for one clock pulse and then goes high again. Counting is "triggered" by writing the initial count.

Mode 5, Hardware Triggered Strobe (Retriggerable). The output is initially high. Counting is triggered by the rising edge of the gate input. When the initial count has expired, the output goes low for one clock pulse and then goes high again.

For more information about the 8254, see the data sheet included in Appendix C.

Digital I/O

The 24 digital I/O lines in the 8255 can be used to transfer data between the computer and external devices. Sixteen lines are available at the I/O connector; eight lines are available at the P9 on-board pads.

For more information about the 8255, see the data sheet included in Appendix C.

Example Programs and Flow Diagrams

Included with the AD1000 is a set of example programs that demonstrate the use of many of the board's features. These examples are in written in C, Pascal, and BASIC. Also included is an easy-to-use menu-driven diagnostics program, RTDDIAG, which is especially helpful when you are first checking out your board after installation and when calibrating the board (Chapter 5).

Before using the software included with your board, make a backup copy of the disk. You may make as many backups as you need.

C and Pascal Programs

These programs are source code files so that you can easily develop your own custom software for your AD1000 board. In the C directory, there are several .H files which are needed to implement the main C programs. These files contain the routines called by the main programs. In the Pascal directory, PSL files contain all of the procedures needed to implement the main Pascal programs.

Analog-to-Digital:

READ	Demonstrates how to take A/D conversions.

Timer/Counters:

TIMER	A short program demonstrating how to program the 8254 for use as a timer.

Digital I/O:

INP0	Simple program that shows how to set up the PPI lines as input lines.
OUT0	Simple program that shows how to set up the PPI lines as output lines.

BASIC Programs

These programs include source code files for easy custom program development.

Analog-to-Digital:

READ	Demonstrates how to take A/D conversions.

Timer/Counters:

TIMER	A short program demonstrating how to program the 8254 for use as a timer.

Digital I/O:

INP0	Simple program that shows how to set up the PPI lines as input lines.
OUT0	Simple program that shows how to set up the PPI lines as output lines.

Flow Diagrams

• Single Convert Flow Diagram (Figure 4-3)

This flow diagram shows you the steps for taking a single sample on a selected channel. A sample is taken each time you send the Start Convert command. All of the samples will be taken on the same channel until you select a new channel. Changing the I/O address before each Start Convert command is issued lets you take the next reading from a different channel.

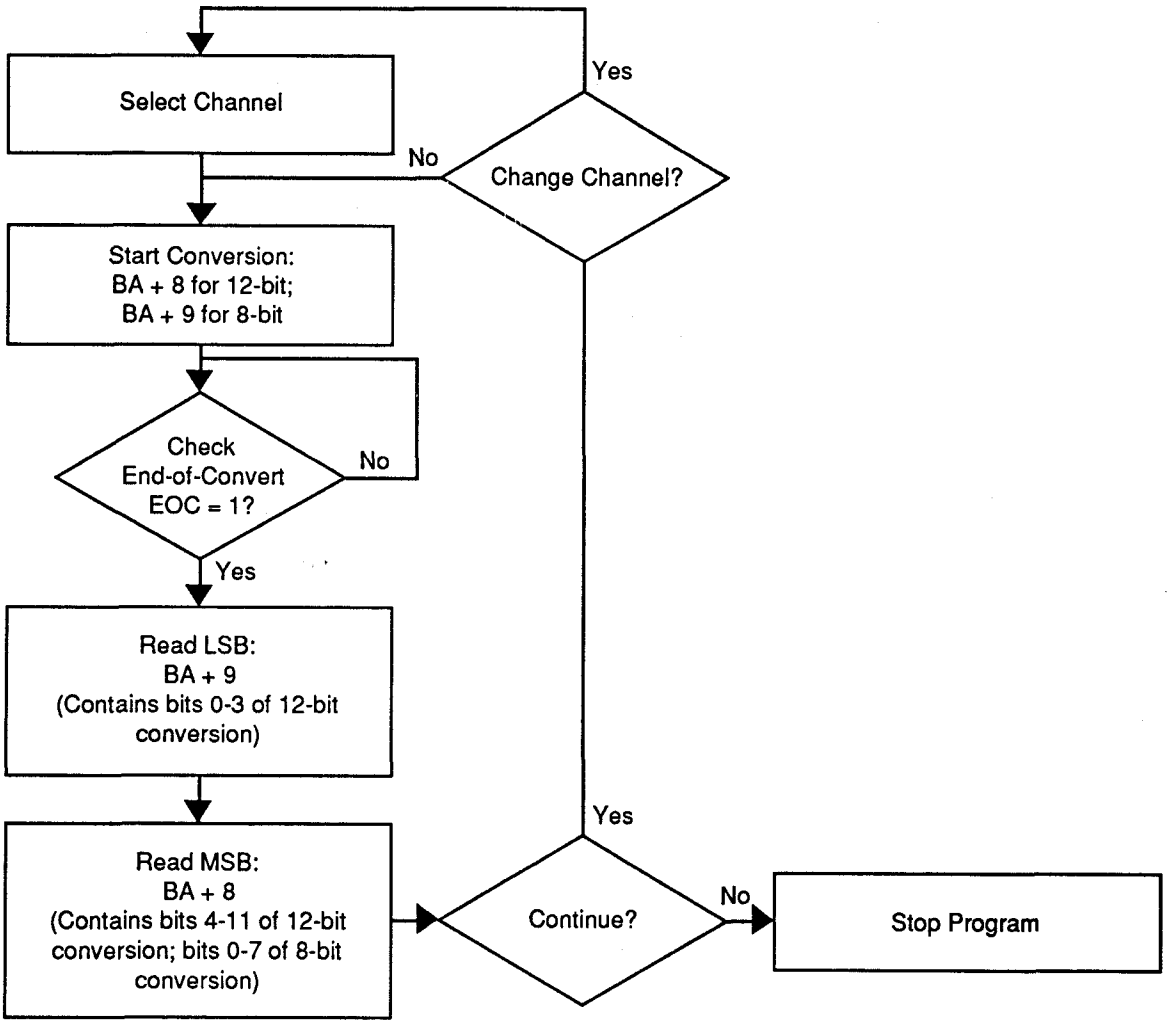


Fig. 4-3 — Single Conversion Flow Diagram

CHAPTER 5

CALIBRATION

This chapter tells you how to calibrate the AD1000 using the RTDDIAG calibration program included in the example software package and the two trimpots (TR1 and TR2) on the board. These trimpots calibrate the A/D converter gain and offset.

This chapter tells you how to calibrate the A/D converter gain and offset. The offset and full-scale performance of the board's A/D converter is factory-calibrated. Any time you suspect inaccurate readings, you can check the accuracy of your conversions using the procedure below, and make adjusts as necessary. Using the RTDDIAG diagnostics program is a convenient way to monitor conversions while you calibrate the board.

Calibration is done with the board installed in your PC. You can access the trimpots with the computer's cover removed. Power up the computer and let the board circuitry stabilize for 15 minutes before you start calibrating.

Required Equipment

The following equipment is required for calibration:

- Precision Voltage Source: -5 to +5 volts
- Digital Voltmeter: 5-1/2 digits
- Small Screwdriver (for trimpot adjustment)

While not required, the RTDDIAG diagnostics program (included with example software) is helpful when performing calibrations. Figure 5-1 shows the board layout. The trimpots used for calibration are located in the upper center area of the board.

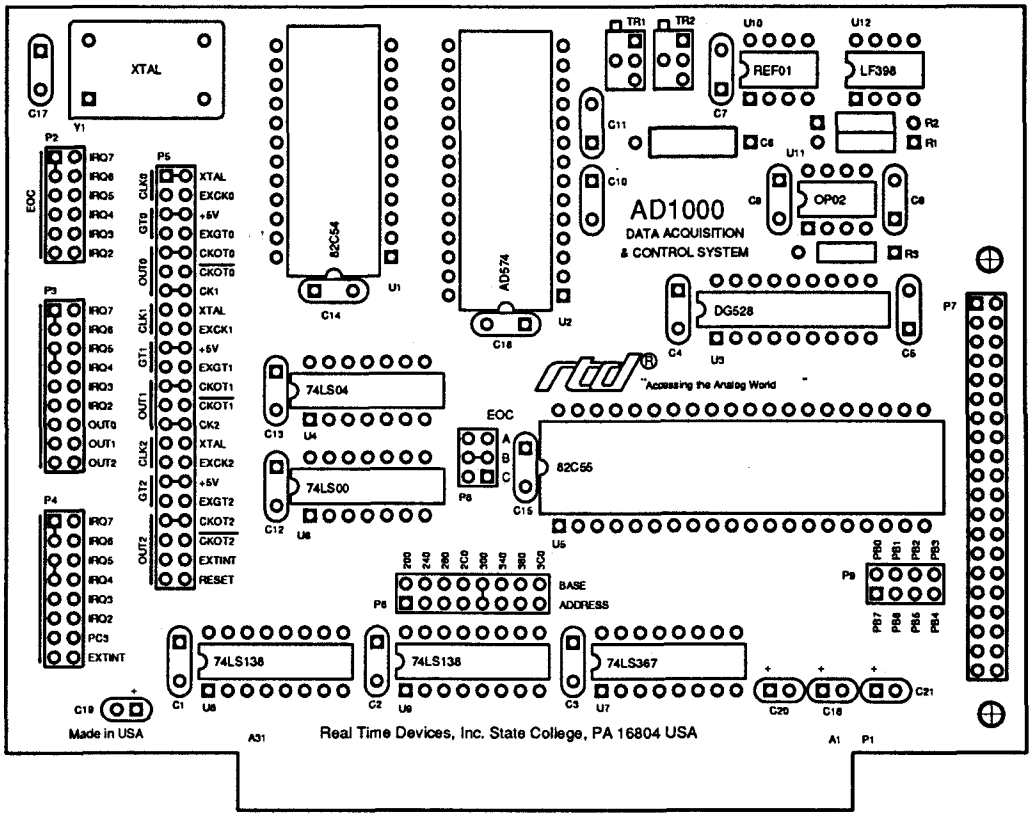


Fig. 5-1 — Board Layout

A/D Calibration

Two adjustments are made to calibrate the A/D converter. One is the offset adjustment, and the other is the full scale, or gain, adjustment. Trimpot TR1 is used to make the offset adjustment, and trimpot TR2 is used for gain adjustment. Adjustments are made using 12-bit resolution. Table 5-1 shows the ideal input voltage range for each bit weight.

Table 5-1 — A/D Converter Calibration Table

A/D Bit Weight	Ideal Input Voltage, ±5V (in millivolts)
4095 (Full Scale)	4997.6
2048	0000.0
1024	-2500.0
512	-3750.0
256	-4375.0
128	-4687.5
64	-4843.8
32	-4921.9
16	-4960.9
8	-4980.5
4	-4990.2
2	-4997.6
1	-5000.0

Use analog input channel 1 to calibrate the board. Connect your precision voltage source to channel 1 (positive side to P7-11 and ground to P7-1 or 7). Ground all other channels. Set the voltage source to -4.99878 volts, start a conversion, and read the resulting data. Adjust trimpot TR1 until it flickers between the values listed in the table below. Next, set the voltage to +4.99634 volts, and repeat the procedure, this time adjusting TR2 until the data flickers between the values in the table.

Data Values for Calibrating -5 to +5 Volt Range		
	Offset (TR1) **Input Voltage = -4.99878V**	**Converter Gain (TR2)** **Input Voltage = +4.99634V**
A/D Converted Data	0000 0000 0000 0000 0000 0001	1111 1111 1110 1111 1111 1111

APPENDIX A

AD1000 SPECIFICATIONS

AD1000 Characteristics Typical @ 25° C

Interface

IBM PC/XT/AT compatible
Jumper-selectable base address, I/O mapped
Jumper-selectable interrupts

Analog Input

8 single-ended inputs
Input impedance, each channel ..... >10 megohms
Input range ..... ±5 volts
Overvoltage protection ..... ±35 Vdc
Settling time ..... 1 µsec, max

A/D Converter HI574

Type ..... Successive approximation
Resolution ..... 12 bits (guaranteed to 11 bits)
Linearity ..... ±1 LSB, typ
Conversion speed ..... 20 µsec, typ
Sample-and-hold acquisition time ..... 20 µsec, max
Throughput ..... 25 kHz

Digital I/O ..... CMOS 82C55

Number of lines ..... 24 (16 at I/O connector & 8 on board)
High-level output voltage ..... 4.2V, min
Low-level output voltage ..... 0.45V, max
High-level input voltage ..... 2.2V, min; 5.5V, max
Low-level input voltage ..... -0.3V, min; 0.8V, max
High-level output current, Isource ..... 100 µA, max
Low-level output current, Isink ..... 1.7 mA, max
Darlington drive current, I(DAR) ..... -1.0 mA, min; -5.0 mA, max
(Available on any 8 pins from port B and port C)
Input load current ..... ±10 µA
Input capacitance,
C(IN)@F=1MHz ..... 10 pF
Output capacitance,
C(OUT)<@F=1MHz ..... 20 pF

Timer/Counter ..... CMOS 82C54

Three 16-bit down counters
Binary or BCD counting
Programmable operating modes (6) ..... Interrupt on terminal count; programmable one-shot; rate generator; square wave rate generator; software-triggered strobe; hardware-triggered strobe
Counter input source ..... External clock (8 MHz, max) or on-board 5 MHz clock
Counter outputs ..... Available externally; used as PC interrupts or cascaded to adjacent counter
Counter gate source ..... External gate or always enabled

Miscellaneous Inputs/Outputs (PC bus-sourced)

±12 volts
Digital ground

Current Requirements

+5 volts ..... 68 mA
+12 volts ..... 20 mA
–12 volts ..... 28 mA

Connector

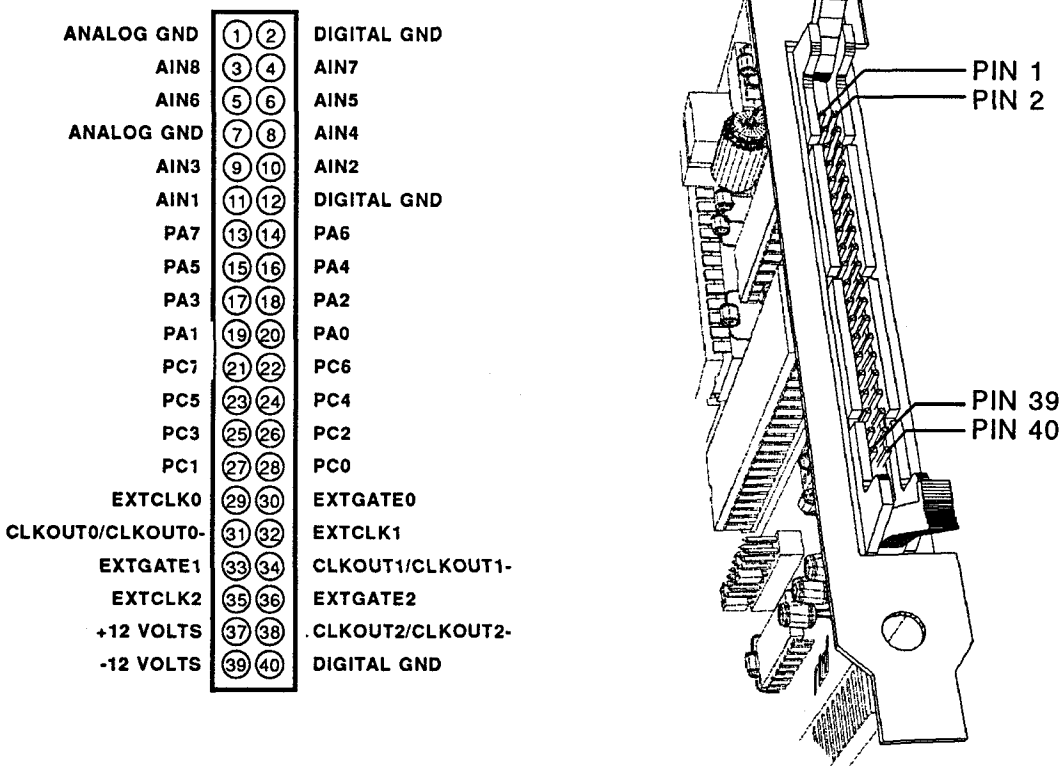
40-pin, right angle, shrouded header with ejector tabs

Size

Short slot — 3.875"H x 5.40"W (99mm x 137mm)

APPENDIX B

CONNECTOR PIN ASSIGNMENTS



AD1000 P7 Connector/Mating Connector		
Manufacturer	**AD1000 P7 Connector**	**P7 Mating Connector**
Fujitsu 3M Robinson Nugent MIL C-83503	FCN-705Q040-AU/M	FCN-707B040-AU/B 3417-7040 IDS-C40PK-C-SR-TG M83503/7-09

APPENDIX C

COMPONENT DATA SHEETS

Intel 82C54 Programmable Interval Timer
Data Sheet Reprint

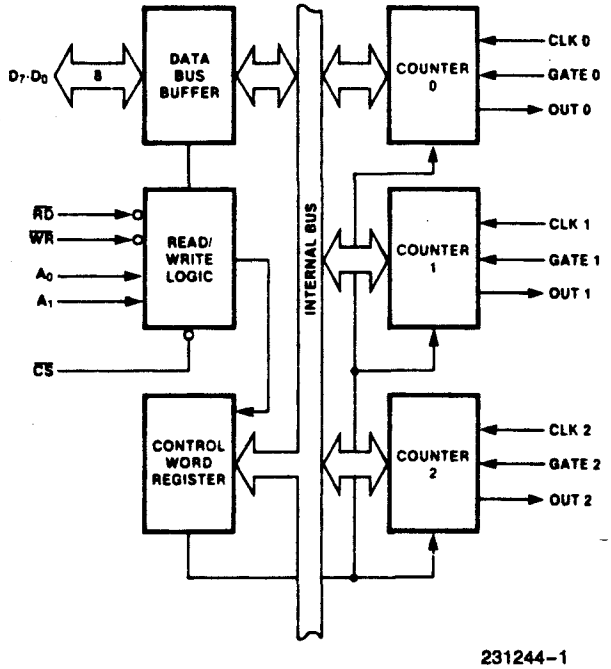
82C54
CHMOS PROGRAMMABLE INTERVAL TIMER

- **Compatible with all Intel and most other microprocessors**
- **High Speed, "Zero Wait State" Operation with 8 MHz 8086/88 and 80186/188**
- **Handles Inputs from DC to 8 MHz — 10 MHz for 82C54-2**
- **Available in EXPRESS — Standard Temperature Range — Extended Temperature Range**
- **Three independent 16-bit counters**
- **Low Power CHMOS — I_{CC} = 10 mA @ 8 MHz Count frequency**
- **Completely TTL Compatible**
- **Six Programmable Counter Modes**
- **Binary or BCD counting**
- **Status Read Back Command**
- **Available in 24-Pin DIP and 28-Pin PLCC**

The Intel 82C54 is a high-performance, CHMOS version of the industry standard 8254 counter/timer which is designed to solve the timing control problems common in microcomputer system design. It provides three independent 16-bit counters, each capable of handling clock inputs up to 10 MHz. All modes are software programmable. The 82C54 is pin compatible with the HMOS 8254, and is a superset of the 8253.

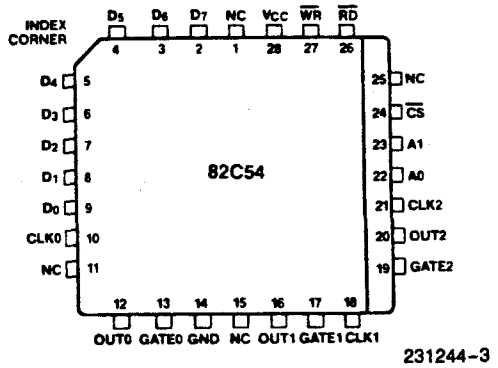
Six programmable timer modes allow the 82C54 to be used as an event counter, elapsed time indicator, programmable one-shot, and in many other applications.

The 82C54 is fabricated on Intel's advanced CHMOS III technology which provides low power consumption with performance equal to or greater than the equivalent HMOS product. The 82C54 is available in 24-pin DIP and 28-pin plastic leaded chip carrier (PLCC) packages.



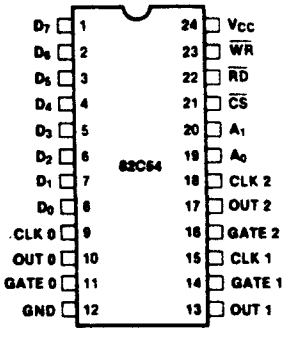
231244-1

Figure 1. 82C54 Block Diagram



231244-3

PLASTIC LEADED CHIP CARRIER



231244-2

Diagrams are for pin reference only.
Package sizes are not to scale.

Figure 2. 82C54 Pinout

September 1989
Order Number: 231244-005

Table 1. Pin Description

Symbol	Pin Number		Type	Function
	DIP	PLCC		
D_7-D_0	1-8	2-9	I/O	Data: Bidirectional tri-state data bus lines, connected to system data bus.
CLK 0	9	10	I	Clock 0: Clock input of Counter 0.
OUT 0	10	12	O	Output 0: Output of Counter 0.
GATE 0	11	13	I	Gate 0: Gate input of Counter 0.
GND	12	14		Ground: Power supply connection.
OUT 1	13	16	O	Out 1: Output of Counter 1.
GATE 1	14	17	I	Gate 1: Gate input of Counter 1.
CLK 1	15	18	I	Clock 1: Clock input of Counter 1.
GATE 2	16	19	I	Gate 2: Gate input of Counter 2.
OUT 2	17	20	O	Out 2: Output of Counter 2.
CLK 2	18	21	I	Clock 2: Clock input of Counter 2.
A_1, A_0	20-19	23-22	I	Address: Used to select one of the three Counters or the Control Word Register for read or write operations. Normally connected to the system address bus.

A_1	A_0	Selects
0	0	Counter 0
0	1	Counter 1
1	0	Counter 2
1	1	Control Word Register

$\overline{CS}$	21	24	I	Chip Select: A low on this input enables the 82C54 to respond to $\overline{RD}$ and $\overline{WR}$ signals. $\overline{RD}$ and $\overline{WR}$ are ignored otherwise.
$\overline{RD}$	22	26	I	Read Control: This input is low during CPU read operations.
$\overline{WR}$	23	27	I	Write Control: This input is low during CPU write operations.
V_{CC}	24	28		Power: +5V power supply connection.
NC		1, 11, 15, 25		No Connect

FUNCTIONAL DESCRIPTION

General

The 82C54 is a programmable interval timer/counter designed for use with Intel microcomputer systems. It is a general purpose, multi-timing element that can be treated as an array of I/O ports in the system software.

The 82C54 solves one of the most common problems in any microcomputer system, the generation of accurate time delays under software control. Instead of setting up timing loops in software, the programmer configures the 82C54 to match his requirements and programs one of the counters for the desired delay. After the desired delay, the 82C54 will interrupt the CPU. Software overhead is minimal and variable length delays can easily be accommodated.

Some of the other counter/timer functions common to microcomputers which can be implemented with the 82C54 are:

- Real time clock
- Even counter
- Digital one-shot
- Programmable rate generator
- Square wave generator
- Binary rate multiplier
- Complex waveform generator
- Complex motor controller

Block Diagram

DATA BUS BUFFER

This 3-state, bi-directional, 8-bit buffer is used to interface the 82C54 to the system bus (see Figure 3).

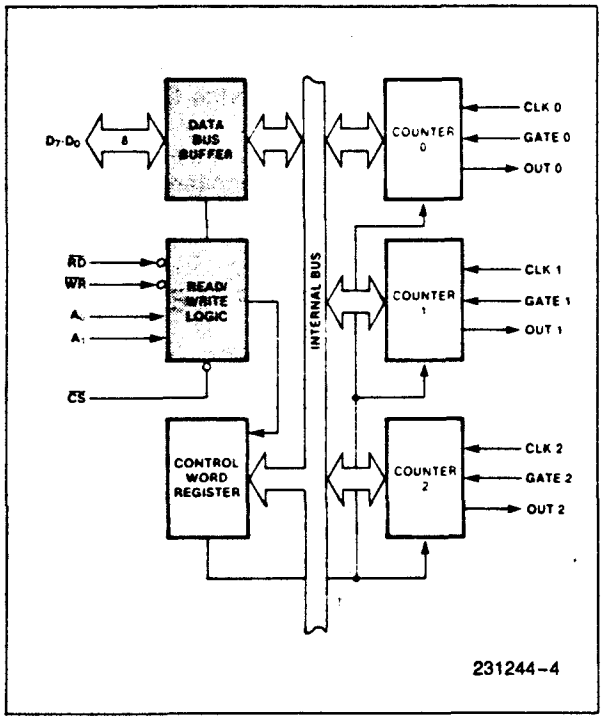


Figure 3. Block Diagram Showing Data Bus Buffer and Read/Write Logic Functions

READ/WRITE LOGIC

The Read/Write Logic accepts inputs from the system bus and generates control signals for the other functional blocks of the 82C54. A_1 and A_0 select one of the three counters or the Control Word Register to be read from/written into. A "low" on the $\overline{RD}$ input tells the 82C54 that the CPU is reading one of the counters. A "low" on the $\overline{WR}$ input tells the 82C54 that the CPU is writing either a Control Word or an initial count. Both $\overline{RD}$ and $\overline{WR}$ are qualified by $\overline{CS}$; $\overline{RD}$ and $\overline{WR}$ are ignored unless the 82C54 has been selected by holding $\overline{CS}$ low.

CONTROL WORD REGISTER

The Control Word Register (see Figure 4) is selected by the Read/Write Logic when A_1, A_0 = 11. If the CPU then does a write operation to the 82C54, the data is stored in the Control Word Register and is interpreted as a Control Word used to define the operation of the Counters.

The Control Word Register can only be written to; status information is available with the Read-Back Command.

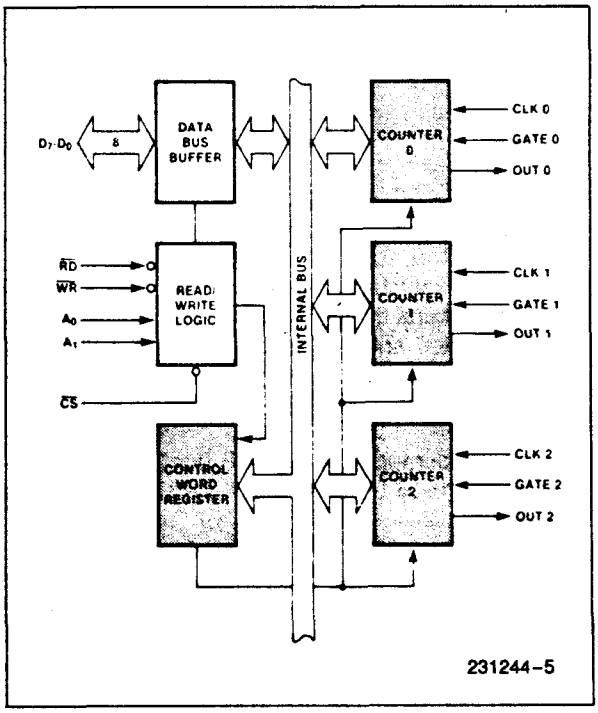


Figure 4. Block Diagram Showing Control Word Register and Counter Functions

COUNTER 0, COUNTER 1, COUNTER 2

These three functional blocks are identical in operation, so only a single Counter will be described. The internal block diagram of a single counter is shown in Figure 5.

The Counters are fully independent. Each Counter may operate in a different Mode.

The Control Word Register is shown in the figure; it is not part of the Counter itself, but its contents determine how the Counter operates.

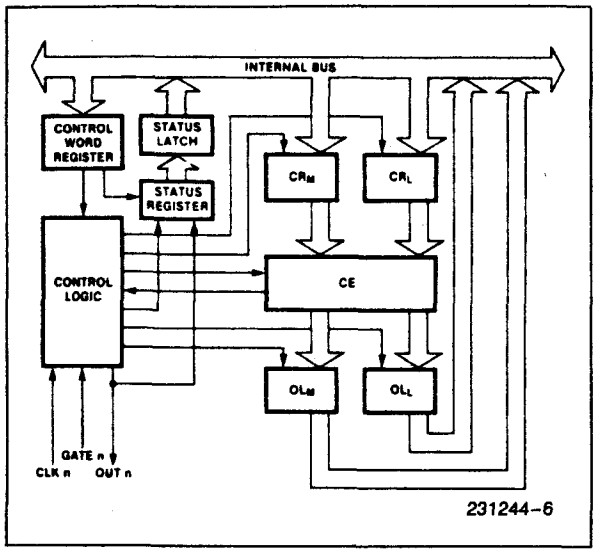


Figure 5. Internal Block Diagram of a Counter

The status register, shown in the Figure, when latched, contains the current contents of the Control Word Register and status of the output and null count flag. (See detailed explanation of the Read-Back command.)

The actual counter is labelled CE (for "Counting Element"). It is a 16-bit presettable synchronous down counter.

OL_M and OL_L are two 8-bit latches. OL stands for "Output Latch"; the subscripts M and L stand for "Most significant byte" and "Least significant byte" respectively. Both are normally referred to as one unit and called just OL. These latches normally "follow" the CE, but if a suitable Counter Latch Command is sent to the 82C54, the latches "latch" the present count until read by the CPU and then return to "following" the CE. One latch at a time is enabled by the counter's Control Logic to drive the internal bus. This is how the 16-bit Counter communicates over the 8-bit internal bus. Note that the CE itself cannot be read; whenever you read the count, it is the OL that is being read.

Similarly, there are two 8-bit registers called CR_M and CR_L (for "Count Register"). Both are normally referred to as one unit and called just CR. When a new count is written to the Counter, the count is stored in the CR and later transferred to the CE. The Control Logic allows one register at a time to be loaded from the internal bus. Both bytes are transferred to the CE *simultaneously*. CR_M and CR_L are cleared when the Counter is programmed. In this way, if the Counter has been programmed for one byte counts (either most significant byte only or least significant byte only) the other byte will be zero. Note that the CE cannot be written into; whenever a count is written, it is written into the CR.

The Control Logic is also shown in the diagram. CLK n, GATE n, and OUT n are all connected to the outside world through the Control Logic.

82C54 SYSTEM INTERFACE

The 82C54 is treated by the systems software as an array of peripheral I/O ports; three are counters and the fourth is a control register for MODE programming.

Basically, the select inputs A_0, A_1 connect to the A_0, A_1 address bus signals of the CPU. The $\overline{CS}$ can be derived directly from the address bus using a linear select method. Or it can be connected to the output of a decoder, such as an Intel 8205 for larger systems.

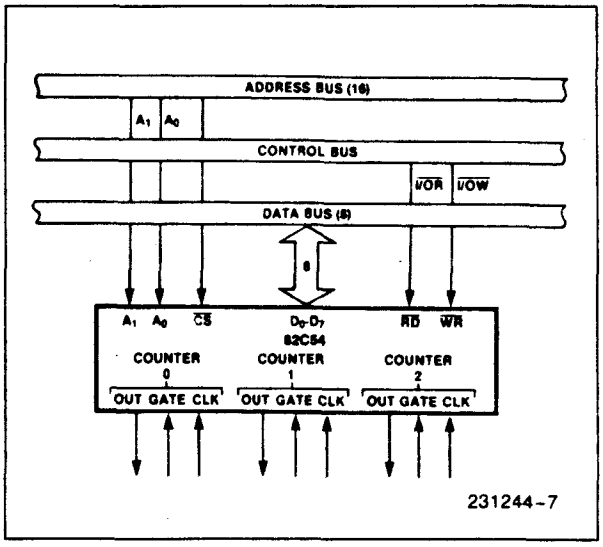


Figure 6. 82C54 System Interface

OPERATIONAL DESCRIPTION

General

After power-up, the state of the 82C54 is undefined. The Mode, count value, and output of all Counters are undefined.

How each Counter operates is determined when it is programmed. Each Counter must be programmed before it can be used. Unused counters need not be programmed.

Programming the 82C54

Counters are programmed by writing a Control Word and then an initial count. The control word format is shown in Figure 7.

All Control Words are written into the Control Word Register, which is selected when A_1, A_0 = 11. The Control Word itself specifies which Counter is being programmed.

By contrast, initial counts are written into the Counters, not the Control Word Register. The A_1, A_0 inputs are used to select the Counter to be written into. The format of the initial count is determined by the Control Word used.

Control Word Format

A_1, A_0 = 11 $\overline{CS}$ = 0 $\overline{RD}$ = 1 $\overline{WR}$ = 0

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
SC1	SC0	RW1	RW0	M2	M1	M0	BCD

SC — Select Counter:

SC1	SC0	
0	0	Select Counter 0
0	1	Select Counter 1
1	0	Select Counter 2
1	1	Read-Back Command (See Read Operations)

M — MODE:

M2	M1	M0	
0	0	0	Mode 0
0	0	1	Mode 1
X	1	0	Mode 2
X	1	1	Mode 3
1	0	0	Mode 4
1	0	1	Mode 5

RW — Read/Write:

RW1	RW0	
0	0	Counter Latch Command (see Read Operations)
0	1	Read/Write least significant byte only.
1	0	Read/Write most significant byte only.
1	1	Read/Write least significant byte first, then most significant byte.

BCD:

0	Binary Counter 16-bits
1	Binary Coded Decimal (BCD) Counter (4 Decades)

NOTE: Don't care bits (X) should be 0 to insure compatibility with future Intel products.

Figure 7. Control Word Format

Write Operations

The programming procedure for the 82C54 is very flexible. Only two conventions need to be remembered:

1) For each Counter, the Control Word must be written before the initial count is written.
2) The initial count must follow the count format specified in the Control Word (least significant byte only, most significant byte only, or least significant byte and then most significant byte).

Since the Control Word Register and the three Counters have separate addresses (selected by the A_1, A_0 inputs), and each Control Word specifies the Counter it applies to (SC0, SC1 bits), no special instruction sequence is required. Any programming sequence that follows the conventions above is acceptable.

A new initial count may be written to a Counter at any time without affecting the Counter's programmed Mode in any way. Counting will be affected as described in the Mode definitions. The new count must follow the programmed count format.

If a Counter is programmed to read/write two-byte counts, the following precaution applies: A program must not transfer control between writing the first and second byte to another routine which also writes into that same Counter. Otherwise, the Counter will be loaded with an incorrect count.

		A_1	A_0
Control Word —	Counter 0	1	1
LSB of count —	Counter 0	0	0
MSB of count —	Counter 0	0	0
Control Word —	Counter 1	1	1
LSB of count —	Counter 1	0	1
MSB of count —	Counter 1	0	1
Control Word —	Counter 2	1	1
LSB of count —	Counter 2	1	0
MSB of count —	Counter 2	1	0

		A_1	A_0
Control Word —	Counter 2	1	1
Control Word —	Counter 1	1	1
Control Word —	Counter 0	1	1
LSB of count —	Counter 2	1	0
MSB of count —	Counter 2	1	0
LSB of count —	Counter 1	0	1
MSB of count —	Counter 1	0	1
LSB of count —	Counter 0	0	0
MSB of count —	Counter 0	0	0

		A_1	A_0
Control Word —	Counter 0	1	1
Counter Word —	Counter 1	1	1
Control Word —	Counter 2	1	1
LSB of count —	Counter 2	1	0
LSB of count —	Counter 1	0	1
LSB of count —	Counter 0	0	0
MSB of count —	Counter 0	0	0
MSB of count —	Counter 1	0	1
MSB of count —	Counter 2	1	0

		A_1	A_0
Control Word —	Counter 1	1	1
Control Word —	Counter 0	1	1
LSB of count —	Counter 1	0	1
Control Word —	Counter 2	1	1
LSB of count —	Counter 0	0	0
MSB of count —	Counter 1	0	1
LSB of count —	Counter 2	1	0
MSB of count —	Counter 0	0	0
MSB of count —	Counter 2	1	0

NOTE:
In all four examples, all counters are programmed to read/write two-byte counts.
These are only four of many possible programming sequences.

Figure 8. A Few Possible Programming Sequences

Read Operations

It is often desirable to read the value of a Counter without disturbing the count in progress. This is easily done in the 82C54.

There are three possible methods for reading the counters: a simple read operation, the Counter Latch Command, and the Read-Back Command. Each is explained below. The first method is to perform a simple read operation. To read the Counter, which is selected with the A1, A0 inputs, the CLK input of the selected Counter must be inhibited by using either the GATE input or external logic. Otherwise, the count may be in the process of changing when it is read, giving an undefined result.

COUNTER LATCH COMMAND

The second method uses the "Counter Latch Command". Like a Control Word, this command is written to the Control Word Register, which is selected when A_1, A_0 = 11. Also like a Control Word, the SC0, SC1 bits select one of the three Counters, but two other bits, D5 and D4, distinguish this command from a Control Word.

A_1, A_0 = 11; $\overline{CS}$ = 0; $\overline{RD}$ = 1; $\overline{WR}$ = 0

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
SC1	SC0	0	0	X	X	X	X

SC1, SC0 - specify counter to be latched

SC1	SC0	Counter
0	0	0
0	1	1
1	0	2
1	1	Read-Back Command

D5,D4 - 00 designates Counter Latch Command

X - don't care

NOTE:
Don't care bits (X) should be 0 to insure compatibility with future Intel products.

Figure 9. Counter Latching Command Format

The selected Counter's output latch (OL) latches the count at the time the Counter Latch Command is received. This count is held in the latch until it is read by the CPU (or until the Counter is reprogrammed). The count is then unlatched automatically and the OL returns to "following" the counting element (CE). This allows reading the contents of the Counters "on the fly" without affecting counting in progress. Multiple Counter Latch Commands may be used to latch more than one Counter. Each latched Counter's OL holds its count until it is read. Counter Latch Commands do not affect the programmed Mode of the Counter in any way.

If a Counter is latched and then, some time later, latched again before the count is read, the second Counter Latch Command is ignored. The count read will be the count at the time the first Counter Latch Command was issued.

With either method, the count must be read according to the programmed format; specifically, if the Counter is programmed for two byte counts, two bytes must be read. The two bytes do not have to be read one right after the other; read or write or programming operations of other Counters may be inserted between them.

Another feature of the 82C54 is that reads and writes of the same Counter may be interleaved; for example, if the Counter is programmed for two byte counts, the following sequence is valid.

1. Read least significant byte.
2. Write new least significant byte.
3. Read most significant byte.
4. Write new most significant byte.

If a Counter is programmed to read/write two-byte counts, the following precaution applies; A program must not transfer control between reading the first and second byte to another routine which also reads from that same Counter. Otherwise, an incorrect count will be read.

READ-BACK COMMAND

The third method uses the Read-Back command. This command allows the user to check the count value, programmed Mode, and current state of the OUT pin and Null Count flag of the selected counter(s).

The command is written into the Control Word Register and has the format shown in Figure 10. The command applies to the counters selected by setting their corresponding bits D3,D2,D1 = 1.

A0, A1 = 11 $\overline{CS}$ = 0 $\overline{RD}$ = 1 $\overline{WR}$ = 0

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	1	$\overline{COUNT}$	$\overline{STATUS}$	CNT 2	CNT 1	CNT 0	0

D_5: 0 = Latch count of selected counter(s)
D_4: 0 = Latch status of selected counter(s)
D_3: 1 = Select counter 2
D_2: 1 = Select counter 1
D_1: 1 = Select counter 0
D_0: Reserved for future expansion; must be 0

Figure 10. Read-Back Command Format

The read-back command may be used to latch multiple counter output latches (OL) by setting the $\overline{COUNT}$ bit D5 = 0 and selecting the desired counter(s). This single command is functionally equivalent to several counter latch commands, one for each counter latched. Each counter's latched count is held until it is read (or the counter is reprogrammed). That counter is automatically unlatched when read, but other counters remain latched until they are read. If multiple count read-back commands are issued to the same counter without reading the

count, all but the first are ignored; i.e., the count which will be read is the count at the time the first read-back command was issued.

The read-back command may also be used to latch status information of selected counter(s) by setting $\overline{\text{STATUS}}$ bit D4=0. Status must be latched to be read; status of a counter is accessed by a read from that counter.

The counter status format is shown in Figure 11. Bits D5 through D0 contain the counter's programmed Mode exactly as written in the last Mode Control Word. OUTPUT bit D7 contains the current state of the OUT pin. This allows the user to monitor the counter's output via software, possibly eliminating some hardware from a system.

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
OUTPUT	NULL COUNT	RW1	RW0	M2	M1	M0	BCD

D_7 1 = Out Pin is 1
0 = Out Pin is 0
D_6 1 = Null count
0 = Count available for reading
D_5-D_0 Counter Programmed Mode (See Figure 7)

Figure 11. Status Byte

NULL COUNT bit D6 indicates when the last count written to the counter register (CR) has been loaded into the counting element (CE). The exact time this happens depends on the Mode of the counter and is described in the Mode Definitions, but until the count is loaded into the counting element (CE), it can't be read from the counter. If the count is latched or read before this time, the count value will not reflect the new count just written. The operation of Null Count is shown in Figure 12.

THIS ACTION:	CAUSES:
A. Write to the control word register:[1]	Null count = 1
B. Write to the count register (CR);[2]	Null count = 1
C. New count is loaded into CE (CR → CE);	Null count = 0

[1] Only the counter specified by the control word will have its null count set to 1. Null count bits of other counters are unaffected.

[2] If the counter is programmed for two-byte counts (least significant byte then most significant byte) null count goes to 1 when the second byte is written.

Figure 12. Null Count Operation

If multiple status latch operations of the counter(s) are performed without reading the status, all but the first are ignored; i.e., the status that will be read is the status of the counter at the time the first status read-back command was issued.

Both count and status of the selected counter(s) may be latched simultaneously by setting both $\overline{\text{COUNT}}$ and $\overline{\text{STATUS}}$ bits D5,D4=0. This is functionally the same as issuing two separate read-back commands at once, and the above discussions apply here also. Specifically, if multiple count and/or status read-back commands are issued to the same counter(s) without any intervening reads, all but the first are ignored. This is illustrated in Figure 13.

If both count and status of a counter are latched, the first read operation of that counter will return latched status, regardless of which was latched first. The next one or two reads (depending on whether the counter is programmed for one or two type counts) return latched count. Subsequent reads return unlatched count.

Command								Description	Results
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0		
1	1	0	0	0	0	1	0	Read back count and status of Counter 0	Count and status latched for Counter 0
1	1	1	0	0	1	0	0	Read back status of Counter 1	Status latched for Counter 1
1	1	1	0	1	1	0	0	Read back status of Counters 2, 1	Status latched for Counter 2, but not Counter 1
1	1	0	1	1	0	0	0	Read back count of Counter 2	Count latched for Counter 2
1	1	0	0	0	1	0	0	Read back count and status of Counter 1	Count latched for Counter 1, but not status
1	1	1	0	0	0	1	0	Read back status of Counter 1	Command ignored, status already latched for Counter 1

Figure 13. Read-Back Command Example

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	A_1	A_0	
0	1	0	0	0	Write into Counter 0
0	1	0	0	1	Write into Counter 1
0	1	0	1	0	Write into Counter 2
0	1	0	1	1	Write Control Word
0	0	1	0	0	Read from Counter 0
0	0	1	0	1	Read from Counter 1
0	0	1	1	0	Read from Counter 2
0	0	1	1	1	No-Operation (3-State)
1	X	X	X	X	No-Operation (3-State)
0	1	1	X	X	No-Operation (3-State)

Figure 14. Read/Write Operations Summary

Mode Definitions

The following are defined for use in describing the operation of the 82C54.

CLK PULSE: a rising edge, then a falling edge, in that order, of a Counter's CLK input.

TRIGGER: a rising edge of a Counter's GATE input.

COUNTER LOADING: the transfer of a count from the CR to the CE (refer to the "Functional Description")

MODE 0: INTERRUPT ON TERMINAL COUNT

Mode 0 is typically used for event counting. After the Control Word is written, OUT is initially low, and will remain low until the Counter reaches zero. OUT then goes high and remains high until a new count or a new Mode 0 Control Word is written into the Counter.

GATE = 1 enables counting; GATE = 0 disables counting. GATE has no effect on OUT.

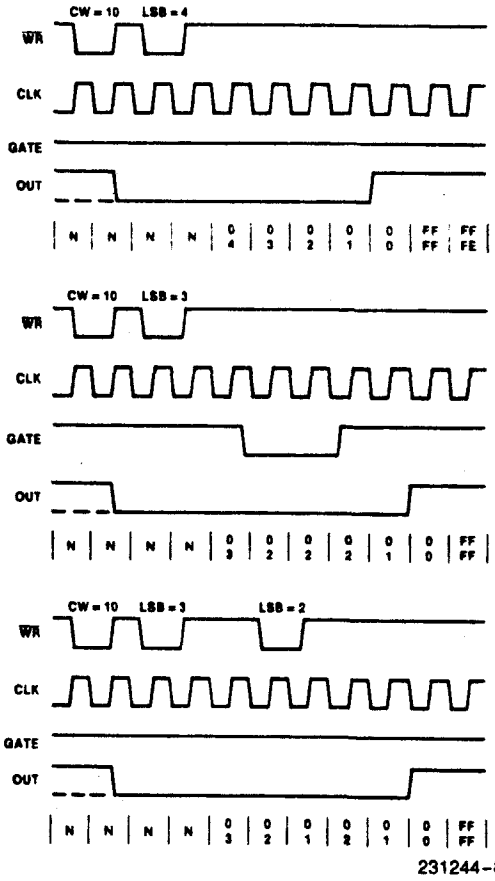
After the Control Word and initial count are written to a Counter, the initial count will be loaded on the next CLK pulse. This CLK pulse does not decrement the count, so for an initial count of N, OUT does not go high until N + 1 CLK pulses after the initial count is written.

If a new count is written to the Counter, it will be loaded on the next CLK pulse and counting will continue from the new count. If a two-byte count is written, the following happens:

1) Writing the first byte disables counting. OUT is set low immediately (no clock pulse required).
2) Writing the second byte allows the new count to be loaded on the next CLK pulse.

This allows the counting sequence to be synchronized by software. Again, OUT does not go high until N + 1 CLK pulses after the new count of N is written.

If an initial count is written while GATE = 0, it will still be loaded on the next CLK pulse. When GATE goes high, OUT will go high N CLK pulses later; no CLK pulse is needed to load the Counter as this has already been done.



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NOTE:
The Following Conventions Apply To All Mode Timing Diagrams:
1. Counters are programmed for binary (not BCD) counting and for Reading/Writing least significant byte (LSB) only.
2. The counter is always selected ($\overline{CS}$ always low).
3. CW stands for "Control Word"; CW = 10 means a control word of 10, hex is written to the counter.
4. LSB stands for "Least Significant Byte" of count.
5. Numbers below diagrams are count values.
The lower number is the least significant byte.
The upper number is the most significant byte. Since the counter is programmed to Read/Write LSB only, the most significant byte cannot be read.
N stands for an undefined count.
Vertical lines show transitions between count values.

Figure 15. Mode 0

MODE 1: HARDWARE RETRIGGERABLE ONE-SHOT

OUT will be initially high. OUT will go low on the CLK pulse following a trigger to begin the one-shot pulse, and will remain low until the Counter reaches zero. OUT will then go high and remain high until the CLK pulse after the next trigger.

After writing the Control Word and initial count, the Counter is armed. A trigger results in loading the Counter and setting OUT low on the next CLK pulse, thus starting the one-shot pulse. An initial count of N will result in a one-shot pulse N CLK cycles in duration. The one-shot is retriggerable, hence OUT will remain low for N CLK pulses after any trigger. The one-shot pulse can be repeated without rewriting the same count into the counter. GATE has no effect on OUT.

If a new count is written to the Counter during a one-shot pulse, the current one-shot is not affected unless the Counter is retriggered. In that case, the Counter is loaded with the new count and the one-shot pulse continues until the new count expires.

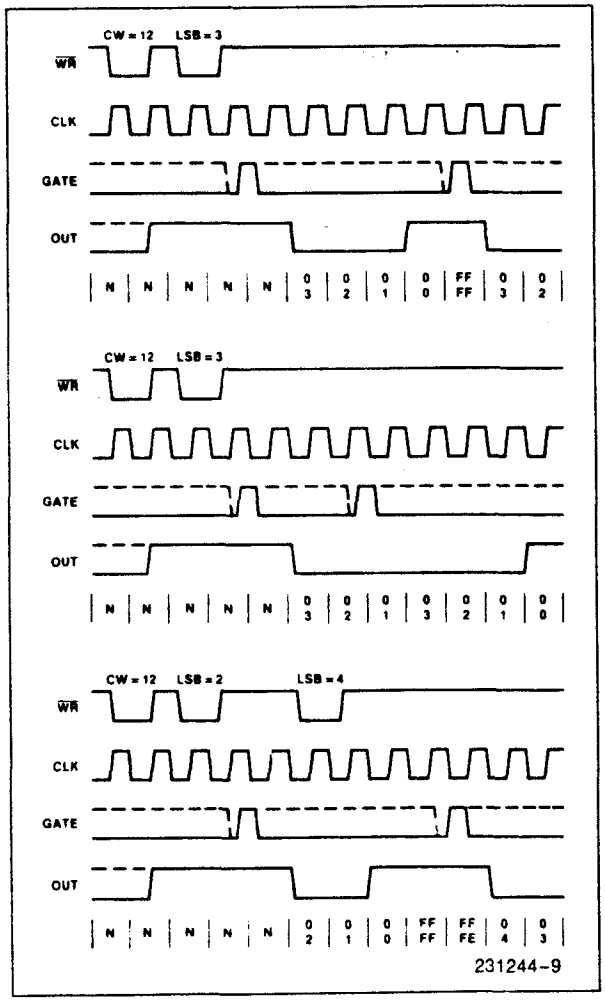


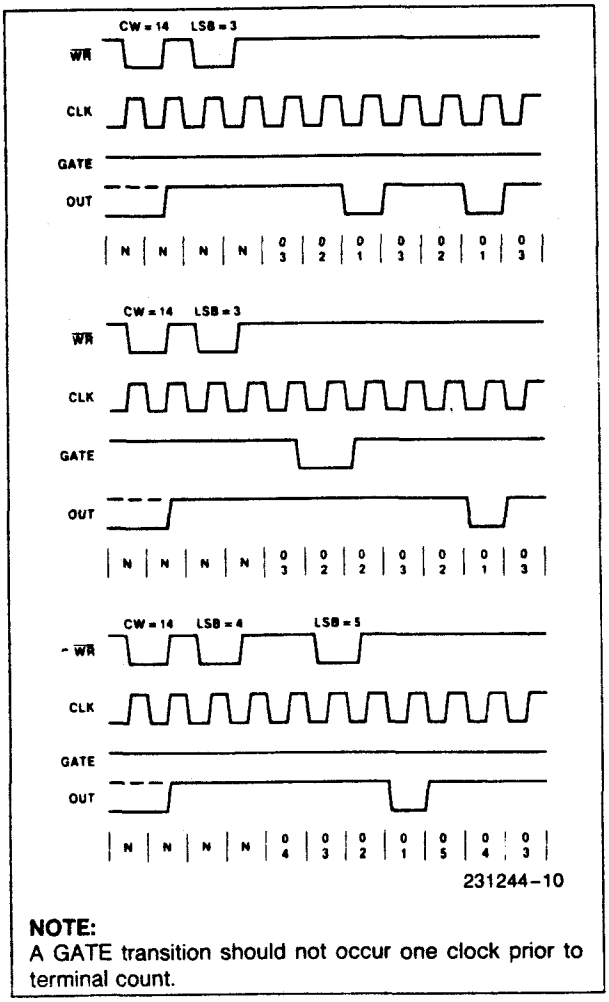
Figure 16. Mode 1

MODE 2: RATE GENERATOR

This Mode functions like a divide-by-N counter. It is typicially used to generate a Real Time Clock interrupt. OUT will initially be high. When the initial count has decremented to 1, OUT goes low for one CLK pulse. OUT then goes high again, the Counter reloads the initial count and the process is repeated. Mode 2 is periodic; the same sequence is repeated indefinitely. For an initial count of N, the sequence repeats every N CLK cycles.

GATE = 1 enables counting; GATE = 0 disables counting. If GATE goes low during an output pulse, OUT is set high immediately. A trigger reloads the Counter with the initial count on the next CLK pulse; OUT goes low N CLK pulses after the trigger. Thus the GATE input can be used to synchronize the Counter.

After writing a Control Word and initial count, the Counter will be loaded on the next CLK pulse. OUT goes low N CLK Pulses after the initial count is written. This allows the Counter to be synchronized by software also.



NOTE:
A GATE transition should not occur one clock prior to terminal count.

Figure 17. Mode 2

Writing a new count while counting does not affect the current counting sequence. If a trigger is received after writing a new count but before the end of the current period, the Counter will be loaded with the new count on the next CLK pulse and counting will continue from the new count. Otherwise, the new count will be loaded at the end of the current counting cycle. In mode 2, a COUNT of 1 is illegal.

MODE 3: SQUARE WAVE MODE

Mode 3 is typically used for Baud rate generation. Mode 3 is similar to Mode 2 except for the duty cycle of OUT. OUT will initially be high. When half the initial count has expired, OUT goes low for the remainder of the count. Mode 3 is periodic; the sequence above is repeated indefinitely. An initial count of N results in a square wave with a period of N CLK cycles.

GATE = 1 enables counting; GATE = 0 disables counting. If GATE goes low while OUT is low, OUT is set high immediately; no CLK pulse is required. A trigger reloads the Counter with the initial count on the next CLK pulse. Thus the GATE input can be used to synchronize the Counter.

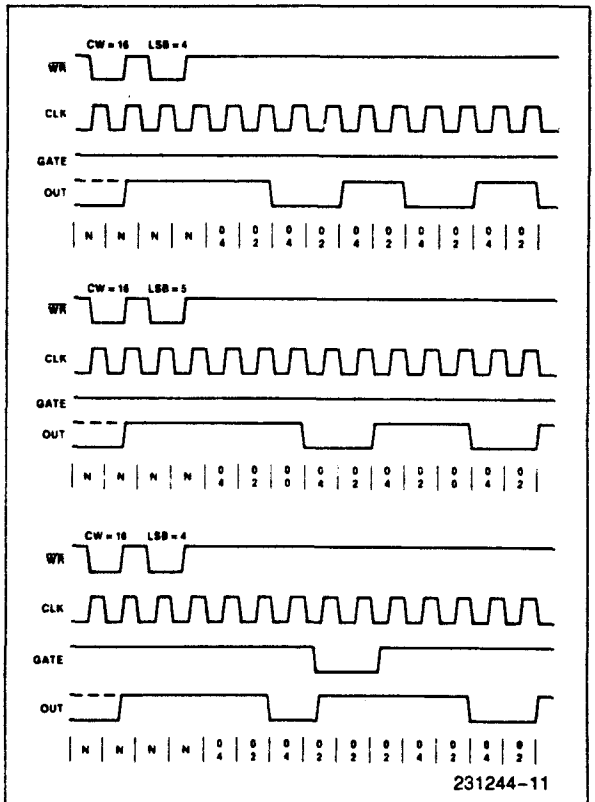
After writing a Control Word and initial count, the Counter will be loaded on the next CLK pulse. This allows the Counter to be synchronized by software also.

Writing a new count while counting does not affect the current counting sequence. If a trigger is received after writing a new count but before the end of the current half-cycle of the square wave, the Counter will be loaded with the new count on the next CLK pulse and counting will continue from the new count. Otherwise, the new count will be loaded at the end of the current half-cycle.

Mode 3 is implemented as follows:

Even counts: OUT is initially high. The initial count is loaded on one CLK pulse and then is decremented by two on succeeding CLK pulses. When the count expires OUT changes value and the Counter is reloaded with the initial count. The above process is repeated indefinitely.

Odd counts: OUT is initially high. The initial count minus one (an even number) is loaded on one CLK pulse and then is decremented by two on succeeding CLK pulses. One CLK pulse *after* the count expires, OUT goes low and the Counter is reloaded with the initial count minus one. Succeeding CLK pulses decrement the count by two. When the count expires, OUT goes high again and the Counter is reloaded with the initial count minus one. The above process is repeated indefinitely. So for odd counts, OUT will be high for (N + 1)/2 counts and low for (N −1)/2 counts.



NOTE:
A GATE transition should not occur one clock prior to terminal count.

Figure 18. Mode 3

MODE 4: SOFTWARE TRIGGERED STROBE

OUT will be initially high. When the initial count expires, OUT will go low for one CLK pulse and then go high again. The counting sequence is "triggered" by writing the initial count.

GATE = 1 enables counting; GATE = 0 disables counting. GATE has no effect on OUT.

After writing a Control Word and initial count, the Counter will be loaded on the next CLK pulse. This CLK pulse does not decrement the count, so for an initial count of N, OUT does not strobe low until N + 1 CLK pulses after the initial count is written.

If a new count is written during counting, it will be loaded on the next CLK pulse and counting will continue from the new count. If a two-byte count is written, the following happens:

1) Writing the first byte has no effect on counting.
2) Writing the second byte allows the new count to be loaded on the next CLK pulse.

This allows the sequence to be "retriggered" by software. OUT strobes low N+1 CLK pulses after the new count of N is written.

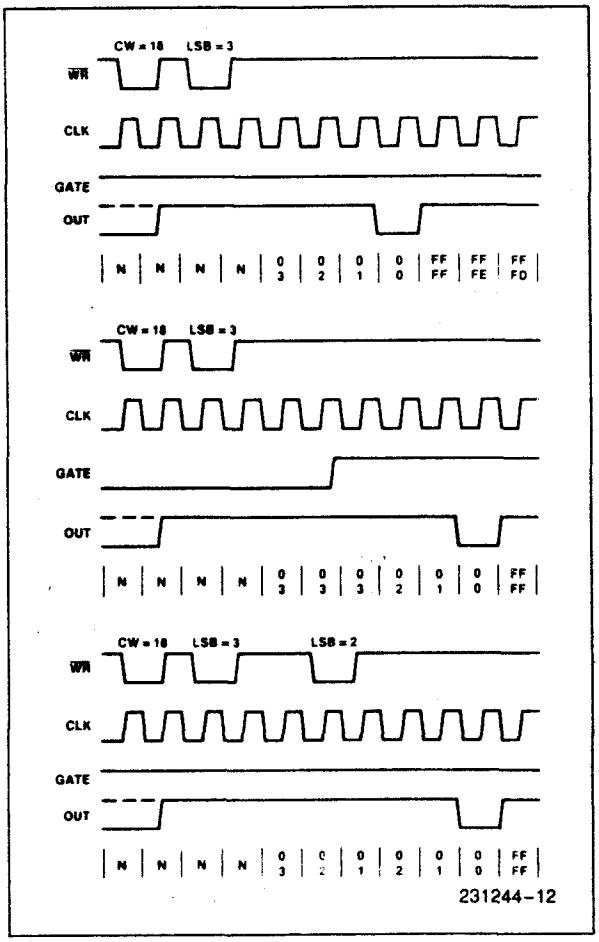


Figure 19. Mode 4

MODE 5: HARDWARE TRIGGERED STROBE (RETRIGGERABLE)

OUT will initially be high. Counting is triggered by a rising edge of GATE. When the initial count has expired, OUT will go low for one CLK pulse and then go high again.

After writing the Control Word and initial count, the counter will not be loaded until the CLK pulse after a trigger. This CLK pulse does not decrement the count, so for an initial count of N, OUT does not strobe low until N+1 CLK pulses after a trigger.

A trigger results in the Counter being loaded with the initial count on the next CLK pulse. The counting sequence is retriggerable. OUT will not strobe low for N + 1 CLK pulses after any trigger. GATE has no effect on OUT.

If a new count is written during counting, the current counting sequence will not be affected. If a trigger occurs after the new count is written but before the current count expires, the Counter will be loaded with the new count on the next CLK pulse and counting will continue from there.

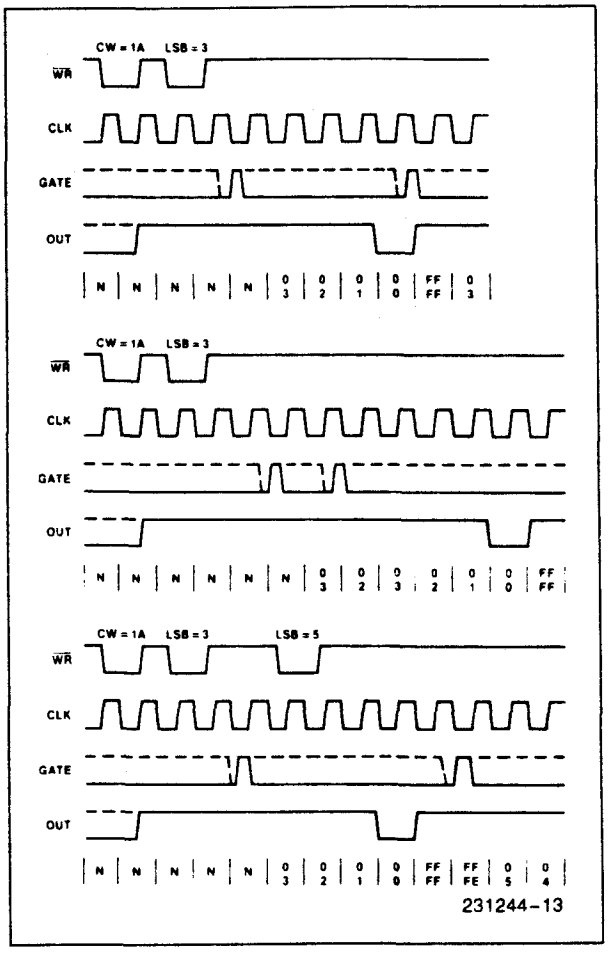


Figure 20. Mode 5

Signal Status Modes	Low Or Going Low	Rising	High
0	Disables counting	—	Enables counting
1	—	1) Initiates counting 2) Resets output after next clock	—
2	1) Disables counting 2) Sets output immediately high	Initiates counting	Enables counting
3	1) Disables counting 2) Sets output immediately high	Initiates counting	Enables counting
4	Disables counting	—	Enables counting
5	—	Initiates counting	—

Figure 21. Gate Pin Operations Summary

MODE	MIN COUNT	MAX COUNT
0	1	0
1	1	0
2	2	0
3	2	0
4	1	0

NOTE:
0 is equivalent to 2^{16} for binary counting and 10^4 for BCD counting

Figure 22. Minimum and Maximum Initial Counts

Operation Common to All Modes

Programming

When a Control Word is written to a Counter, all Control Logic is immediately reset and OUT goes to a known initial state; no CLK pulses are required for this.

GATE

The GATE input is always sampled on the rising edge of CLK. In Modes 0, 2, 3, and 4 the GATE input is level sensitive, and the logic level is sampled on the rising edge of CLK. In Modes 1, 2, 3, and 5 the GATE input is rising-edge sensitive. In these Modes, a rising edge of GATE (trigger) sets an edge-sensitive flip-flop in the Counter. This flip-flop is then sampled on the next rising edge of CLK; the flip-flop is reset immediately after it is sampled. In this way, a trigger will be detected no matter when it occurs—a high logic level does not have to be maintained until the next rising edge of CLK. Note that in Modes 2 and 3, the GATE input is both edge- and level-sensitive. In Modes 2 and 3, if a CLK source other than the system clock is used, GATE should be pulsed immediately following $\overline{WR}$ of a new count value.

COUNTER

New counts are loaded and Counters are decremented on the falling edge of CLK.

The largest possible initial count is 0; this is equivalent to 2^{16} for binary counting and 10^4 for BCD counting.

The Counter does not stop when it reaches zero. In Modes 0, 1, 4, and 5 the Counter "wraps around" to the highest count, either FFFF hex for binary counting or 9999 for BCD counting, and continues counting. Modes 2 and 3 are periodic; the Counter reloads itself with the initial count and continues counting from there.

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias.....0°C to 70°C
Storage Temperature .....−65° to +150°C
Supply Voltage .....−0.5 to +8.0V
Operating Voltage .....+4V to +7V
Voltage on any Input.....GND −2V to +6.5V
Voltage on any Output ..GND−0.5V to V_{CC} + 0.5V
Power Dissipation .....1 Watt

**Notice: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. CHARACTERISTICS

(T_A=0°C to 70°C, V_{CC}=5V± 10%, GND=0V) (T_A = −40°C to +85°C for Extended Temperature)

Symbol	Parameter	Min	Max	Units	Test Conditions
V_{IL}	Input Low Voltage	−0.5	0.8	V	
V_{IH}	Input High Voltage	2.0	V_{CC} + 0.5	V	
V_{OL}	Output Low Voltage		0.4	V	I_{OL} = 2.5 mA
V_{OH}	Output High Voltage	3.0 V_{CC} − 0.4		V V	I_{OH} = −2.5 mA I_{OH} = −100 µA
I_{IL}	Input Load Current		±2.0	µA	V_{IN}=V_{CC} to 0V
I_{OFL}	Output Float Leakage Current		±10	µA	V_{OUT}=V_{CC} to 0.0V
I_{CC}	V_{CC} Supply Current		20	mA	Clk Freq= 8MHz 82C54 10MHz 82C54-2
I_{CCSB}	V_{CC} Supply Current-Standby		10	µA	CLK Freq = DC $\overline{CS}$ = V_{CC}. All Inputs/Data Bus V_{CC} All Outputs Floating
I_{CCSB1}	V_{CC} Supply Current-Standby		150	µA	CLK Freq = DC $\overline{CS}$ = V_{CC}. All Other Inputs, I/O Pins = V_{GND}, Outputs Open
C_{IN}	Input Capacitance		10	pF	f_c = 1 MHz
$C_{I/O}$	I/O Capacitance		20	pF	Unmeasured pins
C_{OUT}	Output Capacitance		20	pF	returned to GND(5)

A.C. CHARACTERISTICS

(T_A = 0°C to 70°C, V_{CC} = 5V ±10%, GND =0V) (T_A = −40°C to +85°C for Extended Temperature)

BUS PARAMETERS (Note 1)

READ CYCLE

Symbol	Parameter	82C54		82C54-2		Units
		Min	Max	Min	Max	
t_{AR}	Address Stable Before $\overline{RD}$ ↓	45		30		ns
t_{SR}	$\overline{CS}$ Stable Before $\overline{RD}$ ↓	0		0		ns
t_{RA}	Address Hold Time After $\overline{RD}$ ↑	0		0		ns
t_{RR}	$\overline{RD}$ Pulse Width	150		95		ns
t_{RD}	Data Delay from $\overline{RD}$ ↓		120		85	ns
t_{AD}	Data Delay from Address		220		185	ns
t_{DF}	$\overline{RD}$ ↑ to Data Floating	5	90	5	65	ns
t_{RV}	Command Recovery Time	200		165		ns

NOTE:
1. AC timings measured at V_{OH} = 2.0V, V_{OL} = 0.8V.

A.C. CHARACTERISTICS (Continued)

WRITE CYCLE

Symbol	Parameter	82C54		82C54-2		Units
		Min	Max	Min	Max	
t_{AW}	Address Stable Before $\overline{WR}\downarrow$	0		0		ns
t_{SW}	$\overline{CS}$ Stable Before $\overline{WR}\downarrow$	0		0		ns
t_{WA}	Address Hold Time After $\overline{WR}\uparrow$	0		0		ns
t_{WW}	$\overline{WR}$ Pulse Width	150		95		ns
t_{DW}	Data Setup Time Before $\overline{WR}\uparrow$	120		95		ns
t_{WD}	Data Hold Time After $\overline{WR}\uparrow$	0		0		ns
t_{RV}	Command Recovery Time	200		165		ns

CLOCK AND GATE

Symbol	Parameter	82C54		82C54-2		Units
		Min	Max	Min	Max	
t_{CLK}	Clock Period	125	DC	100	DC	ns
t_{PWH}	High Pulse Width	60(3)		30(3)		ns
t_{PWL}	Low Pulse Width	60(3)		50(3)		ns
T_R	Clock Rise Time		25		25	ns
t_F	Clock Fall Time		25		25	ns
t_{GW}	Gate Width High	50		50		ns
t_{GL}	Gate Width Low	50		50		ns
t_{GS}	Gate Setup Time to CLK $\uparrow$	50		40		ns
t_{GH}	Gate Hold Time After CLK $\uparrow$	50(2)		50(2)		ns
T_{OD}	Output Delay from CLK $\downarrow$		150		100	ns
t_{ODG}	Output Delay from Gate $\downarrow$		120		100	ns
t_{WC}	CLK Delay for Loading(4)	0	55	0	55	ns
t_{WG}	Gate Delay for Sampling(4)	−5	50	−5	40	ns
t_{WO}	OUT Delay from Mode Write		260		240	ns
t_{CL}	CLK Set Up for Count Latch	−40	45	−40	40	ns

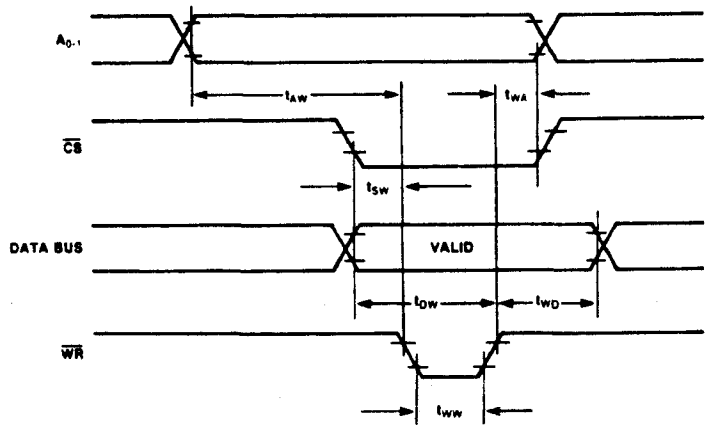
NOTES:
2. In Modes 1 and 5 triggers are sampled on each rising clock edge. A second trigger within 120 ns (70 ns for the 82C54-2) of the rising clock edge may not be detected.
3. Low-going glitches that violate t_{PWH}, t_{PWL} may cause errors requiring counter reprogramming.
4. Except for Extended Temp., See Extended Temp. A.C. Characteristics below.
5. Sampled not 100% tested. T_A = 25°C.
6. If CLK present at T_{WC} min then Count equals N+2 CLK pulses, T_{WC} max equals Count N+1 CLK pulse. T_{WC} min to T_{WC} max, count will be either N+1 or N+2 CLK pulses.
7. In Modes 1 and 5, if GATE is present when writing a new Count value, at T_{WG} min Counter will not be triggered, at T_{WG} max Counter will be triggered.
8. If CLK present when writing a Counter Latch or ReadBack Command, at T_{CL} min CLK will be reflected in count value latched, at T_{CL} max CLK will not be reflected in the count value latched. Writing a Counter Latch or ReadBack Command between T_{CL} min and T_{WL} max will result in a latched count vallue which is ± one least significant bit.

EXTENDED TEMPERATURE (T_A = −40°C to +85°C for Extended Temperature)

Symbol	Parameter	82C54		82C54-2		Units
		Min	Max	Min	Max	
t_{WC}	CLK Delay for Loading	−25	25	−25	25	ns
t_{WG}	Gate Delay for Sampling	−25	25	−25	25	ns

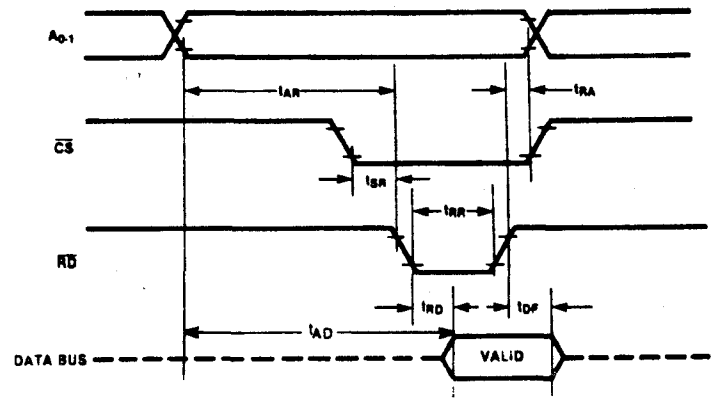
WAVEFORMS

WRITE



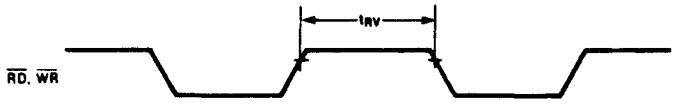
231244-14

READ



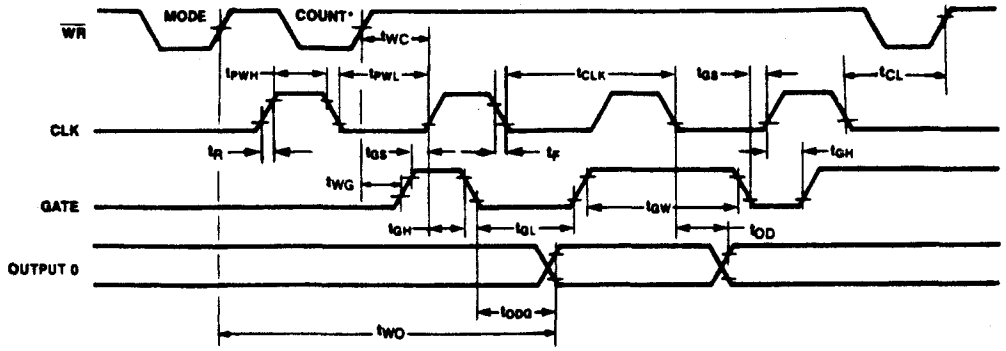
231244-15

RECOVERY



231244-16

CLOCK AND GATE



231244-17

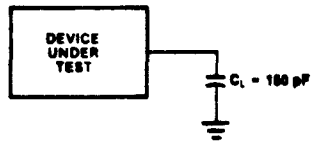
* Last byte of count being written

A.C. TESTING INPUT, OUTPUT WAVEFORM

231244-18

A.C. Testing: Inputs are driven at 2.4V for a logic "1" and 0.45V for a logic "0." Timing measurements are made at 2.0V for a logic "1" and 0.8V for a logic "0."

A.C. TESTING LOAD CIRCUIT



231244-19

C_L = 150 pF
C_L includes jig capacitance

Intel 82C55A Programmable Peripheral Interface
Data Sheet Reprint

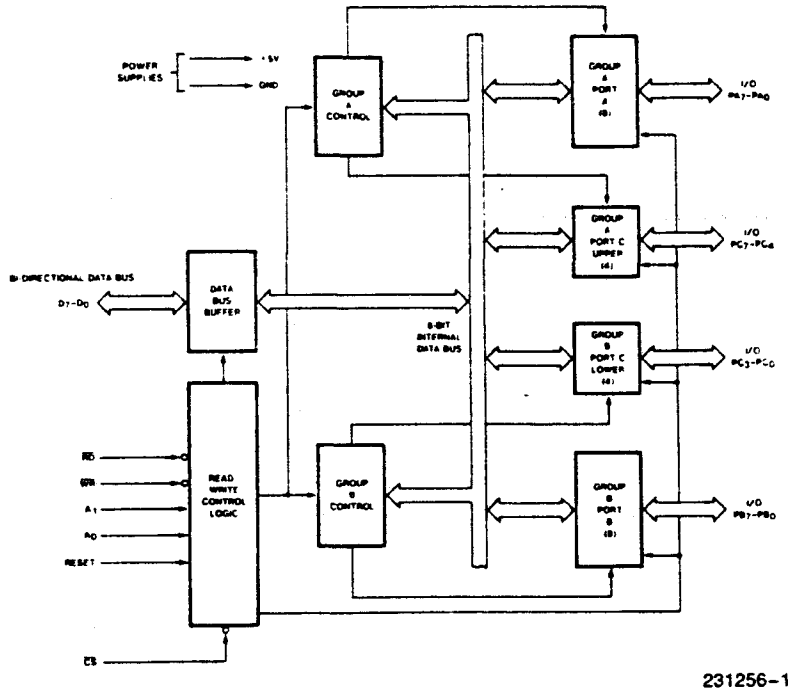
82C55A
CHMOS PROGRAMMABLE PERIPHERAL INTERFACE

- **Compatible with all Intel and Most Other Microprocessors**
- **High Speed, "Zero Wait State" Operation with 8 MHz 8086/88 and 80186/188**
- **24 Programmable I/O Pins**
- **Low Power CHMOS**
- **Completely TTL Compatible**
- **Control Word Read-Back Capability**
- **Direct Bit Set/Reset Capability**
- **2.5 mA DC Drive Capability on all I/O Port Outputs**
- **Available in 40-Pin DIP and 44-Pin PLCC**
- **Available in EXPRESS**
  - **Standard Temperature Range**
  - **Extended Temperature Range**

The Intel 82C55A is a high-performance, CHMOS version of the industry standard 8255A general purpose programmable I/O device which is designed for use with all Intel and most other microprocessors. It provides 24 I/O pins which may be individually programmed in 2 groups of 12 and used in 3 major modes of operation. The 82C55A is pin compatible with the NMOS 8255A and 8255A-5.

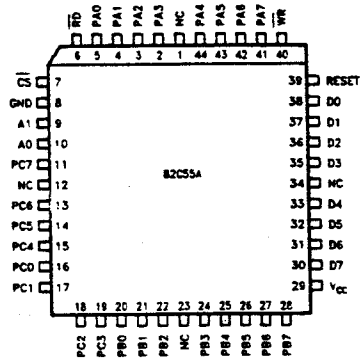
In MODE 0, each group of 12 I/O pins may be programmed in sets of 4 and 8 to be inputs or outputs. In MODE 1, each group may be programmed to have 8 lines of input or output. 3 of the remaining 4 pins are used for handshaking and interrupt control signals. MODE 2 is a strobed bi-directional bus configuration.

The 82C55A is fabricated on Intel's advanced CHMOS III technology which provides low power consumption with performance equal to or greater than the equivalent NMOS product. The 82C55A is available in 40-pin DIP and 44-pin plastic leaded chip carrier (PLCC) packages.

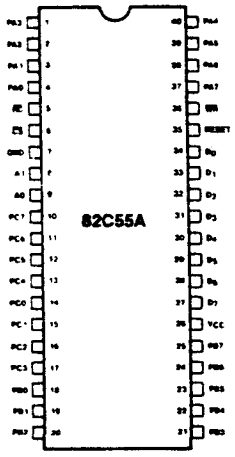


231256-1

Figure 1. 82C55A Block Diagram



231256-31



231256-2

Figure 2. 82C55A Pinout

Diagrams are for pin reference only. Package sizes are not to scale.

September 1987
Order Number: 231256-004

Table 1. Pin Description

Symbol	Pin Number Dip	Pin Number PLCC	Type	Name and Function
PA_{3-0}	1-4	2-5	I/O	**PORT A, PINS 0-3:** Lower nibble of an 8-bit data output latch/ buffer and an 8-bit data input latch.
$\overline{RD}$	5	6	I	**READ CONTROL:** This input is low during CPU read operations.
$\overline{CS}$	6	7	I	**CHIP SELECT:** A low on this input enables the 82C55A to respond to $\overline{RD}$ and $\overline{WR}$ signals. $\overline{RD}$ and WR are ignored otherwise.
GND	7	8		**System Ground**
A_{1-0}	8-9	9-10	I	**ADDRESS:** These input signals, in conjunction $\overline{RD}$ and $\overline{WR}$, control the selection of one of the three ports or the control word registers.

A_1	A_0	$\overline{RD}$	$\overline{WR}$	$\overline{CS}$	Input Operation (Read)
0	0	0	1	0	Port A - Data Bus
0	1	0	1	0	Port B - Data Bus
1	0	0	1	0	Port C - Data Bus
1	1	0	1	0	Control Word - Data Bus
					Output Operation (Write)
0	0	1	0	0	Data Bus - Port A
0	1	1	0	0	Data Bus - Port B
1	0	1	0	0	Data Bus - Port C
1	1	1	0	0	Data Bus - Control
					Disable Function
X	X	X	X	1	Data Bus - 3 - State
X	X	1	1	0	Data Bus - 3 - State

PC_{7-4}	10-13	11,13-15	I/O	**PORT C, PINS 4-7:** Upper nibble of an 8-bit data output latch/ buffer and an 8-bit data input buffer (no latch for input). This port can be divided into two 4-bit ports under the mode control. Each 4-bit port contains a 4-bit latch and it can be used for the control signal outputs and status signal inputs in conjunction with ports A and B.
PC_{0-3}	14-17	16-19	I/O	**PORT C, PINS 0-3:** Lower nibble of Port C.
PB_{0-7}	18-25	20-22, 24-28	I/O	**PORT B, PINS 0-7:** An 8-bit data output latch/buffer and an 8-bit data input buffer.
V_{CC}	26	29		**SYSTEM POWER:** + 5V Power Supply.
D_{7-0}	27-34	30-33, 35-38	I/O	**DATA BUS:** Bi-directional, tri-state data bus lines, connected to system data bus.
RESET	35	39	I	**RESET:** A high on this input clears the control register and all ports are set to the input mode.
$\overline{WR}$	36	40	I	**WRITE CONTROL:** This input is low during CPU write operations.
PA_{7-4}	37-40	41-44	I/O	**PORT A, PINS 4-7:** Upper nibble of an 8-bit data output latch/ buffer and an 8-bit data input latch.
NC		1, 12, 23, 34		No Connect

82C55A FUNCTIONAL DESCRIPTION

General

The 82C55A is a programmable peripheral interface device designed for use in Intel microcomputer systems. Its function is that of a general purpose I/O component to interface peripheral equipment to the microcomputer system bus. The functional configuration of the 82C55A is programmed by the system software so that normally no external logic is necessary to interface peripheral devices or structures.

Data Bus Buffer

This 3-state bidirectional 8-bit buffer is used to interface the 82C55A to the system data bus. Data is transmitted or received by the buffer upon execution of input or output instructions by the CPU. Control words and status information are also transferred through the data bus buffer.

Read/Write and Control Logic

The function of this block is to manage all of the internal and external transfers of both Data and Control or Status words. It accepts inputs from the CPU Address and Control busses and in turn, issues commands to both of the Control Groups.

Group A and Group B Controls

The functional configuration of each port is programmed by the systems software. In essence, the CPU "outputs" a control word to the 82C55A. The control word contains information such as "mode", "bit set", "bit reset", etc., that initializes the functional configuration of the 82C55A.

Each of the Control blocks (Group A and Group B) accepts "commands" from the Read/Write Control Logic, receives "control words" from the internal data bus and issues the proper commands to its associated ports.

Control Group A - Port A and Port C upper (C7–C4)
Control Group B - Port B and Port C lower (C3–C0)

The control word register can be both written and read as shown in the address decode table in the pin descriptions. Figure 6 shows the control word format for both Read and Write operations. When the control word is read, bit D7 will always be a logic "1", as this implies control word mode information.

Ports A, B, and C

The 82C55A contains three 8-bit ports (A, B, and C). All can be configured in a wide variety of functional characteristics by the system software but each has its own special features or "personality" to further enhance the power and flexibility of the 82C55A.

Port A. One 8-bit data output latch/buffer and one 8-bit input latch buffer. Both "pull-up" and "pull-down" bus hold devices are present on Port A.

Port B. One 8-bit data input/output latch/buffer. Only "pull-up" bus hold devices are present on Port B.

Port C. One 8-bit data output latch/buffer and one 8-bit data input buffer (no latch for input). This port can be divided into two 4-bit ports under the mode control. Each 4-bit port contains a 4-bit latch and it can be used for the control signal outputs and status signal inputs in conjunction with ports A and B. Only "pull-up" bus hold devices are present on Port C.

See Figure 4 for the bus-hold circuit configuration for Port A, B, and C.

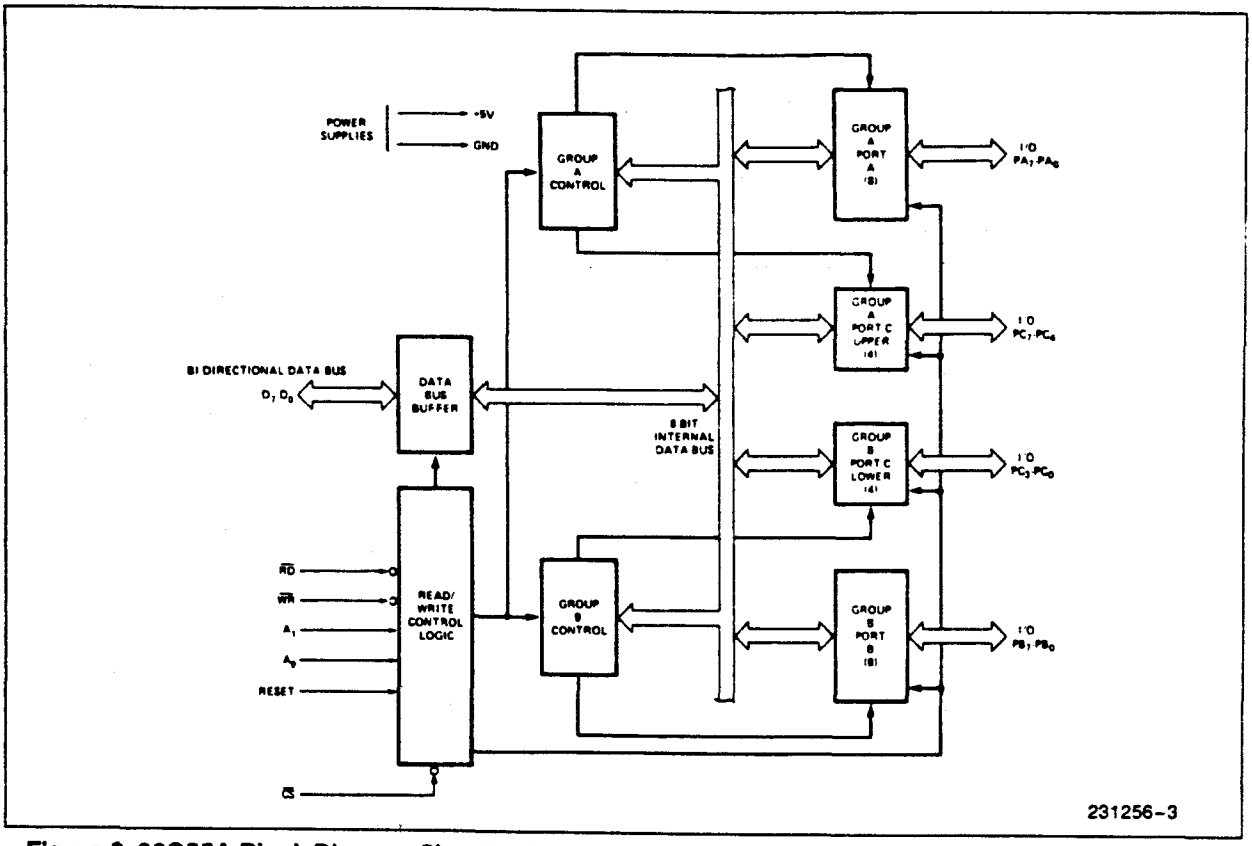
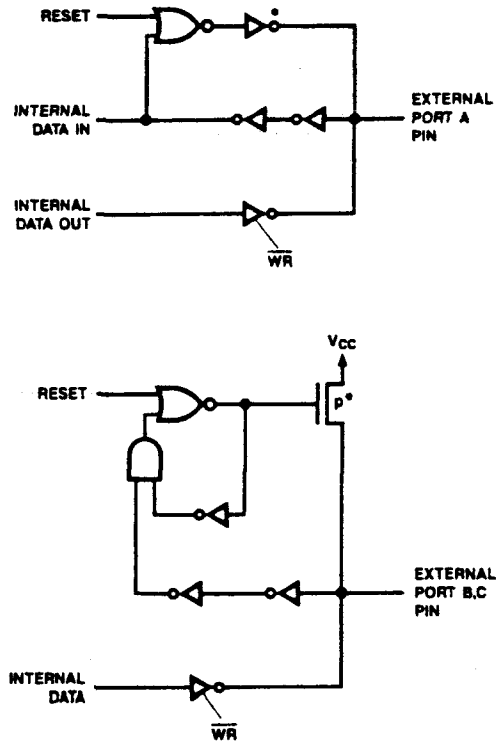


Figure 3. 82C55A Block Diagram Showing Data Bus Buffer and Read/Write Control Logic Functions



***NOTE:**
Port pins loaded with more than 20 pF capacitance may not have their logic level guaranteed following a hardware reset.

Figure 4. Port A, B, C, Bus-hold Configuration

82C55A OPERATIONAL DESCRIPTION

Mode Selection

There are three basic modes of operation that can be selected by the system software:

Mode 0 — Basic input/output
Mode 1 — Strobed Input/output
Mode 2 — Bi-directional Bus

When the reset input goes "high" all ports will be set to the input mode with all 24 port lines held at a logic "one" level by the internal bus hold devices (see Figure 4 Note). After the reset is removed the 82C55A can remain in the input mode with no additional initialization required. This eliminates the need for pullup or pulldown devices in "all CMOS" designs. During the execution of the system program, any of the other modes may be selected by using a single output instruction. This allows a single 82C55A to service a variety of peripheral devices with a simple software maintenance routine.

The modes for Port A and Port B can be separately defined, while Port C is divided into two portions as required by the Port A and Port B definitions. All of the output registers, including the status flip-flops, will be reset whenever the mode is changed. Modes may be combined so that their functional definition can be "tailored" to almost any I/O structure. For instance; Group B can be programmed in Mode 0 to monitor simple switch closings or display computational results, Group A could be programmed in Mode 1 to monitor a keyboard or tape reader on an interrupt-driven basis.

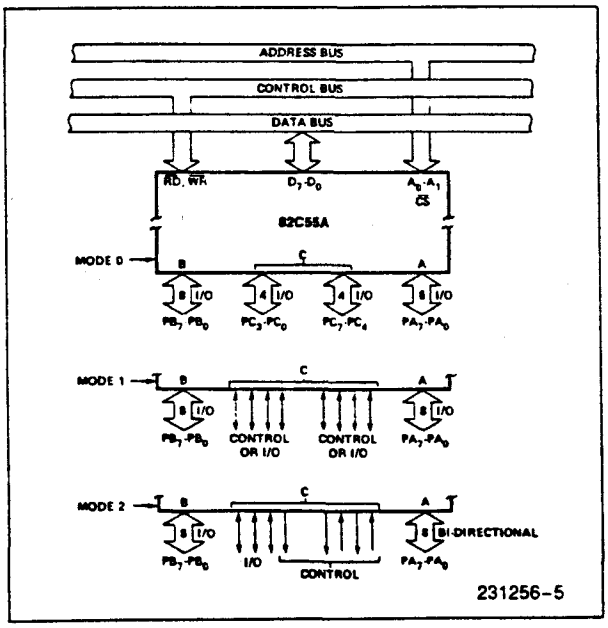


Figure 5. Basic Mode Definitions and Bus Interface

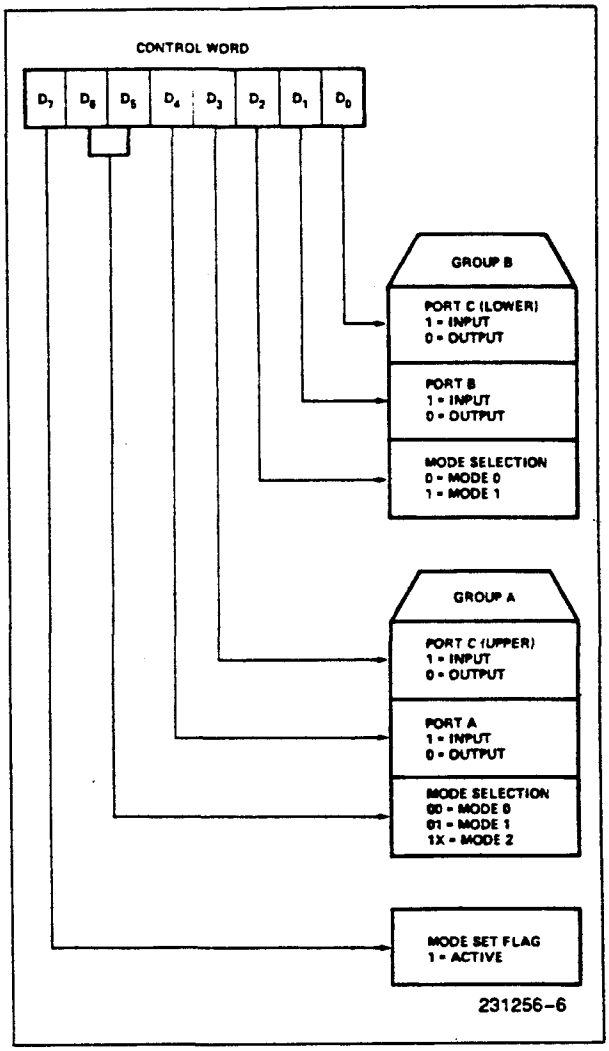


Figure 6. Mode Definition Format

The mode definitions and possible mode combinations may seem confusing at first but after a cursory review of the complete device operation a simple, logical I/O approach will surface. The design of the 82C55A has taken into account things such as efficient PC board layout, control signal definition vs PC layout and complete functional flexibility to support almost any peripheral device with no external logic. Such design represents the maximum use of the available pins.

Single Bit Set/Reset Feature

Any of the eight bits of Port C can be Set or Reset using a single OUTput instruction. This feature reduces software requirements in Control-based applications.

When Port C is being used as status/control for Port A or B, these bits can be set or reset by using the Bit Set/Reset operation just as if they were data output ports.

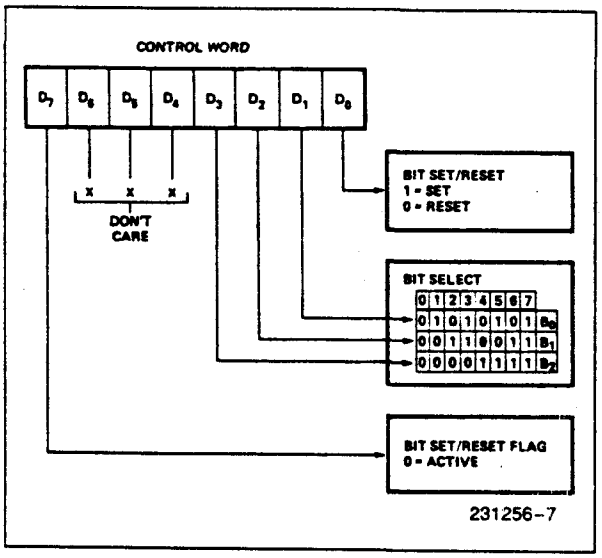


Figure 7. Bit Set/Reset Format

Interrupt Control Functions

When the 82C55A is programmed to operate in mode 1 or mode 2, control signals are provided that can be used as interrupt request inputs to the CPU. The interrupt request signals, generated from port C, can be inhibited or enabled by setting or resetting the associated INTE flip-flop, using the bit set/reset function of port C.

This function allows the Programmer to disallow or allow a specific I/O device to interrupt the CPU without affecting any other device in the interrupt structure.

INTE flip-flop definition:

(BIT-SET)—INTE is SET—Interrupt enable
(BIT-RESET)—INTE is RESET—Interrupt disable

Note:
All Mask flip-flops are automatically reset during mode selection and device Reset.

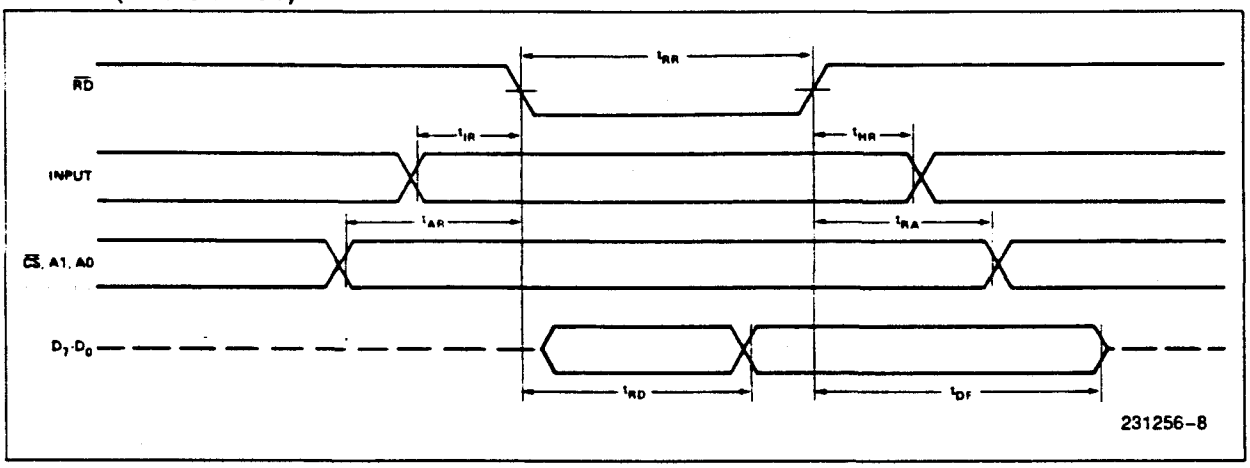
Operating Modes

Mode 0 (Basic Input/Output). This functional configuration provides simple input and output operations for each of the three ports. No "handshaking" is required, data is simply written to or read from a specified port.

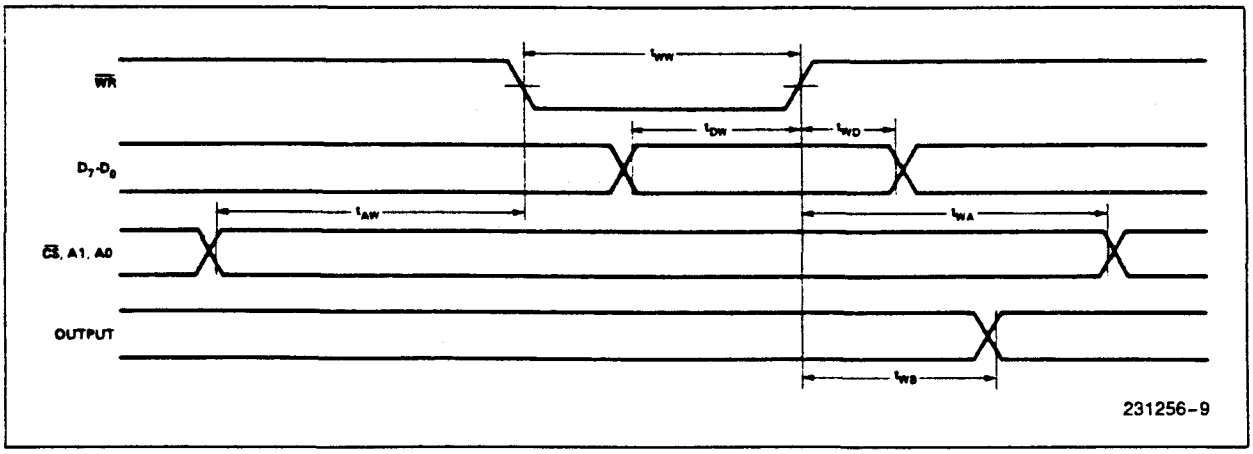
Mode 0 Basic Functional Definitions:

- Two 8-bit ports and two 4-bit ports.
- Any port can be input or output.
- Outputs are latched.
- Inputs are not latched.
- 16 different Input/Output configurations are possible in this Mode.

MODE 0 (BASIC INPUT)



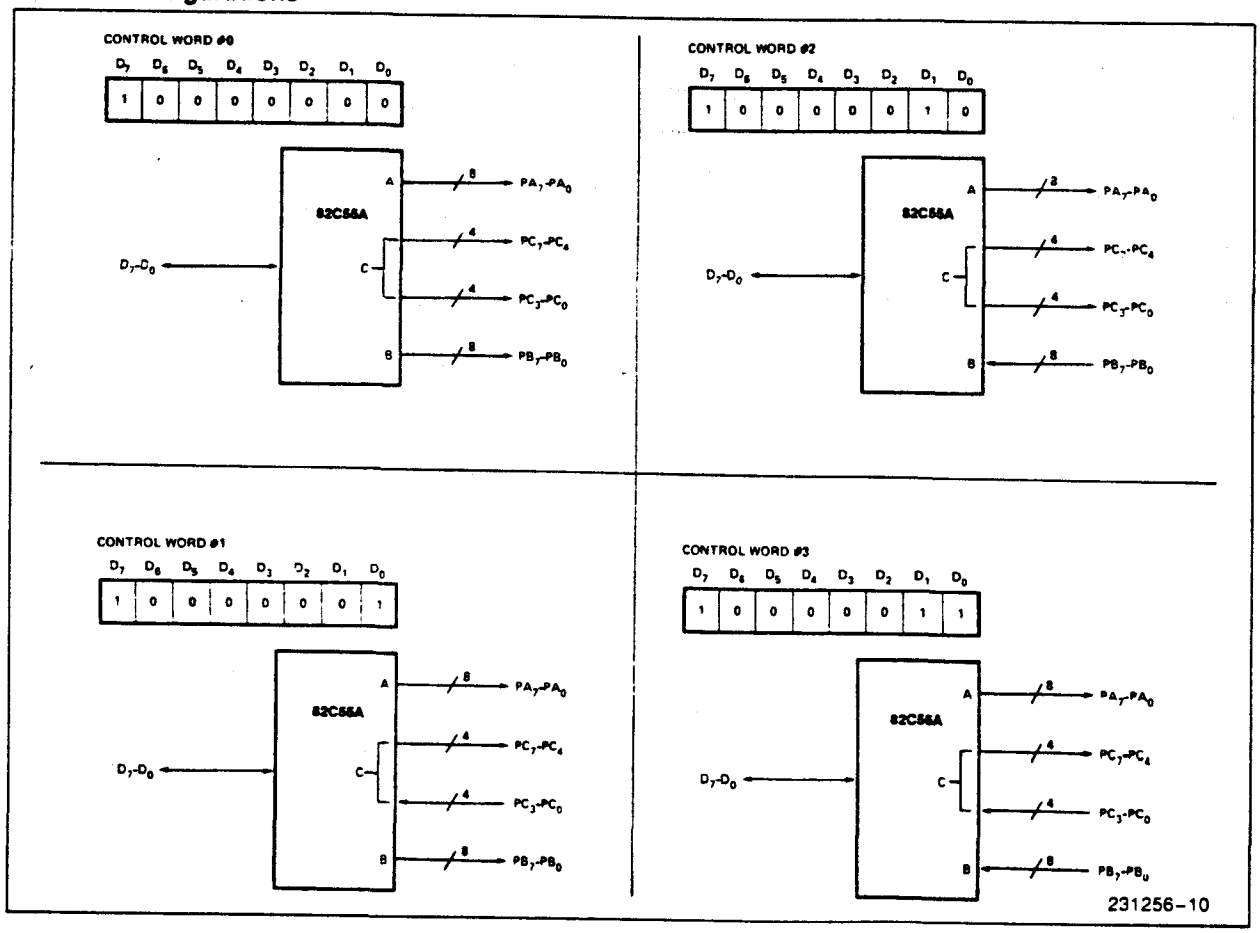
MODE 0 (BASIC OUTPUT)



MODE 0 Port Definition

A		B		GROUP A			GROUP B	
D_4	D_3	D_1	D_0	PORT A	PORT C (UPPER)	#	PORT B	PORT C (LOWER)
0	0	0	0	OUTPUT	OUTPUT	0	OUTPUT	OUTPUT
0	0	0	1	OUTPUT	OUTPUT	1	OUTPUT	INPUT
0	0	1	0	OUTPUT	OUTPUT	2	INPUT	OUTPUT
0	0	1	1	OUTPUT	OUTPUT	3	INPUT	INPUT
0	1	0	0	OUTPUT	INPUT	4	OUTPUT	OUTPUT
0	1	0	1	OUTPUT	INPUT	5	OUTPUT	INPUT
0	1	1	0	OUTPUT	INPUT	6	INPUT	OUTPUT
0	1	1	1	OUTPUT	INPUT	7	INPUT	INPUT
1	0	0	0	INPUT	OUTPUT	8	OUTPUT	OUTPUT
1	0	0	1	INPUT	OUTPUT	9	OUTPUT	INPUT
1	0	1	0	INPUT	OUTPUT	10	INPUT	OUTPUT
1	0	1	1	INPUT	OUTPUT	11	INPUT	INPUT
1	1	0	0	INPUT	INPUT	12	OUTPUT	OUTPUT
1	1	0	1	INPUT	INPUT	13	OUTPUT	INPUT
1	1	1	0	INPUT	INPUT	14	INPUT	OUTPUT
1	1	1	1	INPUT	INPUT	15	INPUT	INPUT

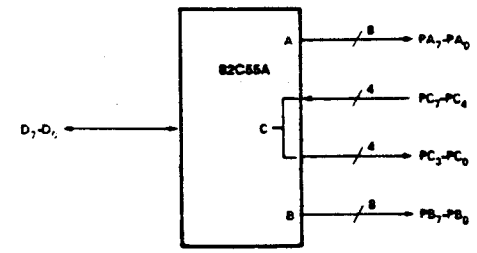
MODE 0 Configurations



MODE 0 Configurations (Continued)

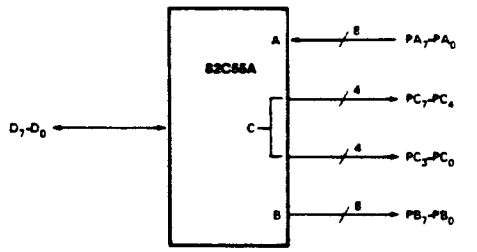
CONTROL WORD #4

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	0	1	0	0	0



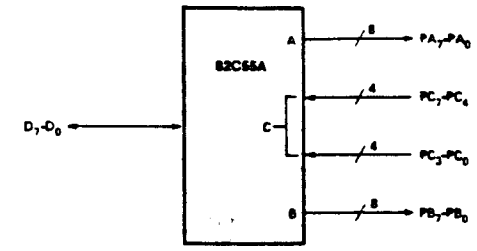
CONTROL WORD #8

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	1	0	0	0	0



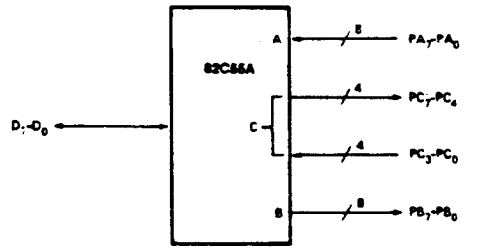
CONTROL WORD #5

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
0	0	0	1	0	0	0	1



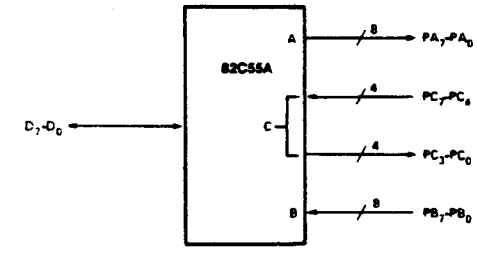
CONTROL WORD #9

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	1	0	0	0	1



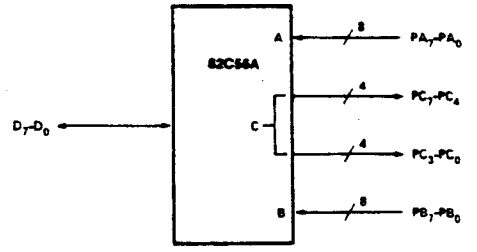
CONTROL WORD #6

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	0	1	0	1	0



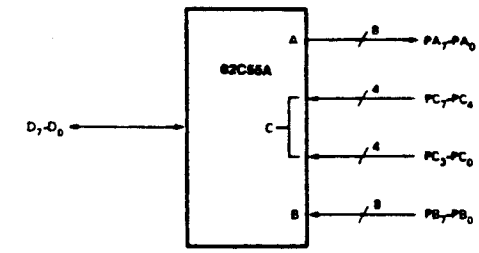
CONTROL WORD #10

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	1	0	0	1	0



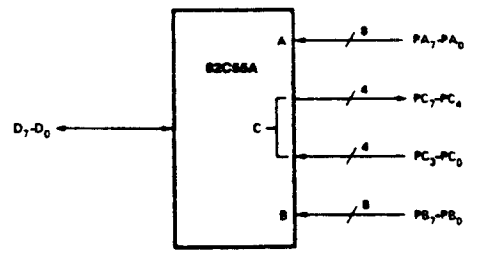
CONTROL WORD #7

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	0	1	0	1	1



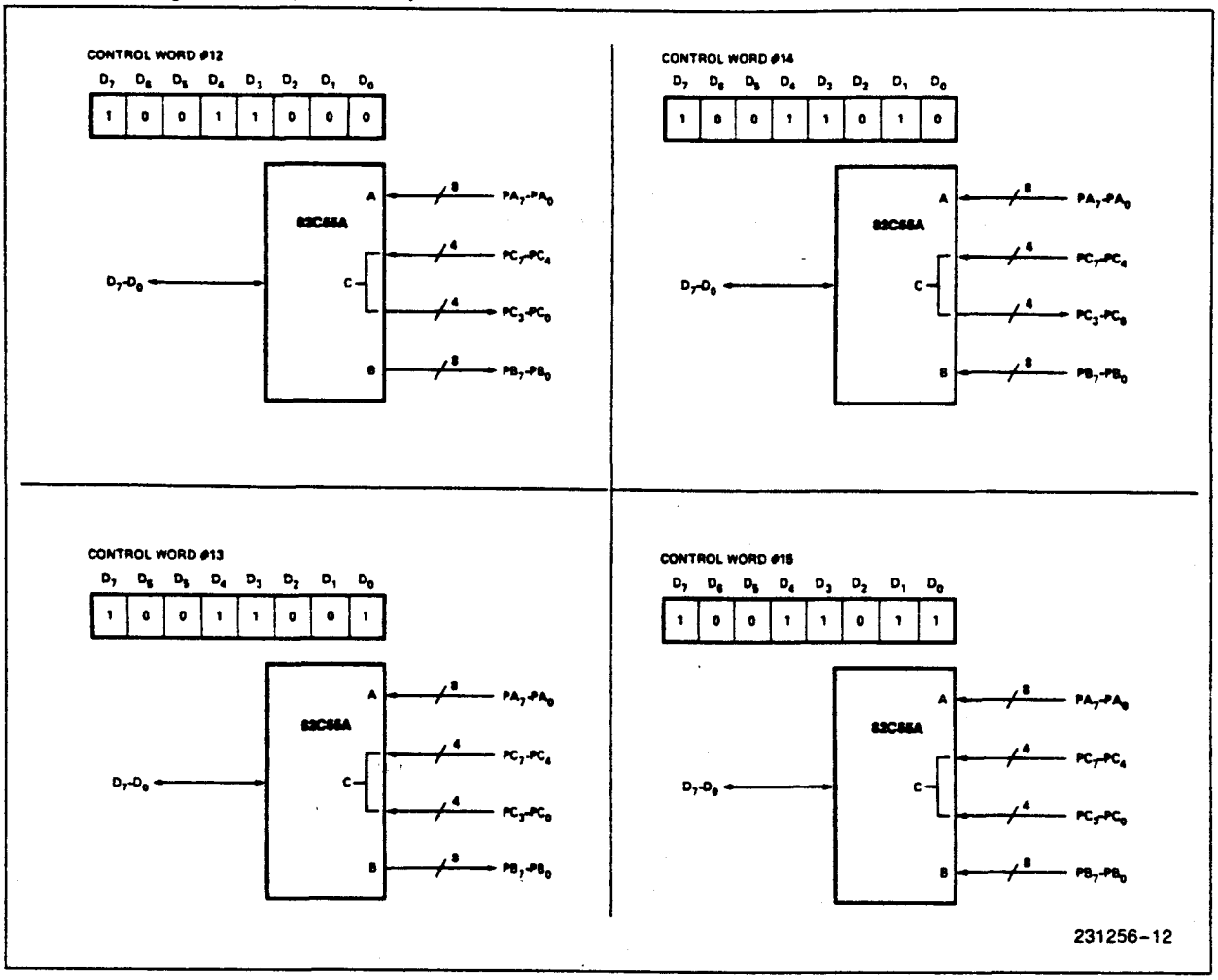
CONTROL WORD #11

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	1	0	0	1	1



231256-11

MODE 0 Configurations (Continued)



Operating Modes

MODE 1 (Strobed Input/Output). This functional configuration provides a means for transferring I/O data to or from a specified port in conjunction with strobes or "handshaking" signals. In mode 1, Port A and Port B use the lines on Port C to generate or accept these "handshaking" signals.

Mode 1 Basic functional Definitions:

- Two Groups (Group A and Group B).
- Each group contains one 8-bit data port and one 4-bit control/data port.
- The 8-bit data port can be either input or output Both inputs and outputs are latched.
- The 4-bit port is used for control and status of the 8-bit data port.

Input Control Signal Definition

$\overline{STB}$ (Strobe Input). A "low" on this input loads data into the input latch.

IBF (Input Buffer Full F/F)

A "high" on this output indicates that the data has been loaded into the input latch; in essence, an acknowledgement. IBF is set by $\overline{STB}$ input being low and is reset by the rising edge of the $\overline{RD}$ input.

INTR (Interrupt Request)

A "high" on this output can be used to interrupt the CPU when an input device is requesting service. INTR is set by the $\overline{STB}$ is a "one", IBF is a "one" and INTE is a "one". It is reset by the falling edge of $\overline{RD}$. This procedure allows an input device to request service from the CPU by simply strobing its data into the port.

INTE A

Controlled by bit set/reset of PC_4.

INTE B

Controlled by bit set/reset of PC_2.

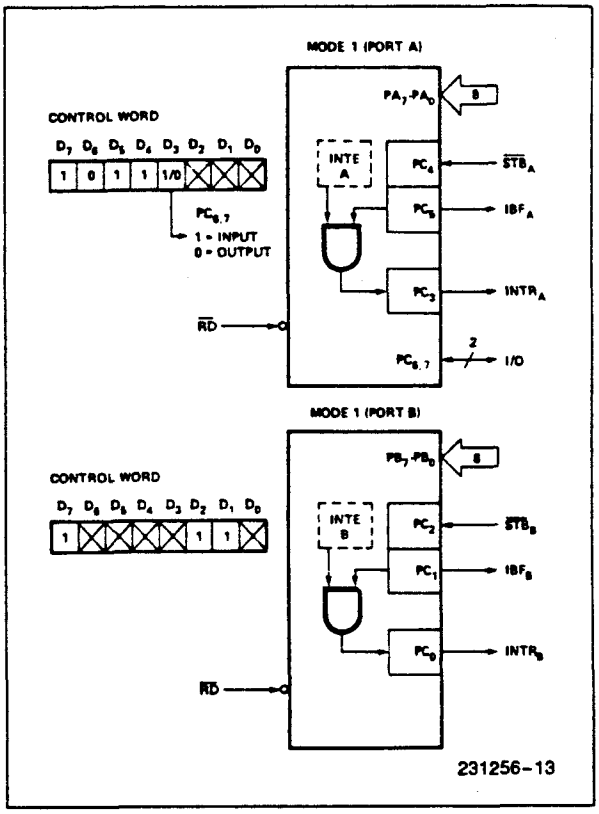


Figure 8. MODE 1 Input

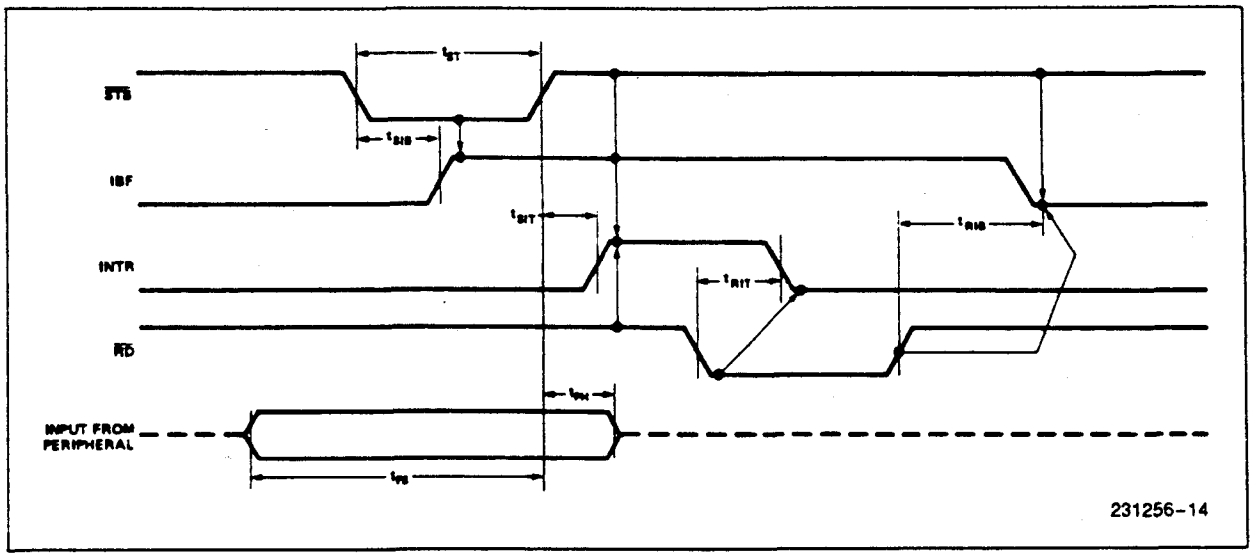


Figure 9. MODE 1 (Strobed Input)

Output Control Signal Definition

$\overline{OBF}$ (Output Buffer Full F/F). The $\overline{OBF}$ output will go "low" to indicate that the CPU has written data out to the specified port. The $\overline{OBF}$ F/F will be set by the rising edge of the $\overline{WR}$ input and reset by $\overline{ACK}$ Input being low.

$\overline{ACK}$ (Acknowledge Input). A "low" on this input informs the 82C55A that the data from Port A or Port B has been accepted. In essence, a response from the peripheral device indicating that it has received the data output by the CPU.

INTR (Interrupt Request). A "high" on this output can be used to interrupt the CPU when an output device has accepted data transmitted by the CPU. INTR is set when $\overline{ACK}$ is a "one", $\overline{OBF}$ is a "one" and INTE is a "one". It is reset by the falling edge of $\overline{WR}$.

INTE A

Controlled by bit set/reset of PC_6.

INTE B

Controlled by bit set/reset of PC_2.

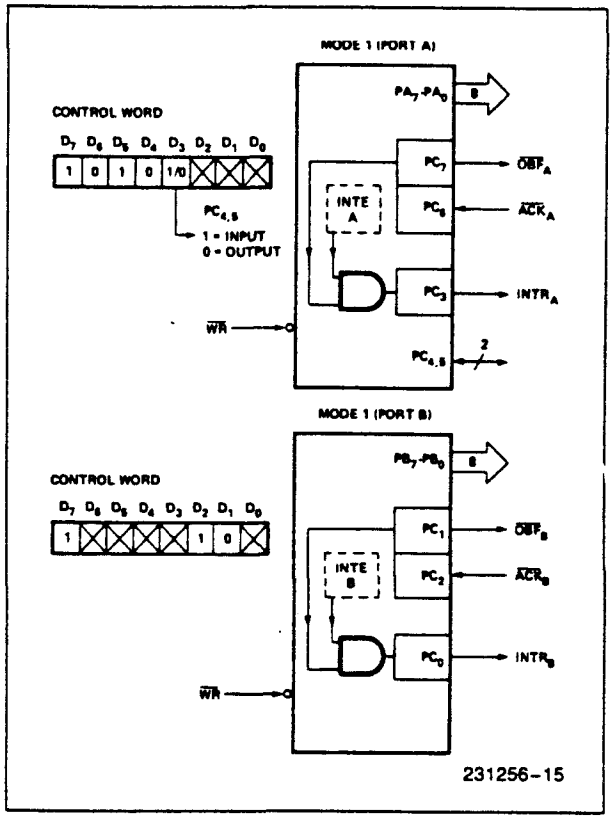


Figure 10. MODE 1 Output

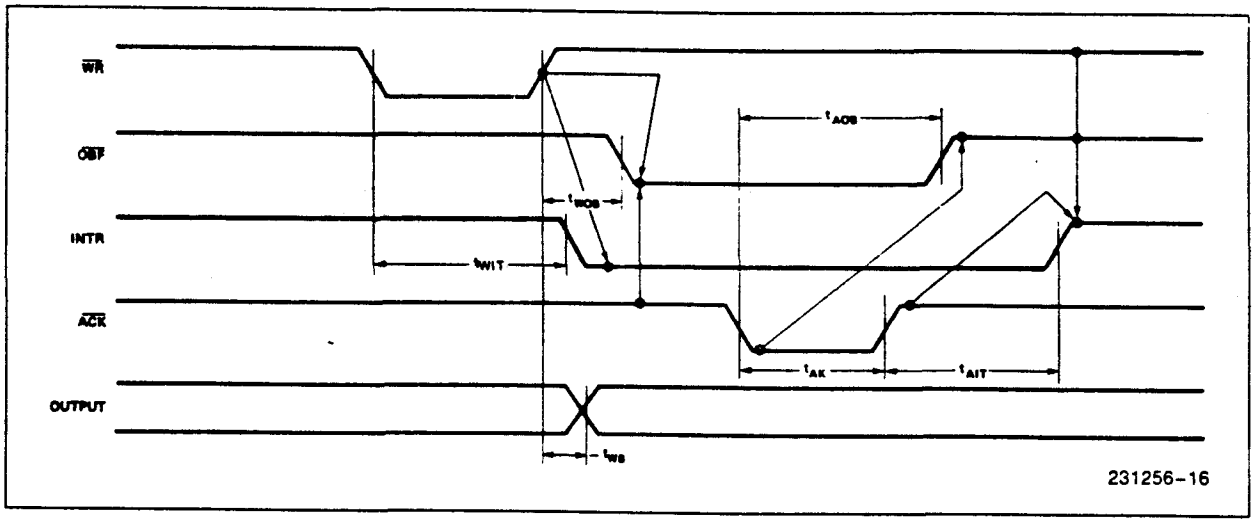


Figure 11. MODE 1 (Strobed Output)

Combinations of MODE 1

Port A and Port B can be individually defined as input or output in Mode 1 to support a wide variety of strobed I/O applications.

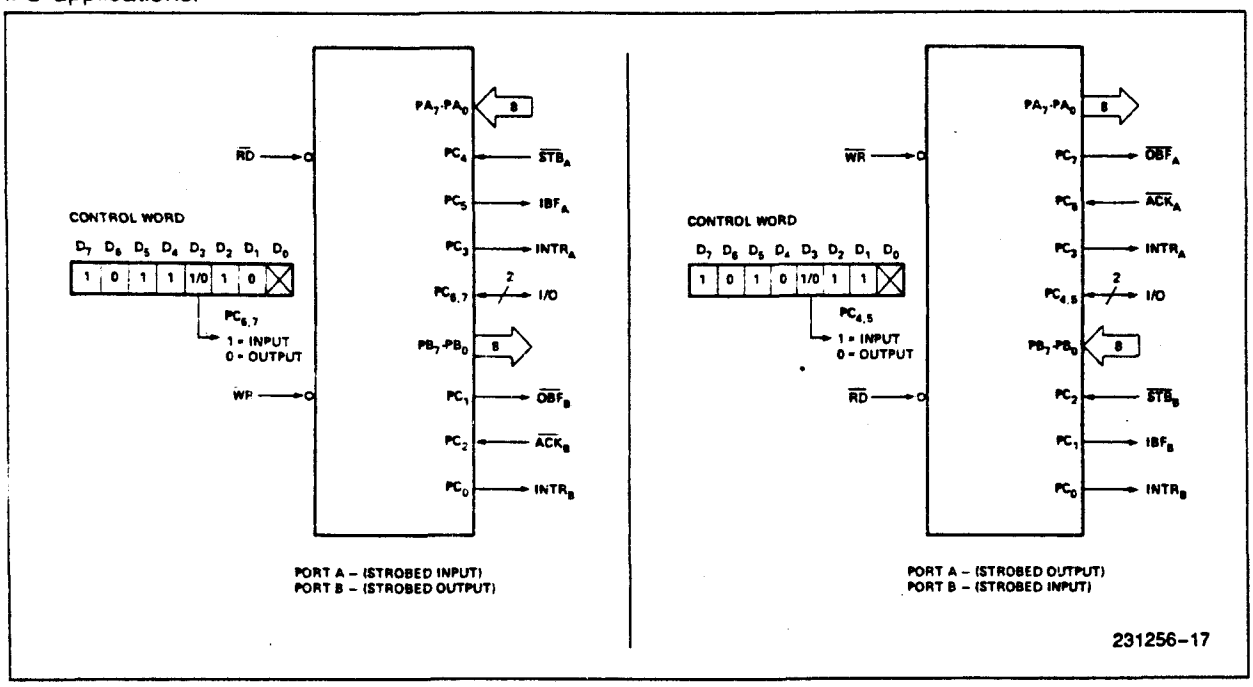


Figure 12. Combinations of MODE 1

Operating Modes

MODE 2 (Strobed Bidirectional Bus I/O). This functional configuration provides a means for communicating with a peripheral device or structure on a single 8-bit bus for both transmitting and receiving data (bidirectional bus I/O). "Handshaking" signals are provided to maintain proper bus flow discipline in a similar manner to MODE 1. Interrupt generation and enable/disable functions are also available.

MODE 2 Basic Functional Definitions:

- Used in Group A **only**.
- One 8-bit, bi-directional bus port (Port A) and a 5-bit control port (Port C).
- Both inputs and outputs are latched.
- The 5-bit control port (Port C) is used for control and status for the 8-bit, bi-directional bus port (Port A).

Bidirectional Bus I/O Control Signal Definition

INTR (Interrupt Request). A high on this output can be used to interrupt the CPU for input or output operations.

Output Operations

$\overline{OBF}$ (Output Buffer Full). The $\overline{OBF}$ output will go "low" to indicate that the CPU has written data out to port A.

$\overline{ACK}$ (Acknowledge). A "low" on this input enables the tri-state output buffer of Port A to send out the data. Otherwise, the output buffer will be in the high impedance state.

INTE 1 (The INTE Flip-Flop Associated with $\overline{OBF}$). Controlled by bit set/reset of PC_6.

Input Operations

$\overline{STB}$ (Strobe Input). A "low" on this input loads data into the input latch.

IBF (Input Buffer Full F/F). A "high" on this output indicates that data has been loaded into the input latch.

INTE 2 (The INTE Flip-Flop Associated with IBF). Controlled by bit set/reset of PC_4.

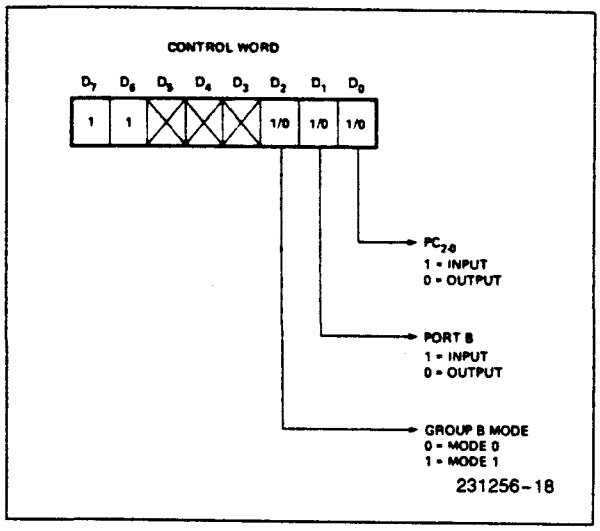


Figure 13. MODE Control Word

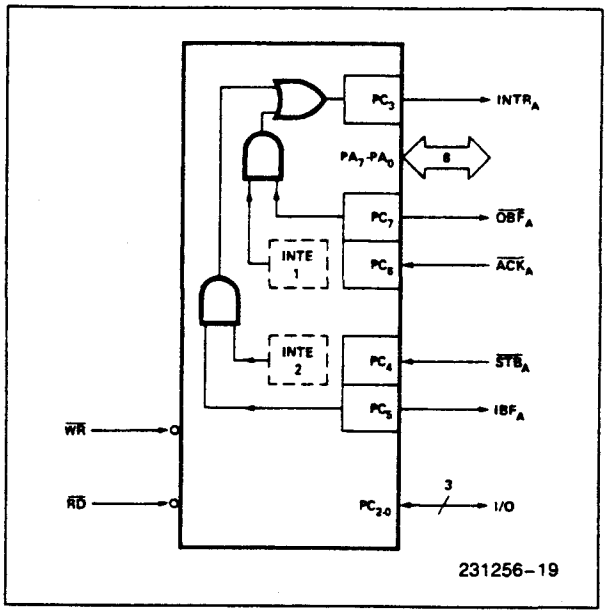


Figure 14. MODE 2

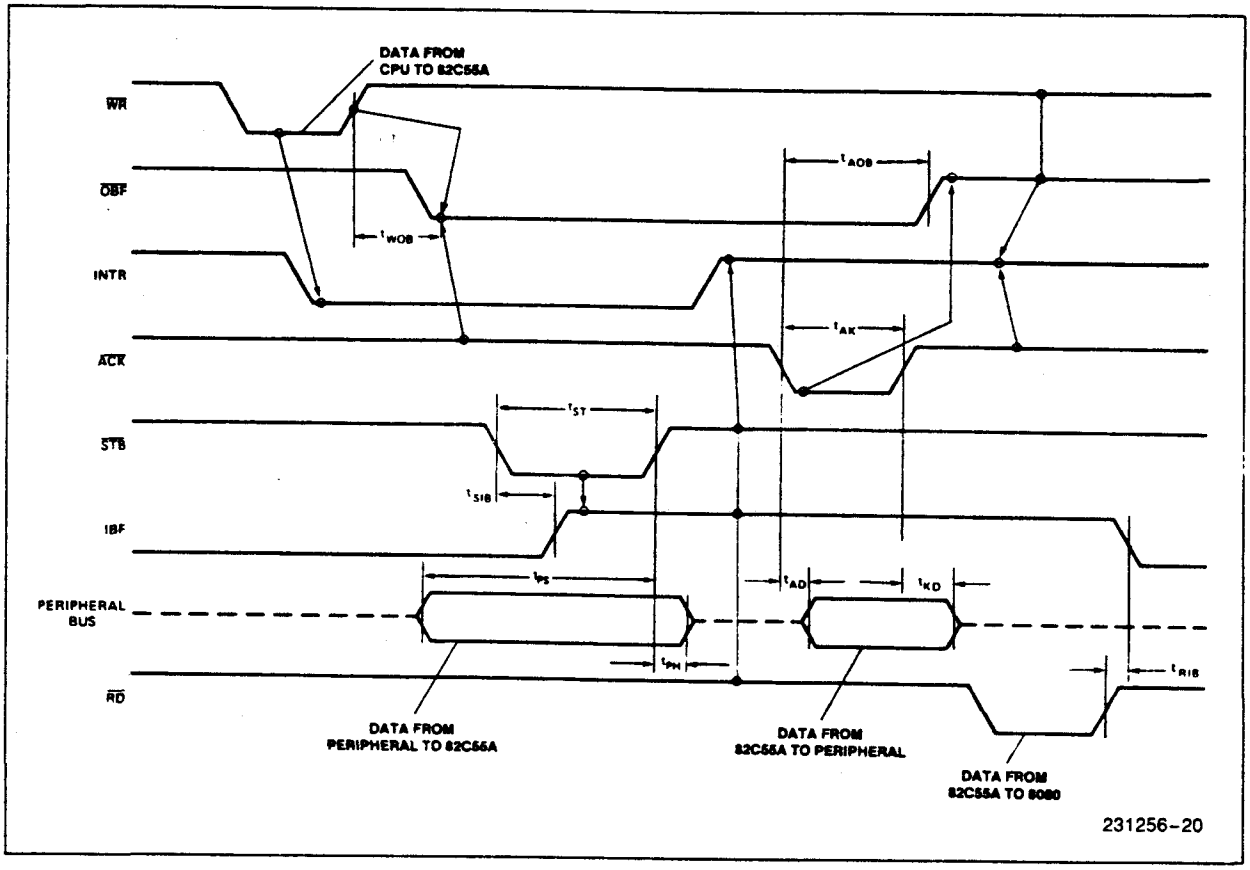


Figure 15. MODE 2 (Bidirectional)

NOTE:
Any sequence where $\overline{WR}$ occurs before $\overline{ACK}$, and $\overline{STB}$ occurs before $\overline{RD}$ is permissible.
($INTR = IBF \bullet \overline{MASK} \bullet \overline{STB} \bullet \overline{RD} + \overline{OBF} \bullet \overline{MASK} \bullet \overline{ACK} \bullet \overline{WR}$)

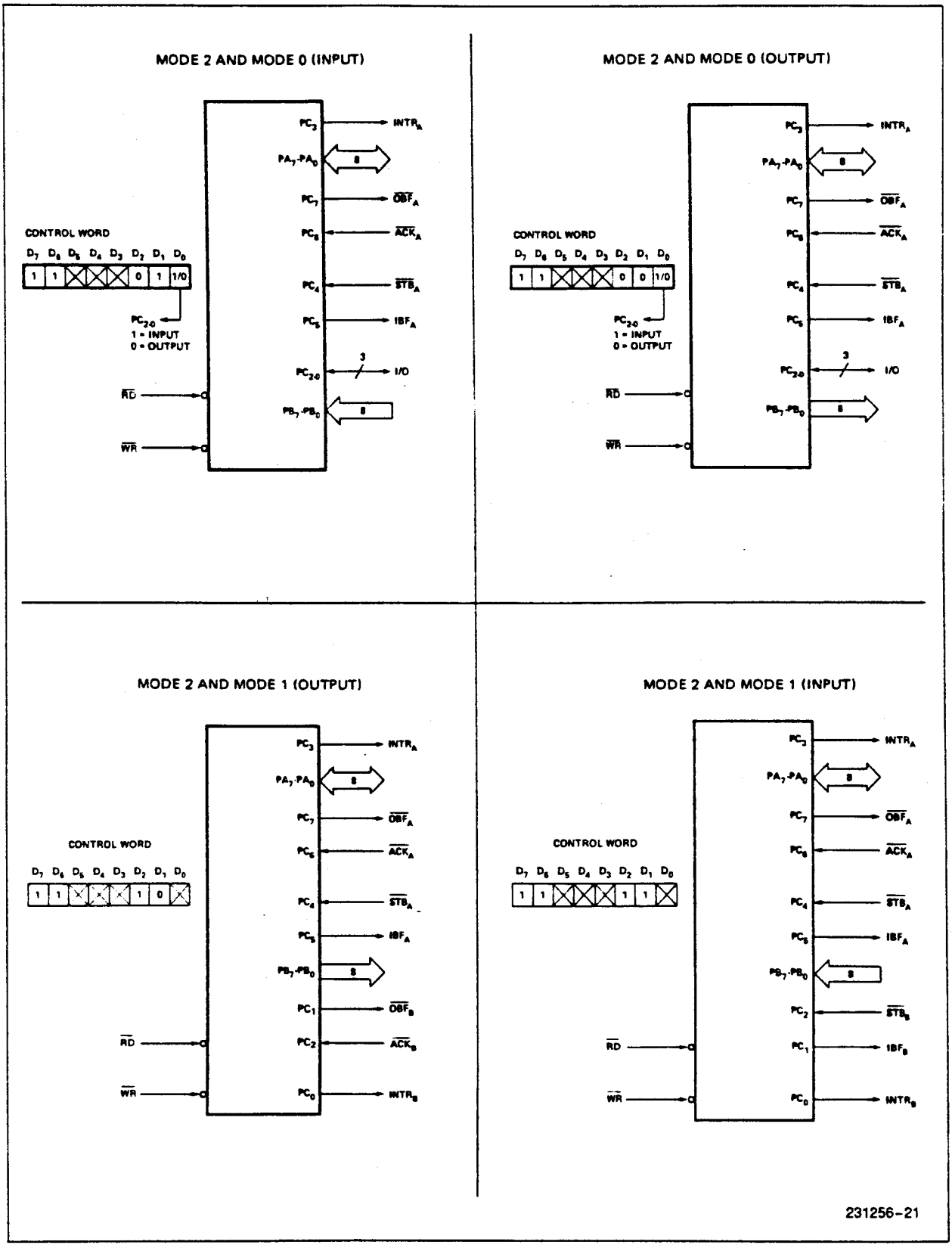


Figure 16. MODE ¼ Combinations

Mode Definition Summary

	MODE 0		MODE 1		MODE 2	
	IN	OUT	IN	OUT	GROUP A ONLY	
PA_0	IN	OUT	IN	OUT	↔	
PA_1	IN	OUT	IN	OUT	↔	
PA_2	IN	OUT	IN	OUT	↔	
PA_3	IN	OUT	IN	OUT	↔	
PA_4	IN	OUT	IN	OUT	↔	
PA_5	IN	OUT	IN	OUT	↔	
PA_6	IN	OUT	IN	OUT	↔	
PA_7	IN	OUT	IN	OUT	↔	
PB_0	IN	OUT	IN	OUT	—	MODE 0 OR MODE 1 ONLY
PB_1	IN	OUT	IN	OUT	—	
PB_2	IN	OUT	IN	OUT	—	
PB_3	IN	OUT	IN	OUT	—	
PB_4	IN	OUT	IN	OUT	—	
PB_5	IN	OUT	IN	OUT	—	
PB_6	IN	OUT	IN	OUT	—	
PB_7	IN	OUT	IN	OUT	—	
PC_0	IN	OUT	$INTR_B$	$INTR_B$	I/O	
PC_1	IN	OUT	IBF_B	$\overline{OBF}_B$	I/O	
PC_2	IN	OUT	$\overline{STB}_B$	$\overline{ACK}_B$	I/O	
PC_3	IN	OUT	$INTR_A$	$INTR_A$	$INTR_A$	
PC_4	IN	OUT	$\overline{STB}_A$	I/O	$\overline{STB}_A$	
PC_5	IN	OUT	IBF_A	I/O	IBF_A	
PC_6	IN	OUT	I/O	$\overline{ACK}_A$	$\overline{ACK}_A$	
PC_7	IN	OUT	I/O	$\overline{OBF}_A$	$\overline{OBF}_A$	

Special Mode Combination Considerations

There are several combinations of modes possible. For any combination, some or all of the Port C lines are used for control or status. The remaining bits are either inputs or outputs as defined by a "Set Mode" command.

During a read of Port C, the state of all the Port C lines, except the $\overline{ACK}$ and $\overline{STB}$ lines, will be placed on the data bus. In place of the $\overline{ACK}$ and $\overline{STB}$ line states, flag status will appear on the data bus in the PC2, PC4, and PC6 bit positions as illustrated by Figure 18.

Through a "Write Port C" command, only the Port C pins programmed as outputs in a Mode 0 group can be written. No other pins can be affected by a "Write Port C" command, nor can the interrupt enable flags be accessed. To write to any Port C output programmed as an output in a Mode 1 group or to change an interrupt enable flag, the "Set/Reset Port C Bit" command must be used.

With a "Set/Reset Port C Bit" command, any Port C line programmed as an output (including INTR, IBF and $\overline{OBF}$) can be written, or an interrupt enable flag can be either set or reset. Port C lines programmed as inputs, including $\overline{ACK}$ and $\overline{STB}$ lines, associated with Port C are not affected by a "Set/Reset Port C Bit" command. Writing to the corresponding Port C bit positions of the $\overline{ACK}$ and $\overline{STB}$ lines with the "Set/Reset Port C Bit" command will affect the Group A and Group B interrupt enable flags, as illustrated in Figure 18.

Current Drive Capability

Any output on Port A, B or C can sink or source 2.5 mA. This feature allows the 82C55A to directly drive Darlington type drivers and high-voltage displays that require such sink or source current.

Reading Port C Status

In Mode 0, Port C transfers data to or from the peripheral device. When the 82C55A is programmed to function in Modes 1 or 2, Port C generates or accepts "hand-shaking" signals with the peripheral device. Reading the contents of Port C allows the programmer to test or verify the "status" of each peripheral device and change the program flow accordingly.

There is no special instruction to read the status information from Port C. A normal read operation of Port C is executed to perform this function.

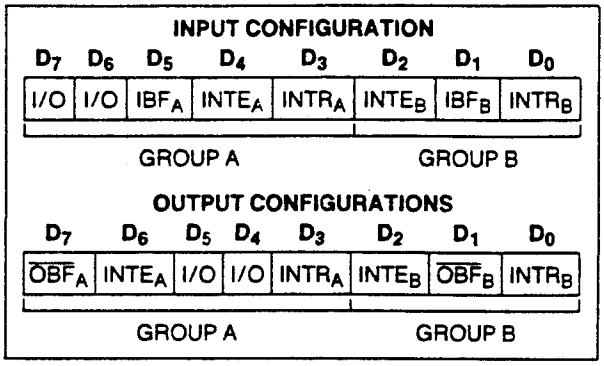


Figure 17a. MODE 1 Status Word Format

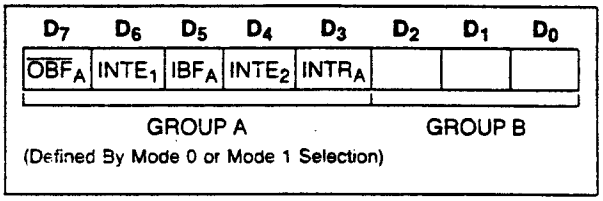


Figure 17b. MODE 2 Status Word Format

Interrupt Enable Flag	Position	Alternate Port C Pin Signal (Mode)
INTE B	PC2	$\overline{ACK}_B$ (Output Mode 1) or $\overline{STB}_B$ (Input Mode 1)
INTE A2	PC4	$\overline{STB}_A$ (Input Mode 1 or Mode 2)
INTE A1	PC6	$\overline{ACK}_A$ (Output Mode 1 or Mode 2

Figure 18. Interrupt Enable Flags in Modes 1 and 2

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias....0°C to + 70°C
Storage Temperature .....− 65°C to + 150°C
Supply Voltage .....− 0.5 to + 8.0V
Operating Voltage .....+ 4V to + 7V
Voltage on any Input.....GND−2V to + 6.5V
Voltage on any Output ..GND−0.5V to V_{CC} + 0.5V
Power Dissipation .....1 Watt

**Notice: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. CHARACTERISTICS

T_A = 0°C to 70°C, V_{CC} = +5V ±10%, GND = 0V (T_A = −40°C to +85°C for Extended Temperture)

Symbol	Parameter	Min	Max	Units	Test Conditions
V_{IL}	Input Low Voltage	−0.5	0.8	V	
V_{IH}	Input High Voltage	2.0	V_{CC}	V	
V_{OL}	Output Low Voltage		0.4	V	I_{OL} = 2.5 mA
V_{OH}	Output High Voltage	3.0 V_{CC} − 0.4		V V	I_{OH} = −2.5 mA I_{OH} = −100 μA
I_{IL}	Input Leakage Current		±1	μA	V_{IN} = V_{CC} to 0V (Note 1)
I_{OFL}	Output Float Leakage Current		±10	μA	V_{IN} = V_{CC} to 0V (Note 2)
I_{DAR}	Darlington Drive Current	±2.5	(Note 4)	mA	Ports A, B, C R_{ext} = 500Ω V_{ext} = 1.7V
I_{PHL}	Port Hold Low Leakage Current	+50	+300	μA	V_{OUT} = 1.0V Port A only
I_{PHH}	Port Hold High Leakage Current	−50	−300	μA	V_{OUT} = 3.0V Ports A, B, C
I_{PHLO}	Port Hold Low Overdrive Current	−350		μA	V_{OUT} = 0.8V
I_{PHHO}	Port Hold High Overdrive Current	+350		μA	V_{OUT} = 3.0V
I_{CC}	V_{CC} Supply Current		10	mA	(Note 3)
I_{CCSB}	V_{CC} Supply Current-Standby		10	μA	V_{CC} = 5.5V V_{IN} = V_{CC} or GND Port Conditions If I/P = Open/High O/P = Open Only With Data Bus = High/Low $\overline{CS}$ = High Reset = Low Pure Inputs = Low/High

NOTES:
1. Pins A_1, A_0, $\overline{CS}$, $\overline{WR}$, $\overline{RD}$, Reset.
2. Data Bus; Ports B, C.
3. Outputs open.
4. Limit output current to 4.0 mA.

CAPACITANCE

T_A = 25°C, V_{CC} = GND = 0V

Symbol	Parameter	Min	Max	Units	Test Conditions
C_{IN}	Input Capacitance		10	pF	Unmeasured pins returned to GND f_c = 1 MHz(5)
$C_{I/O}$	I/O Capacitance		20	pF	

NOTE:
5. Sampled not 100% tested.

A.C. CHARACTERISTICS

T_A = 0° to 70°C, V_{CC} = +5V ±10%, GND = 0V

T_A = −40°C to +85°C for Extended Temperature

BUS PARAMETERS

READ CYCLE

Symbol	Parameter	82C55A-2		Units	Test Conditions
		Min	Max		
t_{AR}	Address Stable Before $\overline{RD}\downarrow$	0		ns	
t_{RA}	Address Hold Time After $\overline{RD}\uparrow$	0		ns	
t_{RR}	$\overline{RD}$ Pulse Width	150		ns	
t_{RD}	Data Delay from $\overline{RD}\downarrow$		120	ns	
t_{DF}	$\overline{RD}\uparrow$ to Data Floating	10	75	ns	
t_{RV}	Recovery Time between $\overline{RD}/\overline{WR}$	200		ns	

WRITE CYCLE

Symbol	Parameter	82C55A-2		Units	Test Conditions
		Min	Max		
t_{AW}	Address Stable Before $\overline{WR}\downarrow$	0		ns	
t_{WA}	Address Hold Time After $\overline{WR}\uparrow$	20		ns	Ports A & B
		20		ns	Port C
t_{WW}	$\overline{WR}$ Pulse Width	100		ns	
t_{DW}	Data Setup Time Before $\overline{WR}\uparrow$	100		ns	
t_{WD}	Data Hold Time After $\overline{WR}\uparrow$	30		ns	Ports A & B
		30		ns	Port C

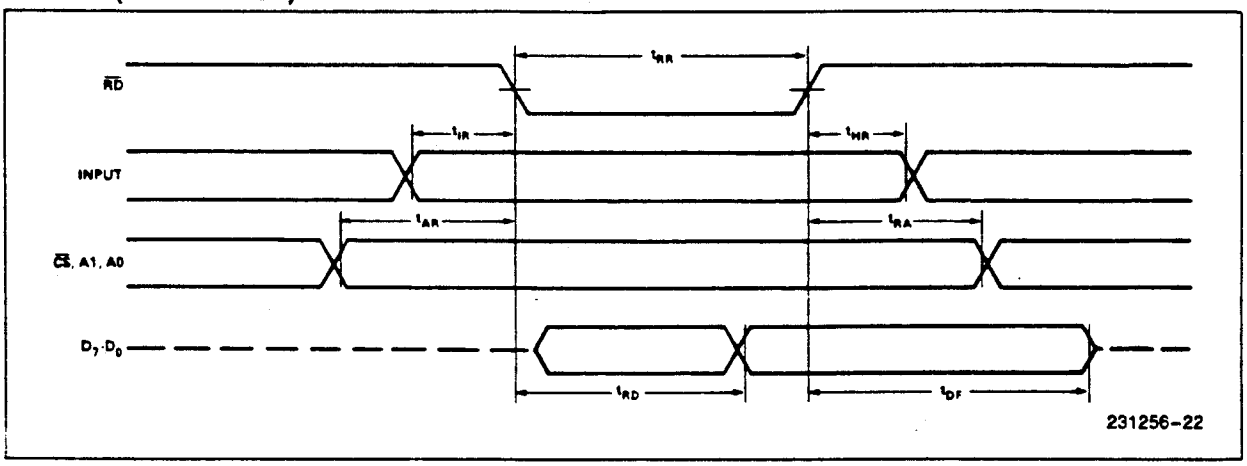
OTHER TIMINGS

Symbol	Parameter	82C55A-2		Units Conditions	Test
		Min	Max		
t_{WB}	$\overline{WR}$ = 1 to Output		350	ns	
t_{IR}	Peripheral Data Before $\overline{RD}$	0		ns	
t_{HR}	Peripheral Data After $\overline{RD}$	0		ns	
t_{AK}	$\overline{ACK}$ Pulse Width	200		ns	
t_{ST}	$\overline{STB}$ Pulse Width	100		ns	
t_{PS}	Per. Data Before $\overline{STB}$ High	20		ns	
t_{PH}	Per. Data After $\overline{STB}$High	50		ns	
t_{AD}	$\overline{ACK}$ = 0 to Output		175	ns	
t_{KD}	$\overline{ACK}$ = 1 to Output Float	20	250	ns	
t_{WOB}	$\overline{WR}$ = 1 to $\overline{OBF}$ = O		150	ns	
t_{AOB}	$\overline{ACK}$ = 0 to $\overline{OBF}$ = 1		150	ns	
t_{SIB}	$\overline{STB}$ = 0 to IBF = 1		150	ns	
t_{RIB}	$\overline{RD}$ = 1 to IBF = 0		150	ns	
t_{RIT}	$\overline{RD}$ = 0 to INTR = 0		200	ns	
t_{SIT}	$\overline{STB}$ = 1 to INTR = 1		150	ns	
t_{AIT}	$\overline{ACK}$ = 1 to INTR = 1		150	ns	
t_{WIT}	$\overline{WR}$ = 0 to INTR = 0		200	ns	see note 1
t_{RES}	Reset Pulse Width	500		ns	see note 2

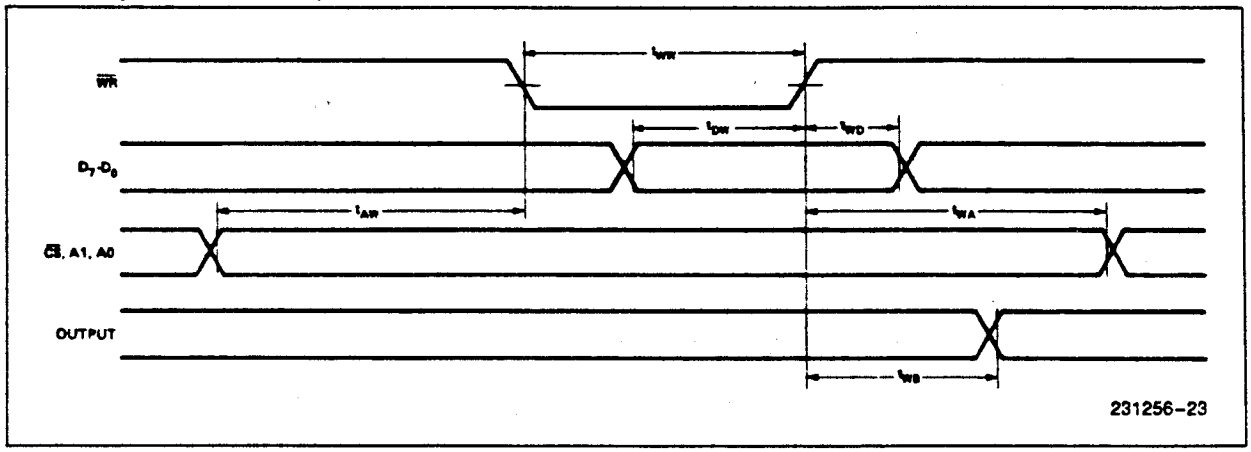
NOTE:
1. INTR ↑ may occur as early as $\overline{WR}$ ↓.
2. Pulse width of initial Reset pulse after power on must be at least 50 μSec. Subsequent Reset pulses may be 500 ns minimum.

WAVEFORMS

MODE 0 (BASIC INPUT)

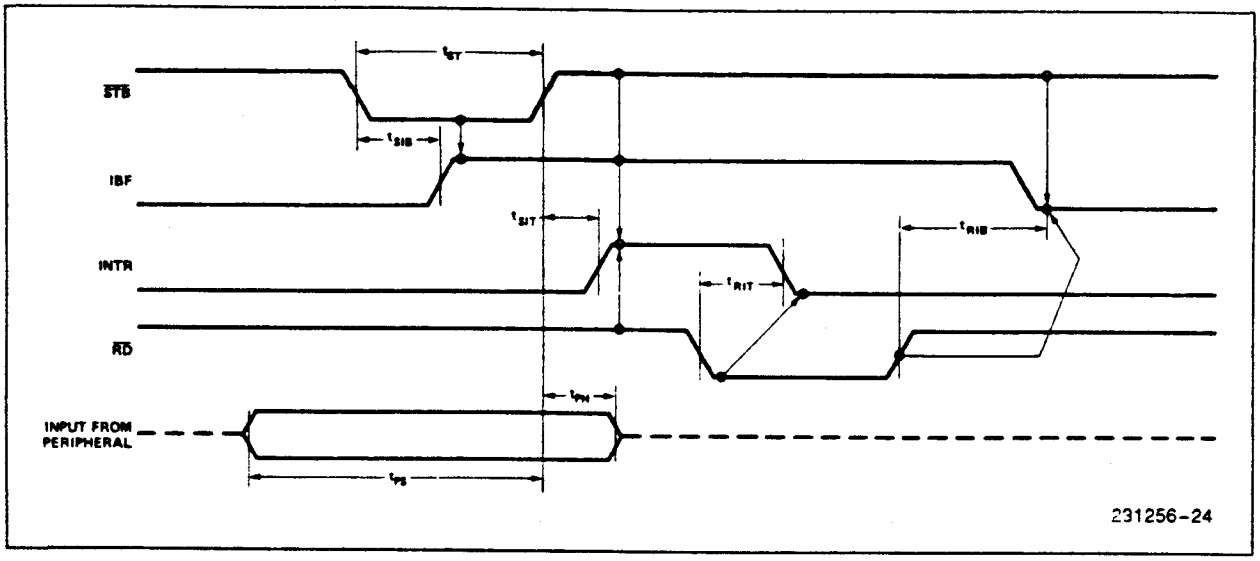


MODE 0 (BASIC OUTPUT)

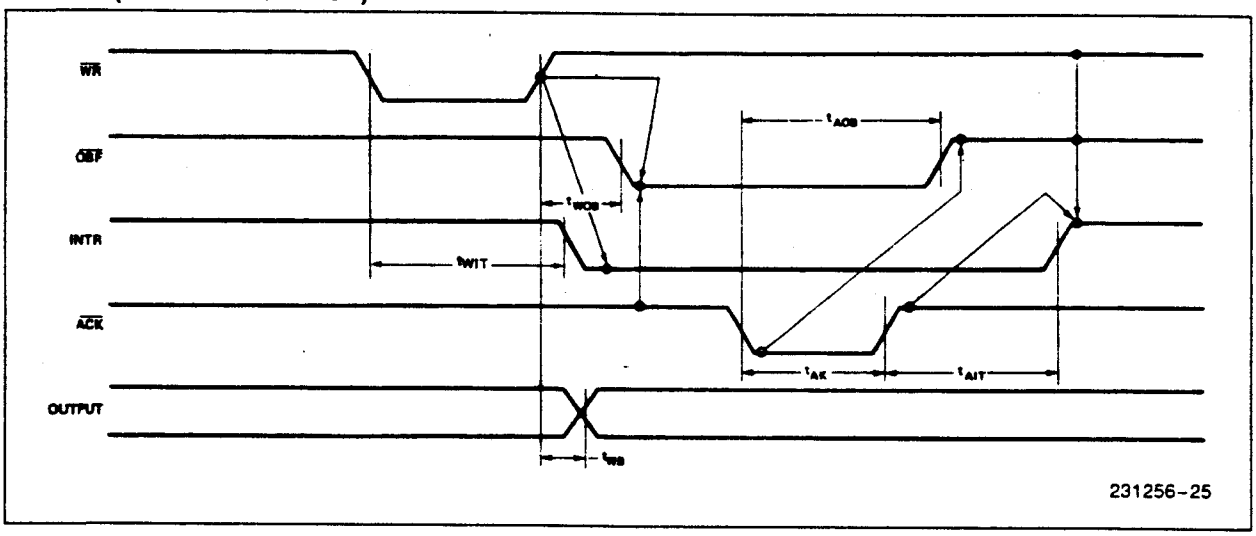


WAVEFORMS (Continued)

MODE 1 (STROBED INPUT)

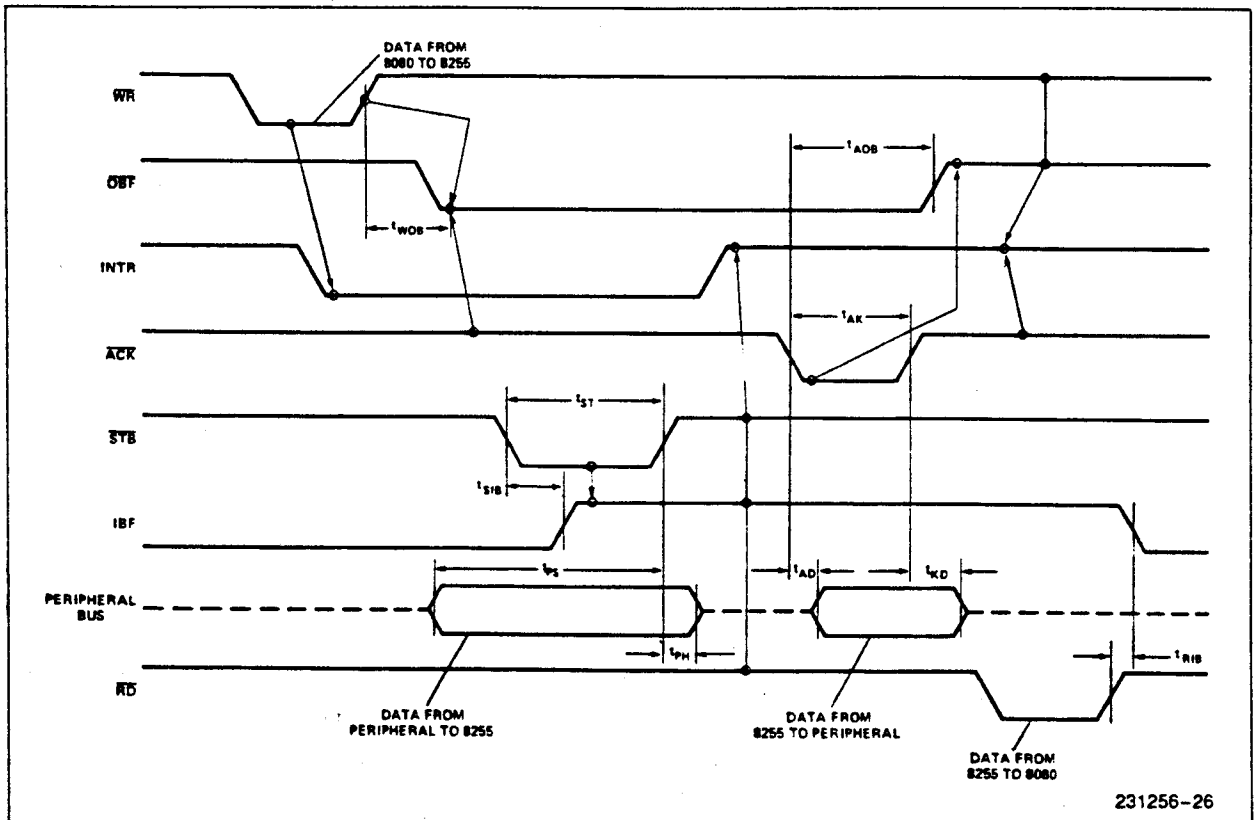


MODE 1 (STROBED OUTPUT)



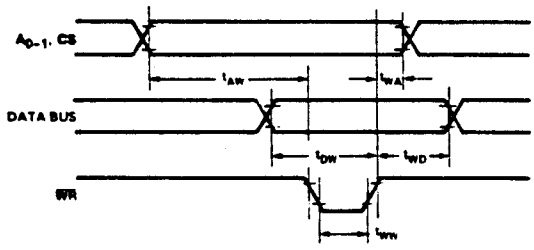
WAVEFORMS (Continued)

MODE 2 (BIDIRECTIONAL)

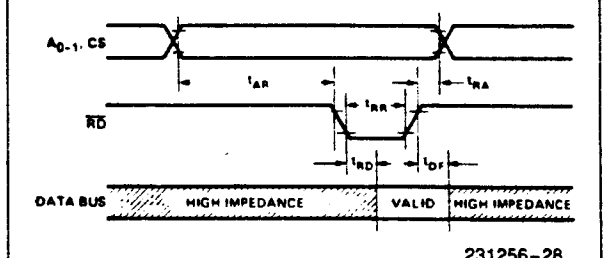


Note:
Any sequence where $\overline{WR}$ occurs before $\overline{ACK}$ AND $\overline{STB}$ occurs before $\overline{RD}$ is permissible.
(INTR = IBF • $\overline{MASK}$ • $\overline{STB}$ • $\overline{RD}$ + $\overline{OBF}$ • $\overline{MASK}$ • $\overline{ACK}$ • $\overline{WR}$)

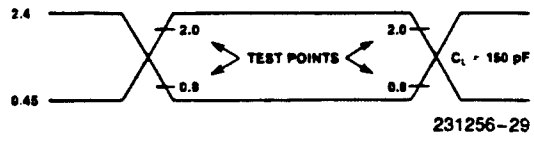
WRITE TIMING



READ TIMING

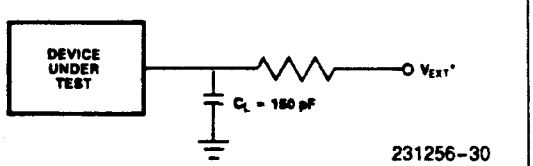


A.C. TESTING INPUT, OUTPUT WAVEFORM



A.C. Testing Inputs Are Driven At 2.4V For A Logic 1 And 0.45V For A Logic 0 Timing Measurements Are Made At 2.0V For A Logic 1 And 0.8 For A Logic 0.

A.C. TESTING LOAD CIRCUIT



*V_{EXT} Is Set At Various Voltages During Testing To Guarantee The Specification. C_L Includes Jig Capacitance.

APPENDIX D

CONFIGURING THE AD1000 FOR SIGNAL*MATH

Jumper Settings

When running SIGNAL*MATH, you may need to change some of the AD1000's on-board jumpers from their current positions. Before using SIGNAL*MATH on the AD1000 board, check the following jumpers:

- P6 — Base address
- P5 — 8254 timer/counter I/O configuration
- P2, P3 & P4 — Interrupts
- P8 — End-of-convert monitor

The board layout is shown in Figure D-1.

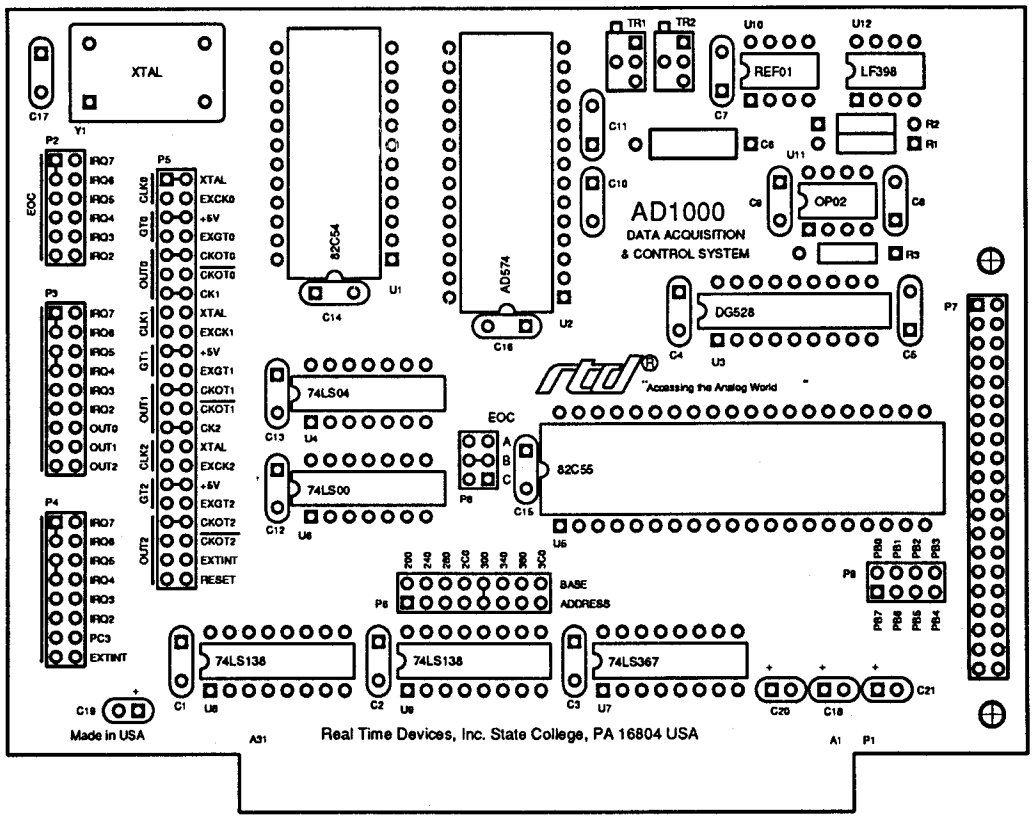


Fig. D-1 — AD1000 Board Layout

P6 — Base Address

SIGNAL*MATH assumes that the base address of your AD1000 is the factory setting of 300 hex (768 decimal). If you change this setting, you **must** run the ADAINST program and reset the base address.

NOTE: When using the ADAINST program, you can enter the base address in decimal or hexadecimal notation. When entering a hex value, you must precede the number by a dollar sign (for example, $300).

P5 — 8254 Timer/Counter I/O Configuration

The 8254 must be configured with the jumpers placed between the pins as shown in Figure D-2. This is the factory setting. Verify that each jumper is in the proper location. Any remaining jumpers must be removed from the P5 header connector.

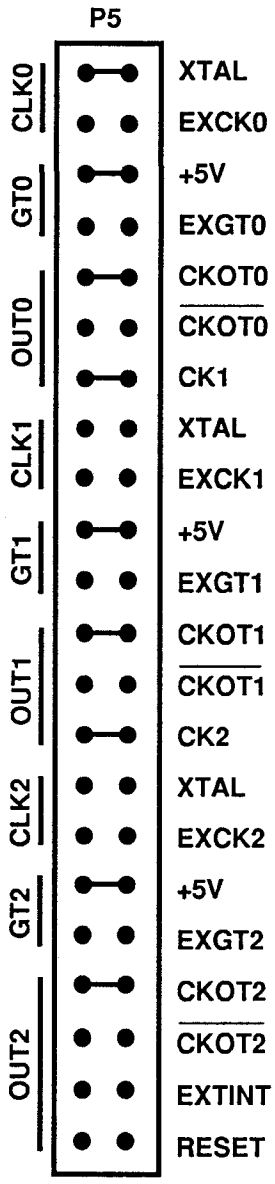


Fig. D-2 — 8254 Timer/Counter Jumpers, P5

P2, P3 & P4 — Interrupts

To select IRQ channels and interrupt sources for SIGNAL*MATH, you must install one jumper on P2 and two jumpers on P3. First, install a jumper on the end-of-convert interrupt header, P2, across the pins of your desired IRQ channel. Then, install a jumper on P3-OUT2, and a second jumper across the pair of P3 pins for the IRQ channel you select.The IRQ selected on P3 **must be different from** the IRQ set on P2! Figure D-3 shows EOC jumpered to IRQ3 and OUT2 jumpered to IRQ4. Make sure that no jumpers are installed on P4.

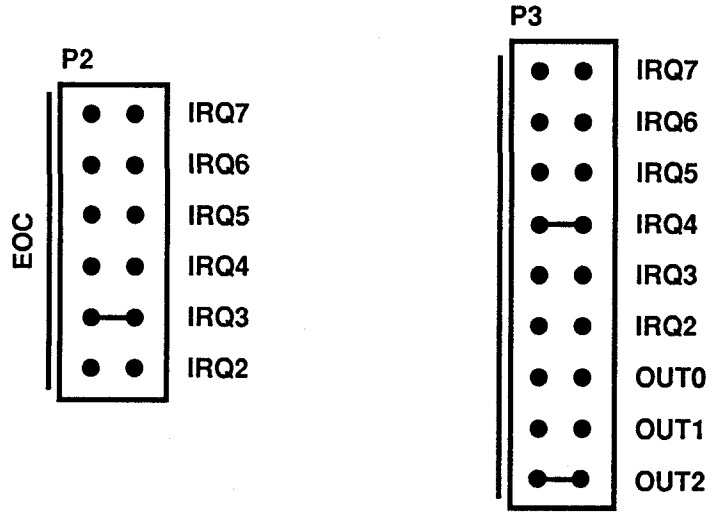


Fig. D-3 — End-of-Convert Interrupt & Timer/Counter Out Jumpers, P2 & P3

P8 — End-of-Convert Monitor

When running SIGNAL*MATH, place a jumper between EOC and PB7, as shown in Figure D-4.

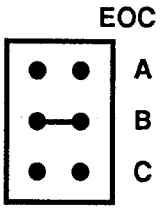


Fig. D-4 — End-of-Convert Jumper, P8

Running ADAINST

After the jumpers are set and the AD1000 board is installed in the computer, you are ready to configure SIGNAL*MATH so that it is compatible with your board's settings. This is done by running the ADAINST driver installation program. After running the program, open AD1000.EXE from the *Open a File* menu. You will see a screen similar to the screen shown in Figure D-5 below. The factory default settings are shown in the illustration. Your settings may or may not match the default settings, depending on whether you have made changes to these settings before.

Base Address. The board's base address setting is entered in the upper right block, as shown in the diagram. The factory setting for all Real Time Devices boards is 300 hex (768 decimal). The base address can be entered as a decimal or hexadecimal value (hex values must be preceded by a dollar sign (for example, $300)). Refer to your board's manual if you need help in determining the correct value to enter.

EOC IT (End-of-Convert Interrupt). In this block, enter the IRQ channel number which corresponds to your jumper setting on P2.

Timer IT (Timer/Counter Interrupt). In this block, enter the IRQ channel number which corresponds to your jumper setting on P3.

LabTech SW IT (Labtech Notebook Software Interrupt). This sets the software interrupt address where Labtech Notebook's rtdLinx/NB-1000 driver is installed. The factory setting is $60. This setting can be ignored when running SIGNAL*MATH.

A/D Parameters. Six A/D board parameters are listed: resolution, number of channels, active DMA channel, gain, loss, and input voltage polarity.

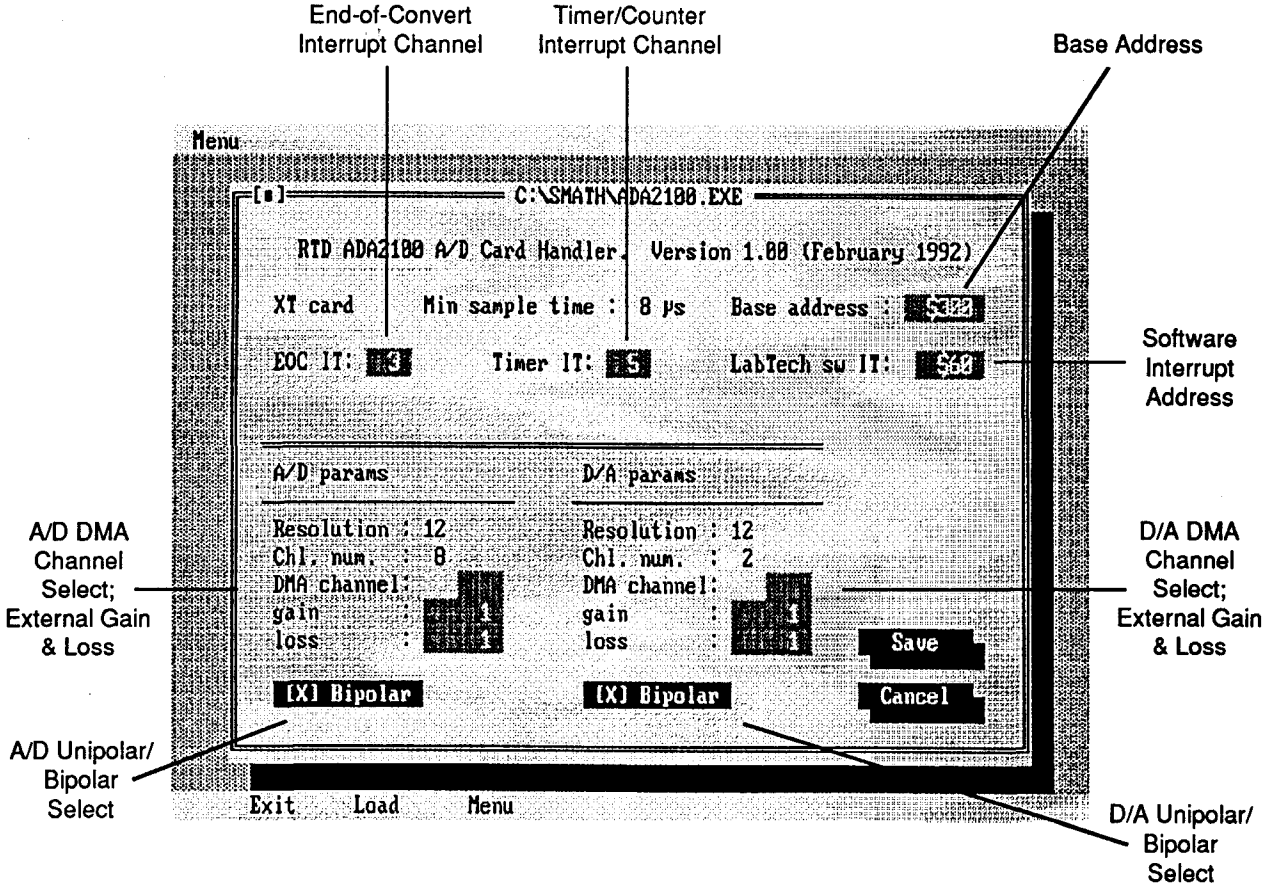


Fig. D-5 — ADAINST.EXE Screen

Resolution and number of channels are fixed by the program for your board.

The DMA channel number block is not valid on the AD1000, and should be left blank.

The next two blocks, gain and loss, are provided so that you can make adjustments for **external gain or loss. If** your input signal is externally attenuated, then you can adjust for this by setting a value other than 1 for loss. If you have an external gain factor, then you can adjust for this condition. Numbers must be entered as whole decimal values. The factory default setting for gain and loss is 1.

Since the input range for the AD1000 is ±5 volts, an X should be placed before Bipolar on the screen (default setting).

D/A Parameters. These settings are not applicable to the AD1000.

APPENDIX E

CONFIGURING THE AD1000 FOR ATLANTIS

If you have purchased ATLANTIS data acquisition and real-time monitoring application software for your AD1000, please note that the ATLANTIS drivers for your board must be loaded from the driver disk into the same directory as the ATLANTIS.EXE program. When running the ATLANTIS data acquisition software you may need to change some of the AD1000's on-board jumpers from their current positions. Before using ATLANTIS on the AD1000 board, check the following jumpers:

- P6 — Base address
- P5 — 8254 timer/counter I/O configuration
- P3 — Timer/counter output interrupt
- P8 — End-of-convert monitor

Figure E-1 shows the board layout.

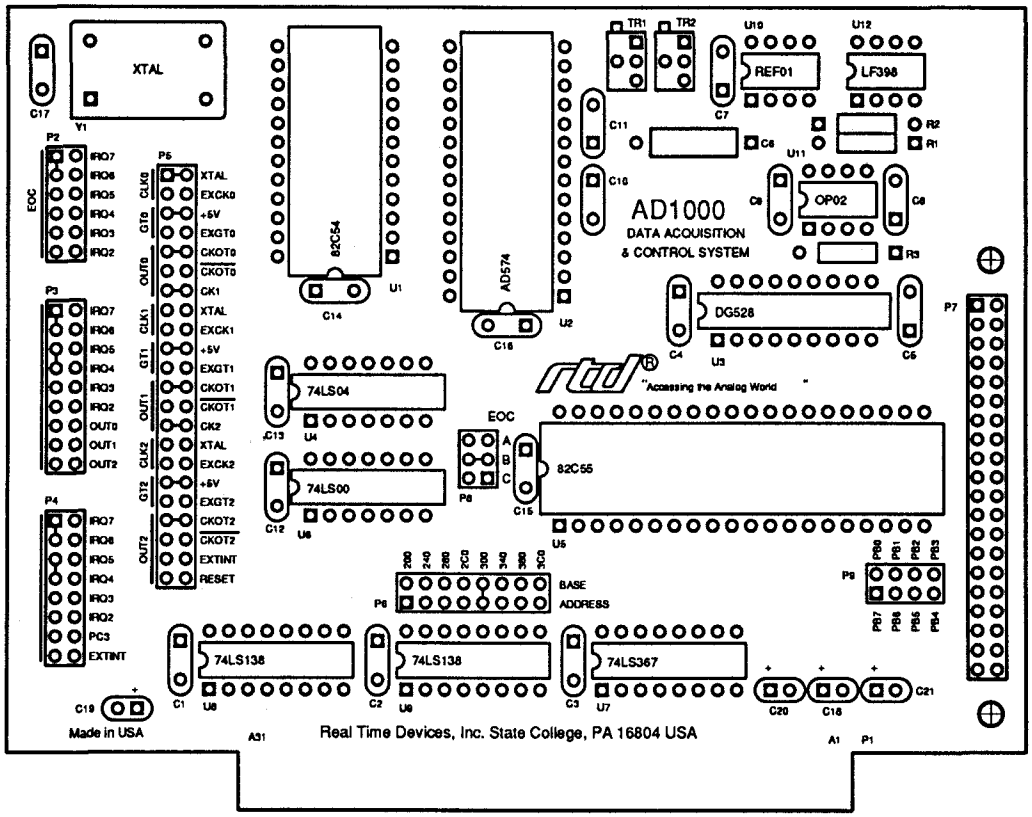


Fig. E-1 — AD1000 Board Layout

P6 — Base Address

ATLANTIS assumes that the base address of your AD1000 is the factory setting of 300 hex (see Chapter 1). If you changed this setting, you **must** run the ATINST program and reset the base address.

NOTE: The base addresses on the AD1000 board are given in hexadecimal. The ATINST program requires the base address to be entered in **decimal** notation. The following table provides the hex and decimal values.

Hexadecimal	Decimal
200	512
240	576
280	640
2C0	704
300	768
340	832
380	896
3C0	960

P5 — 8254 Timer/Counter I/O Configuration

The 8254 must be configured with the jumpers placed between the pins as shown in Figure E-2. This is the factory setting. Verify that each jumper is in the proper location. Any remaining jumpers must be removed from the P5 header connector.

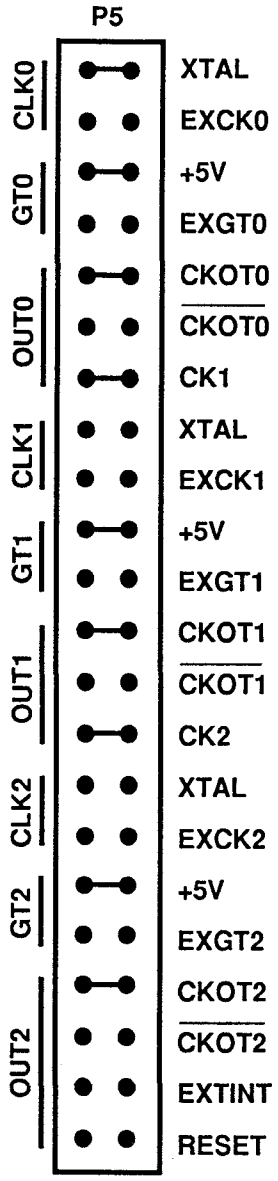


Fig. E-2 — 8254 TimerCounter Jumpers for ATLANTIS, P5

P3 — Timer/Counter Output Interrupt

To select an IRQ channel and an interrupt source, you must install the two jumpers which are stored on this header connector. To configure this header for ATLANTIS, place one jumper across the pins of your desired IRQ channel, and place the second jumper across the pins of OUT2, the output from timer/counter 2 in the 8254. Make certain that there are no other jumpers on this connector and that there are no jumpers installed across the pins on P2 or P4 (the factory setting for all interrupt jumpers is disabled, as shown in Chapter 1). Also, make sure that the IRQ channel you have selected is not used by any other device in your system. Figure E-3 shows you how to configure P3 for IRQ channel 4.

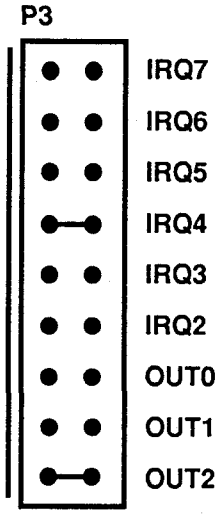


Fig. E-3 — 8254 Timer/Counter Output Interrupt Jumpers for ATLANTIS, P3

P8 — End-of-Convert Monitor

The end-of-convert signal is monitored through PB7 when using ATLANTIS. The factory setting of this connector is PB7, the middle set of pins on P8, as shown in Figure E-4. If the factory setting has been changed, place the jumper across the pins for PB7.

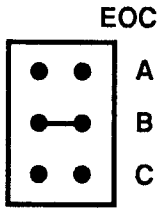


Fig. E-4 — End-of-Convert Jumper, P8

APPENDIX F

WARRANTY

LIMITED WARRANTY

Real Time Devices, Inc. warrants the hardware and software products it manufactures and produces to be free from defects in materials and workmanship for one year following the date of shipment from REAL TIME DEVICES. This warranty is limited to the original purchaser of product and is not transferable.

During the one year warranty period, REAL TIME DEVICES will repair or replace, at its option, any defective products or parts at no additional charge, provided that the product is returned, shipping prepaid, to REAL TIME DEVICES. All replaced parts and products become the property of REAL TIME DEVICES. **Before returning any product for repair, customers are required to contact the factory for an RMA number.**

THIS LIMITED WARRANTY DOES NOT EXTEND TO ANY PRODUCTS WHICH HAVE BEEN DAMAGED AS A RESULT OF ACCIDENT, MISUSE, ABUSE (such as: use of incorrect input voltages, improper or insufficient ventilation, failure to follow the operating instructions that are provided by REAL TIME DEVICES, "acts of God" or other contingencies beyond the control of REAL TIME DEVICES), OR AS A RESULT OF SERVICE OR MODIFICATION BY ANYONE OTHER THAN REAL TIME DEVICES. EXCEPT AS EXPRESSLY SET FORTH ABOVE, NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND REAL TIME DEVICES EXPRESSLY DISCLAIMS ALL WARRANTIES NOT STATED HEREIN. ALL IMPLIED WARRANTIES, INCLUDING IMPLIED WARRANTIES FOR MECHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED TO THE DURATION OF THIS WARRANTY. IN THE EVENT THE PRODUCT IS NOT FREE FROM DEFECTS AS WARRANTED ABOVE, THE PURCHASER'S SOLE REMEDY SHALL BE REPAIR OR REPLACEMENT AS PROVIDED ABOVE. UNDER NO CIRCUMSTANCES WILL REAL TIME DEVICES BE LIABLE TO THE PURCHASER OR ANY USER FOR ANY DAMAGES, INCLUDING ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES, EXPENSES, LOST PROFITS, LOST SAVINGS, OR OTHER DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PRODUCT.

SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES FOR CONSUMER PRODUCTS, AND SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS, SO THE ABOVE LIMITATIONS OR EXCLUSIONS MAY NOT APPLY TO YOU.

THIS WARRANTY GIVES YOU SPECIFIC LEGAL RIGHTS, AND YOU MAY ALSO HAVE OTHER RIGHTS WHICH VARY FROM STATE TO STATE.

AD1000 Board User-Selected Settings	
Base I/O Address:	
(hex)	(decimal)
IRQ Channel Selected:	
P2 — A/D End-of-Convert	IRQ Channel #:
P3 — 8254 Timer/Counter Out	IRQ Channel #:
P4 — External Interrupt/PC3	IRQ Channel #:
End-of-Convert PPI Monitor Bit Selected:	
A/D End-of-Convert	PPI Bit #: (PA7, PB7, or PC7)