AMPLICON
200 SERIES

PC215E

PROGRAMMABLE DIGITAL INPUT/OUTPUT AND COUNTER/TIMER BOARD

This Instruction Manual is supplied with the PC215E to provide the user with sufficient information to utilise the purchased product in a proper and efficient manner. The information contained has been reviewed and is believed to be accurate and reliable, however **Amplicon Liveline Limited** accepts no responsibility for any problems caused by errors or omissions. Specifications and instructions are subject to change without notice.

PC215E Instruction Manual Part Nº 85 956 294 Issue A3

Prepared by Jonathan East

Approved for issue by A.S. Gorbold, Operations Director

DECLARATION OF CONFORMITY

AMPLICON LIVELINE LIMITED
CENTENARY INDUSTRIAL ESTATE
HOLLINGDEAN ROAD
BRIGHTON BN2 4AW UK

We declare that the product(s) described in this Instruction Manual perform in conformity with the following standards or standardisation documents:

Electro Magnetic Compatibility (EMC):

EMC Directive	89/336/EEC
LVD Directive	73/23/EEC
CE Directive	93/68/EEC

Jim Hicks, I.Eng, FIEIE
Managing Director
Amplicon Liveline Limited

PROGRAMMABLE DIGITAL I/O AND COUNTER/TIMER BOARD

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1. INTRODUCTION

1.1 The Amplicon 200 Series

The **Amplicon 200 Series** of Personal Computer based data acquisition products provides very high performance, affordable hardware with comprehensive software support. The 200 Series is designed for users requiring fast or complex data input/output to the host PC and comprises a range of boards and software to handle most analog and digital signal types.

When a large scale system is required, multiple boards can be added from the 200 Series without conflict. The capacity of the PC mounted hardware can be extended by external expansion panels to provide a comprehensive system with low cost per channel and maintained high performance.

1.2 The 200 Series Digital I/O Counter/Timer Family

The family of 200 Series digital input/output products may be configured in a variety of ways to provide flexible, expansible systems.

Five digital input/output boards with timer/counter facilities are offered. These five boards are complemented by four external panels for signal conditioning and user connection through individual terminals. Support and demonstration software for all variants is offered.

A full, itemised list of hardware products is shown below, and a configurator diagram showing how these products interact is also given. To complete the family, a common software package supports all digital I/O boards and the expansion panels.

1.2.1 Typical Applications

- TTL compatible digital input/output
- Relay output with isolated contacts, high level ground referenced source drivers (any combination)
- Isolated high or low level digital input, ground referenced high or low level digital input (any combination)
- Interrogation of contact closure matrix - up to 1296 points per PC272E
- Elapsed time, period, frequency measurement
- Differential, ratiometric count
- Monostable and astable generation
- Frequency division, frequency multiplication, digitally controlled oscillator
- Voltage controlled oscillator (in conjunction with PC226E, PC30AT, PC26AT or PC27E)

1.2.2 Product List

Product Number	Product Type	Brief Description
PC212E	Counter/timer, Digital I/O board	12 counters, clock/gate source, 24 line digital I/O
PC214E	Counter/timer, Digital I/O board	3 counters, 48 line digital I/O
PC215E	Counter/timer, Digital I/O board	6 counters, clock/gate source, 48 line digital I/O
PC218E	Counter/timer board	18 counters, clock/gate source
PC272E	Digital I/O board	72 line digital I/O
EX233	Termination/distribution panel	78 Terminals, 3 x 37 way distribution connectors
EX213	Output panel	24 relay or high level logic source drivers
EX230	Input panel	24 isolated or non-isolated, high or low level inputs
EX221	Input/output panel	16 inputs, 8 outputs
90 966 349	78 way Screened Cable 1m	I/O board to EX233 Termination/distribution panel
90 956 109	37 way Screened Cable 1m	PC36AT or EX233 to I/O panel
91 945 753	37 way Screened Connector Kit	
PC36AT	*24 Line Digital I/O Board*	
908 919 50	*37 way screw terminal assy*	
919 459 53	*78 way Screened Connector Kit*	

1.3 Product Configurator

Figure 1 - Product Configurator Block Diagram - shows how the six digital I/O boards (including the PC36AT) may be connected, using the supplied cables, to form a variety of systems. The simplest usable system configuration comprises one board from the PC212E, PC214E, PC215E, PC218E or PC272E range, a 78 way cable and an EX233. This system provides user terminals to all I/O functions of the board. More complex, configurable systems include isolated or common ground input and output at low or high level.

All five boards employ the concept of I/O Groups, where a group can be six 16 bit counter timers with interconnects, or 24 lines of digital input/output. These groups are integrated as necessary to provide the specified functionality.

A software configurable clock and gate source group provides five precise frequencies for counter/timer input, and also allows for counter/timer inter-connection.

The user I/O connector map recognises this grouping and allows any combination of expansion panels to be directly added to any of the boards, with each panel mapped onto a counter/timer group or digital I/O group.

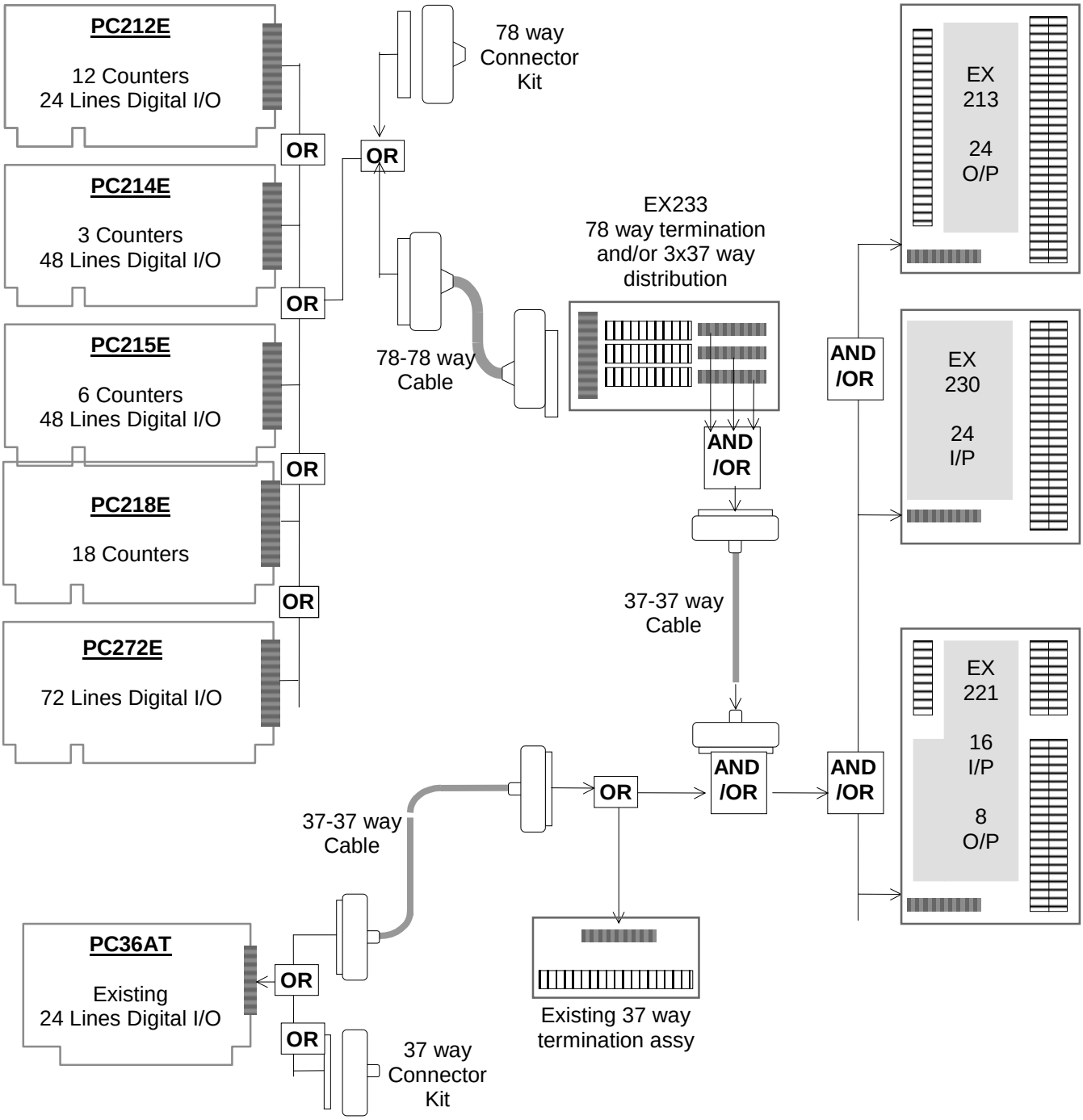


Figure 1 - Product Configurator Block Diagram

1.4 Features of the PC215E

- Six 16-bit, 10 MHz counter/timers, each with six programmable counter modes
- Crystal clock/divider with 5 rates, independently software-selectable for each counter/timer clock input
- Independent software-selectable clock and gate inputs for each counter/timer
- 48 programmable digital I/O lines, with three operating modes
- Six software-selectable interrupt sources - two timer output and four digital I/O

1.5 PC215E General Description

The PC215E is a half-size ISA bus plug-in board which provides 48 programmable digital input/output lines, and six independent programmable 16 bit counter/timers. The board can be installed in IBM© or fully compatible PC/AT computers.

The flexible addressing system provided on the board allows the base address to be set within the range 000 to $FF0_{16}$. The board interrupt level can be software selected to IRQ3, IRQ5, IRQ7, IRQ9, IRQ10, IRQ11, IRQ12 or IRQ15, and any number of five possible interrupt sources can be software selected.

A 10 MHz on-board crystal oscillator provides an accurate, stable clock source for the counter/timers, independent of the system clock frequency. A divider circuit provides five selectable frequencies (10 MHz, 1 MHz, 100 kHz, 10 kHz and 1 kHz) derived from the oscillator, and each of the counter/timer clock inputs can be automatically connected to any of these clock sources, or to its own individual external clock source, or to the output of another counter/timer.

Each of the counter/timer gate inputs can be enabled and disabled in software, or automatically connected to its own external gate source, or the output of another counter/timer.

A block diagram of the PC215E is given in Figure 2.

1.5.1 The Software

The PC215E is supplied with a 3½" diskette containing the software, which supports all five of the boards in the 200 Series Digital I/O Counter/Timer Family. This software is described fully in section 6 of this manual.

1.5.1.1 Windows Installation Program

The software is installed onto the user's hard disk by a Windows installation program. See section 2 of this manual for information on getting started.

1.5.1.2 Windows DLL

A Windows Dynamic Link Library (DLL) containing over 50 functions provides an Applications Program Interface (API) to the PC215E, and the other boards in the family. The library functions allow the boards to be easily applied to many different applications, and also provide an easy way of accessing the board's features. The 16-bit DLL can be called by any language which uses Windows calling conventions, and example programs written in Microsoft Visual Basic are also provided.

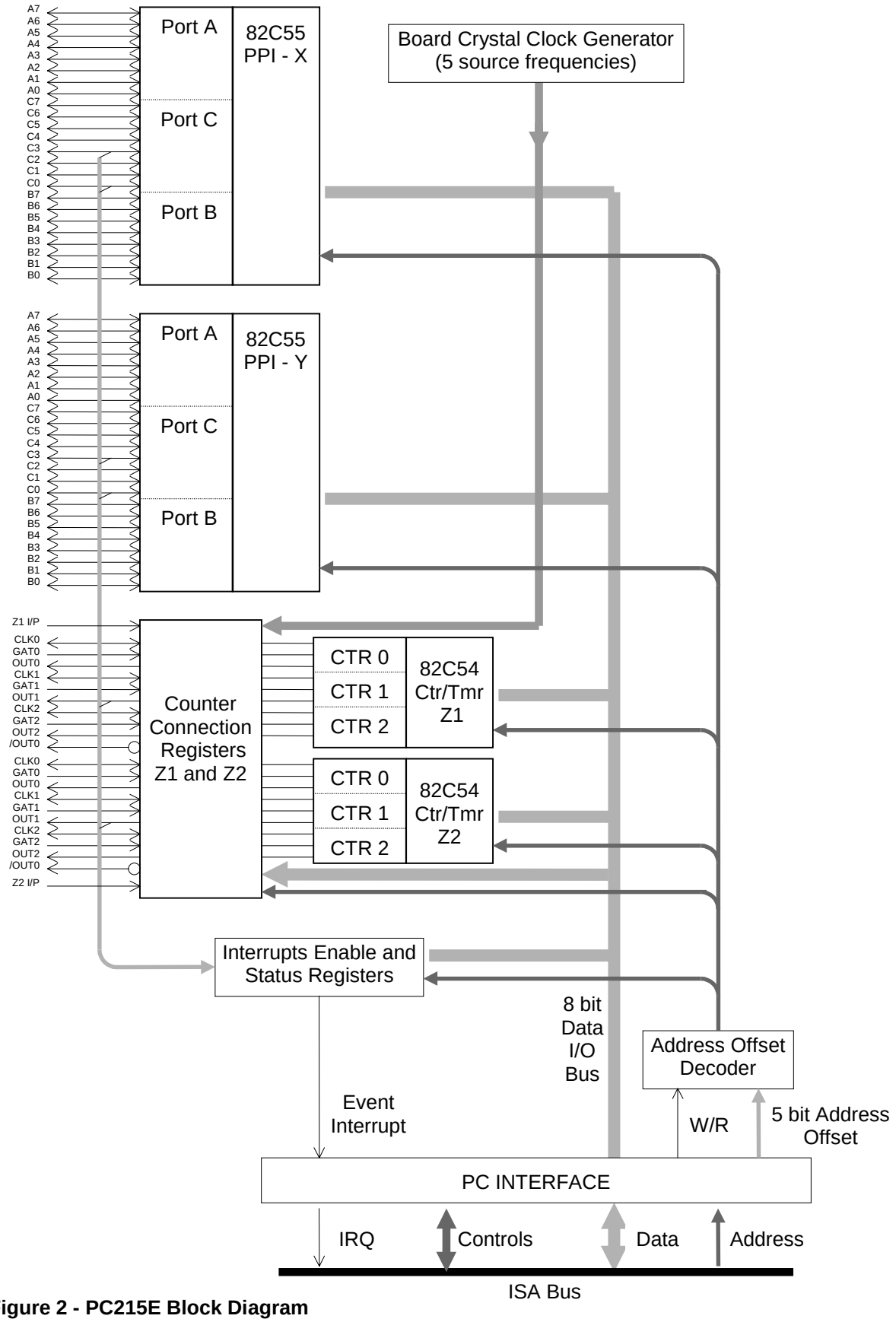


Figure 2 - PC215E Block Diagram

1.5.1.3 DOS Library

A DOS library for Microsoft and Borland C/C++ is supplied, which has exactly the same functionality as the Windows DLL. Four example 'C' programs are also provided, and these can be recompiled with either Microsoft C/C++ or Borland C++.

1.5.1.4 LABTECH NOTEBOOK Drivers

A LABTECH NOTEBOOKpro driver is provided with template files for each of the boards in the family.

1.6 What the PC215E Package Contains

CAUTION

Some of the components on the board are susceptible to electrostatic discharge, and proper handling precautions should be observed. As a minimum, an earthed wrist strap must be worn when handling the PC215E outside its protective bag. Full static handling procedures are defined in British Standards Publication BSEN100015/BSEN100015-1:1992.

When removed from the bag, inspect the board for any obvious signs of damage and notify Amplicon if such damage is apparent. Do not plug a damaged board into the host computer. Keep the protective bag for possible future use in transporting the board.

The package as delivered from **Amplicon Liveline Ltd**. contains:-

Item 1 PC215E board is supplied in a protective bag. When removing the board, observe the precautions outlined in paragraph 1.6

Item 2 200 Series Digital I/O Counter/Timer Software Diskette (Part Nº 90 956 209), supplied on 3 1/2" diskette(s).

Item 3 This PC215E Instruction Manual (Part Nº 85 956 294)

Any additional accessories (termination boards, cables, optional software etc.) may be packed separately.

1.7 The Amplicon Warranty Covering the PC215E

This product is covered by the warranty as detailed in the Terms and Conditions stated in the current domestic or international **Amplicon Liveline** catalogue.

1.8 Contacting Amplicon Liveline Limited for Support or Service

The PC215E board is produced by Amplicon Liveline Limited and maintenance is available throughout the supported life of the product.

1.8.1 Technical Support

Should this product appear defective, please check the information in this manual and any 'Help' or 'READ.ME' files appropriate to the program in use to ensure that the product is being correctly applied.

If a problem persists, please request Technical Support on one of the following numbers:

Telephone:	UK	01273 608 331
	International	+44 1273 608 331
Fax:	UK	01273 570 215
	International	+44 1273 570 215
Internet		support@amplicon.co.uk
		www.amplicon.co.uk

1.8.2 Repairs

If the PC215E requires repair then please return the goods enclosing a repair order detailing the nature of the fault. If the PC215E is still under warranty, there will be no repair charge unless any damage as a consequence of improper use.

For traceability when processing returned goods, a Returned Materials Authorisation (RMA) procedure is in operation. Before returning the goods, please request an individual RMA number by contacting Amplicon Customer Services by telephone or fax on the above numbers. Give the reason for the return and, if the goods are still under warranty, the original invoice number and date. Repair turnaround time is normally five working days but the Service Engineers will always try to co-operate if there is a particular problem of time pressure.

Please mark the RMA number on the outside of the packaging to ensure that the package is accepted by the Goods Inwards Department.

Address repairs to:
Customer Services Department
AMPLICON LIVELINE LIMITED
Centenary Industrial Estate
Hollingdean Road
BRIGHTON UK BN2 4AW

2. GETTING STARTED

2.1 General Information

The PC215E software diskette contains six ready-to-run executable programs, three for DOS and three for Windows. These programs allow the user to perform I/O operations on the PC215E immediately after installing the board and software onto a PC.

2.2 Installing the Board

ENSURE THAT THE POWER TO THE COMPUTER IS SWITCHED OFF BEFORE INSTALLING OR REMOVING ANY EXPANSION BOARD. OBSERVE HANDLING PRECAUTIONS NOTED IN SECTION 1.6.

REPAIR OF DAMAGE CAUSED BY MIS-HANDLING IS NOT COVERED UNDER THE AMPLICON WARRANTY.

DO NOT MAKE ANY MODIFICATIONS OTHER THAN SWITCH CHANGES TO A BOARD THAT IS ON EVALUATION

Please refer to the manufacturer's hardware manual supplied with the PC for instructions on how to remove the cover and install devices into an ISA bus slot. The PC215E may be installed in any available position in the machine provided that there is no restriction specified for that location by the computer manufacturer. If available, the end slot furthest from any other I/O card should be chosen to minimise the risk of the switched signals inducing interference in the PC circuits.

2.3 System Requirements

When installing one or more PC215E boards, ensure that the host computer has sufficient capacity. Take into account other boards or adapters that may be installed in the computer when assessing physical space, address space in the I/O map, interrupt levels and the power requirements. A minimum host computer configuration is:

- IBM© or fully compatible PC/AT with 286 or higher processor, 3 1/2" high density floppy disk drive, hard disk drive and monitor.
- One free, ISA bus to accommodate a 1/2 length I/O card slot.
- Sufficient power available. +5 VDC at 30 mA is required for each PC215E (unloaded).
- DOS 6.0 or higher to run the DOS demonstration programs.
- Microsoft Windows 3.1 or higher to use the DLL and run the Windows demonstration programs.

2.4 Backing up the Software Diskettes

It is important that a backup copy of the software diskette(s) is made and the original stored in a cool, dry, safe place. The diskette(s) can be copied onto a blank diskette and/or the software copied onto the hard disk. A supplied Windows setup program installs the software on the hard disk. Refer to the DOS or Windows manual for information on disk copying. Always use the working copy.

2.5 Software Installation

To install the PC215E software onto your hard disk, insert disk 1 into drive A: and select '**File|Run**...' from the Windows Program Manager, or, if you are using Windows 95, select '**Run**...' from the Start menu. In the dialogue box that follows, type

A:\SETUP <RETURN>

The PC215E software installation program will now run. Follow the instructions on the screen to complete the installation. See section 6 'Programming The PC215E' for information on running the software.

2.6 Configuration Switch and Jumper Settings

Before installing this board in the host computer, the configuration needs to be set to the user's requirements. Setting is by means of an on-board in-line switch and a pluggable jumper whose functions are described below.

2.6.1 Base Address Selection

The base address of the PC215E can be selected in the range 000 to $FF0_{16}$. If more than one PC215E is installed in a single PC, each board must have a different base address and these will be separated by at least 32 bytes. It is normally convenient to have the base addresses at contiguous even locations. The factory default base address is 300_{16}.

Conflict of I/O addresses with other devices in the host PC or fitted adaptors is a common cause of operational problems and care should be taken to ensure that the PC215E base address is chosen where no port assignment is in contention.

The board's base address is set by switch SW1. This switch bank comprises a row of eight single-pole, single-throw switches with each 'up' or 'ON' position selecting a logic 1, and each 'down' or 'OFF' position selecting a logic 0. The most significant hex digit of the base address is coded by the four most left switches, and the middle hex digit is coded by the four most right switches of SW1. The least significant hex digit is always 0.

Figure 3 below shows the factory default setting of 300_{16}

Most significant digit 0011	=	3_{16}
Middle digit 000	=	0_{16}
Least significant Default	=	0_{16}

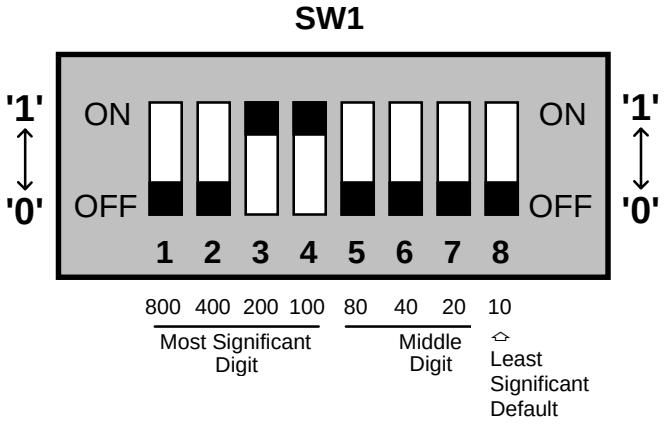


Figure 3 - DIL Switch Selection for Base Address

2.6.2 PC I/O Map

The standard PC/AT I/O map assignments are listed below.

I/O addresses 000_{16} to $0FF_{16}$ are reserved for the PC system board use and I/O addresses 100_{16} to $3FF_{16}$ are available on the I/O channel. The installation of the PC215E at a base address that uses unlisted ports may result in conflicting assignments with third party adapters.

Hex Range	Usage	Hex Range	Usage
1F0-1FF	Hard Disc (AT)	360-36F	Network
200-20F	Game/Control	378-37F	Parallel Printer
210-21F	Reserved	380-38F	SDLC
238-23B	Bus Mouse	3A0-3AF	SDLC
23C-23F	Alt. Bus Mouse	3B0-3BB	MDA
270-27F	Parallel Printer	3BC-3BF	Parallel Printer
2B0-2DF	EGA	3C0-3CF	EGA
2E0-2E7	GPIB (AT)	3D0-3DF	CGA
2E8-2EF	Serial Port COM4	3E8-3EF	Serial Port COM3
2F8-2FF	Serial Port COM2	3F0-3F7	Floppy Disc
300-31F	Prototype Card	3F8-3FF	Serial Port COM1

2.6.3 Selection of Interrupt Request (IRQ) Level

Selection of the required Interrupt Request Level is by means of a jumper in a single position on header J1. Eight levels are available, but only one of these may be selected, and a level should be chosen that does not conflict with any other assignments within the host computer.

The factory default setting is IRQ level 5.

The following table shows the available levels on the PC215E and normal usage of all hardware interrupts. The one of eight position jumper is illustrated in Figure 4.

PC215E Jumper 1	IRQ Name	Interrupt Number	Usage Description	
—	0	8	Timer)	Not available on the
—	1	9	Keyboard)	Bus Connectors
—	IRQ2	A	Int 8 - 15	
3	IRQ3	B	COM or SDLC	
—	IRQ4	C	COM or SDLC	
5	IRQ5	D	LPT	
—	IRQ6	E	Floppy Disk	
7	IRQ7	F	LPT	
—	IRQ8	70	Real Time Clock	
9	IRQ9	71	Re-directed to IRQ2	
10	IRQ10	72	Unassigned	
11	IRQ11	73	Unassigned	
12	IRQ12	74	Unassigned	
—	IRQ13	75	Co-processor	
—	IRQ14	76	Hard Disk	
15	IRQ15	77	Unassigned	

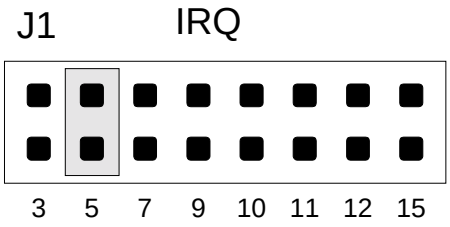


Figure 4 - Jumper for IRQ Level Selection

2.7 Test Points

Test point TP1 on the PC215E is not fitted as standard, and is for factory test and programming purposes only. Do not make connections to this point.

3. MAKING THE CONNECTIONS

3.1 The Input/Output Connector

These input/output connections are made through the connector protruding from the PC adaptor slot corresponding to the chosen board position. For completeness of connection information, the standard PC back-plane bus connections are also shown in paragraph 3.6.

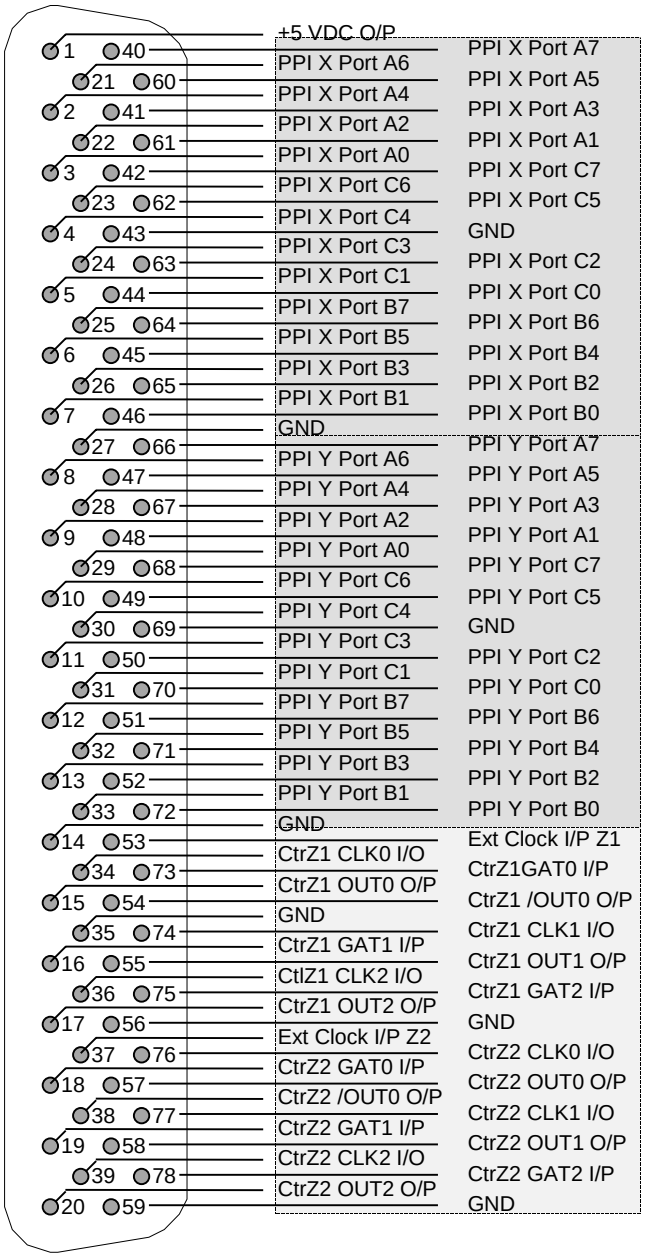


Figure 5 - PC215E Input/Output Connector Pin Designations

All connections of external devices to the PC215E digital I/O and counter/timer channels are made via a 78-way 'D' connector, SK1. The pin designations for SK1 are shown in Figure 5.

Please note that the counter/timer clock and gate input sources are selected in software. if you select one of the five internal frequencies or the Z1EXTCLK input as the clock source to a counter/timer, you must ensure that no external signal is connected to the counter/timer's CLK I/O pin on SK1. In this case, the internal signal selected will be available as an output signal on the CLK I/O pin..

Similarly, if you select one of the internal gate signals as the source to a counter/timer's gate input, you must ensure that no external signal is connected to the counter/timer's GAT I/P pin on SK1.

3.2 Cable Connections

A screened 78 way cable with metal shielded 'D' connectors (Part Nº 90 966 349) is available to provide cable connections to the PC215E. Alternatively, a mating 78 way 'D' pin connector kit is available (Part Nº 91 945 953) should the user wish to construct custom cables.

A range of external expansion panels is also available to offer a variety of digital I/O operations to the range of PC212E, PC214E, PC215E, PC218E and PC272E digital I/O and counter/timer boards. These expansion panels are also compatible with the existing PC36AT Programmable Digital I/O board (Part Nº 90 893 163).

3.2.1 Features Summary of the Expansion Panels

As with the digital I/O boards, the expansion panels are of modular design employing common circuit groups and constructional techniques.

Expansion Panels Common Features

- 200 Series compatible
- DIN rail mounting
- Cage clamp terminals
- Common circuit groups
- 78 way shielded connector for user I/O
- 37 way shielded interconnect cables
- Connection groups compatible with I/O boards
- Multiple ground I/O connections
- User manual

Expansion Panels Individual Features

- **EX233** - Termination and Distribution Panel (TTL level termination and/or distribution)
- **EX213** - 24 Line Digital Output Panel (24 Isolated relay outputs; 24 high level source drivers)
- **EX230** - 24 Line Digital Input Panel (24 isolated high or low level inputs; 24 common high or low level inputs)
- **EX221** - 16 Line Input, Eight Line Output Panel (16 isolated or common hi/lo level inputs; eight relay and driver outputs)

3.3 Use of Shielded Cables

In order to maintain compliance with the EMC directive, 89/336/EEC, it is mandatory that the final system integrator uses good quality screened cables for external connections. It is up to the final system integrator to ensure that compliance with the Directive is maintained. Amplicon Liveline offers a series of good quality screened cables for this purpose. Please contact our sales staff.

3.4 Digital Input/Output Conditions

Specifications of the digital input/output lines on PPI X and PPI Y Ports A, B and C are:-

Inputs -

'Low' input voltage	–0.5 V to +0.8 V
'High' input voltage	+2.2 V to +5.3 V

When an input line is left open circuit, the state is indeterminate. Ensure that signals to any inputs are within the above limits, and that any unused input lines are grounded or masked out in software. The output currents shown below must not be exceeded.

Outputs -

'Low' output voltage	+0.4v max at +2.5 mA
'High' output voltage	+3.5v min at –400µA

3.5 Counter/Timer Input/Output Conditions

Specifications of the counter/timer input/output lines of Z1 and Z2 Counter 0, Counter 1 and Counter 2 are:-

Clock and Gate Inputs -

'Low' input voltage	0 V to 0.5 V
'High' input voltage	+2.1 V to +10 V

See sections 5.3.19 and 5.3.20 for more details on the clock and gate input selection. The output currents shown below must not be exceeded.

Outputs -	'Low' output voltage	+0.3 V max at +5.0 mA
	'High' output voltage	+3.8 V min at –5.0 mA

3.6 PC Back-plane Bus Connections

Connections between the host PC/AT and the PC215E are through a 62 way and a 36 way edge connector on the PC/AT ISA bus. The user will not normally require access to this I/O connector information, but for troubleshooting and diagnostic purposes, Figure 6 lists these standard back-plane connections. The PC215E does not use all of the signals. *Note: Pin B4 is IRQ9 which is re-directed as IRQ2. (Via the computer's second Programmable Interrupt Controller)

62 Pin Connector

	Ground	<		B1	A1	<		-I/O CHCK	(bracket end of board)
	+ Reset	<		B2	A2	<	>	SD7	
	+5 Volts	<		B3	A3	<	>	SD6	
	+IRQ2/9*		>	B4	A4	<		SD5	
	-5 Volts	<		B5	A5	<	>	SD4	
	+DRQ2	>		B6	A6	<	>	SD3	
	-12 Volts	<		B7	A7	<	>	SD2	
	-0WS	<	>	B8	A8	<	>	SD1	C
	+12 Volts	<		B9	A9	<	>	SD0	O
	Ground	<		B10	A10	<		I/O CHRDY	M
S	-SMEMW	<		B11	A11	<	>	AEN	P
O	-SMEMR	<		B12	A12	<	>	SA19	O
L	-IOW	<	>	B13	A13	<	>	SA18	N
D	-IOR	<	>	B14	A14	<	>	SA17	E
E	-DACK3	<	>	B15	A15	<	>	SA16	N
R	+DRQ3	<	>	B16	A16	<	>	SA15	T
	-DACK1	<	>	B17	A17	<	>	SA14	
S	+DRQ1	<	>	B18	A18	<	>	SA13	S
I	-DACK0	<	>	B19	A19	<	>	SA12	I
D	CLK	<	>	B20	A20	<	>	SA11	D
E	+IRQ7	<	>	B21	A21	<	>	SA10	E
	+IRQ6	<	>	B22	A22	<	>	SA9	
	+IRQ5	<	>	B23	A23	<	>	SA8	
	+IRQ4	<	>	B24	A24	<	>	SA7	
	+IRQ3	<	>	B25	A25	<	>	SA6	
	-DACK2	<	>	B26	A26	<	>	SA5	
	+T/C	<		B27	A27	<	>	SA4	
	+BALE	<		B28	A28	<	>	SA3	
	+5 Volts	<		B29	A29	<	>	SA2	
	OSC	<		B30	A30	<	>	SA1	
	Ground	<		B31	A31	<	>	SA0	

36 Pin Connector

–MEMCS16	>	**D1**	**C1**		>	SBHE
–I/OCS16	>	**D2**	**C2**	<	>	LA23
+IRQ10	>	**D3**	**C2**	<	>	LA22
+IRQ11	>	**D4**	**C4**	<	>	LA21
+IRQ12	>	**D5**	**C5**	<	>	LA20
+IRQ15	>	**D6**	**C6**	<	>	LA19
+IRQ14	>	**D7**	**C7**	<	>	LA18
–DAC0	<	**D8**	**C8**	<	>	LA17
+DRQ0	>	**D9**	**C9**		>	–MEMR
–DACK5	<	**D10**	**C10**		>	–MEMW
+DRQ5	>	**D11**	**C11**	<	>	SD08
–DACK6	<	**D12**	**C12**	<	>	SD09
+DRQ6	>	**D13**	**C13**	<	>	SD10
–DACK7	<	**D14**	**C14**	<	>	SD11
+DRQ7	>	**D15**	**C15**	<	>	SD12
+5 VoltS	<	**D16**	**C16**	<	>	SD13
–MASTER	>	**D17**	**C17**	<	>	SD14
Ground	<	**D18**	**C18**	<	>	SD15

Figure 6 - PC Backplane - ISA Bus Connections

4. USING THE PC215E

This chapter describes the various operations associated with implementing the user's application. Programming and usage operations are discussed and include references to the various register operations and software library functions required for each application. Details of the registers and software are given in chapters 5 and 6 respectively.

Reference should also be made to chapter 2 'Getting Started' and chapter 3 'Making the Connections' before implementing any of the described operations.

4.1 Multiple PC215E Boards in a Single Application

More than one PC215E board may be installed in a single host PC. Furthermore, up to eight of any combination of boards in the PC214E, PC215E, PC212E, PC218E and PC272E range may be installed in a single host PC.

To install more than one board in the host PC, the following points should be checked:

1. Sufficient space is available to mount the required number of boards.
2. Sufficient power is available for all the plug in boards and adapters. Each PC215E requires +5V at up to 30 mA (unloaded).
3. The base address of each board is set by switch SW1 to a different value, preferably at contiguous even addresses, and with no conflict with other installed devices. Suitable base addresses for four boards could be 300_{16}, 320_{16}, 340_{16} and 360_{16}.
4. The interrupt level (IRQ) of each board is set by jumper J1 to a different value, and with no conflict with other installed devices.

4.2 User Applications

The PC215E board features two uncommitted 82C55 CMOS Programmable Peripheral Interface devices, PPIX and PPIY, and two uncommitted 82C54 CMOS Counter/Timer devices, Z1 and Z2, all of which can each be configured in a variety of operating modes. The operational mode for each device is established by writing to its control register.

The Windows DLL and the DOS 'C' library contain functions that implement a number of typical applications for these devices. These functions can be used with any board in the PC214E, PC215E, PC212E, PC218E and PC272E range. The following paragraphs describe the twelve applications.

4.2.1 Differential Counter

Two timer/counters can be used to form a Differential Counter pair from which the *ratio* of, or the *difference* between, the two count values is derived. See section 6.6.5 "Differential Counter Functions".

The function *TCsetDiffCounters* allows you to specify the two timer/counters to be used as a differential pair. The function registers the timer/counter pair as being 'in use' and unavailable for any other application. Provision is also made by *TCsetDiffCounters* to specify the clock and gate connections for both timer/counters.

The functions *TCgetDiffCount* and *TCgetRatio* can be called at any time after *TCsetDiffCounters*, and these two functions latch and read the current count values of the timer/counters, using the read-back command, and return the difference and ratio of the two count values respectively. Function *TCfreeDiffCounters* can be called when finished with the differential counter, and releases the timer/counter pair so they become available for use by another application.

4.2.2 Monostable Multivibrator

Mode 1 of the 82C54 timer/counter provides a digital one-shot output. This can be used to implement a monostable multivibrator pulse. In this mode, the output of the timer goes low at the falling edge of the first clock succeeding the gate trigger, and is kept low until the counter value becomes 0. Once the output is set high, it remains high until the clock pulse succeeding the next gate trigger.

Function *TCsetMonoshot* allows you to specify a timer/counter and a monostable pulse duration (in seconds). See section 6.6.6.1 "Send Monostable Pulse - TCsetMonoShot". The function calculates the counter/timer clock source and initial count value required to generate the specified pulse length, and programs the timer/counter accordingly.

It is the responsibility of the user to provide the external gate signal to trigger the monostable output.

4.2.3 Astable Multivibrator

An extension of the monostable multivibrator is to have two such timer/counters each generating an output pulse of specified duration, but each being triggered by the end of the other timer/counter's pulse. By adjusting the two pulse duration times, an astable multivibrator waveform with a given frequency and mark-to-space ratio can be attained.

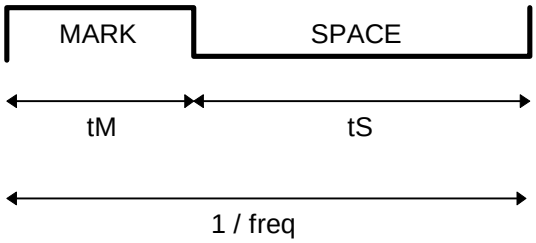
This application is implemented in function *TCsetAstable* - see section 6.6.6.2. The *msratio* argument to the function specifies the mark-to-space ratio, and this is defined as follows:

mark-to-space ratio = mark time / overall period

The function registers the timer/counters as being 'in use' and unavailable for any other application. Function *TCfreeAstable* can be called when finished with the astable multivibrator, and releases the timer/counters so they become available for use by another application.

The output of each timer/counter must be connected externally via the user connector, SK1, to the gate input of the other timer/counter.

The *TCsetAstable* function calculates the input clock frequencies and counter divide ratios (CDRs) for the two timers and makes the selections automatically.



msratio = tM / (tM + tS) where *msratio* = mark to space ratio
tM = mark time (seconds).
tS = space time (seconds).
freq = output frequency (Hz)

Note: the 82C54 timer/counters outputs are switched to the low level by the *next clock* after the gate trigger, possibly causing the mark-to-space ratio to become distorted by one or two clock pulses. This will become more apparent at higher frequencies.

4.2.4 Stopwatch

In mode 2, the output of the 82C54 timer/counter starts high; goes low for one clock pulse when the count value decrements to 1, and then is set to high again. The initial count value is then automatically re-loaded; counting continues and the sequence repeats. The output can be used as a clock signal for another timer/counter, and any number of timer/counters can be cascaded in this way.

Section 6.6.7 "Millisecond Stopwatch Functions" contains function *TCsetStopwatch* which sets up two timer/counters in this way with a clock input frequency of 1 kHz. Function *TCstartStopwatch* sets the counters counting, and function *TCgetElapsedTime* latches and reads the two count values to calculate the elapsed time, in milliseconds, since the counters were first set off by *TCstartStopwatch*. This stopwatch can count milliseconds for nearly 50 days. Function *TCfreeStopwatch* releases the timer/counters so they can become available for use by another application when the stopwatch is no longer required.

4.2.5 Event Recorder

An extension of the stopwatch described above is to record the elapsed times when an external event occurs. This is possible by connecting an event's status output to an 82C55 digital input channel on SK1, and causing this digital input to generate an interrupt to the computer's CPU. The interrupt service routine would then read the elapsed time from the stopwatch timer/counters and store the time into memory.

The function described in section 6.6.7.4 "Prepare an Event Time Recorder - TCsetEventRecorder" allows you to specify a digital input chip (PPIX or PPIY) from which Port C bit 0 will be used as the event input, and interrupt source. Once the board's interrupt has been enabled (see function *enableInterrupts* - section 6.6.2.1) and a stopwatch timer has been started, a positive going signal on the PPI Port C bit 0 pin on SK1 will cause the elapsed time to be recorded into memory.

4.2.6 Frequency/Period Measurement

Another use for the pulse generation capabilities of the 82C54 is for one counter/timer to provide a precise GATE signal during which a second timer/counter counts an external event. In mode 0, a high level on the gate input validates counting, and a low level invalidates it (i.e. counting stops). Also a low-to-high transition on the gate input causes the initial count value to be re-latched into the counting element.

Section 6.6.8 contains two functions *TCgetExtFreq* and *TCgetExtPeriod* both of which program a timer/counter to provide a one-shot gate pulse of precise duration 6.5535 ms to a second timer/counter. The second timer/counter has an external signal as its clock input. When the gate pulse is over, the second timer/counter's counting stops, and its value is then read. A simple calculation can then be made to determine the number of external clock cycles received during the 6.5535 ms, and from this the external frequency and period can be estimated.

The timer/counter you specify in calls to *TCgetExtFreq* and *TCgetExtPeriod* is the second timer/counter described above: The input frequency range supported by *TCgetExtFreq* is 153 Hz to 10 MHz, and the input period range supported by *TCgetPeriod* is 6.54 ms to 100 ns.

4.2.7 Frequency Generation

In mode 3 the output of the timer/counter is a periodic square wave, whose frequency is the input clock frequency divided by the programmed counter divide ratio (CDR). The function *TCgenerateFreq* described in section 6.6.8.3 calculates the CDR required to generate a specific frequency on a given timer/counter. The function automatically selects an appropriate input clock frequency.

The function *TCgenerateAccFreq* described in section 6.6.8.4 uses two cascaded timer/counters, both in mode 3. The flexibility of having two CDRs adds another degree of freedom into the calculation of the CDR values, and a more accurate output frequency can be attained.

4.2.8 Frequency Multiplication

An extension of the frequency measurement and frequency generation capabilities described in sections 4.2.6 and 4.2.7 above is to combine the two into a process that measures an external frequency on one timer/counter; multiplies the frequency value by a given factor and generates this new frequency on a second timer/counter. Function *TCmultiplyFreq* described in section 6.6.8.5 performs this operation.

4.2.9 Digitally Controlled Oscillator

The combination of the 82C55 PPI and 82C54 counter/timer devices on the PC215E board make it possible to implement a digitally controlled oscillator, whereby the value of a binary number read into a PPI input channel is used to calculate the frequency of a square wave generated on a timer/counter output. To turn this process into a continuous background task, a second timer/counter can be deployed to generate an 'update' signal by generating a periodic interrupt. The interrupt service routine then performs the DCO operation in the background.

Function *TCsetDCO* (section 6.6.9.1) sets up such an arrangement - allowing you to specify the digital input channel, the output timer/counter and the second timer/counter used to generate the 'update' interrupts. The function also allows for a flexible update rate and output frequency range. The digital input channel width (i.e. the number of bits in the digital input word) can be

selected to either 1, 4, 8, 12, 16 or 24 bits by calling function *DIOsetChanWidth* (see section 6.6.10.3 for more details). The PPI Port(s) used by the digital input channel must be programmed as input by calling function *DIOsetMode* for each port (see section 6.6.10.2 "Configure a Digital I/O Port for Input or Output - DIOsetMode").

The *enableInterrupts* and *disableInterrupts* functions must then be called to enable and disable the 'update' interrupts, and, when finished, function *TCfreeDCO* frees up the resources used so they can be used again by another program.

4.2.10 Voltage Controlled Oscillator

In combination with one of Amplicon's data acquisition boards, providing an analog (voltage) input channel, a Voltage Controlled Oscillator can be implemented. The operation would be identical to the DCO described above, except that, rather than reading a digital input channel, an **analog input** channel voltage can be measured to provide the frequency control.

Function *TCsetVCO* (section 6.6.9.2) implements such an arrangement using the PC215E combined with one of the following data acquisition boards also available from Amplicon:

- PC226E (order code 909 561 63)
- PC30AT (order code 908 931 53)
- PC26AT (order code 908 931 73)
- PC27E (order code 909 561 13)

The data acquisition board must be configured with the following jumper selections to give a +10V unipolar analog input range:

1. **PC226E** not applicable - analog input range is software-programmable.

2. **PC30AT** J8 = UNI
   J7 = 1
   J3 = C
   J10 = /D11

3. **PC26AT** J7 = UNI
   J1 = 1
   J2 - C
   J8 = /D11

4. **PC27E** J1 = UP (+4V unipolar)

Care must also be taken to ensure that the base address and interrupt levels of the PC215E and data acquisition card do not clash.

4.2.11 Switch Matrix

The high number of digital I/O channels available on the PC215E board lends itself to a switch matrix scanner implementation. The status of a matrix of switches can be obtained by sending test patterns into the matrix, and then reading status patterns back from the matrix.

Section 6.6.11 describes functions which allows either PPIX, or both PPIX and PPIY to be used as such a device. Using only PPIX up to 144 switches can be scanned, and using both PPIX and PPIY up to 576 switches can be scanned. Group A ports of the 82C55 device(s) - Port A and Port C-upper - are set for output to send test patterns to the matrix, and group B ports - Port B and Port C-lower - are set for input to read the switch status information. The user must ensure that the switch matrix is wired as detailed below.

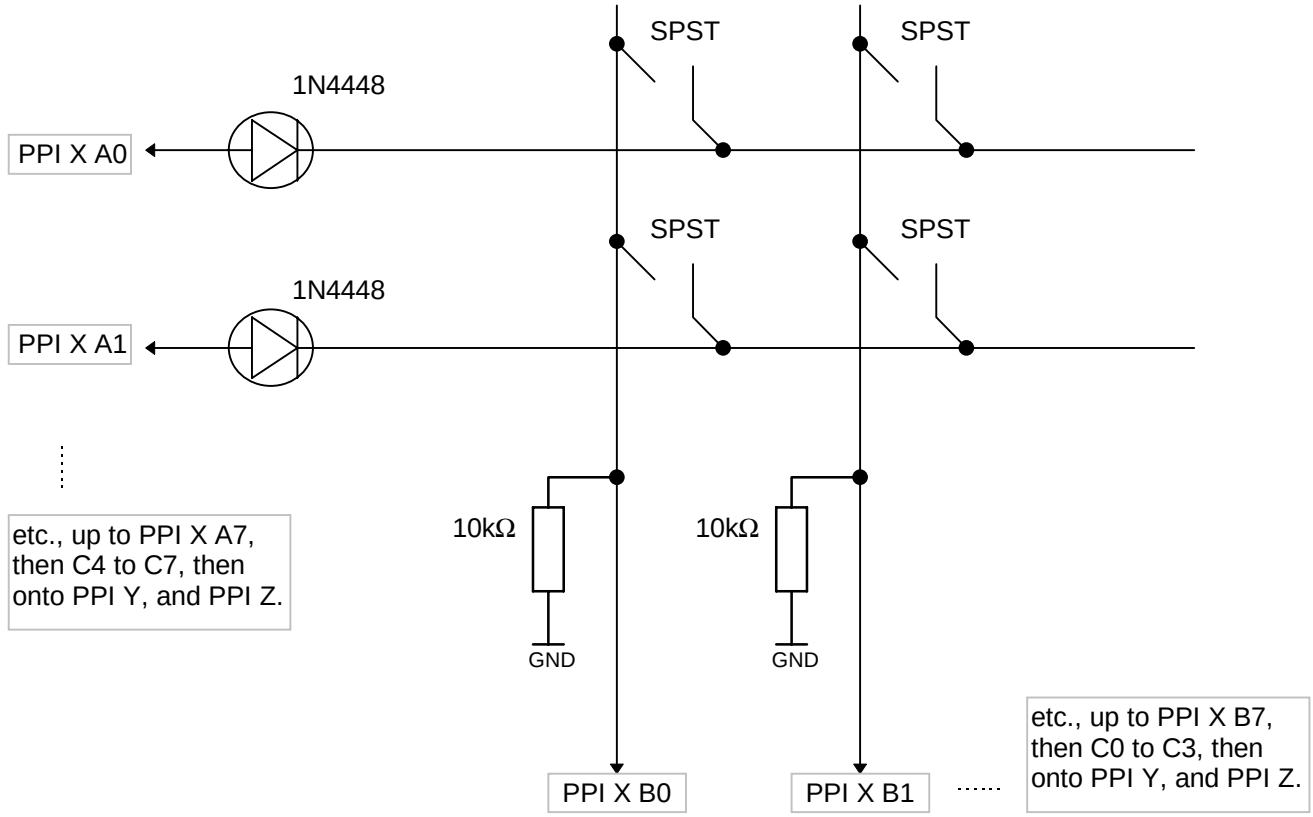


Figure 7 - Switch Matrix Configuration

Function *DIOsetSwitchMatrix* allows you to setup the matrix, specifying the matrix order. For the PC215E, this can be 12 X 12 or 24 X 24 switches. The function also registers the PPIs used as being 'in use' and unavailable for use by other programs. Function *DIOgetSwitchStatus* returns the status of a given switch in the matrix, and function *DIOfreeSwitchMatrix* frees the PPIs so they can be used by other programs when the switch matrix is no longer required.

4.2.12 8-Bit Bi-Directional Bus

In mode 2 it is possible for an 82C55 PPI device to transfer data in two directions through a single 8-bit port. In this mode, Port C handles the necessary control signals, Port A becomes the 8-bit bi-directional port, and Port B is free to be programmed (with Group B) for basic input or basic output operation. Please refer to the manufacturer's 82C55 data sheet included in the appendices of this manual for a full description of the bi-directional bus operation mode of the 82C55 device.

Section 6.6.12 describes function *DIOsetBiDirectionalBus* which programs a given PPI chip for this mode of operation. The PPI's Port C bit 3 interrupt source is used to generate PC215E interrupts, which will occur when either

a) the device's Output Buffer is empty and ready for another data byte to write to the Port A bus, or
b) the device's Input Buffer contains a data byte received from the Port A bus.

Two data buffers are required by the function: one which contains output data to be sent to Port A (byte by byte) whenever a 'write' interrupt occurs, and another empty buffer into which incoming data will be stored (byte by byte) whenever a 'read' interrupt occurs. Please note that functions *enableInterrupts* and *disableInterrupts* must be called to enable and disable these interrupts.

Care must also be taken when connecting the Port C control signals to other devices on the bi-directional bus.

5. STRUCTURE AND ASSIGNMENTS OF THE REGISTERS

The set of demonstration programs and routines provided with the PC215E allows the user access to all the operational functions of the board. However, in some circumstances, the user may wish to program the application at the lowest level using input/output instructions. This section provides the necessary information on the accessible registers.

5.1 Register Assignments

The PC215E registers occupy 32 consecutive address locations in the I/O space. A table summarising the register assignments is shown in Figure 8. Please note that the actual register address is the base address configured on the board plus the register offset given in the table. See section 2.6.1 for information on setting the base address.

5.2 Register Groups

All five boards in the PC214E, PC215E, PC212E, PC218E and PC272E series have the same register map, which is split up into five groups

5.2.1 Cluster X, Y and Z Groups

Each of the Cluster X, Y and Z groups is populated with either an 82C55 Programmable Peripheral Interface (PPI) device to provide digital input/output, or two 82C54 Counter/Timer devices, and each of the boards in the range deploy various combinations of these devices. The PC215E board has only two PPI groups (X and Y) and one Counter/Timer group (Z).

5.2.2 Counter Connection Register Group

The Counter Connection Register group provides software-programmable clock and gate connections for the six Counter/Timers.

5.2.3 Interrupts Group

The Interrupt group provides software-programmable interrupt source selection and interrupt source status information.

The consistency of register definitions across the range does mean that some boards, like the PC215E, have unused address spaces**. It is advised that such addresses are treated as reserved**, and not used for other purposes. A summary of PC215E register definitions is given in Figure 8 - PC215E Register Assignments.

ADDRESS	Description	Write/Read	Bits	Group
BA + 00	PPI X Port A	Write/Read	8	
BA + 01	PPI X Port B	Write/Read	8	
BA + 02	PPI X Port C	Write/Read	8	
BA + 03	PPI X Control	Write/Read	8	Cluster
BA + 04				X
BA + 05				
BA + 06				
BA + 07				
BA + 08	PPI Y Port A	Write/Read	8	
BA + 09	PPI Y Port B	Write/Read	8	
BA + 0A	PPI Y Port C	Write/Read	8	
BA + 0B	PPI Y Control	Write/Read	8	Cluster
BA + 0C				Y
BA + 0D				
BA + 0E				
BA + 0F				
BA + 10	Ctr Z1 - 0	Write/Read	8	
BA + 11	Ctr Z1 - 1	Write/Read	8	
BA + 12	Ctr Z1 - 2	Write/Read	8	
BA + 13	Ctr Z1 - Control	Write/Read	8	Cluster
BA + 14	Ctr Z2 - 0	Write/Read	8	Z
BA + 15	Ctr Z2 - 1	Write/Read	8	
BA + 16	Ctr Z2 - 2	Write/Read	8	
BA + 17	Ctr Z2 - Control	Write/Read	8	
BA + 18				
BA + 19				Counter
BA + 1A	Clk con Z1/2		8	Connections
BA + 1B				Registers
BA + 1C				
BA + 1D	Gat con Z1/2		8	
BA + 1E	Int's enable/stat		6	Interrupts
BA + 1F	Spare			

Figure 8 - PC215E Register Assignments

5.3 The Register Details

The following paragraphs describe the operations of each of the accessible registers. Additional information on register usage can be found in section 4 "USING THE PC215E".

5.3.1 Programmable Peripheral Interface PPI-X Data Register Port A

This eight bit register writes to and reads from port A of the 82C55 Programmable Peripheral Interface PPI-X. All input/output lines PA0 to PA7 of this device are available to the user on connector SK1 as digital I/O.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
00_{16}	Write and Read	8 bits	82C55 Programmable Peripheral Interface X Port A Data Register	**PPI-X A**

FUNCTION

The PPI-X Port A Data Register is used to write or read 8 bit data to port A of the 82C55 Programmable Peripheral Interface device PPI-X.

The PPI can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C55 data sheets in the appendices.

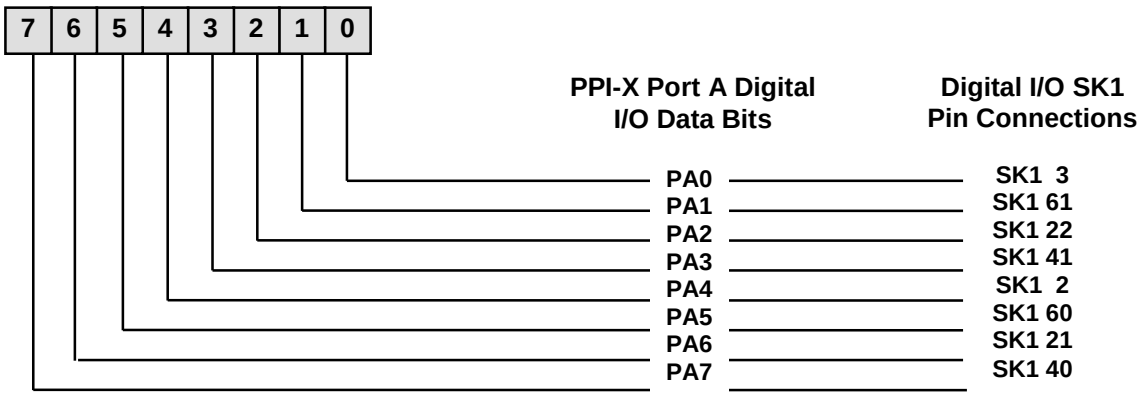
The eight data bits of port A are data input, data output or bi-directional data I/O according to the PPI mode:

Mode 0	Input or Output
Mode 1	Input or Output
Mode 2	Bi-Directional Input/output

The modes and programming of PPI operations are outlined in chapters 4 and 6 with the Digital I/O connections shown in chapter 3.

BIT ASSIGNMENTS

The bit layout of the PPI-X port A data register is shown below.



5.3.2 Programmable Peripheral Interface PPI-X Data Register Port B

This eight bit register writes to and reads from port B of the 82C55 Programmable Peripheral Interface PPI-X. All input/output lines PB0 to PB7 of this device are available to the user on connector SK1 as digital I/O.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
01_{16}	Write and Read	8 bits	82C55 Programmable Peripheral Interface X Port B Data Register	**PPI-X B**

FUNCTION

The PPI-X Port B Data Register is used to write or read 8 bit data to a port of the 82C55 Programmable Peripheral Interface device.

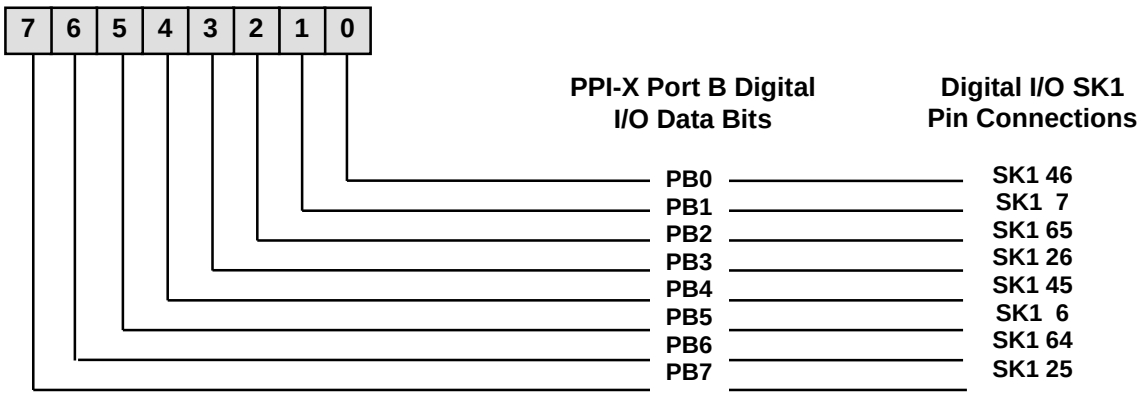
The PPI can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C55 data sheets in the appendices.

The eight data bits of port B are data input or data output in all modes

The modes and programming of PPI operations are outlined in chapters 4 and 6 with the Digital I/O connections shown in chapter 3.

BIT ASSIGNMENTS

The bit layout of the PPI-X port B data register is shown below.



5.3.3 Programmable Peripheral Interface PPI-X Data Register Port C

This eight bit register writes to and reads from port C of the 82C55 Programmable Peripheral Interface PPI-X. All input/output lines PC0 to PC7 of this device are available to the user on connector SK1 as digital I/O.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
02_{16}	Write and Read	8 bits	82C55 Programmable Peripheral Interface X Port C Data Register	**PPI-X C**

FUNCTION

The PPI-X Port C Data Register is used to write or read 8 bit data to a port of the 82C55 Programmable Peripheral Interface device

The PPI can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C55 data sheets in the appendices.

The eight data bits of port C are split into two groups, the upper port C bits 4 to 7 and the lower port C bits 0 to 3. These bits can be data input, data output or control/handshake lines according to the PPI mode:

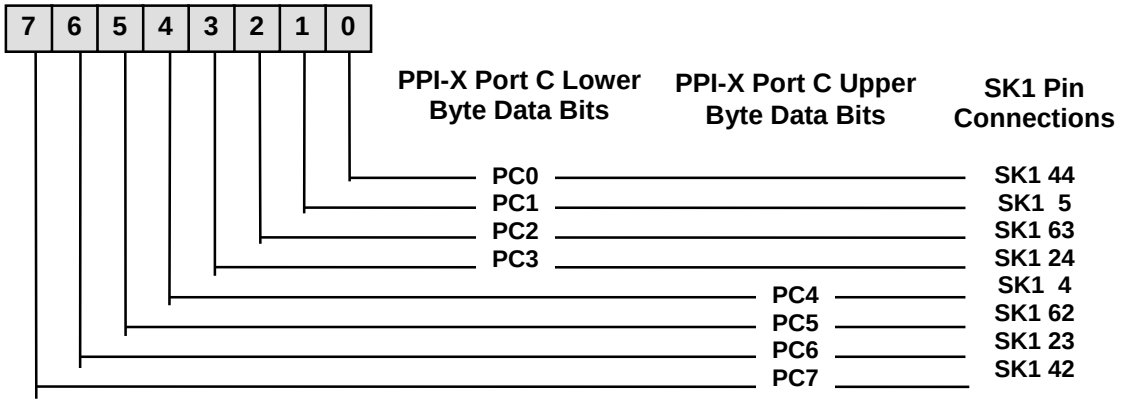
Mode	Port C Upper	Port C Lower
Mode 0	Input or Output	Input or Output
Mode 1	Control/Data	Control/Data
Mode 2	5 bit Control (PC3 to PC7)	3 bit Control/Data (PC0 to PC2)

With bit 7 'Command Select' set to '0', any of the eight bits of port C can be set or reset using a single output instruction. When port C is being used as status/control for port A or port B, these bits can be set or reset using the Bit Set/Reset operation just as if they were data output ports.

The modes and programming of PPI operations are outlined in chapters 4 and 6 with the Digital I/O connections shown in chapter 3.

BIT ASSIGNMENTS

The bit layout of the PPI-X Port C data register is shown below.



5.3.4 Programmable Peripheral Interface PPI-X Command Register

This is the command register for the PPI and can be used to set the operational mode of the three digital I/O ports or to manipulate the bits of port C.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
03_{16}	Write	8 bits	82C55 Programmable Peripheral Interface PPI-X Command Register	**PPI-X CMD**

FUNCTION

Provides a command word to define the operation of the PPI-X ports A, B and C. Any port programmed as output is initialised to all zeroes when a command word is written. A separate feature allows any bit of port C to be set or reset using a single instruction.

The programming procedure for the 82C55 is flexible, but the command word must be written before data bytes are loaded. As the command register and each port have separate addresses (offsets 0 to 3) and each command word specifies the mode of each port, no other special instruction sequence is required.

The Three Modes

The register function depends on the setting of bit 7 'Command Select' and the three mode selections assume that bit 7 is set to '1'. which allows mode configuration.

Mode 0 provides basic input and output operations through each of the ports A, B and C. Output data bits are latched and input data follows the signals applied to the I/O lines. No handshaking is needed.

- 16 different configurations in mode 0
- Two 8 bit ports and two 4 bit ports
- Inputs are not latched
- Outputs are latched

Mode 1 provides strobed input and output operations with data transferred through port A or B and handshaking through port C.

- Two I/O groups (Group A - also known as Group 0 or Group I)
  (Group B - also known as Group 1 or Group II)
- Both groups contain an 8 bit port and a 4 bit control/data port
- Both 8 bit data ports can be latched input or latched output

Mode 2 provides strobed bi-directional operation using port A as the bi-directional data bus. Port C3 to C7 bits are used for interrupts and handshaking bus flow control similar to mode 1. NOTE: Port B and port C0 to C2 bits may be defined as mode 0 or 1, input or output in conjunction with port A in mode 2.

- An 8 bit latched bi-directional bus port and 5 bit control port
- Both input and outputs are latched
- An additional 8 bit input or output port with a 3 bit control port

Single Bit Set/Reset Feature

With bit 7 'Command Select' set to '0', any of the eight bits of port C can be set or reset using a single output instruction. This feature reduces the software overhead in control based applications.

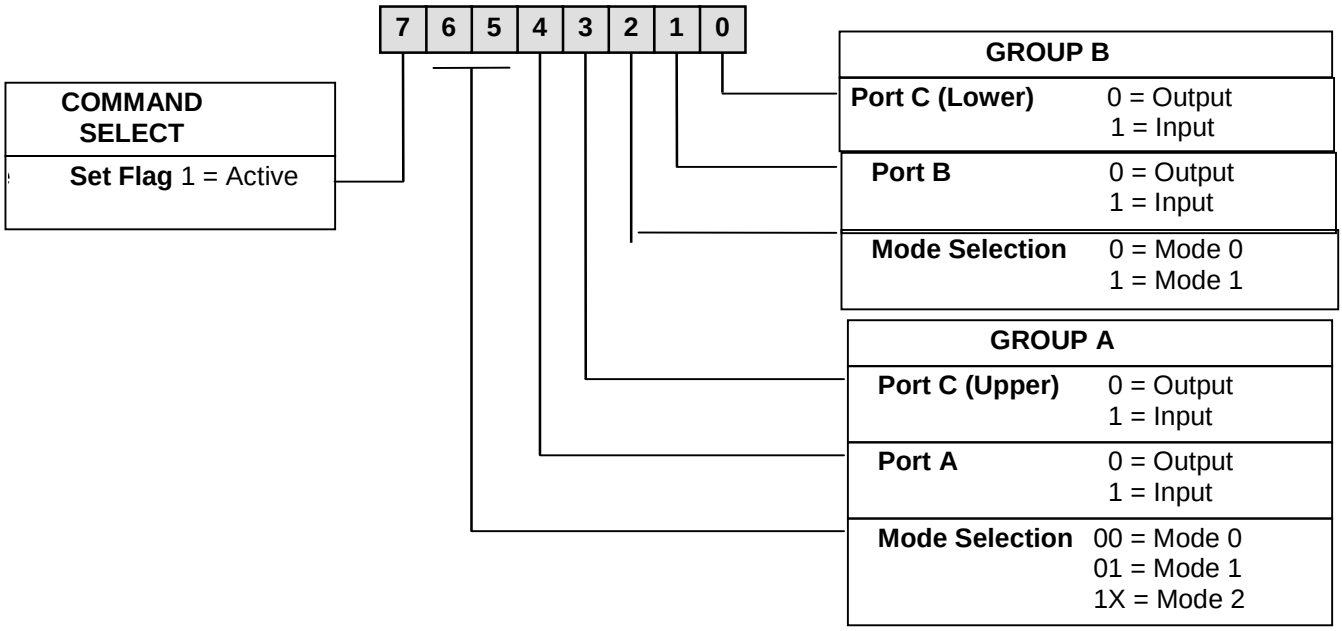
When port C is being used as status/control for port A or port B, these bits can be set or reset using the Bit Set/Reset operation just as if they were data output ports.

BIT ASSIGNMENTS

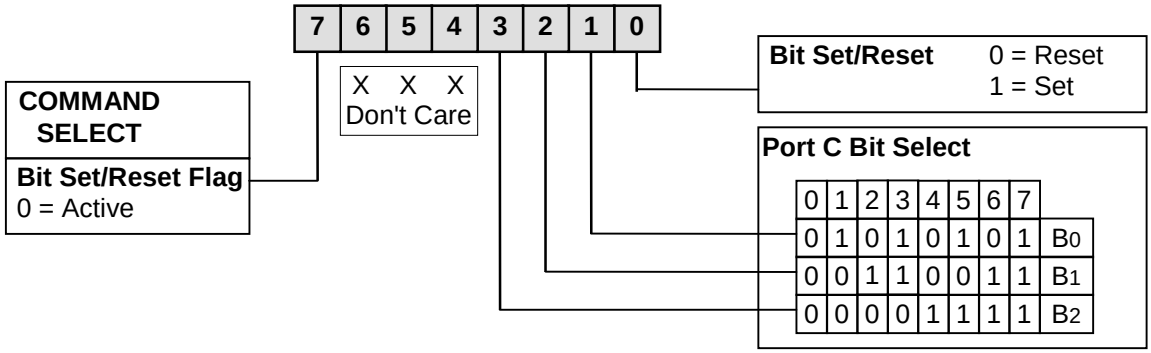
Bit layouts of the PPI-X command word register is shown below.

Further information on programming the 82C55 PPI is given in chapters 4 and 6. A full description of the operating modes and all other features of the 82C55 are available in the 82C55 device manufacturer's data sheet in the appendices.

Command Word for Mode Definition Format



Command Word for Bit Set/Reset Format



5.3.5 Programmable Peripheral Interface PPI-Y Data Register Port A

This eight bit register writes to and reads from port A of the 82C55 Programmable Peripheral Interface PPI-Y. All input/output lines PA0 to PA7 of this device are available to the user on connector SK1 as digital I/O.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
08_{16}	Write and Read	8 bits	82C55 Programmable Peripheral Interface Y Port A Data Register	**PPI-Y A**

FUNCTION

The PPI-X Port A Data Register is used to write or read 8 bit data to port A of the 82C55 Programmable Peripheral Interface device PPI-Y.

The PPI can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C55 data sheets in the appendices.

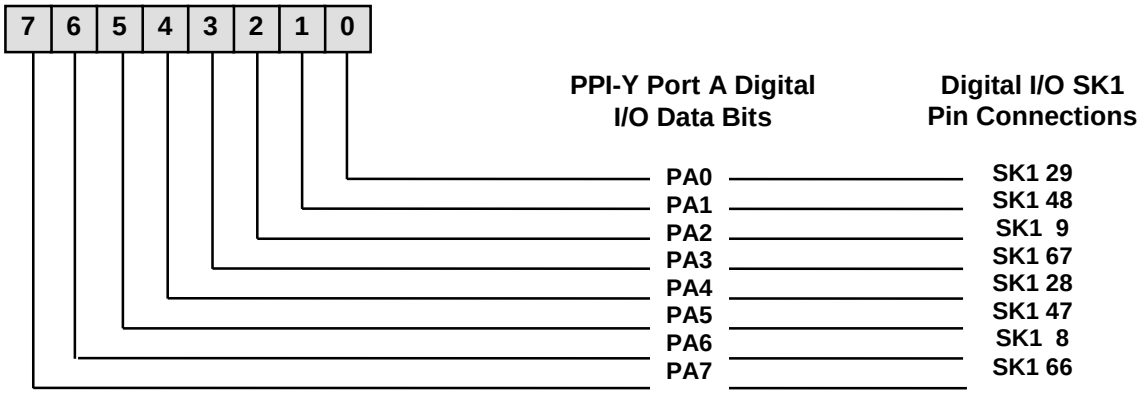
The eight data bits of port A are data input, data output or bi-directional data I/O according to the PPI mode:

Mode 0 Input or Output
Mode 1 Input or Output
Mode 2 Bi-Directional Input/output

The modes and programming of PPI operations are outlined in chapters 4 and 6 with the Digital I/O connections shown in chapter 3.

BIT ASSIGNMENTS

The bit layout of the PPI-Y port A data register is shown below.



5.3.6 Programmable Peripheral Interface PPI-Y Data Register Port B

This eight bit register writes to and reads from port B of the 82C55 Programmable Peripheral Interface PPI-Y. All input/output lines PB0 to PB7 of this device are available to the user on connector SK1 as digital I/O.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
09_{16}	Write and Read	8 bits	82C55 Programmable Peripheral Interface Y Port B Data Register	**PPI-Y B**

FUNCTION

The PPI-Y Port B Data Register is used to write or read 8 bit data to a port of the 82C55 Programmable Peripheral Interface device.

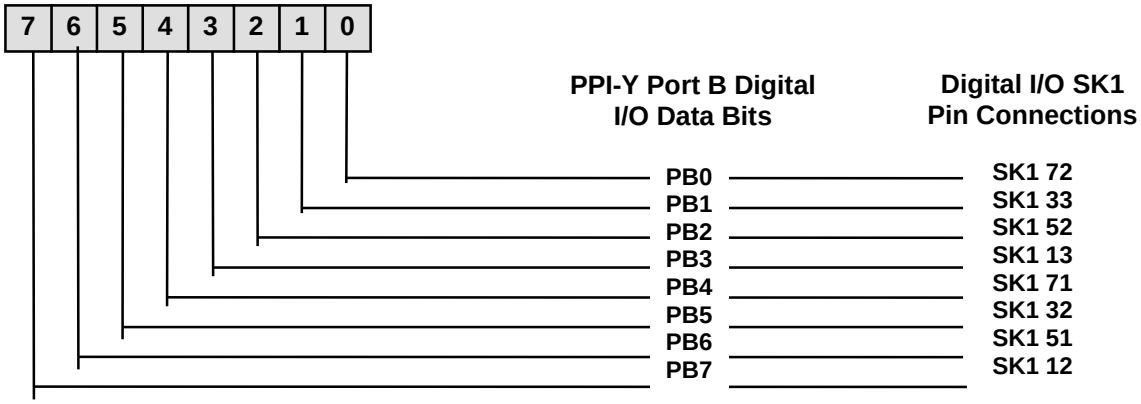
The PPI can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C55 data sheets in the appendices.

The eight data bits of port B are data input or data output in all modes

The modes and programming of PPI operations are outlined in chapters 4 and 6 with the Digital I/O connections shown in chapter 3.

BIT ASSIGNMENTS

The bit layout of the PPI-Y port B data register is shown below.



5.3.7 Programmable Peripheral Interface PPI-Y Data Register Port C

This eight bit register writes to and reads from port C of the 82C55 Programmable Peripheral Interface PPI-Y. All input/output lines PC0 to PC7 of this device are available to the user on connector SK1 as digital I/O.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
$0A_{16}$	Write and Read	8 bits	82C55 Programmable Peripheral Interface Y Port C Data Register	**PPI-Y C**

FUNCTION

The PPI-Y Port C Data Register is used to write or read 8 bit data to a port of the 82C55 Programmable Peripheral Interface device

The PPI can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C55 data sheets in the appendices.

The eight data bits of port C are split into two groups, the upper port C bits 4 to 7 and the lower port C bits 0 to 3. These bits can be data input, data output or control/handshake lines according to the PPI mode:

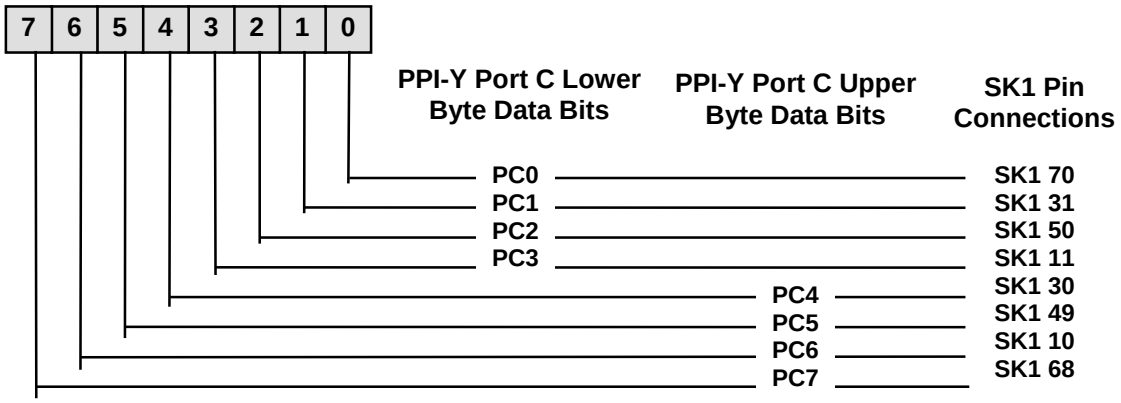
Mode	Port C Upper	Port C Lower
Mode 0	Input or Output	Input or Output
Mode 1	Control/Data	Control/Data
Mode 2	5 bit Control (PC3 to PC7)	3 bit Control/Data (PC0 to PC2)

With bit 7 'Command Select' set to '0', any of the eight bits of port C can be set or reset using a single output instruction. When port C is being used as status/control for port A or port B, these bits can be set or reset using the Bit Set/Reset operation just as if they were data output ports.

The modes and programming of PPI operations are outlined in chapters 4 and 6 with the Digital I/O connections shown in chapter 3.

BIT ASSIGNMENTS

The bit layout of the PPI-Y port C data register is shown below.



5.3.8 Programmable Peripheral Interface PPI-Y Command Register

This is the command register for the PPI and can be used to set the operational mode of the three digital I/O ports or to manipulate the bits of port C.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
$0B_{16}$	Write	8 bits	82C55 Programmable Peripheral Interface PPI-Y Command Register	**PPI-Y CMD**

FUNCTION

Provides a command word to define the operation of the PPI-Y ports A, B and C. Any port programmed as output is initialised to all zeroes when a command word is written. A separate feature allows any bit of port C to be set or reset using a single instruction.

The programming procedure for the 82C55 is flexible, but the command word must be written before data bytes are loaded. As the command register and each port have separate addresses (offsets 0 to 3) and each command word specifies the mode of each port, no other special instruction sequence is required.

The Three Modes

The register function depends on the setting of bit 7 'Command Select' and the three mode selections assume that bit 7 is set to '1'. which allows mode configuration.

Mode 0 provides basic input and output operations through each of the ports A, B and C. Output data bits are latched and input data follows the signals applied to the I/O lines. No handshaking is needed.

- 16 different configurations in mode 0
- Two 8 bit ports and two 4 bit ports
- Inputs are not latched
- Outputs are latched

Mode 1 provides strobed input and output operations with data transferred through port A or B and handshaking through port C.

- Two I/O groups (Group A - also known as Group 0 or Group I)
- (Group B - also known as Group 1 or Group II)
- Both groups contain an 8 bit port and a 4 bit control/data port
- Both 8 bit data ports can be latched input or latched output

Mode 2 provides strobed bi-directional operation using port A as the bi-directional data bus. Port C3 to C7 bits are used for interrupts and handshaking bus flow control similar to mode 1. NOTE: Port B and port C0 to C2 bits may be defined as mode 0 or 1, input or output in conjunction with port A in mode 2.

- An 8 bit latched bi-directional bus port and 5 bit control port
- Both input and outputs are latched
- An additional 8 bit input or output port with a 3 bit control port

Single Bit Set/Reset Feature

With bit 7 'Command Select' set to '0', any of the eight bits of port C can be set or reset using a single output instruction. This feature reduces the software overhead in control based applications.

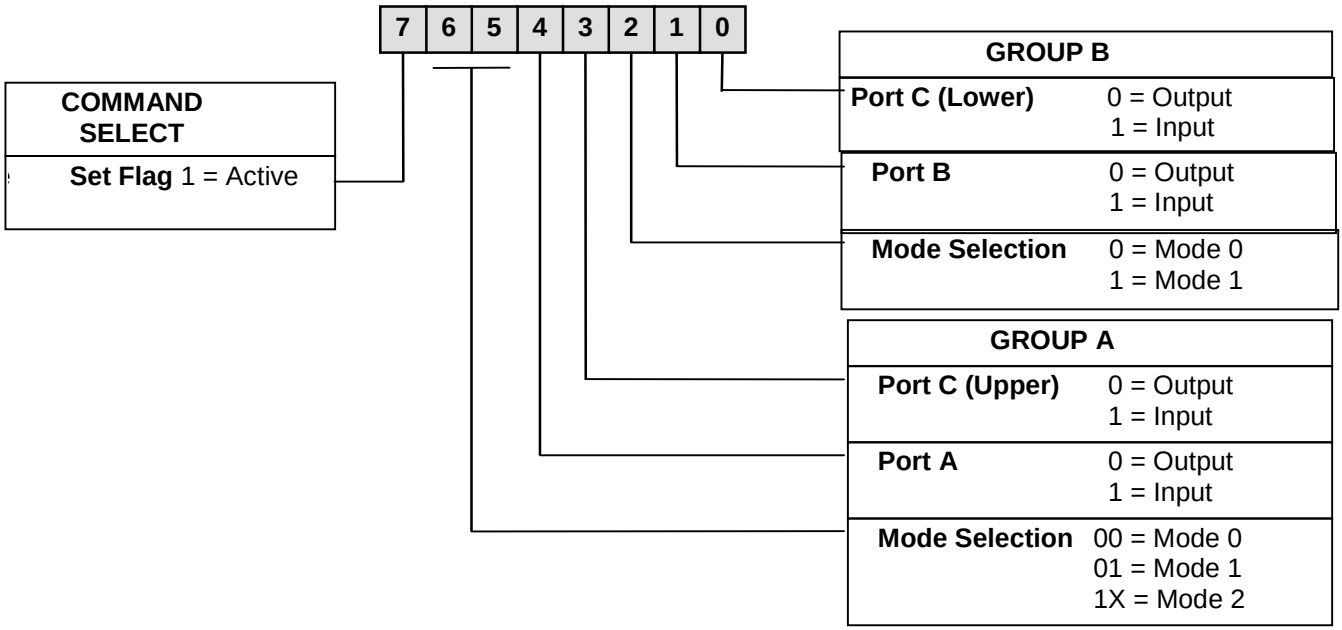
When port C is being used as status/control for port A or port B, these bits can be set or reset using the Bit Set/Reset operation just as if they were data output ports.

BIT ASSIGNMENTS

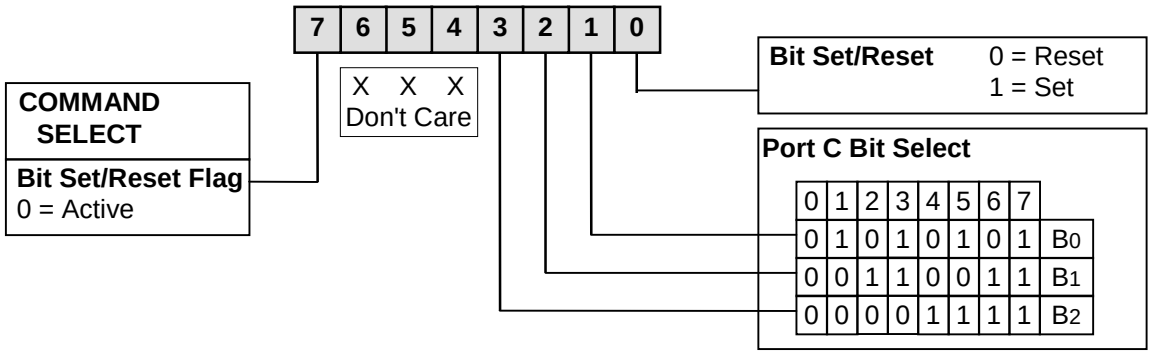
Bit layouts of the PPI-Y command word register is shown below.

Further information on programming the 82C55 PPI is given in chapters 4 and 6. A full description of the operating modes and all other features of the 82C55 are available in the 82C55 device manufacturer's data sheet in the appendices.

Command Word for Mode Definition Format



Command Word for Bit Set/Reset Format



5.3.9 Z1 Counter 0 Data Register

The 82C54 Programmable Timer Counter Z1 provides three 16 bit counter/timers which can be independently programmed to operate in any one of six modes with BCD or Binary count functions. The register definition for Z1 Counter 0 Data is as follows.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
10_{16}	Write and Read	8 bits	82C54 Counter/Timer Z1 Counter 0 Data Register	**Z1 CT0**

FUNCTION

The Z1 Counter 0 Data Register is used to write and read 8 bit data to the 82C54 Z1 counter/timer 0. The counter is normally configured for 16 bit operation and to ensure validity of the data it is important to always write/read two bytes to the register, least significant byte first. Please note that the 16-bit count values written to this register are not latched into the counting element until the next clock pulse (assuming the gate input is high). Subsequent read operations from this register will therefore not reflect the new count value until this clock pulse has latched the data.

The counter can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C54 data sheets in the appendices.

The input to counter 0 can be any of the five internal master clock frequencies (10 MHz, 1 MHz, 100 kHz, 10 kHz or 1 kHz), an external clock, the Z1 External Clock signal or the output of Z2 counter 2. This clock source selection is made by writing to the Group Z Clock Connection Register described in Section 5.3.19.

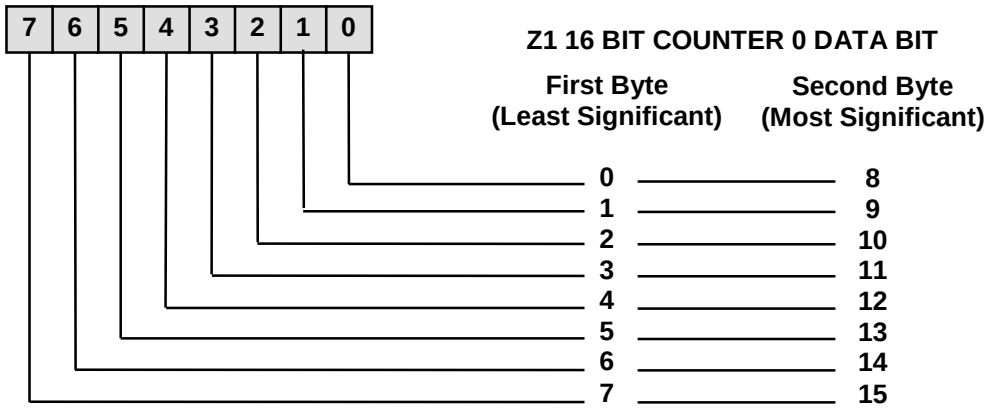
The output of counter 0 is available on the user socket, SK1 pin 15, and also as a possible clock source for counter 1. The inverted output of Z1 counter 0 is also available on SK1 pin 54.

The gate input to counter 0 can be selected as VCC (permanently enabled), GND (permanently disabled), the inverted output of Z2 Counter 1, or an external gate signal on SK1 pin 73. This gate selection is made by writing to the Group Z Gate Connection Register described in Section 5.3.20.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6.

BIT ASSIGNMENTS

The bit layout of the Z1 counter 0 data register is shown below.



5.3.10 Z1 Counter 1 Data Register

The 82C54 Programmable Timer Counter Z1 provides three 16 bit counter/timers which can be independently programmed to operate in any one of six modes with BCD or Binary count functions. The register definition for Z1 Counter 1 Data is as follows.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
11_{16}	Write and Read	8 bits	82C54 Z1 Counter/Timer Counter 1 Data Register	**Z1 CT1**

FUNCTION

The Z1 Counter 1 Data Register is used to write and read 8 bit data to the 82C54 Z1 counter/timer 1. The counter is normally configured for 16 bit operation and to ensure validity of the data it is important to always write/read two bytes to the register, least significant byte first. Please note that the 16-bit count values written to this register are not latched into the counting element until the next clock pulse (assuming the gate input is high). Subsequent read operations from this register will therefore not reflect the new count value until this clock pulse has latched the data.

The counter can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C54 data sheets in the appendices.

The input to counter 1 can be any of the five internal master clock frequencies (10MHz, 1 MHz, 100 kHz, 10 kHz or 1 kHz), an external clock, the Z1 External Clock signal or the output of Z1 counter 0. This clock source selection is made by writing to the Group Z Clock Connection Register described in Section 5.3.19.

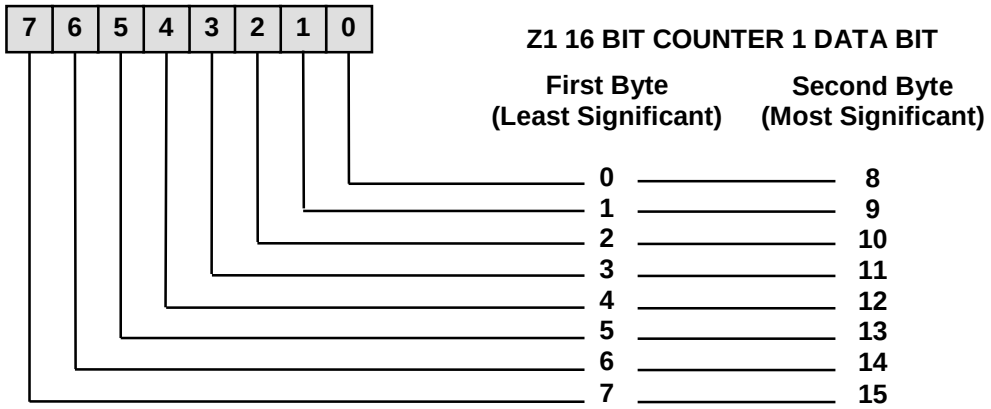
The output of counter 1 is available on the user socket, SK1 pin 55, and also as a possible clock source for counter 2.

The gate input to counter 1 can be selected as VCC (permanently enabled), GND (permanently disabled), the inverted output of Z2 Counter 2, or an external gate signal on SK1 pin 16. This gate selection is made by writing to the Group Z Gate Connection Register described in Section 5.3.20.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6.

BIT ASSIGNMENTS

The bit layout of the Z1 counter 1 data register is shown below.



5.3.11 Z1 Counter 2 Data Register

The 82C54 Programmable Timer Counter Z1 provides three 16 bit counter/timers which can be independently programmed to operate in any one of six modes with BCD or Binary count functions. The register definition for Z1 Counter 2 Data is as follows.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
12_{16}	Write and Read	8 bits	82C54 Z1 Counter/Timer Counter 2 Data Register	**Z1 CT2**

FUNCTION

The Z1 Counter 2 Data Register is used to write and read 8 bit data to the 82C54 Z1 counter/timer 2. The counter is normally configured for 16 bit operation and to ensure validity of the data. It is important to always write/read two bytes to the register, least significant byte first. Please note that the 16-bit count values written to this register are not latched into the counting element until the next clock pulse (assuming the gate input is high). Subsequent read operations from this register will therefore not reflect the new count value until this clock pulse has latched the data.

The input to counter 2 can be any of the five internal master clock frequencies (10 MHz, 1 MHz, 100 kHz, 10 kHz or 1 kHz), an external clock, the Z1 External Clock signal or the output of Z1 counter 1. This clock source selection is made by writing to the Group Z Clock Connection Register described in Section 5.3.19.

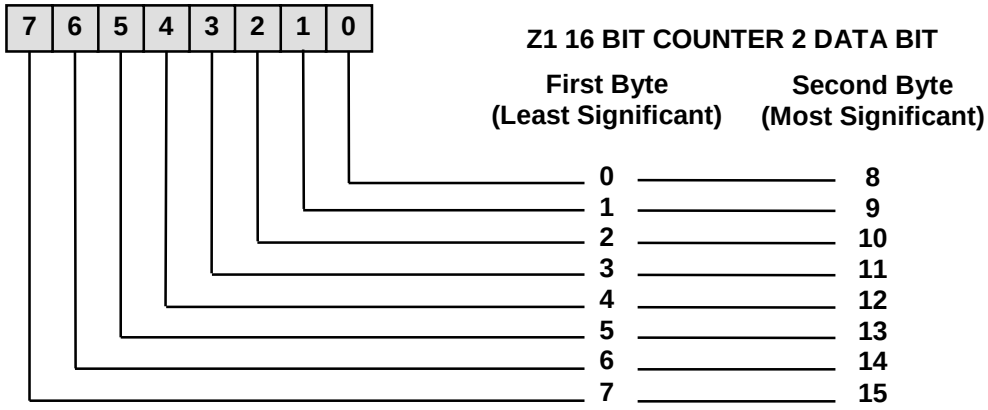
The output of counter 2 is available on the user socket, SK1 pin 17, and also as a possible clock source for Z2 counter 0.

The gate input to counter 2 can be selected as VCC (permanently enabled), GND (permanently disabled), the inverted output of Z1 Counter 0, or an external gate signal on SK1 pin 75. This gate selection is made by writing to the Group Z Gate Connection Register described in Section 5.3.20.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6.

BIT ASSIGNMENTS

The bit layout of the Z1 counter 2 data register is shown below.



5.3.12 Counter/Timer Z1 Control Register

The Z1 control register provides the means to configure the three sixteen bit counter/timers of the 82C54 Z1. An outline of its operation is given here, but reference should be made to the 82C54 device manufacturers' data sheets in the appendices before programming of the counter is attempted.

The Counter Timer Control register is a WRITE register. The READ register at the same location BA + 13_{16} returns the status of the 82C54 Z1 Counter/Timer when used with the Read-Back command.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
13_{16}	Write	8 bits	82C54 Z1 Counter/Timer Control Register	**Z1 CTC**

FUNCTION

Provides a control word to define the operation of the Z1 counters 0, 1 and 2.

The programming procedure for the 82C54 is flexible, but the following two conventions must be followed:

- For each counter, the control word must be written before the initial count is loaded.
- The initial count must follow the count format specified in the control word. This format is normally least significant byte followed by most significant byte (control word bits 5, 4 = 1 1) but can be L.S. byte only or M.S. byte only.

As the control register and each counter have separate addresses (offsets 0, 1, 2 and 3) and each control word specifies the counter it applies to (bits 6 and 7) no special instruction sequence is required.

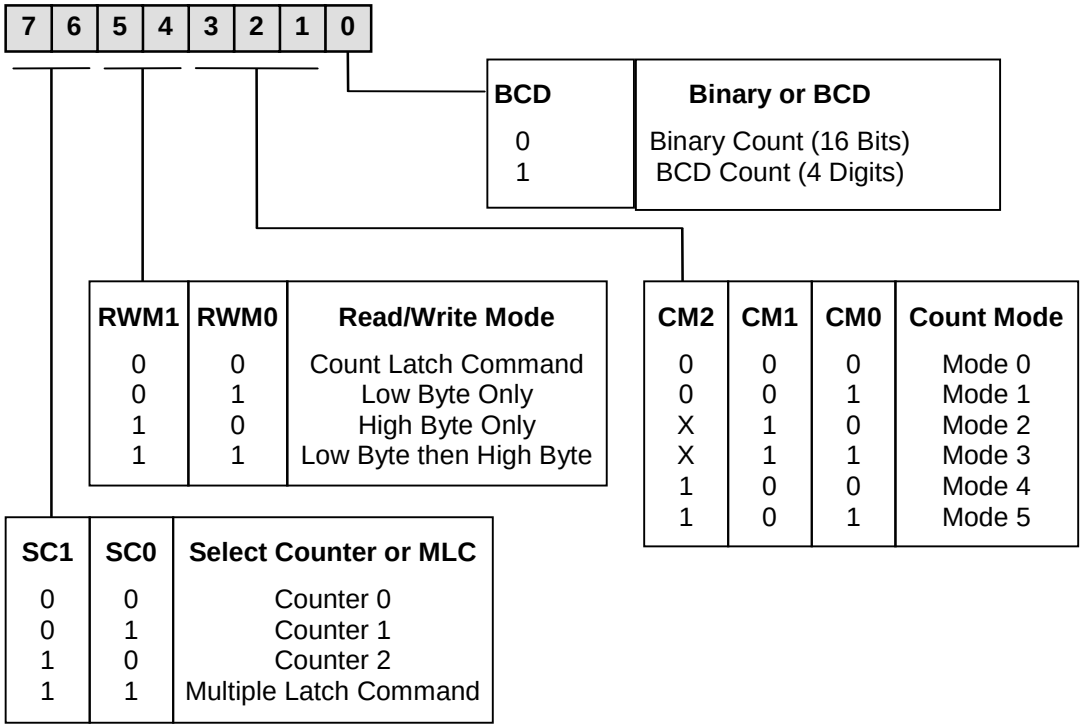
When a control word is written to a counter, all control logic is reset and OUT goes to a known initial state depending on the mode selected. The six counter modes are:

Mode 0	Interrupt on Terminal Count
Mode 1	Hardware Re-triggerable One-shot
Mode 2	Rate Generator
Mode 3	Square Wave
Mode 4	Software Triggered Mode
Mode 5	Hardware Triggered Strobe (Re-triggerable)

BIT ASSIGNMENTS

Bit layout of the Z1 counter control word register is shown below. Two other commands that can be written to the Control Register are the Counter Latch Command and the Read-Back Command. The formats for these two commands are also shown below.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6. A full description of the six operating modes and all other features of the 82C54 are available in the 82C54 device manufacturer's data sheet in the appendices.



5.3.13 Z1 Counter/Timer Status Register

This status register provides the means to interrogate the three sixteen bit counter/timers of the 82C54 Z1. An outline of its operation is given here, but reference should be made to the 82C54 device manufacturers' data sheets in the appendix before programming of the counter is attempted.

The Z1 counter Status Register is a READ register. The WRITE register at the same location BA + 13_{16} controls the operation of the 82C54 Counter/Timer Z1 and issues a Read-Back command before the status is interrogated.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
13_{16}	Read	8 bits	82C54 Z1 Counter/Timer Status Register	**Z1 CTS**

FUNCTION

When the Read-Back Command requests the status of the counters, the status register provides the count value, programmed mode, the current state of the OUT pin and Null Count Flag of the selected counter(s).

Counter Latch Command

7	6	5	4	3	2	1	0

Bits 3 to 0 = Don't care
Bits 5 and 4 = 0
Designates Counter Latch Command
Bits 7 and 6
00 = Counter 0
01 = Counter 1
10 = Counter 2
11 = Read-back Command

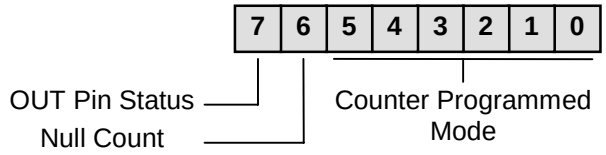
Read-back Command

7	6	5	4	3	2	1	0

Bit 0 = 0
Bit 1 = Select Counter 0
Bit 2 = Select Counter 1
Bit 3 = Select Counter 2
Bit 4 = /Latch Status of Selected Counter(s)
Bit 5 = /Latch Count of Selected Counter(s)
Bits 6 and 7 = 1
Designates Read-back Command

BIT ASSIGNMENTS

Bit layout of the counter/timer status word register is shown below.



Bits 5…0 Counter's programmed Mode exactly as written in the last Mode Control Word

Bit 6 State of the addressed counter element

0 Count available for reading
1 Null Count

Bit 7 State of the addressed counter OUT pin

0 OUT pin is '0'
1 OUT pin is '1'

5.3.14 Z2 Counter 0 Data Register

The 82C54 Programmable Timer Counter Z2 provides three 16 bit counter/timers which can be independently programmed to operate in any one of six modes with BCD or Binary count functions. The register definition for Z2 Counter 0 Data is as follows.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
14_{16}	Write and Read	8 bits	82C54 Counter/Timer Z2 Counter 0 Data Register	**Z2 CT0**

FUNCTION

The Z2 Counter 0 Data Register is used to write and read 8 bit data to the 82C54 Z2 counter/timer 0. The counter is normally configured for 16 bit operation and to ensure validity of the data it is important to always write/read two bytes to the register, least significant byte first. Please note that the 16-bit count values written to this register are not latched into the counting element until the next clock pulse (assuming the gate input is high). Subsequent read operations from this register will therefore not reflect the new count value until this clock pulse has latched the data.

The counter can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C54 data sheets in the appendices.

The input to counter 0 can be any of the five internal master clock frequencies (10 MHz, 1 MHz, 100 kHz, 10 kHz or 1 kHz), an external clock, the Z2 External Clock signal or the output of Z1 counter 2. This clock source selection is made by writing to the Group Z Clock Connection Register described in Section 5.3.19.

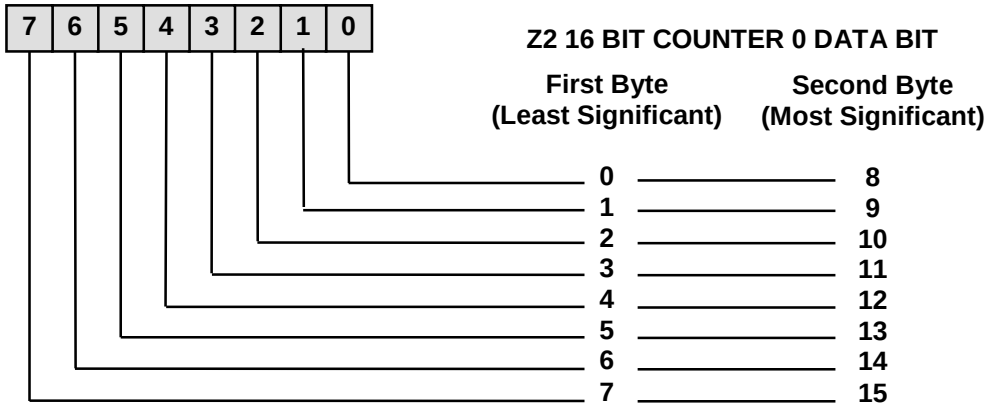
The output of counter 0 is available on the user socket, SK1 pin 57, and also as a possible clock source for Z2 counter 1. The inverted output of Z2 counter 0 is also available on SK1 pin 38.

The gate input to counter 0 can be selected as VCC (permanently enabled), GND (permanently disabled), the inverted output of Z1 Counter 1, or an external gate signal on SK1 pin 18. This gate selection is made by writing to the Group Z Gate Connection Register described in Section 5.3.20.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6.

BIT ASSIGNMENTS

The bit layout of the Z2 counter 0 data register is shown below.



5.3.15 Z2 Counter 1 Data Register

The 82C54 Programmable Timer Counter Z2 provides three 16 bit counter/timers which can be independently programmed to operate in any one of six modes with BCD or Binary count functions. The register definition for Z2 Counter 1 Data is as follows.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
15_{16}	Write and Read	8 bits	82C54 Z2 Counter/Timer Counter 1 Data Register	Z2 CT1

FUNCTION

The Z2 Counter 1 Data Register is used to write and read 8 bit data to the 82C54 Z2 counter/timer 1. The counter is normally configured for 16 bit operation and to ensure validity of the data it is important to always write/read two bytes to the register, least significant byte first. Please note that the 16-bit count values written to this register are not latched into the counting element until the next clock pulse (assuming the gate input is high). Subsequent read operations from this register will therefore not reflect the new count value until this clock pulse has latched the data.

The counter can be configured to operate in several modes. Further details may be found by reference to the device manufacturer's 82C54 data sheets in the appendices.

The input to counter 1 can be any of the five internal master clock frequencies (10 MHz, 1 MHz, 100 kHz, 10 kHz or 1 kHz), an external clock, the Z2 External Clock signal or the output of Z2 counter 0. This clock source selection is made by writing to the Group Z Clock Connection Register described in Section 5.3.19.

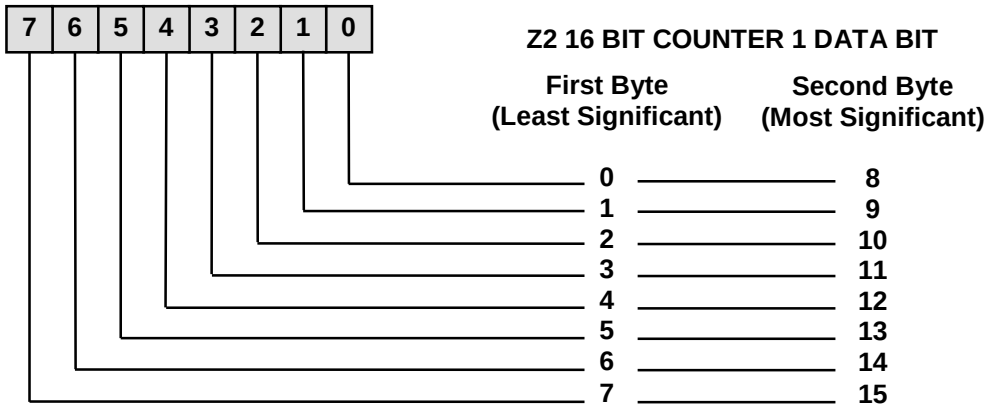
The output of counter 1 is available on the user socket, SK1 pin 58, and also as a possible clock source for counter 2.

The gate input to counter 1 can be selected as VCC (permanently enabled), GND (permanently disabled), the inverted output of Z1 Counter 2, or an external gate signal on SK1 pin 19. This gate selection is made by writing to the Group Z Gate Connection Register described in Section 5.3.20.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6.

BIT ASSIGNMENTS

The bit layout of the Z2 counter 1 data register is shown below.



5.3.16 Z2 Counter 2 Data Register

The 82C54 Programmable Timer Counter Z2 provides three 16 bit counter/timers which can be independently programmed to operate in any one of six modes with BCD or Binary count functions. The register definition for Z2 Counter 2 Data is as follows.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
16_{16}	Write and Read	8 bits	82C54 Z2 Counter/Timer Counter 2 Data Register	**Z2 CT2**

FUNCTION

The Z2 Counter 2 Data Register is used to write and read 8 bit data to the 82C54 Z2 counter/timer 2. The counter is normally configured for 16 bit operation and to ensure validity of the data. It is important to always write/read two bytes to the register, least significant byte first. Please note that the 16-bit count values written to this register are not latched into the counting element until the next clock pulse (assuming the gate input is high). Subsequent read operations from this register will therefore not reflect the new count value until this clock pulse has latched the data.

The input to counter 2 can be any of the five internal master clock frequencies (10MHz, 1 MHz, 100 KHz, 10 kHz or 1 kHz), an external clock, the Z2 External Clock signal or the output of Z2 counter 1. This clock source selection is made by writing to the Group Z Clock Connection Register described in Section 5.3.19.

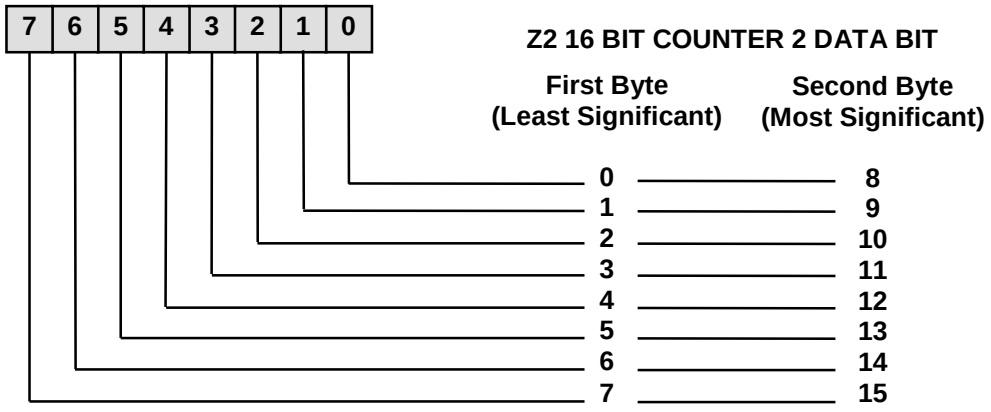
The output of counter 2 is available on the user socket, SK1 pin 20, and also as a possible clock source for Z1 counter 0.

The gate input to counter 2 can be selected as VCC (permanently enabled), GND (permanently disabled), the inverted output of Z2 Counter 0, or an external gate signal on SK1 pin 78. This gate selection is made by writing to the Group Z Gate Connection Register described in Section 5.3.20.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6.

BIT ASSIGNMENTS

The bit layout of the Z2 counter 2 data register is shown below.



5.3.17 Counter/Timer Z2 Control Register

The Z2 control register provides the means to configure the three sixteen bit counter/timers of the 82C54 Z2. An outline of its operation is given here, but reference should be made to the 82C54 device manufacturers' data sheets in the appendices before programming of the counter is attempted.

The Counter Timer Control register is a WRITE register. The READ register at the same location BA + 13_{16} returns the status of the 82C54 Z2 Counter/Timer when used with the Read-Back command.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
17_{16}	Write	8 bits	82C54 Z2 Counter/Timer Control Register	**Z2 CTC**

FUNCTION

Provides a control word to define the operation of the Z2 counters 0, 1 and 2.

The programming procedure for the 82C54 is flexible, but the following two conventions must be followed:

- For each counter, the control word must be written before the initial count is loaded.
- The initial count must follow the count format specified in the control word. This format is normally least significant byte followed by most significant byte (control word bits 5, 4 = 1 1) but can be L.S. byte only or M.S. byte only.

As the control register and each counter have separate addresses (offsets 0, 1, 2 and 3) and each control word specifies the counter it applies to (bits 6 and 7) no special instruction sequence is required.

When a control word is written to a counter, all control logic is reset and OUT goes to a known initial state depending on the mode selected.

The six counter modes are:

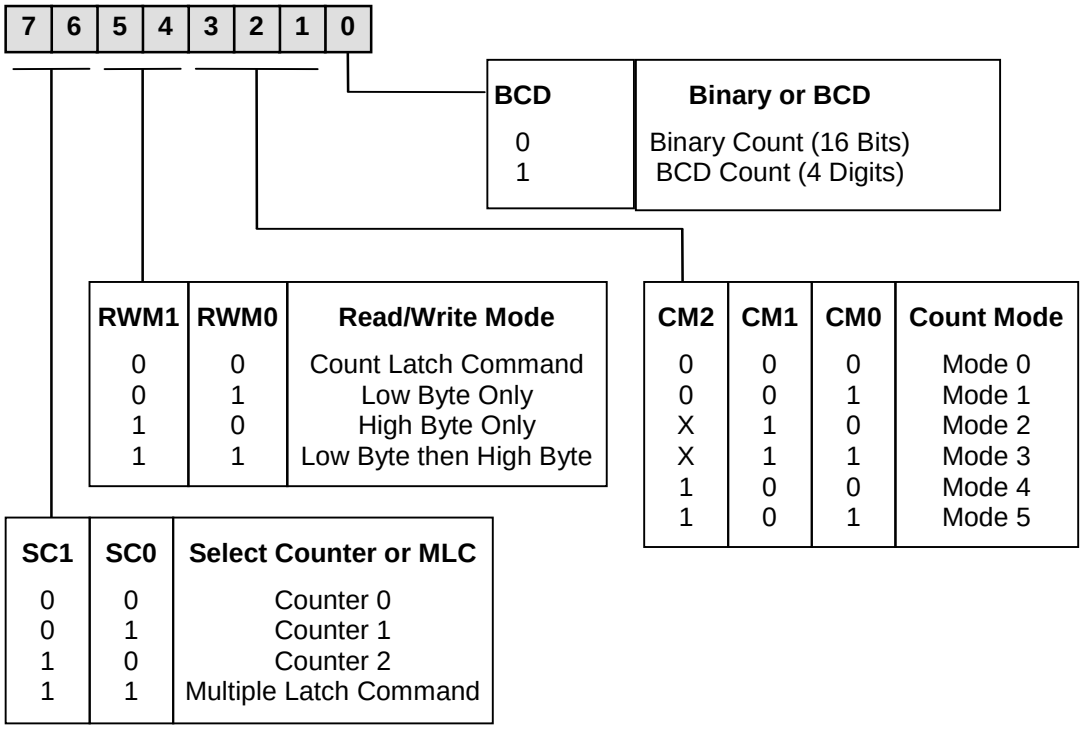
Mode 0	Interrupt on Terminal Count
Mode 1	Hardware Re-triggerable One-shot
Mode 2	Rate Generator
Mode 3	Square Wave
Mode 4	Software Triggered Mode
Mode 5	Hardware Triggered Strobe (Re-triggerable)

BIT ASSIGNMENTS

Bit layout of the Z2 counter control word register is shown below.

Two other commands that can be written to the Control Register are the Counter Latch Command and the Read-Back Command. The formats for these two commands are also shown below.

Further information on programming the 82C54 Programmable Counter/Timer is given in chapters 4 and 6. A full description of the six operating modes and all other features of the 82C54 are available in the 82C54 device manufacturer's data sheet in the appendices.



5.3.18 Z2 Counter/Timer Status Register

This status register provides the means to interrogate the three sixteen bit counter/timers of the 82C54 Z2. An outline of its operation is given here, but reference should be made to the 82C54 device manufacturers' data sheets in the appendix before programming of the counter is attempted.

The Z2 counter Status Register is a READ register. The WRITE register at the same location BA + 13_{16} controls the operation of the 82C54 Counter/Timer Z2 and issues a Read-Back command before the status is interrogated.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
17_{16}	Read	8 bits	82C54 Z2 Counter/Timer Status Register	**Z2 CTS**

FUNCTION

When the Read-Back Command requests the status of the counters, the status register provides the count value, programmed mode, the current state of the OUT pin and Null Count Flag of the selected counter(s).

Counter Latch Command

7	6	5	4	3	2	1	0

Bits 3 to 0 = Don't care
Bits 5 and 4 = 0
Designates Counter Latch Command
Bits 7 and 6
00 = Counter 0
01 = Counter 1
10 = Counter 2
11 = Read-back Command

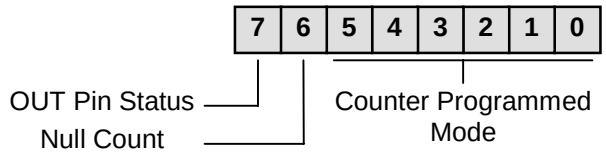
Read-back Command

7	6	5	4	3	2	1	0

Bit 0 = 0
Bit 1 = Select Counter 0
Bit 2 = Select Counter 1
Bit 3 = Select Counter 2
Bit 4 = /Latch Status of Selected Counter(s)
Bit 5 = /Latch Count of Selected Counter(s)
Bits 6 and 7 = 1
Designates Read-back Command

BIT ASSIGNMENTS

Bit layout of the counter/timer status word register is shown below.



Bits 5…0 Counter's programmed Mode exactly as written in the last Mode Control Word

Bit 6 State of the addressed counter element

0 Count available for reading
1 Null Count

Bit 7 State of the addressed counter OUT pin

0 OUT pin is '0'
1 OUT pin is '1'

5.3.19 Group Z Clock Connection Register

This is the register that can be used to select the counter/timer clock sources for the six counter/timers on the PC215E board.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
$1A_{16}$	Write	8 bits	Group Z Counter/timer Clock Selection Register	ZCLK_SCE

FUNCTION

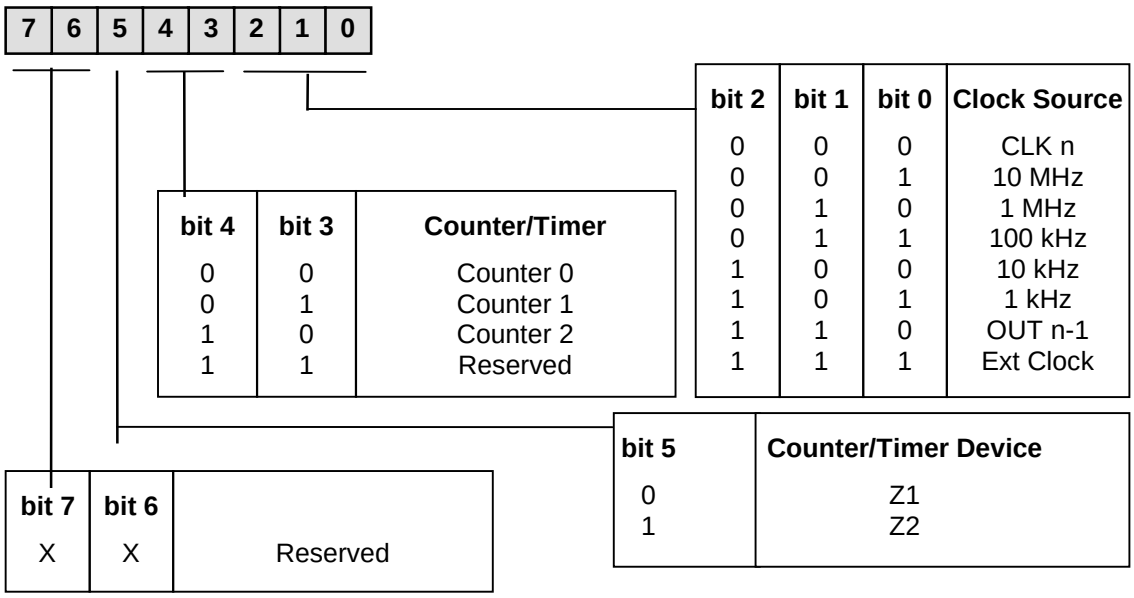
Individually selects one of the eight possible Counter/Timer clock sources for each of the six counter/timers on the PC215E board. The selected source will then appear on the clock input of the specified counter/timer.

The Eight Clock Sources

The eight possible clock sources are as follows:

1. The counter/timer's CLK input from the SK1 connector
2. The internal 10 MHz clock
3. The internal 1 MHz clock
4. The internal 100 kHz clock
5. The internal 10 kHz clock
6. The internal 1 kHz clock
7. The output of the preceding counter/timer
8. The dedicated external clock input for Z1/Z2

BIT ASSIGNMENTS



5.3.20 Group Z Gate Connection Register

This is the register that can be used to select the counter/timer gate input sources for the six counter/timers on the PC215E board.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
$1D_{16}$	Write	8 bits	Group Z Counter/timer Gate Selection Register	ZGAT_SCE

FUNCTION

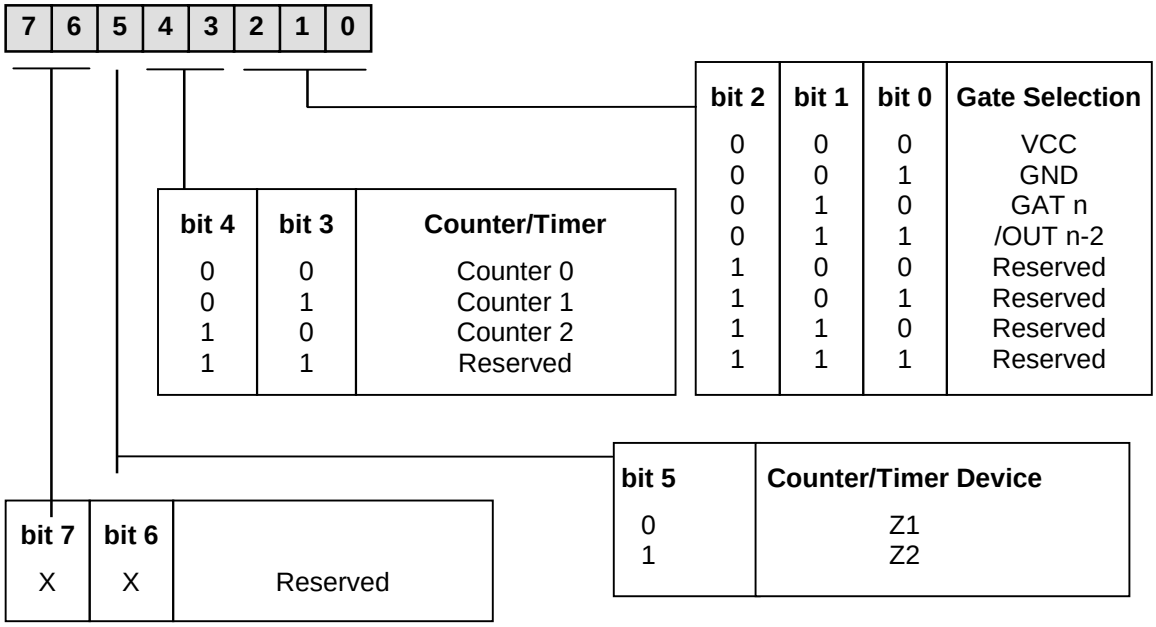
Individually selects one of the four possible Counter/Timer gate input signal sources for each of the six counter/timers on the PC215E board. The selected source will then appear on the gate input of the specified counter/timer.

The Four Gate Sources

The four possible gate sources are as follows:

1. VCC (internal +5V d.c.) i.e. gate permanently enabled
2. GND (internal 0V d.c.) i.e. gate permanently disabled
3. The counter/timer's GAT input from the SK1 connector
4. OUT n-2 the inverted output of counter/timer n-2

BIT ASSIGNMENTS



5.3.21 Interrupt Source Selection Register

This is the register that can be used to select one or more interrupt source for the PC215E board.

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
$1E_{16}$	Write	8 bits	Interrupt Source Selection Register	**INT_SCE**

FUNCTION

Selects one or more of the six PC215E interrupt sources. The selected source(s) will then have the ability to drive the board's interrupt request level, as selected on jumper J1. See Section 2.6.3 for details on selecting the PC215E interrupt request level. If more than one source is selected, the interrupt routine must interrogate the board to determine which source generated the interrupt. The Interrupt Status register provides this information - see section 5.3.22.

Note: The selected interrupt source signals are latched into the Interrupt Status register - i.e. once a selected interrupt source signal goes high, it remains high until the corresponding bit in the Interrupt Source Selection register is cleared (set to 0). Therefore, after servicing the asserted interrupt sources, the interrupt routine must write a zero to this register to clear all latched interrupt source signals, then re-write the mask word to re-select the required interrupt source(s).

The Six Interrupt Sources

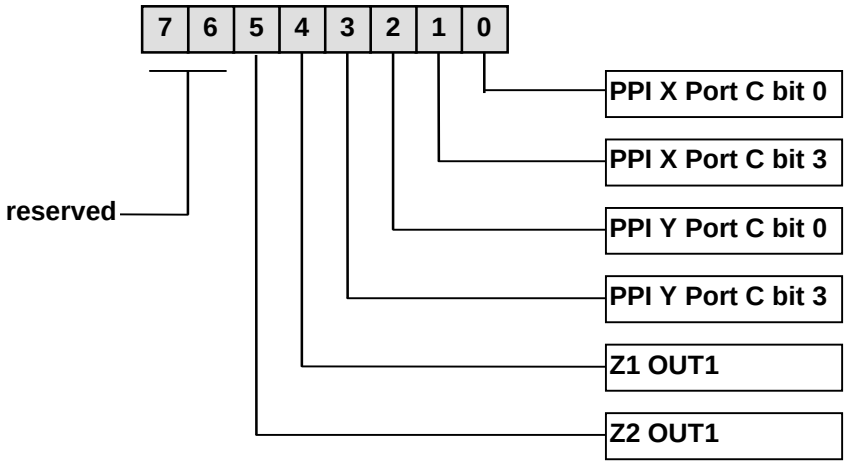
The six sources are as follows:

1. PPI X Port C bit 0 digital input/output
2. PPI X Port C bit 3 digital input/output
3. PPI Y Port C bit 0 digital input/output
4. PPI Y Port C bit 3 digital input/output
5. Z1 Counter 1 output
6. Z2 Counter 1 output

For the PPI interrupt sources, Port C of the relevant PPI device can be either an input port or as an output port, and this is programmed by sending a control word to the PPI's Command Register.

BIT ASSIGNMENTS

Bit layouts of the Interrupt Source register is shown below.



5.3.22 Interrupt Status Register

This is the register that can be used to determine the status of the PC215E board's interrupt source(s).

Register Offset	Write and/or Read	Register Width	Register Title	Mnemonic
$1E_{16}$	Read	8 bits	Interrupt Status Register	**INT_STAT**

FUNCTION

Gives the digital status of the selected interrupt sources. In order to read its status, a source must have previously been selected as an interrupt source - see section 5.3.19.

A high level in the bit position of a given source indicates that the source has been set high, and this bit will remain high until the corresponding bit in the Interrupt Source Selection register is cleared.

A low level in the bit position of a given source indicates that either

1. it has not been selected as an interrupt source, or
2. it has been selected as an interrupt source and is set low.

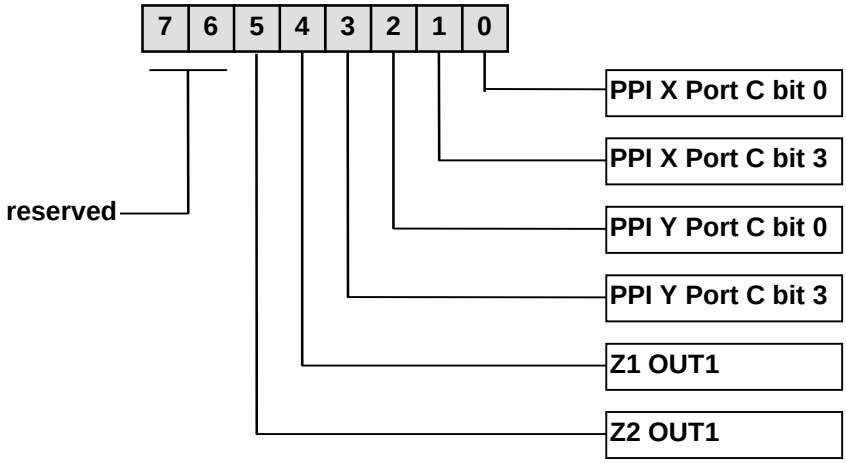
The Six Interrupt Sources

The six sources are as follows:

1. PPI X Port C bit 0 digital input/output
2. PPI X Port C bit 3 digital input/output
3. PPI Y Port C bit 0 digital input/output
4. PPI Y Port C bit 3 digital input/output
5. Z1 Counter 1 output
6. Z2 Counter 1 output

BIT ASSIGNMENTS

Bit layouts of the Interrupt Source register is shown below.



6. PROGRAMMING THE PC215E

The distribution diskette supplied with the PC215E contains a Windows setup program, which installs the software onto the user's hard disk drive, and creates a new Windows program group containing shortcuts to the executable programs and help files. This software includes:

Executable programs for immediate use

Three Windows and three DOS programs ready to run from an icon or the DOS prompt, providing examples of programming the PC215E, using the Windows/DOS library functions.

Dynamic Link Library (DLL) for programming Windows 3.11 applications

A library of over 40 functions providing easy access to all the features of the PC215E board, and also providing implementations of common applications for the PC215E board. The functions in the DLL can be accessed by any programming language which supports Windows and uses the defined Windows calling conventions. The DLL supports all of the boards in the PC214E, PC215E, PC212E, PC218E and PC272E series of digital I/O boards.

'C' Library for programming DOS applications

A DOS library providing identical functionality to the Windows DLL is included, which supports the Microsoft C/C++ and Borland C++ compilers. Again, this library supports all of the boards in the PC214E, PC215E, PC212E, PC218E and PC272E series.

Interface software for other languages

Generic LABTECH NOTEBOOK drivers for the Digital I/O and Timer Counter devices provided on the PC214E, PC215E, PC212E, PC218E and PC272E boards are also provided.

6.1 Copyright

Software supplied on the PC215E diskette is **Amplicon** copyright. Permission is granted for the purchaser of the PC215E to incorporate any part of the **Amplicon** copyright software into related application programs, and to use, resell or otherwise distribute such application programs for operation with PC215E hardware purchased from **Amplicon Liveline Limited.**

6.2 Files installed from the Distribution Diskette

The files installed from the 3.5 inch high density diskette are listed in the ReadMe file, README.TXT. Please refer to this file for the latest information.

Any last minute information will be described in the README.TXT file which should be examined before proceeding.

6.3 Windows DLL and Examples

The PC215E DLL is a 16-bit Windows programmer's interface to the PC215E board. Provided that the compiler/interpreter supports Windows, i.e. uses the Windows calling conventions, all the functions can be called by software written in any language.

For C/C++ language applications, the software includes a ready prepared header file, DIO_TC.H which covers all function definitions and declared constants. Similarly for Visual Basic there is a module DIO_TC.BAS for inclusion in a project make file for DLL declarations and constant definitions. For other languages the user will need to compile a suitable header in which the DLL functions and constants are declared, and these files can be used as an example.

The software includes Visual Basic examples as both runtime and source code. The runtime examples can be used to exercise and become familiar with the hardware. The source code serves two purposes. Firstly it can be used as a source of reference to see how the DLL functions are used. Also it provides a starting point for anyone who wishes to write software with similar functionality.

6.4 DOS 'C' Library and Examples

The 'C' library is a DOS programmer's interface to the PC215E board. The software includes 'C' examples as both runtime and source code. The source code can be compiled using the Microsoft C/C++ or Borland C++ compilers - conditional compilation based on a #define at the top of the program file allows the source code to be compatible with both languages.

To define the 'C' compiler in use, a single line in file DIO_TC.H must be changed for Microsoft or Borland C/C++ users. The line that is not required must be removed (or made inoperative by commenting out)

The following example extracted from the 'C' source shows the program set up for Borland C++

```
#define __BORLAND_C__             // Borland C++ users use this
//#define __MICROSOFT_C__         // Microsoft C/C++ users use this
```

Section 6.6 describes the library functions available. Please note that in C/C++, the function syntax lines given should always end with a semi-colon. Where arguments to functions are described as pointers, the address of a user-declared variable is required. This is easily done by using the '&' reference operator. For example, function *TCgetCount* requires a pointer to a variable declared as long, into which the count value result will be placed. A typical 'C' code example for displaying the Z1 Counter 0 count value would be

```
long count;                       // declare count as long

TCgetCount( h, Z1, 0, &count );   // pass count by reference
printf( "count = %ld", count );   // count now contains new value
```

where h is a handle to a registered board. N.B. The large memory model should be used when compiling the library and example programs.

6.4.1 Borland C++ User Information

1) Ensure that the library DIO_TC.C and the header file DIO_TC.H are in a directory where the compiler can locate them. Failure to find these files may cause ‘unresolved external’ compilation errors.

2) At the beginning of the application program, add the following line:

```
#include "DIO_TC.H"
```

3) Add the file DIO_TC.C to the project list in the environment and use the MAKE command to compile and link.

6.4.2 Microsoft C/C++ User Information

1) Ensure that the library DIO_TC.LIB and the header file DIO_TC.H are in a directory where the compiler can locate them. Failure to find these files may cause ‘unresolved external’ compilation errors.

2) At the beginning of the application program, add the following line:

```
#include "DIO_TC.H"
```

3) Compile the Microsoft C/C++ DIO_TC library with the following command-lines:

```
cl -Ml -c DIO_TC.C
lib DIO_TC.LIB +DIO_TC.OBJ
```

4) Compile the application program using the large model and linking with the DIO_TC library by typing the following command line:

```
cl -Ml myprog.c -link DIO_TC.LIB
```

6.5 Using the Dynamic Link Library

6.5.1 Visual Basic

To open one of the Visual Basic example projects provided with the DLL, from within Microsoft Visual Basic select 'File|Open Project...' and select one of the .MAK project files provided in the WINDOWS\VB subdirectory of the PC215E software directory. The project window will now appear on the desktop. Double-click on any file in the project to view the source code, or select Run to run the program.

To create your own PC215E Visual Basic program from scratch, perform the following steps:

- From within Microsoft Visual Basic, select 'File|New Project'. A new project window will appear, into which the standard Visual Basic Control (VBX) files are automatically loaded. Also an empty Form1 design window will appear.

- Select 'File|Add file...' and select the following files from the WINDOWS\VB subdirectory of the PC215E software directory:

DIO_TC.BAS	- PC215E DLL declarations and global constants
REGISTER.FRM	- Board registration form
CONSTANT.TXT	- Visual Basic global constants

- Double-click on the empty Form1 design window to bring up the code window for the Form_Load() subroutine. At runtime, this routine will get called when the program first starts up.

- Type the following lines into the Form_Load() subroutine:

```
hBoard = ERRSUPPORT
Load REGISTER
REGISTER.Show modal
Unload REGISTER
```

  These lines of code will cause the Board Registration dialog box to pop up so that the PC215E board can be registered with the DLL.

- Put away the code window, and select the Form1 design window

- Select 'Window|Menu Design...' to bring up the dialog box from which you design the form's menubar. Type 'Exit' as the caption and 'mnuExit' as the name for the first menu bar item, then click on OK to put the dialog box away.

- The menubar will now appear in the Form1 design window. Click on the 'Exit' item to bring up the code window for the mnuExit_Click() subroutine. At runtime, this routine will get called whenever the 'Exit' menu is selected.

- Type the following lines into the mnuExit_Click() subroutine:

```
Dim e As Integer
e = freeBoard( hBoard )
if e <> OK then
Call ReportError( e )
End If
End
```

  These lines of code un-registers the board from the DLL as the program closes.

These eight steps will create the shell of a VB application that can now be run. The program at this stage does nothing more than register a PC215E board (or any other board in the PC214E, PC215E, PC212E, PC218E and PC272E series) with the DLL on start-up, and free that board on exit.

Section 6.6 describes the library functions available. Where arguments to functions are described as pointers, the address of a user-declared variable is required. This is taken care of automatically by Visual Basic because all arguments to the DLL functions are passed by reference, unless the 'ByVal' prefix is used on an argument in the function declaration in the DLL's Visual Basic include file, DIO_TC.BAS. For example, function *TCgetCount* requires a pointer to a variable declared as long, into which the count value result will be placed. A typical VB code example for displaying the Z1 Counter 0 count value would be

```
Dim count As Long                ' declare count as long

i = TCgetCount( h, Z1, 0, count )
Text1.Text = Str$( count )       ' count now contains new value
```

6.6 Windows and DOS Library Functions

Details are given of each of the functions provided in the supplied Windows Dynamic Link Library (DLL) and DOS 'C' Library.

6.6.1 Initialisation Functions

6.6.1.1 Register a Board with the Library - registerBoard

Registers a board with the library. This function returns a Board Handle (positive integer) which must be used in all subsequent calls to library functions for this board. No more than eight boards can be registered at any one time.

```
i = registerBoard (model, ba, irq)
```

where	*model*	**Integer**: Board's model number. The following pre-defined constants may be used for the boards supported:- PC214E = 214 PC215E = 215 PC272E = 272 PC212E = 212 PC218E = 218
	ba	**Integer**: Board's base address. Factory default is 300 hex. See section 2.6.1 for details on selecting the board's base address.
	irq	**Integer**: Board's Interrupt level. Factory default is 5. See section 2.6.3 for details on selecting the board's interrupt level.
Returns **Integer**:	Board handle to be used in all subsequent function calls for that board.	
or	ERRSUPPORT ERRBASE ERRIRQ	
Prior Calls	none	
See Also	freeBoard	

6.6.1.2 Get the Name of a Board - getBoardModel

Returns the model name of a registered board.

```
i = getBoardModel (h)
```

where	*h*	**Integer**: Board's handle as issued by the registerBoard function.
Returns **Integer**:	Board's model number. Possible values are:- 214: Amplicon PC214E 215: Amplicon PC215E 272: Amplicon PC272E 212: Amplicon PC212E 218: Amplicon PC218E	
or	ERRHANDLE	
Prior Calls	registerBoard	
See Also		

6.6.1.3 Un-register a Board with the DLL - freeBoard

Frees a previously registered board from the library's register. This board can be re-registered by another program.

```
i = freeBoard (h)
```

where	*h*	**Integer**: Board handle as issued by the registerBoard function.
Returns **Integer**:	OK	
or	ERRHANDLE	
Prior Calls	registerBoard	
See Also		

6.6.2 Interrupt Control Functions

6.6.2.1 Enable a Board's Interrupt Source(s) - setIntMask

Enables or disables one or more of a board's interrupt sources, by writing a mask byte to the board's Interrupt Mask register. For the PC215E, PC212E, PC218E and PC272E boards, any number of the interrupt sources can be enabled (a single interrupt is generated, but the interrupt service routine interrogates each source in turn and, if asserted, services that interrupt).

```
i = setIntMask (h, mask)
```

where	*h*	**Integer**: Board handle as issued by the registerBoard function.
	mask	**Integer**: Mask byte. The bit designations for the board's Interrupt Mask Register will vary from board to board. Refer to section 5.3.21 for a description of the interrupt sources, and their functionality.
Returns **Integer**:	OK	
or	ERRHANDLE ERRSUPPORT	
Prior Calls	registerBoard	
See Also	enableInterrupts disableInterrupts	

6.6.2.2 Read a Board's Interrupt Source Status - getIntStat

Returns a board's interrupt source status byte, by reading from the board's Interrupt Status register. The status of each bit is returned, irrespective of whether it has been enabled using the setIntMask function. See section 5.3.21 for a description of the interrupt sources.

```
i = getIntStat (h)
```

where	*h*	**Integer**: Board handle as issued by the registerBoard function.
Returns **Integer**:	Interrupt status byte. See section 2.6.4 for a description of the interrupt sources.	
or	ERRHANDLE ERRSUPPORT	
Prior Calls	registerBoard	
See Also		

6.6.2.3 Enable a Board's Interrupts- enableInterrupts

Enables the interrupt level registered for a board, by unmasking the corresponding bit in the Interrupt Mask register (IMR) of the 82C59 Programmable Interrupt Controller (PIC) on the host computer. The interrupt sources un-masked by a previous call to the setIntMask function are now enabled. See section 2.6.4 for details of the interrupt sources.

```
i = enableInterrupts (h)
```

where	*h*	**Integer**: Board handle as issued by the registerBoard function.
Returns **Integer**:	OK	
or	ERRHANDLE	
Prior Calls	registerBoard	
See Also	disableInterrupts setIntMask TCsetEventRecorder DIOsetBiDirectionalBus TCsetDCO TCsetVCO	

6.6.2.4 Disable a Board's Interrupts - disableInterrupts

Disables the interrupt level registered for a board, by masking the corresponding bit in the IMR of the PIC on the host computer.

```
i = disableInterrupts (h)
```

where	*h*	**Integer**: Board handle as issued by the registerBoard function
Returns **Integer**:	OK	
or	ERRHANDLE	
Prior Calls	registerBoard enableInterrupts setIntMask	
See Also		

6.6.3 Data Buffer Functions

6.6.3.1 Allocate an Integer Data Buffer - allocateIntegerBuf

Creates a data buffer, by allocating a block of memory of integer data. The function returns a Buffer Handle (positive integer). Up to four integer data buffers can be created. The Buffer Handle must be used in any subsequent function calls to identify that particular data buffer. Two integer data buffers are required by the function DIOsetBiDirectionalBus

```
b = allocateIntegerBuf (nItems)
```

where	*nItems*	**Long**: Number of data items to be allocated. If there is insufficient memory available for the size of the buffer, an error is returned.
Returns **Integer**:	Buffer Handle (positive integer). This handle must be used in all subsequent function calls to identify the buffer.	
or	ERRSUPPORT ERRMEMORY	
Prior Calls	registerBoard	
See Also	freeIntegerBuf	

6.6.3.2 Allocate a Long Integer Data Buffer - allocateLongBuf

Creates a data buffer, by allocating a block of memory of long integer data. The function returns a Buffer Handle (positive integer). Up to four long data buffers can be created. The Buffer Handle must be used in any subsequent function calls to identify that particular data buffer. A long integer data buffer is required by the function TCsetEventRecorder

```
b = allocateLongBuf (nItems)
```

where	*nItems*	**Long**: Number of data items to be allocated. If there is insufficient memory available for the size of the buffer, an error is returned.
Returns **Integer**:	Buffer Handle (positive integer). This handle must be used in all subsequent function calls to identify the buffer.	
or	ERRSUPPORT ERRMEMORY	
Prior Calls	registerBoard	
See Also	freeLongBuf	

6.6.3.3 Free up an Integer Data Buffer - freeIntegerBuf

Frees a block of memory previously allocated for the given data buffer by the allocateIntegerBuf function.

```
i = freeIntegerBuf (b)
```

where	*b*	**Integer**: buffer handle as issued by the allocateIntegerBuf function.
Returns **Integer**:	OK	
or	ERRBUFFER	
Prior Calls	registerBoard allocateIntegerBuf	
See Also		

6.6.3.4 Free up a Long Integer Data Buffer - freeLongBuf

Frees a block of memory previously allocated for the given data buffer by the allocateLongBuf function.

```
i = freeLongBuf (b)
```

where	*b*	**Integer**: buffer handle as issued by the allocateLongBuf function.
Returns **Integer**:	OK	
or	ERRBUFFER	
Prior Calls	registerBoard allocateLongBuf	
See Also		

6.6.3.5 Read Data from an Integer Buffer - readIntegerBuf

Reads a data item from an integer buffer, which is returned via a user-supplied pointer. The pointer must reference an integer variable.

```
i = readIntegerBuf (b, item, p)
```

where	*b*	**Integer**: buffer handle, as issued by the allocateIntegerBuf function
	item	**Long**: index of the data item in the buffer.
	p	**Pointer**: points to an integer variable to be used for the result
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE	
Prior Calls	registerBoard allocateIntegerBuf	
See Also		

6.6.3.6 Read Data from Long Buffer - readLongBuf

Reads a data item from long integer buffer, which is returned via a user-supplied pointer. The pointer must reference a long integer variable.

```
i = readLongBuf (b, item, p)
```

where	*b*	**Integer**: buffer handle, as issued by the allocateLongBuf function
	item	**Long**: index of the data item in the buffer.
	p	**Pointer**: points to a long integer variable to be used for the result
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE	
Prior Calls	registerBoard allocateLongBuf	
See Also		

6.6.3.7 Write Data to an Integer Buffer - writeIntegerBuf

Writes a single integer data item to an integer data buffer.

```
i = writeIntegerBuf (b, item, data)
```

where	b	**Integer**: buffer handle
	item	**Long**: index of item in buffer
	data	**Integer**: data value
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE ERRDATA	
Prior Calls	registerBoard allocateIntegerBuf	
See Also		

6.6.3.8 Write Data to a Long Integer Buffer - writeLongBuf

Writes a single long integer data item to a long data buffer.

```
i = writeLongBuf (b, item, data)
```

where	b	**Integer**: buffer handle
	item	**Long**: index of item in buffer
	data	**Long**: data value
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE ERRDATA	
Prior Calls	registerBoard allocateLongBuf	
See Also		

6.6.3.9 Copy a block of Data to an Integer Buffer - copyToIntegerBuf

Copies a block of integer data to an integer buffer.

```
i = copyToIntegerBuf (b, start, nItems, p)
```

where	*b*	**Integer**: buffer handle as issued by the allocateBuf function.
	start	**Long**: index of the starting item in the buffer.
	nItems	**Long**: number of items to copy.
	p	**Pointer**: pointer to the beginning of the memory block to copy.
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE ERRDATA	
Prior Calls	allocateIntegerBuf	
See Also	freeIntegerBuf	

6.6.3.10 Copy a block of Data to a Long Integer Buffer - copyToLongBuf

Copies a block of long integer data to a long integer buffer.

```
i = copyToLongBuf (b, start, nItems, p)
```

where	*b*	**Integer**: buffer handle as issued by the allocateBuf function.
	start	**Long**: index of the starting item in the buffer.
	nItems	**Long**: number of items to copy.
	p	**Pointer**: pointer to the beginning of the memory block to copy.
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE ERRDATA	
Prior Calls	allocateLongrBuf	
See Also	freeLongBuf	

6.6.3.11 Copy a Block of Integer Data from an Integer Buffer - copyFromIntegerBuf

Copies a segment of an integer data buffer to a block of memory.		
`i = copyFromIntegerBuf (b, start, nIems, p)`		
where	*b*	**Integer**: buffer handle as issued by the allocateBuf function.
	start	**Long**: index of the starting item in the buffer.
	nItems	**Long**: number of items to copy.
	p	**Pointer**: pointer to the beginning of the integer memory block to which data is to be copied.
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE ERRDATA	
Prior Calls	allocateIntegerBuf	
See Also	freeIntegerBuf	

6.6.3.12 Copy a Block of Long Integer Data from a Long Buffer - copyFromLongBuf

Copies a segment of a Long Integer data buffer to a block of memory.		
`i = copyFromLongBuf (b, start, nIems, p)`		
where	*b*	**Integer**: buffer handle as issued by the allocatBuf function.
	start	**Long**: index of the starting item in the buffer.
	nItems	**Long**: number of items to copy.
	p	**Pointer**: pointer to the beginning of the long integer memory block to which data is to be copied.
Returns **Integer**:	OK	
or	ERRBUFFER ERRRANGE ERRDATA	
Prior Calls	allocateLongBuf	
See Also	freeLongBuf	

6.6.3.13 Query Number of Interrupt Operations to date on a Buffer - getIntItem

This function can be called for any data buffer currently being used for Event Recorder or Bi-Directional Bus data. In these two cases, data is read from or written to the buffer when the relevant interrupt occurs. This function returns the index within the specified buffer of the data item to be read or written to on the next relevant interrupt, giving an indication of how much of the buffer contains valid data.

```
i = getIntItem(hB, item)
```

where	*hB*	**Integer**: buffer handle as issued by the allocateBuf functions.
	item	**Pointer to Long**: pointer to a variable (declared as a long integer), into which the result (the index of the buffer item to be used on the next relevant interrupt) will be stored.
Returns **Integer**:	OK	
or	ERRHANDLE	
Prior Calls	registerBoard allocateIntegerBuf allocateLongBuf enableInterrupts	
See Also	disableInterrupts	

6.6.4 Timer/Counter Functions

6.6.4.1 Test if Timer/Counter is free - TCisAvailable

Checks if a particular timer/counter channel is currently available on a board. A counter/timer may not be available for one of two reasons:

1. the counter/timer is not provided by the board specified, or
2. the counter/timer is being used by some other function.

```
i = TCisAvailable(h, chip, chan)
```

where	*h*	**Integer**. Board handle as previously issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip, i.e. 0, 1, or 2.
Returns **Integer**:	0 = Timer/counter NOT available, 1 = Available	
or	ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard	
See Also	TCfreeResource	

6.6.4.2 Free-up Timer/Counter - TCfreeResource

Frees a timer/counter channel previously reserved for use by one of the following functions:

TCsetMonoShot
TCgenerateFreq
TCmultiplyFreq
TCdivideFreq

N.B.: TCmultiplyFreq and TCdivideFreq use 2 timer/counters, so TCfreeResource should be called twice when you've finished this these two functions.

```
i = TCfreeResource(h, chip, chan)
```

where	h	**Integer**. Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard	
See Also		

6.6.4.3 Connect Timer/Counter Clock Source - TCsetClock

Configures a timer/counter clock input source.

```
i = TCsetClock(h, chip, chan, clk)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	clk	**Integer**. Clock source. Use one of the following pre-defines constants representing the valid clock sources: CLK_CLK = 0: external CLK(*chan*) i/p CLK_10MHZ = 1: internal 10 MHz CLK_1MHZ = 2: internal 1 MHz CLK_100KHZ = 3: internal 100 kHz CLK_10KHZ = 4: internal 10 kHz CLK_1KHZ = 5: internal 1 kHz CLK_OUTN_1 = 6: OUT (*chan*-1) CLK_EXT = 7: external EXTCLK (*chip*) i/p
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard	
See Also	TCsetGate	

6.6.4.4 Connect Timer/Counter Gate Source - TCsetGate

Configures a timer/counter gate input source.

```
i = TCsetGate(h, chip, chan, gat)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	gat	**Integer**. Gate source. Use one of the following pre-defined constants:- GAT_VCC = 0: Enabled GAT_GND = 1: Disabled GAT_EXT = 2: GAT(chan) - external i/p GAT_OUTN_2 = 3: /OUT(chan-2)
Returns **Integer**:	OK	
or	ERRSUPPORT ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard	
See Also	TCsetClock	

6.6.4.5 Configure Timer/Counter Mode - TCsetMode

Sets a timer counter to one of its five available modes of operation. Reading and loading of count values by LSB followed by MSB is selected, as is a 16-bit binary count.

```
i = TCsetMode (h, chip, chan, mde)
```

where	*h*	**Integer**: Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	mde	**Integer**. Counter mode (0 to 5). See the appendix for the 82C54 data sheet.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard TCsetClock TCsetGate	
See Also	TCsetCount	

6.6.4.6 Read Timer/Counter Status - TCgetStatus

Returns the mode and status of a timer/counter by performing a read-back operation on the channel.

```
i = TCgetStatus (h, chip, chan)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
Returns **Integer**:	Timer counter status byte. See 82C54 data sheet in the appendix for details.	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetMode TCsetCount	
See Also	TCgetCount	

6.6.4.7 Set Timer Count Value - TCsetCount

Sends a 16-bit count value to a timer/counter.

```
i = TCsetCount (h, chip, chan, count)
```

where	h	**Integer**. Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	count	**Long Integer**. 16-bit Count value.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard TCsetClock TCsetGate TCsetMode	
See Also	TCgetCount	

6.6.4.8 Read Timer's current Count Value - TCgetCount

Latches and reads a timer/counter's 16-bit count value, using the read-back command.

```
i = TCgetCount (h, chip, chan, count)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	count	**Pointer to Long**. Pointer to a variable, declared as a long integer, into which the count value result will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetClock TCsetGate TCsetMode TCsetCount	
See Also	TCgetUpCount	

6.6.4.9 Read Timer's current Up-Count - TCgetUpCount

Latches and reads a timer counter value, in the same way as TCgetCount, but returns the actual number of clock pulses received, rather than the count value. Note that the 82C54 timers count down to zero from the initial count value, so this function returns ((initial count) - (current count)). Only counter modes 2 or 3 should be used with this function.

```
i = TCgetUpCount (h, chip, chan, count)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	chip	**Integer**. Address offset of the timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	count	**Pointer to Long**. Pointer to a variable declared as a long integer, into which the up-count value will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetGate TCsetClock TCsetMode TCsetCount	
See Also	TCgetCount	

6.6.5 Differential Counter Functions

6.6.5.1 Setup Differential Counter Pair - TCsetDiffCounters

Sets up two counter/timers for a differential count operation. If the gate sources specified are both GAT_VCC, counting will start immediately. Otherwise the user must provide the gate signals or set the gates high by a call to TCsetGate. See section 4.2.1 for more details on the Differential Counter application.

`i = TCsetDiffCounters (h, chip1, chan1, clk1, gat1, chip2, chan2, clk2, gat2)`

where

h — **Integer**. Board handle as issued by the registerBoard function.

chip1 — **Integer**. Address offset of timer/counter chip #1. One of the following pre-defined constants may be used:

X1 = 0
X2 = 4
Y1 = 8
Y2 = 12
Z1 = 16
Z2 = 20.

chan1 — **Integer**. Timer/counter #1 channel number within the chip (0, 1 or 2).

clk1 — **Integer**. Timer #1 clock source. Use one of the following pre-defined constants:-

CLK_CLK = 0: CLK(*chan#1*) - external i/p
CLK_10MHZ = 1: 10 MHz
CLK_1MHZ = 2: 1 MHz
CLK_100KHZ = 3: 100 kHz
CLK_10KHZ = 4: 10 kHz
CLK_1KHZ = 5: 1 kHz
CLK_OUTN_1 = 6: OUT(*chan#1*-1)
CLK_EXT = 7: EXTCLK(chip) - external i/p

gat1 — **Integer**. Timer #1 gate source. Use one of the following pre-defined constants:-

GAT_VCC = 0: Enabled
GAT_GND = 1: Disabled
GAT_EXT = 2: GAT(chan) - external i/p
GAT_OUTN_2 = 3: /OUT(chan-2)

chip2 — **Integer**. Address offset of timer/counter chip #2. One of the following pre-defined constants may be used:

X1 = 0
X2 = 4

		Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan2	**Integer**. Timer/counter #2 channel number within the chip (0, 1 or 2).
	clk2	**Integer**. Timer #2 clock source. Use one of the following pre-defined constants:- CLK_CLK = 0: CLK(*chan#1*) - external i/p CLK_10MHZ = 1: 10 MHz CLK_1MHZ = 2: 1 MHz CLK_100KHZ = 3: 100 kHz CLK_10KHZ = 4: 10 kHz CLK_1KHZ = 5: 1 kHz CLK_OUTN_1 = 6: OUT(*chan#1*-1) CLK_EXT = 7: EXTCLK(chip) - external i/p
	gat2	**Integer**. Timer #2 gate source. Use one of the following pre-defined constants:- GAT_VCC = 0: Enabled GAT_GND = 1: Disabled GAT_EXT = 2: GAT(chan) - external i/p GAT_OUTN_2 = 3: /OUT(chan-2)
Returns **Integer**:	Differential counter handle (positive integer). Use this handle as the hD parameter in calls to TCgetDiffCount, TCgetRatio and TCfreeDiffCounters when referring to this particular differential counter pair.	
or	ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard	
See Also	TCsetGate TCfreeDiffCounters	

6.6.5.2 Read Differential Count - TCgetDiffCount

Returns the difference between the count values of the two counters specified in the TCsetDiffCounters function.

```
i = TCgetDiffCount (h, hD, diff)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	hD	**Integer**. Differential counter handle as issued by the TCsetDiffCounters function.
	diff	**Pointer to Long**. pointer to a variable, declared as a long integer, into which the 16-bit count value representing (Count#2 - Count#1) will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetDiffCounters	
See Also	TCgetRatio TCfreeDiffCounters	

6.6.5.3 Read Differential Ratio - TCgetRatio

Returns the ratio of the count values of the two counter/timers specified in function TCsetDiffCounters.

```
i = TCgetRatio (h, hD, ratio)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	hD	**Integer**. Differential counter handle as issued by the TCsetDiffCounters function.
	ratio	**Pointer to Float**. pointer to a variable declared as a single floating-point into which the value representing the ratio of counts (Counter#2/Counter#1) will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetDiffCounters	
See Also	TCsetGate TCfreeDiffCounters	

6.6.5.4 Free Differential Counter Pair - TCfreeDiffCounters

Frees the counter/timers associated with a differential pair, as setup by function TCsetDifferentialCounters. Call this function when finished with the differential counter.

```
i = TCfreeDiffCounters (h, hD)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	hD	**Integer**. Differential counter handle as issued by the TCsetDiffCounters function.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetDiffCounters	
See Also	TCgetDiffCount TCgetRatio	

6.6.6 Frequency Generation Functions

6.6.6.1 Send Monostable Pulse - TCsetMonoShot

Creates a single pulse of specified duration on the output of a timer/counter, using the timer's 'Hardware Retriggerable One-Shot' mode. In this mode, the timer output will go low for the duration specified on the clock pulse following a gate trigger. Subsequent gate triggers will retrigger the pulse. See section 4.2.2 for more details on the Monostable application.

`i = TCsetMonoShot (h, chip, chan, duration)`

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	duration	**Float**. Pulse duration time, in seconds.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard	
See Also	TCsetGate	

6.6.6.2 Generate Astable Multivibrator Waveform - TCsetAstable

Generates a clock signal of specified frequency and mark-to-space ratio. This is implemented on two counters, both in mode 1 (digital one-shot). One counter counts the mark time and the other counts the space time. The outputs of each counter/timer control the gate of the other, so that when the mark times-out, the space counter is triggerred and vice versa. N.B. the user must connect each counter's gate to the other's output on the user connector SK1. See section 4.2.3 for more details on the Astable application.

```
i = TCsetAstable (h, chip, chan, chipS, chanS, freq, msratio)
```

where	*h*	**Integer**. Board handle as issued by function registered board.
	chip	**Integer**. Address offset of timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	chipS	**Integer**. Address offset of secondary timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chanS	**Integer**. Secondary timer/counter channel number within the chip (0, 1 or 2).
	freq	**Float**. Desired frequency, in Hertz.
	msratio	**Float**. Desired mark to space ratio, defined as (mark time/period), i.e. 0 is D.C. 0V, 1 is D.C. 5V, 0.5 is symmetrical square wave, i.e. high for 1 and low for 1.
Returns **Integer**:	Handle to the astable multi-vibrator (positive integer). Use this handle to call the TCfreeAstable function when finished, in order to free up the counter/timers for re-use.	
or	ERRHANDLE ERRDATA	
Prior Calls	registerBoard	
See Also	TCfreeAstable	

6.6.6.3 Free-up Astable Multi-vibrator Counter/Timers - TCfreeAstable

Frees the two timer counters used for an astable multi-vibrator, as setup by the TCsetAstable function.

`i = TCfreeAstable (h, hA)`

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	hA	**Integer**. Astable multi-vibrator handle as issued by function TCsetAstable.
Returns **Integer**:	OK	
or	ERRHANDLE ERRDATA	
Prior Calls	registerBoard TCsetAstable	
See Also		

6.6.7 Millisecond Stopwatch Functions

6.6.7.1 Prepare a Millisecond Stopwatch - TCsetStopwatch

Sets up a stopwatch, which uses two timer/counters to count in milliseconds for just under 50 days. See section 4.2.4 for more details on the Stopwatch application.

`i = TCsetStopwatch (h, chip, chan)`

where	*h*	**Integer**. Handle to previously registered board
	chip	**Integer**. Address offset of timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2). This channel and the next channel (chan + 1) are used. The second channel may be on the next timer/counter chip.
Returns **Integer**:	Positive handle to the stopwatch. Use this in calls to the other stopwatch functions to refer to this stopwatch.	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard	
See Also	TCsetEventRecorder TCstartStopwatch TcfreeStopwatch	

6.6.7.2 Start a Millisecond Stopwatch - TCstartStopwatch

Starts a stopwatch which has been previously setup by the TCsetStopwatch function.

```
i = TCstartStopwatch (h, hS)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	hS	**Integer**. Handle to stopwatch as issued by the TCsetStopwatch function.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetStopwatch	
See Also	TCgetElapsedTime TCfreeStopwatch	

6.6.7.3 Get Stopwatch Elapsed Time - TCgetElapsedTime

Gets the elapsed time, in milliseconds, since a given stopwatch was started.

```
i = TCgetElapsedTime (h, hS, lPtr)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	hS	**Integer**. Stopwatch handle as issued by the TCsetStopwatch function.
	lPtr	**Pointer to Long**. Pointer to a variable defined as a long integer into which the elapsed time result will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetStopwatch TCstartStopwatch	
See Also	TCgetTimeString TCsetEventRecorder	

6.6.7.4 Prepare an Event Time Recorder - TCsetEventRecorder

Sets up an event recorder which records the times of positive edges on a PPI Port C bit 0 digital input (DI) line. The times recorded are the elapsed time since the given stopwatch was started). This is performed by using a stopwatch, previously setup by a call to TCsetStopwatch, and enabling the DI line to generate an interrupt. An interrupt service routine (ISR) stores the elapsed time from the stopwatch into a previously allocated data buffer for each event. See section 4.2.5 for more details on the Event Recorder application.

```
i = TCsetEventRecorder (h, hS, chip, hB)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	hS	**Integer**. Stopwatch handle as issued by the TCsetStopwatch function.
	chip	**Integer**. Address offset of the digital input chip from which Port C bit 0 will be used as the event input. Use one of the following pre-defined constants:- PPIX = 0 PPIY = 8 PPIZ = 16
	hB	**Integer**. Buffer handle as issued by the allocateBuf function. This function must have been called with the type argument set to 4, since the time reading is a 4-byte long integer.
Returns **Integer**:	Positive handle to the event recorder. Use this handle to call the TCfreeEventRecorder function when finished.	
or	ERRHANDLE ERRCHAN ERRBUFFER	
Prior Calls	registerBoard TCsetStopwatch allocateBuf	
See Also	TCfreeEventRecorder enableInterrupts	

6.6.7.5 Free-up Event Recorder Timer and Digital Input Channels - TCfreeEventRecorder

Frees up the event recorder handle. This function is necessary so that the interrupt service routine can decide whether a PPI Port C0 interrupt is an event recorder, or some other user-defined task.

```
i = TCfreeEventRecorder (h, hE)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	hE	**Integer**. Event recorder handle as issue by function TCsetEventRecorder.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetStopwatch allocateLongBuff TCsetEventRecorder	
See Also	disableInterrupts TCfreeStopwatch copyFromLongBuf freeLongBuf	

6.6.7.6 Convert Milliseconds into Time String - TCgetTimeStr

Converts a 32-bit word representing an elapsed time in milliseconds to a time string in the format “DD HH:MM:SS.TTT”. Such 32-bit elapsed times are produced by the stopwatch functions.

```
i = TCgetTimeStr (ms, strPtr)
```

where	*ms*	**Long**. Elapsed time in milliseconds.
	strPtr	**Pointer to string**. Pointer to target string for result.
Returns **Integer**:	OK	
or	ERRDATA	
Prior Calls	registerBoard TCsetStopwatch TCgetElapsedTime	
See Also		

6.6.7.7 Free-up Stopwatch Counter/Timers - TCfreeStopwatch

Frees the timer/counters used by a stopwatch, as previously setup by TCsetStopwatch. Call this function when the stopwatch is no longer required.

```
i = TCfreeStopwatch (h, hS)
```

where	*h*	**Integer**. Board handle as issued by the registerBoard function.
	hS	**Integer**. Stopwatch handle as issued by function TCsetStopwatch.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetStopwatch	
See Also		

6.6.8 Frequency Input and Output Functions

6.6.8.1 Measure Period of an External Signal - TCgetExtPeriod

Returns the period of an external signal, measured in microseconds. The external signal must be connected to the clock input of the timer channel specified in the *chan* argument. See section 4.2.6 for more details on the Frequency/Period Measurement application.

```
i = TCgetExtPeriod (h, chip, chan, fPtr)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of timer/counter chip #2. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2). Another timer/counter (*chan*-2) will also be used to provide the gate signal. This second timer/counter may be on the previous chip.
	fPtr	**Pointer to Float**. Pointer to a variable declared as a single floating-point into which the period will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRRANGE	
Prior Calls	registerBoard	
See Also	TCgetExtFreq	

6.6.8.2 Measure Frequency of an External Signal - TCgetExtFreq

Returns the frequency of an external signal, in Hertz. The external signal must be connected to the clock input of the timer specified in the *chan* argument. See section 4.2.6 for more details on the Frequency/Period Measurement application.

```
i = TCgetExtFreq (h, chip, chan, fPtr)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2). Another timer/counter (*chan* - 2) will be used to provide the gate pulse. This counter/timer may be on the previous chip.
	fPtr	**Pointer to Float**. Pointer to a variable declared as a single floating-point, into which the frequency result will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRRANGE	
Prior Calls	registerBoard	
See Also	TCgetExtPeriod	

6.6.8.3 Generate a Frequency - TCgenerateFreq

Generates a square wave of specified frequency on a single timer/counter. See section 4.2.7 for more details on the Frequency Generation application.

```
i = TCgenerateFreq (h, chip, chan, freq)
```

where	*h*	**Integer**. Board handle as issued by the function registerBoard.
	chip	**Integer**. Address offset of timer/counter chip. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2).
	freq	**Float**. Desired frequency in Hertz.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRRANGE	
Prior Calls	registerBoard	
See Also	TCgenerateAccFreq	

6.6.8.4 Generate an Accurate Frequency - TCgenerateAccFreq

Generates a square wave frequency accurate to 0.1% using two cascaded timer/counters. See section 4.2.7 for more details on the Frequency Generation application.

```
i = TCgenerateAccFreq (h, chip, chan, freq)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of timer/counter chip #2. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	chan	**Integer**. Timer/counter channel number within the chip (0, 1 or 2). Another timer/counter (*chan* - 1) will be used by this function. This timer/counter may be on the previous chip.
	freq	**Float**. Desired frequency, in Hertz.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRRANGE	
Prior Calls	registerBoard	
See Also	TCgenerateFreq	

6.6.8.5 Multiply an External Frequency - TCmultiplyFreq

Measures an external signal's frequency, then generates another signal whose frequency is the external frequency multiplied by a specified number. N.B. this function is not on-going, and must be called at a regular interval to keep the generated frequency tracking the external signal. Note that the output signal will be a square wave. See section 4.2.8 for more details on the Frequency Multiplication application.

```
i = TCmultiplyFreq (h, ipChip, ipChan, opChip, opChan, factor)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	ipChip	**Integer**. Address offset of the timer/counter chip on which the input frequency will be measured.
	ipChan	**Integer**. Input timer/counter channel on which to perform the frequency measurement. The external signal must be connected to the clock input of this channel. Another timer channel (chan-2) will also be used to provide the gate signal. This may be on the previous chip.
	opChip	**Integer**. Address offset of the timer/counter chip on which to generate the output frequency. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	opChan	**Integer**. Output timer/counter channel number within the chip (0, 1 or 2).
	factor	**Float**. Divisor value.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRRANGE	
Prior Calls	registerBoard	
See Also	TCdivideFreq TCfreeResource	

6.6.8.6 Divide an External Frequency - TCdivideFreq

Measures an external signal's frequency, then generates another signal whose frequency is the external frequency divided by a specified number. N.B. this function is not on-going, and must be called at a regular interval to keep the generated frequency tracking the external signal. Note the output signal will be a square wave.

```
i = TCdivideFreq (h, ipChip, ipChan, opChip, opChan, divisor)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	ipChip	**Integer**. Address offset of the timer/counter chip on which the input frequency will be measured.
	ipChan	**Integer**. Input timer/counter channel on which to perform the frequency measurement. The external signal must be connected to the clock input of this channel. Another timer channel (chan-2) will also be used to provide the gate signal. This may be on the previous chip.
	opChip	**Integer**. Address offset of the timer/counter chip on which to generate the output frequency. One of the following pre-defined constants may be used: X1 = 0 X2 = 4 Y1 = 8 Y2 = 12 Z1 = 16 Z2 = 20.
	opChan	**Integer**. Output timer/counter channel number within the chip (0, 1 or 2).
	divisor	**Float**. Division Factor
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN ERRDATA	
Prior Calls	registerBoard	
See Also	TCmultiplyFreq TCfreeResource	

6.6.9 Digitally- and Voltage-Controlled Oscillator Functions

6.6.9.1 Prepare a Digitally-Controlled Oscillator - TCsetDCO

Implements a digitally controlled oscillator (DCO) which periodically reads a data value from a digital input channel and generates an external frequency based on the value. The digital input channel can be 1, 4, 8, 12, 16, or 24-bits wide, as specified by a previous call to function DIOsetChanWidth. The digital channel must have already been setup as an input with a call to function DIOsetMode. See section 4.2.9 for more details on the Digitally Controlled Oscillator application.

`i = TCsetDCO (h, diChip, diChan, opChip, opChan, udFreq, udChip, MinF, MaxF)`

where

h — **Integer**. Board handle as issued by function registerBoard.

diChip — **Integer**. Address offset of the digital input chip. Use one of the following pre-defined constants:-

PPIX = 0
PPIY = 8
PPIZ = 16

diChan — **Integer**. Digital input channel.

opChip — **Integer**. Address offset of the timer/counter chip to be used for frequency output. One of the following pre-defined constants may be used:

X1 = 0
X2 = 4
Y1 = 8
Y2 = 12
Z1 = 16
Z2 = 20.

opChan — **Integer**. Frequency output timer/counter channel number within the chip (0, 1 or 2)

udFreq — **Float**. Update frequency in Hertz.

udChip — **Integer**. Address offset of a timer/counter chip of which counter 1 will be used to generate the update interrupts. One of the following pre-defined constants may be used:

X1 = 0
X2 = 4
Y1 = 8
Y2 = 12
Z1 = 16
Z2 = 20.

MinF — **Float**. Output frequency corresponding to DI data value 0.

	MaxF	**Float**. Frequency corresponding to the maximum digital input data value, which itself depends on the channel width specified in DIOsetChanWidth
Returns **Integer**:	Positive handle to DCO. Use this handle to call TCfreeDCO when finished	
or	ERRHANDLE ERRCHAN ERRDATA ERRRANGE	
Prior Calls	registerBoard	
See Also	TCsetVCO enableInterrupts TCfreeDCO	

6.6.9.2 Prepare a Voltage-Controlled Oscillator - TCsetVCO

Implements a voltage controlled oscillator which periodically reads a voltage from an analog input channel and generates an external frequency based on the value. The analog input channel can be from an Amplicon PC226E, PC30AT, PC26AT or PC27E data acquisition board. Please ensure the board is configured for a 10V unipolar input range (or 4V unipolar, for the PC27E). See section 4.2.10 for more details on the Voltage Controlled Oscillator application.

`i = TCsetVCO (h, AImodel, AIbaseAddr, AIchan, opChip, opChan, udFreq, udChip, freq0V, freq10V)`

where

h — **Integer**. Board handle as issued by function registerBoard.

AImodel — **Integer**. Model name of the analog input card being used. Use one of the following pre-defined constants:

PC226E = 226
PC30AT = 30
PC26AT = 26
PC27E = 27

AIbaseAddr — **Integer**. Analog input card base address.

AIchan — **Integer**. Analog input card channel number.

opChip — **Integer**. Address offset of the Frequency Output timer/counter chip. One of the following pre-defined constants may be used:

X1 = 0
X2 = 4
Y1 = 8
Y2 = 12
Z1 = 16
Z2 = 20.

opChan — **Integer**. Frequency output timer/counter channel within the chip (0, 1 or 2).

udFreq — **Float**. Update rate, in Hertz.

udChip — **Integer**. Address offset of the Update Rate timer chip. One of the following pre-defined constants may be used:

X1 = 0
X2 = 4
Y1 = 8
Y2 = 12
Z1 = 16
Z2 = 20.

Counter1 of this chip will be used to generate

		the update ticks.
	freq0V	**Float**. Output frequency, in Hertz, corresponding to 0.0 Volts on the analog input channel.
	freq10V	**Float**. Output frequency, in Hertz, corresponding to +10.0 Volts on the analog input channel (or +4.0 Volts if using a PC27E).
Returns **Integer**:	Positive handle to VCO. Use this handle to call TCfreeDCO when finished.	
or	ERRHANDLE ERRCHAN ERRDATA ERRRANGE ERRPC226	
Prior Calls	registerBoard	
See Also	TCsetDCO enableInterrupts TCfreeDCO	

6.6.9.3 Free-up a DCO or VCO's Timer/Counters - TCfreeDCO

Frees the timer/counter & DIO resources used by a DCO, or VCO, as previously setup by TCsetDCO or TCsetVCO. Call this function when you've finished using the DCO or VCO.

```
i = TCfreeDCO (h, hO)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	hO	**Integer**. DCO or VCO handle, as issued by TCsetDCO or TCsetVCO, respectively.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard TCsetDCO TCsetVCO enableInterrupts	
See Also	disableInterrupts	

6.6.10 Digital Input/Output Functions

6.6.10.1 Test if Digital I/O Chip is Free - DIOisAvailable

Checks if a particular Digital I/O (DIO) chip is available on a board. A DIO chip may not be available for one of two reasons:

1. the DIO chip is not provided by the board specified, or
2. the DIO chip is being used by some other function.

```
i = DIOisAvailable (h, chip)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of the DIO chip. Use one of the following pre-defined constants: PPIX = 0 PPIY = 8 PPIZ = 16.
Returns **Integer**:	0 = DIO Chip NOT Available, 1 = Available	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard	
See Also	DIOfreeResource	

6.6.10.2 Configure a Digital I/O Port for Input or Output - DIOsetMode

Sets up a digital I/O port for basic input or output.

```
i = DIOsetMode (h, chip, port, isInput)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of the DIO chip. Use one of the following pre-defined constants:- PPIX = 0 PPIY = 8 PPIZ = 16
	port	**Integer**. DIO port within the chip. Port C is split into two 4-bit nibbles, which can be programmed independently. Use one of the following pre-defined constants:- PORTA = 0 PORTB = 1 PORTC_L = 2 PORTC_U = 3
	isInput	**Integer**. Non-zero if port is to be set as input, zero if port is to be set as output.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard	
See Also	DIOsetChanWidth DIOsetData DIOgetData	

6.6.10.3 Re-define Channel Width within a Digital I/O Chip - DIOsetChanWidth

Redefines the number of bits per DIO channel to be used in subsequent calls to the DIOsetData and DIOgetData functions. The default channel width is 8-bits, and this can be changed to 1, 4, 8, 12, 16, or 24. After calling this function, the chan argument in the DIOsetData and DIOgetData functions refers to the group of bits of width *numBits*, starting at Port A bit 0. Note that the three ports (A, B, C-upper and C-lower) must be setup correctly for input or output accordingly by calling the DIOsetMode function for each.

```
i = DIOsetChanWidth (h, chip, numBits)
```

where

h — **Integer**. Board handle as issued by function registerBoard.

chip — **Integer**. Address offset of the DIO chip. Use one of the following pre-defined constants:-

PPIX = 0
PPIY = 8
PPIZ = 16

numBits — **Integer**. Bit width to be used in subsequent calls to functions DIOsetData, DIOgetData and TCsetDCO. Valid widths are 1, 4, 8, 12, 16, or 24.

numBits	channels per chip
1	24
4	6
8	3
12	2
16	1
24	1

Returns Integer: OK

or ERRHANDLE
ERRCHAN
ERRDATA

Prior Calls: registerBoard

See Also: DIOsetMode
DIOsetData
DIOgetData

6.6.10.4 Send Digital Output Data - DIOsetData

Writes a data value to a DIO channel. It is assumed that the channel has already been set as an output by a call to function DIOsetMode.

```
i = DIOsetData (h, chip, chan, data)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of the DIO chip. Use one of the following pre-defined constants:- PPIX = 0 PPIY = 8 PPIZ = 16
	chan	**Integer**. DIO channel. Note the channel numbering depends on the channel width as set by DIOsetChanWidth (default is 3 8-bit channels).
	dat	**Long**. Digital data word.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard DIOsetMode DIOsetChanWidth	
See Also	DIOgetData	

6.6.10.5 Read Digital Input Data - DIOgetData

Reads a data value from a DIO channel. It is assumed that the channel has already been set as an input by a call to function DIOsetMode.

```
i = DIOgetData (h, chip, chan, data)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of the DIO chip. Use one of the following pre-defined constants:- PPIX = 0 PPIY = 8 PPIZ = 16
	chan	**Integer**. DIO channel. Note the channel numbering depends on the channel width as set by function DIOsetChanWidth (default is three 8-bit channels).
	dat	**Pointer to Long**. Pointer to a variable, declared as a long integer, into which the digital data word will be placed.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard DIOsetMode DIOsetChanWidth DIOsetData	
See Also		

6.6.11 Switch Scanner Matrix Functions

6.6.11.1 Setup a Switch Scanner Matrix - DIOsetSwitchMatrix

Sets up one, two or three 82C55 DIO chips as a switch matrix scanning device. The *order* of the matrix specified can be 12 (for a 12 X 12 matrix scanning 144 switches, using PPIX), 24 (for a 24 X 24 matrix scanning 576 switches, using PPIX and PPIY), or 36 (for a 36 X 36 matrix scanning 1296 switches, using PPIX, PPIY and PPIZ). Group A (ports A and C-upper) are set for output, to send test patterns to the matrix, and group B (port B and C-lower) are set for input to read the switch status information back in. The user must ensure that the switch array is wired correctly with suitable diodes and resistors, otherwise the board could get damaged. See section 4.2.11 for details. Only one switch matrix implementation is available per board.

```
i = DIOsetSwitchMatrix (h, order)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	order	**Integer.** Order of the matrix (12, 24 or 36)
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard	
See Also	DIOgetSwitchStatus DIOfreeSwitchMatrix	

6.6.11.2 Query Status of a Switch within the Scan Matrix - DIOgetSwitchStatus

Queries the status of a particular switch in the switch matrix setup by the DIOsetSwitchMatrix function. The grid reference of the switch is given, and the function performs a test on that switch and returns 1 for switch on (closed) or 0 for switch off (open).

```
i = DIOgetSwitchStatus (h, xcoord, ycoord)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	xcoord	**Integer**. X-co-ordinate of the position of the switch in the matrix (origin is at port A0/B0 of PPIX). Valid values should be in the range 0 - *order* (as specified in DIOsetSwitchMatrix).
	ycoord	**Integer**. Y-co-ordinate of the position of the switch in the matrix (origin is at port A0/B0 of PPIX). Valid values should be in the range 0 - *order* (as specified in DIOsetSwitchMatrix).
Returns **Integer**:	Zero, if switch was OFF (open). Non-zero if switch was ON (closed).	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard DIOsetSwitchMatrix	
See Also	DIOfreeSwitchMatrix	

6.6.11.3 Free-up the Digital I/O Chip(s) from a Switch Matrix - DIOfreeSwitchMatrix

Frees the DIO resources used by the switch matrix as setup in function DIOsetSwitchMatrix.

```
i = DIOfreeSwitchMatrix (h)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard DIOsetSwitchMatrix	
See Also		

6.6.12 Bi-Directional Data Bus Functions

6.6.12.1 Prepare an 8-bit Bi-Directional Data Bus - DIOsetBiDirectionalBus

Programs Group A of a DIO chip for Mode 2 'Strobe bi-directional bus I/O operation'. Group B (Port B and Port C-lower) are not used in the bi-directional bus, and are programmed by this function for Mode 0 input or output as specified in the *isPBip* and *isPCLip* arguments. They can be accessed in the normal way using the DIOsetData and DIOgetData functions. Up to three bi-directional buses are available per board (if PPIs are available). See section 4.2.12 for more details on the Bi-directional Bus application.

```
i = DIOsetBiDirectionalBus (h, chip, isPBip, isPCLip, bIn, bOut)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	chip	**Integer**. Address offset of the DIO chip. Use one of the following pre-defined constants:- PPIX = 0 PPIY = 8 PPIZ = 16
	isPBip	**Integer**. Non-zero if Port B is to be set as input, zero if output.
	isPCLip	**Integer**. Non-zero if Port C-lower are to be set as input, zero if output.
	bIn	**Integer**. Handle to a buffer previously allocated as 2-bytes per item by the allocateBuf function. This buffer will be used to store incoming digital input data from the bus.
	bOut	**Integer**. Handle to a buffer previously allocated as 2-bytes per item by the allocateBuf function. This buffer should contain digital output data to be send out onto the bus upon request.
Returns **Integer**:	Positive handle to the bi-directional bus. Use this handle in the call to DIOfreeBiDirectionalBus when finished, to free the DIO resources.	
or	ERRHANDLE ERRCHAN ERRBUFFER	
Prior Calls	registerBoard	
See Also	enableInterrupts DIOfreeBiDirectionalBus	

6.6.12.2 Free-up Bi-Directional Data Bus Digital I/O Chip - DIOfreeBiDirectionalBus

Frees up the DIO chip used by the given Bi-Directional bus handle.

```
i = DIOfreeBiDirectionalBus (h, hI)
```

where	*h*	**Integer**. Board handle as issued by function registerBoard.
	hI	**Integer**. Bi directional bus handle as issued by function DIOsetBiDirectionalBus.
Returns **Integer**:	OK	
or	ERRHANDLE ERRCHAN	
Prior Calls	registerBoard DIOsetBiDirectionalBus disableInterrupts	
See Also		

6.7 PC215E Library Error Codes

Mnemonic	Returned Value	Meaning
OK	0	Operation successful.
ERRSUPPORT	-1	Operation not supported by board, or the maximum boards/buffers are already registered.
ERRBASE	-2	Base address is invalid or in use.
ERRIRQ	-3	Interrupt level is invalid or in use.
ERRHANDLE	-4	Invalid board handle, or board not registered.
ERRCHAN	-5	Invalid channel number
ERRDATA	-6	Invalid data
ERRRANGE	-7	Out of range
ERRMEMORY	-8	Insufficient Memory
ERRBUFFER	-9	Invalid buffer handle - not allocated
ERRPC226	-10	PC226 board not found (for VCO function)

6.8 PC215E Interface Guide For LABTECH NOTEBOOK

The LABTECH NOTEBOOK drivers supplied by **Amplicon** on the PC215E distribution diskette are specifically designed to interface the PC215E hardware to the LABTECH NOTEBOOK Data Acquisition and Analysis software package.

The appropriate drivers to support the functionality of the board are provided with all Amplicon 200 Series products.

A list of I/O types supported by the LABTECH NOTEBOOK software, and their compatibility with some of the Amplicon 200 series I/O boards is given in the following table. Functions provided by the Amplicon I/O boards which are not listed in the table are not supported by the LABTECH NOTEBOOK software.

LABTECH Software I/O Types

Module	AD Normal	AD Hi-Spd	DA	DI/DO	TEMP	STRN	CNT	FREQ	PLSE
AMPLICON Board Types									
PC224/34	No	No	Yes	No	No	No	Yes	Yes	Yes
PC226	Yes	Yes	No	Yes	Yes	No	No	No	No
PC230	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
PC237	No	No	No	Yes	No	No	No	No	No
PC263	No	No	No	DO	No	No	No	No	No
PC214E	No	No	No	Yes	No	No	Yes	Yes	Yes
PC215E	**No**	**No**	**No**	**Yes**	**No**	**No**	**Yes**	**Yes**	**Yes**
PC212E	No	No	No	Yes	No	No	Yes	Yes	Yes
PC218E	No	No	No	No	No	No	Yes	Yes	Yes
PC272E	No	No	No	Yes	No	No	No	No	No

Figure 9 - LABTECH NOTEBOOK Driver Functions

where:
AD = Analog Input
DA = Analog Output
DI = Digital Input
DO = Digital Output
TEMP = Temperature Measurement
STRN = Strain Measurement
CNT = Counter Input
FREQ = Frequency Measurement
PLSE = Frequency Output.

The PC215E provides the following I/O types supported by LABTECH NOTEBOOK:

- Six 8-bit Digital Input/Output channels
- Two Frequency Output channels
- Two Counter Input channels
- Two Frequency Measurement channels

6.8.1 Channel Assignments:

Digital Input/Output channels:

Channel 0	PPIX Port A
Channel 1	PPIX Port B
Channel 2	PPIX Port C
Channel 3	PPIY Port A
Channel 4	PPIY Port B
Channel 5	PPIY Port C

Frequency Output channel:

Channel 0	Z1 Counter 2
Channel 1	Z2 Counter 2

Counter Input channel:

Channel 0	Z1 Counter 0
Channel 1	Z2 Counter 0

Frequency Measurement channel:

Channel 0	Z1 Counter 0
Channel 1	Z2 Counter 0

6.8.2 Configuring the Board

The following connections are required to set the board up for the supported LABTECH NOTEBOOK channel types:

Frequency Output channels:
Frequency output available on Counter 2 OUT

Counter Input channels:
Connect the input signal to Counter 0 CLOCK

Frequency Measurement channels:
Connect the input signal to Counter 0 CLOCK

6.9 Guide to User Programming

When developing an application specific program, it is advised that the supplied dynamic link library functions are used for Windows applications and extracts are taken from the DOS examples. However if there are good reasons for writing low level code then a study of the source code supplied will be of assistance.

For programming at register level, reference should to be made to section 5 describing the function and assignments of each I/O register in the PC215E.

6.10 Signal Centre

Signal Centre is a Signal Processing Applications Program available from Amplicon, with support for the PC215E. Operates under Microsoft Windows.

APPENDICES

APPENDIX A - GLOSSARY OF TERMS

The following glossary explains some terms used in this manual and in data acquisition and control applications.

Active Filter: An electronic filter that combines active circuit devices with passive circuit elements such as resistors and capacitors. Active filters typically have characteristics that closely match ideal filters.

ADC (A/D): Analog to Digital converter. *q.v.*

Alias Frequency: A false lower frequency component that appears in analog signal reconstructed from original data acquired at an insufficient sampling rate.

Algorithm: A set of rules, with a finite number of steps, for solving a mathematical problem. An algorithm can be used as a basis for a computer program.

Analog to Digital Converter (ADC): A device for converting an analog voltage to a parallel digital word where the digital output code represents the magnitude of the input signal. See 'Successive Approximation'.

Analog Switch: An electronic, single pole, two way switch capable of handling the full range of analog signal voltage, and operating under the control of a logic signal.

Array: Data arranged in single or multidimensional rows and columns.

ASCII: American Standard Code for Information Interchange. A code that is commonly used to represent symbols in computers.

Assembler: A program that converts a list of computer instructions written in a specific assembly language format that can be executed by a specific processor.

Bandpass Filter: A type of electrical filter that allows a band of signals between two set frequencies to pass, while attenuating all signal frequencies outside the bandpass range.

Base Address: A unique address set up on an I/O card to allow reference by the host computer. All registers are located by an offset in relation to the base address.

BASIC: The most common computer language. BASIC is an acronym for Beginners All-purpose Symbolic Instruction Code. BASIC is not rigorously structured and relies on English-like instructions which account for its popularity.

Binary Coded Decimal (BCD): A system of binary numbering where each decimal digit 0 through 9 is represented by a combination of four bits.

BIOS: Basic Input Output System. BIOS resides in ROM on a computer system board and provides device level control for the major I/O devices on the system.

Bipolar: A signal being measured is said to be bipolar when the voltage on its 'high' terminal can be either of positive or negative polarity in relation to its 'low' terminal.

Bit: Contraction of binary digit. The smallest unit of information. A bit represents the choice between a one or zero value (mark or space in communications technology).

Buffer: A storage device used to compensate for a difference in rate of data flow, or time of occurrence of events, when transferring data from one device to another. Also a device without storage that isolates two circuits.

Bus: Conductors used to interconnect individual circuitry in a computer. The set of conductors as a whole is called a bus.

Byte: A binary element string operated on as a unit and usually shorter than a computer word. Normally eight bits.

C: A high level programming language, developed around the concept of structured programming and designed for high operating speeds. Microsoft 'C' and Turbo 'C' are dialects of C.

Channel: One of several signal/data paths that may be selected.

Character: A letter, figure , number, punctuation or other symbol contained in a message or used in a control function.

Code: A set of unambiguous rules specifying the way in which characters may be represented.

Conversion Time: The time required for a complete conversion of a value from analog to digital form (ADC) or analog to digital form (DAC). Inverse of Conversion Rate.

Cold Junction: See Thermocouple Reference Junction

Cold Junction Compensation (CJC): A technique to compensate for thermocouple measurement offset when the reference or cold junction is at a temperature other than 0° C.

Common Mode Rejection Ratio (CMR): A measure of the equipment's ability to reject common mode interference. Usually expressed in decibels as the ratio between the common mode voltage and the error in the reading due to this common mode voltage.

Common Mode Voltage: In a differential measurement system, the common mode voltage usually represents an interfering signal. The common mode voltage is the average of the voltages on the two input signal lines with respect to ground level of the measuring system.

Comparator: An electronic circuit used to compare two values and set an indicator that identifies which value is greater.

Compiler: High level language used to pre-process a program in order to convert it to a form that a processor can execute directly.

Contact Closure: The closing of a switch, often controlled by an electromagnetic or solid state relay.

Conversion Time: The time required, in an analog/digital input/output system, from the instant that a channel is interrogated (such as with a read instruction) to the moment that accurate an accurate representation of the data is available. This could include switching time, settling time, acquisition time , converter processing time etc.

Counter: In software, a memory location used by a program for the purpose of counting certain occurrences. In hardware, a circuit that can count pulses.

Counter/Timer Device: Converts time-dependent digital signals to a form that can be further processed by the host PC. Typical functions include pulse counting, frequency and pulse width measurement. This can relate to time, number of events, speed etc.

Crosstalk: A phenomenon in which a signal in one or more channels interferes with a signal or signals in other channels.

Current Loop: **(**a) Data communications method using presence or absence of current to signal logic ones and zeros.

(b) A method of analog signal transmission where the measured value is represented by a current. The common current loop signal is in the range 4 to 20 mA, but other standards include 1 to 5 mA or 10 to 50 mA.

DAC (D/A): Digital to Analog Converter. *q.v.*

Data Acquisition or Data Collection: Gathering information from sources such as sensors and transducers in an accurate, timely and organised manner.

Debouncing: Either a hardware circuit or software delay to prevent false inputs from a bouncing relay or switch contact.

Decibel (dB): A logarithmic representation of the ratio between two signal levels.

Digital-Analog Multiplier: Same as Multiplying DAC. *q.v.*

Digital Signal: A discrete or discontinuous signal; one whose various states are identified with discrete levels or values.

Digital to Analog Converter: A device for converting a parallel digital word to an analog voltage, where the magnitude of the output signal represents the value of the digital input.

DIP Switch: A set of switches contained in a dual in line package.

Drift: Small variations in a measured parameter over a period of time.

Drivers: Part of the software that is used to control a specific hardware device.

Expansion Slots: The spaces provided in a computer for expansion boards that enhance the basic operations of the computer.

FIFO: First In First Out. A buffer memory that outputs data in the same order that they are input.

Form A, Form B, Form C Contacts: Relay contact sets which are normally open, normally closed and changeover respectively.

Four Quadrant Operation: In a multiplying DAC, four quadrant operation means that both the reference signal and the number represented by the digital input may both be either positive or negative polarity. The output obeys the rules of multiplication for algebraic sign.

GAL (Generic Array Logic): Programmable logic device where the architecture and functionality of each output is defined by the system designer.

Handshaking: Exchange of predetermined codes and signals between two data devices to establish and control a connection.

Hardware: The visible parts of a computer system such as the circuit boards, chassis, peripherals, cables etc. It does not include data or computer programs.

Hexadecimal (Hex): A numbering system to the base 16.

Input/Output (I/O): The process of transferring data from or to a computer system including communication channels, operator interface devices or data acquisition and control channels.

Interface: A shared boundary defined by common physical interconnection characteristics, signal characteristics and meanings of interchanged signals.

Interrupt: A computer signal indicating that the CPU should suspend its current task to service a designated activity.

I/O Address: A method that allows the CPU to distinguish between different boards and I/O functions in a system. See Base Address.

Latch: A device to store the state of a digital signal until it is changed by another external command signal. The action of storing this signal.

Least Significant Bit (LSB): In a system in which a numerical magnitude is represented by a series of digits, the least significant bit (binary digit) is the digit that carries the smallest value or weight.

Linearity: Compliance with a straight line law between the input and output of a device.

Load Voltage Sensing: A technique for maintaining accuracy of an analog signal at the load by monitoring the voltage and compensating for errors due to cable and source resistance.

Micro Channel Architecture (MCA): A unique architecture defined by IBM™ to provide a standard input/output bus for Personal System computers.

Monotonic: A DAC is said to be monotonic if the output increases as the digital input increases, with the result that the output is always a single valued function of the input.

Most Significant Bit (MSB): In a system in which a numerical magnitude is represented by a series of digits, the most significant bit (binary digit) is the digit that carries the greatest value or weight.

Multiplexer: A multiple way analog switch *q.v.*, where a single path through the switch is selected by the value of a digital control word.

Multiplying DAC: A Multiplying DAC (or Digital-Analog Multiplier) operates with varying or AC reference signals. The output of a Multiplying DAC is proportional to the product of the analog 'reference' signal and the fractional equivalent of the digital input number.

Noise: An undesirable electrical interference to a signal.

Normal Mode Signal: Aka Series mode signal. In a differential analog measuring system, the normal mode signal is the required signal and is the difference between the voltages on the two input signal lines with respect to ground level of the measuring system.

Offset: (a) A fixed, known voltage added to a signal.
(b) The location of a register above the base address.

Pascal: A high level programming language originally developed as a tool for teaching the concepts of structured programming. It has evolved into a powerful general-purpose language popular for writing scientific and business programs. Borland Turbo Pascal is a dialect of Pascal.

Passive Filter: A filter circuit using only resistors, capacitors and inductors.

PC: Personal Computer (Also printed circuit - see PCB)

PCB: Printed Circuit Board

Port: An interface on a computer capable of communication with another device.

Range: Refers to the maximum allowable full-scale input or output signal for a specified performance.

Real Time: Data acted upon immediately instead of being accumulated and processed at a later time.

Reed Relay: An electro-mechanical relay where the contacts are enclosed in a hermetically sealed glass tube which is filled with an inert gas.

Repeatability: The ability of a measuring system to give the same output or reading under repeated identical conditions.

Resolution: A binary converter is said to have a resolution of n-bits when it is able to relate 2^n distinct analog values to the set of n-bit binary words.

Rollover: Symmetry of the positive and negative values in a bipolar conversion system.

RTD (Resistive Temperature Device): An electrical circuit element characterised by a defined coefficient of resistivity.

Sample/Hold: A circuit which acquires an analog voltage and stores it for a period of time.

Sensor: Device that responds to a physical stimulus (heat, light, sound, pressure, motion etc.) producing a corresponding electrical output.

Settling Time: The time taken for the signal appearing at the output of a device to settle to a new value caused by a change of input signal.

Signal to Noise Ratio: Ratio of signal level to noise in a circuit. Normally expressed in decibels.

Simultaneous Sample/Hold: A data acquisition system in which several sample/hold circuits are used to simultaneously sample a number of analog channels and hold these values for sequential conversion. One sample/hold circuit per analog channel is required.

Software: The non-physical parts of a computer system that includes computer programs such as the operating system, high level languages, applications program etc.

Spike: A transient disturbance of an electrical circuit.

Stability: The ability of an instrument or sensor to maintain a consistent output when a consistent input is applied.

Successive Approximation: An analog to digital conversion method that sequentially compares a series of binary weighted values with the analog input signal to produce an output digital word in 'n' steps where 'n' is the number of bits of the A/D Converter. *q.v.*

Symbol: The graphical representation of some idea. Letters and numerals are symbols.

Syntax: Syntax is the set of rules used for forming statements in a particular programming language.

Thermocouple: A thermocouple is two dissimilar electrical conductors, known as thermo-elements, so joined as to produce a thermal emf when the measuring and reference junctions are at different temperatures.

Thermocouple Measuring Junction: The junction of a thermocouple which is subjected to the temperature being measured.

Thermocouple Reference Junction: The junction of a thermocouple which is at a known temperature. aka Cold Junction.

Throughput Rate: The maximum repetitive rate at which a data conversion system can operate with a specified accuracy. It is determined by summing the various times required for each part of the system and then taking the reciprocal of this time.

Transducer: Device that converts length, position, temperature, pressure, level or other physical variable to an equivalent voltage or current accurately representing the original measurement.

Trigger: Pulse or signal used to start or stop a particular action. Frequently used to control data acquisition processes.

Unipolar: A signal being measured is said to be unipolar when the voltage on its 'high' terminal is always the same polarity (normally positive) in relation to its 'low' terminal.

Word: The standard number of bits that can be manipulated at once. Microprocessors typically have word lengths of 8, 16 or 32 bits.

Wrap, Wraparound: Connection of a FIFO buffer such that the contents once loaded, are continuously circulated.

APPENDIX B PC215E CIRCUIT LAYOUT DRAWING

A PCB layout drawing of the PC215E Board is given below. A full set of circuit drawings is available upon request.

B.1 PC215E Assembly Detail

A short description of each user setting and indicator is given in the following table.

Component Reference	Function
SW1	Switch for Base Address Selection
J1	Jumper for IRQ Level Selection

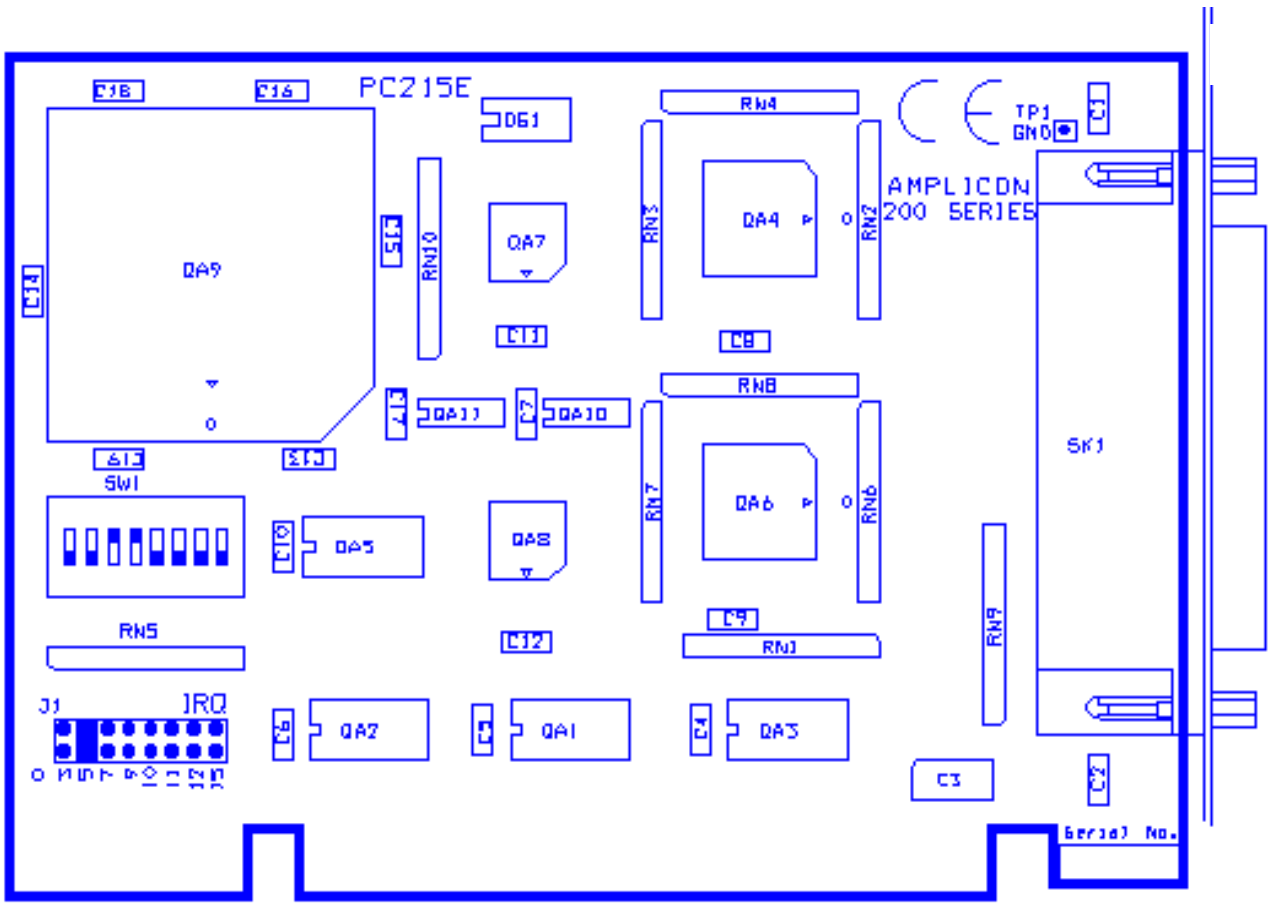


Figure 10 - PC215E Printed Circuit Layout