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Model Railway Computer Control Centre

Final Year Project Report

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Model Railway Computer Control Centre
By Stephen Parascandolo

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A CD-ROM containing the Project Report, Source Code, Installation Software and Supporting Documentation is attached to the rear cover of Volume 2.

Chapter 1 Introduction

Model Railway Computer Control Centre

Realistic PC based Signalling for the Model Railway

Think of Model Railways, and you probably think of a Hornby train set or a carefully modelled scene by elderly anoraks with finely crafted steam engines from the past. Whilst these stereotypes remain true, there is more to model railways.

Some modellers prefer instead to recreate in miniature, the current railway scene. In the UK, this has seen the increasing use of multiple unit operation, modern standard locomotive designs and with privatisation, a huge array of colourful liveries. Few notice the increasingly complicated signalling systems that allow the trains to operate safely on crowded and complex track layouts.

A common feature of many so called, *Modern Image* layouts, is to incorporate a working signalling system to add interest. Modern Signalling is colour light and computer controlled. The left hand cover photo shows a real VDU based control centre at Stoke On Trent. A basic tutorial in signalling is presented in Chapter 2.

In order to control realistic signalling for more complex track layouts, the switching and interlocking required results in very complex hardware based solutions, often with hundreds of electromechanical relays or a bewildering amount of logic gates. For this reason, a number of railway modellers are turning to computer technology where software can be used to save a mass of complex logic in hardware.

The Model Electronic Railway Group (MERG) are an international group of like minded railway modellers who have developed a number of electronic solutions to model railway problems and make them available as kits to members. A key product family is the Remote Panel Control (RPC) system which provides Input and Output capabilities to a PC via the serial or USB ports. The system is described in more detail in Chapter 3.

During a work placement year, the author worked for a railway signalling company, GE Transportation Systems. Amongst the product range is the Modular Control System (MCS) which is a VDU based signalling indication and control system. The MCS system linked to safety critical Solid State Interlockings (SSIs) which made the vital interlocking checks.

This project sets out to develop software to provide modern signalling for the model railway. As safety is not such an important consideration, implementation can be on a standard PC and the User Interface, Interlocking and Hardware interface can be integrated into a single piece of software.

1.1 About this Report

This report takes attempts to take a logical approach, taking the reader through every aspect of this software project. This Introduction chapter establishes the background to the project and sets out the key Aims and Objectives that the project is trying to meet.

Chapter 2 provides a tutorial on the fundamental aspects of Railway Signalling in the UK which is essential to understand the design decisions taken.

Chapter 3 has been provided to briefly explain the MERG RPC hardware system that this software is being developed for. It also explains about the test bed for my project, the Beckenham and West Wickham MRCs “Horton” layout. Photos and diagrams assist in putting the theory and project into context.

Chapter 4 takes the reader into the Design of the Software. Starting with the development of the project requirements and developing in detail the software design and structure.

Details of the functionality of the final software and the testing strategies employed can be found in Chapter 5 and 6 while Chapter 7 gives a critical evaluation of the design decisions and project outcome, looking to future developments and looking back with hindsight at elements of the design.

Full specifications of the RPC Hardware Interface, specific details on the implementation on *Horton*, References for the project and the Visual Basic.NET source code can be found in the Appendixes. The Source code and Installation files together with this report are also provided on CD at the back of Volume 2 of this report.

1.2 Aims and Objectives

The software should: -

[1] Provide Realistic Signalling on the Model Railway

The project is aiming for realistic modern signalling on the model railway. Further details on relevant signalling can be found in Chapter 2.

However, there are some limitations and assumptions at this stage. It is assumed that like on the real railway, a signaller will set the routes using the software, causing signals to clear and points to change. And, a driver will drive the train, obeying the signals. The trains are not controlled or driven by the software – although there may be an interlock configured with the train power supply.

As a further limitation, and reflecting the operation of most model railways, there is no timetable or sequence being operated and so there is no requirement for an "Automatic Route Setting" system which would automatically set routes based on a timetable. The signaller sets all routes manually.

It has to be assumed that the layout is suitably constructed and wired with suitably chosen track sections (circuits), signal positions and wiring. For the software to be effective, the layout needs to be signalled prototypically albeit with some simplifications.

[2] Provide a User Interface similar to Real VDU Control Centre

A key objective is a desire to not just provide realistic signalling, i.e. correct signal aspects and interlocking, but also for the User Interface to be similar to that found on real VDU based control systems. This extends to many of the symbols and colours used as well as the method of operation and mouse clicks. For the real railway, this is set out in Railway Standards GK/RT/0025 and RT/E/S/17504. Railway Safety Ltd does not permit their reproduction in this report.

The display has to update in real time based on what is happening on the railway. Train movements can then be observed on the screen – there is no theoretical reason why the signaller can not be remote from the layout.

In addition, a key operating concept, Entry – Exit (or NX) route setting is required to speed and aid route setting. This is explained further in Chapter 2.

By providing a similar user interface, the operating experience for the layout operators is enhanced and in addition, by projecting the computer screen onto a screen at exhibitions, provides a dramatic and obvious demonstration to the public of how the layout being is operated. This generates interest and educates on signalling principles.

[3] Be Functional and Practical

This is not simply a university project – The author fully intends to use the software developed to control a real model railway layout. In addition, it is intended to provide the software free of charge and open source on the internet for others to use. So this software must be fully functional and address the practical needs of model railway layouts.

To this end, the software must be reliable and able to operate continuously for long periods. A number of detailed design issues also need to be thought out to adapt standard signalling practice to be useful and workable on a typical model railway. A degree of flexibility is required to allow non standard extras to be controlled. Railway modellers are ingenious and always finding new things to add. Examples might include playing announcements, crossing warning lights or train sound effects.

[4] Be User Configurable

It should be stressed that the software is not just for a single model railway layout. The software needs to be fully configurable for any reasonable exhibition sized layout. This presents a number of challenges but makes the software a great deal more flexible. The design of the layout is not a task that needs to be carried out frequently – indeed once entered, it would only need changing if the physical track or signalling was changed or if some aspects of the interlocking needed to be amended.

The infrequent change of the layout details mean that this section of the software can be designed primarily for functionality and only secondly on usability grounds. It does not matter if it takes some time to set out a complex layout.

A further issue that follows on is that the data created needs to be saved to disk and opened again at a later date – data can not be recreated from scratch for each use of the software.

[5] Be as simple as possible to configure

The interlocking data needs to be as user friendly as possible. Real systems and some other model railway software relies on a script based approach. This puts off many railway modellers who whilst understanding signalling, are not comfortable with even the simplest elements of software.

[6] Develop within certain limitations

Finally, there are some limitations to the software which need to be set out at this early stage. These have been set to match the author's interest and personal requirements but also to limit the project to some realistic boundaries!

These limitations are very simply that the software is designed for use only with the MERG RPC Hardware System (running in RS232 mode only) and that the signalling recreated is based on UK Colour Light signalling practice.

The software must be PC based and designed to work under MS Windows on a modern PC. This is the most widely available platform. In addition, the RPC hardware is designed to work with the RS232 serial port, easily available on most PCs.

1.3 Summary

The project has been introduced and 6 clearly defined objectives defined. These Objectives are used extensively in the Chapter 4 to determine the direction of the Design decisions.

Chapter 2 considers the Signalling concepts which the software is required to implement and replicate.

Chapter 2 Background

Modern UK Signalling Practice

This section is designed to explain the UK Signalling principles which must be understood in order to appreciate the design decisions taken. Whilst being based on prototypical signalling, model railway signalling clearly does not have the serious safety implications of the real railway. For this reason, even on well signalled model railways, such as Horton, described in this chapter, the signalling does not come close to that required of the real railway.

This tutorial on signalling will only focus on the aspects that are relevant to model railways and to this project. Some areas have been simplified and there are some areas where the Model Railway requires additional features to be practical in an exhibition environment.

Any differences to signalling concepts for model railways have been identified but large areas of Signalling Practice have been omitted for simplicity as they are not relevant to the project.

For further reading, the author recommends: -

"BR Signalling Handbook" by Stanley Hall. ISBN 0-7110-2052-3 Ian Allan Publishing Ltd, 1992
Railway Technical Web Pages - http://www.trainweb.org/railwaytechnical/sigind.html

2.1 Why Have Signalling?

Signalling is a vital element of any railway. It ensures the safety of the train and therefore the passengers. From the earliest railways, as soon as there was more than one train on a network of railway tracks, there was the potential of trains colliding! Unlike road vehicles, trains can not stop quickly. Even with modern braking systems, a High Speed Train takes over a mile to stop from full speed – 125mph.

And so you have the two key reasons for signalling: -

1) Keep trains apart from each other

2) Give trains sufficient warning of the need to stop

Neither of this is particularly relevant for model railways but the signals positioning and indications are based on these key facts – even if they are only for show on the model.

2.2 Early Signalling

Early signalling consisted of a “policeman” who stood by the side of the line and indicated for a train to stop or proceed. After allowing one train to go, he would wait a specified time before allowing a second train to proceed. After some time, a signal was developed to replace hand signals and the semaphore signal was invented. This was fine until the train in front broke down around the corner and the second just ploughed in the back!

Block Sections

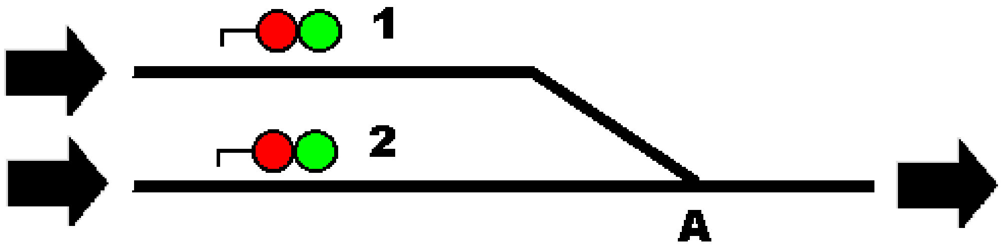
“Policemen” were soon replaced by railway signalmen and the newly invented signals became mechanically controlled from signal boxes. Following some accidents and with the development of the electric telegraph, systems were developed to allow communication between adjacent signal boxes. The signalman at the far end of a section could then tell the other signalman that the train had arrived safely and the line must be clear to allow a second train.

The rules were very simple – signal boxes had to be positioned at suitable positions along the line – usually at stations, and only one train was allowed in the “block section” between signal boxes at any one time.

Soon the systems developed further, to electrically interlock the signals with the electric telegraph between the signal boxes. And as train speeds rose, Distant Signals were positioned ahead of the “Stop signals” to give advanced warning of the need to slow down.

Junctions and Conflicts

We now come to junctions – that is where one line joins another using a switching piece of track, called *Points*. Quite obviously, two into one doesn’t go. Signals protect all junctions and conflicting movements. Before a signal can be cleared, the points must be moved to the correct position for the movement. Points have two positions, one for each direction, known as “Normal” and “Reverse”. Only one movement can be signalled across a simple junction at a time.



• Diagram 2.1 shows a simple junction layout. Signal 1 could not clear at the same time as Signal 2. Points, A must be set correctly before the signal is cleared. Also, Points A must not move while there is a train on the points.

This simple concept is known as interlocking and on both real and model railways is vital to the safe and successful operation of the railway. It obviously extends to much more complicated layouts to ensure that no two conflicting movements can simultaneously have clear signals at the same time.

Track Circuits

As well as protecting points from moving under trains, signallers need to know or be reminded where the trains are. *Track Circuits* were developed to detect where trains are and provide train detection. This is achieved by splitting the track into sections. These are then electrically isolated from each other by providing insulated joints in the rails and electrically connecting all other rail joints.

A power supply is fed into one end across the two rails and a relay placed at the other end. If a train is on the track, its wheels short circuit the relay and cause the relay to de energise. The track circuit becomes *Occupied*. When the relay is energised, the track circuit is *Clear*. The relay can then control lamps in the signal box or other interlocking as required.

2.3 Modern Signalling

Centralised Control

To maximise efficiency and man power and to apply area wide regulation of lots of trains through a network of lines, signal boxes got larger and more centralised. This was achieved by the introduction of power signal boxes with electric, colour light signals and motorised points and widespread introduction of track circuits.

• Photo 2.2 Large Power Signal Box at Exeter, © P.S.Bellamy

These centres consist of large illuminated track diagrams and push button control, often with many signalmen in a single signal centre.

Track Circuit Block

In a large centre, Track Circuits are widely used. "Block Sections" as described previously are replaced by one or more Track Circuits. Signals interlock with the Track Circuits to ensure that the line is clear as far as the next signal. On the Signalman's diagram (or *Panel*), Occupied Track Circuits show as a row of red lights along the track.

Away from station and junction areas, automatic signals are provided which require no action from the signaller. They work automatically based on Track Circuits ahead and the aspect (colour) of the following signal.

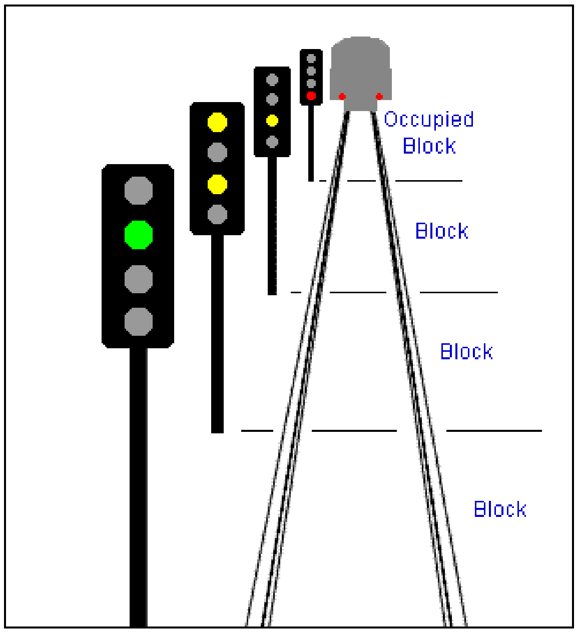
Signals

Modern Colour Light signals combine the standard semaphore signal with distant signals to give drivers advanced warning of following signals. This permits higher line speed and provides higher track capacity by allowing trains to follow each other more closely, although at lower speeds. There are three types, *Two Aspect, Three Aspect and Four Aspect* – Two and Three Aspect signals are used on quieter lines with fewer trains and slower speeds.

Two Aspect Signals, simply show Red or Green. Distant, Yellow/Green signals are often placed ahead of home signals.

Three Aspect Signals, show Red, Yellow or Green. Yellow indicated that the signal ahead is at Red and therefore gives advanced warning for the driver to slow down.

Four Aspect Signals are most common on busy routes. A Double Yellow aspect is included to give advanced warning of a single Yellow signal.



• Diagram 2.3 Sequence of Four Aspect Signal aspects behind a train, © Railway Technical Web Pages

The author appreciates that other types and variations of main signals exist for various reasons.

Route Setting

In older signal boxes, signallers had to operate a mechanical lever or switch for each individual point that had to be changed and then another for any signals required to be changed. If the layout was complicated, a single train movement could require numerous actions. With larger areas of control, route setting systems developed. This has now been established as the *Entry – Exit* or *NX Route Setting* system.

The track layout and signal positions are shown in schematic form on a console. Each Signal has a push button. Routes are defined as the path from one signal (The *Entry Signal*) to the next (The *Exit Signal*). To set the route, signallers simply press the first signal and then press the next signal the train will come to. The route setting system will "call" all points in that route the required position and allow the *Entry Signal* to show a proceed aspect, which it evaluates based on the track circuit occupation beyond it.

If there were 3 signals in a row, S1, S2 and S3, the signaller would need to set Route S1-S2 followed by S2 – S3. There is only a single button for each signal, so the signaller would press S1, S2, S2, S3. A Route may be cancelled by "pulling" the button at the *Entry Signal*.

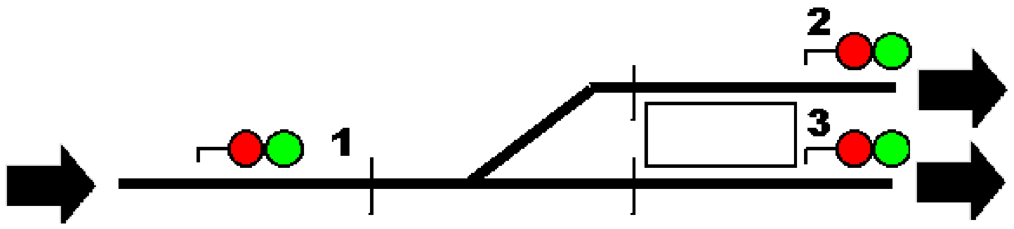
Routes can be used to simplify the interlocking. If two routes conflict, it is obvious only one can be set at the same time. Once requested, if the route is available, points are called. If these are detected correctly set and all the track sections are clear, the Route will set, enabling the Entry signal to clear. The Route Set is indicated by a row of white lights on the track diagram.

In Depth features

Route Release

In modern signalling centres, after the passage of a train over a route, the route automatically cancels itself. If a second train needed to travel, the signaller would have to set the route again. This is known as *Train Operated Route Release (TORR)*. It should be realised that the Entry signal itself would return to danger (Red) automatically as the train occupied track circuits beyond the Entry Signal. The route needs to stay set until the train is clear of all track circuits within the route in order to protect the route for that train.

There is a limitation to this however. Consider the following example.



• Diagram 2.5 Route Release Example

Train x is signalled from Signal 1 to Signal 2 at the end of a station platform. The train stops at the station. As the train has not cleared all the track circuits within the route, the route stays set. Train y is now waiting at Signal 1 and wants to go to Signal 3. The route is clear but the original route is still set. There must be a method for the initial route to timeout once the train arrives at the platform so a second route can be set. An equivalent system is needed for the model railway for the same reason.

Call On / Shunt signals

For shunting movements at slow speed, often in sidings, a special type of signal is used which shows Stop or Proceed. Call On signals are similar in appearance but are used to allow trains to enter already part occupied platforms. A separate Exit button is used to select this rather than a normal signal aspect. When these signals are mounted on the same post as a main signal, the shunt signal doesn't have a stop aspect, as there is already a Red, stop aspect on the main signal. This is reflected in the signallers display.

Isolated Exits

For Call On signals and at the end of a line – a terminus or dead end siding, there is no Exit Signal, but a button is still required to act as the exit signal for the route setting. These are known as *Isolated Exits*.

Auto Buttons

When referring to Routes, it was stated that if a second train comes, the signaller has to set each route again. This is fine if trains go different ways at a diverging junction but if many of them go the same way, it is rather inefficient. For this reason, Controlled Signals are often provided with an *Auto Button* or *A Button*. After setting a route, a separate Auto Button may be set. This allows the signal to clear again on its own once the first train is clear of the route. When a different route is required, the Auto Button can be cancelled and another route set. (Real installations are slightly more complicated than this)

Auto signals – ER Buttons

All signals so far described have been *Controlled* – The signaller sets them for each movement. Away from junctions, there may be many miles of *Automatic* signals. These always try to show the best possible aspect to the driver and are only affected by the occupation of track circuits beyond them. For emergencies, they may be provided with *Emergency Replacement (ER)* buttons to force them to Red.

Point Keys

For maintenance, safety protection, or if the points are failing to operate properly, it can be useful to manually operate individual points. Switches, known as *Point Keys* are provided for this purpose. These have three states – Normal, Centre and Reverse. When Centred, the points are free for the Route Setting system to call as required. When Normal or Reverse, the points are moved and locked in that position although if set correctly, a route may be set through them.

Point Pairs

Two points may operate as a pair. A common configuration is a crossover, allowing trains to move from one line, to an adjacent one. One control operates both *ends* of a crossover – two sets of points.

2.4 Computer Based Signalling

VDU based signalling control

Large Signal Centres are now moving from illuminated panels with push buttons to computer based control on VDUs. The track layout and all indications are shown on screens to the signaller. Control switches are replaced with clicks on screen elements with a tracker ball. The left hand cover photo shows a typical arrangement.

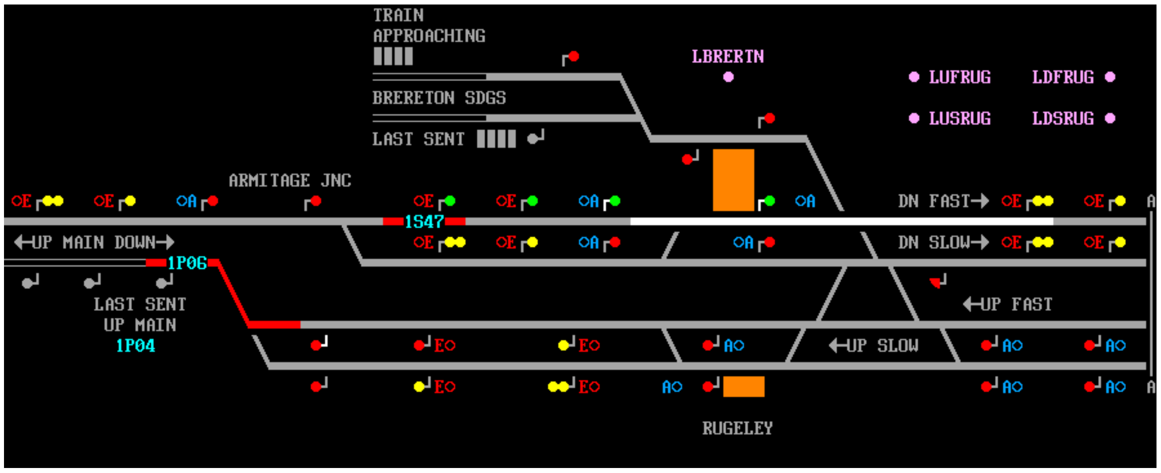
Often Automatic Route Setting can be provided using timetable data. As defined in Objective 1, this is not to be developed for Model Railways.

Electronic interlocking

Electromechanical relays to perform interlocking and route setting functions are replaced with Vital Computer Processors, data links and interlocking data.

Symbols

A series of symbols have been developed to depict the schematic of the railway and signalling states on the screen. Model Railway Computer Control Centre (MRCC) needs to look similar to meet Objective 2.



• Figure 2.4 Typical Screen Layout, © SimSig (Simulation Screenshot). This shows many features not described or required for model railways.

Mouse Actions

There are pre-defined mouse actions to control the railway which need to be similar to meet Objective 2.

Signaller Action	L / R Click	Click on?
Key Points	L (Normal) R (Reverse)	Point Tips
Route Setting	Left	Entry Signal, then Exit Signal
Cancel Route	Right	Entry Signal
Set Misc Control or A Button	Left	Control symbol
Cancel Misc Control or A Button	Right	Control symbol

2.5 Model Railway Features

On the model railway, some things have to be different to the real railway for practical reasons. Safety is not as important! One example is for Points – in reality, these would be locked if there was a train on them, on a model, unreliable track circuits may lock them unnecessarily. Running trains is more important than safety on a model! In any case, model track circuiting is far more complex – See Chapter 3 for how the RPC system achieves this.

Junction Indicators

Junction Indicators are rows of white lights on top of signals to indicate to the driver that a diverging route is to be taken. They only display when the signal is showing a proceed aspect and the route is set for the diverging route. On the Model Railway, a separate output bit controls the Junction Indicators and this needs to be defined with a Signal and a Route to control the output.

ATP Relays

To prevent embarrassing collisions on Model Railways, sections of track ahead signals protecting junctions can be electrically isolated, bringing the electric train to an immediate halt. This is achieved through an *Automatic Train Protection (ATP)* relay in the power supply to that section. The relay can be connected to an output bit and the software needs to ensure the output is set when the signal is not at danger or if a move in the reverse direction is signalled.

Miscellaneous

There will always be miscellaneous functions which may be useful. Extra Controls and interlocks for various reasons or gimmicks such as sound effects, working level crossings or warning lights might be some of the extras that add interest to the model. A flexible system for configuring additional inputs and outputs would be a real benefit.

2.6 Summary

This chapter has set out the signalling that is required to be implemented. Chapter 4 develops these into the Project Requirements. The next chapter provides information on the Hardware system that provides the interface to the model railway.

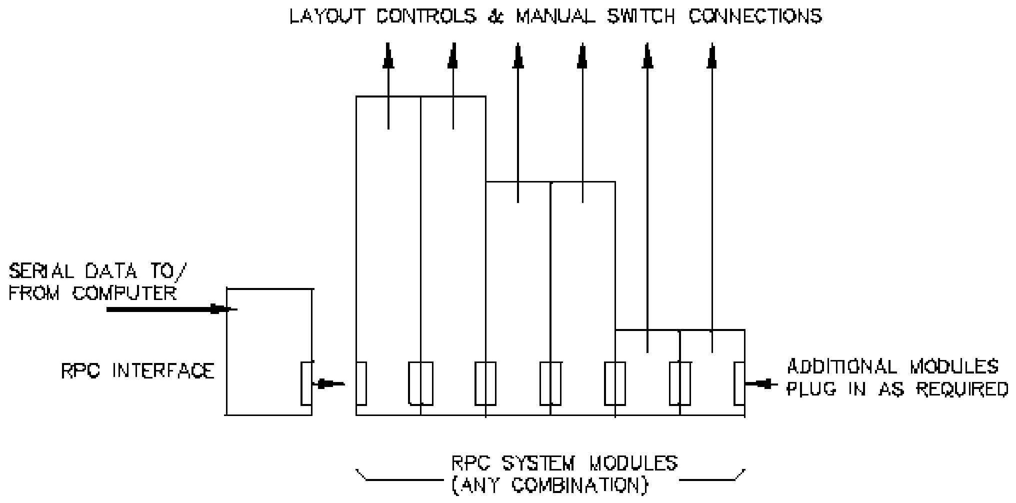
Chapter 3

Hardware System

3.1 Remote Panel Control System

Developed by the Model Electronic Railway Group

The scope of this project relates only to the software development. However, the software is ultimately being designed to integrate with a hardware system. Initially, this is limited by Objective 6 to the MERG Remote Panel Control (RPC) system and only in RS232 mode. However, the design should be such that it would be straightforward to change to a similar hardware system or alternative RPC interface.


LAYOUT CONTROLS & MANUAL SWITCH CONNECTIONS
SERIAL DATA TO/ FROM COMPUTER
RPC INTERFACE
ADDITIONAL MODULES PLUG IN AS REQUIRED
RPC SYSTEM MODULES (ANY COMBINATION)

• Diagram 3.1 MERG RPC System Stack Diagram © MERG

The RPC system (when running RS232 mode) is based around an RS232 serial connection to the PC. At the head of an RPC "stack" of modules is an RPIC Interface module based around a PIC microprocessor. This handles the serial communications with the PC and sends and receives data from plug in modules making up the stack.

Input and Output Modules are available and plugged in as required to suit user requirements. Key modules are the SRI4 and SRO4 32 bit Input and Output modules respectively. Other modules include Relay Output boards and importantly, the FTC Track Circuit board. This detects trains in sections for model railways based around a current sensor which is required as model railways use the running rails to power the trains and conventional relay track circuits can not be used.

The software needs to know the configuration to determine the range of Input or Output bits available to assign to devices on the screen synchronise with the hardware. Input and Output ranges are separate, i.e. there is an input bit 0 and an output bit 0 and these are independent.

MERG Technical Bulletins in the G16 series define the logic for this modules and standard aspect codes for multiplexed operation of signals.

There is a comprehensive serial protocol defined for PC – RPIC communication and this provides for individual bit, byte or whole system changes within a single message. MERG Technical Bulletin G16/4 defines this protocol and this is presented in Appendix A.

3.2 Horton Layout

The test bed for the software is the Horton Layout which the author has largely designed and constructed. Some statistics are presented here as a measure of a typical large layout's requirements. This will provide a reference point when analysing performance of the software and assists in the design of the user interface.

Size	8m x 3m (28' x 10')
Simultaneous train movements	6
Points	23
Signals	24
Routes	43
Track Circuits	39
RPC Modules	SRO4 x 3 DPR x 2 FTC x 5 SRI4 x 1

• Figure 3.2 Statistics for Horton (excluding old section of layout)

Further Details including RPC Bit allocation and a track diagram are to be found in Appendix B.

Beckenham and West Wickham MRC: http://www.bwwmrc.org.uk
MERG: http://www.merg.org.uk

Chapter 4 Design

4.1 Developing Requirements

This project is unusual in that there is a very clearly defined set of requirements which were known early on. The requirements are simply to work towards a solution that meets Objectives 1 to 6 as set out in Chapter 1. The detailed requirements are to implement as much of the functionality described in Chapter 2 as possible. The detailed explanation of relevant signalling is by far the best way of presenting what needs to be achieved.

4.1.1 Additional Functionality

In terms of functionality, a number of additional features were considered and the design seeks to implement these where possible or ensure that the design does not preclude them.

- Point Detection would allow input bits to provide feedback on whether points have actually moved.
- Intelligent response from the Interlocking would ensure that if a request was rejected, an explanation of why would be provided to the user. This is not provided on real signalling systems but would assist less experienced operators.
- A Train Describer would allow an identity to be associated with each train and track that train around the layout. This is of limited use on a model railway.
- Event Logging would allow a recording to be made of events that occur during operation of the system. A logical development would firstly be passive playback to view how the operating session went, and finally to active playback whereby once a sequence of actions was recorded, the system could repeat it and potentially relieve the need for operators.

4.2 Assessment of Options

Objective 6 presented within Chapter 1 sets out some limitations in order to be practical. The key decisions are that the system must be PC based under MS Windows utilising the RS232 interface to the RPC hardware system.

Objective 4 sets out the need for the system to be user configurable for different layouts. Objective 2 requires some careful attention with the User Interface design.

4.2.1 Software Tools

An early decision was made to use a modern development environment. This was primarily to familiarise the author with current software tools which is good experience but also to allow the simple development of a professional looking application. Several existing applications to work with the RPC system are outdated – some are even DOS based. I wished to have a 32 bit windows application. Well known and therefore well supported development tools were chosen – The author was inexperienced and needed the support of websites, forums, books and other documentation. This pointed towards Microsoft products.

A shortlist was drawn up of: -

- MS Visual J
- MS Visual C
- MS Visual Basic

Visual J, being based on Java was ideal for an object orientated approach. However, its support for Serial Port communication was limited. The software was to run on a stand alone PC where as Java pointed more towards a Server – Client environment.

The clear choice was between Visual C and Visual Basic. Again, the author's inexperience played a significant role. Having worked with VBA behind MS access, the author was more comfortable with VB. The project was considered to be sufficiently complex without the steep learning curve of some elements of Visual C. The memory management of Visual Basic was considered to be useful to a beginner as VB's "garbage collector" deals with freeing up RAM, helping to eliminate "memory leaks" which common in C programmes if not carefully understood.

Further research revealed that the current version of Visual Basic, Visual Basic .NET provided VB with almost the same functionality as C. The .NET framework provides for reuse of many key structures which are common across all .NET applications. .NET will be integrated into the next version of Windows, and until then, applications will only run on PCs with the .NET framework installed. The .NET framework is available free of charge from Microsoft and is redistributable.

Key Advantages of Visual Basic .NET

- Easy to Program and learn the language. Wide range of support books, websites, forums and documentation.
- Full support for Object Orientation including Inheritance, polymorphism and interfaces.
- Built in, efficient data storage types such as *ArrayList* and *SortedList*.
- Automated Memory Management and freeing up of dynamically allocated memory when no longer required.
- Good, simple graphical functionality which is essential for the GUI with specialist symbols.
- Built in serialization functions to serialize objects to file

4.2.2 Programming Philosophy

The choice between traditional procedural programming and Object Orientated design was an easy one to make. Railway signalling consists of a limited set of devices, many similar to each other. Object Orientation was an obvious solution. Each device becomes an object and the objects interact with each other.

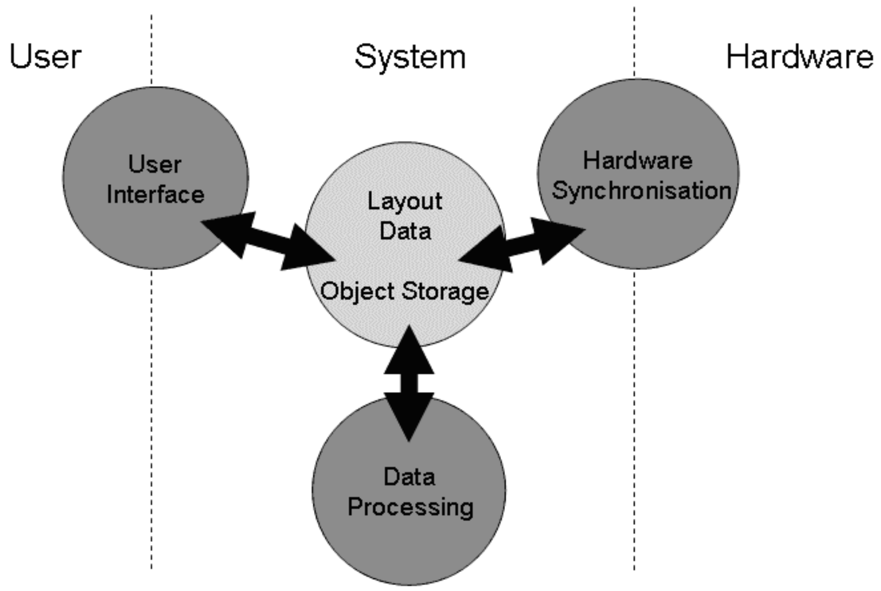
The approach is more flexible and allows for iteration of the design as understanding of the problem and programming techniques developed. The system instantly becomes more expandable, more flexible and simpler to understand.

4.3 System Fundamentals

It was quickly decided that there needed to be a central storage of all User Configured data. A database was considered but rejected as being unnecessary and over complicated and so a *LayoutData* class was developed to store the required data.

4.3.1 Multi Threaded Solution

After considering the Operate Mode requirements, a multi - threaded approach was decided to be the most straightforward to allow devices such as signals and track circuits to continuously update at the same time as the user was interacting with the user interface. At the same time, the hardware should be constantly synchronising with the software. So, there are three Operate and Test Mode threads: *GUI*, *DataProcessing* and *Hardware*, all communicating through the objects that make up the layout, which are stored within the *LayoutData* class.



• Diagram 4.1 Multi-Threaded Approach and Central Data Storage

Design Mode requires only the User Interface thread and the Layout Data. This design also accommodates the testing strategy very well. The Hardware thread can be coded and tested by the Hardware Test Utility and then integrated with the rest of the system to form Operate Mode which utilises all three threads.

4.3.2 Modes of Operation

There need to be at least two modes of operation. A Design Mode where users define the layout and interlocking and an Operate Mode where the system runs as a VDU based signalling control centre as described in Chapter 2. This concept is already adopted by at least three existing software packages for control of the RPC system and is the most logical method.

However, with the complexity of interlocking data, coupled with the fact that many layouts are large and often kept in storage when not exhibited, there is a need for an off line test of the interlocking configuration. If the user, having set up and configured the layout, had the ability to simulate inputs from the layout, any errors where data was valid but not what was intended could be rectified.

This would also be useful for training and more importantly, would be the only practical way to test the software functionality without the need for a large layout. Chapter 6, Testing explains the testing methodology in detail.

Therefore, there will be three modes – Design, Test and Operate. Only Operate mode will connect to the hardware.

A need has also been identified to test the layout wiring and electronics. The Hardware Test Utility should consist of a simple display of all input and output bits and the ability to set and clear individual bits. This will also form a key part of the Testing strategy.

4.3.3 User Interface

The User Interface has been considered as being fundamental to the system because the Operating mode relies on specific symbols to both display the status of the layout and allow the user to request operations on the layout. The whole screen, with the sole exception of the menu is therefore available for the *Signalling Display*.

The obvious solution for the Design Mode is to view the same graphical image as required when in Operating Mode. The layout can then be built up and amended as required using a what-you-see-is-what-you-get interface. The alternative approach would be to have some kind of text data format to be interpreted into a graphical display. This would make designing layouts difficult and not user friendly.

The Signalling Display

A decision was taken to split the Signalling Display into a grid of lots of small *tiles*. This is easier to manage than elements of differing sizes and it also gives way to creating a symbol set of bitmap images. The alternative approach of drawing the symbols would probably have led to a performance increase as less processing is required, however it was decided that the most straightforward approach should be taken, and this was to draw a set of bitmap images.

An example was found in a textbook of the User Interface for a Chess Game[1]. This was heavily modified to provide a grid of 80 x 64 tiles. This was evaluated based on the complexity of a typical large layout to fit on a screen with a sensible tile size of 16 x 16 pixels, being the smallest size to be able to draw a signal symbol and have user controls at a useable size.

The whole display would therefore fill a large screen running at 1200 x 1600 resolution. Scrollbars are provided for lower resolutions.

A symbol set was designed of 16 x 16 pixel symbols, each with a code and any tile could have its symbol changed to any of the symbols. Appendix C shows the symbol set and the codes used. Clicking on a tile would result in parameters identifying which tile had been clicked. One object only may be assigned to each tile, giving each object an *x,* y*,* and *symbol code*.

This is very important as this gives way to a central index of each tile in the grid, referencing the relevant objects from the store of object. There would have been significant problems linking to the correct objects if a system other than a grid was chosen.

In addition to objects that are related to a display tile, *Routes,* and the RPC Module Configuration are not directly related to the screen.

[1] Visual Basic .NET for Experienced Programmers, Prentice Hall : Fig 13.26

Menu Bar

It was decided that a Menu bar would be provided to give control to the users when designing and configuring layouts and to allow changes of mode, and exiting the software. This allows easy disabling of commands by setting the *Enabled* property.

Other options would have resulted in less space being available for the signalling display and this is unacceptable as the whole display is used as an overview of the layout to the operator. Floating windows for example, would obstruct the display.

Signalling Data

The direction for interlocking data to take is also fundamental to the way the system operates. The interlocking data which is linking all the types of device together as required could be based on user typed scripts, executed when called, as used by the Solid State Interlocker application. It was considered that whilst greater flexibility is gained by having, for example, signal aspects, based on an IF / THEN / ELSE structure, it would not be user friendly. Railway modellers are not necessarily computer programmers, and would rather deal only with signalling terminology.

For this reason, the objects have been designed to work with the minimum of information and required data is only of a signalling nature and inputted via standard windows controls, and not by any form of scripting.

Scripting would again benefit performance as scripts would only be run as required but it was decided to avoid it for simplicity, both in programming and for users setting up layout data.

Summary

The User Interface, featuring the signalling display, is at the heart of the system from the users point of view. The grid concept underpins the way the system references the Device objects and this is explained further in section 4.4.2.

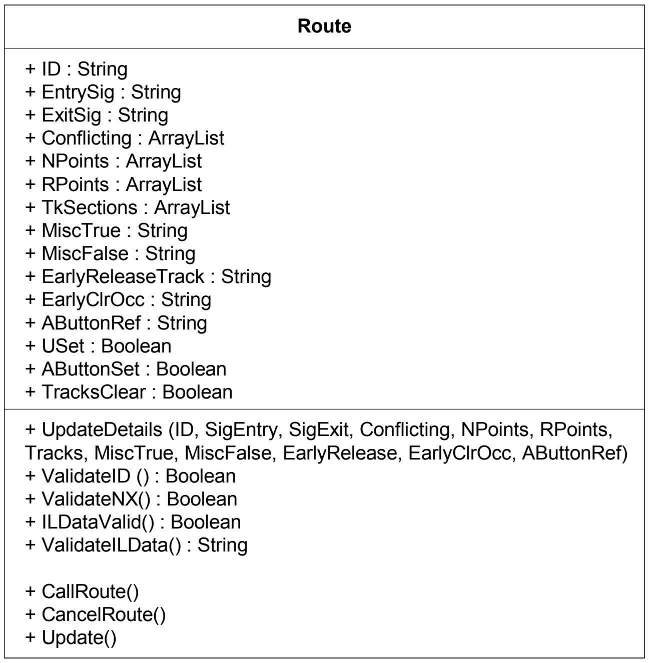
The Symbol Set can be found in Appendix C and examples and explanation of the elements of the User Interface are shown in Appendix D.

4.4 Detailed Design

4.4.1 Device Objects

The objects were modelled in UML. After some iteration the following Class diagram was decided. As will be analysed in the Conclusion, with the benefit of experience, it would not be done in the same way if repeated. It is appreciated that it may have helped to break down objects further but it was considered that the additional code required would probably exceed that used to repeat some blocks of similar code in multiple objects.

Diagram 4.3 on the following page shows the UML Class Diagram of Device Objects, showing the Generalisation that has been designed. Key Associations are also shown for the Point and Track associations. In addition to these objects, there is a Route Class. The Route Class is shown in Diagram 4.2 below. The Device Objects and Routes are stored within the Layout Data Class and their operation described further in subsequent sections.



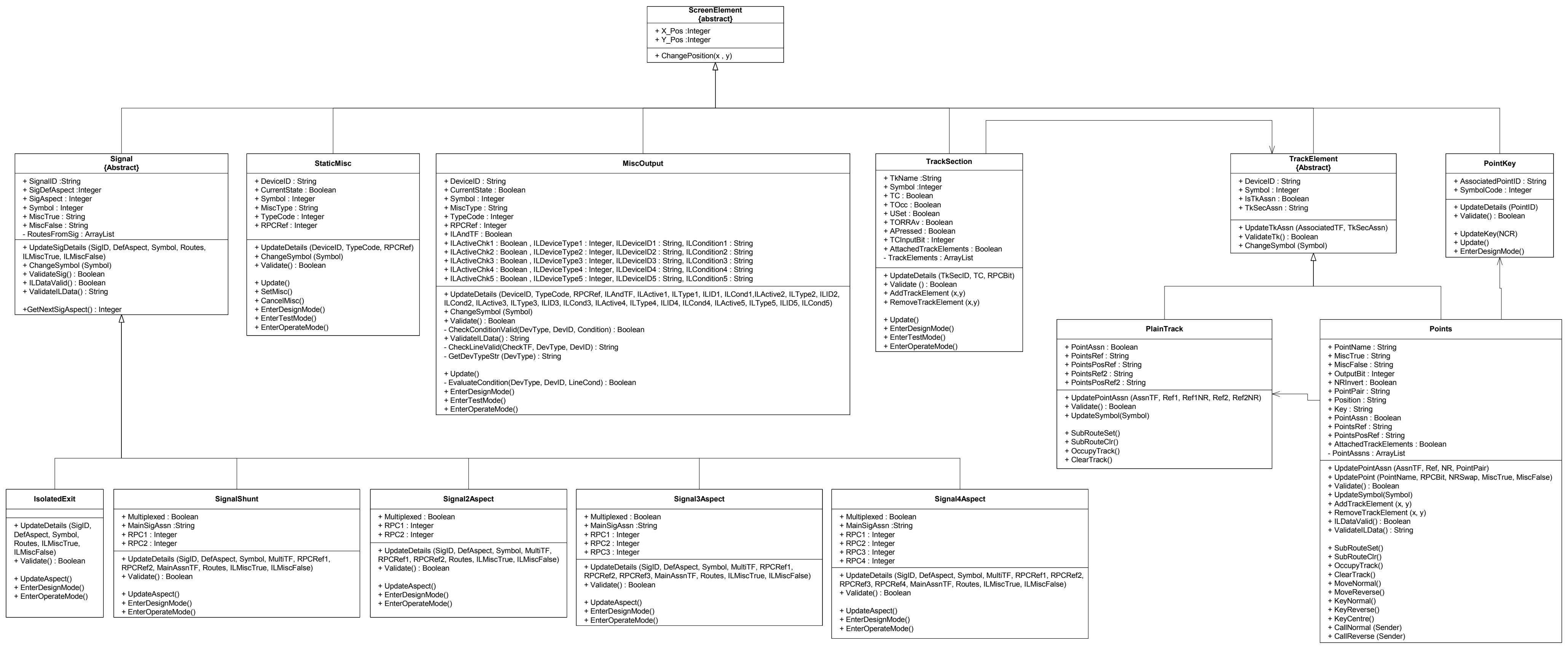
```
Route

+ ID : String
+ EntrySig : String
+ ExitSig : String
+ Conflicting : ArrayList
+ NPoints : ArrayList
+ RPoints : ArrayList
+ TkSections : ArrayList
+ MiscTrue : String
+ MiscFalse : String
+ EarlyReleaseTrack : String
+ EarlyClrOcc : String
+ AButtonRef : String
+ USet : Boolean
+ AButtonSet : Boolean
+ TracksClear : Boolean

+ UpdateDetails (ID, SigEntry, SigExit, Conflicting, NPoints, RPoints,
Tracks, MiscTrue, MiscFalse, EarlyRelease, EarlyClrOcc, AButtonRef)
+ ValidateID () : Boolean
+ ValidateNX() : Boolean
+ ILDataValid() : Boolean
+ ValidateILData() : String

+ CallRoute()
+ CancelRoute()
+ Update()
```

• Diagram 4.2 UML Class Diagram for Route Class



• Diagram 4.3 UML Class Diagram of Device Objects

4.4.2 Layout Data Class

A central data depository was planned to allow a single location to retrieve objects from. It was also logical to have data stored within a single class in order to use the .NET serialization functions to Save to disk and reconstruct from Disk.

The .NET framework provides a simple, dynamic, efficient object storage mechanism, known as an *ArrayList*. It is said to be a cross between an Array and a Linked List. An *ArrayList* is provided for each type of object. For the main Device Objects, a further *ArrayList*, *Devices* contains the *ArrayList*'s holding the objects. Routes objects are stored in similar *SortedList* structure to aid efficient retrieval by *RouteID*.

The Layout Data Class also manages the data retrieval by other objects and to do that, a number of indexes are maintained.

A key Index is the *DeviceIndex* which is an 80 x 64 x 2 array. Layer 1 maintains a value for *Object Type* which is a numeric value referring to the location of the Object Collection within the *Devices ArrayList*, or -1, indicating that position on the grid is empty, and hence available for objects to be created. Layer 2 of the Array maintains the position within each Object Collection of the specific Object Instance. This Index is essentially the link between the grid position on the user interface, which is used as the main reference point for Device Objects, and the actual location of the object in memory.

Devices which require them and Routes must have unique names to act as references and so indexes are maintained to record names currently in use.

A register of Hardware Bits allocated is kept to ensure that the number of bytes available can not be reduced (by changing the Module Configuration) while objects exist referencing a bit that would no longer be available. The maximum number of bytes available in the current hardware configuration is also stored.

A very large number of functions are provided to aid retrieval of data and updating of indexes from the class. Interfaces are also set up through functions provided in this class and the Operate Mode *DataUpdate()* functions are all in this class to call *Update()* functions of each object instance requiring continuous update.

The Data Processing thread, simply calls these Update functions on a regular basis. The easiest way of understanding this class is by reference to the comments included within the Source Code – data.vb is the file involved. Much of this class is very straightforward but it performs a vital function at the centre of the system, as diagram 4.1 shows.

Subsequent sections refer to some of these processes in more detail.

4.4.3 Design Mode

Design mode is the mode started in and finished in to ensure data is consistent when performing file operations. When returning to Design Mode, updating is removed and objects returned to a known state – the same state new objects are created in.

The user clicks on the signalling display and if the tile is empty, a selected symbol is displayed. This action enables the Insert Menu, allowing access to the Insert/Edit forms for device types. If the selected tile is occupied, only edit options are enabled, allowing parameters for that object to be amended or for the object to be deleted.

Setting up a layout is an infrequent operation, and the main interest in this application is the Operate mode. For this reason, the Design Mode is crude and basic, yet functional. It represents a considerable amount of coding time, most of which was spent designing and testing the Data Validation elements. Section 4.4.4 refers.

User Interface

Each object has a form containing all the controls required to obtain all the information for that object. The form also has its own, separate instance of the object in question, known as *tempobject*. There are two reasons for this. The first is to aid usability – whilst laying out a track for example, many adjacent cells may require the same type of object with similar parameters. The form objects are not disposed of after each use, they are simply hidden. When an update is complete, the *tempobject* data is copied into the relevant location in the *LayoutData*. So the next time the form is called, on an empty tile, the previous data is already present in the form. If the form is called from an occupied tile, the data is copied from the *LayoutData* to the *tempobject*.

The second benefit is to assist with ensuring that invalid data is not allowed in the *LayoutData*. If the new or altered data (temporarily stored within *tempobject*) is invalid, data validation prevents the data from being accepted and the data is not copied into *LayoutData*.

4.4.4 Data Validation

One of the most essential elements of the system is data validation. The purpose of Data Validation is very clear - to ensure the data is valid, complete and accurately cross referenced. It is designed to be robust enough to prevent illegal data to be accepted that would cause the system to crash or cause data corruption. It is not however designed to ensure the data is necessarily sensible or correct from a signalling point of view.

A two stage validation has been developed. The first stage must be passed before an object can be created or updated. The second is checked and a detailed error report generated if required but the data is accepted. In all cases, a relevant error message is displayed to the user.

All the second level checks are run again before changing modes and the user is prevented from changing modes if the checks fail. The reason for this two stage approach is to give more flexibility in entering data. If rules were rigidly enforced all the time, the user would have to create objects in precisely the right order to pass all the validation checks first time. This would become very frustrating.

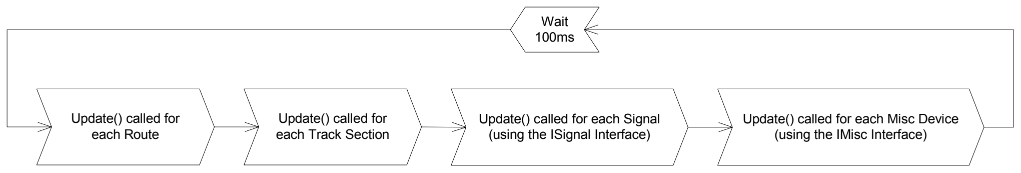
The two stage approach allows a reference to be made but for the referenced device to be created later.

An example of Data Validation Code is given in section 4.5.1.

4.4.5 Test and Operate Modes

Test and Operate modes are very similar to each other but work quite differently to Design mode. Before changing from Design Mode, the second level of data validation is checked and if successful, all devices are set up for the new mode. The Signal and Miscellaneous Devices interfaces are set up and Signals are set to their default aspect (as specified by the user). Symbols are changed to their default state and in Operate Mode, some symbols are hidden as they are not required (Track Sections and Hidden Miscellaneous Devices).

The Data Processing thread is then launched and this executes with the following sequence: -


Wait
100ms
Update() called for each Route
Update() called for each Track Section
Update() called for each Signal (using the ISignal Interface)
Update() called for each Misc Device (using the IMisc Interface)

- Diagram 4.4 Data Processing Thread

Each step, causes the *Update()* function of the individual objects stored within the *LayoutData* to be called and the objects have the necessary code to update as required. A semaphore is used to indicate when the Data Processing Thread is actually processing data and user requests made during this time, wait until it is complete before executing to avoid data corruption through multiple threads amending the same data. 100ms was considered to be fast enough to appear as though the system was behaving in Real Time. The Performance Testing in section 6.3 looks further at performance issues.

Where one change will have a knock on effect on another object, the latter object will simply update again at the next cycle of the Data Processing thread and to the user the delay will not be noticeable. This is particularly relevant to the Calculated Miscellaneous Outputs which evaluate their state based on other objects and significant logic could be built up if required using this type of device.

In Test Mode, there the Hardware Object is set up but no synchronisation takes place with the Hardware. Hardware Inputs are simulated by the user clicking the symbols on the screen, which are hidden and inactive in Operate Mode. The User Action calls the *SimulateInput (bit, state)* function in the Hardware Object and this changes bits in the Input Array (Refer to Section 4.4.6 Hardware). Hence, the Data Processing sees no difference to Operate Mode and this proves useful for Testing as described in section 6.1.

When leaving Test or Operate Mode, the Data Processing thread is stopped and Devices are returned to their Design Mode states to allow Design Mode to be consistent. Layout Data can only be saved to file in Design Mode. When leaving the application with data changed and not saved, the user is prompted to do so, the software switching itself back to Design Mode if required. File Open can only take place in Design Mode.

4.4.6 Hardware Class

The Hardware Class is responsible for all hardware aspects of the software. Essentially it maintains two arrays of Boolean values that are dimensioned according to the number of Modules connected. One form is provided to obtain this information and the maximum number of bytes is stored with the Layout Data. *ReadBit(bit)* allows the Input Array to be read back and objects poll this as part of their update routines. *SetBit(bit)* and *ClearBit(bit)* set bits in the Output Array.

The Hardware Object contains a synchronize function which uses RPC Type 0 messages to send and receive all bytes from the hardware to and from the arrays. RPC Type 3, 4 and 5 messages are also coded and these are used by the integral Hardware Test utility which provides a simple user interface to deal direct with the Hardware. The RPC Message formats are defined in Appendix A.

Connect and Disconnect functions prompt the user for which Port to use. The code for the Com Port Select form and the separate RS232 Class which provides serial communications are taken directly from an RS232 Tester application[2] found on the web and were reused. Once connected, a new thread is launched to perform the synchronisation at the same rate as the Data Processing thread.

4.5 In Depth Extracts

This section looks in detail at the design of two elements of the project; Points and Routes.

The Points example focuses on the Design Mode with samples of Data Validation and Object Creation and modification.

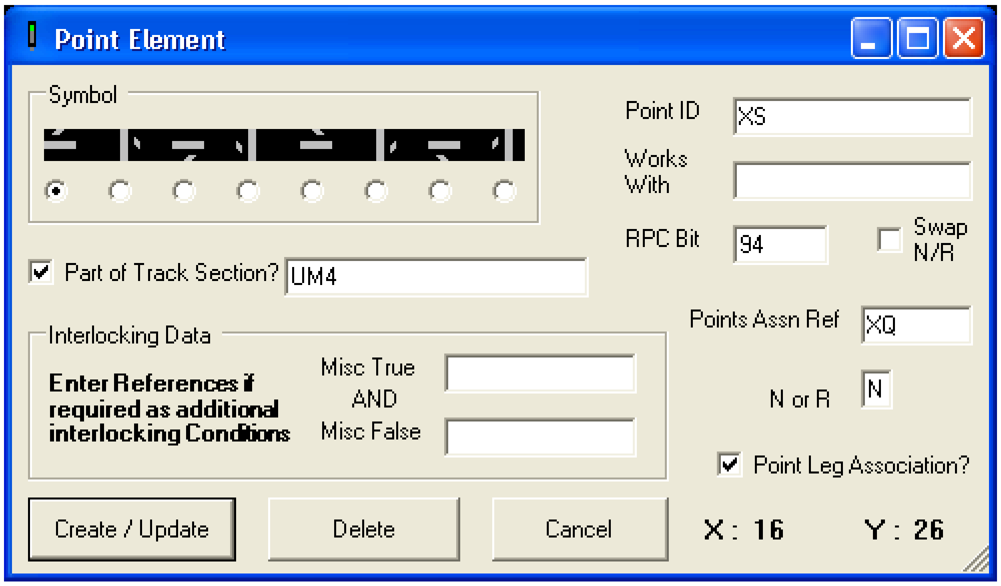
The Routes example shows how this critical element of the interlocking works in Test and Operate Modes. This shows the complex nature of the logic for interlocking and animation of the correct symbols on the screen.

[2] http://www.freevbcode.com/ShowCode.Asp?ID=4666

4.5.1 Points

Points Form

The Point Form used in Design Mode to obtain the data for the point is shown below.



Point ID: XS
Works With:
RPC Bit: 94
Swap N/R: ☐
Part of Track Section? ✓ UM4
Points Assn Ref: XQ
N or R: N
Point Leg Association? ✓
Interlocking Data
Enter References if required as additional interlocking Conditions
Misc True
AND
Misc False
X : 16 Y : 26

• Figure 4.5 Points Form

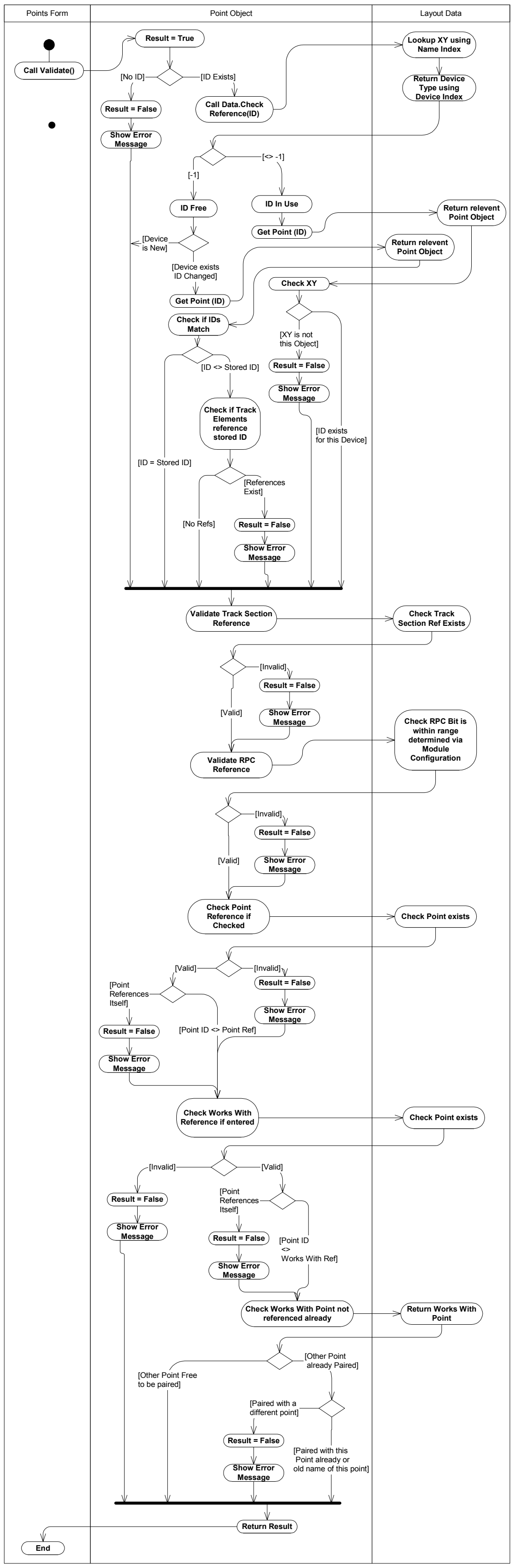
The form is largely self explanatory. The Track Section makes the reference with an electrically isolated track section on the layout. Many Point and Plain Track elements representing single tiles of the display are associated with a single Track Section. Interlocking data is used for additional interlocking based around Miscellaneous Devices to be added.

Works With is the Point ID of the point it works with if the point operates as a pairs with another point. The RPC Bit reference is the output bit that moves the points. Points are assumed to have the "Normal" direction as the horizontal or vertical track in the symbol – Checking the Swap N/R makes the diagonal the "Normal" direction.

Point Leg Association is required for animating the screen correctly. If checked, the reference given must be valid.

Data Validation

As data is changed, the *tempobject* is updated as described in Section 4.4.4.



● Diagram 4.6 UML Activity Diagram of Points Object 1st Stage Data Validation

Pressing Create/Update, the first stage is to validate the data, as held in the *tempobject*. For a Points Object, the Validation process is as shown in Diagram 4.6 (left). Other objects validate in a similar manner.

Following the successful completion of this 1st stage validation check, the second stage checks are made. These are for the interlocking data which is allowed to contain illegal references but must be fixed before leaving design mode. Warning messages are displayed to the user and the object created or updated by copying *tempobject* to the Layout Data Class.

At the same time, various indexes are updated and related objects may be updated. For example, the Works With reference would cause the reverse reference to be added to the other point.

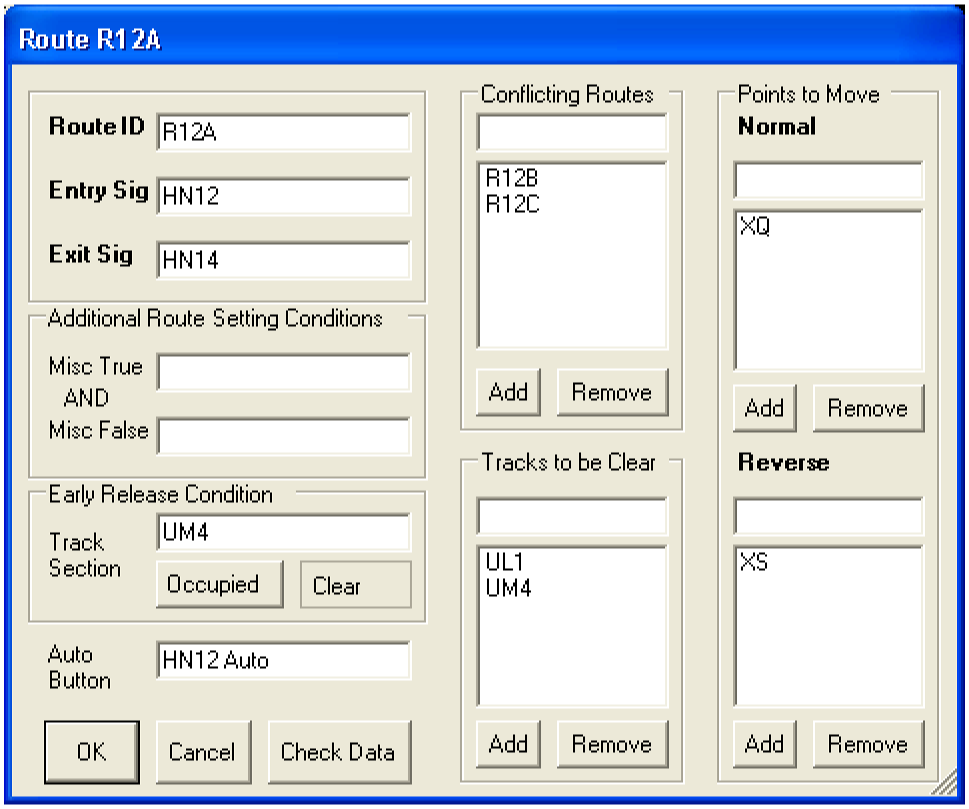
As can be seen, this section is the most complex in the project and accounted for a significant amount of development time. By ensuring only valid data is allowed and all possibilities have been covered, the

Test and Operate modes become straightforward and very few validation checks are needed during Operating, improving performance and adding reliability.

Validation code for each object can be found in the Source Code in the appendixes, in ScreenElements.vb

4.5.2 Routes

Route Objects underpin the signalling interlocking as described in section 2.3. The form is complex but straightforward if the signalling theory in Chapter 2 has been understood. The form is provided here as a reference whilst the Route setting operation is described for Test/Operate Mode.


Route R12A

Route ID: R12A
Entry Sig: HN12
Exit Sig: HN14

Additional Route Setting Conditions
Misc True:
AND
Misc False:

Early Release Condition
Track Section: UM4

Auto Button: HN12 Auto

Conflicting Routes
R12B
R12C

Tracks to be Clear
UL1
UM4

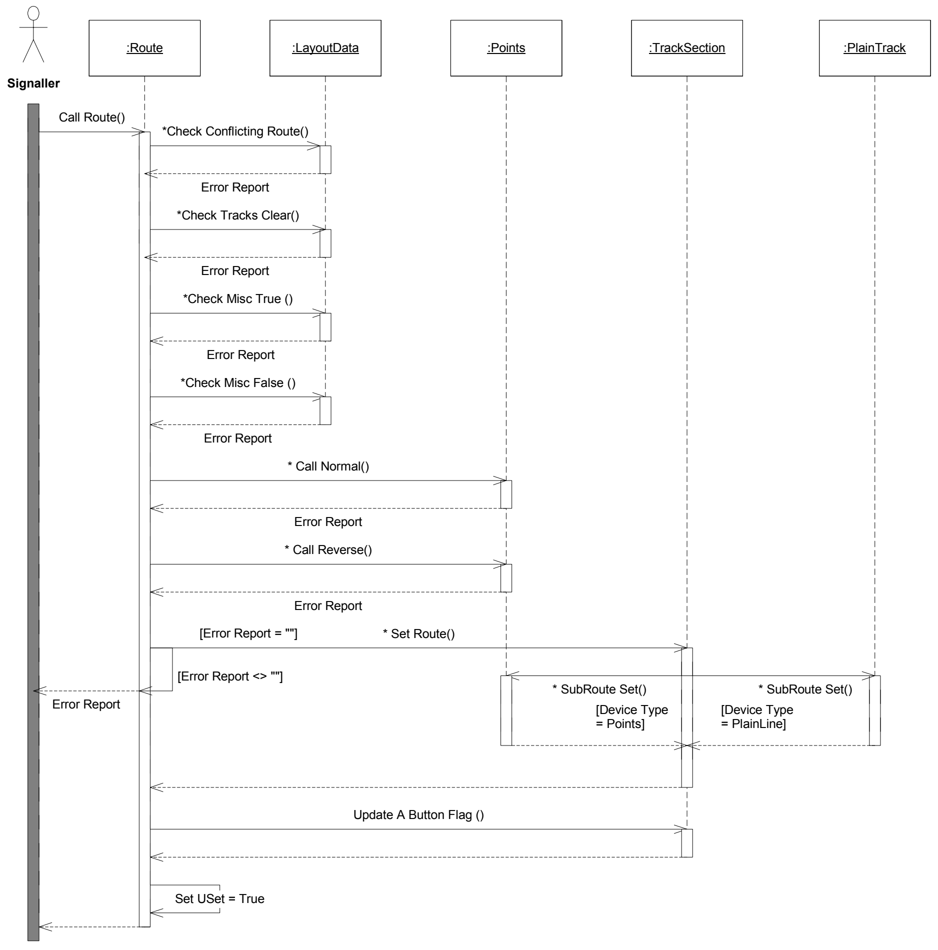
Points to Move
Normal
XQ
Reverse
XS

• Figure 4.7 Routes Form

The following pages show the operations of Route Set and Route Cancel, including the related objects. Much of this code relates to the animation of the tracks. Tracks with a Routes Set show in White, otherwise, they display in Grey and tracks occupied (by a train) in show in Red. However, the white (and Red while a route is set), only applies to the path through a Track Section that is set. This complicates the animation, which as will be seen, is controlled through the Track Section elements. Signals aspects are based on other signals and Routes and these are not shown here.

Route Set

The UML Interaction Sequence Diagram is shown in Diagram 4.8. At each stage until the Set Route call, an error report is added to for any errors encountered in the route checking and calling of the points. If the error report is empty, the route gets set, if not, the error report is shown to the user, giving feedback on why the route can't be set. This is an intelligent response from the interlocking, achieving one of the additional features in 4.1.1.



- Figure 4.8 UML Object Interaction Sequence Diagram for Route Setting

Route Cancel

Route Cancel works in a similar way to Route Set, but is much simpler. In addition, if an Auto Button is specified for a Route, cancelling the Route also cancels the A Button. The Code extracts that follow (from ScreenElements.vb) show how the Route Cancel is achieved.

```
Public Sub CancelRoute()
    Dim i As Integer
    For i = 0 To TrackSections.Count - 1
        Data.GetTKSection(TrackSections(i)).USet = False   [See Fig 4.10 below]
        Data.GetTKSection(TrackSections(i)).TORRAv = False
        If AButton <> "" Then
            Data.GetStaticMisc(AButton).CancelMisc()
            Data.GetTKSection(TrackSections(i)).APressed = False
        End If
    Next
    Me.USet = False
End Sub
```

• Figure 4.9 Code Extract for CancelRoute() from Route Class

```
'Clear Route
            Dim i As Integer
            For i = 0 To Me.TrackElements.Count - 1
                Dim xy As Point = CType(TrackElements(i), Point)
                Select Case (Data.GetDeviceType(xy.X, xy.Y))
                    Case 9 'Plain Track
                        CType(Data.GetDevice(xy.X, xy.Y), PlainTrack).SubRouteClr() [See Fig. 4.11 below]
                    Case 10 'Points
                        CType(Data.GetDevice(xy.X, xy.Y), Points).SubRouteClr()
                    Case Else
                End Select
            Next
```

• Figure 4.10 Code Extract for Setting USet Property of TrackSection to False(Not Set)

Figure 4.9 is executed by the Route Class when the route is cancelled. Figure 4.10 occurs for each TrackSection in that Route. The Track Section then passes this on to all the track elements that make up that section. These can be either PlainTrack or Points. Figure 4.11 goes on to show the SubRouteClr() function within PlainTrack.

```
Public Sub SubRouteClr()
    'Displays Route Clear
    If Data.GetTKSection(MyBase.TkSecAssn).TOcc = True Then
        'Track Occupied and Route Cancelled
        'Check if Track is Red
```

```
            'Leave Red
        Else
            If (MyBase.Symbol - 98) Mod 3 = 0 Then
                'Change White - Red
                MyBase.ChangeSymbol(MyBase.Symbol + 1)
                GUI.UpdateDisplay(MyBase.X_Pos, MyBase.Y_Pos)
            Else
                'Change Grey - Red (Flood Track)
                MyBase.ChangeSymbol(MyBase.Symbol + 2)
                If TORRInProgressFlag = False Then GUI.UpdateDisplay(MyBase.X_Pos, MyBase.Y_Pos)
            End If
        End If
    Else
        'Track Not Occupied and Route Clear
        If (MyBase.Symbol - 98) Mod 3 = 0 Then
            'Change White - Grey
            MyBase.ChangeSymbol(MyBase.Symbol - 1)
            GUI.UpdateDisplay(MyBase.X_Pos, MyBase.Y_Pos)
        End If
    End If
End Sub
```

• Figure 4.11 Code Extract for SubRouteClr() function of PlainTrack Class

This code shows the complexity of evaluating the symbols to be displayed to provide the correct colours on the screen to meet the signalling requirements. The design of the Symbol Set, shown in Appendix C is invaluable as it was structured in a logical manner. This reduced the complexity of the logic required here, allowing common rules to be applied for most sections to calculate the appropriate colour change, even though the symbols may be for different orientations of track on the display.

The use of extensive comments in the code to aid its reading and understanding is shown to good effect in these extracts.

4.6 Summary

This Design Section has finalised requirements and outlined the fundamentals of the design with the multi-threaded approach to aid development and testing. This was followed by the detailed design showing how the modes of operation work and outlining the Layout Data class at the heart of the system. The Objects were defined and an introduction given to how they interact with each other.

The In Depth Extracts have followed some key concepts in greater detail via UML diagrams and source code walkthroughs. Clearly, there is far more to this project than what can be covered in this report. The full source code and further examples of the User Interface can be found in the Appendixes.

The next section looks briefly at Implementation of the project and references the supporting documentation.

Chapter 5 Implementation

The Design was used, together with the Testing Plan set out in Section 6.1.1 to help form the Project Plan which has been presented in Appendix E. That appendix also includes the monthly progress reports and an assessment of how the implementation followed the plan.

Other supporting documentation has been placed in the appendixes including details of the wiring of Horton in Appendix B, MERG technical bulletins in Appendix A and Symbol codes in Appendix C.

Appendix D contains details of the user interface that was designed and gives an indication of how the software looks. Appendix G presents the source code, which is also supplied, along with the completed installation software on the CD-ROM at the back of Volume 2.

A Project Website was also set up to allow others to comment on the design or assist with testing. The Installation Software and other documentation are available for download at *http://homepage.ntlworld.com/dodonet/stephen/mrcc/*

With a software project, trying out or observing a demonstration of the finished software represents the best way of understanding the implementation of this design.

Chapter 6 looks at the Testing of the software, starting with the detailed strategy that was developed to integrate with the design to form a logical and workable project plan.

Chapter 6 Testing

6.1 Strategy

In line with real railway practice, testing was considered to be of critical importance. Reliability of the software was essential as prolonged operation was envisaged whilst operating the model railway at Exhibitions. This requirement was set out as Objective 3 in section 1.3.

With such a complex set of requirements and functionality, robust planning, design and testing was needed to ensure that as many operating scenarios as possible were tested in a controlled manner. Without a clear strategy for testing, it would become very easy to miss a bug or design flaw until it was too late, making it difficult to trace and time consuming to rectify.

The choice made early in Chapter 4 of an Object Orientated approach was a key part of the Testing Strategy in that it allows for iteration of the design and testing as the project develops, as opposed to the traditional “waterfall” approach.

As a result of this decision, testing was not left as an isolated activity to take place on the completion of the project. It was an integral part of the design process and testing helped to formulate the order in which the project was executed in order to minimize the risk of failure at the end of the process.

6.1.1 Testing Plan

The Testing Plan is broken into many layers which build up to a comprehensive test of the final product.

[A] Module Testing

Each Function or section of code was tested as extensively as was practical, as quickly after coding as possible. The Visual Studio Integrated Development

Environment (IDE) provides extensive syntax checking as the code is written and many other checks are made when the code is compiled.

Once any build errors had been rectified, that particular element of the code was executed to ensure functionality as planned. This required extensive and repetitive tests in some cases. These tests were not exhaustive however, due largely to time constraints, but were completed until a reasonable degree of confidence could be obtained.

[B] Development Order

The Project Plan (see Appendix E) was built around the testing strategy. The first stage of the design was the development of the System Fundamentals in section 4.3. Diagram 4.1 in Chapter 4 shows the Multi-Threaded solution whereby the project is broken into three threads (Hardware, User Interface and Data Processing) communicating with a central Layout Data object store.

The first section to be coded was the Hardware Interface. This was chosen as it would underpin the system in Operate Mode. Without this, the software would not work with the model railway layout. It was also considered to be a high risk for failure as a result of the use of the RS232 port and the implementation of a specified message protocol with the RPIC microprocessor.

The Hardware Interface included a built in Hardware Test Utility which synchronised with a screen display of each bit. Each Hardware output could be controlled and all bits read back from a pair of arrays within a Hardware Object. Extensive testing was carried out to the hardware to ensure it functioned as planned and failure mode tests were carried out on the serial link. Once complete, the Hardware thread could be bolted on to the other threads of the software in the knowledge that it had been tested and would work with the hardware when that stage was finally reached.

Design Mode was the next to be developed and involved the creation of the Layout Data class and various elements of the User Interface. Again, testing could be carried out using only the Layout Data and User Interface Thread.

The Test and Operate Mode Functions were then coded and the Data Processing thread created. Test Mode could then be tested using the Layout Data together with the User Interface and Data Processing threads. This allowed almost all the functionality of Operate Mode to be tested without the need for Hardware.

Finally, when tested satisfactorily, the already tested Hardware Thread was joined to Test Mode to create Operate Mode. This allowed tests to concentrate only on issues relating to the integration of all the components, as each had been tested in isolation in advance.

[C] User Interface Correspondence Testing

As the Design section makes clear, the User Interface is very important in this project. This extends beyond the signalling display to the dialogs in Design Mode which allow the creation and modification of device objects.

It is vital therefore to ensure that both of these accurately reflect the data that is stored within the Layout Data class at all times. The data visible on the screen has to be proved to be correct as it is being relied upon in subsequent tests. As a result, a number of tests were carried out to ensure that on viewing the properties of an object, the correct object was retrieved from the object store and all controls on that form were correctly updated to reflect the data from that object. Equally data entered had to be correctly stored in the Layout Data.

[D] Data Validation

Section 4.4.4 sets out the way Data Validation has been implemented. However, the reasons behind that design lie in this Testing Strategy. There are fundamentally two approaches to writing modules of code. The first is to ensure that all data passed to or processed by the function is validated before being processed, while the second assumes the data to be valid to start with. In many cases, the first is considered to be the best. However, for most of this project, the second approach was taken.

The reason for this is that the system is a closed system. It revolves around the Layout Data class which holds all the objects making up the user defined data. The plan is simply to validate data extensively in Design Mode to ensure that the data stored is valid and many cross checks are made. Data which does not affect the storage and creation of the object is allowed to be stored with errors in the Layout Data but the second stage of the two stage Data Validation ensures that the user can not leave Design Mode until these are corrected. The end result is that almost all of

Design and Operate Modes can operate without validation checks, confident that the data they use is valid.

Again, extensive testing was carried out by trying many combinations of invalid data. These were entered in each dialog in Design Mode to ensure all errors were recognised and appropriate error messages were returned to the user.

[E] Random Testing

In addition to the structured tests designed to test particular sections of code, random testing was carried out by individuals who were not aware of the software design. As the developer, it is very easy to always use the software as designed. It was felt that getting other people to try the software without a manual and simply directed to experiment with certain features would be a good test of unexpected scenarios.

This was particularly useful in the testing of the complex Design Mode where the Data Validation code was protecting the software from getting into a situation where it may crash. Data Validation code has to work by covering every scenario imaginable. Random testing is particularly useful in finding scenarios that just couldn't be thought of when the code was designed. A number of loopholes were corrected in this way.

Friends and family, with varying computing skills and railway knowledge were used and observed, although not aided, whilst using the software. In addition, a copy of the software was placed on the internet and members of the Model Electronic Railway Group invited to try it.

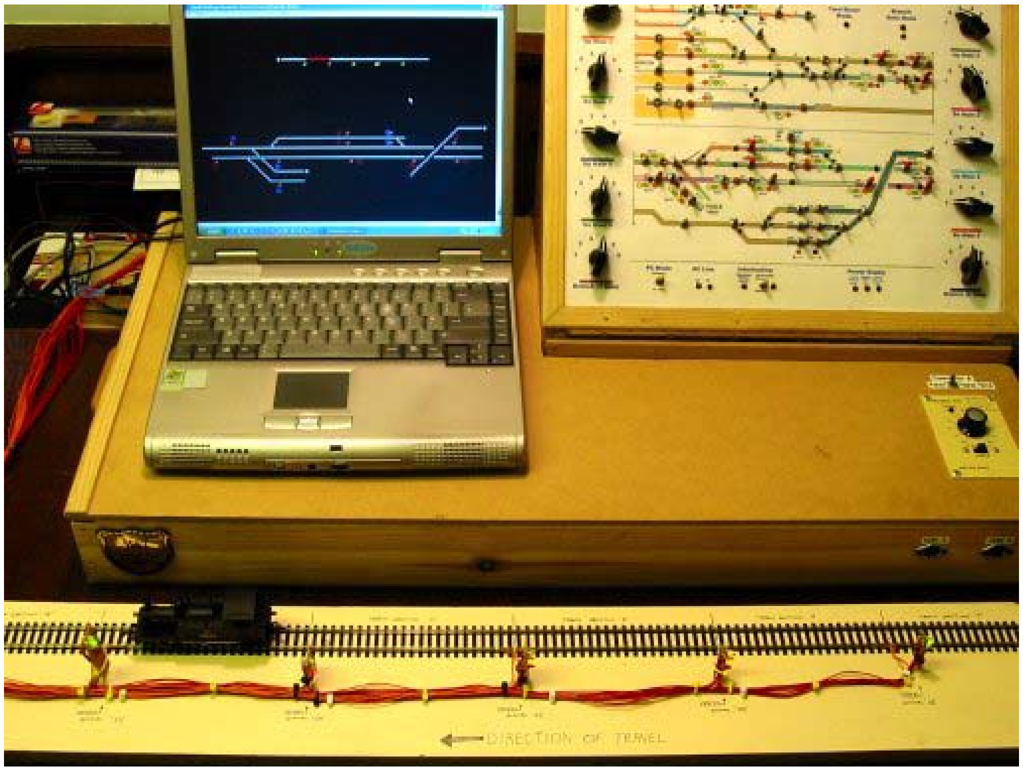
[F] Test Mode

It was identified early on that there was a need to test both the software functionality and operation, and also the user defined data, without the need to set up a complete model railway layout with relevant hardware. Horton, for example, is 24 square metres and setting it up is no easy task. The Test Mode as described in section 4.3.2 provides for testing without the hardware. Hardware inputs are simulated by user mouse actions on the screen.

This proved invaluable during development and for testing the Operate Mode functions. The Test Mode removes the need for significant hardware to be wired up and allows complex layouts or interlocking configurations to be tested virtually with no need to actually build or wire them. This is needed to test features that the test be layout, Horton doesn't have. Scenarios that wouldn't be possible can also be simulated in comfort at the PC saving considerable time.

[G] Demonstration Track

In order to test the Operate Mode of the software without setting up a full layout, the ultimate testing tool was created in the form of a small test track. The track is vastly over signalled with six track sections and five 4 – Aspect signals on a short length of single track.



• Photo 6.1 Demonstration and Test Track together with PC running Model Railway Computer Control Centre Software and Control Panel housing RPC Hardware

The test track, which is fully wired with the hardware system by small modifications to the Horton Control Panel, allows a train to run up and down operating track circuits with the software displaying its position and updating the signal aspects as required.

This is an ideal way to test the final Operate Mode and prove that the software really does work as designed with the hardware to provide a signalling control centre for a model railway.

The test track is a convenient way to test the performance of the software and also to investigate how the software copes with failure modes such as breaking the serial link to the hardware whilst operating.

6.1.2 Limitations

The primary limitation to the testing is that there are 5120 tiles on the signalling display, giving 5120 possible objects. There are 9 different object types or an empty square resulting in 5120^{10} combinations of objects. The data within each object contain many more permutations giving trillions of combinations. Clearly only a tiny fraction of these can be tested but the choice of tests is the key to testing such a project.

The other major limitation that must be stated is that the tests performed are logical ones – They ensure hopefully that the software is robust and reliable. They also make some cross checks on user entered data. Checks also ensure that most of the functionality and signalling described in Section 2 works correctly when the relevant data for the users layout entered. However, the software and the testing does not in any way ensure that the data entered is sensible or will work as intended. It simply helps to ensure that when the right data is entered, it will work. *Valid Data* is not necessarily *Correct Data* for the specific application of a product and the same applies to many real computer systems.

6.1.3 Summary

This comprehensive strategy has allowed a significant degree of confidence to be built up into the reliability and functionality of the software. With such a system, an exhaustive test is completely impossible but with a well designed testing strategy, a small amount of testing can cover a very large number of possible combinations.

By integrating the testing strategy into the design of the software, sections of the project can be tested as component parts before the final system is brought together. This minimizes the risk of the final product failing to achieve its objectives and allows iteration in the design process.

Multiple layers of testing built up to provide a significant testing effort, culminating in a full scale test track to permit full functional testing of the software.

6.2 Functional Testing

The testing plan described was followed throughout the development process. This section looks at the results of testing each element of the plan and gives examples of some of the structured tests which were used.

6.2.1 Module Testing

Each section of code was tested as it was coded in order to verify it had the desired effect. In many cases, immediate changes were made as run time errors occurred. Usually these were obvious. In other cases, the Debugging tools provided by the Visual Studio IDE were used to set breakpoints or monitor the state of variables and data stored. After iteration, all sections of code were believed to be functioning correctly.

6.2.2 Development Order

The approach proved worthwhile as later stages fell into place very quickly. Test Mode was coded quickly and largely worked first time and Operate Mode was also developed rapidly with minimal effort.

Tests revealed some problems with integration however. Whilst the multi-threaded approach was designed carefully, a number of additional semaphores were needed to prevent threads from clashing with each other. Many of these problems were timing related and only occurred occasionally. After testing had revealed problems, the debugging information was used to pinpoint the location of the error and a thorough mental walkthrough of the code carried out to identify the loophole.

For example, the update thread had a semaphore to indicate it was processing and the GUI was put in a loop until the processing was complete before making a user request. It was discovered that this check could be reached towards the end of the Update thread's sleep time. The loop would be passed as the Update thread was not processing but as it executed, the Update thread would wake up and clash. A second semaphore was required to provide the opposite check that the GUI was busy.

Mode changing was also a key area for testing. This included the requirement to switch to Design Mode on closing the application and ensuring the processing or hardware synchronisation was stopped in a controlled way during mode changes. Tests were carried out by requesting actions followed immediately by mode changes for example.

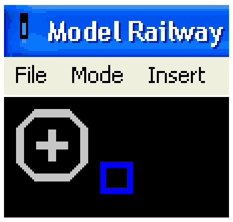
6.2.3 User Interface Correspondence Testing

As objects were created or modified, the debugger was used to pause execution to examine the data in Layout Data and check that the expected data had been changed. Problems were found with the Temp Objects (see 4.4.3) when the form displayed and updated with data from the Temp Object. However, as the data was copied into the form, the change to form controls caused an event to update the Temp Object behind for a group of controls, resulting in data being lost in the Temp Object. A *formlock* variable was used to prevent the problem.

To verify that each control was updated on viewing a Design form and that each control was stored in the layout data, a test was developed for the Plain Track dialog, the first to be coded.

Example Test

The layout in Figure 6.2 was created (it uses most symbol types for plain track). Data was then added to each whereby each field had changed from the adjacent tile and was documented. The Design form was then called up for each tile in turn, to ensure that the data displayed was 100% correct. This proves both storage and retrieval of the correct objects and the correspondence of the User Interface. Each property was then changed to a sequence and a further check made to ensure the update of the object worked correctly.



• Figure 6.2 Test Layout as part of User Interface Correspondence Testing

6.2.4 Data Validation and Random Testing

The rigorous testing with invalid data and the use of random testing to identify unexpected scenarios worked well. The data validation tests consisted of entering data that was designed to trigger each branch of the data validation code. For second stage data validation, other items would then be added as required such that the original interlocking data was now valid. A further check was made to ensure that the error had been removed from the list when it no longer applied.

A small number of loopholes were identified with random testing which would not have been found if this technique had not been employed. All faults found were rectified and retested.

6.2.5 Test Mode

Test Mode, which was identified as a requirement for users to test that their data was fit for purpose, proved invaluable in simulating real life situations without the need for hardware or physical wiring. It was ideal to test all aspects of the software and is a good training tool too.

Testing involved creating a section of real model railway (a section of Horton was used) and using the controls to set routes and mimic train movements. This allowed the testing of interlocking and track animation. Features like Route Release and Signal Aspects were also tested extensively, including unexpected and unrealistic scenarios.

One test revealed that when a track section went clear through points, the whole section would flash red momentarily as it cleared. This was identified to be a result of TORR (see section 2.3) rightly clearing the route as the track cleared. However, this occurred before the red indication had been removed and so parts of the track not on the set route saw the route cancelled and the track occupied and flooded in red briefly. A small modification prevented the change to red if TORR was in progress. The code which deals with this is shown in figure 4.11.

Numerous other minor faults were quickly rectified as a result of the decision to provide this testing facility as part of the software.

6.2.6 Demonstration Track

The demonstration track was a good final test for the software allowing a thorough and realistic test of actual operating conditions.

A number of problems were found whilst trying using the demonstration track. Firstly, the logic was wrong on Track Circuits, resulting in inverted operation. A simple modification was made.

The second problem was more subtle but at various times, it was found the hardware would freeze and require a reset before continuing. The archives of the MERG group were searched to reveal a similar problem had been reported by other members. The problem related to modern software techniques such as multi-threading and the interaction with the Windows operating system which can result in Windows delaying outgoing messages. If the software continues to read and then write a second message, it is possible for the input buffer of the microprocessor to get corrupted, causing it to lock up. Advice of MERG members was taken which resulted in modifications to the code to extend the timeout allowed by the software. Changes were also made to prevent sending subsequent messages if a timeout was raised by the software and delay until such time as the hardware would have timed out. In addition, a firmware upgrade was made to the RPIC microprocessor which is designed to improve the reliability of the “inter-byte” timeout on the hardware.

Problems were also experienced with some mode changes where some loopholes were found that could lead to a potential failure of the software. Some error messages were improved to give the user more guidance on what to do to recover the situation.

Tests were also made to ensure that failure conditions were dealt with. Tests involving power failure on the microprocessor and link failure, breaking the serial connection, were made and the software found to react appropriately.

6.3 Performance Tests

An important element of the software was for it to appear to be working in real time. This is especially important on model railways, where short track sections and proportionally fast trains result in less time for operators to make decisions.

6.3.1 Reaction and Response Times

After creating a substantial portion of the data for Horton and adding the test track to it (*demo.mrc* provided as a sample on the CD-ROM), tests were carried out in both Test and Operate Mode to asses the speed at which the software responds.

Using an Intel Pentium 4, 1.8 GHz machine, with 512 Mb RAM and Windows XP SP1, the software functioned very well. Graphics on the screen animated almost instantly although the colour changing of whole track section was visibly not an instantaneous action.

Reaction to events or requests, whether by hardware or simulation, was again almost instantaneous, such that meaningful timings were not possible. A limitation of the hardware was noted in that the hardware for track circuits takes about 200ms to clear detect a clear track and as a result, running a train fast on the test track with very short sections can result in state where a track section shows occupied after it has cleared for a very short time.

Using an AMD K6, 380 MHz machine, with 64 Mb RAM and Windows 2000, reaction was again good but delays were noticeable in changing symbols on the screen, especially with long track sections. This is likely to be partly a result of retrieving these from disk each time and performing some graphics processing to obtain the correct symbol.

6.3.2 System Resources

Whilst using the Pentium 4 machine, the software was seen to have a continuous requirement of less than 1% CPU usage in Operate mode when continuous processing is taking place. This rises momentarily when a user makes a request such as setting a route. Memory usage was steady at about 30Mb although this fluctuates as the software allocates memory and the garbage collector frees unused memory. Forums suggest that about 29Mb is usually eaten by the .NET framework and so this is normal. Future versions of Windows will include the framework and will result in much more efficient use of memory, with individual applications not showing such high usage.

On the older machine, CPU usage was maintained at about 20%. This is poor and shows the amount of processing power used by the application. It is likely that a significant part of this is a result of the high number of type conversions being carried out and some inefficient coding of the data storage and retrieval of my software. This is addressed in Chapter 7.

Point Keys

Whilst testing the software, the CPU and memory usage were monitored using the Windows Task Manager. The importance in doing this was demonstrated when it was observed that the addition of point keys to a layout resulted in a massive hit on performance in Test and Operate Modes. On the newer machine, CPU usage reached 30% and memory was seen to rise continuously with time.

It was found that when coding the Point Key's *Update()* function, no check was made to see if the symbol had to be changed – it was redrawn at each cycle of the Data Processing thread. This was a minor error but had severe impact on performance.

6.3.3 Hardware Requirements

Microsoft state the minimum requirement for running applications on the .NET framework as an Intel Pentium 90Mhz processor; Windows 98, ME, NT4, 2000 (with latest service pack) or XP; 32Mb RAM with 96Mb recommended. The framework requires 70Mb of disk space (160Mb during installation); 800x600 graphics at 256 colours; a mouse and Internet Explorer v5.01 or later.

Model Railway Computer Control Centre requires just 700kb of disk space and, as the test have shown, a modern processor and more RAM gives significant benefits.

6.4 Summary

The application of a robust testing strategy and continuous testing as part of the development process has lead to a reliable, functional application that meets most of the original requirements.

The final chapter evaluates the project and looks at what has been achieved and what elements could have done improved.

Chapter 7 Conclusions

7.1 Achievements

The project has been a great success. A working application has been completed, testing and is working, fulfilling the original aims and objectives set out in chapter one.

Looking back to the requirements that were set out at the start of chapter four, most of the signalling functionality has been included and is working as planned. Beyond the basic functionality, one of the additional requirements that was identified has also been achieved – that of an intelligent response from the interlocking when a request is rejected.

The final application has also been completed largely to the original project plan and has been finished on time at a steady pace throughout. The good planning which went into the development of the plan and the integration of the Design with the Testing strategy has also paid off. Risky areas of the software such as the hardware interface were tackled first to give maximum time to rectify any problems.

Equally, the rigorous approach to testing at all stages of the project has captured errors as they were coded, at an early stage, making the task of solving them more straightforward. Testing of the threads of the project in isolation and then integrating them in a controlled manner has further simplified the fault finding actions where problems have occurred.

In designing and developing the application, a much greater appreciation of the benefits of the Object Orientated programming philosophy has been gained. Theoretical concepts have been taken forward into a practical solution for a real life, complex object problem. After working with the initial object model, and on discovering the power of interfaces in order to implement polymorphism, it was realised that it was a very useful tool indeed. A great deal of code for the aspect sequencing in particular was saved by using this approach.

The project has proved a useful vehicle for developing the project management skills and discipline required to understand and bring together many subsections of a complex problem into a single, working system. With approximately 15,000 lines of code, this was a very large project to undertake, given the authors limited previous software experience.

The author has gained significantly from the exercise. Not only has a useful and working application been developed, but a good appreciation and understanding of a major, modern, object orientated programming language has been obtained.

7.2 Critical Review

With the benefit of software experience that the project has provided, and a degree of hindsight, it is possible to identify areas of the project that could have been done better.

7.2.1 Missing Functionality

Of the basic signalling outlined in chapter two, the only significant omission was that of an automatic signal. This was in fact largely due to an oversight which was not identified early enough to easily rectify. Controlled signals, with Auto buttons have been included and the data can be worked in such a way as to provide the functionality of an automatic signal although there are some minor drawbacks.

A number of the more obscure features, such as junction indicators and ATP relays have not been addressed individually but the use of two types of Miscellaneous device has given the software a great deal of flexibility for ingenious users who understand how to manipulate the data to their advantage.

7.2.2 Data Format and Version Problems

A decision was made to abandon a planned structured data format to store objects on disk. A structured format, such as XML would have been developed and it would have been human readable. However, to save time, the .NET serialization functions were used to perform a binary serialization. Whilst this was very straightforward and fast to implement, it introduced a limitation.

If the Object model is amended or additional properties added to an object, a serialization saved using the old model, can not be deserialized into the new model. This presents a limitation to future development of the application as complex layouts that had been created, would have to be recreated from scratch. If a structured data format was used, additional properties could be added, but an old file could still be open but with no data for the new properties.

7.2.3 Graphics

The basic structure of the graphics code was based on an example of a Chess Game GUI in a textbook (see section 4.3.3). This greatly assisted with getting the graphics functioning, allowing time to develop other areas of the software.

However, the approach resulted in some limitations. Firstly, in design mode, if an object is selected, there is no identification of which tile is selected. If the tile is empty, a selection symbol is displayed but if a tile is occupied, you can't replace the graphic with selected because you would not be able to see the original symbol. A solution would be to create a second, transparent layer of graphics over the original signalling display to display the selection symbol.

As the graphics are based on 16x16 pixel tiles, there is no method for adding text labels to the signalling display. Solutions could include displaying text on the proposed second graphics layer, or perhaps adding the labels as "tool tips" as the mouse is hovered over the symbols.

When the Performance Testing was conducted (see section 6.3), it was obvious that there was a delay incurred drawing tiles of the signalling display. On investigation, the graphics symbols are stored on disk. A single file, *symbols.png* holds all the symbols in a row as a single graphic. Every time a tile is changed, the file is accessed and the correct symbol retrieved through a graphics function from the larger image. This is likely to be the cause of the delay. The solution would be to load all the graphics symbols into memory on startup, including the processing to split each symbol from the single image.

7.2.4 Object Model and Retrieval

With improved understanding of the power of Object Orientation and the functionality provided under .NET to implement OO theory, a much improved and simplified object model could be created. In many cases, repetitive code was required which was a clear sign that the object model was deficient. Signals for example didn't require separate objects for each type.

Point Associations

Some sections of the model should have been broken down further. Point Association which is used to correctly animate track sections based on the settings of points within a track section should have been separated from both the Plain Track and Points objects into a single shared object. This would have allowed the validation of the Point Association to be required only in a single object, rather than two. It would also give unlimited flexibility to adding further Point Associations for complex track layouts. The existing design allows only for a fixed number for each track section, which has been identified as being inadequate.

Object Retrieval

Reviewing the final code, it is obvious that there is a lack of consistency in the object retrieval from the *LayoutData* object where all other objects are stored. Many functions are used to retrieve objects and these together are inefficient. Different types of objects are retrieved in different ways and much of the data validation is carried out by the Design Forms, and not by the central data store – within the *LayoutData* object. Data Validation involving other objects should be carried out by *LayoutData* and not outside, as this results in a large number of Type Conversions (the *CType* keyword). Much of the Operate Mode functionality suffers from similar problems

The problems have come as a result of developing the software at the same time as learning the language. Later parts of the code, are much more efficiently coded, but still have to work with earlier structures. The solution to this problem would be a fundamental redesign of the *LayoutData* object. This underpins the operation of all aspects of the software and would be a major exercise.

7.3 Future Enhancements

A number of future enhancements to the software have been identified, which are practical additions to add functionality and address some of the problems identified in previous section. A number of these will be implemented by the author before the software is suitable for taking full control of the Beckenham and West Wickham MRC's Horton layout (see Appendix 2).

Automatic Signals

Automatic Signals will be added to the software, probably by adding an additional Boolean value to the Signal Object. This would restrict the number of Routes from the signal to one in Design Mode. In Operate Mode, the single route given, would be set automatically and Route Cancel inhibited.

Symbols

The Symbols will be accessed from file, processed and stored in memory on starting the software. Symbol changes will simply require retrieval from memory and not from disk, with no graphics processing. This should give significant performance gains, especially on older machines.

Data Logger

A data logger with playback facility could be added relatively easily to the software. This feature was identified and described as an Additional Feature in Chapter 4.

RS485 Multi-drop Support

The RPIC module and the RPC hardware system can be configured using an RS485 Multi-drop protocol, rather than RS232. The RPC System Overview in Appendix A explains this mode further. Changes would be required to the Hardware object to support the protocol and changes made to the RPC Bit References for each device to allow the entry of a Processor Identifier. This mode of operation is used by many MERG members to save physical wiring and would give the software a wider potential user base.

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http://www.google.com

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Other Documentation

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G16/3 RPC System Overview

Gordon Hopkins

Model Electronic Railway Group, 1996

Issue 1

(Reproduced in Appendix A)

G16/4 RPC Interface Specification

Gordon Hopkins

Model Electronic Railway Group, 2001

Issue 2

(Reproduced in Appendix A)

G16/5 RPC Remote Panel Interface PIC Module

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G16/6 RPC Double Pole Relay Module

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Model Electronic Railway Group, 1997

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G16/8 RPC Floating Track Circuit Module

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Issue 1

G16/16 RPC Multiple Aspect Signal Driver Module

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G16/19 Shift Register Input 4 Bytes Module

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Model Electronic Railway Group, 1999

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G16/22 Serial Communications and Shift Registers

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Model Electronic Railway Group, 1999

Issue 1

Railtrack Standards

IECC Operating Specification for Signalling Control and Indication Purposes

RT/E/S/17504

Railtrack PLC, 2001

Issue 2

Appendix A

RPC System Overview

The following Model Electronic Railway Group (MERG) technical bulletin G16/3 explains the philosophy of the MERG RPC system. This is for background information on the hardware system.

The technical bulletin was written by MERG Member, Gordon Hopkins.

G16/3 Page 1

RPC PC – RPIC Interface Specification

The following Model Electronic Railway Group (MERG) technical bulletin G16/4 details the communications specification with the hardware system. Only the RS232 mode has been implemented in this software.

The technical bulletin was written by MERG Member, Gordon Hopkins.

Appendix B

Horton Layout

Horton is a layout of the Beckenham and West Wickham Model Railway Club. Full details and photos of the layout can be found at http://www.bwwmrc.org.uk

The following pages show the layout information and track diagram, followed by the RPC Bit allocation. The latter is a vital reference document as to the wiring of the modules within the Control Panel.

Sample Layout File, Horton.MRC provided on the CD-ROM at the back of Volume 2, is an extract of this layout and is set up to work with the RPC Bit allocation shown here.

The Testing of Operate Mode was carried out to the Horton Control Panel as described in the Testing Section.

Horton Layout Information – Page 1

Horton Layout Information – Page 2

Horton RPC Bit Allocation – Page 1

Horton RPC Bit Allocation – Page 2

Horton RPC Bit Allocation – Page 3

Horton RPC Bit Allocation – Page 4

Appendix C

Symbol Set

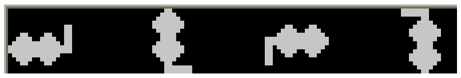
The symbol set was carefully designed to provide for all the symbols needed to represent each type of device in each possible state combination.

They were designed to fit together to make up a larger image and numbered logically to allow algorithms to remain the same for different orientations for example.

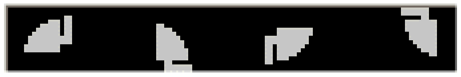
Each symbol is a 16 x 16 pixel bitmap image.

All were created as one .PNG file (2560 x 16 pixels to hold 160 symbols).

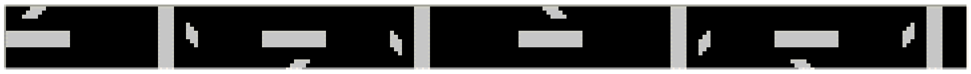
Symbol Types



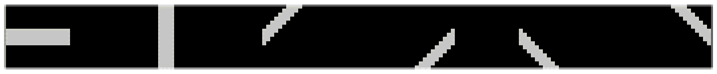
S1 S2 S3 S4



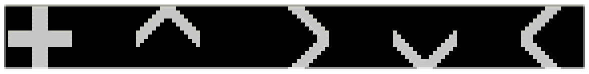
S5 S6 S7 S8



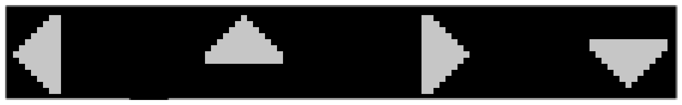
P1 P2 P3 P4 P5 P6 P7 P8

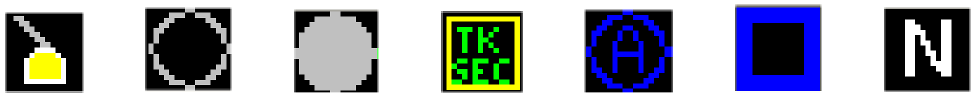


T1 T2 T3 T4 T5 T6



D1 D2 D3 D4 D5


X1 X2 X3 X4



M1 M2 M3 M4 A1 Z1 K1

Symbol Codes

Signals		Code			Points	Code		Track	Code		Misc.	Code
S1	Grey	0	P1	N	All Grey	36	T1	Grey	100	M1	Off	133
S1	DGrey	1	P1	N	All Red	37	T1	White	101	M1	On	134
S1	Red	2	P1	N	Route Set	38	T1	Red	102			
S1	Yellow	3	P1	N	Route + Occ	39				M2	Grey	135
S1	DYellow	4	P1	R	All Grey	40	T2	Grey	103	M2	Green	136
S1	Green	5	P1	R	All Red	41	T2	White	104	M2	Red	137
			P1	R	Route Set	42	T2	Red	105	M2	Yellow	138
S2	Grey	6	P1	R	Route + Occ	43						
S2	DGrey	7					T3	Grey	106	M3	Grey	139
S2	Red	8	P2	N	All Grey	44	T3	White	107	M3	Green	140
S2	Yellow	9	P2	N	All Red	45	T3	Red	108	M3	Red	141
S2	DYellow	10	P2	N	Route Set	46				M3	Yellow	142
S2	Green	11	P2	N	Route + Occ	47	T4	Grey	109			
			P2	R	All Grey	48	T4	White	110	M4	Tk Section	143
S3	Grey	12	P2	R	All Red	49	T4	Red	111	M4	TC Clear	144
S3	DGrey	13	P2	R	Route Set	50				M4	TC Occ	145
S3	Red	14	P2	R	Route + Occ	51	T5	Grey	112			
S3	Yellow	15					T5	White	113	Auto Button		
S3	DYellow	16	P3	N	All Grey	52	T5	Red	114	A1	Manual	146
S3	Green	17	P3	N	All Red	53				A1	Auto	147
			P3	N	Route Set	54	T6	Grey	115			
S4	Grey	18	P3	N	Route + Occ	55	T6	White	116	Exits		
S4	DGrey	19	P3	R	All Grey	56	T6	Red	117	X1	Grey	148
S4	Red	20	P3	R	All Red	57				X1	White	149
S4	Yellow	21	P3	R	Route Set	58	D1	Grey	118			
S4	DYellow	22	P3	R	Route + Occ	59	D1	White	119	X2	Grey	150
S4	Green	23					D1	Red	120	X2	White	151
			P4	N	All Grey	60						
S5	Grey	24	P4	N	All Red	61	D2	Grey	121	X3	Grey	152
S5	Red	25	P4	N	Route Set	62	D2	White	122	X3	White	153
S5	White	26	P4	N	Route + Occ	63	D2	Red	123			
			P4	R	All Grey	64				X4	Grey	154
S6	Grey	27	P4	R	All Red	65	D3	Grey	124	X4	White	155
S6	Red	28	P4	R	Route Set	66	D3	White	125			
S6	White	29	P4	R	Route + Occ	67	D3	Red	126	Black Tile		
										Z1	Black	156

S7	Grey	30
S7	Red	31
S7	White	32
S8	Grey	33
S8	Red	34
S8	White	35

P5	N	All Grey	68
P5	N	All Red	69
P5	N	Route Set	70
P5	N	Route + Occ	71
P5	R	All Grey	72
P5	R	All Red	73
P5	R	Route Set	74
P5	R	Route + Occ	75
P6	N	All Grey	76
P6	N	All Red	77
P6	N	Route Set	78
P6	N	Route + Occ	79
P6	R	All Grey	80
P6	R	All Red	81
P6	R	Route Set	82
P6	R	Route + Occ	83
P7	N	All Grey	84
P7	N	All Red	85
P7	N	Route Set	86
P7	N	Route + Occ	87
P7	R	All Grey	88
P7	R	All Red	89
P7	R	Route Set	90
P7	R	Route + Occ	91
P8	N	All Grey	92
P8	N	All Red	93
P8	N	Route Set	94
P8	N	Route + Occ	95
P8	R	All Grey	96
P8	R	All Red	97
P8	R	Route Set	98
P8	R	Route + Occ	99

D4	Grey	127
D4	White	128
D4	Red	129
D5	Grey	130
D5	White	131
D5	Red	132

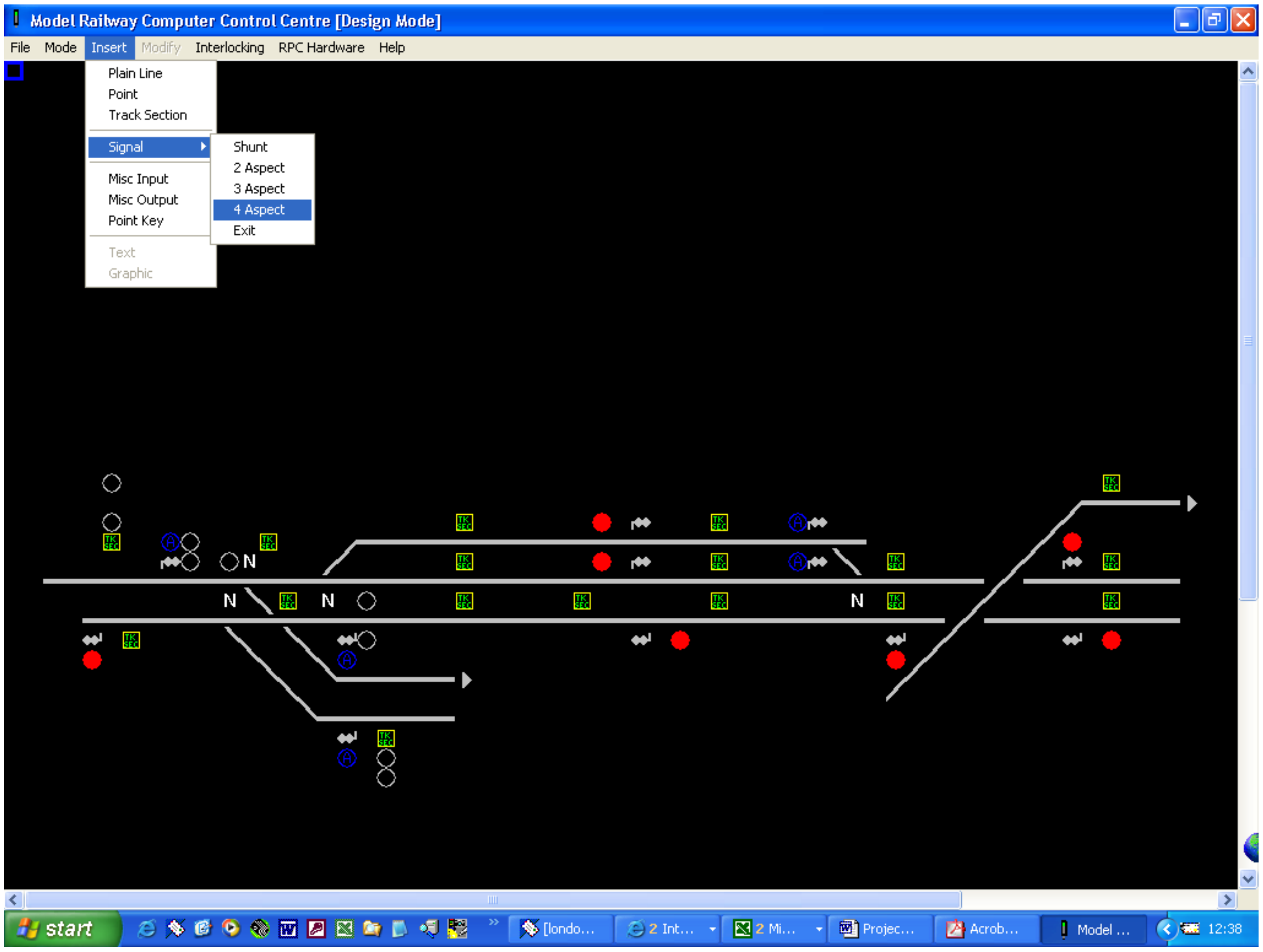
Z1	Black Outline	157
Point Keys		
K1	Normal	158
K1	Reverse	159

Appendix D

User Interface Samples

Section 4.3.3 explains the theory behind the elements of the User Interface. Examples are given here, together with an indication of their use and purpose. A full User Manual has not been written as part of this project.

Main Screen

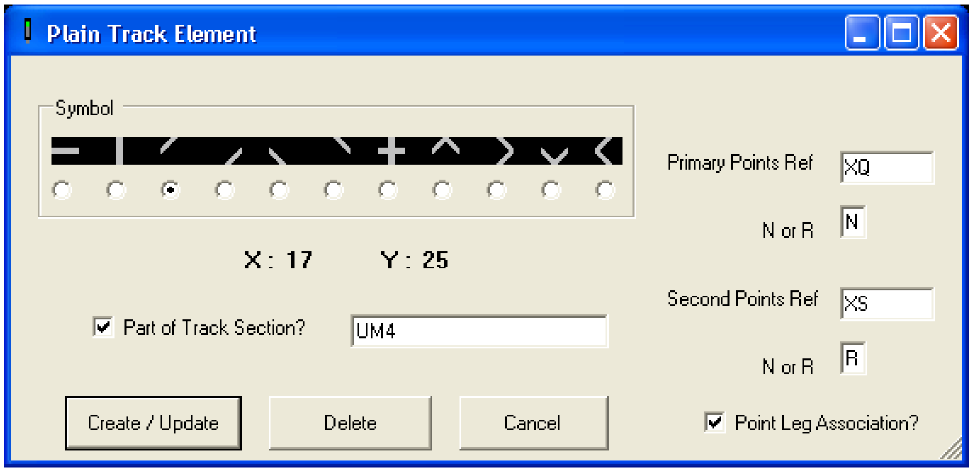


• Figure D.1 Main Screen in Design Mode showing Menu based commands and WYSIWYG Interface.

Design Mode Forms

In Design Mode, the user uses the mouse to select a tile to work with. If empty, the tile shows a selected symbol (a blue square as shown top left in figure D.1 on the previous page). The Insert or Modify menus are then available as required to Insert devices or modify or delete existing ones. A selection of Design Mode forms are shown in the following pages and these provide the opportunity to enter or view all stored information about the layout.

In addition, the Routes Table on the Interlocking Menu allow Routes to be defined.

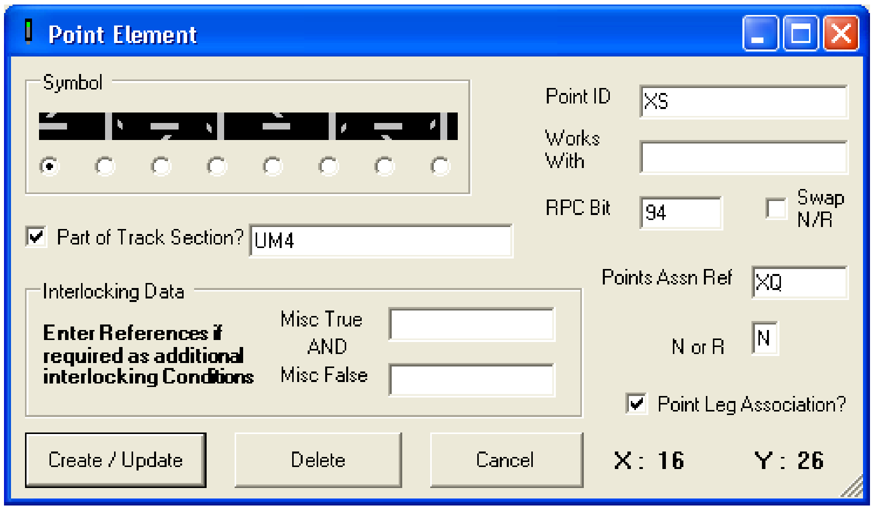


X : 17 Y : 25

Part of Track Section? [✓] UM4

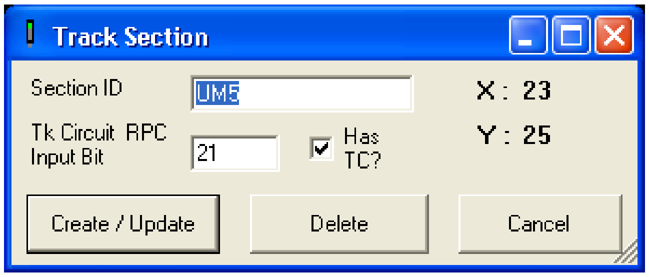
Primary Points Ref: XQ
N or R: N
Second Points Ref: XS
N or R: R
Point Leg Association? [✓]

• Figure D.2 Plain Track Form



Point ID: XS
Works With:
RPC Bit: 94
Swap N/R [ ]
Part of Track Section? [✓] UM4
Points Assn Ref: XQ
N or R: N
Enter References if required as additional interlocking Conditions
Misc True AND Misc False
Point Leg Association? [✓]
X : 16 Y : 26

• Figure D.3 Point Form



Track Section

Section ID: UM5

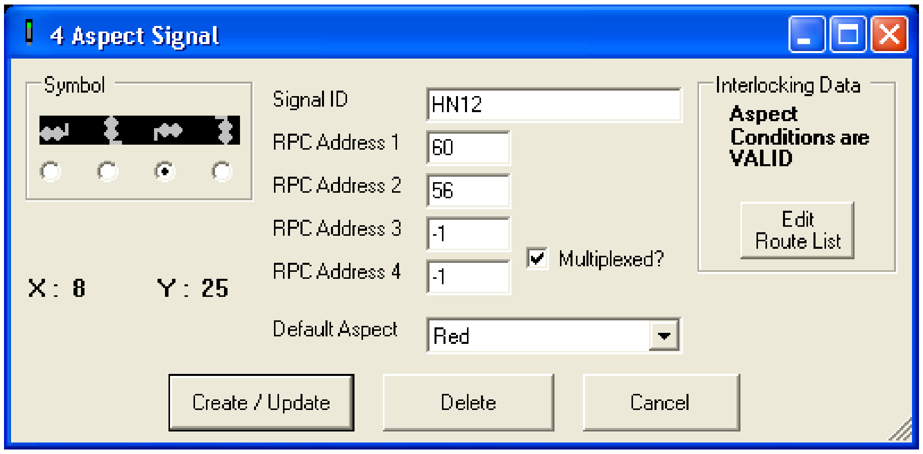
Tk Circuit RPC Input Bit: 21

[✓] Has TC?

X : 23

Y : 25

• Figure D.4 Track Section Form



4 Aspect Signal

Symbol: ○ ○ ● ○

X : 8   Y : 25

Signal ID: HN12

RPC Address 1: 60

RPC Address 2: 56

RPC Address 3: -1

RPC Address 4: -1

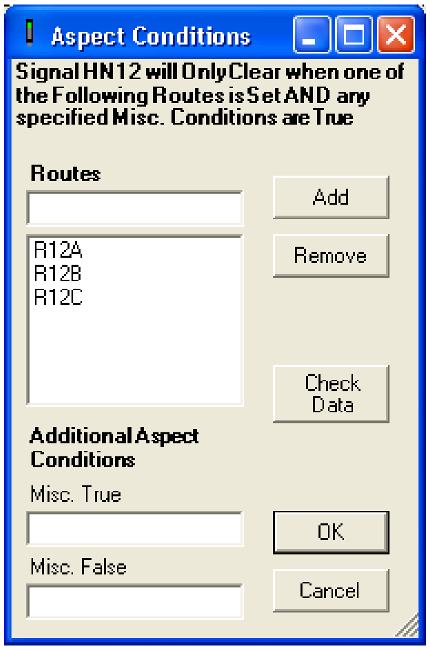
[✓] Multiplexed?

Default Aspect: Red

Interlocking Data

Aspect Conditions are VALID

• Figure D.5 Four Aspect Signal Form



Aspect Conditions

Signal HN12 will Only Clear when one of the Following Routes is Set AND any specified Misc. Conditions are True

Routes

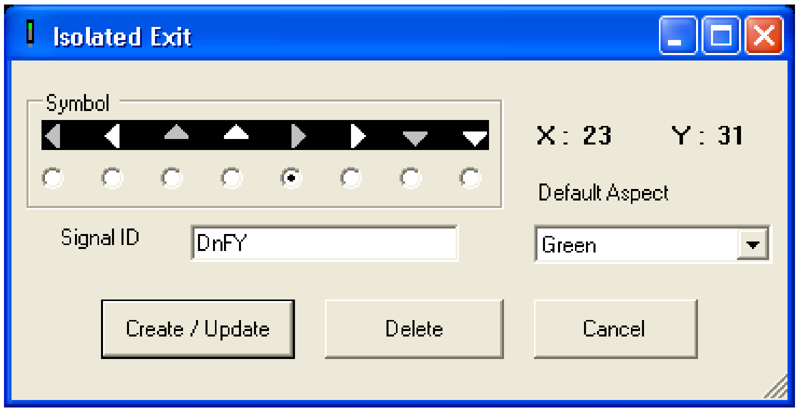
R12A
R12B
R12C

Additional Aspect Conditions

Misc. True

Misc. False

• Figure D.6 Aspect Conditions Form

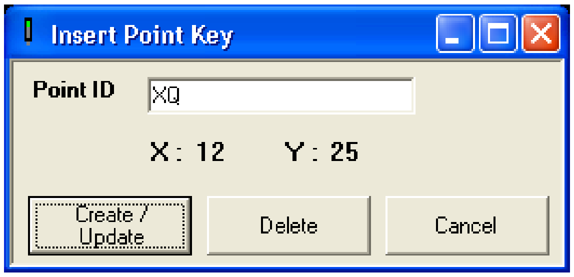


X : 23 Y : 31

Default Aspect: Green

Signal ID: DnFY

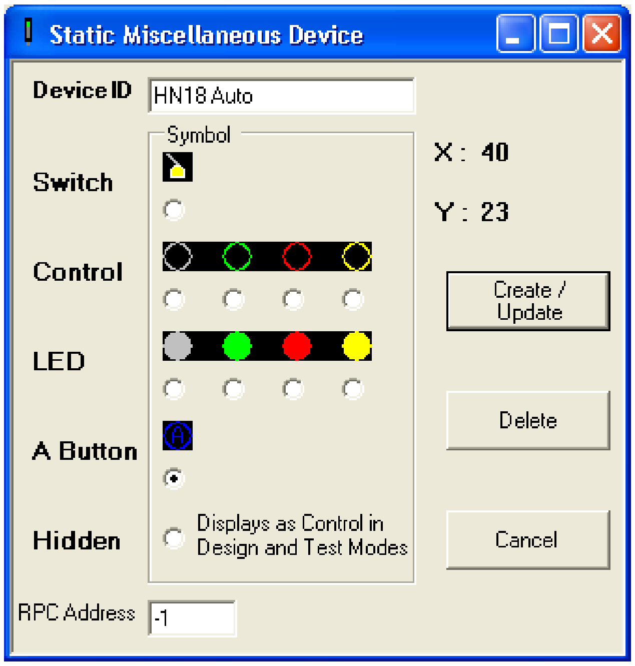
• Figure D.7 Isolated Exit Form



Point ID: XQ

X : 12 Y : 25

• Figure D.8 Point Key Form



Device ID: HN18 Auto

X : 40

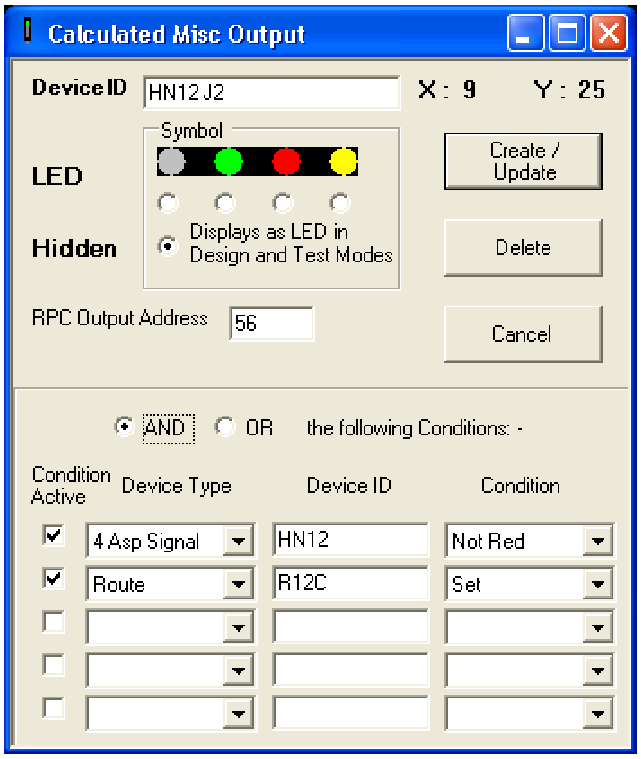
Y : 23

A Button [✓]

Hidden: Displays as Control in Design and Test Modes

RPC Address: -1

• Figure D.9 Miscellaneous Input Form



Device ID HN12 J2 X : 9 Y : 25

LED Symbol

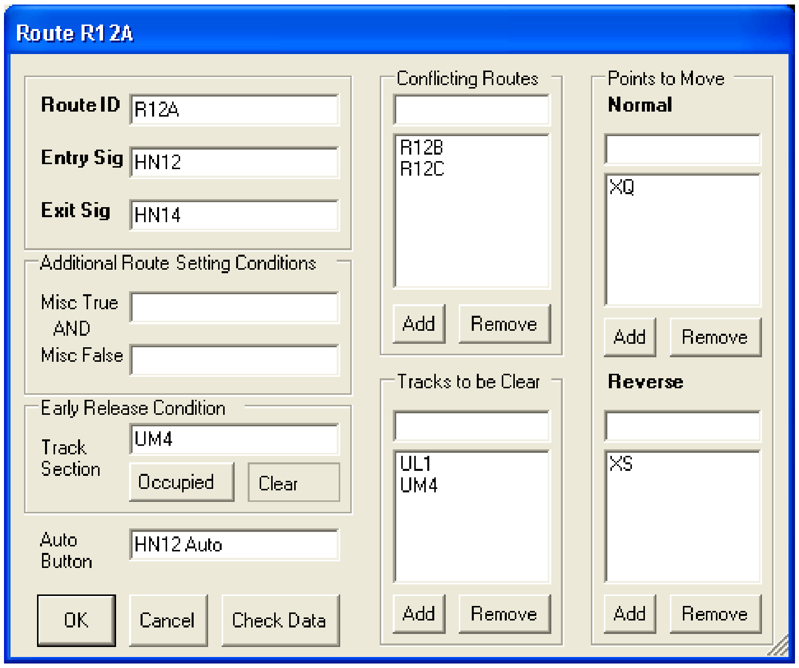
Hidden [✓ Displays as LED in Design and Test Modes]

RPC Output Address 56

[✓ AND] OR the following Conditions: -

Condition Active	Device Type	Device ID	Condition
✓	4 Asp Signal	HN12	Not Red
✓	Route	R12C	Set

• Figure D.10 Miscellaneous Output Form



Route ID R12A

Entry Sig HN12

Exit Sig HN14

Additional Route Setting Conditions

Misc True
AND
Misc False

Early Release Condition

Track Section UM4

Auto Button HN12 Auto

Conflicting Routes

R12B
R12C

Tracks to be Clear

UL1
UM4

Points to Move

Normal

XQ

Reverse

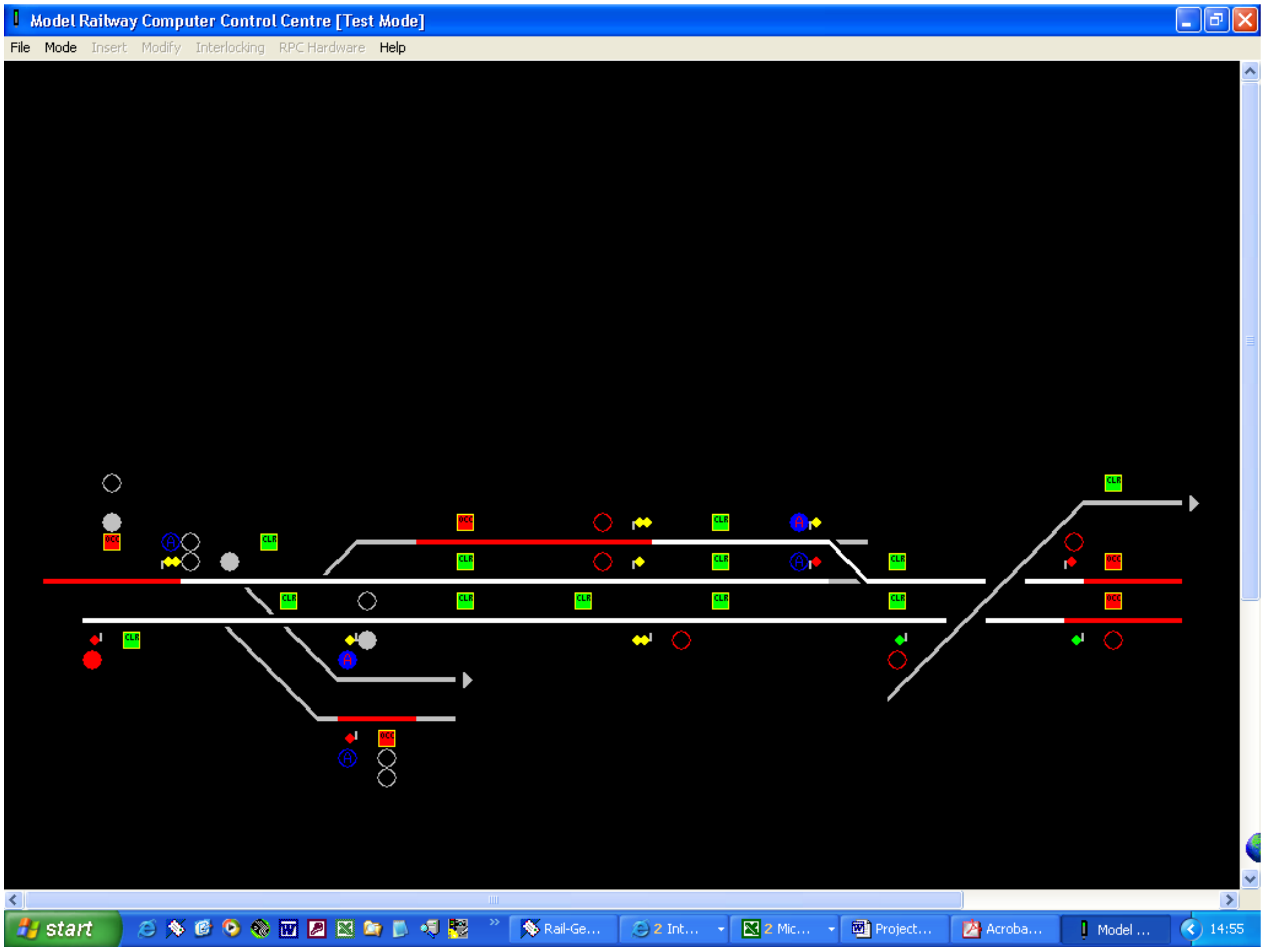
XS

• Figure D.11 Route Form

Test Mode

Test Mode as described in Section 4 allows simulation of the layout to check on the interlocking data entered. Symbols are provided for simulating inputs from the layout by user mouse actions.

This is in addition to the normal Operate Mode actions to control the layout. This Mode in all other ways acts like Operate Mode but no synchronisation to hardware takes place.



• Figure D.12 Main Screen in Test Mode showing Trains, Routes Set and Signal Aspects

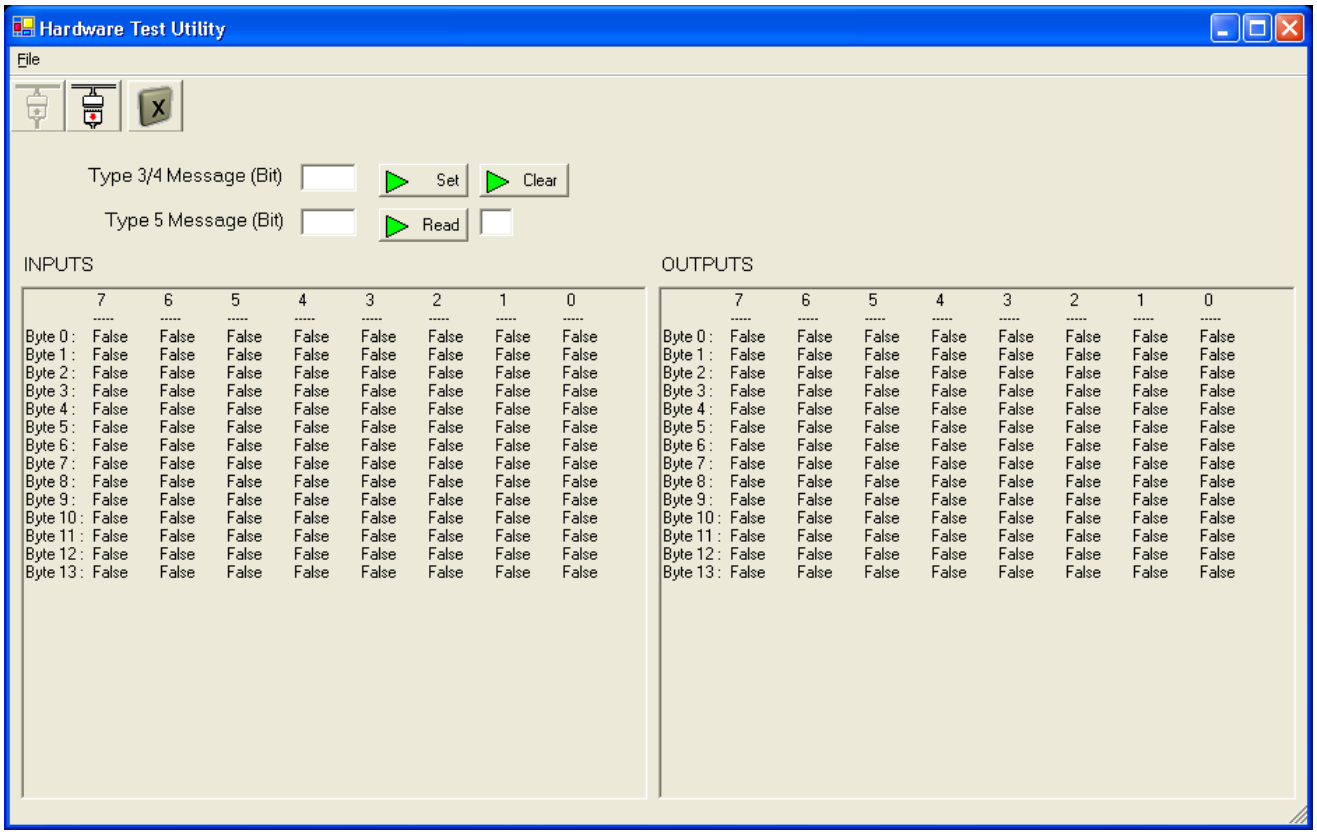
Hardware Test Utility

The Hardware Test Utility was coded first to understand the interface specification described in Appendix A to communicate through the RS232 link to the RPC hardware system. This utility also allows for the hardware class to be tested in isolation, as described in Section 5.

In addition, layout functions and module functionality can be tested without the need to enter full layout data.

Controls are provided to Connect and Disconnect from the Hardware and to Set, Clear and Read individual bits.

The screen shows the current state of all Inputs and Outputs and this is continuously synchronised with the hardware.



INPUTS

	7	6	5	4	3	2	1	0
Byte 0 :	False	False	False	False	False	False	False	False
Byte 1 :	False	False	False	False	False	False	False	False
Byte 2 :	False	False	False	False	False	False	False	False
Byte 3 :	False	False	False	False	False	False	False	False
Byte 4 :	False	False	False	False	False	False	False	False
Byte 5 :	False	False	False	False	False	False	False	False
Byte 6 :	False	False	False	False	False	False	False	False
Byte 7 :	False	False	False	False	False	False	False	False
Byte 8 :	False	False	False	False	False	False	False	False
Byte 9 :	False	False	False	False	False	False	False	False
Byte 10 :	False	False	False	False	False	False	False	False
Byte 11 :	False	False	False	False	False	False	False	False
Byte 12 :	False	False	False	False	False	False	False	False
Byte 13 :	False	False	False	False	False	False	False	False

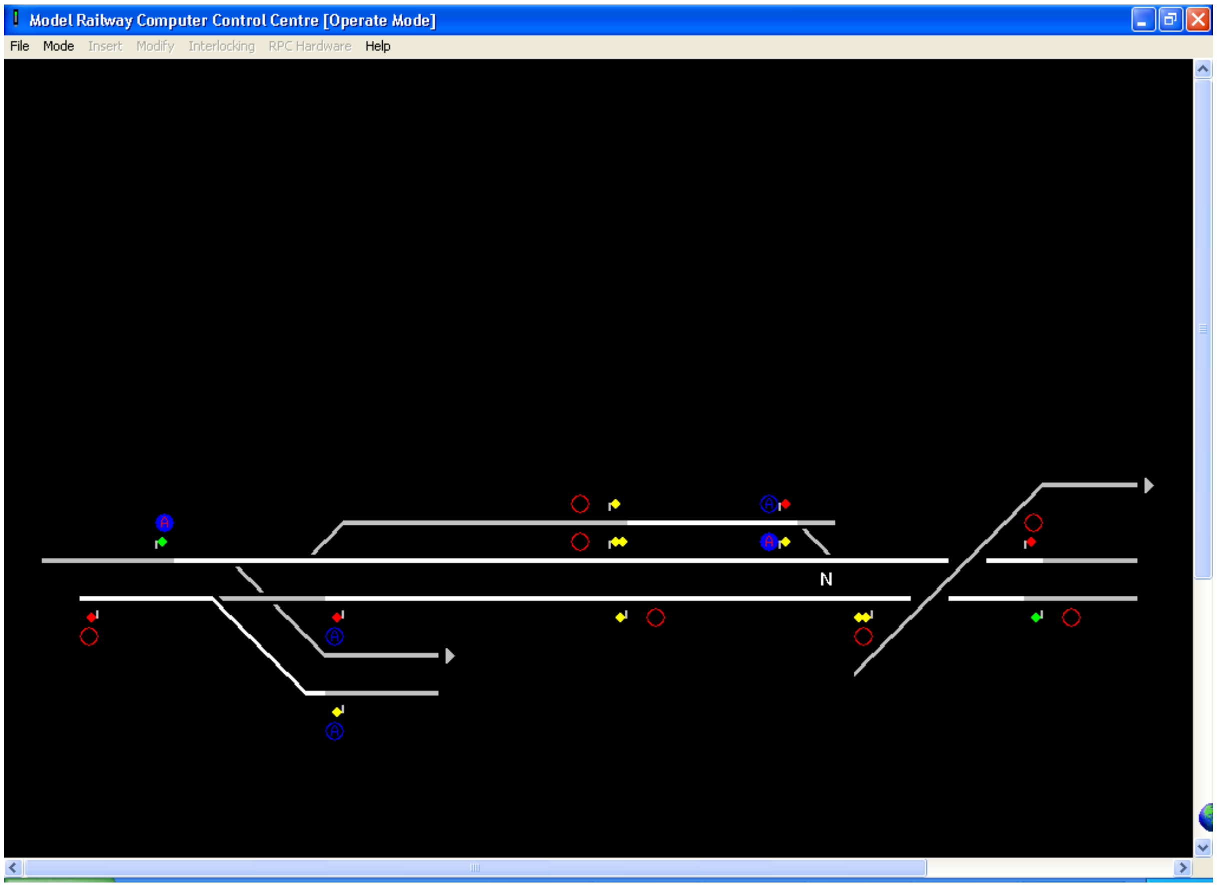
OUTPUTS

	7	6	5	4	3	2	1	0
Byte 0 :	False	False	False	False	False	False	False	False
Byte 1 :	False	False	False	False	False	False	False	False
Byte 2 :	False	False	False	False	False	False	False	False
Byte 3 :	False	False	False	False	False	False	False	False
Byte 4 :	False	False	False	False	False	False	False	False
Byte 5 :	False	False	False	False	False	False	False	False
Byte 6 :	False	False	False	False	False	False	False	False
Byte 7 :	False	False	False	False	False	False	False	False
Byte 8 :	False	False	False	False	False	False	False	False
Byte 9 :	False	False	False	False	False	False	False	False
Byte 10 :	False	False	False	False	False	False	False	False
Byte 11 :	False	False	False	False	False	False	False	False
Byte 12 :	False	False	False	False	False	False	False	False
Byte 13 :	False	False	False	False	False	False	False	False

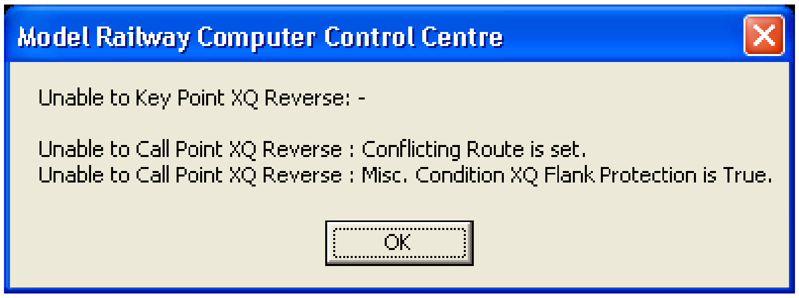
• Figure D.13 Hardware Test Utility

Operate Mode

Operate Mode hides all Hidden Miscellaneous devices and Track Section symbols, leaving a view that is very similar to the real VDU control screen shown in Section 2. The interlocking returns messages to inform the user if the requested action is not available.


Model Railway Computer Control Centre [Operate Mode]
File Mode Insert Modify Interlocking RPC Hardware Help
N

• Figure D.14 Main Screen in Operate Mode



Unable to Key Point XQ Reverse: -

Unable to Call Point XQ Reverse : Conflicting Route is set.
Unable to Call Point XQ Reverse : Misc. Condition XQ Flank Protection is True.

• Figure D.15 Intelligent Response from Interlocking to Request that is not available

Appendix E

Project Progress

The project has progressed well and closely matched the original schedule. This was the result of a clear objectives and a robust, well thought out project plan. The plan has allowed the project to meet timely milestones and complete on time.

Project Plan

The Project Plan was worked out at the beginning of the project and has been worked to throughout. The Plan was updated as work progressed. The final version, reflecting the completed project is presented on the following four pages. The plan has been colour coded to indicate actual progress compared with the plan.

The plan shows that there were some overruns on the predicted time. This is largely due to having little prior programming experience and as a result, there was no benchmark to predict development time from. In particular, Defining Data Formats took longer than expected. It was initially expected that a text file would be used and a custom format designed to output all data. Research revealed the Serialization techniques available in Visual Basic. This took some time to research and implement and as a result, the activity overran the schedule.

Towards the end of the project, it the design work really paid off and the project fell together very easily. As a result many activities were completed early. The “Additional Features” were built into the design at a much earlier stage than expected and the initial development built in advanced features at the same time.

Some activities such as Testing and the Project report started earlier but took longer to complete. This was partly due to taking a more relaxed pace but also due to using the extra time to complete more testing and produce the report to a higher standard.

[Project Plan Page 1]

[Project Plan Page 2]

[Project Plan Page 3]

[Project Plan Page 4]

Monthly Progress Reports

In accordance with the Department Project Handbook, Monthly Progress reports were prepared to summarise achievements and current problems at the end of each month and present a plan for the next month.

The seven monthly reports, for October 2002 through April 2003 are presented on the following pages.

[October 2002 Progress Report]

[November 2002 Progress Report]

[December 2002 Progress Report]

[January 2003 Progress Report]

[February 2003 Progress Report]

[March 2003 Progress Report]

[April 2003 Progress Report]

Appendix F

Financial Statement

Excluding the hardware that was outside the scope of this project, and obviously development time, the only financial cost has been for software and textbooks.

Item	**Cost**
Visual Basic .NET Standard Edition	£83.35
Visual Basic .NET for Experienced Programmers	£32.99
Visual Basic .NET Threading Handbook	£19.39
Visual Basic .NET Serialization Handbook	£19.49
Total Project Costs	**£155.22**

All items were purchased online at the best prices possible. Suppliers were Insight UK and Computer Manuals Ltd.

Stephen Parascandolo

Brunel University
BEng Computer Systems Engineering
Student ID: 9900239/1
Supervisor: Dr Ian Dear
Tutor: Mr Peter VanSanten

Model Railway Computer Control Centre

Final Year Project Report

May 2003

Volume 2 – Source Code and CD-ROM

Appendix G

Source Code

The full Source Code of the project follows.

Source Files, this report and the Installation software for the project are also included on CD-ROM attached to the rear cover of this Volume.

Updates and other information can also be downloaded from the Web at: -

http://homepage.ntlworld.com/dodonet/stephen/mrcc/

N.B.
RS232.vb is from www.vbcode.com as explained in the main text.

It should be noted whilst viewing the source code that the emphasis in coding has very much been one of achieving functionality and meeting the Objectives of this project, rather than to serve as a textbook example of Software Code. This is a real life problem, not a straightforward textbook sample. As the Chapter 7 looks at, the author acknowledges that with hindsight, the code wouldn't be structured in the same way if repeated.