DIG-64

Digital Input / Output Card

User Manual

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1.0	1/6/98	EGW	First issue
1.1	5/8/98	EGW	Minor typographical errors corrected.
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INTRODUCTION

The DIG-64 is a PC-compatible ISA card that provides the user with 16 digital opto-isolated inputs, 16 relay outputs and 32 TTL-level digital input/outputs.

The card features user selectable base address and interrupt level. In addition the field replaceable series resistance packs allow selection of the input voltage range.

The card is fitted with “Polyswitch” resettable fuses to protect each of the relay outputs and the +5 volt and +12 volt feeds out of the card. These “fuses” rupture if their rating is exceeded and then heal themselves once power is removed for 20 minutes or so. This prevents unnecessary repair work when errors are made during installation or wiring.

ABOUT THE MANUAL

This manual is organised into four chapters, and two appendices. Each chapter covers a different aspect of using the DIG-64. In order to get the best results from the product, the user is urged to read all chapters, paying particular note to Chapter 1, which deals with the initial installation of the card. The appendices may be used for reference at any time.

Chapter 1 Explains how to configure the card to run in your computer via the user selectable links.

Chapter 2 Details the connections to and from the card.

Chapter 3 Gives details of the card's address mapping and internal register details allowing the user to write custom software to control the card.

Chapter 4 Details the card's technical specification. Use this section to determine the card's suitability for a particular application.

Appendix A Gives a brief introduction to Binary and Hexadecimal numbering systems for those unfamiliar with the concepts.

Appendix B Lists the IBM-PC I/O address map, interrupt and DMA allocations and should be used along with Chapter 1 when first installing the card.

Appendix C Shows the Printed Circuit Board layout.

CHAPTER 1
INSTALLING THE DIG-64

Before installing the card into your computer system, there are a number of user-configurable links that must be set.

The positioning of these links will depend upon the computer system into which the card is being fitted. Before fitting any links to the card please read the next section.

If you are unfamiliar with binary and hexadecimal number systems a primer is included in the appendix.

Base Address

For correct operation of the card in the host computer, the range of addresses that the card will occupy must be set. The base address represents the first address that the card will use. The DIG-64 requires a total of 16 contiguous addresses (including the base address) for correct operation. All Blue Chip Technology cards are factory set to a default base address of 300_{hex}. Check to ensure that the base address and the full range of addresses are free for use.

If the addresses are not free another range must be chosen. As a guide, please use the information contained in the appendix to assist in choosing a suitable base address.

If you are not sure, refer to your computer system handbook for information relating to other peripheral devices, possibly already installed (additional communications cards, parallel ports or games ports etc.).

If the addresses are available for use then proceed as follows:-

- Locate the row of header pins (LK1). These pins are marked “BASE ADDRESS”. Each pair of pins represents a binary digit starting with the pair of pins marked with an arrow. This pair of pins represents the lowest hex value (010_{hex}), subsequent pins represent increasing values. The highest single base address link is 200_{hex}.

- To select an address, a link position must be left open. Placing a link on a pair of pins de-selects that particular address.

Example:

To select a base address of 300 $_{hex}$, the links should be set as follows:-

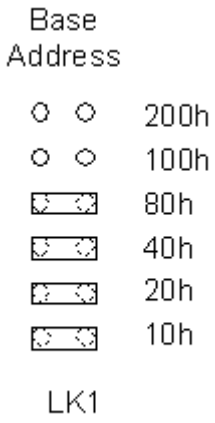


Figure 1 Example Base Address Selection

Interrupt Selection

As part of the link between the DIG-64 and the host computer, an interrupt signal may be set to occur when an input changes state. The application software can then use the interrupt to service the calling device. The use of interrupts is not essential but can enhance the functionality of the card.

The default manufacturing setting is that port A bit 0 going low will generate an interrupt on the selected interrupt line (LK2). If an interrupt is not required, do not fit a link at LK2. Other inputs can be "wire or'ed" to generated interrupts by manufacturing build options. Please contact the Sales Office for further details. The DIG-64 can use any one of Interrupt Channels IRQ-2 to -7.

As with the selection of base addresses, the chosen Interrupt Channel must be free for use and not be selected by any other peripheral in the system. The Appendix may be used to identify the Interrupt Channels that are normally already in use by most systems and which ones will probably be free for use.

Check that the selected channel is free for use.

If you are not sure, refer to your computer system handbook for information relating to other peripheral devices, possibly already installed (additional communications cards, parallel ports or games ports etc.).

If the Interrupt Channel chosen is available for use by the DIG-64 then set the card as follows:-

- Locate the row of header pins labelled LK2.
- To select an interrupt, place a link on the pair of pins corresponding to the chosen Interrupt Request Channel. Only one channel should be selected, all other pins must be left open.

Caution

If mercury-wetted reed relays are used, it is imperative that the circuit board is used in a vertical plane. This ensures that the mercury pool inside the relays is in the correct position relative to the contacts. A note to that effect is included on issue level 2, circuit boards.

When the card is installed in a PC, the card should held vertically with the gold fingers pointing down, and then tapped gently on a hard surface. This ensures that the pool of mercury drops to the bottom of the reed capsule.

Failure to observe these precautions will result in erratic operation of the relay contacts.

CHAPTER 2
CONNECTION DETAILS

Opto Isolator Inputs – J3

The following table refers to the 37 way 'D' socket at the rear of the card (J3), which receives the incoming signals to the opto-isolators. Pin 1 of the connector is at the top right when looking 'into' the pins of the connector. The inputs are applied across X-Y pairs, and are not polarity-sensitive.

PIN	SIGNAL	PIN	SIGNAL
1	+5 volts	20	0 volts
2	0 volts	21	0 volts
3	Port B bit 7 – X	22	Port B bit 7 – Y
4	Port B bit 6 – X	23	Port B bit 6 – Y
5	Port B bit 5 – X	24	Port B bit 5 – Y
6	Port B bit 4 – X	25	Port B bit 4 – Y
7	Port B bit 3 – X	26	Port B bit 3 – Y
8	Port B bit 2 – X	27	Port B bit 2 – Y
9	Port B bit 1 - X	28	Port B bit 1 – Y
10	Port B bit 0 – X	29	Port B bit 0 – Y
11	Port A bit 7 – X	30	Port A bit 7 – Y
12	Port A bit 6 – X	31	Port A bit 6 – Y
13	Port A bit 5 – X	32	Port A bit 5 – Y
14	Port A bit 4 – X	33	Port A bit 4 – Y
15	Port A bit 3 - X	34	Port A bit 3 – Y
16	Port A bit 2 - X	35	Port A bit 2 – Y
17	Port A bit 1 - X	36	Port A bit 1 – Y
18	Port A bit 0 - X	37	Port A bit 0 – Y
19	+12 volts		

Relay Outputs – J4

The following table refers to the 40-way plug at the inner end of card (J4), which provides the relay contact outputs. Pin 1 of the connector is at the bottom right when looking 'into' the pins of the connector with the gold edge connector pointing down. The port outputs are uncommitted relay contacts across X-Y pairs, and are not polarity-sensitive.

PIN	SIGNAL	PIN	SIGNAL
1	+12 volts	2	Port C bit 0 – X
3	Port C bit 0 – Y	4	Port C bit 1 – X
5	Port C bit 1 – Y	6	Port C bit 2 – X
7	Port C bit 2 – Y	8	Port C bit 3 – X
9	Port C bit 3 – Y	10	Port C bit 4 – X
11	Port C bit 4 – Y	12	Port C bit 5 – X
13	Port C bit 5 – Y	14	Port C bit 6 – X
15	Port C bit 6 – Y	16	Port C bit 7 – X
17	Port C bit 7 – Y	18	Port D bit 0 – X
19	Port D bit 0 – Y	20	Port D bit 1 – X
21	Port D bit 1 – Y	22	Port D bit 2 – X
23	Port D bit 2 – Y	24	Port D bit 3 – X
25	Port D bit 3 – Y	26	Port D bit 4 – X
27	Port D bit 4 – Y	28	Port D bit 5 – X
29	Port D bit 5 – Y	30	Port D bit 6 – X
31	Port D bit 6 – Y	32	Port D bit 7 – X
33	Port D bit 7 – Y	34	0 volts
35	0 volts	36	0 volts
37	+5 volts	38	
39		40	

External Relay Output Connector

The on-board relay outputs (available at J4) may be brought out to the PC back-panel by using the optional cable connector assembly. This has a 37-way D-type connector mounted on a PC bracket, which connects to J4. When this is used the outputs are as follows:

PIN	SIGNAL	PIN	SIGNAL
1	+12 volts	20	Port C bit 0 – X
2	Port C bit 0 – Y	21	Port C bit 1 – X
3	Port C bit 1 – Y	22	Port C bit 2 – X
4	Port C bit 2 – Y	23	Port C bit 3 – X
5	Port C bit 3 – Y	24	Port C bit 4 – X
6	Port C bit 4 – Y	25	Port C bit 5 – X
7	Port C bit 5 – Y	26	Port C bit 6 – X
8	Port C bit 6 – Y	27	Port C bit 7 – X
9	Port C bit 7 – Y	28	Port D bit 0 – X
10	Port D bit 0 – Y	29	Port D bit 1 – X
11	Port D bit 1 – Y	30	Port D bit 2 – X
12	Port D bit 2 – Y	31	Port D bit 3 – X
13	Port D bit 3 – Y	32	Port D bit 4 – X
14	Port D bit 4 – Y	33	Port D bit 5 – X
15	Port D bit 5 – Y	34	Port D bit 6 – X
16	Port D bit 6 – Y	35	Port D bit 7 – X
17	Port D bit 7 – Y	36	0 volts
18	0 volts	37	0 volts
19	+5 volts		

Note the transposition of the connector pin numbers.

Digital Input/Output Ports – J5, 6 & 7

Three additional connectors are provided to facilitate connection of a further 32 digital I/O signals at TTL levels only.
These are arranged as follows:

Port E PIO 1 port A bits 0 – 7 Connector J5
Port F PIO 1 port B bits 0 – 7 Connector J6
Port G PIO 1 port C bits 0 – 7 Connector J6
Port E PIO 2 port A bits 0 – 7 Connector J7

The connector details are as follows:

Digital I/O Port E – J5 (10 way header)

PIN	SIGNAL	PIN	SIGNAL
1	PIO 1 port A bit 0	2	PIO 1 port A bit 1
3	PIO 1 port A bit 2	4	PIO 1 port A bit 3
5	PIO 1 port A bit 4	6	PIO 1 port A bit 5
7	PIO 1 port A bit 6	8	PIO 1 port A bit 7
9	0 volts	10	0 volts

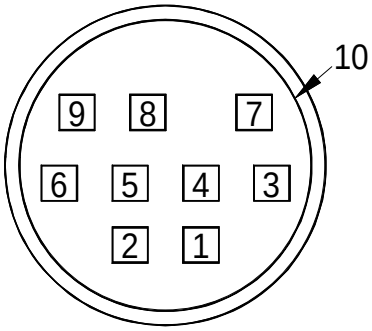
Digital I/O Port F & G – J6 (20 way header)

PIN	SIGNAL	PIN	SIGNAL
1	PIO 1 port C bit 0	2	PIO 1 port C bit 1
3	PIO 1 port C bit 2	4	PIO 1 port C bit 3
5	PIO 1 port C bit 4	6	PIO 1 port C bit 5
7	PIO 1 port C bit 6	8	PIO 1 port C bit 7
9	0 volts	10	0 volts
11	PIO 1 port B bit 0	12	PIO 1 port B bit 1
13	PIO 1 port B bit 2	14	PIO 1 port B bit 3
15	PIO 1 port B bit 4	16	PIO 1 port B bit 5
17	PIO 1 port B bit 6	18	PIO 1 port B bit 7
19	0 volts	20	0 volts

Digital I/O Port H – J7 (9-pin mini-DIN)

PIN	SIGNAL	PIN	SIGNAL
1	PIO 2 port A bit 0	2	PIO 2 port A bit 1
3	PIO 2 port A bit 2	4	PIO 2 port A bit 3
5	PIO 2 port A bit 4	6	PIO 2 port A bit 5
7	PIO 2 port A bit 6	8	PIO 2 port A bit 7
9	0 volts	10	0 volts

View of Mini-DIN Connector (from rear panel)



DIGITAL INPUTS

The input signals at the card bracket of the DIG-64 are opto-isolated for operation with either a DC or AC signal, regardless of polarity. The incoming signals are isolated from the PC power supplies and also from each other. When the input signal is high enough to cause the LED within the opto-isolator to switch on, the output will be read by the PC as a logic low ("0"). When the input signal is too low to switch on the opto-isolator, the output will be read by the PC as a logic high ("1"). The input signals are applied between the desired pair of connections (X & Y).

Input Conditioning

Two DIL resistor packs (RN2 and RN4) are provided on the front of the board to condition the input current to a suitable level for the opto-isolators. The value of these resistors must be calculated to ensure that the current passed through the opto-isolator is limited to 10mA. The opto-isolator will drop 1.5V constantly.

REQUIRED RESISTANCE = (INPUT VOLTAGE - 1.5V) * 100 ohms

The following table gives some common examples using preferred resistor values:

Input Voltage	Resistor Value
5V	330R (fitted as standard)
10V	820R
12V	1K
24V	2K2

Note: The resistors are 8 individual resistor elements in a 16-pin DIL package. RN4 is the input conditioning resistor pack for input port A, and RN2 conditions input port B.

DIGITAL OUTPUTS

The DIG-64 board provides the user with 16 volt-free contacts for use in general control applications. The relay contacts will handle voltages up to mains potential at low currents or small voltages with a current handling up to 2 Amps, depending upon relay type. The relays may be standard dry reed relays, or mercury-wetted reed relays.

The operating program can read back the status of the drive to the relays. Note the returned values are the inverse of the data written to the relays, i.e. if AA_{hex} is written to relay outputs 0-7 then the value returned will be 55_{hex}.

Printed Circuit Boards at issue level 1.0 and 1.1 required reed relays with an in-built back-EMF suppression diode across the relay coil. Printed Circuit Boards at issue level 2.0 and later are fitted with separate suppression diodes, permitting the use of relays without the in-built diodes.

Caution

If mercury-wetted reed relays are used, it is imperative that the circuit board is used in a vertical plane. This ensures that the mercury pool inside the relays is in the correct position relative to the contacts. A note to that effect is included on issue level 2, circuit boards.

When the card is installed in a PC, the card should held vertically with the gold fingers pointing down, and then tapped gently on a hard surface. This ensures that the pool of mercury drops to the bottom of the reed capsule.

Failure to observe these precautions will result in erratic operation of the relay contacts.

CHAPTER 3
PROGRAMMING DETAILS

Addressing

The address maps for DIG-64 is shown below. The card occupies a total of sixteen contiguous addresses of which twelve are used. Some of the address registers are both read and write.

Address	Read Function	Write Function
Base + 0	Opto inputs 0 to 7	None
Base + 1	Opto inputs 8 to 15	None
Base + 2	Relay feedback 0 to 7	Relay outputs 0 to 7
Base + 3	Relay feedback 0 to 7	Relay outputs 8 to 15
Base + 4	PIO 1, Port A Input/Output Register – Port E	
Base + 5	PIO 1, Port B Input/Output Register – Port F	
Base + 6	PIO 1, Port C Input/Output Register – Port G	
Base + 7	None	PIO 1, Control Register
Base + 8	PIO 2, Port A Input/Output Register – Port H	
Base + 9	PIO 2, Port B Input/Output Register – Not available	
Base + 10	PIO 2, Port C Input/Output Register – Not available	
Base + 11	None	PIO 2, Control Register

PIO Programming

The DIG-64 has two µPD71055 (8255) PIO devices, fitted as standard. The first device is located at I/O address Base +4 to +7. It supports three 8-bit programmable input/output channels which are connected to ports E, F & G. The second PIO device is located at Base +8 to +11 and supports one 8-bit programmable input/output channel. The remaining two 8-bit channels are not connected.

Each of the channels can be assigned as either input or output. See below for further details.

The following table gives a summary of the most commonly used ‘control words’ which must be written to the control port to configure each PIO before using this board.

The PIO can operate in one of 3 modes (mode 0-2).

In the first mode (mode 0) the PIO provides simple I/O for three 8-bit ports. Data is simply written to or read from a specified port (A, B or C) without the use of handshaking. The following Control Code Table assumes mode 0 is required.

Mode 1 enables the transfer of data to or from a specified 8-bit port (A or B) in conjunction with strobes or handshaking signals.

In mode 2 data is transferred via one bi-directional 8-bit port (A) with handshakes (Port C).

Control Word Table

Control Word (Hex)	Control Word (Decimal)	Sets All of Port A To	Sets All Of Port B To	Sets High 4 Bits of Port C To	Sets Low 4 Bits of Port C To
80	128	Output	Output	Output	Output
81	129	Output	Output	Output	Input
82	130	Output	Input	Output	Output
83	131	Output	Input	Output	Input
88	136	Output	Output	Input	Output
89	137	Output	Output	Input	Input
8A	138	Output	Input	Input	Output
8B	139	Output	Input	Input	Input
90	144	Input	Output	Output	Output
91	145	Input	Output	Output	Input
92	146	Input	Input	Output	Output
93	147	Input	Input	Output	Input
98	152	Input	Output	Input	Output
99	153	Input	Output	Input	Input
9A	154	Input	Input	Input	Output
9B	155	Input	Input	Input	Input

Example Program

The following program in Microsoft Basic will test the operation of the first channel on each of the PIOs, providing a link is made between corresponding connectors.

```
10   P1=&H304 : REM BASE OF FIRST PIO
15   P2 = &H308 : REM BASE OF SECOND PIO
20   GOSUB 60
25
30   P1 = &H308 : P2 = &H304
40   GOSUB 60
50   GOTO 10 : REM LOOP CONTINUOUSLY
55
60   OUT P1+3, &H8B : OUT P2+3, &H9B
70   F = 0
90   A = 1
100  OUT P1, A
110  IF INP (P2) <> A THEN PRINT ″ERROR″, P, A, INP (P2) : F = F + 1
120  A = A + A
130  IF A = 256 THEN GOTO 150
140  GOTO 100
150  IF F > 0 THEN PRINT P, ″FAILED″, F : GOTO 170
160  PRINT P, ″PASSED″
170  NEXT P
180  RETURN
```

The above program runs continuously and can only be stopped by pressing control and break on the PC keyboard.

CHAPTER 4

TECHNICAL SPECIFICATION

Number Of Opto-isolated Input Channels	16
Number Of Relay contact pairs	16
Number of TTL digital input/output channels	32
Interrupt Signal Options (Default from PIO 1 port A bit 0)	IRQ-2 to -7 inclusive

Input Characteristics

All inputs are opto-isolated from computer Ground and each other. Inputs may be either AC or DC signals.

Isolation Voltage	100 Volts
Voltage Input Range	Min. 3 Volts Max. 24 Volts*
Input Load Current	10ma @ 24v Input*

* Depends on series resistance packs fitted.

Relay Contact Characteristics

(Mercury Wetted Reed Relays)

Switching voltage	Max 500 volts
Switching current	Max 2 Amps DC peak/AC resistive
Carry current	Max 3 Amps DC peak/AC resistive
Contact rating	50 watts DC peak/AC resistive
Life expectancy	$200x10^6$ at 1 volt / 10mA
Static contact resistance	40mΩ
Contact material	Mercury (16mg)
Operate time	Max 1.75mSecs
Release time	Max 1.5 mSecs

Note: We do not recommend high voltage operation because of the limitations of the connectors used and their presence within a computer system.

Digital Input/Outputs

Number Of I/O Channels	32 arranged as 1 x 3 x 8 and 1 x 1 x 8 I/O bits
Signal Levels	5 Volt TTL Logic Levels
Outputs	
Logic Low Level	0 Volts (min.) - 0.4 Volts (max.) @ I_{OL} = 2.5mA
Logic High Level	3.5 Volts (min.) - 5 Volts (max.) @ I_{OH} = -400µA
Drive Current	2.5 mA. (Logic Low) Vout = 0.4 Volts -400 µA (Logic High) Vout = 3.5 Volts
Input Loading	-10 µA (Logic Low) +10 µA (Logic High)

Addresses

Total I/O Address Range Required	16 Bytes

Board Connections

Opto-Isolated Inputs	37 way D type socket
Relay Outputs	40 way header
Digital Input/Output	1 x 10 way header 1 x 20 way header 1 x 9 way mini DIN (plus screen)
Bus:	PC 8-bit ISA

Protection

Relay Outputs	Raychem RXE110 rated @ 0.89 Amps @ 40ºC or 1.10Amps @ 20ºC "Trips" in 15 seconds at 3 Amps @ 20ºC
+5 & +12 volt Outputs	Raychem RUE110 rated @ 0.91 Amps @ 40ºC or 1.10 Amps @ 20ºC "Trips" in 60 seconds at 3 Amps @ 20ºC

Dimensions

	Board	Overall
Length	250	253
Height	120	127
Width	15	25

Electromagnetic Compatibility (EMC)

This product meets the requirements of the European EMC Directive (89/336/EEC) and Amending Directives, and is eligible to bear the CE mark.

It has been assessed whilst operating in a Blue Chip Technology Icon industrial PC. However, because the board can be installed in a variety of computers, certain conditions have to be applied to ensure that the compatibility is maintained. It meets the requirements for an industrial environment (Class A product) subject to those conditions.

- The board must be installed in a computer system that provides screening suitable for the industrial environment.

- Any recommendations made by the computer system manufacturer/supplier must be complied with regarding earthing and the installation of boards.

- The board must be installed with the backplate securely screwed to the chassis of the computer to ensure good metal-to-metal contact.

- Most EMC problems are caused by the external cabling to boards. It is imperative that any external cabling to the board is totally screened, and that the screen of the cable connects to the metal end bracket of the board and hence to earth. It is recommended that round,screened cables with a braided wire screen are used in preference to those with a foil screen and drain wire. Use metal connector shells that connect around the full circumference of the screen; they are far superior to those which connect the screen by a simple “pig-tail”. Standard ribbon cable will not be adequate unless it is contained wholly within the cabinetry housing the industrial PC.

- Ensure that the screen of the external cable is bonded to a good RF earth at the both end of the cable.

- Cables that connect externally to boards at TTL levels should not exceed two metres in length. This restriction does not apply to the opto-isolated input/output connections.

Failure to observe these recommendations may invalidate the EMC compliance.

Warning This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

EMC Specification

A Blue Chip Technology Icon industrial PC fitted with this card meets the following specification:

Emissions	EN 55022:1995	
	Radiated	Class A
	Conducted	Class A
Immunity	EN 50082-1:1997 incorporating:	
	Electrostatic Discharge	EN 61000-4-2
	Radio Frequency Susceptibility	EN 61000-4-3
	Conducted Susceptibility	EN 61000-4-6
	Fast Burst Transients	EN 61000-4-4

Appendix A - NUMBERING SYSTEMS

Binary and Hexadecimal Numbers

The normal numbering system is termed DECIMAL because there are ten possible digits (0 to 9) in any single column of numbers. Decimal numbers are also referred to as numbers having a Base 10. When counting, the numbers increment in the units column from 0 up to 9. The next increment resets the units column to 0 and carries over 1 into the next column. This 1 indicates that there has been a full ten (the base number) counts in the units column. The second column is therefore termed the “tens” column.

It is more convenient when programming to use a number system that provides a clearer picture of the hardware at an operational or register level. The two most common number systems used are BINARY and HEXADECIMAL. These two systems provide an alternative representation to decimal numbers.

For a binary number there are only 2 possible values (0 or 1) and as a result binary numbering is often known as Base 2. When counting in binary numbers, the number increments the units column from 0 to 1. At the next increment the units column is reset to 0 and 1 is carried over to the next column. This column indicates that a full two counts have occurred in the units column. Now the second column is termed the “twos” column.

Hexadecimal numbers may have 16 values (0 to 9 followed by the letters A to F). It is also known as a system with the Base 16. With this counting system the units increment from 0 to 9 as with the decimal system, but at the next count the units column increments from 9 to A and then B, C and so on up to F. After F the units column resets to 0 and the next column increments from 0 to 1. This 1 indicates that sixteen counts have occurred in the units column. The second column is termed the “sixteens” column.

The following table shows how the three systems indicate successive numbers

Decimal Base 10		Binary Base 2					Hexadecimal Base 16	
0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	1	0	1
0	2	0	0	0	1	0	0	2
0	3	0	0	0	1	1	0	3
0	4	0	0	1	0	0	0	4
0	5	0	0	1	0	1	0	5
0	6	0	0	1	1	0	0	6
0	7	0	0	1	1	1	0	7
0	8	0	1	0	0	0	0	8
0	9	0	1	0	0	1	0	9
1	0	0	1	0	1	0	0	A
1	1	0	1	0	1	1	0	B
1	2	0	1	1	0	0	0	C
1	3	0	1	1	0	1	0	D
1	4	0	1	1	1	0	0	E
1	5	0	1	1	1	1	0	F
1	6	1	0	0	0	0	1	0
1	7	1	0	0	0	1	1	1
1	8	1	0	0	1	0	1	2
1	9	1	0	0	1	1	1	3
2	0	1	0	1	0	0	1	4

Notice how the next higher column does not increment until the lesser one to its right has overflowed.

Binary representation is ideally suited where a visual representation of a computer register or data is needed. Each column is termed a BIT (from **B**inary dig**IT**). Only five Bits are shown in the above table. With larger numbers, more Bits are required. Normally Bits are arranged in groups of eight termed BYTES. By definition there are 8 BITS per BYTE. Each Bit (or column) has a value. In the binary table above the rightmost or least significant column each digit has a value of 1. Each digit in the next column has a value of 2, the next 4, then 8 and so on.

The following diagram illustrates this.

BIT No	7	6	5	4	3	2	1	0
DECIMAL VALUE	128	64	32	16	8	4	2	1

To determine the decimal value of a binary pattern, add up the decimal number of each column containing a binary “1”.

BIT No	7	6	5	4	3	2	1	0
DECIMAL VALUE	128	64	32	16	8	4	2	1
BINARY NUMBER	1	1	0	0	0	1	1	0

The above example shows the binary pattern that is equivalent to 198 $_{\text{Decimal}}$.

The binary string defining a Byte can be unwieldy. To make it less error prone, the 8 bits forming a byte are divided into two groups of 4 bits, known as NIBBLES. With four bits there

are 16 possible numeric combinations (including zero). A convenient method of representing each nibble is to use the hexadecimal base 16 system.

When converting binary to hex, the byte is divided into nibbles each represented by a single hex digit. This technique is applied to the selection of the base address for the circuit board. The following diagram illustrates the construction of a hex number.

BIT No	7	6	5	4	3	2	1	0
NIBBLE VALUE	8	4	2	1	8	4	2	1
BINARY NUMBER	1	1	0	0	0	1	1	0

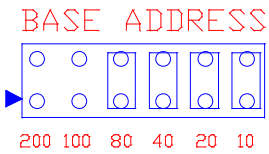
HEXADECIMAL: C 6

Hexadecimal upper nibble = (1 x 8) + (1 x 4) + (0 x 2) + (0 x 1) = 12
lower nibble = (0 x 8) + (1 x 4) + (1 x 2) + (0 x 1) = 6

The resulting value is C6 $_{Hex}$, since 12 $_{Decimal}$ equals C $_{Hex}$.

Base Address Selection

Each column can be physically represented on the board by a pair of pins. In practice, the boards cover a range of addresses (usually 16 $_{Decimal}$). Therefore the low order four bits are not included, but two higher order bits are added. This gives an address range of 0 to 3F0 $_{Hex}$. The following diagram shows a typical set of pins.



Here a link is fitted to denote a binary or logic “0”, or left open to indicate a binary or logic “1”. The example shows a base address setting of 300 $_{Hex}$.

Appendix B - PC MAPS

PC/XT/AT I/O Address Map

Address	Allocated to:
000-01F	DMA Controller 1 (8237A-5)
020-03F	Interrupt Controller 1 (8259A)
040-05F	Timer (8254)
060-06F	Keyboard Controller (8742) Control Port B
070-07F	RTC and CMOS RAM, NMI Mask (Write)
080-09F	DMA Page Register (Memory Mapper)
0A0-0BF	Interrupt Controller 2 (8259)
0F0	Clear NPX (80287) Busy
0F1	Reset NPX (80287)
0F8-0FF	Numeric Processor Extension (80287)
1F0-1F8	Hard Disk Drive Controller
200-207	Reserved
278-27F	Reserved for Parallel Printer Port 2
2F8-2FF	Reserved for Serial Port 2
300-31F	Reserved
360-36F	Reserved
378-37F	Parallel Printer Port 1
380-38F	Reserved for SDLC Communications, Bisync 2
3A0-3AF	Reserved for Bisync 1
3B0-3BF	Reserved
3C0-3CF	Reserved
3D0-3DF	Display Controller
3F0-3F7	Diskette Drive Controller
3F8-3FF	Serial Port 1

PC/XT Interrupt Map

Number	Allocated to:
NMI	Parity
0	Timer
1	Keyboard
2	Reserved
3	Asynchronous Communications (Secondary) SDLC Communications
4	Asynchronous Communications (Primary) SDLC Communications
5	Fixed Disk
6	Diskette
7	Parallel Printer

PC/AT Interrupt Map

Level		Allocated to:
CPU NMI		Parity or I/O Channel Check
CTLR 1	CTLR 2	(Interrupt Controllers)
IRQ 0		Timer Output 0
IRQ 1		Keyboard (Output Buffer Full)
IRQ 2		Interrupt from CTLR 2
	IRQ 8	Real-time Clock Interrupt
	IRQ 9	S/w Redirected to INT 0AH (IRQ 2)
	IRQ 10	Reserved
	IRQ 11	Reserved
	IRQ 12	Reserved
	IRQ 13	Co-processor
	IRQ 14	Fixed Disk Controller
	IRQ 15	Reserved
IRQ 3		Serial Port 2
IRQ 4		Serial Port 1
IRQ 5		Parallel Port 2
IRQ 6		Diskette Controller
IRQ 7		Parallel Port 1

DMA Channels

0	Memory Refresh
1	Spare
2	Floppy Disk Drive
3	Spare

Appendix C - BOARD LAYOUT