BiSON Birmingham Solar-Oscillations Network

TECHNICAL REPORT NO. 243

BeebSub #56C — An Improved BBC Computer Substitute

Ian Barnes, Barry Jackson, and Brek A. Miller
The University of Birmingham, Edgbaston, Birmingham B15 2TT

2004 November 3

This technical report series is published by:

THE UNIVERSITY OF BIRMINGHAM

High-Resolution Optical-Spectroscopy Group

School of Physics and Astronomy
The University of Birmingham
Edgbaston, Birmingham B15 2TT, United Kingdom
Telephone: +44-121-414-4551 FAX: +44-121-414-1438

BeebSub #56C — An Improved BBC Computer Substitute

Ian Barnes, Barry Jackson, and Brek A. Miller
The University of Birmingham, Edgbaston, Birmingham B15 2TT

2004 November 3

Abstract

The improved BBC Computer Substitute in Izaña is described.

1 Introduction

In 2003 December, the old BBC computer that was collecting Mark I data from the BBC scalers was replaced with a new PC. The BBC scalers [1] have a 10-ms window in which the data can be read. Although the typical interrupt latency for the Izaña PC is 25 μs, the worst-case latency measured while the system is under a heavy load is 30 ms. This means that if the computer tries to read the data from the scalers itself, it may miss points.

To solve this problem, we have created a BBC Computer Substitute (BeebSub) which reads the data from the scalers in place of the BBC computer. It then forwards the data to the new PC over an RS-232 connection.

Two of these devices were built and sent [2, 3] to Izaña in 2003 December. They are called BeebSub #56A and BeebSub #56B. The first device actually started out as PIC Development System #3 (Picdev #3) [4]. It was used to test the interrupt latency of the PC and was then transformed into BeebSub #56A.

Both of these devices performed well. However, on very rare occasions, the PIC has crashed. This latest version, the BeebSub #56C, incorporates filters and clamps to deal with the electrical problems causing the crashes.

2 Unit Design

2.1 Front Panel

The front panel is shown in Figure 1. This panel contains the main power switch and a number of LEDs. From left to right the BeebSub front panel contains:

- Main power switch.
- A single LED that shows the status of the +5-V DC power supply.
- Three LEDs that indicate which mode the BeebSub is in (Run, Program or Reset).
- Two LEDs that show the status of the clock and data lines when in Program mode. These are not used in Run or Reset modes.
- Fourteen LEDs that show the status of the I/O ports of the PIC microcontroller.
- Four LEDs that show the status of the RS-232 Rx and Tx lines.

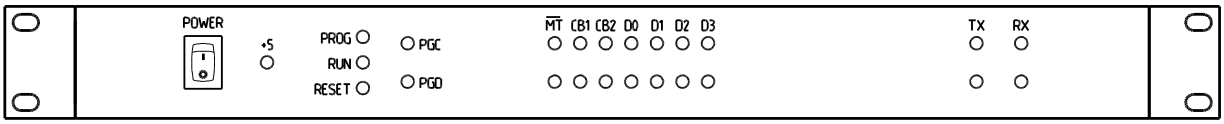


Figure 1: The front panel.

2.2 Rear Panel

The rear-panel of the BeebSub is shown in Figure 2. The rear-panel connectors are summarized in Table 1.

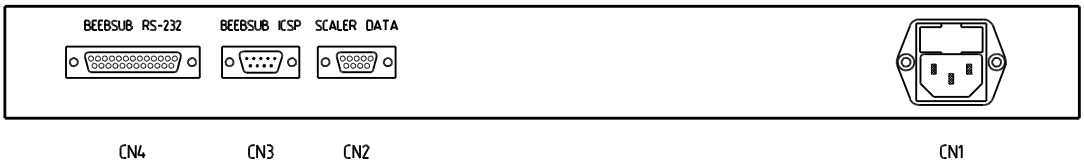


Figure 2: The rear panel.

Table 1: Rear-Panel Connectors

	Connector	*Label*	*Description*
CN4	25-pin female D	BeebSub RS-232	Serial data
CN3	9-pin male D	BeebSub ICSP	In-circuit serial programming
CN2	9-pin female D	Scaler Data	
CN1	male IEC		Mains

2.3 Connections

The pin-outs of some of the connectors situated on the rear of the BeebSub are shown in Tables 2 to 4.

Table 2: RS-232 Connector (CN4)

Pin	*Label*	*I/O*	*Description*
1	CGND		Chassis ground
2	TxD	I	Transmit data
3	RxD	O	Receive data
7	GND		Signal ground

Table 3: ICSP Connector (CN3)

Pin	*Label*	*I/O*	*Description*
1	V_{FLASH}	I	Connects to $\overline{\text{MCLR}}$ on PIC
2	PGC+	I	Programming clock
3	PGD+	I/O	Programming data
4	RD/$\overline{\text{WR}}$+	I	High when PGD should be output
5	CGND	—	Chassis ground
6	DGND	—	Digital ground
7	PGC−	I	
8	PGD−	I/O	
9	RD/$\overline{\text{WR}}$−	I	

Table 4: Scaler Data Connector (CN2)

Pin	*Signal*	*I/O*	*PIC Pin*	*PIC Name*	*Description*
1	$\overline{\text{MT}}$	I	33	RB0/INT	Not empty
2	CB1	I	34	RB1	Next digit is ready
3	CB2	O	35	RB2	Request next digit
4	D0	I	19	RD0/PSP0	Data
5	D1	I	20	RD1/PSP1	Data
6	D2	I	21	RD2/PSP2	Data
7	D3	I	22	RD3/PSP3	Data
8	DGND	—			Digital Ground
9	CGND	—			Chassis Ground

Table 5: Scaler-Data Cable

Station: Izaña.
Cable: 12-wire, 7/0.2-mm, Shielded.
Length: 7 m

Cable Label:	Scaler Data	Scaler Data	
Connects to:	BeebSub	BBC Scalers	
Connects to Label:	Scaler Data	*none*	
Connector:	9-pin male D	14-pin male IEEE-488	
$\overline{\text{MT}}$	1	6	black
CB1	2	12	brown
CB2	3	13	red
D0	4	2	orange
D1	5	3	yellow
D2	6	4	green
D3	7	5	blue
Digital Gnd	8	1	violet
		7	grey
		11	white
Chassis Gnd	9	—	shield

3 System Design

The BeebSub is a 1U rack case which contains a toroidal transformer and five separate PCBs, these are:

PIC PCB	The main board in the BeebSub containing most of the electronics including the PIC microcontroller.
POWER-LED PCB	Shows the status of the +5-V DC supply.
ICSP-LED PCB	Shows which mode the PIC is in and also the state of the Clock and Data lines when in program mode.
IO-LED PCB	Shows the status of each of the I/O lines used on the PIC.
RS-232-LED PCB	Shows the status of the Rx and Tx lines of the RS-232 interface.

All of the PCBs, apart from the PIC board, are mounted on the front panel enabling the user to visually check that the unit is functioning.

3.1 System Wiring Diagram

A wiring diagram of the BeebSub enclosure can be found in Figure 3.

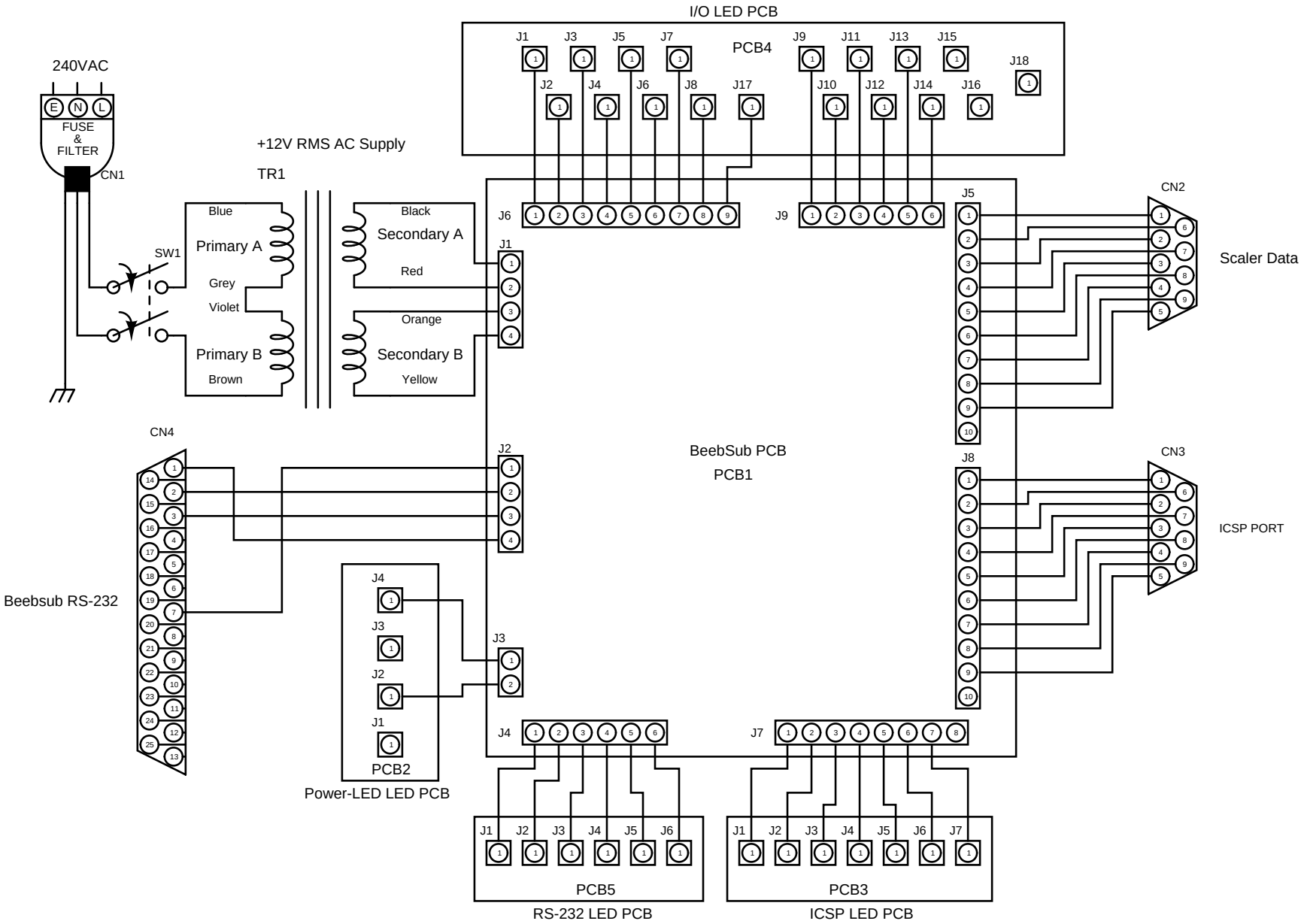


Figure 3: BeebSub System Wiring diagram.

3.2 BeebSub Parts List

The parts list for the BeebSub unit is given in Table 6. Note that the ID field relates to the wiring diagram given in Figure 3.

Table 6: Parts List - BeebSub System

ID	Part Number	Description	Unit Cost*
–	RS 224-234	rack case 1 U × 84 HP × 254 mm	52.57
CN1	FEC 453-705	filtered IEC inlet	16.45
CN2	RS 408-3172	9-pin female IDC D-connector	1.53
CN3	RS 408-3144	9-pin male IDC D-connector	1.53
CN4	Rapid 15-0160	25-pin female D-connector	0.15
SW1	Rapid 75-0330	red visirocker switch	0.53
TR1	Rapid 88-2500	15-VA 6-V 1.25-A toroidal transformer	5.10
J1–J2	Rapid 22-0915	4-way Molex KK crimp housing	0.019
J3	Rapid 22-0905	2-way Molex KK crimp housing	0.01
J4, J9	Rapid 22-0925	6-way Molex KK crimp housing	0.026
J5, J8	Rapid 19-0300	10-way IDC cable-mounted socket	0.10
J6	Rapid 22-2355	9-way Molex KK crimp housing	0.039
J7	Rapid 22-0930	8-way Molex KK crimp housing	0.035
–	Rapid 22-1097	Molex KK crimp terminal (100 pack)	1.70
–	Rapid 33-3525	M3 × 12 hexagonal PCB Spacer (100 pack)	1.90
–	Rapid 33-2950	M3 × 6 Pozidriv countersunk screw (100 pack)	0.95
PCB1	BS-PIC-1	BeebSub PIC PCB Assembly	0.00
PCB2	PWR-LED-2	Power-LED PCB Assembly	0.00
PCB3	ICSP-LED-1	ICSP LED PCB Assembly	0.00
PCB4	IO-LED-1	I/O LED PCB Assembly	0.00
PCB5	232-LED-2	RS232-LED PCB Assembly	0.00

*All prices correct at time of going to press.

4 PIC Board

The PIC Board contains most of the necessary electronics of the BeebSub. The BeebSub is a microprocessor-based system based around a Microchip PIC 16F877 microcontroller. The PIC has the ability to be programmed in-circuit via the ICSP port situated on the back of the unit.

The PIC board also contains a +5-V power supply, RS-232 communications driver, as well as all the electronics to drive the various panel-mounted LEDs.

4.1 Schematic Diagram

There are several drawings that make up the circuit schematic for the PIC Board. They are summarized in Table 7.

Table 7: PIC Board Drawings

Drawing	*Figure*	*Page*
Hierarchical Block Diagram	4	10
+5-V DC Power Supply & Decoupling	5	11
In-Circuit Serial Programming (ICSP)	6	12
PIC Microcontroller & I/O Interface	7	13
I/O LED Drivers	8	14
RS-232 Communications	9	15

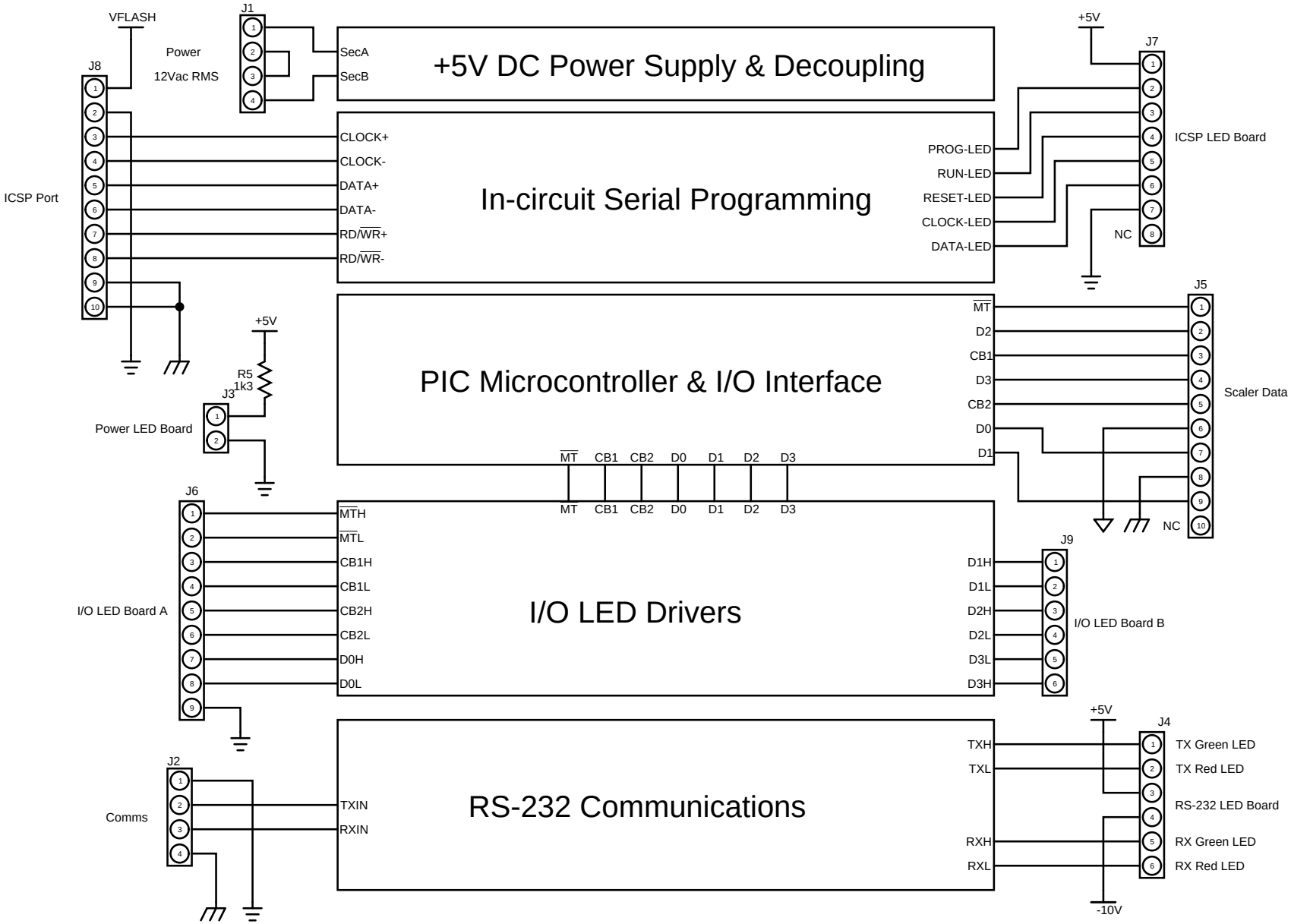


Figure 4: Hierarchical block diagram of the PIC board.

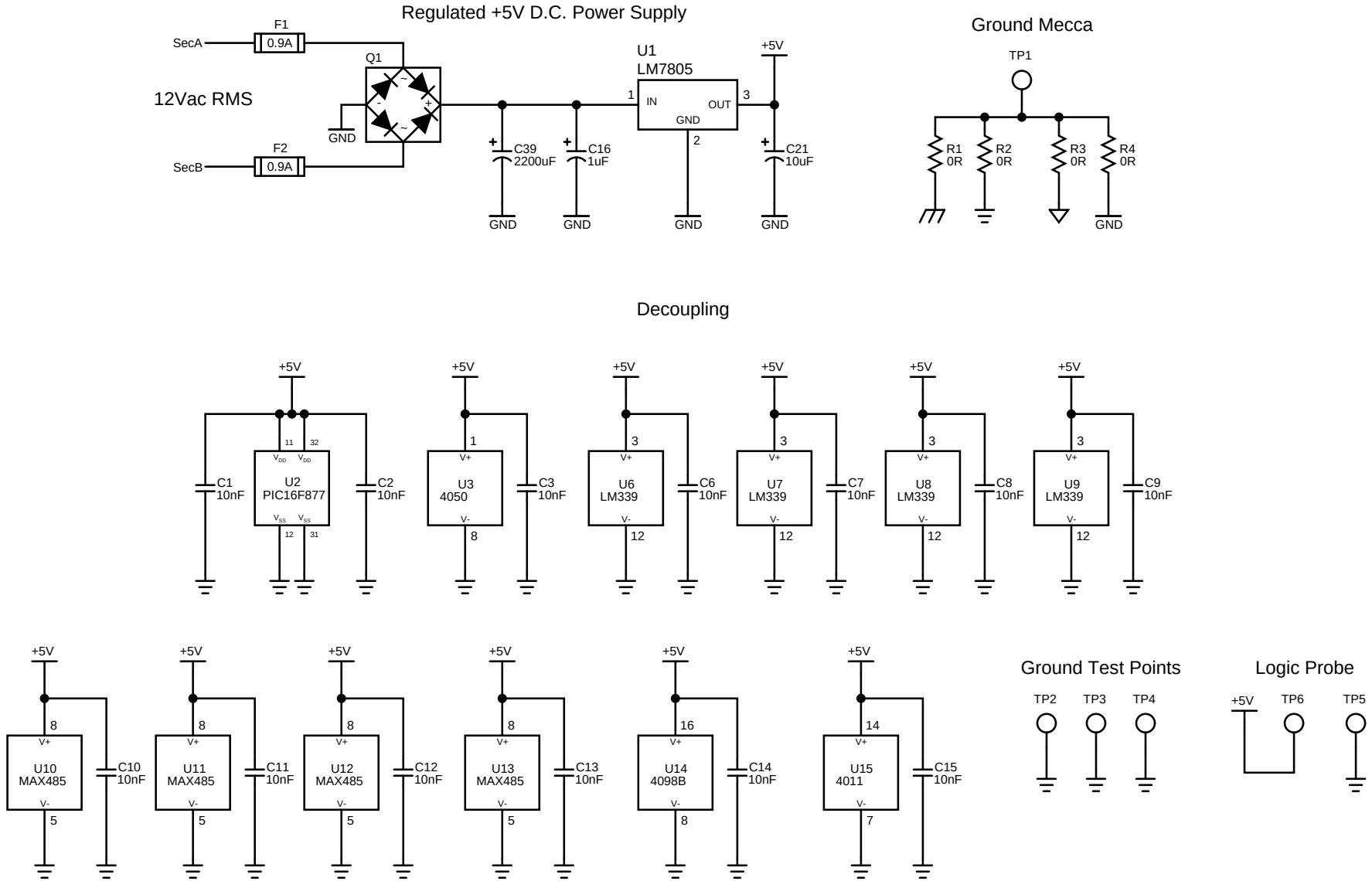


Figure 5: Schematic diagram of the power supply section of the PIC board.

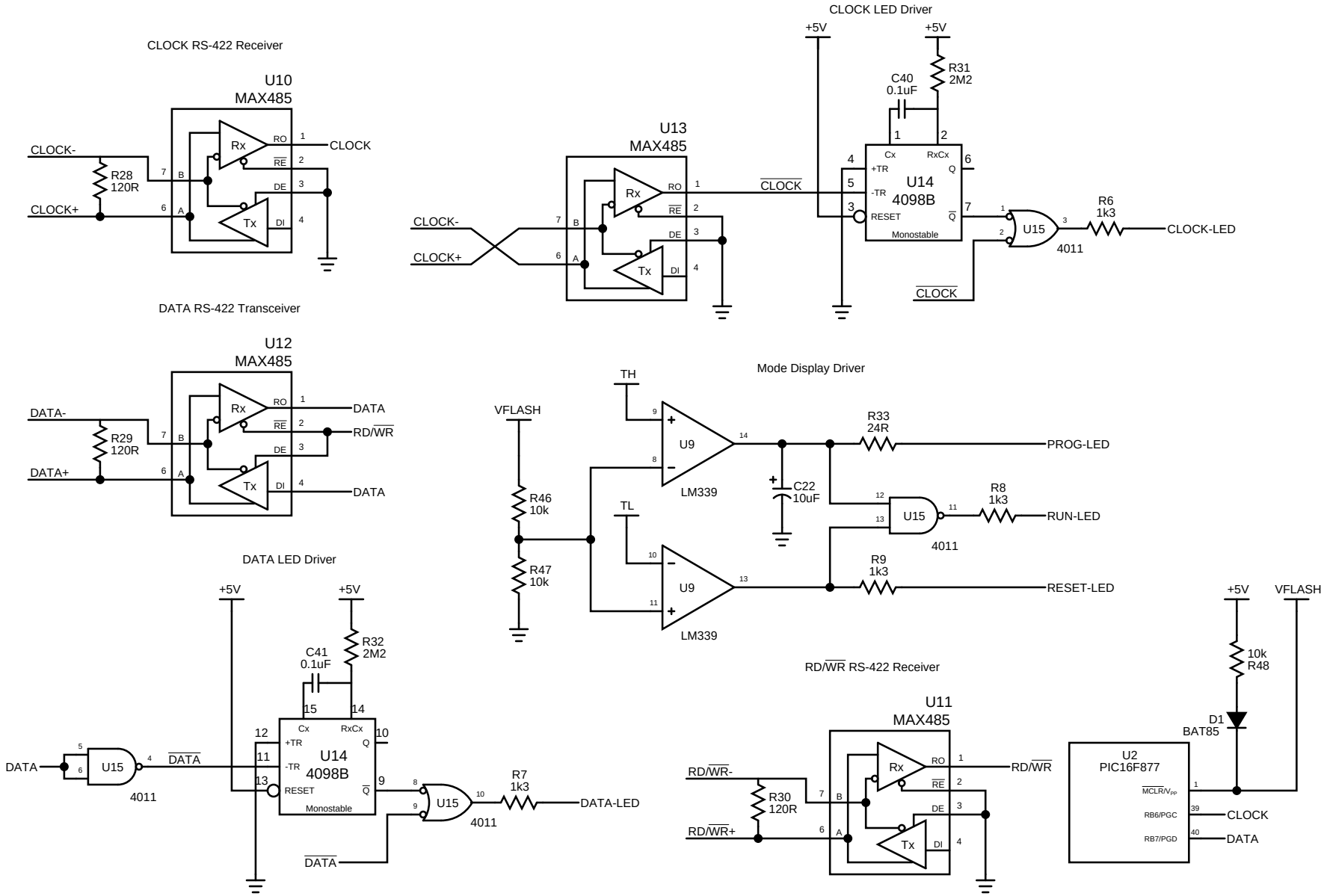


Figure 6: Circuit schematic for the In-Circuit Serial Programming (ICSP) section of the PIC board.

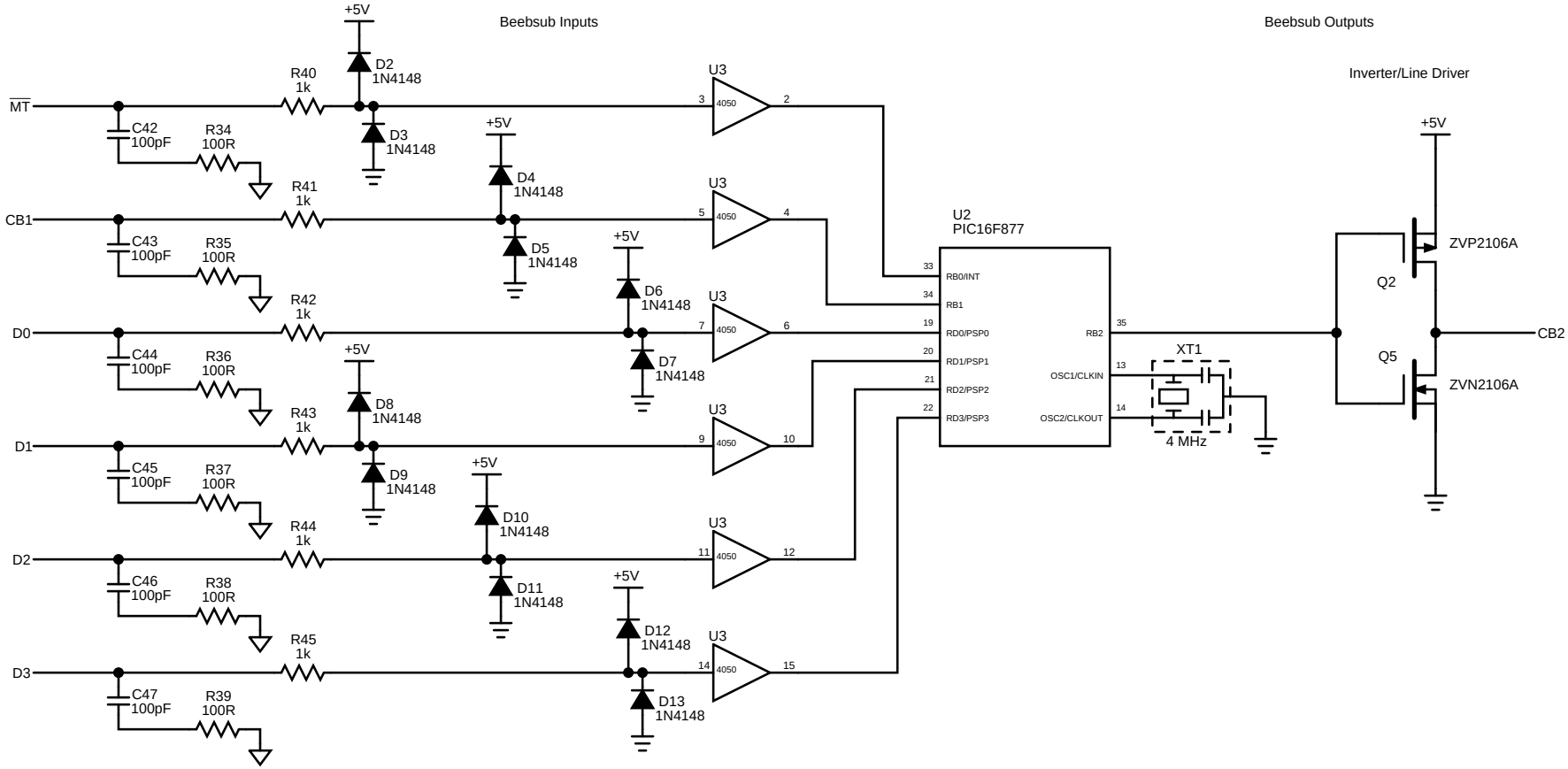


Figure 7: Circuit schematic for the I/O interface section of the PIC board.

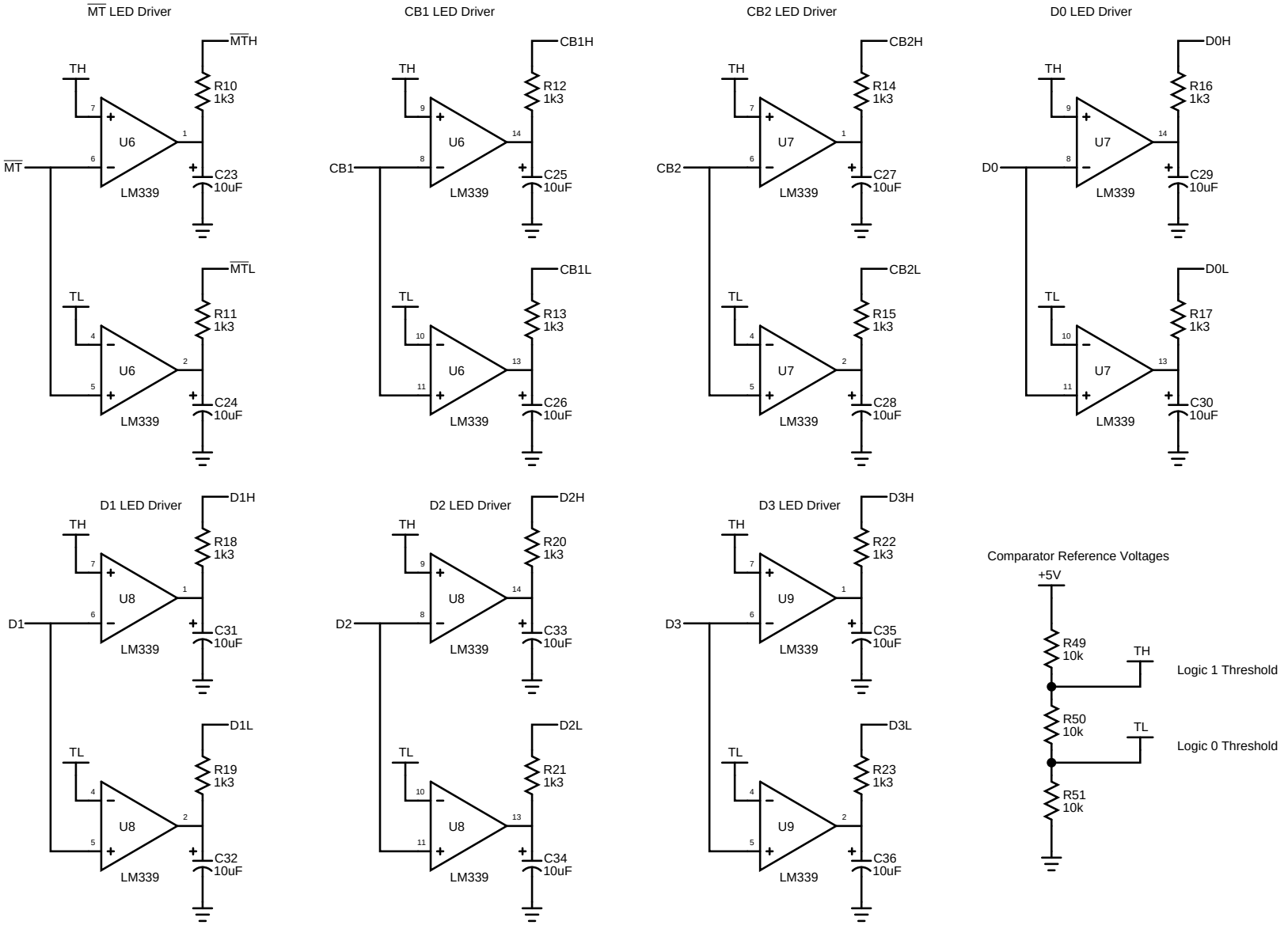


Figure 8: Circuit schematic for the I/O LED drivers section of the PIC board.

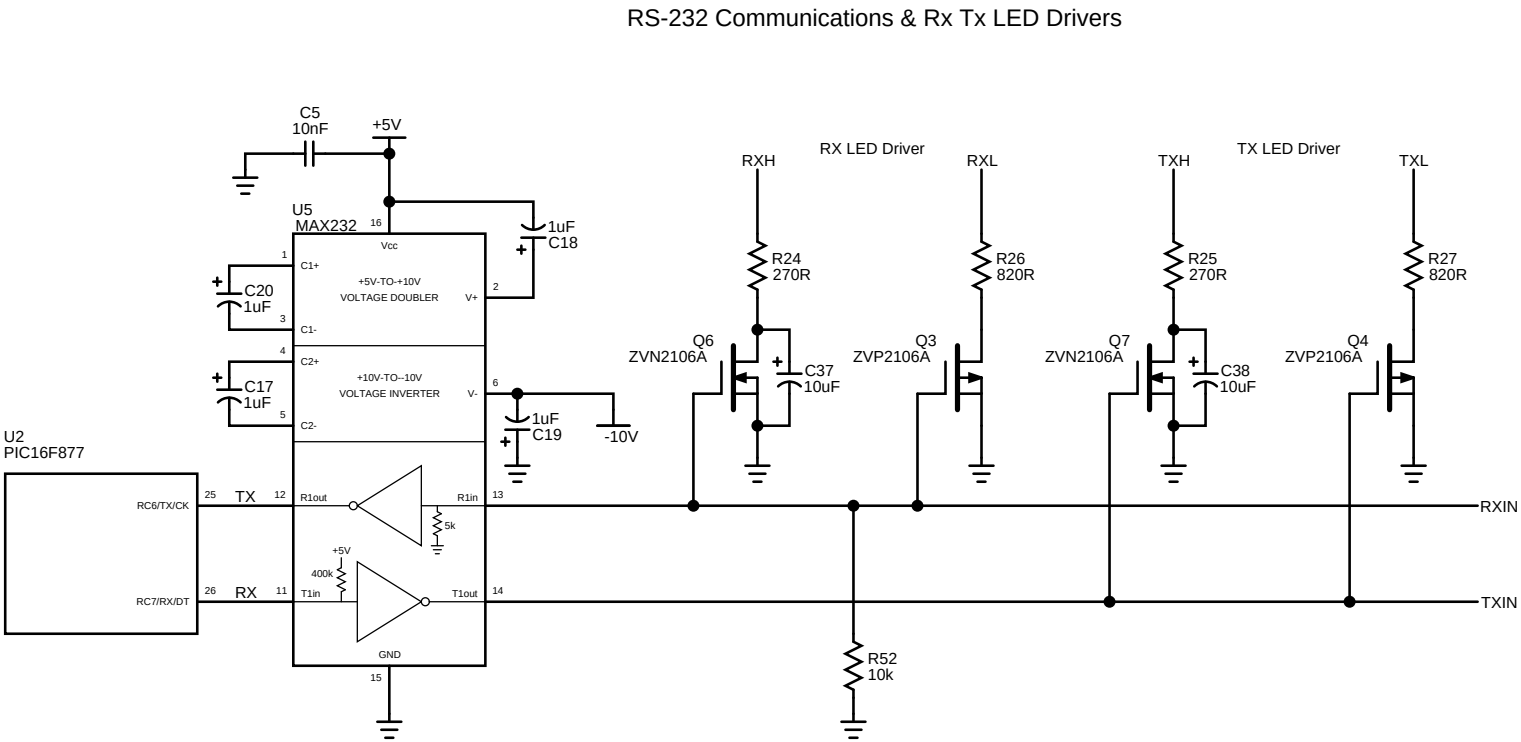


Figure 9: Circuit schematic of the RS-232 section of the PIC Board.

4.2 PCB Layout

The PIC PCB is a double-sided PCB.Due to the PCB being double-sided and the amount of holes and vias on this PCB, it will be manufactured by an outside contractor.

The component-side layout is given in Figure 10. The solder-side layout is given in Figure 11.

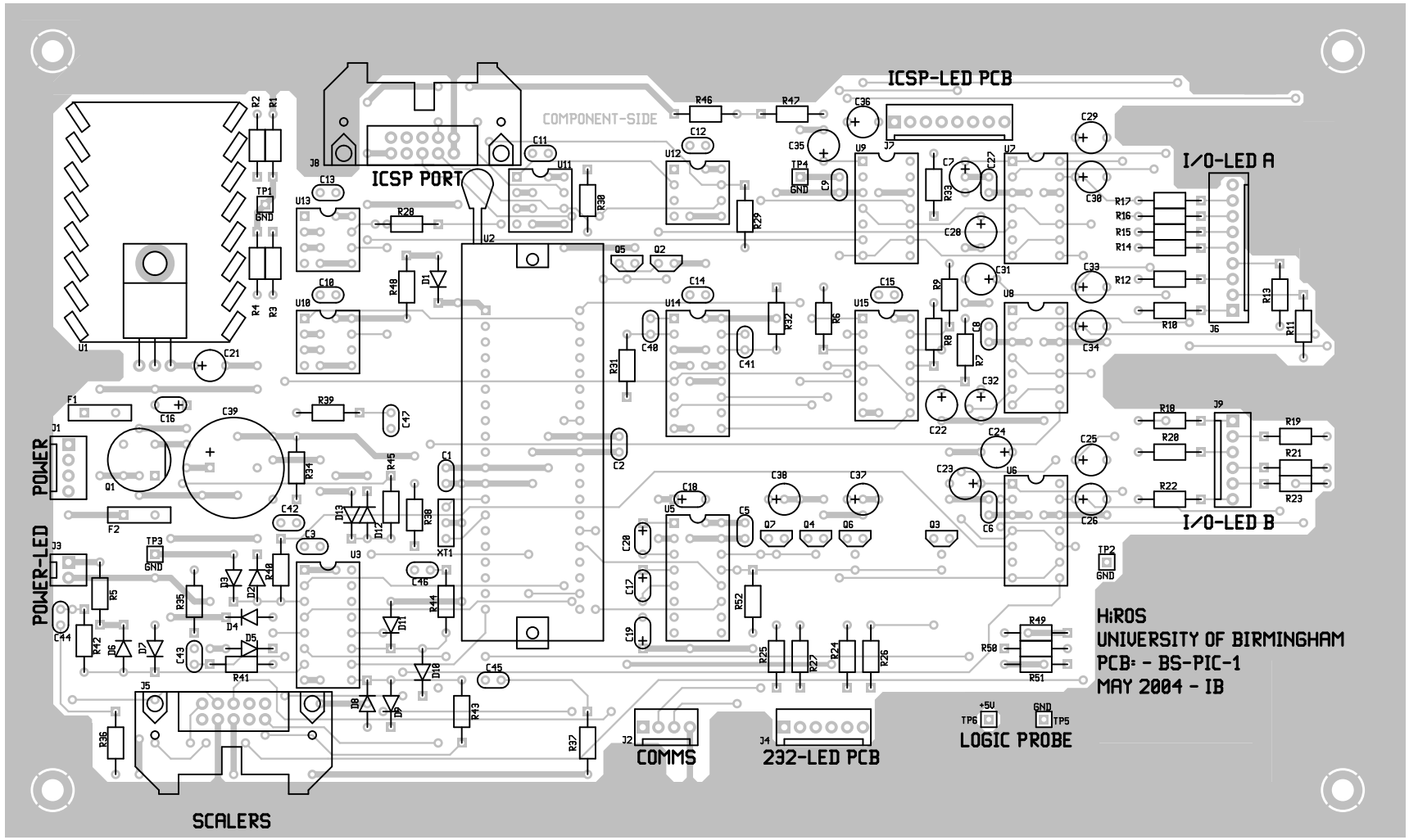


Figure 10: PIC Board component silkscreen & component-side tracks.

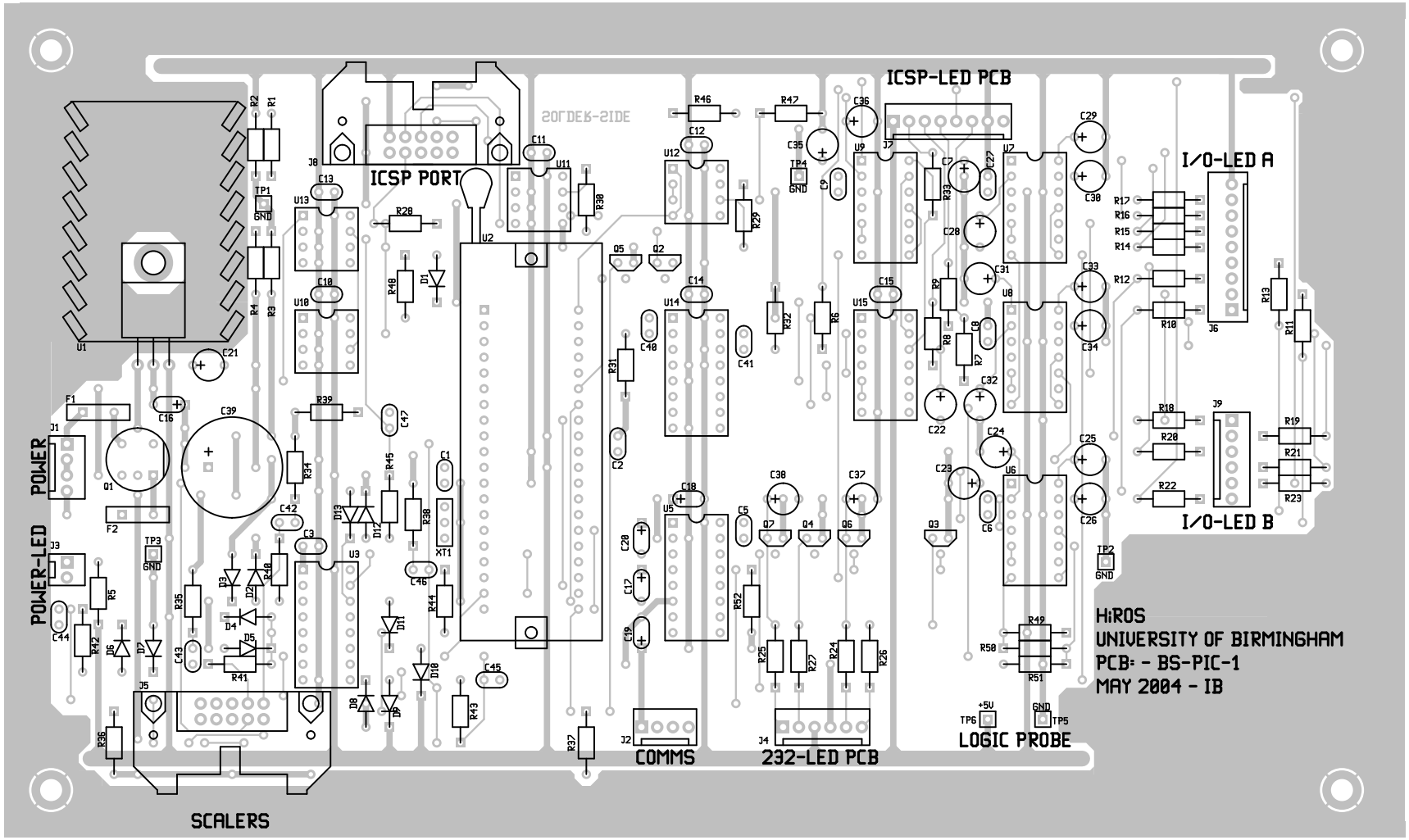


Figure 11: PIC Board component silkscreen & solder-side tracks.

4.3 PIC PCB Parts List

4.3.1 Resistors

Table 8: Parts List - Resistors

ID	Part Number	Description	Unit Cost*
R1–R4	FEC 508-792	0 Ω link MCF series	0.010
R5–R23	FEC 543-410	1.3 kΩ 0.25 W 1%MF25 series	0.047
R24–R25	FEC 543-240	270 Ω 0.25 W 1% MF25 series	0.047
R26–R27	FEC 543-866	820 Ω 0.25 W 1% MF25 series	0.047
R28–R30	FEC 543-160	120 Ω 0.25 W 1% MF25 series	0.047
R31–R32	FEC 336-749	2.2 MΩ 0.6W 1% MRS25 series	0.040
R33	FEC 542-994	24 Ω 0.25 W 1% MF25 series	0.047
R34–R39	FEC 543-147	100 Ω 0.25 W 1% MF25 series	0.047
R40–R45	FEC 453-380	1 kΩ 0.25 W 1% MF25 series	0.047
R46–R52	FEC 543-627	10 kΩ 0.25 W 1% MF25 series	0.047

*All prices correct at time of going to press.

4.3.2 Capacitors

Table 9: Parts List - Capacitors

ID	Part Number	Description	Unit Cost*
C1–C3 C5–C15	Rapid 08-1000	10 nF 100 V ceramic	0.036
C16–20	Rapid 11-0688	1 μF 35 V tantalum	0.12
C21–C38	Rapid 11-0698	10 μF 35 V tantalum	0.34
C39	Rapid 11-0765	2200 μF 35 V radial electrolytic	0.28
C40-C41	Rapid 08-1015	0.1 μF 100 V ceramic	0.049
C42–C47	Rapid 08-0940	100 pF 25 V ceramic	0.01

*All prices correct at time of going to press.

4.3.3 Semiconductors

Table 10: Parts List - Semiconductors

ID	Part Number	Description	Unit Cost*
U1	Rapid 47-3290	LM7805 +5-V 1-A voltage regulator	0.145
U2	Rapid 73-3202	PIC16F877-04P microcontroller	3.90
U3	Rapid 83-0382	4050 hex non-inverting buffer	0.13
U5	Rapid 82-0148	MAX232CPE RS-232 line driver	1.18
U6–U9	Rapid 82-0242	LM339 quad comparator	0.09
U10–U13	Rapid 82-0308	MAX485CPA RS-485/RS-422 transceiver	1.62
U14	Rapid 83-0426	4098B dual monostable	0.40
U15	Rapid 83-0328	4011 quad dual-I/P NAND	0.20
Q1	RS 659-832	1.5-A 400-V bridge rectifier	0.33
Q5–Q7	Rapid 47-0156	ZVN2106A n-channel MOSFET	0.22
Q2–Q4	Rapid 47-0174	ZVP2106A p-channel MOSFET	0.29
D1	Rapid 47-3108	BAT85 Schottky diode	0.045
D2–D13	Rapid 47-3308	1N4148 small-signal diode	0.006

*All prices correct at time of going to press.

4.3.4 Miscellaneous

Table 11: Parts List - Miscellaneous

ID	Part Number	Description	Unit Cost*
J1–J2	Rapid 22-0915	4-pin Molex KK vertical header	0.042
J3	Rapid 22-0955	2-pin Molex KK vertical header	0.022
J4, J9	Rapid 22-0970	6-pin Molex KK vertical header	0.062
J6	Rapid 22-2395	9-pin Molex KK vertical header	0.095
J7	Rapid 22-0975	8-pin Molex KK vertical header	0.085
J5, J8	Rapid 19-0200	10-way right-angled IDC connector	0.185
TP1–TP5	Rapid 17-1810	black test terminal (100 pack)	7.50
TP6	Rapid 17-1819	yellow test terminal (100 pack)	7.50
XT1	Rapid 90-0625	4-MHz ceramic resonator	0.19
F1–F2	Rapid 26-4614	0.9-A resettable fuse	0.26
–	Rapid 22-1580	40-pin ZIF IC socket	8.27
–	Rapid 22-0400	8-pin turned-pin IC socket	0.078
–	Rapid 22-0405	14-pin turned-pin IC socket	0.132
–	Rapid 22-0410	16-pin turned-pin IC socket	0.145
–	Rapid 36-0250	TO-220 heatsink	0.38
–	Rapid 36-0480	TO-3P SP2000 thermal pad (10 pack)	5.50
–	Rapid 33-4210	M3 × 6 panhead bolt (100 pack)	1.80
–	Rapid 33-4305	M3 nut (100 pack)	1.50

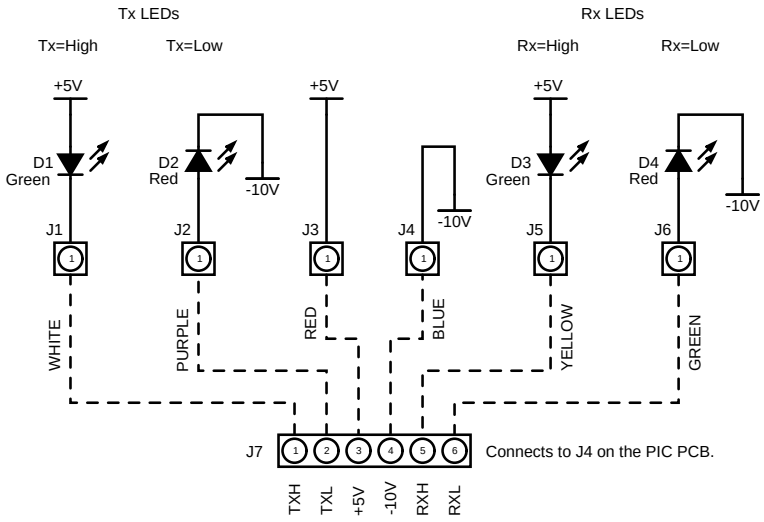
*All prices correct at time of going to press.

5 RS-232 LED Board

The RS-232 LED Board is mounted on the front panel of the case. It contains four LEDs that display the state of the RS-232 lines. A green LED indicates that the line is high whilst a red LED signifies that the line is low. Should the cable accidentally become disconnected then none of the LEDs will be illuminated. The status of the TX line is on the left whilst the RX line is on the right.

5.1 Circuit Schematic

The schematic diagram for the RS-232 LED board is shown in Figure 12.



NOTES:

1. Dashed lines indicate a wire connection to an off-board component rather than a PCB track.
2. D1-D4 are mounted on 7.6mm LED spacers.
3. J1-J6 are pads on the PCB with strain-relief holes for soldered wire connections.
4. J7 is a Molex KK crimp housing connected to J1-J6 using 8-core screened cable (screen not used) soldered to the PCB.

Figure 12: Schematic Diagram for the RS-232 LED Board.

5.2 PCB Layout

The component layout and solder-side tracks are shown in Figure 13. The board is single-sided and is made in-house, therefore there will not be a silkscreen on the finished board. For further details on how to manufacture PCBs using the etch tanks consult the document BTR-208.

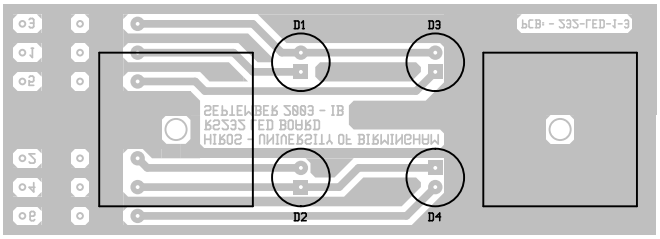


Figure 13: RS-232 LED Board component layout and solder-side tracks.

5.3 RS-232 LED Board Parts List

All of the components that are required to manufacture the RS-232 LED Board are given in Table 12.

Table 12: Parts List - RS-232 LED Board

ID	Part Number	Description	Unit Cost*
–	232-LED-2	RS-232 LED PCB	0.00
D1, D3	Rapid 56-0435	green low-current 5-mm LED	0.038
D2, D4	Rapid 56-0430	red low-current 5-mm LED	0.049
J7	Rapid 22-0925	6-way Molex KK crimp housing	0.026
–	Rapid 22-1097	Molex KK crimp terminal (100 pack)	1.70
D1–D4	Rapid 38-0770	7.6-mm 5-mm-LED spacer (25 pack)	2.00
–	Rapid 33-2135	9.5-mm self-adhesive PCB pillar (25 pack)	1.87

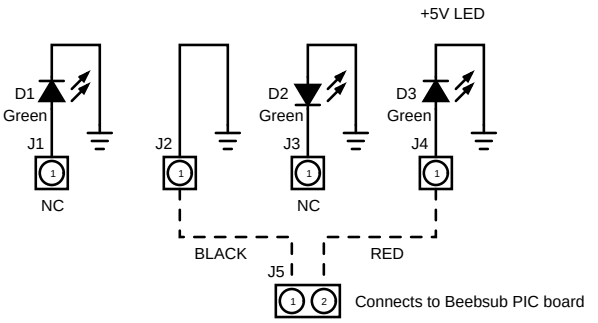
*All prices correct at time of going to press.

6 Power LED Board

The Power LED Board contains a single front-panel-mounted LED which is illuminated when the +5-V DC power supply is present.

6.1 Circuit Schematic Diagram

The schematic diagram for the Power LED board is shown in Figure 14.



NOTES

1. All Dashed lines indicate a wire connection to an off-board component rather than a PCB track.
2. J1-J4 are pads on the PCB with strain-relief holes for soldered wire connections.
3. J5 is a Molex KK crimp housing connected to J2,J4 using 7/0.2 cable twisted together.
4. For the Beebsub de-populate D1-D2.
5. D3 is mounted on a 7.6mm LED spacer.

Figure 14: Schematic Diagram for the Power LED Board.

6.2 PCB Layout

The component layout and solder-side tracks are shown in Figure 15. The board is single-sided and is made in-house, therefore there will not be a silkscreen on the finished board. For further details on how to manufacture PCBs using the etch tanks consult the document BTR-208.

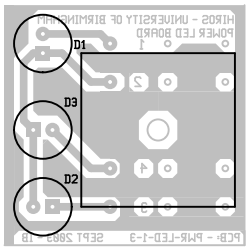


Figure 15: Power LED Board component layout and solder-side tracks.

6.3 Power LED Board Parts List

Table 13: Parts List - Power LED Board

ID	Part Number	Description	Unit Cost*
–	PWR-LED-1	Power LED PCB	0.00
D1–D3	Rapid 56-0435	5-mm green low-current LED	0.038
J5	Rapid 22-0905	2-way Molex KK crimp housing	0.01
–	Rapid 22-1097	Molex KK crimp terminal (100 pack)	1.70
–	Rapid 38-0770	7.6-mm 5-mm-LED spacer (25 pack)	2.00
–	Rapid 33-2135	9.5-mm self-adhesive PCB pillar (25 pack)	1.87

*All prices correct at time of going to press.

7 ICSP LED Board

The ICSP LED Board is mounted on the front panel of the case. It contains five LEDs that display the mode that the PIC of the BeebSub is currently in, and also the state of the clock and data lines when in programming mode.

On the left there are three LEDs that indicate the mode that the BeebSub is currently operating in. These different modes are summarized in Table 14.

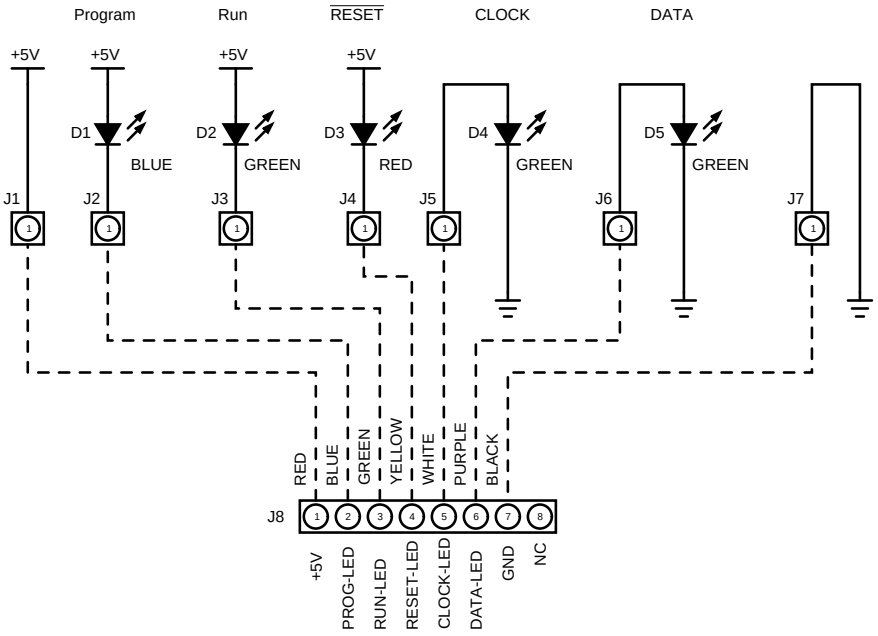
Table 14: BeebSub Modes

LED Colour	*System Mode*	*Description*
Blue	Program	The system firmware is being updated
Green	RunD	System is running normally
Red	Reset	System is doing a hardware reset

During Program Mode two green LEDs to the right of the mode LEDs illuminate when the clock or data lines are high. These LEDs are not used in Run or Reset mode.

7.1 Circuit Schematic Diagram

The schematic diagram for the ICSP LED board is shown in Figure 16.



NOTES

1. All dashed lines indicate a wire connection rather than a PCB Track.
2. D1-D5 are mounted on 7.6mm LED spacers.
3. J1-J7 are pads on the PCB with strain-relief holes for soldered wire connections.
4. J8 is a Molex KK crimp housing connected to J1-J7 using 8-core screened cable (screen not used) soldered to the PCB.
5. J8 is to be fully loaded with crimp terminals.

Figure 16: Schematic Diagram for the ICSP LED Board.

7.2 PCB Layout

The solder-side tracks and the component layout are shown in Figure 17. The board is single-sided and is made in-house, therefore there will not be a silkscreen on the finished board. For further details on how to manufacture PCBs using the etch tanks consult the document BTR-208.

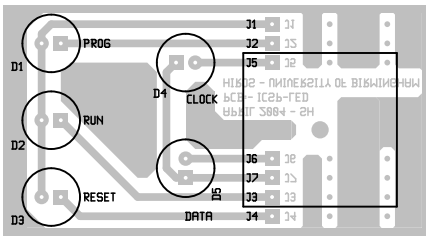


Figure 17: ICSP LED Board component layout and solder-side tracks.

7.3 ICSP LED Board Parts List

All of the components that are required to manufacture the ICSP LED Board are given in Table 15.

Table 15: Parts List - ICSP LED Board

ID	Part Number	Description	Unit Cost*
–	ICSP-LED-1	ICSP LED PCB	0.00
D1	Rapid 55-1810	5-mm blue LED	0.215
D3	Rapid 56-0430	5-mm red low-current LED	0.049
D2, D4–D5	Rapid 56-0435	5-mm green low-current LED	0.038
J8	Rapid 22-0930	8-way Molex KK crimp housing	0.035
D1–D5	Rapid 38-0770	7.6-mm 5-mm-LED spacer (25 pack)	2.00
–	Rapid 22-1097	Molex KK crimp terminal (100 pack)	1.70
–	Rapid 33-2135	9.5-mm self-adhesive PCB pillar (25 pack)	1.87

*All prices correct at time of going to press.

8 IO-LED Board

The IO-LED board contains red and green LEDs to indicate the status of the system I/O lines. A green LED indicates that the corresponding line is high whilst red indicates that it is low.

8.1 Circuit Schematic Diagram

The schematic diagram for the IO-LED board is given in Figure 18

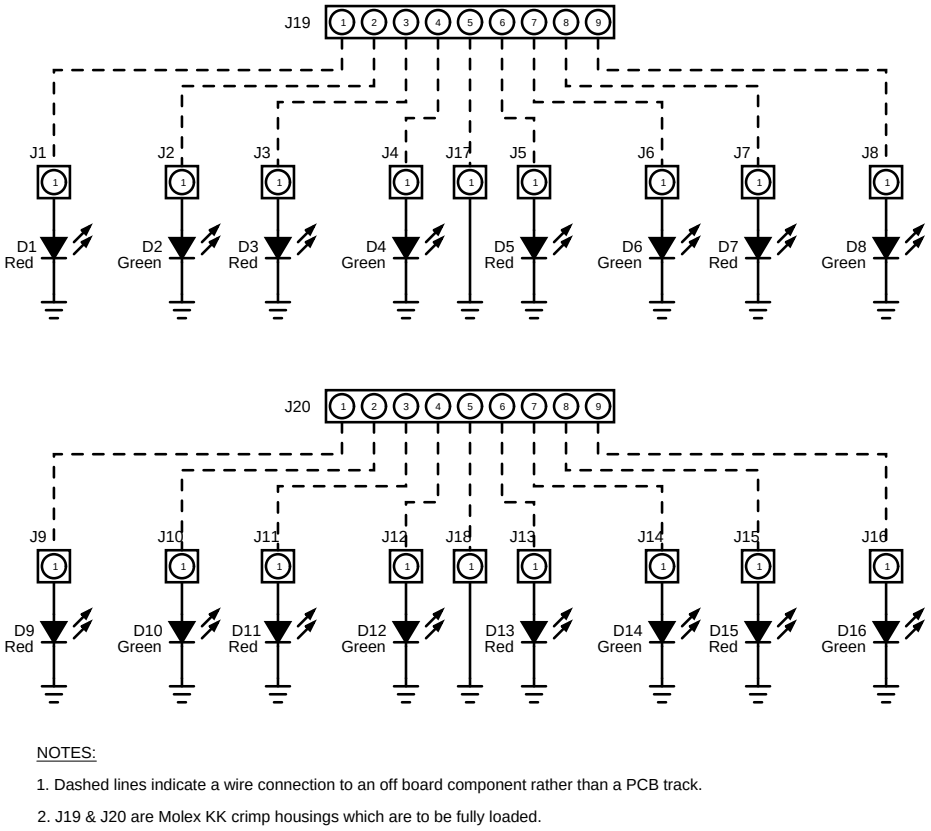


Figure 18: Schematic Diagram for the IO-LED Board.

8.2 PCB Layout

The IO-LED board is a single-sided PCB and therefore can be made in-house or by an outside contractor. For further details on how to manufacture boards using the in-house etch-tanks consult BTR-208. The silkscreen and solder-side tracks are given in Figure 19.

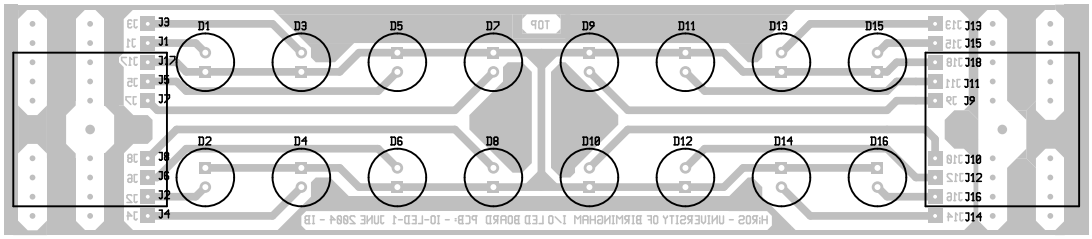


Figure 19: IO-LED Board component layout and solder-side tracks.

9 Blunders

During the testing of the BeebSub it was discovered that some blunders had been accidentally made in the design phase of the project. This section describes the errors that were found and the action taken in order to make the system function as intended.

9.1 Blunders on the PIC Board

A couple of errors were found on the PIC board.

- The pin-out of Q1 was found to be incorrect.
- There was a problem with the RS-232 communications. This was traced to an error on the schematic. The RX and TX lines between the PIC (U2) and the MAX232 (U5) were in fact swapped over and hence connected to the wrong pins. The correct connection between the PIC and the MAX232 is U2-25 connects to U5-11 and U2-26 connects to U5-12.

9.2 Modifications to the PIC Board

The following modifications to the PIC board are required to fix the errors that were found.

- Q1 should be rotated anti-clockwise by 90°, compared with the silkscreen that is on the board. This means that the flat edge of the rectifier should be facing towards the voltage regulator.
- On the component-side of the PCB cut the track that links U2 pin 25 to U5 pin 12 (the track passes in between C17 and C20).
- On the solder-side of the PCB cut the track to the via that is adjacent to U2 pin 26 (track runs between two vias adjacent to pins 21 and 26 of U2).
- On the solder-side of the PCB solder a wire link to connect U2 pin 25 to U5 pin 11.
- On the solder-side of the PCB solder a wire link to connect U2 pin 26 to U5 pin 12.
- Remove TP6 and solder a length of red 7/0.2 cable to the board (this is required to fix a blunder on the IO-LED board - see next section for details).

9.3 Blunders on the IO-LED Board

There was only one blunder on the IO-LED board but it affected all of the red LEDs on the Board. All of the LEDs are driven by logic from the PIC board. The mistake that was made was that on the IO-LED board both red and green LEDs used the same circuitry which they should not have done. The green LEDs have the cathodes tied to GND and +5V supplied to the anode via the LED driver circuit on the PIC board. For the red LEDs the anodes should have been tied to +5V and the cathodes driven by the LED driver on the PIC board sinking current to light the LED.

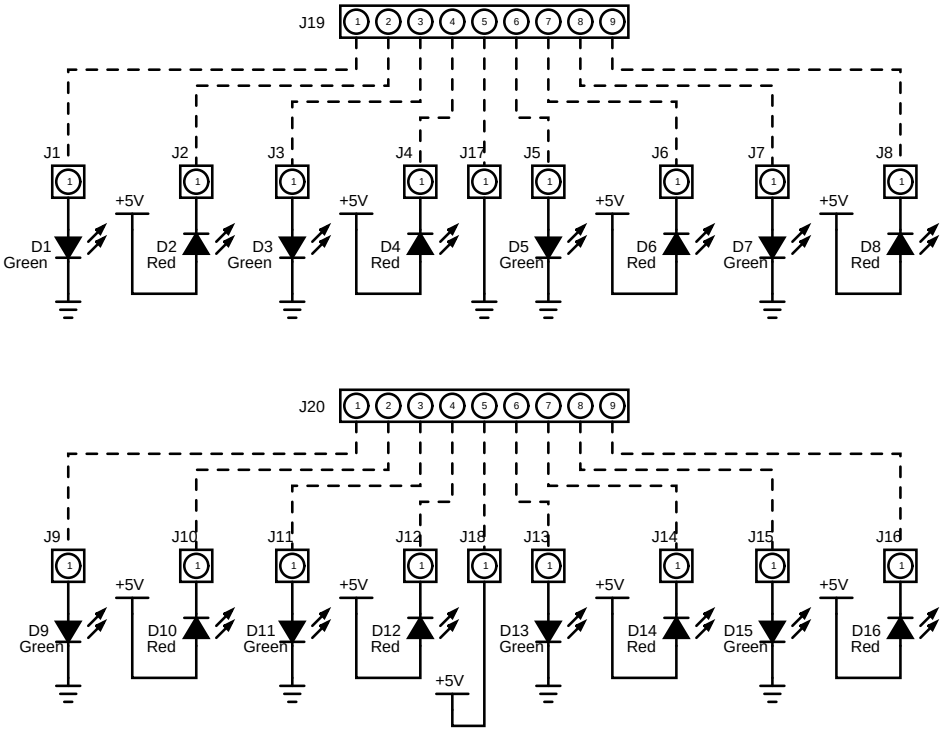
9.4 Modifications to the IO-LED Board

The following modifications to the IO-LED board are required in order to make the red LEDs work as intended.

- Reverse all red LEDs (D2, D4, D6, D8, D10, D12 and D14).
- Cut the track between D13 pin 1 and D15 pin 1.
- Cut the GND track in the centre of the board that links the two GND rails together.
- On the component-side fit a 0Ω resistor between D15 pin 1 and D16 pin 1.
- Connect a red 7/0.2 wire from TP6 on the PIC board to J18 pin 1 (this wire provides the +5-V feed to the red LEDs).

9.5 Schematic Diagram of the Modified IO-LED Board

Figure 20 shows the schematic diagram of the modified IO-LED board.



NOTES:

1. Dashed lines indicate a wire connection to an off board component rather than a PCB track.
2. J19 & J20 are Molex KK crimp housings which are to be fully loaded.
3. De-populate D15-D16.

Figure 20: Schematic Diagram for the Modified IO-LED Board.

10 RS-232 Interface

The BeebSub communicates with the computer through an RS-232 connection. The connector for this link is at the far left on the rear panel. It is a 25-pin, female D-connector. The only pins used in this connector are: 1 (chassis ground), 2 (transmit data, TxD), 3 (receive data, RxD), and 7 (signal ground). The BeebSub is configured as data communications equipment (DCE) and transmits on pin 3 and receives on pin 2. The RS-232 settings are 9600 baud, 8 bits, no parity. No handshaking (hardware nor software) is provided.

Four LEDs on the front panel show the state of the TxD and RxD lines. The left column is for the TxD line and the right column is for the RxD line. The red LEDs on the bottom are illuminated when the corresponding line is low. The green LEDs on the top are illuminated when the line is high.

The BeebSub communicates with the computer using one-line messages. Each message begins with a dollar sign ("$", ASCII 36) and ends with a carriage-return/line-feed pair. The BeebSub will send an asterisk ("*", ASCII 42) followed by a two-character checksum at the end of each message.

The checksum is calculated by XORing the ASCII values of all of the characters in the message that follow the dollar and precede the asterisk. The dollar and asterisk are not included in the checksum calculation. The resulting checksum is included in the message as a two-characters hexadecimal value.

The following messages are sent from the BeebSub to the computer.

10.1 Counter Data

`$C,<DIGIT-STRING>,<OVERFLOW>*<CK><CR><LF>`

`<DIGIT-STRING>` The string of hex digits read from the BBC scalers.

`<OVERFLOW>` Zero ("0", ASCII 48) if all of the digits read from the BBC scalers are present in this message, or one ("1", ASCII 49) if the BBC scalers returned more digits than would fit in this message. The BeebSub can buffer only 96 digits.

The BeebSub will send one counter-data message every time the BBC scalers raise the $\overline{\text{MT}}$ line.

10.2 Error Message

$E,<*ERROR-CODE*>,<*DESCRIPTION*>*<*CK*><*CR*><*LF*>

<*ERROR-CODE*> A numeric error code.

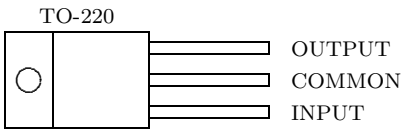
<*DESCRIPTION*> A description of the error in text form for humans to read.

The BeebSub can send these two error messages:

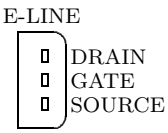
```
$E,01,!MT stuck low*72
$E,02,!MT stuck high*0B
```

A Component Pin-Outs

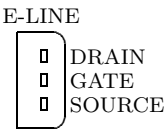
The pin-outs of some of the components is shown in Figures 21 to 22.



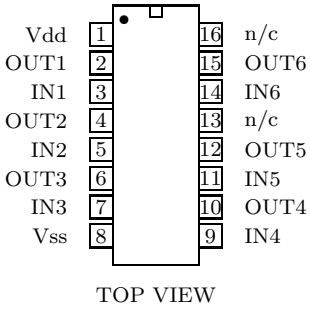
(a) LM7805



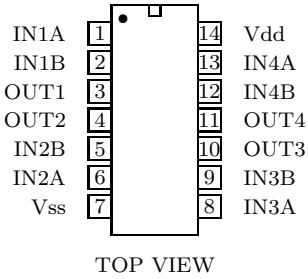
(b) ZVN2106A



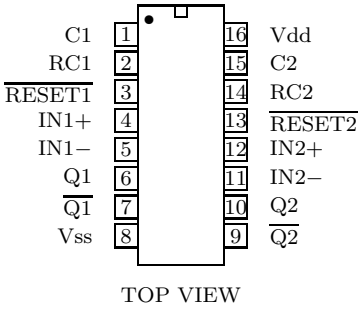
(c) ZVP2106A



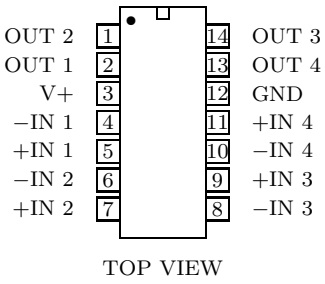
(d) 4050



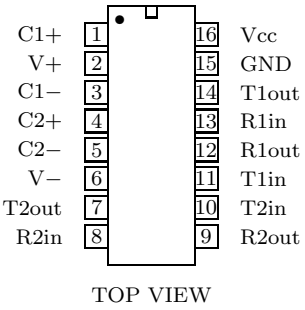
(e) 4011



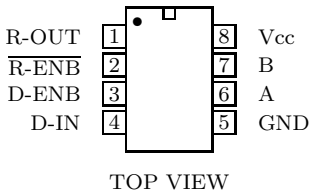
(f) 4098



(g) LM339

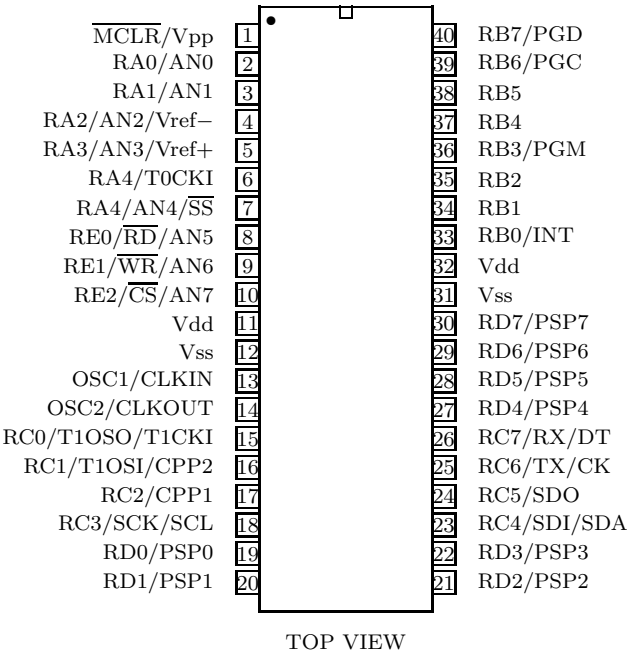


(h) MAX232



(i) MAX485

Figure 21: Pin-outs of various components.



(a) PIC 16F877

Figure 22: Pin-outs of various components.

References

[1] Clive P. McLeod. Mark I scaler system. *BISON Technical Report Series,* Number 184, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, July 2002.

[2] Ian Barnes, Barry Jackson, and Brek A. Miller. BeebSub #56A and BeebSub #56B — BBC computer substitutes. *BISON Technical Report Series,* Number 218, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, November 2003.

[3] George R. Isaak and Brek A. Miller. The grand opening of the Izaña Zoo in 2003 December. *BISON Technical Report Series,* Number 222, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, March 2004.

[4] Ian Barnes, Barry Jackson, and Brek A. Miller. Picdev #3 — A PIC development system. *BISON Technical Report Series,* Number 217, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, November 2003.

[5] Ian Barnes. In-house PCB manufacture using PCB etch tanks. *BISON Technical Report Series,* Number 208, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, September 2003.