**Type 2 Liverpool Ringing Simulator**

07 – Multi-PC Guide

A circuit board

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# Document History

|  |  |  |  |
| --- | --- | --- | --- |
| **Version** | **Author** | **Date** | **Changes** |
| 1.0 | A J Instone-Cowie | 01/10/2019 | First Release. |
| 1.1 | A J Instone-Cowie | 18/08/2020 | Minor update. |
| 1.2 | A J Instone-Cowie | 27/08/2021 | Alternative DB9 enclosure drilling option, DB9 part. |
| 1.3 | A J Instone-Cowie | 19/06/2024 | Update external links. |
| 1.4 | A J Instone-Cowie | 26/06/2024 | Updated Farnell/Screwfix part numbers. |
| 1.5 | A J Instone-Cowie | 28/08/2024 | Improve diagrams following feedback, add module configurations table. |
| 1.6 | A J Instone-Cowie | 07/05/2025 | Eagle to KiCad PCB design tool migration. Updated schematics and board layouts. |

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*Cover photograph: A completed Type 2 Basic Serial Splitter PCB.*

*PC ports vector graphic design by <https://www.vecteezy.com>  
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# Licence

**

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# Documentation Map

A screenshot of a cell phone

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Figure 1 – Documentation Map

# About This Guide

This guide contains information on building modules which allow multiple PCs to be used concurrently with the Type 2 Liverpool Ringing Simulator:

* Second PC module
* Basic Serial Splitter module

If you are planning to use multiple PCs, it is strongly recommended that you complete and test the core Simulator modules first (Power, Interface, Sensors), as described in the ***Build & Installation Guide***, before moving on to build the multiple PC modules.

In this guide you will find:

* Parts lists and schematics.
* Detailed construction and configuration information.

Notes on configuring the main Simulator Software Packages for use with multiple PCs can be found in the relevant software guides.

Please note that this is a Build-it-Yourself project. No pre-built hardware is available.

# Using Multiple PCs

The Liverpool Ringing Simulator currently supports two alternative modules to use multiple Simulator PCs concurrently. For example, typically this allows more than one ringer with headphones to use the simulator with a simulated band at the same time.

* The **Second PC** module, as its name suggests, allows a second Simulator PC to be use concurrently with the PC connected to the Power module.
* The **Basic Serial Splitter** module supports up to four Simulator PCs, or up to eight PCs with an expansion board. Up to two Basic Serial Splitters can also be daisy-chained together, supporting a maximum of 16 PCs.

You can use either the Second PC module, or the Basic Serial Splitter module, depending on how many PCs you want to connect in total.

## Second PC Module

A second Simulator PC can be connected via a Second PC module. This module utilises the second transmitter in the Simulator Interface MAX233 RS-232 serial line driver IC, and a spare core in the Power/Data cable, to provide a separate data feed to the Second PC.

The Second PC module is similar in size and shape to the Power module and is daisy-chained between the Power module and the Simulator Interface module on an RJ45 cable, in a similar manner to the chains of sensors. It also provides surge protection diodes on the power and serial lines.

A typical configuration with a Second PC module is illustrated in the following diagram (only eight sensors are shown to save space, up to 16 may be connected):

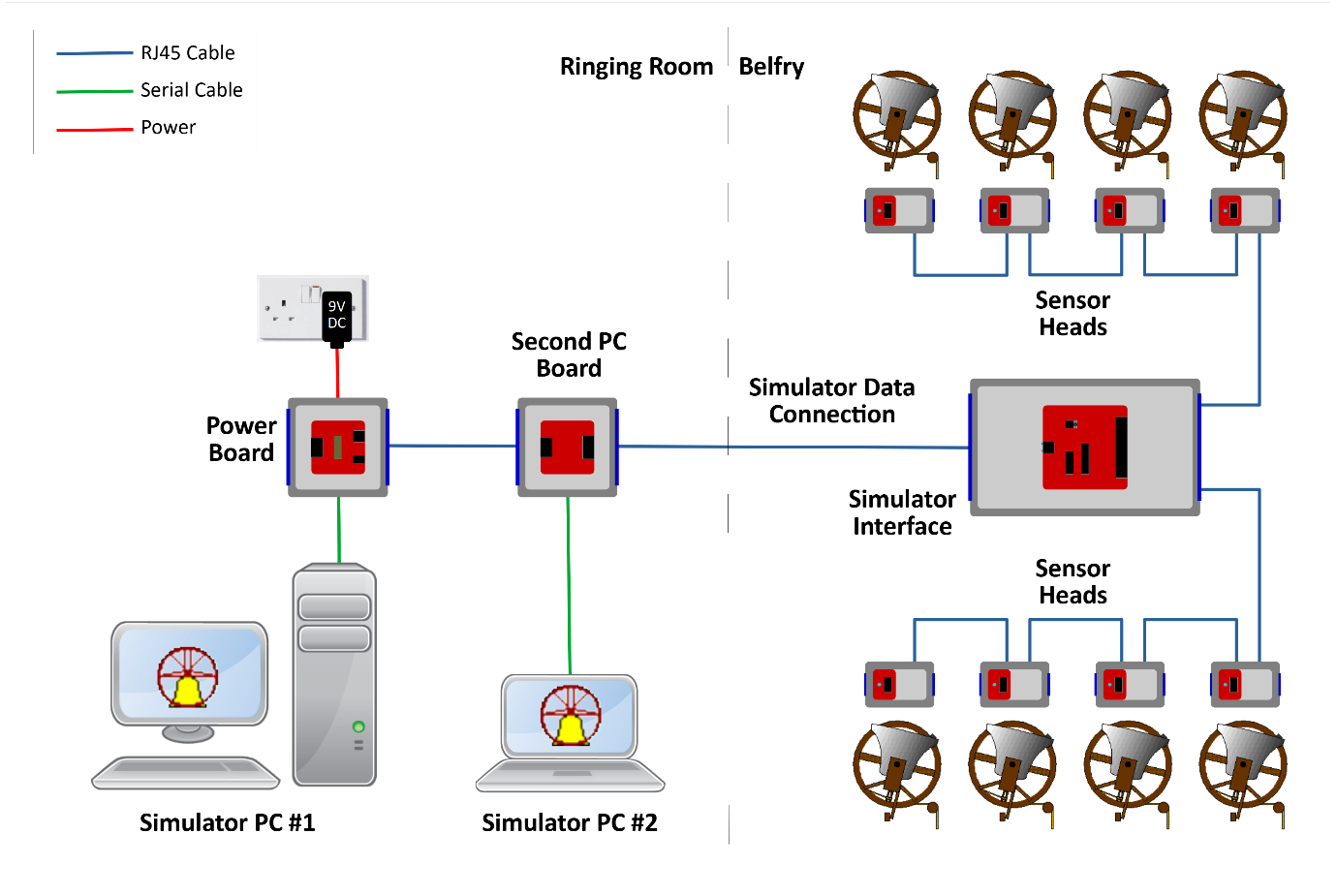


Figure 2 – Second PC Module General Arrangement

The Second PC receives a read-only copy of the same signals from the Simulator Interface module as the primary PC. Both PCs run their own copies of the Simulator Software Package (or even of different software packages), and the Simulator Software on each PC is configured to filter out unwanted signals.

Only the PC connected to the Power module can be used to configure the Simulator Interface.

**The Second PC module requires Revision D or later of the Simulator Interface PCB.** A modification is possible for older interface boards, and this is described in an Appendix below.

## Basic Serial Splitter Module

The Basic Serial Splitter module uses additional RS-232 receiver and line driver ICs to copy the stream of signals from the Simulator Interface to multiple PCs. The minimum configuration of the Basic Serial Splitter (the “Master Board”) supports up to four PCs, but this can be linked to a second “Expander Board” which supports four more PCs.

Up to two Basic Serial Splitters can be daisy-chained between the Power module and the Simulator Interface module on RJ45 cables, supporting a maximum of 16 Simulator PCs. The Basic Serial Splitter module also provides surge protection diodes on the power and serial lines.

The maximum configuration of two daisy-chained Basic Serial Splitters is illustrated in the following diagram (only four sensors are shown to save space, up to 16 may be connected):

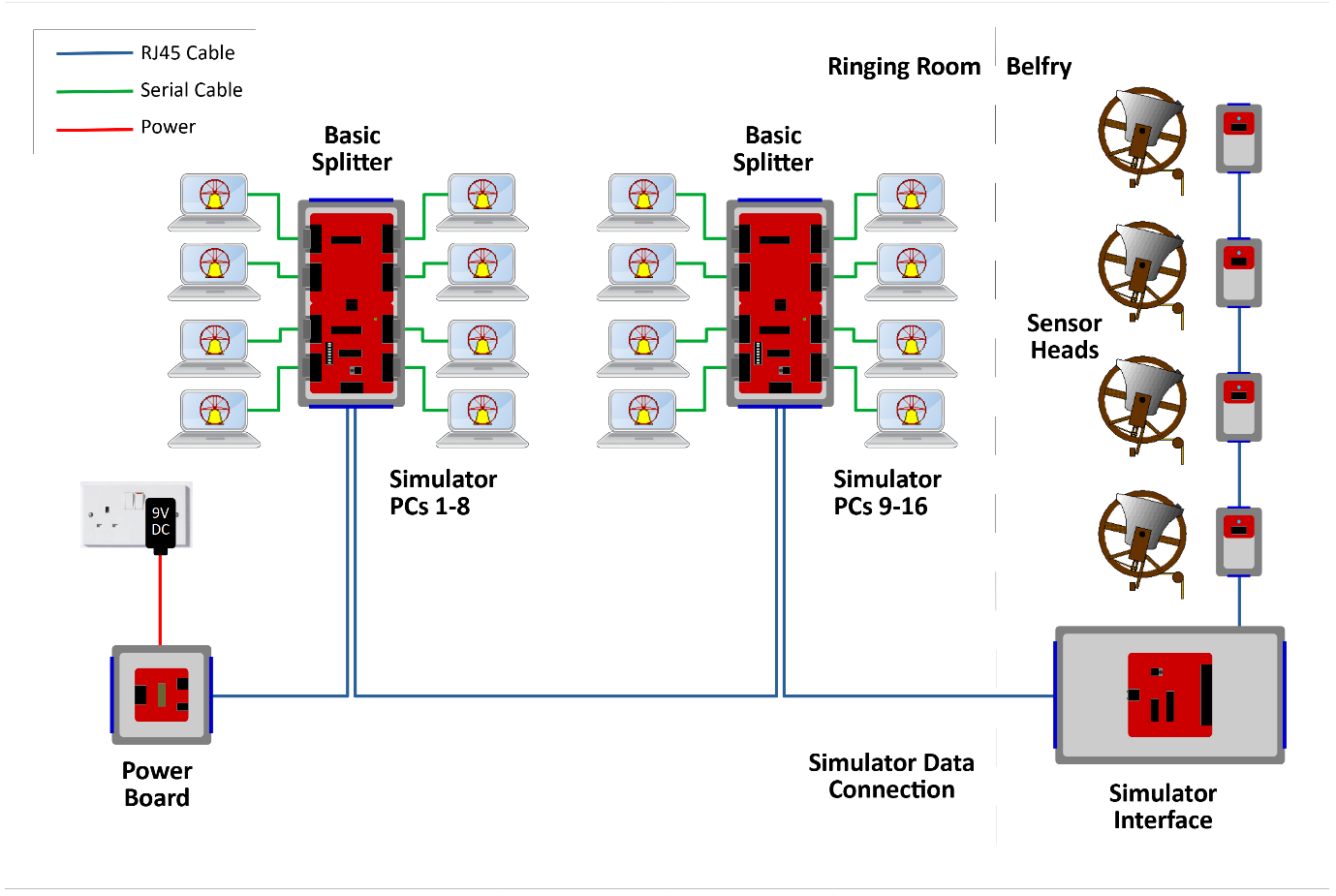


Figure 3 – Basic Serial Splitter Modules General Arrangement

All Simulator PCs receive a read-only copy of the same signals from the Simulator Interface. Each PC runs its own copy of the Simulator Software Package (or even of different software packages), and the Simulator Software on each PC is configured to filter out unwanted signals.

The PC connector on the Power module is not used with the Basic Serial Splitter.

Any one PC connected to the Basic Serial Splitter can be used to send configuration data to the Simulator Interface, selectable by a switch on the splitter. (If two Basic Serial Splitters are daisy-chained together, only PCs connected to the Splitter nearest to the Power module can be used to configure the Interface.)

**Daisy-chaining two Basic Serial Splitters requires Revision D or later of the Simulator Interface PCB.** A modification is possible for older interface boards, and this is described in an Appendix below.

## Modules Configurations

In addition to one Simulator Interface module[[2]](#footnote-2), one Power Module, and between one and 16 Sensor Modules (all covered in the ***Build & Installation Guide***), the multi-PC modules required depend on the number of Simulator PCs to be connected. The following table describes the possible configurations.

Table 1 – Multi-PC Module Configurations

|  |  |  |
| --- | --- | --- |
| **Number of Simulator PCs** | **Multi-PC Modules Required** | **Simulator PC Serial Connections** |
| 1 | None | Power Module |
| 2 | 1 x Second PC Board | Power Module & Second PC Board |
| 3 or 4 | 1 x Basic Serial Splitter (Master) | Basic Serial Splitter  (Power Module serial connector not used) |
| 5 to 8  (Option 1) | 1 x Basic Serial Splitter (Master)  1 x Basic Serial Splitter (Expander) | Basic Serial Splitters  (Power Module serial connector not used) |
| 5 to 8  (Option 2) | 2 x Basic Serial Splitter (Master) | Basic Serial Splitters  (Power Module serial connector not used) |
| 9 to 12 | 2 x Basic Serial Splitter (Master)  1 x Basic Serial Splitter (Expander) | Basic Serial Splitters  (Power Module serial connector not used) |
| 13 to 16 | 2 x Basic Serial Splitter (Master)  2 x Basic Serial Splitter (Expander) | Basic Serial Splitters  (Power Module serial connector not used) |

# What You Will Need

## Skills

Like the rest of the Liverpool Ringing Simulator, the multi-PC modules are Build-it-Yourself projects. Please refer to the main ***Build & Installation Guide*** for details of the skills and tools you will require to build the Simulator.

The Basic Serial Splitter module is more complex to build than the core Simulator modules, so it is probably best to complete and test the core modules before moving on to the multi-PC modules.

Advice and guidance are available from the project via the contact form on the website.

## Parts

Please refer to the main ***Build & Installation Guide*** for suggested sources of parts for the multi-PC modules. As with the core Simulator modules, where possible Farnell or CPC part numbers have been given.

## PCBs

**Surplus development PCBs may be available from the Liverpool Ringing Simulator Project, please enquire about availability via the contact form on the website.**

The multi-PC modules use two basic types of PCB:

* Second PC Board.
* Basic Serial Splitter Board

Note that the Basic Serial Splitter has been designed so that the same type of PCB can be built either as the Master Board or the optional Expander Board.

Suggested sources of PCBs are listed in the main ***Build & Installation Guide***, and PCB design files, known as “Gerber files”, are available from the project GitHub repository:

* <https://github.com/Simulators/simulator-type2>

### PCB Design Software Change

The Cadsoft Eagle design tool, now owned by AutoDesk, and originally used for all Liverpool Ringing Simulator Project PCBs, is being discontinued. As of May 2025, PCB designs have been migrated to the open source KiCad EDA package, and KiCad CAD files and KiCad-generated Gerber files have been made available in the GitHub repository.

The project documentation has also being updated with schematics and PCB layouts generated by KiCad, but board photographs may continue to show boards designed using Eagle. There may be cosmetic differences between the Eagle and KiCad versions of PCBs, but the functionality of the first KiCad and final Eagle versions of boards will be the same, except where noted otherwise.

# Hardware Assembly

This section describes the assembly of the multi-PC module options. It also covers the suggested enclosures.

Before you start construction of the multi-PC module hardware, check the ***Release Notes*** and the issues log on the project GitHub repository for any open or late-breaking issues which may affect your build:

* <https://github.com/Simulators/simulator-type2/issues>

## Polarised Components

A number of the components of the multi-PC modules are polarised and must be fitted the right way round for correct operation. Guidance is given in the main ***Build & Installation Guide*** on correct orientation of the polarised components, but if in any doubt consult the component supplier or the manufacturer’s data sheets. Fitting a polarised component the wrong way round may result in damage to the component.

## Second PC Board

### Parts List

Table 2 – Second PC Module PCB Parts List

|  |  |  |
| --- | --- | --- |
| **Reference** | **Component** | **Notes** |
| PCB | Type 2 Second PC Board PCB |  |
| PC Connector | Right Angle PCB D Sub Connector 9 Pin | Farnell 1848372\* |
| Connector | AMP TE Connectivity 5406526-1 | Farnell 2452587 |
| D1 | SA12A | Farnell 2679618 |
| D2, D3, D4 | SA15CA | Farnell 2762809 |

(\* Farnell part 1848372 has threaded screw lock posts for cable plugs fitted with locking screws. If you do not want these, use alternative part 1084701 instead.)

### Schematic

A computer screen shot of a computer

AI-generated content may be incorrect.

### Parts

The following photograph shows the complete set of parts required for the Second PC module PCB.

A circuit board

Description automatically generated

Figure 4 – Second PC Module Parts

### PCB Layout

The following diagram shows the layout of the Second PC module PCB. All components are mounted on the top (silkscreen) side of the board.

A red circuit board with white text and black text

AI-generated content may be incorrect.

Figure 5 – Second PC Module PCB Layout

### Construction

All the components on the Second PC module PCB are mounted on top, silkscreen, side of the board.

* If your Second PC PCB came from a panelized PCB, lightly file down any remaining nibs from the edges of the board.
* Pay close attention to the correct orientation of the polarised diode D1.
* D2, D3 & D4 are not polarised.
* There is no need to fit pins to the test point holes TP1 – TP2.

A completed Second PC module is shown in the following photograph.

A circuit board

Description automatically generated

Figure 6 – Completed Second PC Module

### Enclosure

The Second PC module may be housed in a 0.75 litre Really Useful Box, with space for a USB-Serial adapter if required, and with the same drilling as for the core Power module. The PCB may be mounted on standoffs, as described in the ***Build & Installation Guide***.

## Basic Serial Splitter Module – Master Board

### Parts List

Table 3 – Basic Serial Splitter Module Master Board Parts List

|  |  |  |
| --- | --- | --- |
| **Reference** | **Component** | **Notes** |
| PCB | Type 2 Basic Serial Splitter PCB |  |
| R1 | 1kΩ 0.25W Metal Film | Farnell 9341102 |
| C1, C2 | 100µF 25V Electrolytic (6.3mm Radial) | Farnell 9451188 |
| C3, C5, C6 | 330nF (0.33µF) 50V MLCC[[3]](#footnote-3) (2.54mm Radial) | Farnell 2819679 |
| C4 | 47nF (0.047µF) 50V MLCC (2.54mm Radial) | Farnell 2819680 |
| C7, C8, C9,  C10, C11, C12 | 100nF (0.1µF) 50V MLCC (2.54mm Radial) | Farnell 1457655 |
| D1 | SA12A | Farnell 2679618 |
| D2, D3, D4 | SA15CA | Farnell 2762809 |
| D5 | 1N4001 | Farnell 1458986 |
| D6 | SA5.0A | Farnell 1886342 |
| IC1 | MC7805CTG (replacement for LM7805) | Farnell 9666095 |
| IC2 | MAX3323EEPE+ | Farnell 2511866 |
| IC3 | MAX208CNG+ | Farnell 2511906 |
| RJ45 Connector | AMP TE Connectivity 5406526-1 | Farnell 2452587 |
| PC1, PC2, PC3, PC4 | Right Angle PCB D Sub Connector 9 Pin | Farnell 1848372\* |
| SW1 | DIP Switch 8-Way SPST | Farnell 9472115 |
| IC Socket | 16-pin, 0.3” pitch | Farnell 2445622 |
| IC Socket | 24-pin, 0.3” pitch | Farnell 2672303 |
| LED1 | Green 3mm | Farnell 1581114 |
| Hardware | 6mm M3 PCB Standoffs, Nuts & Screws | eBay |

(\* Farnell part 1848372 has threaded screw lock posts for cable plugs fitted with locking screws. If you do not want these, use alternative part 1084701 instead.)

### Schematic

A computer screen shot of a computer

AI-generated content may be incorrect.

### Parts

The following photograph shows the complete set of parts required for the Basic Serial Splitter Module Master Board.

A circuit board

Description automatically generated

Figure 7 – Basic Serial Splitter Module Master Board Parts

### PCB Layout

The following diagram shows the layout of the Basic Serial Splitter Master PCB. All components are mounted on the top (silkscreen) side of the board. Note that the Expander uses an identical PCB.

A red circuit board with blue lines and dots

AI-generated content may be incorrect.

Figure 8 – Basic Serial Splitter Module Master Board Layout

### Construction

All the components on the Basic Serial Splitter Module Master Board are mounted on top, silkscreen, side of the board.

* Start by soldering the components with the lowest profile (resistors, ceramic capacitors), then the remainder of the components in order of increasing height, ending with the RJ45 and 9-Pin Serial connectors.
* The use of IC sockets for IC2 & IC3 is strongly recommended.
* When fitting the voltage regulator, carefully bend the pins through 90 degrees so that the mounting hole in the tab lines up with the mounting hole in the PCB. Secure the regulator to the board with an M3 nut, bolt and washer before soldering the pins. A tiny smear of heatsink compound between the tab and board will improve heatsinking. No additional heatsink is required.
* Before fitting the socketed ICs, connect the board to a power supply (using the Power module and a short RJ45 cable) and check using a multimeter that the supply voltage appears on the pins of TP2, and that +5V and 0V appear on the pins of TP1 and the correct pins of the IC sockets. The pins are identified in the diagram below. The green power LED should also light. Disconnect the power supply and fit the ICs.

A screenshot of a cell phone

Description automatically generated

Figure 9 – Voltage Check Pin Locations

* Pay close attention to the correct orientation of the polarised components D1, D5, D6, C1, C2, IC1, IC2, IC3 & LED1.
* Diodes D2, D3 & D4 are not polarised.
* The mounting lugs of the RJ45 and 9-Way D-Sub connectors clip into the holes in the PCB. Make sure the connector pins are correctly aligned with the holes before clipping the connector into the board, and then soldering the pins.

A completed Basic Serial Splitter module Master Board is shown in the following photograph.

A circuit board

Description automatically generated

Figure 10 – Completed Basic Serial Splitter Module Master Board

## Basic Serial Splitter Module – Expander Board

The Expander Board links to the Master Board and provides four additional serial ports for Simulator PCs. Only one Expander can be linked to a Master Board.

### Parts List

Table 4 – Basic Serial Splitter Module Expander Board Parts List

|  |  |  |
| --- | --- | --- |
| **Reference** | **Component** | **Notes** |
| PCB | Type 2 Basic Serial Splitter PCB |  |
| C8, C9, C10,  C11, C12 | 100nF (0.1µF) 50V MLCC (2.54mm Radial) | Farnell 1457655 |
| IC3 | MAX208CNG+ | Farnell 2511906 |
| PC5, PC6, PC7, PC8 | Right Angle PCB D Sub Connector 9 Pin | Farnell 1848372\* |
| IC Socket | 24-pin, 0.3” pitch | Farnell 2672303 |
| Master Connector | 8-Way Right Angle Header | Farnell 2356196 |
| Expand Connector[[4]](#footnote-4) | 8-Way Right Angle Socket | Farnell 1668343 |
| Hardware | 6mm M3 PCB Standoffs, Nuts & Screws | eBay |

(\* Farnell part 1848372 has threaded screw lock posts for cable plugs fitted with locking screws. If you do not want these, use alternative part 1084701 instead.)

### Parts

The following photograph shows the complete set of parts required for the Basic Serial Splitter Expander PCB.

A circuit board

Description automatically generated

Figure 11 – Basic Serial Splitter Module Expander Board Parts

### Construction

The Basic Serial Splitter module Expander uses the same PCB as the Master board, shown in the diagram in the previous section. All the components are mounted on top, silkscreen, side of the board.

* Fit only the parts listed in the Expander parts list above. All remaining positions on the Expander PCB can be left empty.
* Note that the 8-Way Right Angle Socket is fitted to the Expand position on the MASTER board, not the Expander. It mates with the 8-Way Right Angle Header fitted to the Master position on the Expander board, as shown in the photographs below.
* The use of an IC socket for IC3 is strongly recommended.
* Before fitting the socketed IC, connect the board to a power supply (via the Master board and a Power Board and a short RJ45 cable) and check using a multimeter that +5V and 0V appear on TP1 and the correct pins of the IC3 socket. The pins are the same as identified in the diagram above. Disconnect the power supply and fit the ICs.
* Pay close attention to the correct orientation of the polarised component IC3.
* The mounting lugs of the 9-Way D-Sub connectors clip into the holes in the PCB. Make sure the connector pins are correctly aligned with the holes before clipping the connector into the board, and then soldering the pins.

A completed Basic Serial Splitter module with Master and Expander Boards is shown in the following photograph.

A circuit board

Description automatically generated

Figure 12 – Basic Serial Splitter Master & Expander PCBs

## Enclosures

The suggested enclosures for the Second PC module and the Basic Serial Splitter module are from the “Really Useful” series of plastic boxes, widely available from hobby and stationery shops, or direct from the manufacturer[[5]](#footnote-5).

* Drilling large diameter holes with twist drills can result in bit grabbing and damage to the enclosure. Use a 20mm hole saw[[6]](#footnote-6) for cable holes, this makes the process of drilling the enclosure much easier and safer.
* Support the inside surface of the enclosure with a block of scrap wood when cutting the holes and cut at a low speed.
* Clean up any rough edges or swarf with a sharp knife.
* Cables are run into the enclosures via PVC grommets, which provide some protection against dust and moisture.
* A set of suitable paper templates is available from the GitHub repository as a PDF and should be printed out full size with no scaling.

### Parts List

Table 5 – Enclosures Parts List

|  |  |  |
| --- | --- | --- |
| **Reference** | **Component** | **Notes** |
| Second PC Module | Really Useful Box® 0.75 Litre | 195 x 135 x 55mm |
| Basic Serial Splitter | Really Useful Box® 0.55 Litre | 220 x 100 x 40mm |
| Grommets | 20mm Closed Grommets | Screwfix 884VT |

### Second PC Module Enclosure

The following diagram shows the holes required in a 0.75 litre Really Useful Box for the Second PC module.

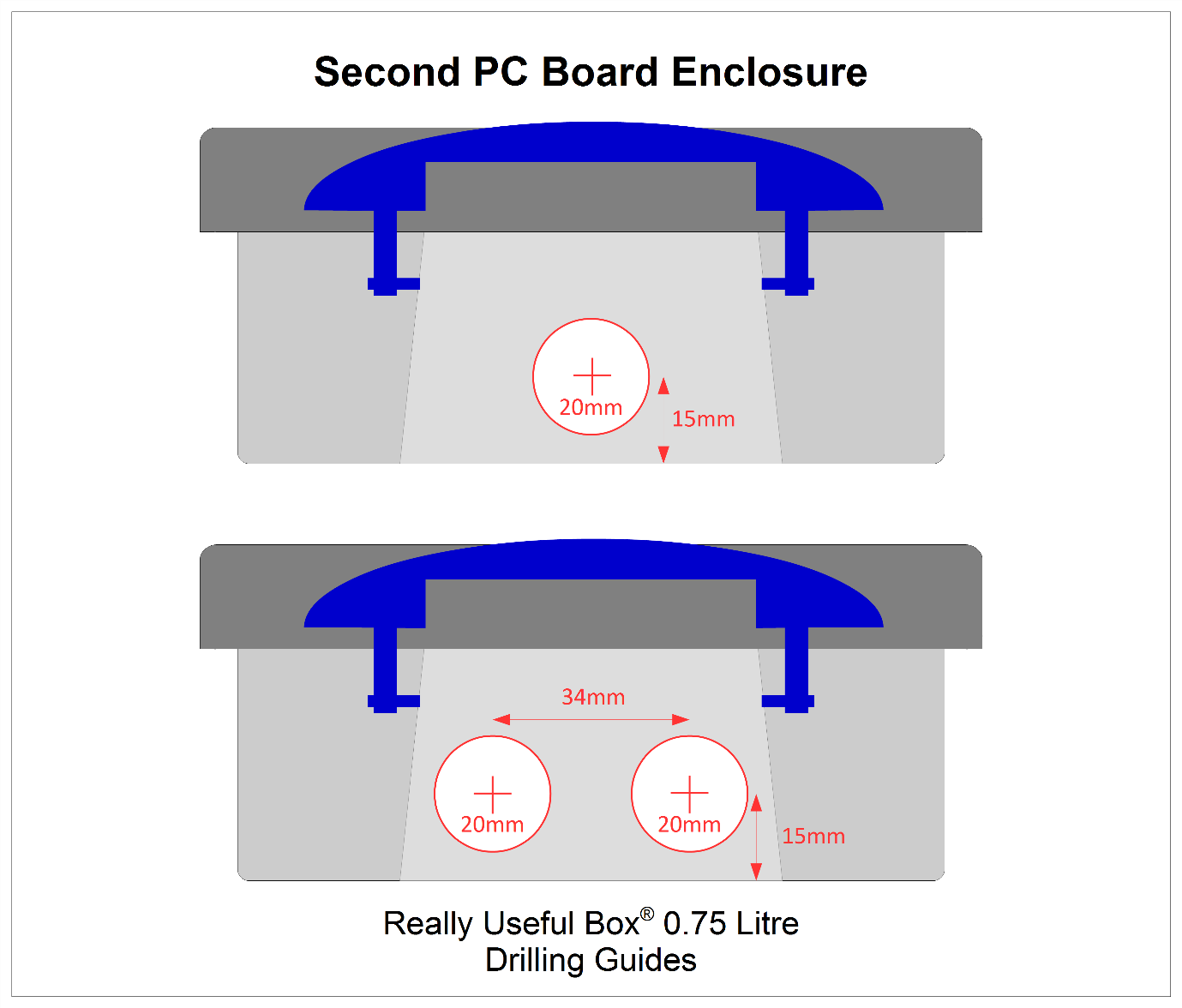


Figure 13 – Second PC Module Enclosure Drilling Guide

### D Sub Serial Connector Alternative Drilling

The single 20mm hole in the Second PC Module enclosure is sufficient for a USB-Serial adapter with a USB-A connector. If you are using an RS-232 cable with a 9-pin D Sub Connector, then a larger hole will be required. Drill two 20mm holes and cut out the area between them as shown by the dotted lines in the diagram below.

Diagram

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Figure – Alternative Drilling Guide for DB9 Connector

### Basic Serial Splitter Enclosure

The following diagram shows the holes required in a 0.55 litre Really Useful Box for the Basic Serial Splitter. A single enclosure is big enough for a linked Master Board and Expander Board.

A screenshot of a cell phone

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Figure 15 – Basic Serial Splitter Module Enclosure Drilling Guide

The two 20mm holes in the end of the enclosure overlap. The material between each pair of 20mm holes in each side of the enclosure should be cut out, leaving two slots. This can be seen in the completed assembly module photograph below.

### PCB Mounting Hardware

The Basic Serial Splitter PCBs should be secured to the base of the enclosure using M3 x 6mm Nylon PCB standoffs, nuts, screws and washers.

A picture containing metalware

Description automatically generated

Figure – PCB Mounting Hardware

The following photograph shows how the bare PCBs can be used to mark out the base of the Basic Serial Splitter enclosure prior to drilling.

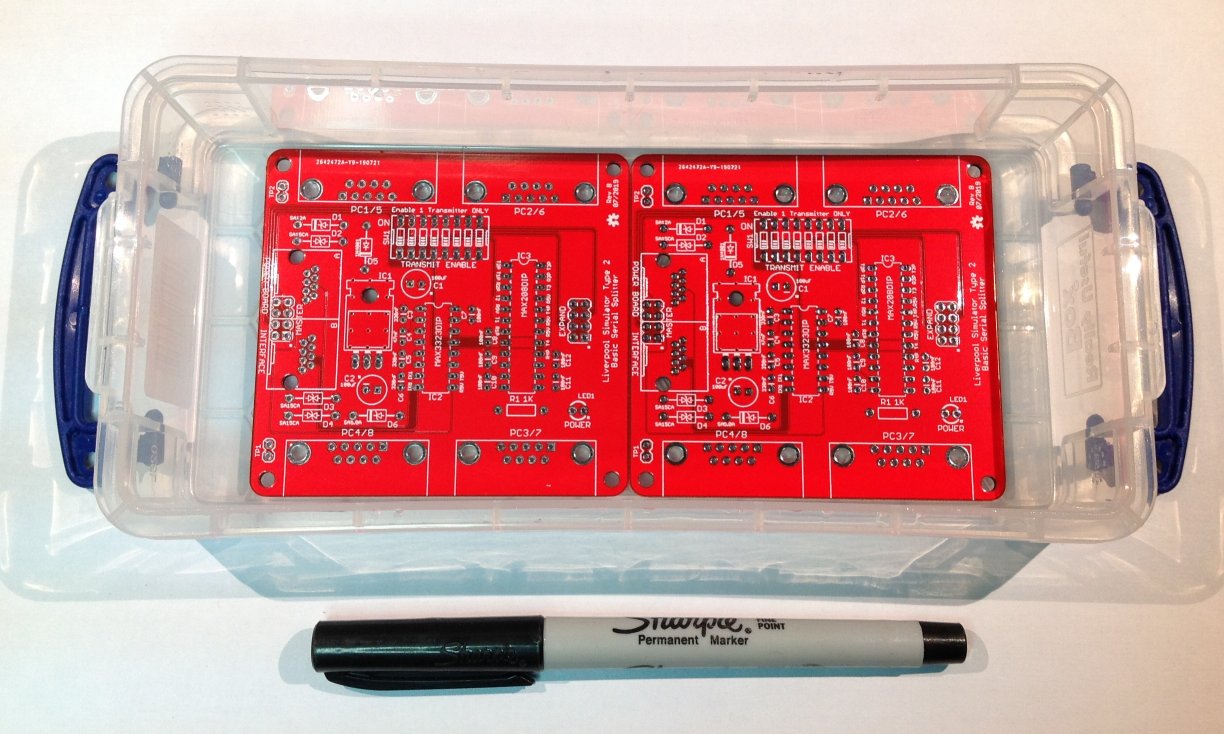


Figure – Enclosure Marking Out

The Basic Serial Splitter enclosure marked out for drilling is shown in the following photograph.

A picture containing indoor, wall, cabinet, open

Description automatically generated

Figure – Enclosure Marked for Drilling

## Completed Assemblies

### Second PC Module

The following photograph shows a completed Second PC Board, with a USB-Serial adapter also inside the enclosure.

A picture containing indoor, refrigerator, open, cabinet

Description automatically generated

Figure 19 – Completed Second PC Module in Enclosure

### Basic Serial Splitter Module

The following photographs show completed Basic Serial Splitter modules, with Master & Expander Boards.

A circuit board

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Figure 20 – Completed Basic Serial Splitter Module in Enclosure

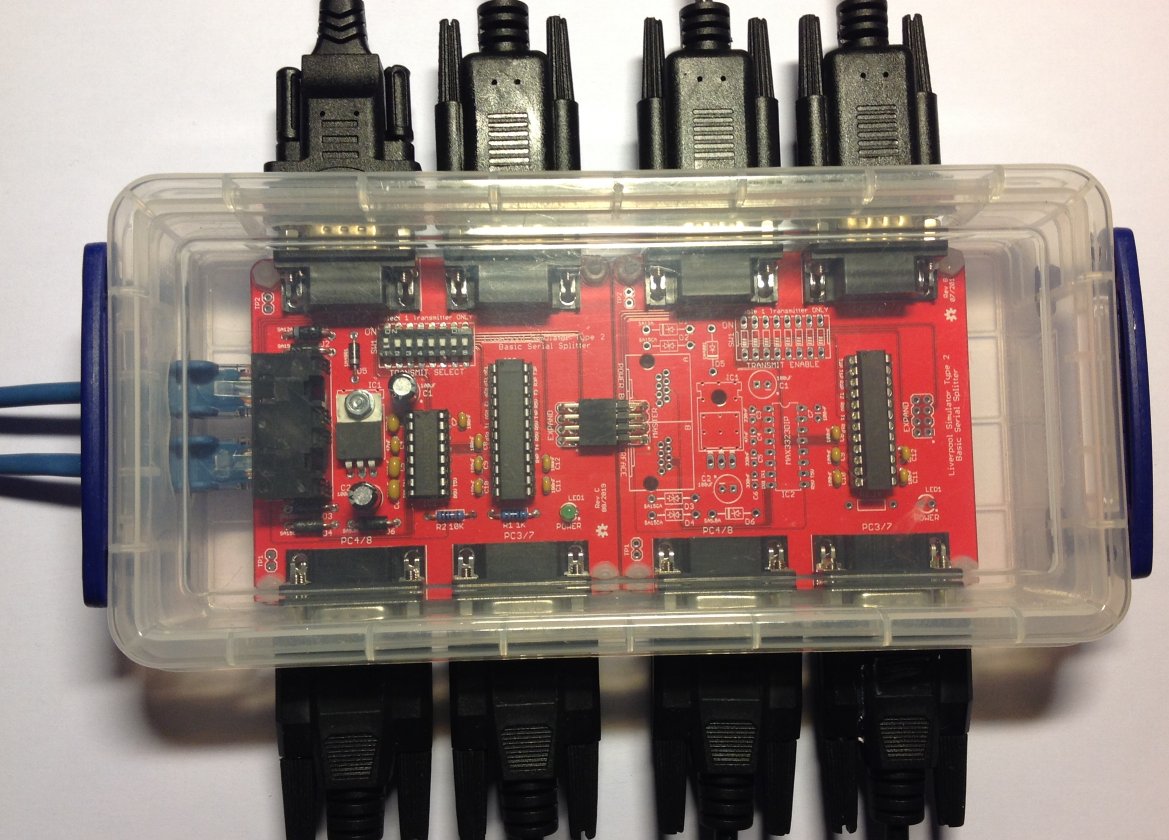


Figure – Completed Basic Serial Splitter Module

## Cabling

### Second PC Module

The Second PC module is daisy-chained between the Simulator Interface module and the Power module, as shown in the following diagram.

* As with the core Simulator cabling, the cable is a standard straight-through (not crossover) Cat5e or Cat6 Ethernet network cable, with RJ45 connectors.
* The maximum total length of cable tested is 30m (25m between Interface and Second PC module, and a further 5m to the Power module), although longer cables may be feasible.

A screenshot of a cell phone

Description automatically generated

Figure – Second PC Module Cabling

### Basic Serial Splitter Module

The Basic Serial Splitter module is daisy-chained between the Simulator Interface module and the Power module, as shown in the following diagram.

* One or two Basic Serial Splitter modules may be connected as shown, providing ports for up to 8 or up to 16 Simulator PCs.
* As with the core Simulator cabling, the cable is a standard straight-through (not crossover) Cat5e or Cat6 Ethernet network cable, with RJ45 connectors.
* The maximum total length of cable tested is 30.5m (25m between Interface and Basic Serial Splitter module, a further 5m to the second Splitter module, and a short cable to the Power module), although longer cables may be feasible.

A screenshot of a cell phone

Description automatically generated

Figure 23 – Basic Serial Splitter Module Cabling

# Appendix: Older Interface Boards

**The Second PC module works with Simulator Interface PCBs from PCB Revision D onwards – no modification of these interface boards is necessary.**

**Daisy-chaining two Basic Serial Splitter modules together works with Simulator Interface PCBs from PCB Revision D onwards – no modification of these interface boards is necessary.**

**A single Basic Serial Splitter module will work with any version of the Simulator Interface PCB.**

Older Simulator Interface PCBs may be modified for use with the Second PC module, or to allow daisy-chaining of two Basic Serial Splitter modules, with the addition of two wire links. On the solder side of the Simulator Interface PCB, fit two small wire links:

* Between pins 1 and pin 2 of IC2.
* Between pin 18 of IC2 and pin 2 of TP5 (pin 1 of TP5 is marked with a square pad).

Remember that when working on the solder side of the PCB the IC pin numbers will be reversed. The locations of the links are shown in the diagram below:

A circuit board

Description automatically generated

Figure 24 – Modification for Older Interface PCBs

An example of a modified Simulator Interface PCB is shown in the following photograph.

A circuit board

Description automatically generated

Figure 25 – Modified Interface Board

# Appendix: Configuring the Interface

When multiple PCs are connected, only one PC can be used to configure the Simulator Interface using a terminal emulator (as described in the ***Build & Installation Guide***).

* When using the Second PC module, only the PC connected to the Power module can be used to configure the Interface.
* The PC connected to the Second PC module is not able to send data to the Interface and cannot be used for configuration.
* When using a single Basic Serial Splitter module, any one PC (selected by the 8-way DIP switch on the PCB) can be used to configure the Interface. Only one PC should be enabled at any time.
* When two Basic Serial Splitter modules are connected, any one PC (selected by the 8-way switch) connected to the Splitter closest to the Power module can be used to configure the Interface. The PCs connected to the Splitter closer to the Interface module are automatically disabled for configuration use.
* The PC connector on the Power module is not used at all when the Basic Serial Splitter(s) is used and must not have a PC connected to it.

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* Liverpool Cathedral
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* St Mary, Chirk, Wrexham
* St John, Higham, Kent
* St Margaret, Crick, Northamptonshire
* St Mary & St Peter, Lois Weedon, Northamptonshire

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1. <https://creativecommons.org/licenses/by-sa/4.0/> [↑](#footnote-ref-1)
2. Configurations with more than one Simulator Interface are possible, but unusual. [↑](#footnote-ref-2)
3. Multi-Layer Ceramic Capacitor [↑](#footnote-ref-3)
4. Note that this component is installed on the MASTER board. [↑](#footnote-ref-4)
5. <https://www.reallyusefulproducts.co.uk/> [↑](#footnote-ref-5)
6. Frequently used by electricians. [↑](#footnote-ref-6)
7. <https://www.simulators.org.uk/> [↑](#footnote-ref-7)
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