PICmicro® Microcontroller development board data sheet

Contents

1   General information

The Matrix PICmicro microcontroller (MCU) development board is designed to form part of the World's best solution for learning PICmicro programming.

The remit of all Matrix products is to Make Education Easier. This philosophy is fulfilled with this development board in two ways:
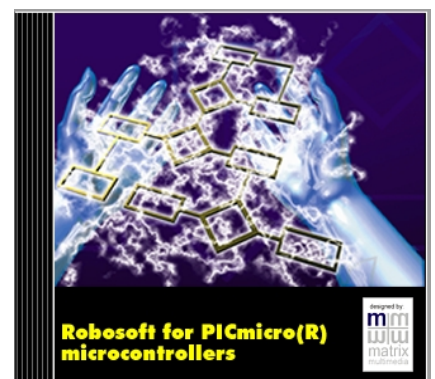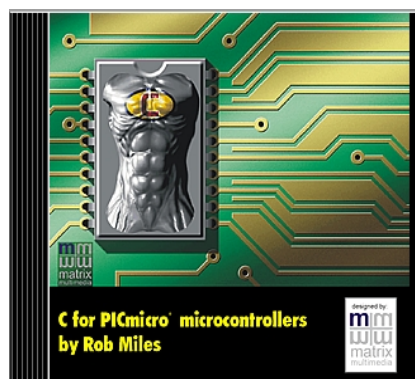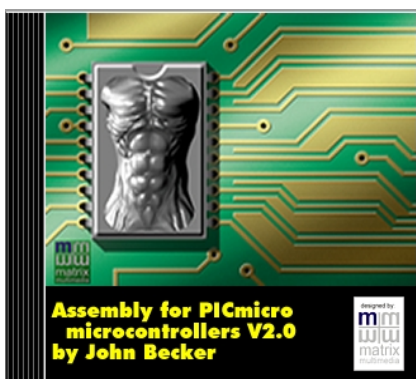
Makes it easier to teach and learn PICmicro programming

- Designed for educational use
- 3 CD ROM based resources in assembly, C, and flow chart programming are available
- Free download software, PPP, provides seamless send and verify functions

Makes it easier to develop PICmicro projects

- Supports low cost Flash-programmable PICmicro devices
- Fully featured displays - 13 individual LEDs, quad 7-segment display and LCD display
- Supports PICmicro microcontrollers with A/D converters
- On-board sensors
- A comprehensive range of external analogue and digital sensors are available for project work
- Fully protected expansion bus for project work
- All inputs and outputs available on screw terminal connectors for easy connection

Three courses and programming systems compatible with this product are available on CD ROM:

Assembly for PICmicro microcontrollers V2.0 by John Becker

C for PICmicro microcontrollers by Rob Miles

Robosoft for PICmicro(R) microcontrollers

2   Features

This page describes the features of the development board:
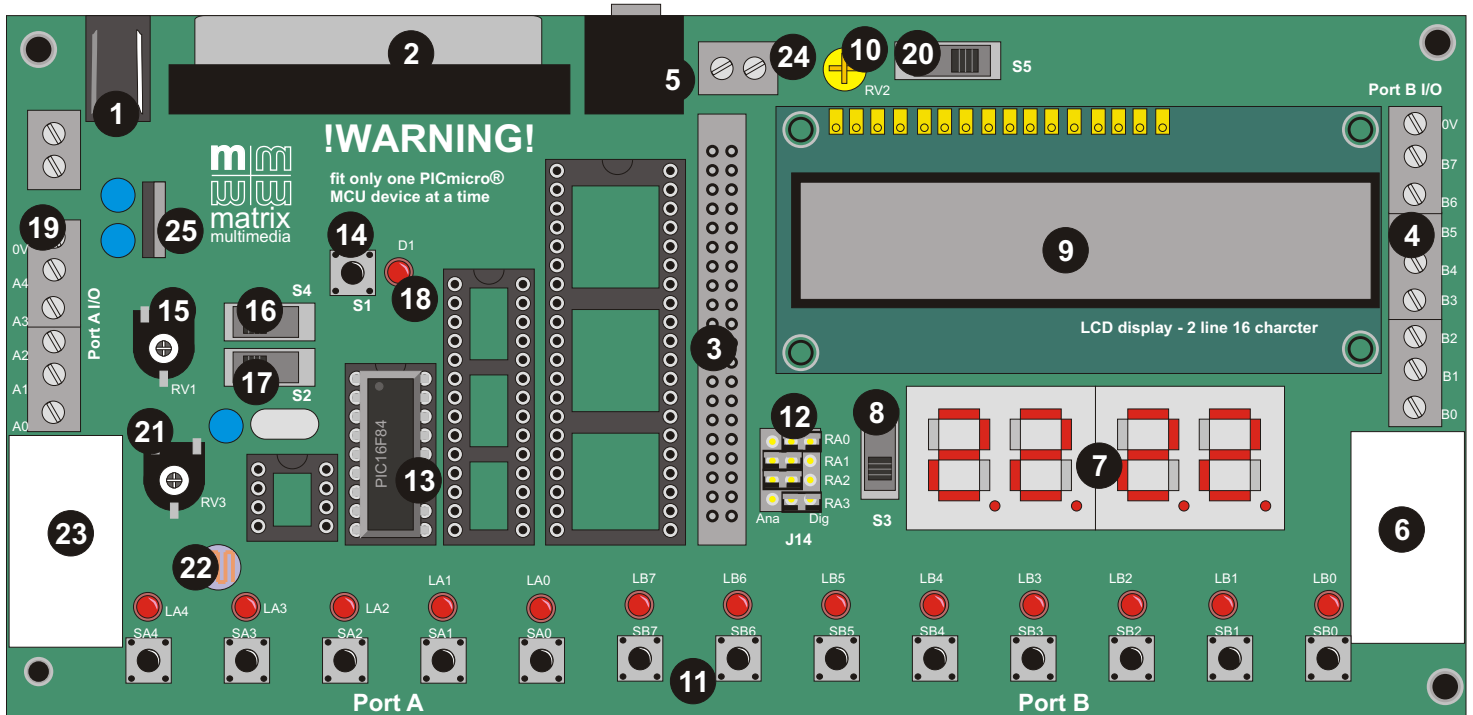
1   Power connector - unregulated 12V supply via PSU jack (positive outer) or 2 terminal screw connector
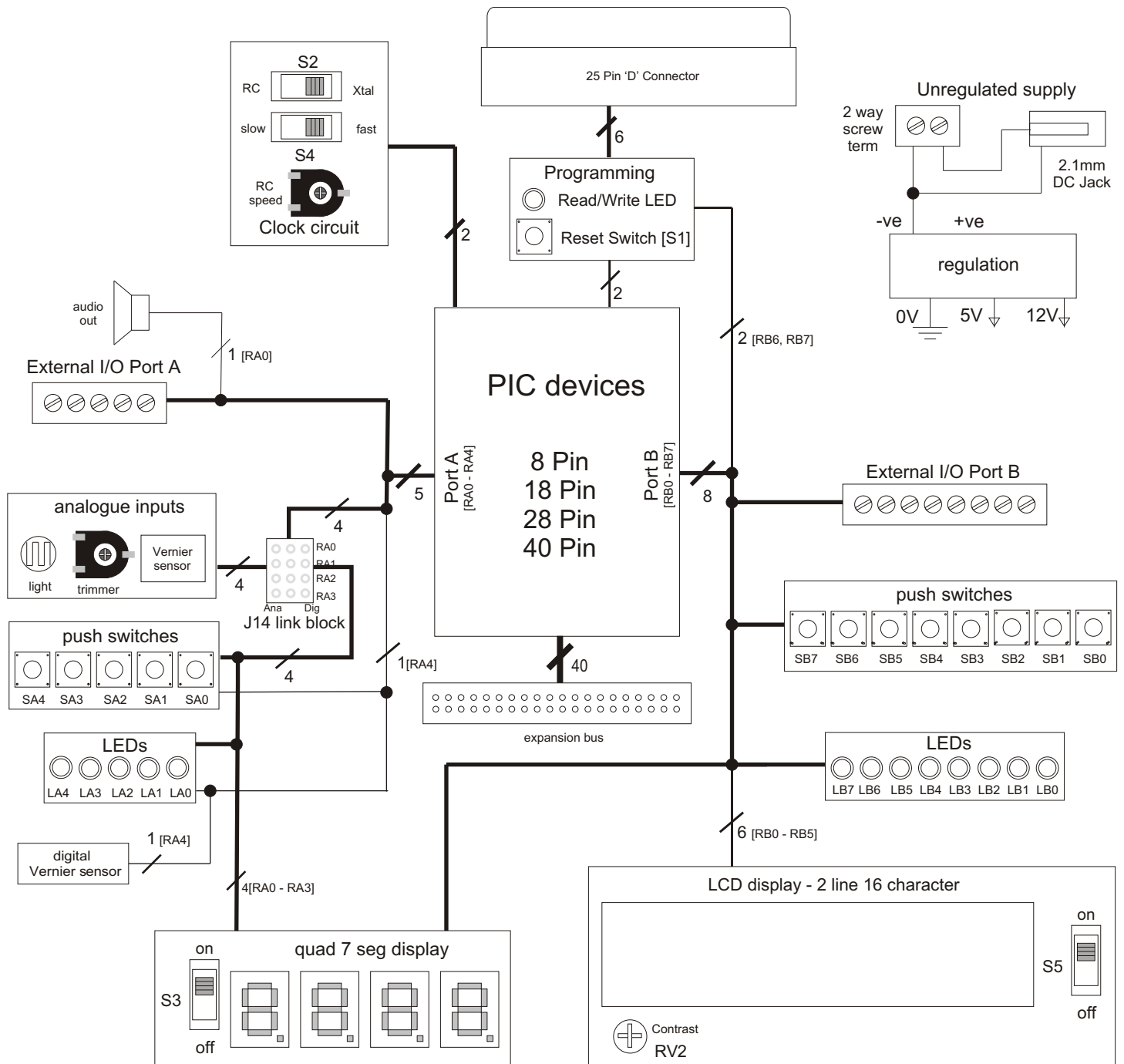2   25 way D-type - connects board to PC parallel port via standard 25 way cable
3   Expansion bus - 40 way expansion bus suitable for IDC cable connection
4   Port B I/O - connections for all port B PICmicro I/O
5   Audio output - connects via coupling capacitor to port A0 for simple tone generation
6   Digital external sensor - connects to selected Port B pins for use with Vernier motion/distance detector and light gate
7   Quad 7-segment display - dual 7- seg. displays in 2 banks
8   7-segment display switch - switches power to 7-segment displays.
9   LCD display **-** 2 line 16 character quasi-intelligent alphanumeric display which is programmed via 4 serial pins on port B of the PICmicro
10   LCD contrast potentiometer - controls contrast on LCD display
11   Port A/B switches and indicators - Individual switches connect +5V to port A/B inputs. Indicators show status when I/O pins are configured as outputs
12   Port A analogue/digital selection jumpers.
13   PICmicro turned pin DIL sockets - DIL sockets for 8, 18, 28 and 40 pin PICmicros - caution: fit only one PICmicro at one time. PIC16F84 fitted as standard. Note that if you are frequently changing the PICmicro device you are using it would be wise to fit additional turned pin sockets / a ZIF socket to the board to preserve the life of your sockets and your PICmicros.
14   Reset switch - Resets PICmicro MCU
15   RC clock speed potentiometer varies clock speed when RC switch is selected
16   RC clock speed switch - controls clock speed (fast or slow) when RC switch is selected
17   Clock crystal / RC switch - controls whether the board runs off a 3.2768MHz crystal or from an on-board RC circuit.
18   Program indicator light - indicates when PICmicro is being programmed.
19   Port A I/O - connections for all port A PICmicro input and outputs
20   LCD display switch - switches power to LCD display.
21   Potentiometer - part of the sensors system - simulates a varying analogue voltage on port A1 for testing code during program development.
22   Light sensor - part of sensors system - on-board light sensor
23   External analogue sensor - allows connection of one of a range of analogue sensors from temperature sensors to heart rate monitors.
24 5V output connector - not normally fitted.

3   Block schematic

Clock circuit

S2: RC — Xtal, slow — fast
S4: RC speed
Clock circuit

PIC devices

25 Pin 'D' Connector

Programming
- Read/Write LED
- Reset Switch [S1]

PIC devices

8 Pin
18 Pin
28 Pin
40 Pin

Port A [RA0 - RA4]
Port B [RB0 - RB7]

2 [RB6, RB7]

Unregulated supply

2 way screw term
2.1mm DC Jack
-ve   +ve
regulation
0V   5V   12V

audio out

External I/O Port A   1 [RA0]

analogue inputs
light   trimmer   Vernier sensor
4

J14 link block
RA0
RA1
RA2
RA3
Ana   Dig

push switches
SA4 SA3 SA2 SA1 SA0
4

LEDs
LA4 LA3 LA2 LA1 LA0

digital Vernier sensor   1 [RA4]

5   Port A
4
1 [RA4]

40   expansion bus

4 [RA0 - RA3]

8   Port B

External I/O Port B

push switches
SB7 SB6 SB5 SB4 SB3 SB2 SB1 SB0

LEDs
LB7 LB6 LB5 LB4 LB3 LB2 LB1 LB0

6 [RB0 - RB5]

quad 7 seg display

on / off   S3
quad 7 seg display

LCD display - 2 line 16 character

on / off   S5
Contrast RV2

Default switch/jumper conditions

S2 = RC [RC mode]
S4 = slow [RC speed]
S3 = off [7 seg displays]
S5 = off [LCD display]
J14 = Digital

Note that J14 jumpers should always remain on the digital position when using a PIC16F84 as it does not have an analogue capability.

4   General description

The PICmicro development board is designed primarily for learning how to program PICmicro applications. It also allows a wide range of PICmicro microcontrollers to be programmed and the 'seamless' nature of the programming software supplied with the product (the PICmicro Parallel Programmer or simply 'PPP') makes it suitable for the development of a range of PICmicro projects.

The board is optimised for use with a PIC16F84 from Arizona Microchip which has a number of features:

- Crystal or RC operation
- 2 ports: Port A - 5 pins and Port B - 8 pins. i.e.: 13 programmable pins which can all be used as inputs and outputs.
- Flash programmable - up to 1,000,000 programming cycles

Whilst the 16F84 has no analogue capability and is not the most functional PICmicro available it has been selected for use with this development board for a number of reasons:

- It is a low cost device - suitable for project work in schools
- It has been widely used in third party projects and there is a wide body of code available for it
- It has a relatively simple internal topology
- It is electrically re-programmable

A full list of other PICmicros that the board can support is listed below.

The board has been designed to allow students with little or no experience of embedded microcontroller programming to be able to produce highly functional designs in as short a time as possible. With this in mind we have included switches on each input/output pin, a quad 7-segment display, a 2 line 16 character alphanumeric display, a choice of crystal or RC oscillator, simple on-board analogue sensor (light) and sensor simulator (potentiometer) and the ability to interface the board to a host of external sensors from Vernier Inc. of the USA.

Full tutorials in programming the PIC16F84 in both assembly code and in C are available. These sets of tutorials are available on CD ROM and require no other software - all compilers and development environments are included on the CDs themselves.

Schematic description - please refer to block schematic

The board is based on a flexible topology that allows the inputs and outputs to be used in a number of ways depending on switch settings on the board. This flexibility means that students will, as they use additional features, need to be aware of how a single input-output (I/O) pin can be used for a number of functions dictated by the circuitry attached to it. This is explained in the Circuits section of this document.

The architecture of the board is split into two main buses - the port A bus and the port B bus. Each line on each bus can be used as either an input or as an output. The connectors and displays on the board are all wired in parallel on the PIC pins for convenience but clearly connecting more than one device to one pin will result in conflict: students will need to be made aware of this.

Port A bus

Under normal operation all of the jumper links in the J14 link block are in the Digital position. This means that the Port A I/O pins are routed to the push switches and LEDs. The actual circuit is described in the Circuits section. Note that operating the push switches whilst a voltage is connected to port A via the external screw terminals is not advisable as it will result in unpredictable results. Port A screw terminal connectors are fed to the pins on the PICmicro via 150 ohm resistors which provide short circuit protection.

With J14 links in the Digital position port A is routed to its push switches (SA0 to SA4), LEDs, digital Vernier sensor I/O, and the quad 7-segment display. Bits RA0, RA1, RA2 and RA3 are used for the common anodes of each of the four 7-segment displays. RA0 is used for tone generation via the jack plug, and bit RA2 is used for the digital Vernier sensor input.

With J14 links in the Analogue position port A is switched to the analogue sensor section of the board. This means that RA0 is connected to the on-board light sensor, RA1 is connected to the potentiometer wiper for sensor simulation, and bit RA2 is connected to the external analogue Vernier sensor connector.

With J14 links in the Analogue position you should be aware that on-board switches and LEDs will not operate.

If you want to use the external port A screw terminal connectors for analogue inputs you should remove the links off J14 altogether.

Port B Bus

Port B I/O pins are routed to its push switches (SB0 to SB7), the LEDs (LB0 to LB7), the quad 7-segment displays, the LCD display and the screw terminal connectors. Note that the screw terminal connectors are fed to the pins on the PICmicro via 150ohm resistors which provide short circuit protection. However operating the push switches whilst a voltage is connected to Port B is not advisable as it will result in unpredictable results.

Port B is also used for programming the PICmicro - the PPP software used for programming the PICmicro will automatically take over pins required for programming, verifying and resetting the PICmicro on the board.

Clock circuitry

During early stages of learning PICmicro programming students often want each clock cycle to be large (1 second) so that they can see code executing very slowly (flashing LEDs don't simply become 'less bright' LEDs) . The PIC16F84 supports this feature by having an RC mode of operation. Use of

RC mode also reduces component count and cost for small projects.

S2 selects between RC mode and Crystal mode.

S4 selects fast or slow operation when RC mode is selected.

RV1 adjusts the speed of the clock within a range dictated by S4.

Power supply circuit

The board is normally operated from an unregulated DC supply of 12V. This allows full operation including programming.

The board can be operated from 8 1.5V AA cells if required but students will lose the ability to program the PICmicro which requires just over 12V.

The optional power supply shipped with the PICmicro board (UK versions) is rated at a maximum of 500mA. You should be aware that the board could consume more current than this if you are connecting several external devices on the external I/O.

If you do require the on-board PICmicro to drive several external outputs you may wish to fit a heat sink to the 7805 regulator. The layout of the printed circuit board should easily accommodate this.

Displays

The LCD display is connected to Port B I/O. The LCD display is turned on by switch S5.

The quad 7-segment display is connected to both Port A and Port B. Port B is used to control each of the 8 segments (7 for the main character and 1 for the full stop). Port A bits 0 to 3 are used to select each of the 4 characters.

The quad 7-segment display is turned on by switch S3. Note that turning on the display will affect the operation of Port B I/O and when using the quad 7-segment displays it is recommended that you do not use Port B for any other purposes. Under certain circumstances you will notice that segments of the quad 7-segment display may be lit up very dimly by Port A/B operation even when S3 is in the off position. This is a feature of the low cost driver circuitry and is unavoidable.

5 Programming software

The PICmicro Parallel Programmer [PPP] allows an assembled program to be sent to virtually any PICmicro microcontroller on the PICmicro Development board. Both raw OBJ files generated by TASM, and ASCII-encoded HEX files generated by MPASM can be sent using PPP. PPP uses a simple user interface which is explained in the accompanying help file. PPP is supplied free with the development board. Features include:

● Operates with the latest parallel port standards

● HEX and OBJ file compatible

● Range of Xtal and RC operation modes

● Reads content of any non-protected PICmicro

● Confirms each byte of code sent

● Bit selection on configuration word available for advanced users

Minimum requirements

● Pentium 100MHz, Parallel printer port, 1 Megabyte of hard drive space, 16Megabytes of RAM, Windows 95/98/ME/NT/2000/XP

Installation

Insert the floppy disk supplied with the PICmicro development board, navigate to the floppy drive on the target computer and execute the install file named "PPP install". A shortcut will be added to the desktop and to the Start menu.

[Administrator Privileges are required to install on Windows NT/2000]

Setup

● Insert the power supply into a wall outlet, then connect to the PICmicro board.

● Connect the parallel cable to both the computer's parallel port and to the PICmicro board.

Configuration

Before sending a program to the PICmicro board, PPP should be set up correctly. Start the PPP program then on the toolbar click on the "Configure the PICmicro" icon [Ctrl - C]. In the configuration box -

● Select chip type

● Select the oscillator type [XT if using the on-board crystal, or RC if using the on-board resistor and capacitor]

● Select the correct port for the parallel cable [on most computers the default is 0x378]

● Leave both the watchdog timer and the power-up timer unchecked unless the program to be sent requires them.

● Enable code protection, if the contents of the PIC should not be read, only after it has been programmed.

[N.B. The configuration word can be altered manually - please refer to PICmicro datasheets for details.]

Sending

To open a file click on the "Open a PICmicro code file" icon on the toolbar [Ctrl - O], navigate to the file to be sent. To send the file click on the "Send the code to the PICmicro" icon on the toolbar [Ctrl - P]. As the code is sent to the PICmicro board the Program LED turns on. When all the code has been sent the LED turns off. If verification has been selected the LED turns on, whilst the code is being read. After all the code has been read the LED turns off and PPP informs the user if all the code had been sent correctly.

6   Testing the development board

When you first receive your development board you should check its operation. There are two parts to this - checking that the hardware works correctly and checking that you can download programs into the PIC16F84 that is supplied with the board.

Your board will be supplied with a PIC16F84 that already has a test program in it. This simple test program simply flashes the I/O port LEDs in turn. Simply connect the power supply to the development board: if the Port A and B LEDs make a 'knight rider' effect then you know that your PICmicro is up and running and your basic circuitry is operational.

Note that the switch settings for this core program are:

S2 - RC position
S4 - slow
J14 - Digital position
S5 - LCD display off
S3 7-seg display off

You can now test the board can communicate with the PC. To do this load PPP (see previous page) and send the file BLANK.HEX to the PICmicro. Further instructions are given in the PPP help file. This will clear your PICmicro.

Your development board should now be inactive - basically there will be no program in the PIC16F84.

Next send the program TUTTEST.HEX to the PICmicro. Once this is complete then your board should be running the same 'knight rider' program as before.

You now know that your development board is up and running correctly. Further test programs for this development board are available from our web site: www.matrixmultimedia.co.uk.You will find the program TEST40.HEX - the factory test routine - particularly useful. This operates on a PIC16F870 and is used in the factory to do a complete and thorough test of your hardware during manufacture.

7 Supported PICmicro microcontrollers

The PPP program has been designed to work with the most popular devices in circulation at the time of developing the PICmicro microcontroller development board (November 2001). These are listed below.

Exhaustive tests have been carried out with selected devices from each of the main PICmicro families. The chips we have used in these tests are shown in red. All the devices listed below should function without difficulty. If you do experience any problems then please contact support@matrixmultimedia.co.uk.
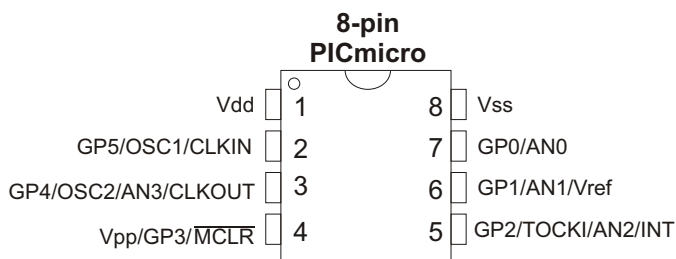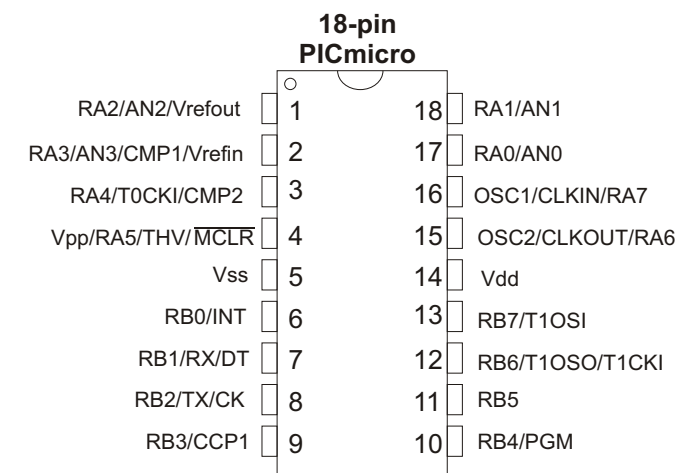
Please also check www.matrixmultimedia.co.uk for updated versions of the PPP software and a more up-to-date list of supported devices.

Supported PIC Devices

	8 Pin	18 Pin	28 Pin	40 Pin
Digital Only		16C61 16CR83 16F83 16CR84 16F84 16F84A	16C62 16C62A 16C62B 16CR62 16C63 16CR63 16C63A 16C66	16C64 16CR64 16C64A 16C65 16C65A 16C65B 16CR65 16C67
Analogue	12C671 12C672 12CE673 12CE674	16C620 16C620A 16CR620A 16C621 16C621A 16C622 16C622A 16CE623 16CE624 16CE625 16C627 16C628 16C710 16C711 16C71 16C712 16C716	16C72 16C72A 16CR72 16C73 16C73A 16C73B 16C76 16F73 16F76 16C745 16C773 16F870 16F872 16F873 16F876	16C74 16C74A 16C74B 16C77 16F74 16F77 16C765 16C774 16F871 16F874 16F877

8 Pin out details and bus connections

Broadly speaking the ranges of PICmicro devices are designed to be upwards compatible: the pin functions on an 18-pin device are available on a 28-pin device and a 40-pin device. This can be seen from the following information taken from the Microchip product selector card:

18-pin PICmicro

Left	Pin		Pin	Right
RA2/AN2/Vrefout	1		18	RA1/AN1
RA3/AN3/CMP1/Vrefin	2		17	RA0/AN0
RA4/T0CKI/CMP2	3		16	OSC1/CLKIN/RA7
Vpp/RA5/THV/$\overline{\text{MCLR}}$	4		15	OSC2/CLKOUT/RA6
Vss	5		14	Vdd
RB0/INT	6		13	RB7/T1OSI
RB1/RX/DT	7		12	RB6/T1OSO/T1CKI
RB2/TX/CK	8		11	RB5
RB3/CCP1	9		10	RB4/PGM

8-pin PICmicro

Left	Pin		Pin	Right
Vdd	1		8	Vss
GP5/OSC1/CLKIN	2		7	GP0/AN0
GP4/OSC2/AN3/CLKOUT	3		6	GP1/AN1/Vref
Vpp/GP3/$\overline{\text{MCLR}}$	4		5	GP2/TOCKI/AN2/INT

Note that GP0 maps to RB7
GP1 maps to RB6
GP2/AN2 maps to RA0/AN0

28-pin PICmicro

Left	Pin		Pin	Right
Vpp/$\overline{\text{MCLR}}$	1		28	RB7/PGO
RA0/AN0	2		27	RB6/PGC
RA1/AN1	3		26	RB5
RA2/AN2/Vrl/Vref-	4		25	RB4
RA3/AN3/Vrh/Vref+	5		24	RB3/PGM/CCP2
RA4/T0CKI	6		23	RB2/INT2
RA5/AN4/SS/Avdd/Lvdin	7		22	RB1/INT1
Vss	8		21	RB0/INT
OSC1/CLKI	9		20	Vdd
OSC2/CLKO/RA6	10		19	Vss
RC0/T1OSO/T1CKI	11		18	RC7/RX/DT
RC1/T1OS/CCP2I	12		17	RC6/TX/CK
RC2/CCP1	13		16	RC5/SDO/D+
RC3/SKC/SCL	14		15	RC4/SKI/SDA/D-

40-pin PICmicro

Left	Pin		Pin	Right
Vpp/$\overline{\text{MCLR}}$	1		40	RB7/PGO/KB13
RA0/AN0	2		39	RB6/PGC/KB12
RA1/AN1	3		38	RB5/KBI1
RA2/AN2/Vrl/Vref-	4		37	RB4/KBI0
RA3/AN3/Vrh/Vref+	5		36	RB3/PGM/CCP2/CANRX
RA4/T0CKI	6		35	RB2/INT2/CANTX
RA5/AN4/SS/Lvdin	7		34	RB1/INT1
RE0/AN5/RD	8		33	RB0/INT0
RE1/AN6/WR	9		32	Vdd
RE3/AN7/CS	10		31	Vss
Avdd	11		30	RD7/PSP7/PD
Avss	12		29	RD6/PSP6/PC
OSC1/CLKI	13		28	RD5/PSP5/PB
OSC2/CLKO/RA6	14		27	RD4/PSP4/ECC/PA
RC0/T1OSO/T1CKI	15		26	RC7/RX/DT
RC1/T1OSI/CCP2	16		25	RC6/TX/CK
RC2/CCP1	17		24	RC5/SKO/D+
RC3/SCK/SCL	18		23	RC4/SDI/SDA/D-
RD0/PSP0/C1IN+	19		22	RD3/PSP3/C2IN-
RD1/PSP1/C1IN-	20		21	RD2/PSP2/C2IN+

This has allowed us to wire the 8, 18, 28, and 40 pin devices in parallel on the development board. Whilst the board is optimised for a PIC16F84 (an 18 pin device) it can also therefore be used for almost any PICmicro. The following table shows you the pin comparison chart for all devices. You will find this chart a useful reference tool.

Pin Comparison Chart

Bus Name	18 Pin	8 Pin	28 Pin	40 Pin
Vpp/$\overline{\text{MCLR}}$	4	4	1	1
Vdd	14	1	20	32
Vss	5	8	8 19	31
OSC1	16	2	9	13
OSC2	15	3	10	14
RA0/AN0	17	5	2	2
RA1/AN1	18		3	3
RA2	1		4	4
RA3/AN3	2		5	5
RA4	3		6	6
RA5/AN4			7	7
RB0	6		21	33
RB1	7		22	34
RB2	8		23	35
RB3	9		24	36
RB4	10		25	37
RB5	11		26	38
RB6	12	6	27	39
RB7	13	7	28	40
RC0			11	15
RC1			12	16
RC2			13	17
RC3			14	18
RC4			15	23
RC5			16	24
RC6			17	25
RC7			18	26
RD0				19
RD1				20
RD2				21
RD3				22
RD4				27
RD5				28
RD6				29
RD7				30
RE0/AN5				8
RE1/AN6				9
RE3/AN7				10

Expansion bus

The pin connections on the expansion bus exactly mirror the pin numbering on the 40 pin DIL socket. The best way of connecting devices to the expansion bus is by using an IDC cable.

9   Liquid Crystal Display

The LCD is a 16 character x 2 lines module. Internally it is 40 characters x 2 lines. Line 1 ranges from H'00' to H'27' and Line 2 ranges from H'40' to H'67'.

0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F	20	21	22	23	24	25	26	27
40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F	50	51	52	53	54	55	56	57	58	59	5A	5B	5C	5D	5E	5F	60	61	62	63	64	65	66	67

Display Window [16x2]   Internal [40x2]

The LCD Module uses a Samsung KS0066U controller, which is similar to the Hitachi HD44780 controller.

The PICmicro board uses port B [B0 to B5] to program the LCD, as shown in the circuit diagram below. When the PICmicro board is turned on, data can only be sent to it after 30ms, this is the time taken for the LCD to initialize [as it clears all the RAM and sets up the Entry Mode].
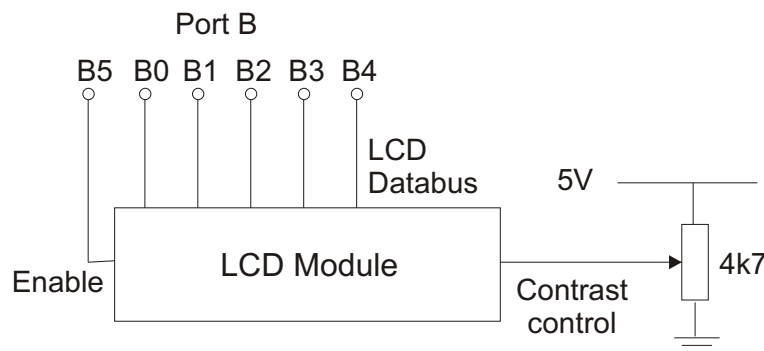
LCD Block Diagram

To send a command to the LCD, data must be sent in two steps, the MSB followed by the LSB [byte is data on B0 to B3]. As each byte is sent to the LCD, B5 must be go high then low, for the LCD to acknowledge the byte. After the second byte has been acknowledged the LCD executes the command. The PICmicro board must wait for at least the length of the execution time for that command, before the next command can be sent. A timing diagram of this process is shown below.
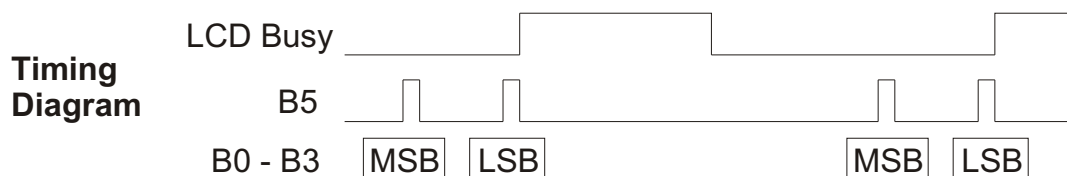
The first command to be sent to the LCD must be 'Function Set' [to setup the LCD], this is usually followed by 'Display Control' and then 'Clear Display'. According to 'Entry Mode Set' after each character is sent to the LCD, the position of the cursor changes [by default it is incremented].

LCD Instruction Set

Instruction	Code						Description	Execution Time
	MSB LSB	B4	B3	B2	B1	B0		
Clear Display	0	0	0	0	0	0	Clear all display data. Set DDRAM address to 0. Move cursor to home position. Entry mode set to increment.	1.53 ms
			0	0	0	1		
Return Home	0	0	0	0	0	0	Set DDRAM address to 0. Move cursor to home position.	1.53 ms
			0	0	1	X		
Entry Mode Set	0	0	0	0	0	0	Sets cursor move direction (I/D), specifies to shift the display (S). These operations are performed during data read/write.	39 us
			0	1	I/D	SH		
Display Control	0	0	0	0	0	0	D is Display ON/OFF bit. C is Cursor ON/OFF bit. B is Blink Cursor ON/OFF bit.	39 us
			1	D	C	B		
Cursor/Display Shift	0	0	0	0	0	1	Sets cursor-move or display-shift (S/C), shift direction (R/L). DDRAM contents remains unchanged.	39 us
			S/C	R/L	X	X		
Function Set	0	0	0	1	0		Configuration data for setting up LCD. [Send First]	39 us
			1	0	X	X		
Set CGRAM Address	0	0	1	A5	A4		Sets the CGRAM address. CGRAM data is sent and received after this setting.	39 us
			A3	A2	A1	A0		
Set DDRAM Address	0	1	A6	A5	A4		Sets the DDRAM address. DDRAM data is sent and received after this setting.	39 us
			A3	A2	A1	A0		
Write Data to RAM	1	D7	D6	D5	D4		Writes data to CGRAM or DDRAM.	43 us
			D3	D2	D1	D0		

DDRAM is Display Data RAM
DDRAM address is location of cursor
CGRAM is Character Generator RAM
X is Don t Care

Bit Name	0	1
I/D	Decrement cursor position	Increment cursor position
SH	No display shift	Display shift
D	Display off	Display on
C	Cursor off	Cursor on
B	Cursor blink off	Cursor blink on
S/C	Move cursor	Shift display
R/L	Shift left	Shift right

LCD Character Set

Hint
please look at our web site for examples of code that shows how to program the 7-segment display. (TEST40.ASM factory test routine.)

10   On-board analogue sensors

To use an analogue sensor, the PICmicro board must manually be set to analogue mode and an analogue-capable PIC must be used. Whilst in analogue mode certain port A pins [A0/RA0,A1/RA1 etc] are able to convert an analogue signal to an 8 or 10 bit digital signal, using the on-board A to D converter inside the PICmicro device.

Please refer to Microchip data sheets for more details.

The analogue sensors are not normally connected to the PICmicro pins but are switched on to them under the control of the jumpers on J14.

Several analogue sensors are relevant:

LDR

A compact cadmium sulphide light dependent resistor is soldered onto the development board. When J14 link RA0 is in the 'analogue' position it is connected to A0 on the PICmicro microcontroller. The resistance of this device reduces as light falling on to it increases.

Technical specification
Dark resistance   1M Ohm
Resistance @ 10 Lux   10-20k Ohm
                         100 Lux   2-4k Ohm
Peak spectral response 540 nm
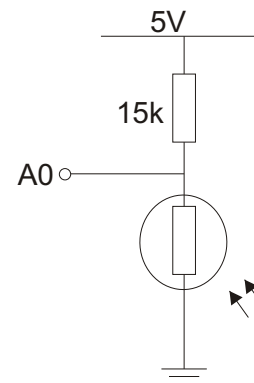
Potentiometer

Most passive sensors are based on a simple potential divider circuit. In order to get your code up and running as simply as possible it is therefore useful to have a simulation of the full operation range (0V to 5V) that a sensor might provide. This function is simulated by a simple 5k preset potentiometer (RV3) with a series 10k resistor, which produces a voltage in the range of 0V to 5V on RA1. Note that J14 / 1 will need to be in the analogue position to use this circuit.
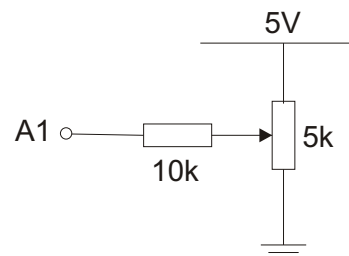
External analogue sensor

In addition to the above the link J14 / 3 also switches a voltage from a range of external active sensors onto pin A3/RA3 of the PICmicro microcontroller. These active sensors are designed specifically for educational purposes by Vernier Inc. of the USA. Details of these sensors are given below.

11 External analogue sensors

A host of external analogue sensors can be attached to the PICmicro board, the output from the sensor goes to RA3.

Light Sensor

The sensor uses a Hamamatsu S1133 silicon photodiode. It produces a voltage which is proportional to light intensity. The spectral response approximates the response of the human Eye.

The switch on the box is used to select the range. If the voltage from the sensor reaches the 2.8-volt maximum, you need to switch to a less sensitive range. If the voltage is very small or 0, you need to select a more sensitive range.

- The 0-600 lux range is selected when the switch is in the middle position. This is the most sensitive range, and is useful for low levels of illumination. The voltage from the sensor will change 1volt/200 lux.
- The 0-6000 lux range is selected when the switch is in the up position. This is a good general purpose range for indoor light levels. The voltage changes 1volt/2219 lux.
- The 0-150,000 lux range is selected when the switch is in the down position. This is used mainly for measurements in sunlight. The voltage changes 1volt/50,000 lux.

Microphone

The microphone uses an electret microphone that has a frequency response covering essentially the range of the human ear [20Hz - 16kHz]. An op-amp circuit amplifies and sends the signal centred at 2.5 volts. You will need to make sure the sound level is in the correct range to produce good wave patterns. If the sound is too loud, the wave pattern will be clipped. Move the microphone further from the sound source, or turn down the volume of the sound.

Stainless steel temperature probe

This uses a 20 k ohm NTC thermistor to measure temperatures in the range of -25°C to 125°C. Accuracy is ±0.2°C at 0°C and ±0.5°C at 100°C. The thermistor is a variable resistor whose resistance decreases non linearly with increasing temperature. The best-fit approximation to this nonlinear characteristic is the Steinhart-Hart equation. At 25°C, the resistance is approximately 4.3% per °C. The Response time after 11 s is 95% of full reading, after 18 s 98%, and after 300 s is 100%.

pH Sensor

The pH Sensor will produce a voltage of 1.75 volts in a pH 7 buffer. The voltage will increase by about 0.25 volts for every pH number decrease. The voltage will decrease by about 0.25 volts/pH number as the pH increases. The pH Sensor is designed to make measurements in the pH range of 0 to 14 within a temperature range of 5°C to 80°C and the 90% of the final reading is attained within 1 second.

Using analogue sensors

To make use of the analogue sensors you will need a PICmicro that has an in-built Analogue to Digital converter (ADC). The PICmicro shipped with the board - the PIC16F84 - does not have an ADC built in. Examples of PICmicros that do have A/D converters built in are:

PIC16F710   4 off 8 bit ADC channels
PIC16F874   4 off 10 bit ADC channels

There are two steps in using an analogue sensor:
1. Reading the value of the voltage at the ADC input
2. Understanding how this relates to the analogue parameter being measured.

Reading the value of the voltage at the ADC input is simply a matter of setting up your ADC and you should refer to the Microchip datasheet for further instructions on this advanced feature.

Relating the resulting hex value to the actual analogue parameter should be possible with the information supplied above and a small amount of mathematics. The results should be of a suitable accuracy for the majority of applications.

 If you require higher accuracy you will need to calibrate your sensor relate the hex values read in by the PICmicro to exact known light levels, pH levels etc. Calibrating the sensors to a high level of accuracy will invariably involve using a known piece of test equipment that is already calibrated.

12   Circuits

Switches and LED's

Port A [A0 - A4] and Port B [B0 - B7] on the PIC can be directly used for I/O on the PICmicro board, using onboard switches and LED's. The basic circuit which allows the same PICmicro connector I/O pin to be used as either an input or an output is as follows:
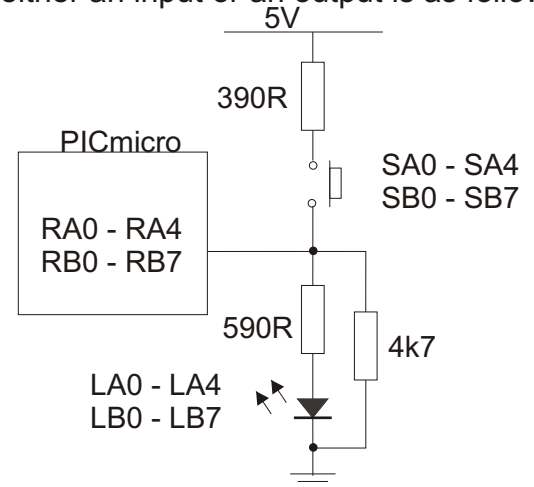
Multiple connections

The development board allows several variations on this basic circuit by the inclusion of switches and links on the board. There are a number of variations of this as follows:

RA0 to RA3

RA0 to RA3 are used to select which 7-segment display is used, are used for analogue inputs and are also connected to the screw terminals. The actual circuit used here is:
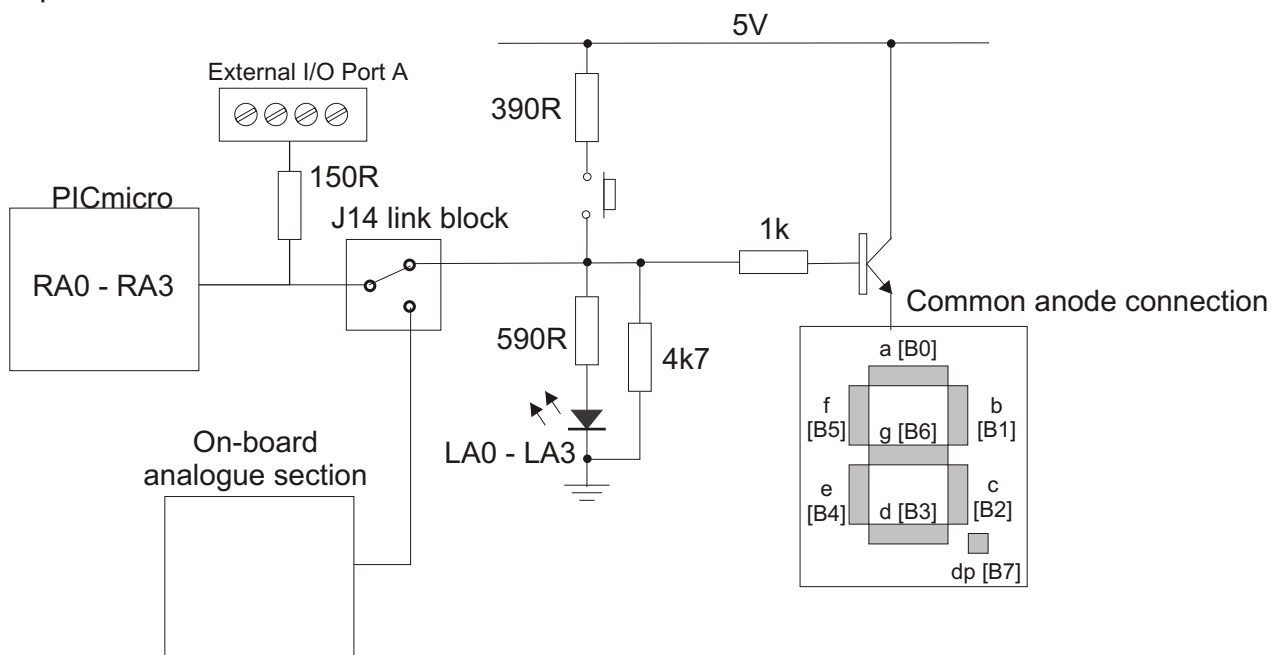
J14 allows students to effectively switch RA0 to RA3 to analogue or digital circuitry. Removing the link altogether will connect RA0 to RA3 only to the Port A screw terminal connectors via 150 ohm protection resistors. Note that the on-board analogue section consists of a potential divider provided by a light sensor, a potentiometer or an external sensor that provides a voltage between 0 and 5V. Under normal operation the links on J14 should be put into the 'digital' position.

RA4

RA4 is not switched by jumper link on J14. It is not connected to the 7-segment displays or the analogue section. RA4 is used for the external Vernier digital sensor.

RB0 to RB5

RB0 to RB5 are all connected to the switches and LEDs as well as to the I/O screw terminals, via 150 ohm protection resistor, and to the LCD and the cathodes of the 7-segment displays.
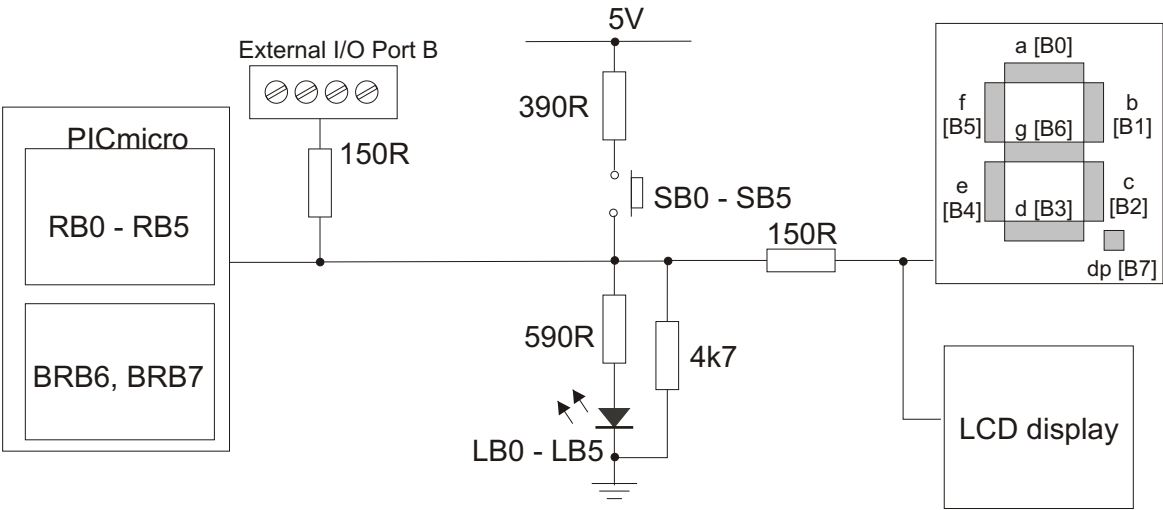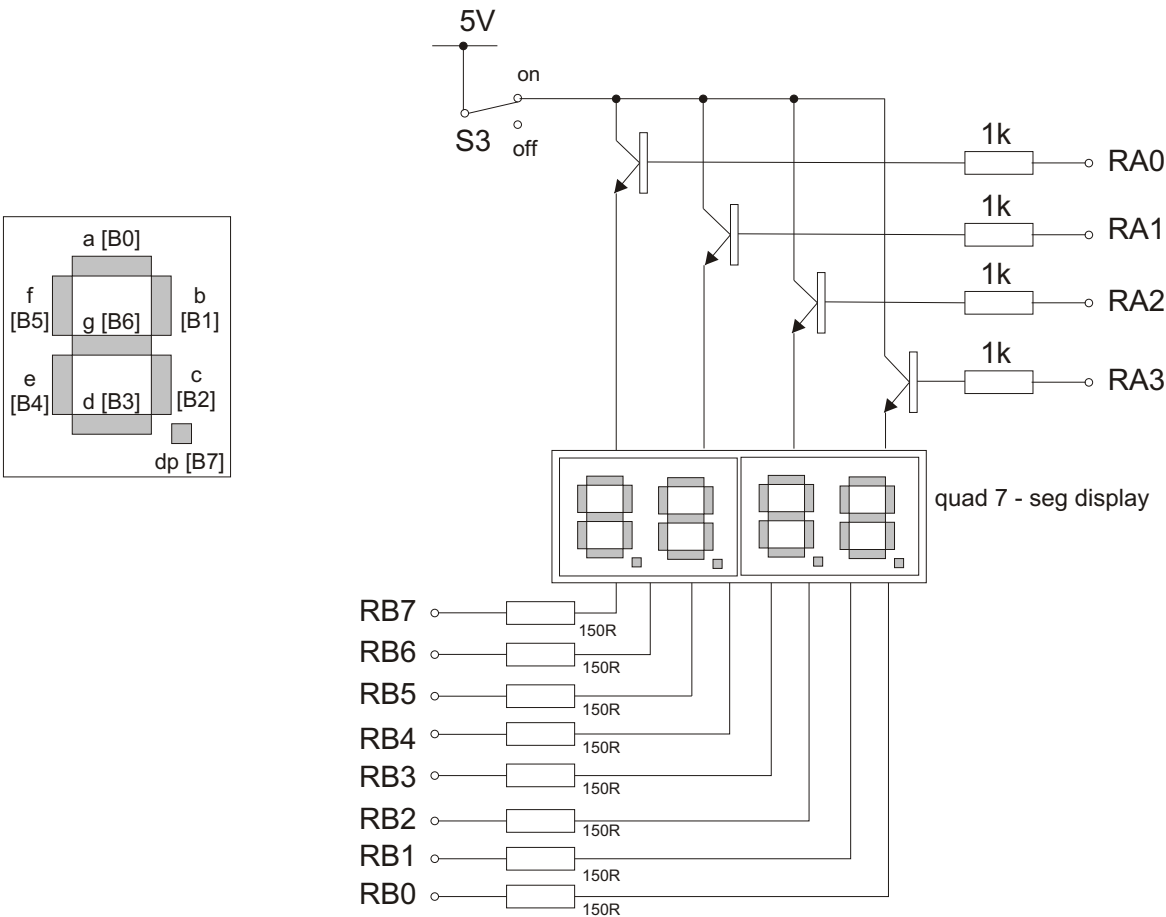

RB6 and RB7

RB6 and 7 have the same circuit as above but are connected to the PICmicro via an analogue switch - Buffered RB6 and Buffered RB7. This circuit is shown in the core PICmicro circuit below.

Quad 7-segment display

To use the quad 7-segment displays S3 must be in the 'on' position. Port A [A0 (left)- A3(right)] is used to select which of the four 7-segment display digits is active and the voltages on Port B [B0 - B7] dictate which segment is lit. To display data on all four 7-segment displays simultaneously a multiplexing program is required.

Core PICmicro circuit

The diagram below shows the core PICmicro circuit.
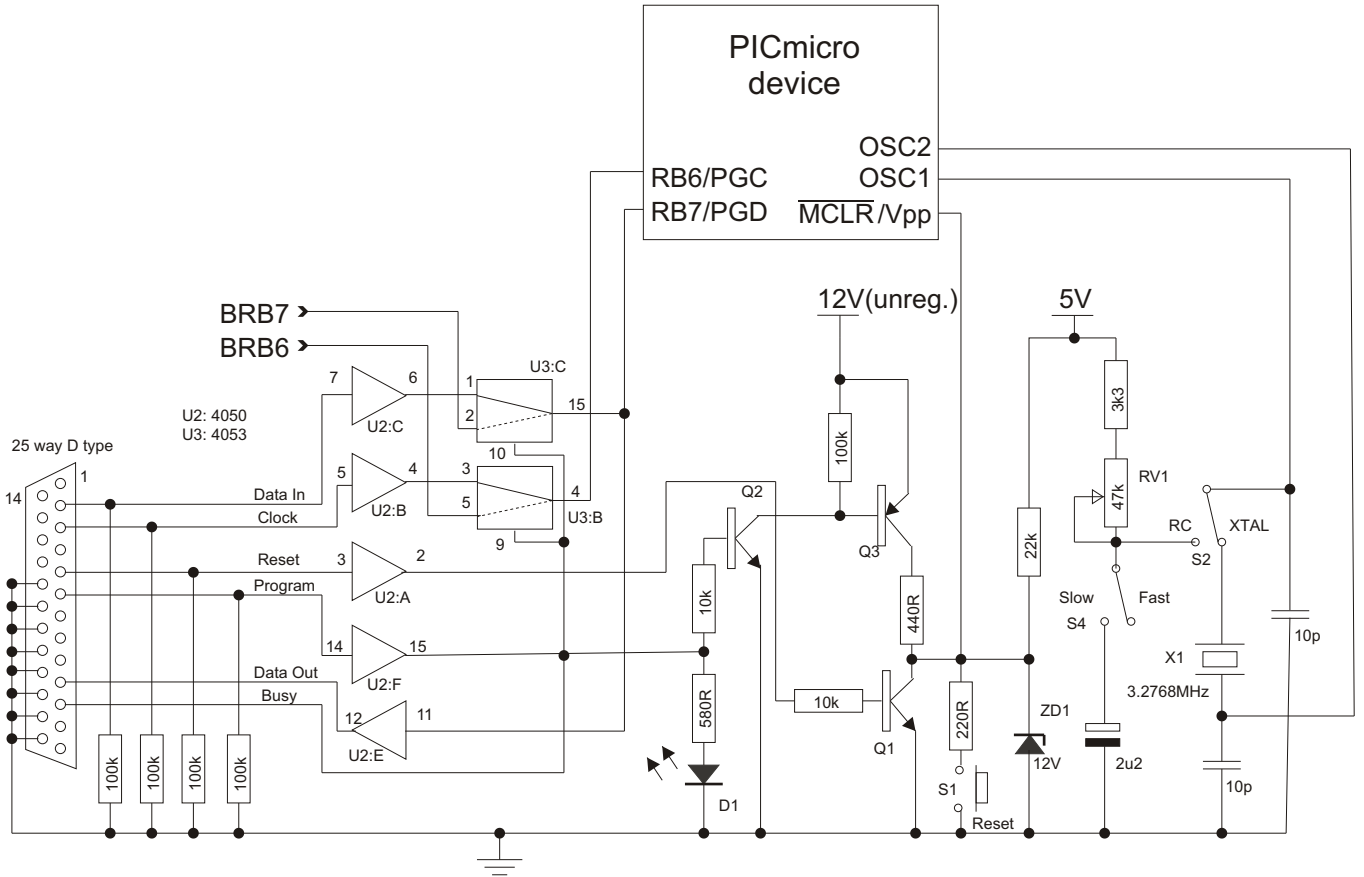
Signals from the PC are buffered, to ensure consistent voltage levels, by U2 - a 4050. The pins RB6 and RB7 are used on the PICmicro device for both programming and reading data and the PC needs direct control of these devices. This is facilitated by the use of two analogue switches U3: C and U3: B which are controlled by the program pin (pin 11) on the parallel port via U2:F. When the program pin is high, data in and clock in are directed to the PICmicro. When the program pin is low then RB6 and RB7 on the PICmicro are routed to the rest of the port B bus (please refer to earlier schematic).

The program pin also ensures that 12V is routed to the PICmicro via the combination of Q2 and Q3 using ZD1 to provide a regulated programming voltage. Automatic reset after programming is provides by the reset line from the parallel port (pin 9) and Q1.

S2 selects between RC oscillation mode and crystal mode. The value of X1 is chosen so that it divides my a multiple of 2 to produce hundredths of a second for accurate timing purposes. When RC mode is selected S4 selects fast or slow operation and RV1 controls the RC constant and hence clock speed within the range dictated by S4.

Please note that this circuit is provided for interest only - there are no user servicable parts on the PICmicro board.

13   External Digital Sensors

Several external digital sensors can be attached to the PICmicro board. The input to the sensor is on A2 and the output from the sensor goes to A4..

Photogate

The photogate has a narrow, infrared beam and fast response time, which provide very accurate signals for timing. When the infrared beam between the source and detector is blocked, the output of the photogate is low, and the light emitting diode (LED) on the photogate goes ON. When the beam is not blocked, the output is high, and the LED is OFF.

Motion Detector

The motion detector emits short bursts of ultrasonic sound waves from the gold foil of the transducer. These waves fill a cone-shaped area about 15° to 20° off the axis of the centre line of the beam. To use this sensor software will need to be written which "listens" for the echo of these ultrasonic waves returning to it. The distance to an object can be determined by measuring how long it takes for the ultrasonic waves to make the trip from the motion detector to an object and back. Using this time, and the speed of sound in air, the distance to the nearest object is determined. Sequential distance readings can be used to detect motion. The motion detector has a range of 0.4m to 6m, the accuracy is within 2mm. The speed of sound in air is 332 m/s.

Sensor product codes

Sensors currently available from Matrix Multimedia are as follows:

Code	Description
HSBAR	Barometer
HSDO	Dissolved oxygen probe
HSEHR	Heart Rate Monitor
HSFLO	Flow rate sensor
HSGPS	Gas Pressure Sensor
HSLS	Light Sensor
HSMD	Motion detector
HSPF	Picket Fence
HSPH	pH Sensor
HSRMB	Respiration Monitor Belt (Requires HSGPS)
HSSPA	Smart pulley attachment
HSTAPE	Bar Tape
HSTMP	Stainless steel temperature probe
HSVPG	Photogate