A LARGE VIRTUAL PIPE ORGAN
OVERVIEW & OPERATION

Designed and built by:
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This document is intended to give an insight into virtual pipe organs and specifically describes the Reynolds instrument that evolved from an idea in 1966 and became useful 2014-2018. It is also an operating manual.

INTRODUCTION: Imagine being able to play a real pipe organ with every pipe reproduced accurately in every conceivable respect including tuning and voicing faults in individual pipes at a sound quality level far greater than the best CD recordings, and with the acoustics that belong to the original organ venue, as well as controllable acoustics in some cases. The idea has been around for a long time, but it had to wait for the development of fast large computing systems if the world's largest organs were to be copied. Take a real console, use it to control a very clever computer program that is loaded with the recordings of all the pipes, all on what is close to a super computer and couple it to a high performance audio system, and you have your virtual pipe organ that is capable of exceptional performance – quite good enough to be considered as a stand-alone instrument which is a cost-effective replacement for a real organ by a very large margin.

The Reynolds Virtual Pipe Organ is a Hauptwerk Version 4.2.1 organ which is close to the maximum of what can be done at present (2019). It has been built with performers in mind, using an operational approach that is close to an AGO (American Guild of Organists) console layout, with a few details from British practices. Software flexibility allows each installation to move beyond some of the limitations of real organs – but staying within what players want without resorting to operations that look like computer access. The main deviations from the common AGO access are the use of a touch screen to address the stops, and a couple of knobs on the audio interface to set levels into the audio reproduction system. The designers of Virtual Organs have many freedoms to tailor the virtual instrument to almost any specific requirement. The architecture of the Reynolds instrument cannot be compared easily with other implementations as the designer has a background that allowed "anything to be emulated" and drew from organs that he was familiar with. The console started as a pedal implementation for another organ using a BERIO T-Organ module as a MIDI encoder, then got extended to a physical 4-manual system which ultimately gained some unique features aimed at playing convenience. This narrative is not intended as a history of what happened over the development years, nor will it attempt to argue "good" vs "bad" sample sets and practices. Rather it is a description of the current state of the unit with a central intention of assisting those who may have to set the instrument up without other assistance. There is material here that should be of assistance to others wishing to attempt a design and build.

THE CONSOLE: The console is entirely bespoke. It includes 4 manuals recovered from commercial low-cost keyboards in the Yamaha Portatone series of low cost MIDI keyboards, with their controllers cut down to the minimum necessary. The pedal board, two addressable Expression pedals, 48 thumb pistons and 12 toe pistons are addressed using a BERIO T-Organ interface which has been extended via D-connectors internally and externally to the console components. The BERIO T-Organ is terminated in a MIDI port. All MIDI ports are concentrated internally using a MOTU combiner with a single USB interface that connects directly to the computer. The Pedal board is a 1905 Fincham 30-note board recovered from a Church Organ in Hobart TASMANIA during a rebuild back in about 1955 which has been connected via a glass reed switch and resistor/diode matrix to the pedal arrays on the BERIO T-Organ. (Fincham was a major organ builder in Australia and this pedal board is a full scale radial concave typical of a high quality unit anywhere in the world – it did require rebuilding to deal with more than half a century of Church usage.) There are three interface connectors on the manual part of the console – a 25-pin D-connector to the pedal board, a 9-pin D-connector to the expression pedals and the single USB connector to the computer. The whole of the console is powered via an internal 12Volt DC supply which runs from 240VAC. The console is a prototype and internally is far from an easily reproducible production item. See a diagram of the console architecture (Figure 2) for details – all of the items are contained within the console physically. All the pistons have individual MIDI addresses spread over two MIDI channels, and under the controls possible using Hauptwerk, the whole is exceptionally programmable, across all types of divisionals, generals, couplers, steppers etc. Following Hauptwerk practice, all stops are accessible via a touch screen, and normally all assignments can be made using no more than the touch screen and a mouse. Once the system is set up, the mouse is not needed and all subsequent “mouse” operations can be achieved by a simple touch on the screen. Fundamentally this is an AGO console that is sufficiently close to that of a modern real pipe organ so that anyone familiar with a real organ can play this instrument without needing to know anything about the internal workings.

THE CENTRAL COMPUTER: The computer is a high performance HP Z800 workstation featuring dual Hexa-core (X5670) XEON processors, and 48GB of RAM. It is fitted internally with a Hauptwerk dongle that provides the licensing for the Hauptwerk system and encrypted sets by Sonus Paradisi. It is connected to the rest of the system by 4 USB ports and a Video interface to a touch screen. See Figure 3, and the section on starting procedures. The base OS is Microsoft Windows 10 64-bit version 1511, which SHOULD NOT be updated or connected to the internet. Such updates may compromise what is currently a compatible and stable system. There could be ongoing support issues with the connected hardware items: the MOTU MicroLite MIDI interface, the Hauptwerk dongle, the Tascam US-144 Mk2 Audio, and of course the Hauptwerk software.

THE HAUPTWERK SOFTWARE: The main organ software is Hauptwerk Version 4.2.1 Advanced Edition, licensed from Milan Digital for unlimited private performance and occasional public performance. It is activated by a dongle which is installed internally to the Computer. Several configuration adjustments have been made to optimise performance and functional assignments. For normal operational purposes, two icons on the Windows 10 taskbar are relevant and must be run in order – see the sections below on operations.

THE SAMPLE SETS: Many sample sets are available from the hard drives that are currently installed. As at 2019 there are about 50 organ sets and variants loaded. Most are demonstration sets and sets that have been modified for various purposes. To invoke some of those the console has to be reconfigured, and this is not considered to be a trivial process unless the operator is fully familiar with the Hauptwerk system. A lot of those sets have limited performance options and sound quality. Three sample sets are fully implemented and considered high performance options:

- Laurenskirk Rotterdam Main Organ: This is a large neo-baroque organ by Marcussen made in 1973 having 85 stops across 4 manuals and is probably the organ of choice for major performances. It is licensed from Sonus Paradisi for individual public performance. The sample set is encrypted and activated from the Milan Digital dongle. It is a Dutch organ with Dutch nomenclature and is in 6 divisions. In this implementation the 48 thumb pistons are set as 8 generals, 4 sets of 8 divisionals, and 6 couplers. The 12 toe pistons are assigned as 8 generals (11-18) on the Left side and 4 of these (11-14) are replicated on the Right side. A future hardware change will allow all 12 to be independent. Piston markings are currently relative to this set. The two expression pedals are set as the enclosed swell (left-pedal controls manual 3) and a pre-programmed crescendo pedal (right) which is NOT linked to the general pistons. (Changing the Crescendo sequence is not a trivial task.) General Cancel and Setter pistons operate normally and can be used to set any of the other pistons in the normal way. The Chamade division can be mapped to either or both the third and/or fourth manual, and note that the manual couplers operate on the Chamade. This is different from the real organ where only the third manual is used. Effectively it allows the fourth manual to be a Chamade Solo independently of the

swell. Note that the two 32' ranks on the pedal organ need a sound system with a high power bass capability down to 17Hz. The most common arrangement for public performance is to use the front ranks only with output to a stereo pair. Changing that arrangement is not a trivial process and can take about an hour to complete and reload. (See the Sonus Paradisi site for more detail about the sample set – stop layout etc.)

- Laurenskirk Rotterdam Transept Organ: This is a smaller Marcussen 3-manual organ of 31 stops from 1959 which is more baroque in its characteristics than the Main Organ and very suitable for recital purposes. It can be adjusted easily for listener position which effectively controls the acoustics. Currently this organ is set up in its original Sonus Paridisi format and is very close to the real organ in most respects. The sample set is the "surround sound version" and is encrypted and activated from the Milan Digital dongle. General and Divisional pistons have been set. (See the Sonus Paradisi site for more detail.). An extended version of this organ also exists which addresses some of the shortfalls of the normal version. This is shown in the organ list as "Transept Extended" and the extended section can only be addressed from the simple jamb layout.
- Cavaille-Coll Composite: Two organs were combined to create a three manuals instrument which is "typically French". The top manual is not used in this configuration except that the pistons there apply to the Pedal Organ. A stepper has been implemented on this set and up/down pistons are the 7th and 8th on the RHS of the second manual. Setting the stepper does take some effort via advanced Hauptwerk features, but is fully functional. Two divisions are fully expressive and controlled from the two expression pedals. This set is not fully licensed and should be considered as a special case.

THE AUDIO SYSTEM: The audio is as varied as the installation venues and usage allow. The usual audio interface to the computer is a TASCAM US-144 Mk2 2-channel module which is self-powered via a USB port and is connected to amplifiers and/or headphones as needed. The current interconnection is a standard line level and the most common reproduction system is a pair of JBL EON15 powered speakers and a JBL PS300 powered subwoofer using parallel porting. The line levels can be set independently for the main and sub speaker systems. That system is more than adequate for venues like St Paul's Cathedral in Melbourne. Where an existing audio system is installed (eg Deakin EDGE and Hamer Hall – both in Melbourne AUSTRALIA) then an isolating DI must be used to link the systems and address any hum problems that may emerge. SPECIAL NOTE: Experience has shown that some high quality audio interfaces cannot be considered to be reliable – the most common problem being unscheduled disconnection.

It has emerged that it is normally essential that a DI of some sort is fitted between the Organ audio and the powered loudspeaker system to control longitudinal hum and some interference sources. A simple DI consisting of no more than a couple of isolating transformers is adequate – providing full performance across the whole audio range.

POWER CONSUMPTION: The console only takes a few watts of power but the HP Z800 incorporates a 1,100 Watt power supply and the monitor a further 100 Watts or so. In planning an installation with large audio needs, the total power can be significant. A typical installation using JBL EON15 and PS300 speakers will require a 240VAC supply that can provide at least 8Amps – ie 2kVA – which is on the limit for most domestic power systems. For public performance, independent power feeds to the audio and organ systems must be used, and domestic multi boards with integrated circuit breakers should be avoided.

ASSEMBLY AND STARTING: After transport the organ does need to be assembled. The console consists of a table-like base, the pedal board that slides into place, the bench (seat) which does have a small adjustment for height by removing two blocks, and the manuals part. When handling, the manuals unit must be kept horizontal and there is a removable protection unit to avoid damage to the lower manual keys. The expression pedals and toe pistons are integrated with the table-like base, which also includes lighting for the pedal board. Finishing touches include a couple of spacers to stop a rear black curtain from fouling the expression pedals, that curtain and a couple of side curtains to cover the base unit. The location of the touch screen can vary from being clamped to the top of the console to sitting on the computer on one side. The music stand slides onto the top of the console according to preference. The electrical assembly of the organ is fairly logical and there are no serious traps for the unwary. (see the layout in Figure 3) The 4 USB ports (console, audio interface, mouse and touch screen interface) should be connected in accordance with Figure 3 and there is usually a similar tag on the computer. (This is important to minimise addressing issues in the computer.) If a computer keyboard is needed for configuration, it can be plugged into an available USB port at any time. The computer mouse is used as an alternative to the touch screen, but can be avoided altogether. Ensure that there is no obstruction to air flow at the FRONT and BACK of the computer – it uses about 4 times the power of a normal PC and needs cooling.

After completing the inter-system wiring, the console and touch screen should be powered on first (the console switch is on the RHS above the top manual – a RED LED indicates when it is on), then after about 5 seconds the computer may be powered on which should start normally implementing Windows 10. The task bar is to the RHS of the screen and there are two logos there that need to be addressed. The audio interface should be started first and when the audio screen appears the Hauptwerk application can be started. The first screen to appear should be the organ choice panel. All these actions can be achieved using the touch screen. Activate the organ of choice which will open another screen which includes a progress bar. That process can take a few minutes and when complete the touch screen will change to the full operating mode showing the stop jambs. At this stage the system should be operational but each of the expression pedals MUST be operated through their range to auto-index the end points. Of course the audio levels and connectivity must be set and checked. Press a general piston and check that all manuals and the pedal board are working. (if not – call for help! A trivial check is to make sure that the audio gains on the Tascam device are not on zero.) Use the organ as a normal AGO instrument. It is suggested that headphones be used to do the initial tests and when satisfactory, the main speakers and/or audio system may be powered up and the levels set. Organists familiar with Hauptwerk should be aware that changing some internal Hauptwerk settings can lead to operational issues, and most of the settings should be left as they are. However some parameters can be changed as needed. (Familiarity with Hauptwerk is assumed, but note that there are some issues with Hauptwerk which may be addressed following future updates. Note in particular that if the system is unstable after changing some items like individual rank pitching, the general restoration process may not work properly and if tuning (in particular) goes awry there seems no option but to shutdown WITHOUT SAVING, rebooting and restarting the programs.)

- Re-pitching: The temperament, pitch and transposition of the organ can be changed from the pulldown menus as normal. Note that different sample sets are usually on the original instrument settings as defaults but changes may be stored for restarts.
- Re-voicing: Revoicing should only be contemplated if there is plenty of time to resolve issues prior to using the organ. Past experience suggests that the Hauptwerk software may be buggy and that changes may not result in predictable outcomes. It may be necessary to totally reboot the system to restore functions and then to return to defaults before trying again.
- Sound levels: DO NOT increase the sound level by setting the output level within Hauptwerk – ie, it may be fine for a few stops but pull everything and the peak levels will crash – this is related to the maximum digital encoding and is not a CPU issue. (Levels have been set during configuration.)
- Polyphony: The polyphony has been set so that no unwanted noises or delays occur when all stops are out. 12 processors are in use and CPU usage is close to the limit. If a player plays by leaning on a keyboard for example then trouble may occur and the polyphony should be reduced.
- Stop sensitivity areas: There may be a coding error, or a problem in the NVIDIA drivers. A couple of the stops are not always mapped properly in the touch screen (touch area) – changing the screen area does address that. Selections using the mouse are always accurate.
- Stuck MIDI: Over the last 4 years of use there was one occasion when a MIDI address got stuck, and using the internal Hauptwerk stopper did not work. No option but to kill the audio level on the TASCAM unit to stop the sound, and then stop and restart the system right back to Windows restart.
- Other operational issues: Should the pedal board not work on all notes, check that the 25-pin cable is plugged in properly at both ends, including the multi ribbon cable attached to the table housing. The pedal board itself is passive so this can be done with the power on and system running. Interrupting the console power or the USB cables to the console or audio interface while running demands a complete restart, mostly because there are auto-ident process associated with those ports. The Hauptwerk dongle is mounted internally in the computer unit, so interruption is unlikely.

The placement of loudspeakers warrants special mention. Most venues have their own acoustics and some will even have audio systems that have been specifically designed for the venue. The virtual organs usually incorporate the acoustics of the original venues where the real organs are installed but some special sets exist as “dry” sets with the express intention of allowing the audio engineers to use the virtual installation to dictate the sound. A result of this is that it is possible to make some bad choices which can produce some very unsatisfactory reverberation times etc. Loudspeaker layout changes, including location, height and direction, may be necessary to produce a satisfactory result.

Experience will dictate what works and what does not work, and that can become a matter of personal taste. Indeed it may not be the same for all organ sets and what works for a “Dry” Laurenskirk Transept installation may not work for the Laurenskirk Main Organ. It is usual practice to locate the loudspeaker system remotely from the audience, but there is the operational complication that organists are commonly located very close to or even within the Organ case and want to hear a different sound. Where multichannel surround sound is used

it can be very effective if some speakers are placed at ground level and others on balconies for example. Sub-woofers are almost always located at ground level and in a way that couples to the building. It has been common practice with this organ to place JBL EON15 powered speakers on stands as high as possible in a conventional L-R stereo arrangement behind other performers. Some original organs have left and right chambers with ranks distributed and if those chambers are mapped into the target building then some of the characteristics of the original organ will be more evident in the virtual case. Interestingly, those who are more familiar with organs may like that whereas other musicians may see it as a disadvantage!

The time delay between key-press and sound can be significant for a real organ, and spacing the speakers away from the console may suit an experienced organist but confuse a novice. The key delay in this virtual organ is about 10 milliseconds or so, but that for the larger pedal notes will be longer because that is normal for real pipes – and this feature is carried over into the virtualisation.

SHUTDOWN: Set expression pedals to normal extremes – press GC then close the Hauptwerk application using the touch screen or mouse – it may ask if you want to save changes – usually yes. Then close the audio application, again from the touch screen or mouse, and perform a Windows 10 normal shutdown. Then switch off the monitor and the console power. (Do NOT turn the console off before the computer has stopped.)

Disassembly for transport is essentially the reverse of the installation – again – remember to keep the manual part of the console horizontal and to install the protective front.

APPENDIX 1: General matters associated with virtual organs.

The concept of a virtual organ has long been the aim of musicians and developers, right back to the beginning of electronic instruments a century ago. Some of the earliest attempts made use of tone wheels of various kinds (most notably the Hammond Organ) to emulate the sound of real pipes etc, and various strategies were employed to assemble the tones into audio streams that could be amplified and reproduced through loudspeakers. Another technique was the use of oscillators to produce the tones – a far more common form of electronic organ, but seriously limited by the amount of equipment needed. The main obstacle was the quantity and quality of sounds that could be generated. Other issues of adjusting phase, intonation etc were compromised by mechanical and electronic limitations. As technology developed there were attempts to store the sounds of real organ pipes on magnetic drums etc but again the complexity of a real organ made the tasks almost impossible at the time. At best the instruments were very limited and could only play a few tones and notes.

With the advent of computers, many of the limitations could be addressed – at least to some extent, but there were still many issues that rendered the resulting instruments of little use until recently – number of tones, the processing of complex relationships, the speed of response etc. By about the year 2000, simple instruments were being produced with the tones stored in memory of various kinds. Limitations in audio reproduction from digital images degraded the result.

The massive development of computers in the last few years has changed all that. Storage memory in very large sizes may not be cheap but it is possible, and importantly the speed of processing has increased so dramatically that it is no longer a serious limitation provided that the budget allows it. Even home computers are now large enough so that a reasonable virtual organ is possible, and an amateur developer can create a single manual organ using a laptop and a MIDI keyboard for very little money which is quite good enough for practicing and even use as a performing instrument.

When attempting to produce an instrument that emulates one of the world's great organs, the scale of things increases and reproducing an actual 4-manual console with a full pedal board becomes a major task. What in a simple instrument was a handful of ranks becomes maybe a hundred ranks, coupling all that to the computer becomes a major communications task and ultimately collecting all the digital signals so that they don't interfere with each other unintentionally pushes electronics to the limits.

The "organ software" has also been an issue and, as in the case of this organ, the Hauptwerk software by Milan Digital has proved to be a very good solution. Collecting and organising the pipe-by-pipe sounds results in maybe 30,000 computer files for a specific organ which again pushes non-volatile storage technology. To be playable, only RAM is fast enough to store those files and everything has to be transferred to volatile RAM on startup for the organ to be useful. A useful virtual organ may contain up to 100 ranks, and respond to a key press in 1/30 second, and include not only the notes but the way that they start and stop and the way that the acoustics in the original building react – and to be able to play maybe 7,000 pipes at once – a far cry from a simple electronic organ that may only have to reproduce 20 notes at a time.

Ordinary Personal Computers are not really up to the virtual organ tasks at the moment and most implementations use the best and fastest that are available – commonly what are called workstations. Up to a dozen processors are common and typically about 48GB of RAM is adequate although up to four times that can be called for in a really big organ working at the very best audio resolution. While early virtual organs used 16-bit sound or even less, most good units today use 24-bit sound, mostly to achieve sound quality and to minimise intermodulation. Stereo sound is adequate for most installations but up to 6-channel surround sound can achieve even greater realism and the use of multiple channels can create the effect of having different organ cases for different divisions etc.

The question of the cost of virtual organs is a common topic, and as in most things, that reflects some quality matters. You can get a cheap MIDI keyboard for less than $100 but a good one costs maybe $1,500 as it will be not only a higher quality but have other features like thumb pistons etc. A rule of thumb in 2018 is that you can assemble a large virtual organ for as little as $40,000 but with good case work and a high quality console could easily cost upwards of $100,000 – still a lot less than a real pipe organ. You can even download a simple organ application with a 30-stop organ that is free for personal use, but if you want the advanced version of Hauptwerk and the Laurenskirk Main Organ then be prepared to pay $2,000 - $3,000 just for the software and employ the services of an experienced "virtual organist" before contemplating the console and computer – let alone the advanced audio system that will be needed to make it all sound decent. Virtual organs are still more expensive than electronic organs of the same size, but with technology change and the rapidly improving supply of components that gap is evaporating.

A keen experimenter could probably put together an attractive 2-manual virtual organ of moderate capability, and for personal home use for around a couple of thousand dollars or even less if they have access to some used items. There are licensing issues for commercial use which change the economics significantly.

The Reynolds virtual organ was a project that started in 1966 using oscillators, an attempt at magnetic storage, the use of tape acoustic generators, modified reed organs of various kinds and at one stage a modified electronic organ. Indeed some of the physical components of those early attempts – the pedal board, the bench and the console case were part of that initial period back in 1966. In 2012 the project was limited to the pedal board that was going to be associated with a harmonium – but new developments changed that direction! The principles have not changed much but the technology is dramatically different. In its present implementation, the Reynolds virtual organ is about as large and capable as they come today.

APPENDIX 2: Layouts and diagrams

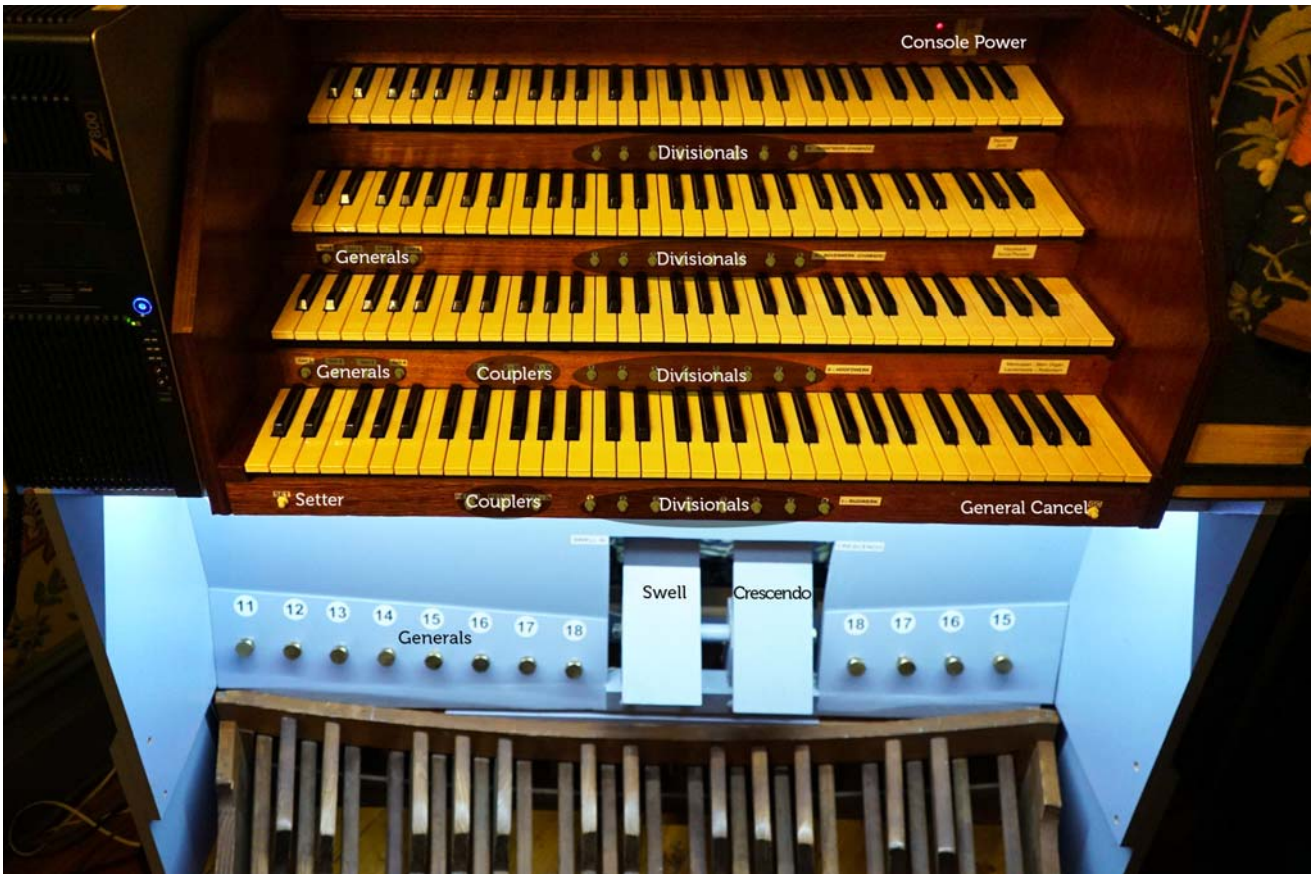

Figure 1: Console showing thumb & toe-pistons and expression pedal layouts

(typical – This arrangement specific to Laurenskirk Rotterdam Main Organ – Sonus Paradisi)

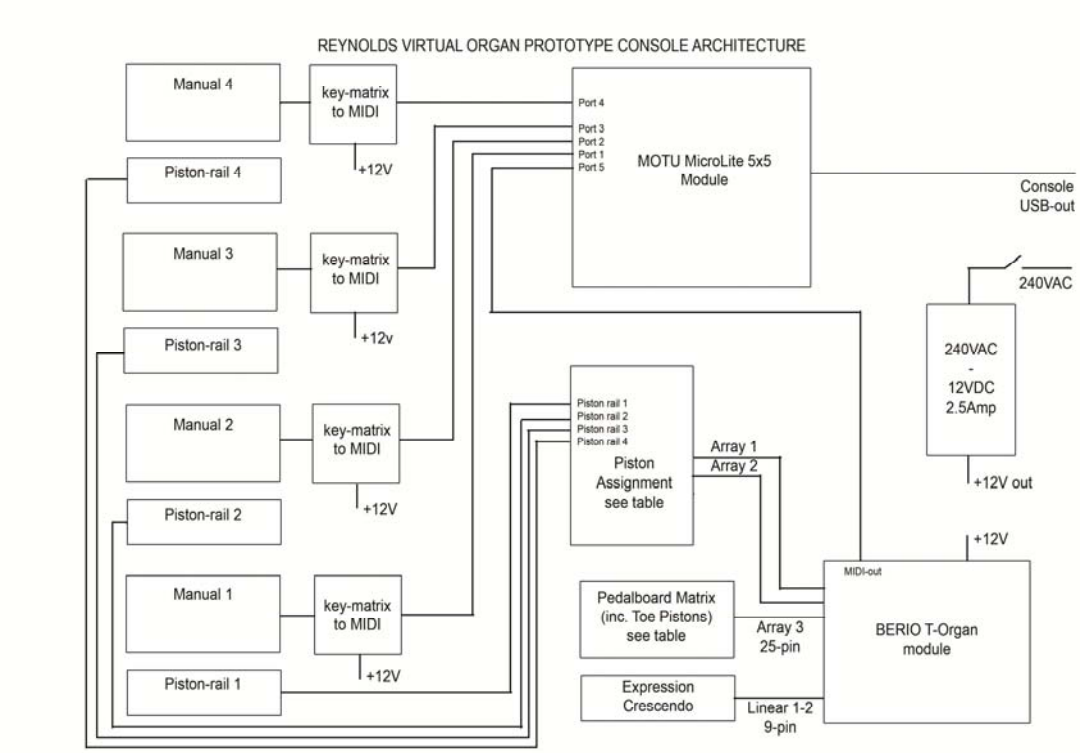

Figure 2: Console Architecture (note: common earth and power negative)

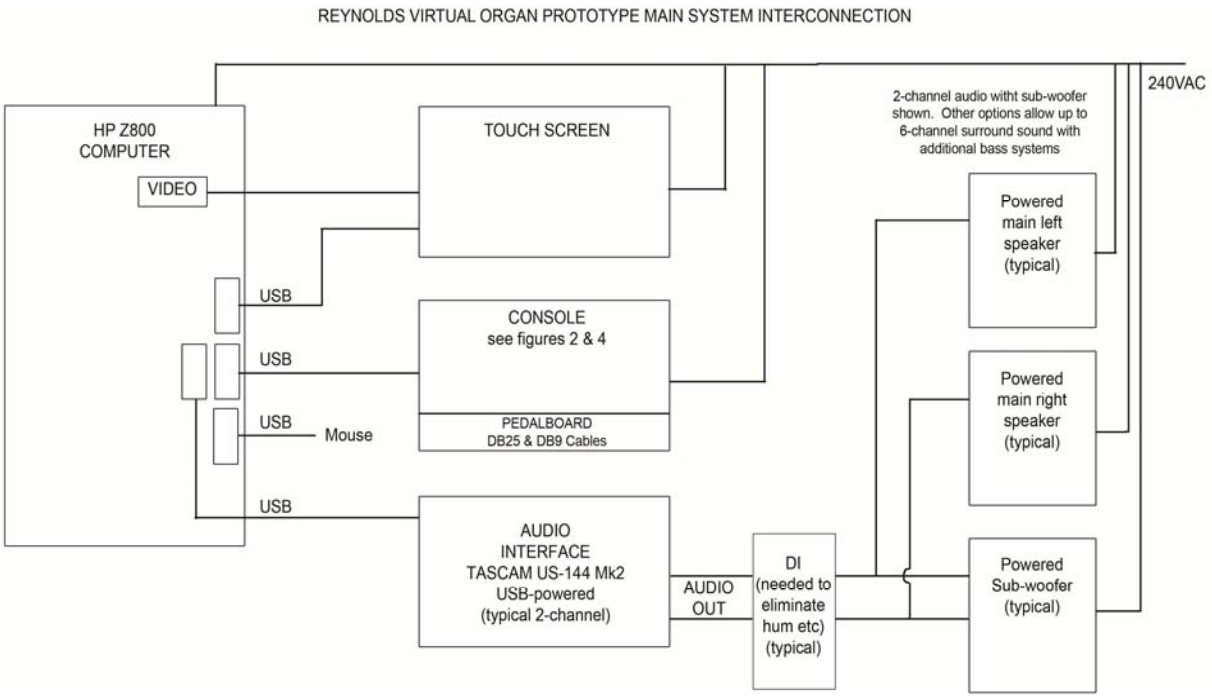

Figure 3: System Interconnections (note: USB assignments as viewed from rear of computer)

REYNOLDS VIRTUAL ORGAN CONSOLE - BERIO T-ORGAN MIDI ARRAY ASSIGNMENTS & PIN-OUTS

MIDI matrices

PISTON RAIL-4

S								13	13	13	13	13	13	13	13	
KM								0	1	2	3	4	5	6	7	

PISTON RAIL-3

S	12	12	12	12				10	10	10	10	10	10	10	10	
KM	4	5	6	7				0	1	2	3	4	5	6	7	

PISTON RAIL-2

S	12	12	12	12	11	11	11	9	9	9	9	9	9	9	9	
KM	0	1	2	3	3	4	5	0	1	2	3	4	5	6	7	

PISTON RAIL-1

S	11				11	11	11	8	8	8	8	8	8	8	8	11
KM	7				0	1	2	0	1	2	3	4	5	6	7	6

PEDAL-BOARD

S	16	16	16	16	16	16	16	16	17	17	17	17	17	17	17
KP	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6
PEDAL NOTE	C	C#	D	D#	E	F	F#	G	G#	A	A#	B	C	C#	D

S	17	18	18	18	18	18	18	18	18	19	19	19	19	19	19
KP	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5
PEDAL NOTE	D#	E	F	F#	G	G#	A	A#	B	C	C#	D	D#	E	F

TOE PISTONS

S	22	22	22	22	22	22	22	22				22	22	22	22
KP	7	6	5	4	3	2	1	0				0	1	2	3

DB25 maps

Pistons

pin	1	2	3	4	5	6	7	8	9	10	11	12	13
line	KM0	KM1	KM2	KM3	KM4	KM5	KM6	KM7	S0	S1	S2	S3	S4
pin	14	15	16	17	18	19	20	21	22	23	24	25	
line	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	NC	

Pedals

pin	1	2	3	4	5	6	7	8	9	10	11	12	13
line	KP0	KP1	KP2	KP3	KP4	KP5	KP6	KP7	S16	S17	S18	S19	S20
pin	14	15	16	17	18	19	20	21	22	23	24	25	
line	S21	S22	S23	NC	NC	NC	NC	NC	NC	NC	NC	NC	

DB9 map

Expression

pin	1	2	3	4	5	6	7	8	9
function	L	+	-	R	NC	NC	NC	NC	NC
wire colour	Br	Gr	Ye	Wh					
(new)	Ye	Rd	Bl	Wh					

NOTES:

KP is Pedal array on T-Organ

KM is first Manual array on T-Organ

S-lines diode anodes to switch

K-lines always octal

Figure 4: MIDI array assignments and pin-outs for the BERIO T-Organ module

(note: See Berio operational notes for appropriate DIP switch settings)

