WIMBORNE MODEL TOWN

DEVELOPMENT

WINTER 2016/17 DESIGN DOCUMENT

Issue 1.0

25th June 2017

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1 INTRODUCTION

This document details the design of proposed enhancements to the Wimborne Model Town. The design has been created to meet the requirements contained in Reference 1 of Table 1 below and a Cross-reference between each requirement and the design elements that fulfil it is given in Annex A.

The document provides a full description of the installed system for use by future developers and maintainers.

2 RELATED DOCUMENTS

The following documents are related to this document.

Table 1: Related Documents

No	Requirement	Iss
1	Wimborne Model Town – Development – 2016/17 Requirements	2.0
2	Wimborne Model Town – Development – 2016/17 – Installation Specification	TBD
3	Wimborne Model Town – Development – 2016/17 – User Manual	TBD

3 DETAILED DESIGN

3.1 Hardware

The full identification and quantities of all hardware items may be found in Annex B.

3.1.1 Minster Bells and MP3 Player

3.1.1.1 Timing and Control

3.1.1.1.1 Raspberry Pi 3

All timing and control will be implemented using a Raspberry Pi 3 (the Minster Pi3)). This small single board computer has a 40 pin connector that carries 26 GPIO channels, plus power and an I^2C bus. Additionally the device has four USB connectors, and one each of Ethernet, HDMI and power connectors. The device also has a Wireless and Bluetooth adaptor built in. This will not be needed for this project other than during development. A Micro SD Card slot is provided to carry the Operating System and program code.

The Minster Pi3 will keep track of time (see Section 3.1.1.1.2 below), and ensure that the various chimes and other sounds are played at the correct intervals.

During development, the Minster Pi3 will be accessed via a monitor, mouse and keyboard and integrated with the system. Once integration is complete, the Minster Pi3 will be run 'headless'.

The Minster Pi3 will be housed in an equipment case installed on a shelf above the model Minster's chancel window.

3.1.1.1.2 Real Time Clock

The Minster Pi3 does not include a Real Time Clock (RTC), so a standard Pi add-on module will be used.

The RTC will be mounted on top of the Minster Pi3.

3.1.1.2 Interfacing and Accessories

3.1.1.2.1 Audio Adaptor

The Minster Pi3 has an analogue audio jack for connecting headphones and the same audio channel is integrated into the HDMI connector. It is possible to utilise a GPIO pin and external circuits to filter the audio, but this is not particularly elegant.

Two channels of audio are needed; one to sound the bells in the model Minster tower and one to play church music in the model Minster Chancel. The analogue audio jack will be routed to the loudspeaker in the tower and the other channel, for the loudspeaker in the Chancel, will be provided by a USB Audio Adaptor . The program will play the chimes using the default channel and the music by directing audio from the player software to the adaptor hardware channel allocated by the Operating System. This will achieve simultaneous playback capability and enable the MP3 and chimes capability to both operate without mutual interference.

The Audio Adaptor will be housed in the same case as the Minster Pi3 .

3.1.1.2.2 Audio Amplifiers

The Minster Pi3 will play the various sounds using software based players, but the output level is too low to be used directly with anything but headphones. A 12 W audio Amplifier will therefore boost the signal from each output, although the output level needed is expected to be considerably less than this.

The Audio Amplifiers will be housed in the same case as the Minster Pi3 .

3.1.1.2.3 Loudspeakers

Three waterproof 10 W loudspeakers will be used so that the public may hear the sounds. Two of these will be housed in the Bell Tower to simulate the bells. These will be wired in parallel to match the impedance of the Audio Amplifier and ensure that the speakers are not overloaded.

The third speaker will be housed in the area above the chancel and will not need to be used at such a high level. To protect this speaker from overload, two resistors wired as a simple potentiometer will limit the input voltage and the volume level will be limited in the software.

3.1.1.2.4 Quarter Jack Solenoids

The hammers on the Quarter Jack bells will be actuated by solenoids and driven from an external power supply.

The solenoids will be housed in model Minster Bell tower and will re-use as much of the existing mechanism as possible.

3.1.1.2.5 MOSFET Driver PCB

The solenoid actuators for the Quarter Jack each require approximately 700 mA from a 12 V source to operate. The Minster Pi3 GPIO pins can only sink or source 16 mA at 3.3 V, so a driver will be required. To minimise spares holdings the same MOSFET Driver PCB that was used for the WMT Lighting Project will be used.

Note: To save costs, these Driver PCBs will NOT be modified by the addition of a more powerful MOSFET device, as was done for the Lighting Project, so the spares will have to be kept separate in the store.

The MOSFET Driver PCB will be housed in the same case as the Minster Pi3.

3.1.1.2.6 WMT Staff Interfaces

Four centre biased switches will be provided to allow WMT Staff to control the Minster functions. These will have the following Actions:

- Enable Extended Hours (see Section 3.2.1.2).
- Trigger Change Rings. A simple On-Off function (see Section 3.2.2).
- Control the selection of music Playlists in the MP3 Player (see Section 3.2.3).
- Control the triggering of the wedding sequence (see Section 3.2.4).

In order to reduce cross-talk and switch bounce, a Debouncing Board will provide roll-off circuits to soften the edges on the generated signals.

3.1.1.3 Power Supplies

The following power supplies will be provided:

- 12 V, 2.3A – Audio Amplifiers and Quarter Jack Hammer.
- 5 V, 2.5 A – Raspberry Pi. See Section3.1.1.2.2.

3.1.2 Audio Guide

3.1.2.1 Server

3.1.2.1.1 Raspberry Pi 3

All audio files will be served from a Raspberry Pi 3 (the Webserver Pi3) configured as a webserver.

During development, the Webserver Pi3 will be accessed via a monitor, mouse and keyboard and integrated with the system. Once integration is complete, the Webserver Pi3 will be run 'headless'.

3.1.2.2 Interfacing and Accessories

3.1.2.2.1 Uninterruptible Power Supply

To prevent possible corruption of the files on the server, an Uninterruptible Power Supply (UPS) add-on module will be provided to hold up power and signal the Pi3 to shut-down cleanly in the event of a power cut or if the Operator decides to shut the system down. On power being resumed, the UPS will automatically signal the Pi3 to boot up.

3.1.2.2.2 Wireless Access Point

The Wireless Access Point will be a TP-Link TL-WA7210N. This device is designed for outdoor use and provides a 12 dBi antenna gain which allows transmission and reception to be directed towards the Town site, while minimising signal strength outside the site.

3.1.2.2.3 Power Supplies

The following power supplies will be provided:

- 5 V, 2.5 A – Raspberry Pi. See Section3.1.2.2.2.
- 12 V, 1 A – Power over Ethernet (PoE) injector (part of TL-WA7210N).

3.1.2.2.4 Sundries

The following miscellaneous items will be provided:

- Micro SD Card for the software and web content on the Pi.

3.1.3 Children’s Quiz

The Children’s Quiz function will share the hardware provided for the Audio Guide.

3.2 Software

The full identification and quantities of all software items may be found in Annex B.

3.2.1 Minster Functions

3.2.1.1 Software Sequence

Code will be written in Python and will implement the following functions:

- Monitor time and trigger the playing of the various sounds in the following sequence. All timings will be programmable:
  - Enable the system at 10 am each morning.
  - Chime the hour two minutes after the real Minster Bells.
  - Trigger the model Quarter Jack hammer two minutes after the real Minster Quarter Jack sounds and simultaneously play the Quarter Jack simulation.
  - Repeat the above sequence, using the correct number if chimes for each hour and the correct number of Quarter Jack chimes for each quarter until the system is disabled at the end of the day at:
    - 5 pm for normal days.
    - 10 pm when Extended Hours are enabled (see Section 3.2.1.2 below).

The above functions will continue until a break is detected or the power is removed.

Note:The Quarter Jack sounds one double chime at 15 minutes past the hour, two double chimes at half past the hour, three double chimes at 15 minutes to the hour and four double chimes on the hour. The chiming of the hour from the main bell commences approximately 4 seconds after the Quarter Jack has finished.

3.2.1.2 Extended Hours

Enabling Extended Hours will be triggered by the Operator pressing down a momentary action switch which is connected to GPIO 20. The Minster Pi3 will detect the event and set a variable to indicate that playing of the bells is required after the normal Opening Hours. Pressing the switch up will reset the variable to the default state, via GPIO pin 21, otherwise this variable will remain set until midnight, when a software function will be invoked to restore default conditions. Feedback will be provided each time the switch is pressed in the form of the following recorded messages played through the loudspeakers:

- ‘Extended Hours Enabled’.
- ‘Normal Operating Hours Set’.

3.2.2 Change Rings

Code will be written in Python and will implement the following functions:

- Monitor time and inhibit the playing of the rings outside opening hours (see Section 3.2.1 above).
- Monitor for an interrupt generated by a member of the WMT staff pressing a momentary action switch down (GPIO pin 22), then:
    - Play an MP3 file of ‘change rings’.
    - Pressing the switch upwards during playback of the change rings will interrupt the playing, via GPIO pin 23.

3.2.3 MP3 Player

Code will be written in Python and will implement the following functions:

- Monitor time and inhibit the playing of the music outside opening hours (see Section 3.2.1 above).
- At approximately 10:04 am, start the MP3 Player automatically, using the Playlist last selected (see below).
- Monitor for an interrupt generated by a member of the WMT staff pressing a momentary action down (GPIO pin 24), then:
    - Count the number of switch presses:
        - The first switch press will pause playback of the Wedding Sequence (see Section 3.2.4 below) and select Playlist 1. A brief message will be played; “Playlist 1 selected” (Not yet implemented).
        - The second switch press will select Playlist 2 and play a brief message; “Playlist 2 selected” (Not yet implemented).
        - The third and subsequent switch presses will select the corresponding Playlist and play a brief message; “Playlist n selected” (Not yet implemented).
        - Store the identity of the current playlist.
    - If the switch is pressed upwards at any time (GPIO pin 25), then the MP3 Player will be disabled, the Playlist identity will be set to ‘0’ and a brief message will be played; “MP3 Player Disabled” (Not yet implemented).

3.2.4 Wedding Sequence

Code will be written in Python and will implement the following functions:

- Monitor for an interrupt generated by a member of the WMT staff pressing a switch (GPIO pin 26):
  - Count the number of switch presses:
    - The first switch press will schedule the Wedding Sequence detailed below to run at three minutes past 11 am and three minutes past 2 pm.
    - The second switch press will trigger an immediate playback of the Wedding Sequence.
    - Pressing the switch upwards will disable the wedding function completely via GPIO pin 27.
  - Wedding Sequence actions:
    - Pause playback of the Change Rings (see Section 3.2.2) or MP3 Player (see Section 3.2.3).
    - Play a short MP3 file of ‘change rings’.
    - Play the Wedding March for approximately three minutes.
    - Pause for approximately 30 seconds.
    - Play Widor’s Toccata and Fugue for approximately five minutes.
    - Approximately 1 minute after the commencement of the Toccata, play an MP3 file of ‘change rings’.
    - Restart the MP3 Player, using the stored playlist identity (see Section 3.2.3) to recommence playing the selected music.

3.2.5 Audio Guide and Children’s Quiz

A webserver will be configured to provide all of the content described below. This will automatically route users who logon on to the Wireless Access Point to its Home Page containing the menu described below.

3.2.5.1 Webserver

The following standard software will be installed on the server:

- Webserver - nginx plus modules.
- DNS server -dnsmasq.

Server code will be written in HTML and Javascript and will implement the following functions:

- Provide a Menu for the user to select:
  - Audio Guide:
    - Different available content as required, such as:
      - Introduction to the Model Town.
      - The Gardens.
      - The Lady Hanham Building.
      - The Model Railway Room.
      - History of the Model Town.
    - Once the desired guide is selected an online MP3 Player will play the content.
  - Children’s Quiz:
    - Different Quizzes as required, such as:
      - Find the shop or building.
      - What shops sell what products.
      - Dolls House queries.
      - Model Trains queries.
      - Any combination of the above.
    - A running total of the score will be maintained and presented to the User at the end of the Quiz.

3.2.5.2 Content Maintenance Tool

The software hosted on the server will provide the framework for the above content, but the initial deployment may well not include all of the items. Content will be provided by the Town Staff and other Volunteers. A Content Maintenance Tool will be provided to allow Town Staff to add, delete and modify the Content in the Audio Guide and Children's Quiz. This Requirement is marked as 'Desirable' in the Requirements Specification and so work will initially focus on getting the webserver framework in place so that the content may be easily added. The following approach will be used:

- The webserver will include 'Staff Only' Pages that provide the following functions:
  - List the current Content.
  - Delete Content.
  - Add Content.
  - Modify Content.

The detailed approach and tools that will be used to realise this capability will be determined during development, but the WMT Staff will be presented with a familiar 'Web Form' in which to make their changes.

Staff will be required to login to the system to protect the content against unauthorised modification.

3.2.6 Operating System

The Operating System used will be Raspbian. During development, of both the Minster Functions and the Webserver, the Operating System will be run normally, but during deployment, the Minster Pi3 will be run in Read-only mode, to allow for uncontrolled shutdowns and restarts.

The Webserver Operating System will be run normally even during deployment to allow 'over-the-air' updates to be carried out by WMT staff. The provided UPS will prevent damage to the files on the SD Card during uncontrolled shutdowns.

3.2.6.1 Software Documentation

Comments will be included in all software developed specifically for the WMT to allow future developers to maintain the code.

A full description of the implementation of code that provides the Minster Functions and Webserver will be provided in the Installation Manual (see Reference 2 in Section 2).

3.3 Environmental

Both systems will be contained within an equipment case.

The Webserver will be installed within the Model Railway building, so the environment is expected to be benign. The equipment case will therefore function mainly to protect the equipment from unauthorised access.

The Minster Bells equipment will be installed within the Model Minster Chancel and bell tower. More attention will therefore be paid to the housing of this hardware, paying due attention to the need to keep the equipment cool. This case will therefore include an internal heatsink to conduct heat from the air inside the case and therefore keep the internal environment below 35º C.

3.4 Operational

3.4.1 Powering Up and Down

The Operator will be able to:

- Start either of the systems by switching on the supply at the mains socket.
- Stop either of the systems by switching off the supply a the mains socket. This will be achieved safely by the methods defined in Sections 3.1.2.2.1 and 3.2.3.2.

3.5 Reliability and Maintainability

3.5.1 Reliability

- All components carrying powers in excess of 1 W will be derated by at least 20 % for power supplies and 50 % for other components.
- The SD Card will be protected from corruption by the methods defined in Sections 3.1.2.2.1 and 3.2.3.2.
- Adequate ventilation will be provided. It is not believed that forced cooling will be required, but if necessary, a fan will be incorporated to cool the components.

3.5.2 Maintainability

- Full documentation will be provided as follows:
  - Design (this document).
  - Installation (to describe how to create the software and write it to the SD Card). See Reference 2 in Section 2.
  - User Manual showing the removal and replacement of components, where the procedure is not straightforward. See Reference 3 in Section 2.
- Spares will be provided as defined in Annex D.

- No special tools will be required to repair the system, other than standard items normally found in a general purpose tool kit.
- Full backups of all software developed will be provided.
- All software will be documented with comments.

3.6 Safety

With the exception of the power supply inputs, all circuits will operate at less than 20 V. The mains inputs to the PSUs will be contained within a protective case.

4 ASSUMPTIONS

The following assumptions are made.

- Future system developers will have a working knowledge of Linux, Python programming and Web development.
- System maintainers will be sufficiently skilled in general maintenance to be able to follow the diagnostic instructions provided in the User Manual.

Annex A

Requirements Cross-Reference

Paragraph Numbers in Column 1 refer to Reference 1 in Section 2.

Functional

No	Requirement	Para
1.1	**Minster Bells**	-
1.1.1	The system shall provide a simulation of the real town's Minster bells to play within the model.	3.1.1, 3.2.1
1.1.1.1	The system shall play the chimes, eg the hours, the quarters (including the Quarter Jack bells), the half hours and the three-quarters.	3.2.1
1.1.1.2	The system shall activate the Quarter Jack at the quarter hours, without actually striking the bells.	3.2.1
1.1.1.3	The playing of the chimes shall commence approximately 2 minutes after the real Minster bells.	3.2.1
1.1.1.4	The system shall play change rings.	3.2.2
1.1.1.5	The playing of change rings shall be optional and capable of being triggered by the WMT staff.	3.2.1
1.1.1.6	The timing of the chimes and the change rings shall be programmable.	3.2.1
1.1.2	The system shall optionally play music, to simulate a service or daily background hymns.	3.2.3
1.1.2.1	It shall be possible to select 'playlists' of music that are to be played or no playlist at all.	3.2.3
1.1.3	The system shall be designed so that a sequence of change rings and wedding music may optionally be selected to simulate a wedding being performed in the Minster.	3.2.4
1.1.3.1	It shall be possible to select the wedding simulation to be performed on	3.2.4

No	Requirement	Para
	demand or at programmable times during the day, eg 11 am and 2 pm.	
1.1.4	The wedding simulation and the music playing shall be mutually exclusive.	3.2.4
1.1.5	The system shall be designed so that the chimes and music only play when the Model Town is open to the public..	3.2.1, 3.2.2, 3.2.3
1.1.5.1	The default playing period for the chimes and wedding march shall be between 10 am and 5 pm each day.	3.2.1, 3.2.2, 3.2.3
1.1.5.2	It shall be possible to extend the playing period for the chimes and wedding march to allow for occasional evening events.	3.2.1.2
1.1.6	The system shall not be mechanical, but instead use some programmable device to control the timing and play the sounds.	3.1.1
1.1.7	At startup, or when the Model Town opens for the day, the music player shall be enabled.	3.2.3
1.1.7.1	The system shall store the current playlist, so that it may be invoked when the music is restarted.	3.2.4
1.1.7.2	When a wedding simulation has been selected, the system shall revert to playing music when the sequence is complete.	3.2.3, 3.2.4
1.2	**Audio Guide**	-
1.2.1	The system shall provide an audio guide.	3.1.2
1.2.2	The scripts for the audio guides will be provided by the Model Town staff and volunteers.	3.2.5
1.2.3	The system shall include an IEEE 802.11 Wireless Access Point and Web Server to meet the Operational requirements in Section 2.2 below.	3.1.2
1.2.4	The system shall automatically route the User’s browser to the Home Page, so they may select the guide easily.	3.2.5
1.3	**Children’s Quiz**	-
1.3.1	The system shall provide a quiz facility for children.	3.1.3

No	Requirement	Para
1.3.2	The questions and answers will be provided by the Model Town staff and volunteers.	3.2.5
1.3.3	The system shall include an IEEE 802.11 Wireless Access Point and Web Server to meet the Operational requirements in Section 2.2 below.	3.1.3
1.3.4	The system shall automatically route the User’s browser to the Home Page, so they may select the quiz easily.	3.2.5

Operational

No	Requirement	Para
2.1	The system shall be designed so that the Town staff can start the new functions at the beginning of each day. if required, by turning on the power.	3.4.1
2.2	The system shall be designed so that the Town staff can stop the new functions at the end of each day, if required, by turning off the power.	3.4.1
2.4	Item 1.2 shall be capable of being accessed using a Smartphone, tablet computer or other portable computing device.	3.2.5.1
2.4.1	Audio content shall be prepared to provide the guidance material.	3.2.5.1
2.4.2	Users shall be provided with a menu, so that they may choose the audio content that they wish to listen to.	3.2.5.1
2.5	Item 1.3 shall be capable of being accessed using a Smartphone, tablet computer or other portable computing device.	3.2.5.1
2.5.1	A framework shall be prepared to contain the questions.	3.2.5.1
2.5.2	Questions shall be selectable by the use of a list which may be worked through sequentially by the users.	3.2.5.1
2.5.3	A selection of answers shall be offered for each question with a scoring system based on the answer being right or wrong.	3.2.5.1
2.5.4	The scoring system shall preferably discriminate between questions that are completely right, completely wrong or nearly right.	3.2.5.1
2.5.5	At the end of the quiz, the user shall be provided with a final score out of	3.2.5.1

	the total maximum score.	

Environmental

No	Requirement	Para
3.1	All components of the system that are installed in the Minster model shall be protected from the ingress of moisture.	3.3
3.2	All components of the system that are installed in the Minster model shall be adequately cooled.	3.3
3.3	All components of the system that constitute the webserver shall be adequately cooled.	3.3

Reliability

No	Requirement	Para
4.1	The system shall be designed to be fail-safe in the event of a power supply failure.	3.5.1
4.2	Components shall be de-rated where possible, especially circuits carrying powers in excess of 1 W.	3.5.1

Maintainability

No	Requirement	Para
5.1	The system shall be designed to be maintainable by suitably qualified Town staff, using only the documentation provided by the developers.	3.5.2
5.1.1	A tool shall be provided to allow Town staff, with minimal training and support documentation, to add new content to Items 1.2 and 1.3	3.2.5.2
5.1.2	Provision shall be made for the WMT staff to modify the music included in each Playlist in Item 1.1.2.	3.1.1.2.2
5.2	Spares shall be provided for any components that are liable to end-of-life or frequent failure.	3.5.2

5.3	Backups of any software developed shall be made available for future maintainers.	3.5.2

Safety

No	Requirement	
6.1	The system shall be designed such that no mains or high voltage supplies are used within the functional parts of the system.	3.6
6.2	Power supplies derived from mains shall be fully enclosed in a protective case.	3.6

Documentation

No	Requirement	Para
7.1	A comprehensive design specification shall be produced.	3.5.2
7.2	The design specification shall include full descriptions of all functionality, parts lists and circuit diagrams.	3.5.2
7.3	All software shall be fully documented with comments.	3.5.2
7.4	An Installation Specification shall be provided that details how to deploy the software and hardware.	3.5.2
7.5	A User Manual shall be provided that details how to use and maintain the software and hardware.	3.5.2

Miscellaneous

No	Requirement	Para
8.1	Where possible and without compromising the other requirements in this document, elements of the current design shall be re-used, such as the mechanism for operating the Quarterjack bells on the front of the model Minster.	3.1.1
8.2.	No budgetary requirements have been set, but the system costs shall	Annex B,

	remain within the overall budget for the Wimborne Model Town.	D

Annex B

Hardware Identity

This Annex defines the hardware required for system implementation. Many of these items are free delivery and some attract a delivery charge of a few pounds. Assume £10-15 total delivery. A list of spares may be found in Annex D. These would be procured at the same time as the Development items, so would attract no additional delivery costs.

Minster Bells Development

Computing Devices

Item	Identity	Qty	Cost Each	Total Cost
Control Computer	Raspberry Pi 3 (Raspberry Pi Foundation).	1	£30	£30

Interfaces and Accessories

Item	Identity	Qty	Cost Each	Total Cost
MOSFET Driver Board	Gearbest.	2	£1.58	£3.16
Solenoid	12 V 0.3 N Push Pull Linear Actuator	2	£3.30	£6.60
USBAudio Adaptor	The Pi Hut	1	£3.00	£3.00
Real Time Clock Module	RasClock - ModMyPi	1	£8.40	£8.40
Audio Amplifier	Kemo 12W Universal Amplifier Module - Maplin	2	£14.99	£29.98
Loudspeaker	8W Mylar Square Speaker 87mm - Maplin	3	£4.99	£14.97
Toggle Switch	Miniature SPDT (On)Off(On) Momentary Toggle Switch	4	£4.99	£4.99
Debouncing Board	Assembled using Veroboard, resistors and capacitors, (costs covered in Miscellaneous Items Table below).	1	-	-

Power Supplies

Item	Identity	Qty	Cost Each	Total Cost
Power Supply for Audio Amplifier & Solenoid	12 V, 2.3 A (Recycled ‘Power Brick’).	1	-	-
Power supply for Raspberry Pi 3	Official Raspberry Pi 3 PSU	1	£6.98	£6.98

Miscellaneous

Item	Identity	Qty	Cost Each	Total Cost
Jumpers	Female to Female Jumper Cables	1 set	£1	£1
Micro SD Card	Amazon	1	£4.35	£4.35
Diodes	For protection of the MOSFETs from back EMF.	2	-	-
Resistors	For potentiometer in audio chain and Debounce Board.	1 set	£5.50	£5.50

Audio Guide and Children’s Quiz Development

Computing Devices

Item	Identity	Qty	Cost Each	Total Cost
Web Server	Raspberry Pi 3 (Raspberry Pi Foundation)	1	£30	£30

Interfaces and Accessories

Item	Identity	Qty	Cost Each	Total Cost
Wireless Access Point	TP-Link TL-WA7210N	1	£28.96	£28.96

Power Supplies

Item	Identity	Qty	Cost Each	Total Cost
Power supply for Raspberry Pi	Official Raspberry Pi 3 PSU	1	£6.98	£6.98
Power supply for TL-WA7210N	Included with Wireless Access Point	1	-	-
Uninterruptable PSU	UPS PIco	1	£24.99	£24.99

Miscellaneous

Item	Identity	Qty	Cost Each	Total Cost
Jumpers	Female to Female Jumper Cables	1 set	£1	£1
Micro SD Card	Amazon	1	£4.35	£4.35

Annex C

Software Identity

This Annex defines the software required for system implementation.

Item	Identity	Qty
Operating System	Raspbian for development and deployment of both systems.	2

Annex D

Spares

This Annex defines the spares required for system maintenance.

Minster Bells

Item	Identity	Qty	Cost Each	Total Cost
MOSFET Driver	Gearbest	1	£1.58	£1.58
Solenoid	12 V 0.3 N Push Pull Linear Actuator	1	£3.30	£6.60
Toggle Switch	Miniature SPDT (On)Off(On) Momentary Toggle Switch (Remainder of pack of 5)	1	-	-
USB Audio Adaptor	The Pi Hut	2	£3.00	£6.00
Real Time Clock Module	RasClock - ModMyPi	1	£8.40	£8.40
Audio Amplifier	Kemo 18W Universal Amplifier Module - Maplin	1	£14.99	£14.99
Loudspeaker	8W Mylar Square Speaker 87mm– Readily available.	0	-	-

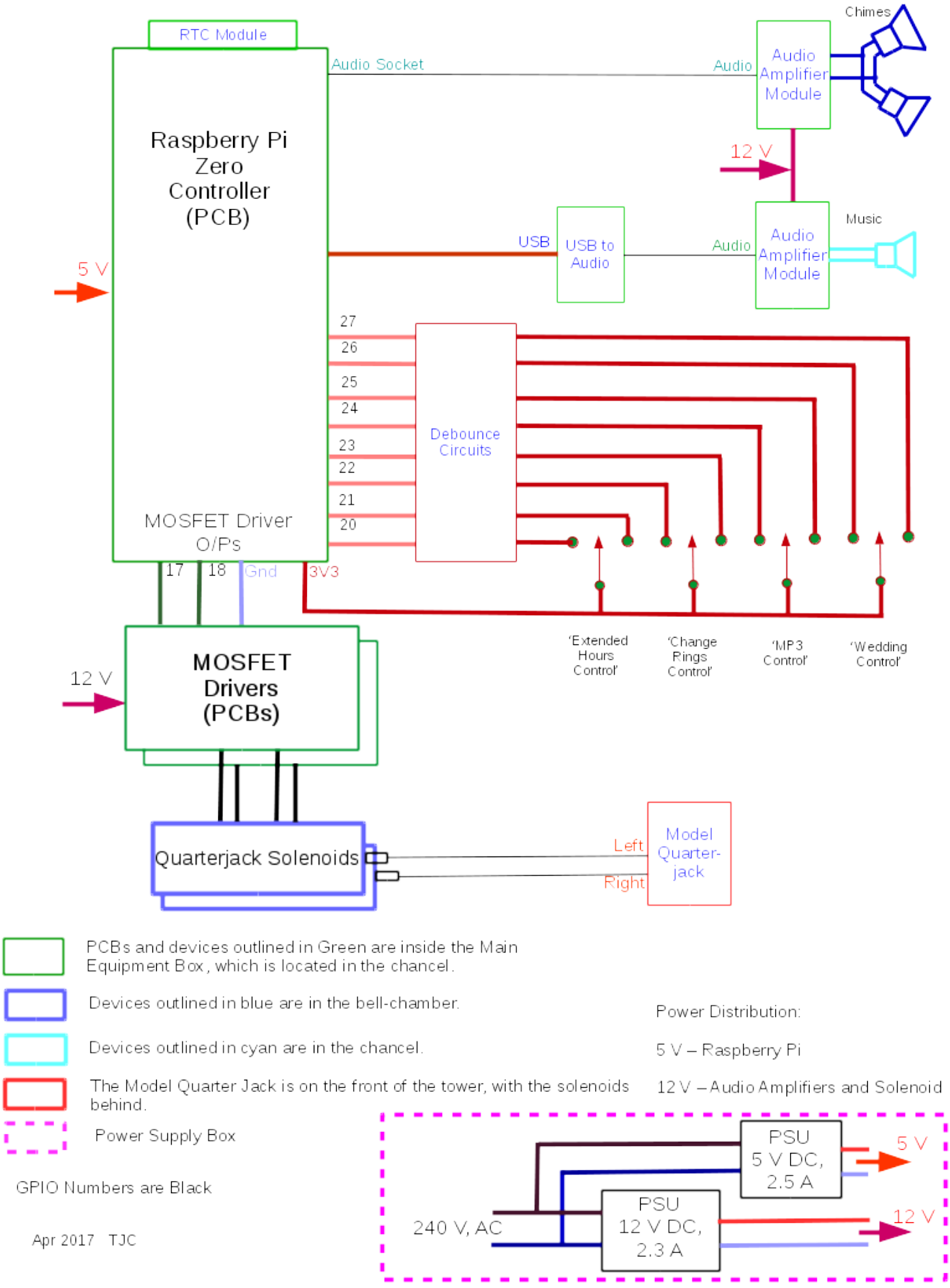
Webserver

Item	Identity	Qty	Cost Each	Total Cost
Wireless Access Point	Readily available, (not necessarily identical).	-	-	-
Uninterruptable PSU	UPS PIco	1	£24.99	£24.99

Common Items

Item	Identity	Qty	Cost Each	Total Cost
Control Computer	Raspberry Pi 3 for both systems. (Will Procure if needed to limit spend.)	0	-	-
Micro SD Card	Amazon	2	£4.35	£8.70

Annex E - System Diagram: Minster Bells and Audio



Annex F - System Diagram: Webserver