Palace of Arts Budapest
Pipe Organ Samples

Professional Edition
Extended Edition

for Hauptwerk™ 3

User's Manual

Printed in Hungary.

Version 2009|A

Table of contents

1 Welcome

Welcome to one of the largest virtual pipe organs in the world and congratulations for your purchase!

Palace of Arts Budapest (PAB) Pipe Organ Samples is a fully playable, freely configurable, intuitively manageable and MIDI-controllable virtual pipe organ, delivering the authentic sound of the 92-stop Pécsi-Mühleisen pipe organ of the Béla Bartók National Concert Hall of the Palace of Arts – Budapest, Hungary.

Designed for operation within Hauptwerk™ software, on both PC and Macintosh computers, Palace of Arts Budapest Pipe Organ Samples sets a new standard in virtual pipe organs used by leading organists, professional musicians, professors and tutors, educational, worship and culture institutions, recording professionals and enthusiasts.

Despite its immense size and capabilities, it is a pipe organ you can play and take with you wherever you go, offering unprecedented flexibility and sound quality never heard before in a virtual instrument.

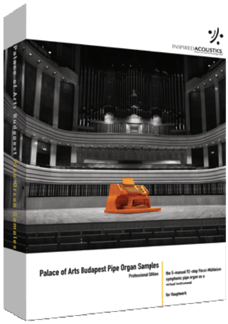
1.1 Highlights

The organ has many unique features, including:

- Fully functional Combination Action exactly duplicating the real organ, *independent of Hauptwerk™'s combination action,* controllable directly from the screen or by means of MIDI. (see *Chapter 3.8*)
- 61-stage crescendo with multiple programs (see *Chapter 3.7*)
- Multiple pages optimized for single or dual touch-screens. (see *Chapter 3.1*)
- and more

1.2 What is contained inside the package

1.2.1 Contents of the box



If your version of PAB Pipe Organ Samples was delivered to you in a physical form rather than a download, please make sure you have the following contents in the box to ensure you have received a complete product:

- Three USB thumb drives (also known as USB sticks) containing the installation data (Professional Edition)
- One External USB hard disk drive (Extended Edition)
- Your personal serial number on a printed registration card
- PAB User's Manual

1.3 Hardware and software requirements

Palace of Arts Budapest Pipe Organ Samples is hosted within Hauptwerk™ virtual pipe organ software, available for both PC and Mac computers from Milan Digital Audio, found at http://www.hauptwerk.com on the Internet. Hauptwerk™ functions with both currently available 32-bit and 64-bit operating systems. Hauptwerk™ Advanced Edition is recommended. A high-performance computer is required to experience full, flawless and convenient operation of this library.

1.3.1 RAM and number of loadable stops

Since Hauptwerk™ loads the sample data into the computer's random access memory (RAM) – and does not stream data from the hard disk – the amount of RAM determines the number of stops you can load for playing at a given time. The theoretical RAM limitation, per program instance is 4 GB in 32-bit operating systems; loading all stops of the organ requires a 64-bit operating system, capable of handling more than 4 GB of RAM. Regardless of operating system, please make sure you are using more than 4 GB of RAM.

Hauptwerk™ allows you to load the library with independent options for each available stop, allowing you to trade off the number of loadable stops with varying degrees of realism (you can, for example, choose to load less than the full complement of release samples). Loading all of the stops in their most complete multi-looped versions and with full release samples will consume much more RAM than loading them with, say, single looped data and/or truncated release tails.

Please refer to the Hauptwerk™ User's Manual for a complete description of how to maximize performance with these features.

Hauptwerk™ offers lossless compression for sample loading. We recommend turning this option ON when loading the samples, since it does not affect the quality of sound, but increases the number of stops one can load at a time.

The following table summarizes the loading requirements for the instrument.

RAM requirements for PAB Professional Edition

Loading setup	Bits	Multiple Loops	Multiple Releases	Subjective Quality	Required RAM
Full organ, 92 stops	24	all	all	maximum	24.1 GB
Full organ, 92 stops	16	all	all	almost maximum	12.8 GB
Full organ, 92 stops	16	first	all	nearly maximum	8.2 GB
Full organ, 92 stops	16	first	one layer	high	5.6 GB

	Bits	Multiple Loops	Multiple Releases	Subjective Quality	Required RAM
Manual 1: Great Organ	24	all	all	maximum	4.9 GB
	16			almost max.	2.8 GB
Manual 2: Pos. expr.	24	all	all	maximum	6.4 GB
	16			almost max.	3.5 GB
Manual 3: Réc. expr.	24	all	all	maximum	6.5 GB
	16			almost max.	3.6 GB
Manual 4: Solo	24	all	all	maximum	4.3 GB
	16			almost max.	2.5 GB
Manual 5: Chamade	24	all	all	maximum	1.4 GB
	16			almost max.	1.0 GB
Pedal	24	all	all	maximum	3.4 GB
	16			almost max.	2.0 GB

RAM requirements for PAB Extended Edition with cathedral acoustics

Loading setup	Bits	Multiple Loops	Multiple Releases	Subjective Quality	Required RAM
Full organ, 92 stops	24	all	all	maximum	more than 32 GB
Full organ, 92 stops	16	all	all	almost maximum	17.3 GB
Full organ, 92 stops	16	first	all	nearly maximum	12.6 GB
Full organ, 92 stops	16	first	one layer	high	7.1 GB

1.3.2 CPU and Polyphony

It is essential that your computer has a high-performance CPU in order to experience full polyphony. A high polyphony capability is required when many stops are drawn and many notes played together.

Note: Polyphony is defined as the number of stops being selected, times the number of notes held per stop, including the duration release tails to sound, at any given time.

A series of fast staccato chords in Tutti will stress your computer the most, because the initial release tails will continue to sound as additional staccato chords are being played. For the most flawless operation, we recommend the use of a 4-core or 8-core CPU or better, equipped with the most RAM that you can afford. As your CPU power increases, you can achieve more polyphony.

Please refer to the Hauptwerk™ User's Manual for a complete description of how to achieve maximum polyphony with your computer.

2 Installation

Installing the PAB Pipe Organ Samples requires that you own a registered, installed copy of Hauptwerk™ virtual pipe organ software, together with a registered, working dongle. See *Chapter 2.2* for more detail about acquiring a Hauptwerk™ license and authorizing the dongle. Please do not attempt to install the PAB library unless you have a registered copy of Hauptwerk™ installed in your computer.

This installation procedure is for Hauptwerk™ version 3.21. If using a later version of Hauptwerk™, the required steps may be slightly different in detail; please refer to your version's copy of the Hauptwerk™ User Guide.

1. Plug in the first USB stick or External Hard Disk Drive into an unused USB slot of your computer. Wait until the computer recognizes the USB drive and, either a drive letter is dispatched to it (PC - Windows), or it is mounted on the desktop (Mac - OS X). Once your computer has accessed the USB stick / External Hard Disk Drive, proceed to the next step.
2. Launch Hauptwerk™ virtual organ software in the "standalone" mode.
3. From within Hauptwerk™, go to the file menu and select Install organ, sample set, temperament or impulse response
   a. The program will prompt you to select the program to install.
   b. Navigate to the USB stick / External Hard Disk Drive to select the first file set to install. All of the available file sets should be installed in order to make the library work.
   c. Click Open and then click OK on the next screen.
   d. Wait until Hauptwerk™ finishes installing the file you have selected.
4. Repeat Step 3 until all files are installed from the first USB stick / External Hard Disk Drive.
   a. Remove the current USB stick from the computer, and plug in the next USB stick.
5. Repeat Steps from 3 to 4 until you have finished installing all of the files from all of the USB sticks.

Important:	**The Extended Edition requires the Professional Edition to be installed first. Please make sure that you install the provided packages in their alphabetic order.**

2.1 Upgrading and updating PAB Pipe Organ Samples

There are two cases for which you may need to apply an upgrade:

1. You wish to apply a new update to your current Edition
2. You own a smaller Edition that you wish to upgrade to a larger Edition

The procedure for installing upgrades and updates is the same as the normal installation process, except that, instead of inserting USB drives, you may receive the update or upgrade files by downloading them from the Inspired Acoustics website, **http://www.inspiredacoustics.com**.

2.2 USB license key authorization for Hauptwerk™ version 3

In order to use PAB Pipe Organ Samples, you must authorize the library through Milan Digital Audio, the company that makes Hauptwerk™. The authorization system they have developed for Hauptwerk™ protects PAB Pipe Organ Samples as well. In order to use PAB Pipe Organ Samples, a license update is necessary to your current USB dongle (USB key).

Note: The PAB Professional and Extended Edition use the same USB authorization and the authorization is required only once. Current owners of the Professional Edition can upgrade to the Extended Edition without the need to re-authorize the USB dongle (USB key).

When you purchased the library, as you know by now, we have notified Milan Digital Audio to issue you a license update for your Hauptwerk™ USB dongle. To obtain this license update for the PAB Pipe Organ Samples, Milan Digital Audio will need a license update request from you. This can be created by clicking on the **File \ Create license update** in Hauptwerk™. Once the file is created and saved on your hard drive, attach it and send it by e-mail to **info@milandigitalaudio.com.** They will respond to you as soon as possible with the license update and the instructions on how to apply it to your own personal copy of Hauptwerk™. It is a very easy process that you can do with a few mouse-clicks and it is very likely that you have already performed these simple steps.

Note: MILAN DIGITAL AUDIO IS ENTIRELY RESPONSIBLE AND LIABLE FOR THE LICENSE AUTHORIZATION PROCESS AND FOR ISSUING YOU THE LICENSE UPDATE.

We have no direct control over this process, but in any case, we guarantee that you receive a fully working copy, even if you did not receive a license key from Milan Digital Audio.

If you have any problems, please contact us through our Website at **http://www.inspiredacoustics.com**.

For more information on how to request and apply license updates in Hauptwerk™, please refer to the Hauptwerk™ User Guide.

3 Controls of the virtual pipe organ

The organ at the Palace of Arts – Budapest contains two working consoles: the upper console, integrated into the main body and pipe case of the organ; the lower (or "stage") console is a movable console, capable of placement at center stage as a solo instrument, or located to either side of the stage during orchestral productions.

Inspired Acoustics has taken extraordinary measures to reproduce every possible sonic nuance of the original pipe organ, and provide every control feature of its stage console in the virtual instrument format. Some features – previously not available in Hauptwerk™ software – were developed by Inspired Acoustics in order to maximize the convenience of your playing experience.

3.1 Pages

The organ controls are organized into so-called "Pages" in the Hauptwerk™ program, to allow convenient operation. Each page of this virtual instrument plays a different role, and allows you to control and monitor the organ's numerous features in a convenient way. The following table summarizes the contents of each page.

Page name	Description	What is it for?
Console	Overview of the stage console.	Check, control, observe and demonstrate everything on one screen, including keyboard, pedal, swell box and crescendo wheel movements.
Center	Stage console: all control elements except keys on one single page, modified for convenient control.	For systems with a single touch display screen, this page allows you to control all stops, combination action and miscellaneous functions
Left	Stage console: stops of the left side, close-up, modified for convenient control.	For systems with two individual touch screens, you can place this screen to the left of the keyboard, to control the left bank of stops, just as on the real instrument.
Right	Stage console: stops of the right side, close-up, modified for convenient control.	For systems with two individual touch screens, you can place this second screen to the right of the keyboard, to control the right bank of stops, just as on the real instrument.
Left Photo	Stage console: stops of the left side, close-up	Same as above for left side (photo realistic).
Right Photo	Stage console: stops of the right side, close-up	Same as above for right side (photo realistic).

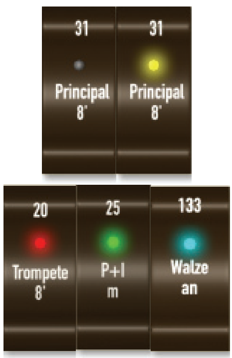
Crescendo 1 Crescendo 2	Programmable crescendo, page 1 Programmable crescendo, page 2	These pages allow you to program the pipe organ's 61-stage crescendo wheel to any desired custom configuration.
Compatibility	Direct access to combination buttons and additional couplers	This page allows you to access compatibility features that work best with your organ console.

3.2 Keys and keyboards

The virtual instrument boasts the Palace of Arts Budapest's full five 61-note manuals and a 32-note set of pedals. All keys and keyboards are shown in a photo-realistic perspective view, fully responsive to mouse control. The notes, pedal keyboard, swellbox pedals and crescendo wheel all faithfully mirror your performance.

3.3 Stops

The stage console of the organ features pushback key stops with colored lights indicating their functional states. Indicator lights come on when individual stops or controls are drawn. There are various "pages" in the Hauptwerk™ displays containing close-up images of the stops. If you manipulate the stops or controls in one page, their on/off status will be synchronized with the other pages as well.



Color	Meaning
yellow	flue pipes and electrical couplers
red	reed pipes
green	mechanical couplers
cyan (blue)	controls related to the crescendo wheel (called the "walze" in the stoplist)

3.4 Buttons

The stage console has several button controls for use during live performance. Some of these buttons control additional sounds, such as the engine Motor or Tuba; other buttons control or trigger functions, such as the Combination Action or the temporary removal/restoration of reed stops.

3.4.1 Optional Engine Sounds (Motor, Tuba)

The Motor and the Tuba button are buttons that will optionally turn on the organ motors. The real organ has a separate electric motor for the stop Tuba Mirabilis 8' on the 4th (Solo) manual. The virtual instrument however allows you to play all stops without any motor noise at all, allowing the creation of super-high-quality totally noise-free recording, something that is (naturally) not even achievable on the real instrument. For those seeking ultimate realism, just turn on the motors!

Note: You can only turn on the Tuba button *after* the Motor is turned on. When the Motor is turned on, the Combination Action will trigger stop action sounds as well. The Crescendo Wheel Programs can store and control turning on or off the Engine for your convenience.

3.4.2 All reeds off button (-Z)

This button, available as both a foot piston on the Console Page and as a separate button with the label –Z, will temporarily disable the reeds from any active configuration of stops.

Interesting fact: Letter Z denotes *Zungen*, the German name of Reeds.

3.4.3 Plenum and Tutti buttons (PL and TT)

PAB Pipe Organ Samples Professional Edition ships with pre-programmed Plenum and Tutti combinations (PL and TT, respectively) for your convenience. If you have not had time (or are disinclined) to prepare preset combinations, just press either of these buttons, and you will get moderate-level or full-level sound, as desired.

This feature is available both as foot pistons marked as PL and TT and as square-shaped wooden buttons on the Center, Left and Right pages.

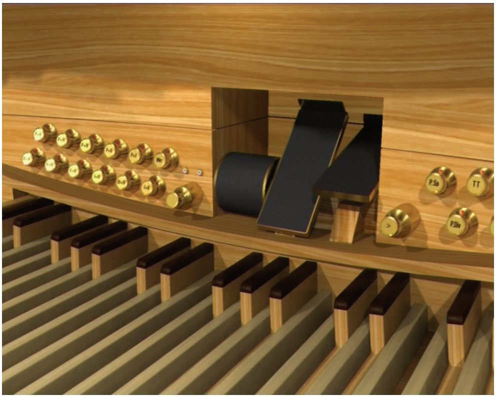
Extended Edition In the Extended Edition you can program these buttons freely using the S button and then pressing the PL or the TT. When you save a combination file in Hauptwerk, your custom TT and PL will also be saved. If you wish to restore the original, just reload the organ.

3.4.4 Cancel and Zero buttons

Due to the large number of stops in this organ, it is not easy to turn off all stops manually. To make this easier, there are Cancel and Zero buttons. Cancel buttons turn off each manual's stops independently, while the Zero button turns all stops and couplers off with a single click, and will also deactivate the PL and TT pistons. The Cancel buttons are located near the stop switches and are labeled with the name of their respective manual.

The Zero or general cancel button turns all stops and couplers off. In Palace of Arts Budapest Pipe Organ Samples it is marked with a zero sign Ø and is located on the right side beneath the first manual on the Console Page.

3.5 Swellboxes



Left pedal: manual II. (Positiv expr.)

Right pedal: manual III. (Récit expr.)

Swellbox Condition: 'heels up' means swellbox shutters are opened (Professional Edition).

Swellboxes are enclosures with vertical venetian blind-type shutters controlled by the swell pedals (or 'swell shoes'). As a given shutter closes, the pipes contained in that swellbox will sound quieter and darker. The Palace of Arts organ's swellbox characteristics, through careful measurement and accurate modeling, are brought to life with breathtaking realism.

Extended Edition

In the Extended Edition you can select the operation direction of the swell pedals. The sign with the arrow shows the pedal position in the closed swellbox state.

3.6 Light Emitting Diode (LED) Numeric Indicators

The original organ is equipped with various numeric indicators on the stage console, to assist the organist in determining the status of combination, divisional and crescendo settings.

The Combination label represents the status of PAB's proprietary combination action, ranging from 000 to 099 in user-programmed combination banks.

The Walze label has two sets of matrix LEDs that represent the operating status of the crescendo wheel: the left Walze display identifies the currently selected crescendo program. The right Walze display shows the actual state of wheel position, from 00 (start of wheel program) to 60 (end of wheel program).

The Positiv and the Récit indicators portray the current positions of the swellbox shutters: from 00 (fully closed) to 20 (fully open).

3.7 Crescendo wheel (Walze)

The crescendo wheel is an axially rotating drum operated by foot control, and is used in place of a conventional crescendo pedal. The Walze is positioned to the left of the foot-operated swellbox pedals. Sliding (rolling) it forward from position 00 to a higher position triggers stops in a preset user-defined manner, according to the sequence contained in the respective Crescendo Program. Cyan lighted stops control the crescendo wheel located in the bank of Manual IV. (Solo) stops.

Note: To enable the crescendo program, turn on the stop *133 Walze An*.

Stop switch	Effect
133 Walze an (Walze On)	Crescendo wheel enabler
134 Koppeln aus Walze (Couplers off Walze)	Disables couplers from the current crescendo wheel position
135 Mixturen aus Walze (Mixtures off Walze)	Disables mixture stops from the current crescendo wheel position
136 Zungen aus Walze (Reeds off Walze)	Disables reed stops from the current crescendo wheel position

Note: You must turn on Stop #133 Walze An to enable the crescendo wheel. If you enable the wheel on a non-zero position of the crescendo wheel, such as 26 for example, the corresponding combination will load.

The virtual instrument supports multiple crescendo programs. While two programs are pre-loaded in the instrument, you can freely modify any of them. The crescendo has 61 stages, from 00 to 60, inclusive.

To toggle the crescendo program between #1 and #2, and back again, push the button labeled **W ▷**.

You will find this button near the Crescendo Indicator. If the current program is the last and you push this button, you will be brought back to the first program.

3.8 Independent Combination Action

The Combination Action of the PAB Pipe Organ Samples is totally unique amongst Hauptwerk™ organ libraries. For the first time, you can control different sets of stops (combinations) stored in the organ's internal memory by a single click or touch, *right from the graphical interface*.

This amazing feature is completely independent of Hauptwerk's™ own combination action system, allowing more convenient use and the possibility to register the virtual organ's stop list in exactly the same way as the real organ.

The key element of PAB's Combination action is the "Increment" and "Decrement" button array, clearly marked with left- and right-facing triangles.

Combination action is used to access presets of different stop configurations with a single click, an essential feature when performing organ pieces in real time.

3.8.1 Features

Each Edition of PAB Pipe Organ Samples is capable of storing different numbers of combinations within its internal memory; the Professional Edition can store up to 100 programs ranging from 000 to 099, the Extended Edition can store 1000 combinations from 000 to 999. You can save and load these programs into a single file by using Hauptwerk™'s built-in Save and Load functionality in the Combinations menu (as of Hauptwerk™ Version 3.21).

The Combination Action, or "Setzer" in its Germanic name, is accessed and controlled by a group of dedicated buttons. Ten numerical buttons (numbered 0 - 9) can directly access the first ten memory positions, and are also used in conjunction with the four buttons marked with arrow-like triangles, permitting rapid navigation within the combination memory. The up-down arrow buttons advance/decrement the selection by ‘tens’, while the left-right buttons advance/decrement by ‘ones’ (see below). The S key is used to Set combinations in memory.

3.8.2 Programming and resetting from Graphical User Interface (GUI) or Musical Instrument Digital Interface (MIDI)

Once you define a stop configuration on the console that you wish to save as a combination preset (also called a “frame”), press the S button once, and then press either a number or a navigation key to select which combination frame you want to program. If you select the same number that was previously active, the previous combination will be overwritten with the new one.

Hint: The easiest way to program a particular stop combination into the next frame is to press the S set button and then press the increment button. This will program the currently set configuration to the next frame and increment the current frame by one to that frame – with a single click.

You can also assign MIDI messages to these buttons so that, if you have a MIDI-capable console, all these functionalities can be directly available to you in physical form as well.

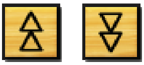
3.8.3 Navigation and use during organ play

Navigating between different combination frames is very easy. You can increment and decrement the current frame by one using the buttons below:

Button	Effect
	Decrement the current combination frame by one number (previous)
	Increment the current combination frame by one number (next)

There are also“Up” and “Down” buttons, to make navigation even easier. The up and down buttons increment and decrement the combination frames by “tens”. It is a simple matter to use these buttons together with the numerical buttons to quickly navigate to the desired combination frame.

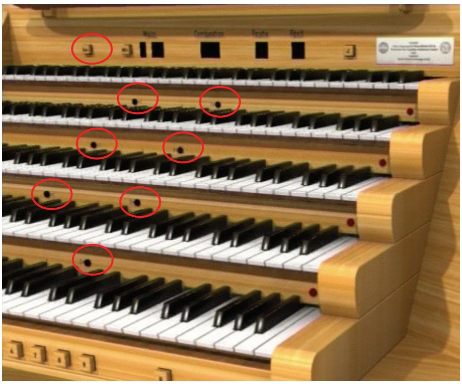
For Example: If you wish to change from combination frame 004 to 025, this is possible by just three clicks. Push the button UP twice (to go from “00_” to “02_”, and then press button 5 to get you to “025”. The newly chosen combination will only be changed when you push the third numerical digit you wish you reach, e.g. number 5. In this way, you can navigate easily, conveniently, and safely.

Button	Effect
	Navigate the system to the next tens of combination without changing the current combination. Then, push one of the number buttons to access the desired combination frame directly.
	Navigate the system to the previous tens of combination without changing the current combination. Then, push one of the number buttons to access the combination frame directly.
Extended Edition 	In the Extended Edition there are buttons to help navigating in the hundreds of combination frames. These buttons work similarly as the single up and down arrow buttons and helps you navigate in the 1000 combination frames this edition offers.

3.8.4 Loading and saving Combinations to files

Saving entire banks of combinations is just as easy as saving Hauptwerk's™ own combinations, and can be configured using the same commands.

3.8.5 Combination frame advancement buttons beneath the keyboards and Seq+



Below each manual on the Console page you will find two small black buttons. These buttons increase and decrease the current frame of the combination action, e.g. from 000 to 001 or vice versa if they are enabled only with the Seq+ button. You will find Seq+ on the top left of the console on the Console Page.

These features were made available should you construct a real organ console with such features and wish to equip it with suitable MIDI control. You will find it very convenient to play and develop stop/combination registration with the help of these buttons.

3.9 Sostenuto (Extended Edition)

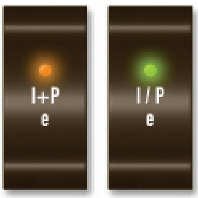
A very special feature of this pipe organ is called the Sostenuto. Once it is turned on, the organ will keep holding the keys that you pressed until you press another note or chord. This is a very useful feature in improvisation when you are playing more notes than the number of fingers you have. Push the Sost. button to activate this feature.

3.10 Pedal division (Extended Edition)

Another very improvisation helper feature of this pipe organ is the ability to split the pedal into two virtual pedal keyboards. Once the pedal is split, the lower part will play the original notes of the pedal, while the upper part will play the pedal couplers only. For example if you couple a Chamade 8' from the fifth manual to the pedal and use this feature, you can play a solo voice with accompaniment just on the pedal. To activate this feature, push the P. div button or the similarly marked foot piston on the Console Page.

You can arbitrarily select the split point of the pedal by pushing the Set P.Div button. Push a pedal key afterwards and the virtual organ will learn the split point.

3.11 Pedal to manual couplers and splits (Extended Edition)



For compatibility reasons reverse couplers were also added to the Extended Edition so that you can play the pedal sounds on any keyboard. There are two possible ways of achieving that. The orange colored pedal couplers adds the pedal stops to the selected manual and works similarly as a coupler, while the green colored switch splits the keyboard so that the lower part will play the selected pedal stops only. The letter *e* means 'electrical' coupler, following the original organ's terminology.

4 Usage tips and recommendations

This section provides tips and recommendations on how the library's creators believe PAB Pipe Organ Samples can be used most efficiently. If you are new to Hauptwerk™, please refer to their detailed User's Guide. As of this time of writing, Version 3.11 of Hauptwerk™ is current.

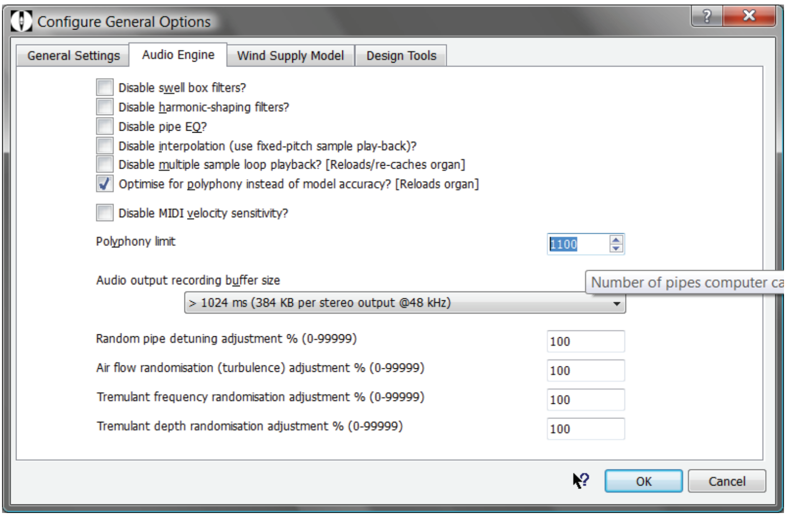
4.1 Before loading the organ

4.1.1 Increase the default polyphony limit

It is recommended that, before loading the organ, you increase the maximum allowed polyphony (polyphony limit) in Hauptwerk™, in order to permit reproduction of the entire intended performance. This very large organ requires more polyphony to operate effectively than provided by Hauptwerk™'s own default setting.

PAB's recommended minimum polyphony setting is about 3 000 to 7 000 notes; please change the default from 1100 to a higher value in this range. 32 768 is the maximum value you can set (as of Hauptwerk™ version 3.11). If you have a more powerful computer you may change this up to 32 768 as well. It is also recommended that you deactivate the *Optimise for polyphony instead of model accuracy* option.

The following screens show the windows located in Hauptwerk™ 's General Organ Options page, where you can adjust the settings. Note that this is for Hauptwerk™ version 3.11; later versions may provide a different way to change the maximum allowed polyphony.



Note that when you set the polyphony limit to a very high value, your CPU may become stressed when many notes are played together. Please refer to Hauptwerk™ 's User Guide for how to set this parameter to your CPU appropriately.

4.2 Answers to frequently asked questions

4.2.1 Why do we recommend convolution reverb instead of release samples?

Multiple layers of release samples are meant to provide a more accurate model than a single release sample, and indeed a much accurate result is obtained, since it is obvious that a long sustained note will have a different release 'footprint' than a short staccato note whose sustained part has not fully developed. However, as the number of release sample layers increase, the loading and computing (mixing) demand also increases. Multiple release sample layers - even if supplied in great number - will always be quantized in time, i.e. their lengths will exactly correspond to only a few particular note durations.

Convolution reverberation, adopting rigorously prepared and measured state-of-the-art impulse responses, provides the appropriate quantization *for any length* of note since the release samples will not be pre-calculated but calculated *as you play*, *in real time*. It is also possible to use release samples and convolution reverb *at the same time* when the release samples are used only for reproducing the valve-closing sound in the case of smaller instruments or ranks producing audible valve-related sounds, or when the sample set is relatively dry.

On the other hand, convolution is not just capable of reverberation, but of filtering as well, so the swellboxes can be also replaced with more accurate, organ-specific models, if measured adequately during the recording.

4.2.2 What is MUPA?

MUPA is the abbreviation of Művészetek Palotája, the Hungarian name of the Palace of Arts – Budapest, where the organ is located. In the professional music world, MUPA has become an icon of quality, professionalism and excellence where the world's leading artists perform on a daily basis.

You can visit the website of the complex at **http://www.mupa.hu**.

5 History and working mechanism of pipe organs

A pipe organ is a keyboard instrument that produces sound by allowing wind (forced air pressure) to travel through pipes or reeds. Pipe organs are most commonly encountered in churches; they are not simply large, majestic musical instruments, but beautiful pieces of art, as well. The pipe organ repertoire is particularly rich in solo music, but the organ is also frequently used to accompany choral and congregational singing.

5.1 History of the pipe organ

As its name implies, the pipe organ consists of pipes; technically, pipes made of animals and plants could be considered its earliest predecessor. Simple flutes made of bamboo could be blown, one at a time, or placed side-by-side, panpipe style, making possible simple tunes. Nevertheless, it is usually the bagpipe that is generally considered the organ's ancestor. Its history goes back at least to the time of the Emperor Nero. Findings from the period prove that the pipe organ and its various ancestors did exist (e.g. the water organ [*hydraulis*] uncovered in 1931, Aquincum, Hungary). Many historical instruments still work today, the earliest surviving workable form of which, located in Sion, Switzerland dates to *circa* 1390.

We have abundant written records – pictures and descriptions in woodblock form – concerning medieval pipe organs. A very characteristic organ type of the period was the *portable organ*, with only a few ranks of pipes and used only on occasion. Later, as the instrument grew, *fixed* solutions became popular (positive organ). A type that had only reed pipes (*regal*) also appeared first in the medieval ages. Its wind chest, made of bronze, was blown with pairs of hand- or foot-operated bellows. Several people were needed for operation (in the 13th century, 70 people had to work on blowing the 400-pipe organ of a cathedral). Until the medieval organs, it was not possible to switch on the various pipe ranks separately (*Blockwerk*). Sliders – which allowed this – appeared only in the 16th century. Organs of this time featured pipes of the same width (they were measured to the width of an egg). Later, as the size of the organ grew, several wind chests were built into the instruments. Each wind chest had its own manual, or playing keys. Later so-called *Werks* ('works', which featured certain stops to create specific sounds) were built on these chests.

By around the 16th century, all the basic pipe styles were formed, the same as can be found in almost all contemporary organs. Wind pressure measurement (a U-shaped glass tube partially filled with water) was first used in the 17th century, allowing pipe organ


C
G

design to be more conscious and precise. At this time stops imitating strings appeared, and at the beginning of the 18th century, in Spain, the swellbox was invented, allowing control (via a pedal) of the dynamic sound of the pipes located in a wooden box, or *enclosure*.

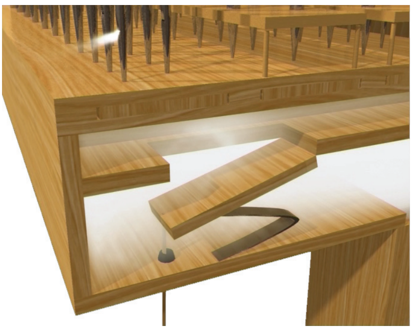
By this time, organs covered the classical voice range and transmission stops were introduced, which used the pipes of other stops, without coupling. Organs built in Italy had no pedals, had only a few "third-sounding" mixture stops, had no reeds but featured the so-called Italian principal stop (Diapason) - essential ever since in modern instruments.

Austrian and South German organs also had few reeds, while Spanish instruments featured many flutes and, cornets, along with quint- and third-sounding mixture stops. Using combinations, (stopped 8' + wide Principal 4' + 2 2/3' and 1 3/5') they could create a trumpet-like sound. Spanish instruments are known for their forceful reed stops. The horizontal "trompettas" built into the façade of the organ, the so-called 'Spanish trumpet', or Chamade is also a Spanish invention.

Organ designs of the baroque and romantic eras are very diverse. Instruments of many important builders have survived; some have found their place in museums, but most of them are still in churches, being used (e.g. the Silbermann organs or the instruments of Cavaillé-Coll) for regular Sunday services. Some instruments were restored or rebuilt (e.g. St. Eustache, Paris), others are still in their original condition (e.g. St. Ouen, Rouen).

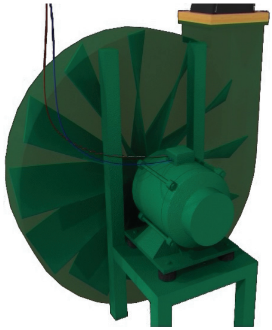
The development of electronics and digital technologies made it possible to control and program the various mechanical parts. Pneumatic actions were enhanced through electrical assistance, with electrical relays being used to open the valves (electro-pneumatic action). In today's modern consoles, MIDI (Musical Instrument Digital Interface) control is increasingly common.

5.2 Parts, mechanism, and sound production



Conventional pipe organs consist of four main parts: the console -, keyboards and other controlling devices; the pipes that produce the sound; the mechanism, or action; and a device that generates wind (air pressure). The pipes and the action are supported and protected by a free-standing structure, the organ case. Traditionally, rows of dummy "façade" pipes or real pipes and carved woodwork in attractive arrangements partially screen openings in the case. As some of the pipes can exceed 20 feet in length, organ cases can be very large and usually play an important artistic role in the shape and design of the final organ installation.

To fully enjoy the beauty of organ sound, the instrument must be positioned and voiced very carefully with respect to its surroundings – most organ music requires a resonant space with three seconds or more of reverberation time. Pipes in an acoustically dry environment sound pale, while fully exposed pipes without encasement typically produce a raw, unfocused sound.



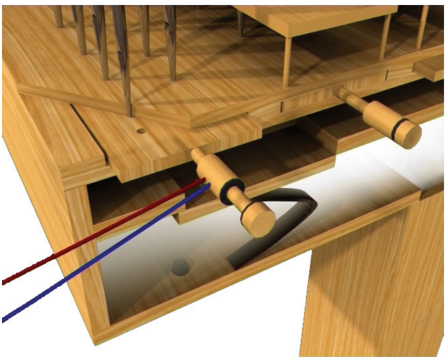
The pipes of the organ stand in rows on an airtight chest supplied with wind (pressurized air) from bellows or a rotary blower. Under each pipe is a valve, or pallet, connected by a system of cranks and levers to its respective key. Normally a wind reservoir, loaded by weights or springs to maintain a constant and consistent value of wind pressure, is interposed between the wind generator and the wind-chest. This reservoir has a safety valve to relieve excessive pressure when the air reservoir becomes full.

The pitch of the notes is determined by the length of their pipes. Among pipes of similar type, one half the speaking length of the other sounds exactly an octave higher. Since the loudness of a pipe sounding on a constant pressure of wind cannot be controlled, the expressive potential of an organ in improved by using several ranks (pipe sets, also called registers or stops). A harmonium has very few, a small organ may have 2-15, a middle-sized organ 15-30 and large church and auditorium organs may have as many as 100 or more ranks. (However, the majesty of the sound of the organ is not determined by numbers of ranks; interestingly, the world's most sonically beautiful instruments usually don't have hundreds of ranks.)

The pallet controlled from each key admits wind to all the pipes belonging to that key; but, in order to allow the organist to use any of the ranks of pipes, alone or in combination, an intermediate mechanism is provided by which he may 'stop off' any rank or ranks. That is why the term *stop* is also used in the sense of 'rank of pipes'.

5.2.1 Stop and key mechanisms

The operative part of the stop mechanism lies between the pallet and the foot holes of the pipes. It normally consists of a strip of wood or plastic running the full length of each rank of pipes. In it is drilled a series of holes, one of which meets exactly the foot hole of each pipe. This perforated strip, or slider, is placed along a closely-fitting guide, in which it may be moved longitudinally. When moved a short



distance, so that the slider's holes are no longer aligned to match the pipes, wind is cut off to that rank, even when the organist opens the pallets by means of the keys. Wind-chests in which the stops operate in this way are called slider chests and were in almost universal use prior to the 20th century. The slider is connected to the console by a system of levers and cranks, and terminates in a knob,pulled outwards, to bring the stop into play, or pushed in to silence it. Certain combinations of stops on each manual are more commonly needed than others so usually there are 'shortcut' knobs or pedals on the console (called pistons). When these combination (or composition) pistons are pushed, stops connected to them are drawn on, and any others already drawn (and not selected) are pushed off.

In order to play two or more interweaving, contrasting melodic lines, with two different voices (soft and loud, harsh and quiet together or in rapid succession) multiple manuals are needed. Each manual division is self-contained and controls its own separate wind-chest and stops. Thus, the organist may vary the sounds produced, either by changing the stops on the manuals being played, or by prearranging the stops to be drawn as a group and changing from one manual to another.

Since the 18th century, organists have had yet a third way, called swell boxes, to control the volume of sound. The pipes of one or more manuals may be enclosed in a box, one side of which has shutters that are connected to a pedal ("sweller," or more simply, "swell pedal") at the console. By opening and closing the shutters, the sound is made louder or softer. Further expressivity is realized by an accessory called a tremulant (tremolo), which by cyclically modifying the flow of pressurized air to the wind-chest, creates a pulsation in the tone of the given rank of pipes.

Since the 14th century, one of the keyboards – those controlling the longer pipes – has been usually played by the organist's feet. Older organs in Italy and Spain had several different pedal keyboards with fewer keys than the modern organs, which now have pedal keyboards of 30 or 32 notes. The organist may wish to combine the stops of two different manuals or to couple one or more of the manuals to the pedals. This is realized by a mechanism called a coupler.

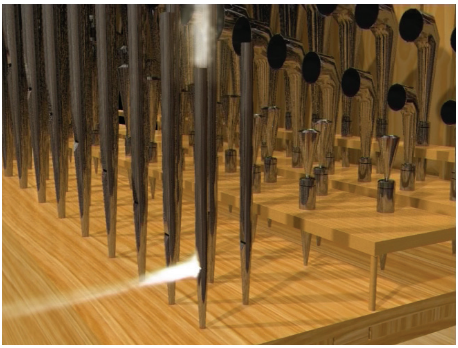
In the simplest mechanical actions, the connection from key to pallet is accomplished by a series of cranks, rollers, and levers that transmit the original motion of the organist's fingers horizontally and vertically from keyboard to wind-chest. The overall distance may be considerable; the main distance is bridged by trackers, slender strips of wood, metal, or plastic, which are kept in constant tension. Adjustment screws are employed to take up slack caused by wear and changes of ambient humidity.

Most of the organs built before the late 19th century have such tracker action, and they are becoming popular again, especially in modern organs built according to historical construction principles. Many organists actually prefer tracker action to all other forms, because of its superior sensitivity of touch – even though in very large organs with tracker action, considerable finger strength and endurance may be necessary to depress the keys.

Organs may also have other forms of action (pneumatic, direct electric, or electro-pneumatic), but these actions normally result in a loss of sensitivity and responsiveness. A successful compromise uses tracker action for each department, with the coupler action being operated electrically. This arrangement has considerable benefits, since the coupling together of three or four manuals with tracker action results in a very heavy touch. Electrical stop action may also be combined with tracker key action, enabling the use of electrical (including solid-state) combinations – an invaluable aid in quickly changing groups of stops, especially in larger instruments. Some organs may have more than one console to play on – usually with a different action.

The Pécsi-Mühleisen organ of Palace of Arts – Budapest is one such instrument, featuring two completely independent consoles.

5.2.2 Flue pipes

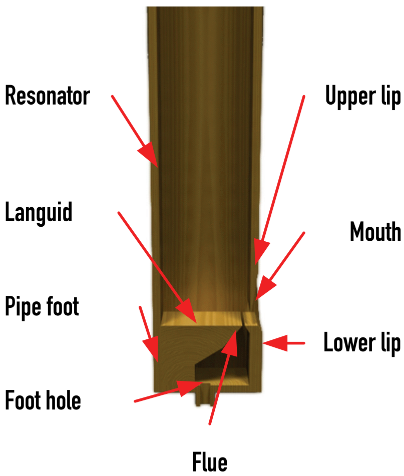


There are two main categories of organ pipes: flue pipes and reed pipes. Flue pipes (metal or wood) account for the majority of the stops of an average organ. The pipe consists of three main parts: the pipe foot, the mouth, and the pipe body or resonator. The pipe foot delivers compressed air, the mouth generates the sound and the pipe body defines the place for the air column to oscillate. When there is a constant air supply, the speaking length of each pipe acts as an air resonator that develops standing waves in the column of air contained in each pipe. The oscillating air pressure is radiated as sound to the ambient air at the openings of the pipe, at the top end of the resonator and at the mouth of the pipe.

The pipe usually stands vertically on the wind-chest, with wind entering at the foot hole. The foot is separated from the speaking length by the languid, a flat plate; the only airway connection between the foot and the speaking length is a narrow slit called the flue. The wind emerges through the flue and strikes the upper lip, producing an audible resonant frequency of the air in the pipe, the pitch of which is determined by and amplified in resonance by the speaking length of the pipe.

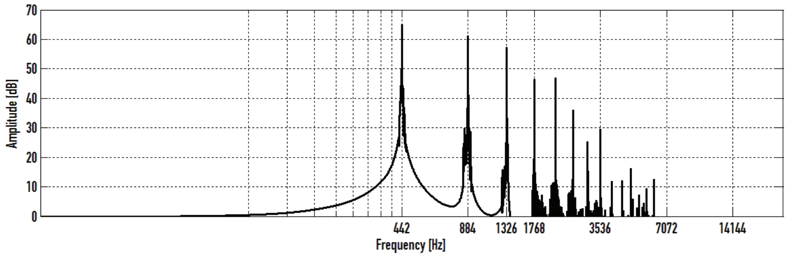
The tone and sound power of a pipe is determined by many factors, including the pressure of the wind supply, the construction material used to make the pipe, the size of the foot hole, the width of the flue, the height and width of the mouth, and the scale, or the diameter of the pipe relative to its resonator. The construction material of which the pipe is made also exerts an influence on its final tone and power; it may be an alloy of lead and tin, wood, or, more rarely, pure tin or copper, and zinc for the bass pipes. The pipes may also vary in shape, a common variant being an upward taper in which the pipe is smaller in diameter at the top than at the mouth. Or, the top of the pipe may be completely closed by a stopper. Such a pipe is said to be *stopped*; a stopped pipe sounds an octave lower in pitch than an open pipe of the same speaking length.

Open pipes of large diameter for a given speaking length are said to be of "large scale," and open pipes of small diameter for a given speaking length are said to be of "small scale." Large-scale pipes produce a fluty or foundational quality of tone that is relatively free of the higher harmonic partial frequencies. Small-scale pipes produce a bright quality of tone that is rich in harmonics, recalling bowed strings. Stopped pipes can be particularly foundational in tone, and they favor odd-numbered (at the expense of even-numbered) partials. Tapered pipes are somewhere between stopped and open pipes in tone quality.



Flue pipes are tuned by increasing or decreasing the speaking length of the resonator. In the past, several methods of tuning were employed, but in modern times this is often done by fitting a cylindrical slide over the free end of the speaking length and sliding it up and down, lengthening or shortening the pipe as required. In stopped pipes the stopper is pushed farther down to sharpen the pitch or is pulled outward to lengthen it, lowering its pitch.

The attack of the note may also be greatly influenced by cutting a series of small triangular-shaped nicks in the leading edge of the languid. This practice of *nicking* has the effect of modifying the turbulence of airflow encountered at the languid. Heavy nicking, commonly practiced in the early 20th century, produces a smooth and sluggish attack. Light nicking or no nicking, as used up to the 18th century and in some more advanced modern organs, produces a vigorous attack, or *chiff*, somewhat like tonguing in a woodwind instrument. If not excessive, this chiff enhances the vitality and clarity of an organ.

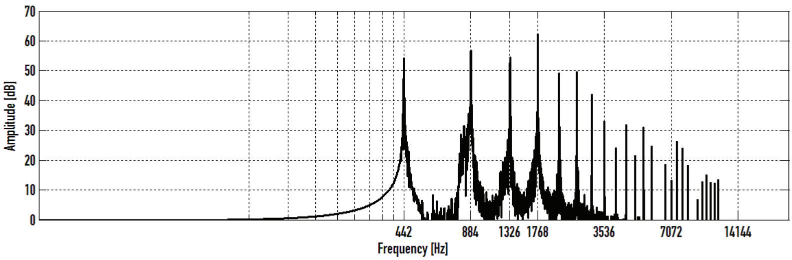


Spectral view of the sound of a flue pipe (Principal 8' from the Grand Orgue –A4; 442 Hz)

5.2.3 Reed pipes

Organ reeds were probably originally copied from instrumental prototypes. A reed stop may contain a beating reed like that of a clarinet or a free reed. The shallot of a beating reed pipe is roughly cylindrical in shape, with its lower end closed and the upper end open. A section of the wall of the cylinder is cut away and finished off to a flat surface. The slit, or shallot opening, thus formed is covered by a thin brass tongue that is fixed to the upper end of the shallot. The tongue is curved and normally only partially covers the shallot opening. But, when wind enters the boot, the pressure of the wind momentarily forces the tongue against the shallot, completely closing the opening. Immediately, the modulus of elasticity of the brass asserts itself, and the tongue reverts to its curved shape, thus uncovering the opening. This process is repeated rapidly. The frequency of the pulsations of air entering the shallot is determined by the effective length of the reed and, in turn, determines the pitch of the note. From there, the air pulses pass into the tube, or resonator, which further stabilizes the pitch and refines the timbral quality of the note. Most reed resonators have a flared shape. As in flue pipes, a wide scale (namely, a wide diameter in relation to a pipe's speaking length) favors a fundamental tone, and a narrow scale favors a bright tone. Cylindrical resonators produce an effect similar to that of stopped flue pipes, the note being an octave lower than the equivalent flared pipe and the tone favoring the odd partials.

Some reed pipes, such as the *Voix Humaine*, have very short resonators of quarter or eighth length. Those ranks of reed pipes whose resonators have no mathematical relationship to the pitch are known as *regals*; regal stops were popular in the 17th century, particularly with the North German school, and their use has been revived in modern times.



Spectral view of the sound of a reed pipe (Trompete Harmonique 8' from the Récit – A4; 442 Hz)

5.2.4 Organ stops

The pitch of any pipe is proportional to its speaking length. Most modern organs have a manual compass of five octaves, from the second C below middle C to the third C above; an open pipe sounding the low C is about 8 feet (2.5 meters) in speaking length (64 vibrations per second). The shortest pipe in the same stop, is thus about 3 inches (8 centimeters) long (~2048 vibrations per second). While large- and small-scale ranks often imitate the tones of flutes and bowed strings respectively, and are named accordingly, the most characteristic tone of the organ is produced by its *Principal* stops. These are of medium scale and moderate harmonic development – neither too dull nor bright. Therefore, from the earliest times, stops were arranged in choruses, and the *principal chorus* is the very backbone of any organ.

A chorus consists of stops of roughly similar quality and power of tone, but at a variety of pitches. A unison principal is known as *Principal 8'* because of its longest (8-foot) C2 pipe. The next stop at an octave pitch would have the largest C2 pipe of 4 feet long. Next comes a 2-foot stop, while the sub-octave pitch is represented by a 16-foot stop. The top pipe of a 2-foot stop has a speaking length of only 19 millimeters (three-quarters of an inch), and this is about the practical upper limit.

Because an organ with no stops higher in pitch than a 2-foot stop would be lacking in brilliance, organs have so-called *mixture stops*, which have several high-pitched pipes to each note tuned in ways that reinforce the natural harmonics of the regular stops. These mixture stops are so high in pitch that they cannot be carried right up to the top note, so they *break back* an octave at some convenient point, sometimes even more than once. The result is a balance of power between bass and treble and a harmonious power that is completely peculiar to the organ and can be produced in no other practical way. As an aside, Maurice Ravel attempted to emulate mixture stops in his orchestral work *Bolero,* by having his flutes and piccolo double the melody line but at pitches that mimicked the natural harmonics of the regular melody line.

Mixture stops also contain ranks sounding at pitches other than in octaves with the 8-foot Principal. In chorus mixtures, these normally sound at a fifth above the unison (e.g., G above C), although ranks sounding at a third above and even at a flat seventh can also be found. These quint- and third-sounding ranks reinforce the natural upper partials of the harmonic series (although they were included in organs long before this was understood).

Off-unison ranks are also available as separate stops, mostly sounding at an interval of a 12th (an octave plus a fifth; 2 2/3'), 17th (two octaves plus a third; 1 3/5'), or 19th (two octaves plus a fifth; 1 1/3') above the unison. These are used melodically to color the unison and octave stops, and they may be wide or narrow in scale. Such stops are known as *mutation* stops, as opposed to the mixtures, or chorus stops. Their use is essential for the historically correct performance of organ music.

6 The Béla Bartók National Concert Hall

6.1 The Palace of Arts, Budapest

After a surprisingly short 28-month construction period, the long-awaited new cultural institution of Budapest and Hungary – the Palace of Arts – was opened on March 14, 2005. The PPP (Public-Private Partnership) construction project was financed by the Ministry of National Cultural Heritage and Trigránit Development Corporation.

The creators of the institute were inspired by the concept of creating a new European cultural citadel as part of the new Millennium City Centre of Budapest. From the very beginning, the jewel in the crown for the Palace of Arts was to be its superb new concert hall– not only because for almost a hundred years no concert halls were built in Budapest, but also because the investors and architects wanted to achieve a level of quality that would guarantee a renowned status on an international scale, to take its place among the very best in the world. Therefore, besides the architects, a company with necessary experience was needed to oversee the critical acoustic design of the hall. The international tender was won by Artec Consulting Inc., and the company lived up to its reputation. The acoustic components – the 40-ton canopy above the stage, the stage's mechanical devices below, the 48 pieces of reverberation chamber doors (each weighing 10 tons in average), the special wall and floor coatings, etc. – were all custom-developed.

The Palace of Arts, in its wide-ranging calendar of events, presents not only the finest representatives of Hungarian art life, but also welcomes artists and ensembles from all around the world.

6.1.1 Venues and halls

The Palace of Arts building complex is home to the following venues and halls:

Béla Bartók National Concert Hall

The National Concert Hall is located at the heart of the new Palace of Arts, and has the dimensions of a Gothic cathedral. Below we describe the Concert Hall in detail.

Festival Theatre

The 452-seat Festival Theatre, in the eastern third of the Palace of Arts building, utilizes the most modern technologies. Thanks to its acoustic design, it can also be used for classical music concerts, chamber operas, jazz concerts, world music and light music events. It has a nearly 750 square meter (8000 square foot) world-class stage with a side stage, a back stage adaptable for projection, and an upper engineering structure of nearly 24 meters (80 feet) that facilitates set movement. The latest electronic technologies in this hall offer the possibility of professional sound and video recording.

Ludwig Múzeum – Museum of Contemporary Arts

The Museum occupies that wing of the building closest to the Danube River. The first floor is used for temporary exhibitions, while the second and third floors house exhibitions drawn from the Museum's vast contemporary art collections. The intentionally neutral, but technically well equipped, halls are suitable for accommodating the demands of the most diverse exhibitions. The special foil used for the general lighting offers high quality scattered light, supplemented by individual lighting units suitable for creating new and unusual lighting effects. The second floor hosts the museum's specialist library and a place to organize educational programs for children.

Glass Hall

The representational hall of the Palace of Arts has chandeliers of unique design that shine in varied colors, with a beautiful view to the Danube River. The hall serves diverse purposes: primarily, the space hosts various receptions and banquets, but the majority of press conferences are also held here. Thanks to its fine acoustic characteristics, it is a suitable venue for chamber concerts also; at the same time it is a popular "playground" of the youngest guests of the Palace of Delights.

Auditorium

The 130-seat hall, with fixed-row seating, hosts professional lectures, conferences and film/video screenings. Its modern technical devices fulfill the requirements of any presentation, while a built-in language interpreter's box and translation equipment aid in bridging the language barrier at international conferences.

Blue Hall

The Blue Hall, which owes its name to its deep blue-colored carpeting, complements the functions of the Auditorium and the Glass Hall, serving catering purposes primarily. As an independent event location, it hosts youth programs and professional meetings with more intimate surroundings for smaller numbers of participants.

6.1.2 Awards

The Palace of Arts was awarded the "FIABCI Prix d'Excellence 2006" in the "specialized" category, which is the equivalent of an Oscar Award for construction and real estate development. It is bestowed on buildings – educational and cultural institutions, libraries, airports etc. – which offer products and services to the general public. FIABCI (the International Real Estate Federation), formed in 1951 and represented in 56 countries, every year organizes the International Prix d'Excellence for International Real Estate development, aiming to select and reward the most successful projects. The principal criteria for judging are: to what extent does a given development serve the interests of society, how much does it improve the living conditions of the local people, and how well does it meet the requirements of its users.

There are very few cultural institutions in Europe that can boast ISO 9000 series Quality Certification. In 2005, the year of its inauguration, the Palace of Arts initiated the detailed assessment process and, after continuous inspection, in 2006 was awarded the latest version of the certification, the ISO 9001:2000, ahead of the Pompidou Centre of Paris.

6.2 The Béla Bartók National Concert Hall

The National Concert Hall, located at the heart of the new Palace of Arts, has the dimensions of a Gothic cathedral. The world-class acoustics are the work of Artec Consulting Inc. (New York), led by Russell Johnson. Their work in creating concert halls and opera houses in countries all over the globe has been widely praised and acknowledged by performers and audiences alike.

The auditorium of the Béla Bartók National Concert Hall accommodates a maximum of nearly 1700 audience members; 130 additional on-stage seats can be added for chamber concerts. For students, there are 136 standing places in the side galleries located on the second and third floors.

The orchestra podium is located in the open auditorium, with mobile units facilitating the creation of three different stage sizes and an orchestra pit, if required. The 40-ton acoustic canopies over the concert podium serve to create the appropriate stage acoustics required for a given performance, as do the reverberation chambers which surround the inner space, if their doors are opened.

The state-of-the-art audio-visual system is capable of producing unique lighting effects, sound recordings and film projections. Professional-quality CD and DVD recordings can be produced in the recording studio adjoining the hall.

In the spring of 2006, the “King” of instruments, a new symphonic organ, took its place in the Béla Bartók National Concert Hall. This magnificent instrument, with its 92 stops and 5 manuals, was under construction for thirteen months, involving the work of some sixty expert craftsmen. The largest pipes were put into place during the hall’s initial construction phase, itself a world first. Made from the finest materials and meeting the most stringent requirements, its tonal quality is unsurpassed--the result of an exhaustive ten-month voicing and tuning period as well as its specially constructed dedicated air-conditioning system.

7 The Organ of the Béla Bartók National Concert Hall

On May 22, 2006, after one and a half years of work, one of the most prestigious symphonic organs of Europe was inaugurated in the Palace of Arts amid spectacular celebrations. Here are just a few numbers that characterize the new organ of the Béla Bartók National Concert Hall: 92 stops, 5 manuals, 6804 pipes, and a 10-month voicing and tuning period.

7.1 Construction of the organ[1]

In Spring 2003, Arcadom Construction Company Ltd., the general contractor of the Palace of Arts building project announced a closed invitation for a tender to build the organ of the Concert Hall. Five of the thirteen organ builder companies invited – Orgelbau Klais Bonn; Jehmlich Orgelbau; Gerhard Grenzing; Rieger Orgelbau; Mander Organs and the consortium of Pécsi Organ-Building Manufacture Ltd. and Mühleisen GmbH – submitted valid bids.

The bids were evaluated with the help of five renowned concert organists: István Baróti, László Fassang, István Lantos, Christophe Mantoux and János Pálúr. The committee included Judit Angster representing the Hungarian Music Council, László Homolya commissioner of the Cultural Ministry, and István Sokorai director of Duna Sétány Székház Ltd, representing the investor. The committee was extended with Arcadom CEO Péter Bálint, acoustic expert Russell Johnson and lead architect Gábor Zoboki. After thorough consideration, the Committee selected and Arcadom signed a contract with the Pécsi–Mühleisen consortium in February 2004.

The specification of the organ changed several times, from the very first phase of discussions until the signing of the preliminary contract. The current disposition (stoplist) was finalized on July 6, 2004, and the frontal aspect of the organ was finalized in August 2004. The preliminary technical plans (part of the submitted bids) needed to be modified, and the detailed construction plans had to be re-aligned continuously as the construction progressed. The largest modifications were of the final disposition, redesigning the organ case, and installing an inner air-conditioning unit. Despite all these midstream modifications, the plans for implementing the organ case were still ready by August 2004.

The two companies started producing the necessary parts in the summer of 2004, and their untiring work lasted until September of 2005. The on-site construction of the inner structure, the wind chests, the pipes of the pedal division, the organ case, and the front pipes started on October 4, 2004. The only way to meet the 2006 deadline was to build and install the organ in parallel with the construction of the concert hall.

[1] Source: www.mupa.hu

The 92 tin display pipes are in an impressive harmony with the surrounding Béla Bartók National Concert Hall. The largest tin pipe is 9.5 meter (32 feet) long and weighs over 480 kilograms (1000 pounds). Except for the Spanish trumpets (Chamades), the front of the organ presented its façade for the first test concerts in January 2005, and it served as a permanent working surface as acoustic engineers voiced the tonal characteristics of the concert hall.

Starting from February 28, 2005, all remaining inner components of the organ were being installed during the late evening and early morning hours. The work had to be done in such a way that the front view of the organ would appear to be finished all the time. To accomplish this feat, the organ's wind chests, bellows, wind trunks, swellboxes and all the other inner components had to be lifted up and built in from within the inside. For certain tasks, this required partial disassembly.

By May 23, 2005, the structure was in a condition ready to start tuning and voicing the ranks of pipes. After collecting audio data and comparing results of live listening tests, the two companies were engaged in continuously voicing the pre-intoned pipes on-site from July 25th until the end of the year.

The technical delivery took place on December 30, 2005 followed by field tests. The organ was inaugurated on May 22, 2006.

7.2 The organ builders

The German Orgelbau Mühleisen and the Pécsi Organ-Building Manufacture Ltd have collaborated for more than ten years on such joint projects as the organs in Stiftskirche in Stuttgart, and the churches in Hamburg, Keitum, Braunschweig and Nienstedten.

7.2.1 Pécsi Organ-Building Manufacture Ltd

The Pécsi Organ-Building Manufacture Ltd, starting as a small enterprise in 1992, has grown to become the largest organ building company in Hungary, whose equipment, technical expertise, and craftsmanship set the standard of quality for all of the Western European workshops. Their craftsmen learned their profession in Hungary, Austria and in Germany. Specializing in building new organs, they conduct restorations, repairs and maintenance routines of historic organs as well.

The company is regularly called upon to meet special requirements as they design their instruments individually, and install each of them in a unique space, taking into account the site's distinctive architectural and acoustic characteristics. They cooperate with and offer their expertise to acoustic experts, restorers and concert organists as well.

Their guiding principle is to completely fill a given space with glorious organ sound, and to create the best possible structure for each organ. They build reliable, excellent instruments both in their appearance and their structure, all based on thousands of working hours – demanding artisan work commensurate with European traditions.

The company has been manufacturing organ parts for Western-European workshops for many years. They are experts in crafting wooden and metal pipes and generally receive original equipment manufacturing orders from Mühleisen, and other market-leading organ companies, such as the German Glatter-Götz, Italian Andrea Zeni, or the Dutch Stinkens.

7.2.2 Werkstätte für Orgelbau Mühleisen

The Werksätte für Orgelbau Mühleisen GmbH was established in 1989 in Leonberg. The company's leader, Konrad Mühleisen, is one of the most prestigious organ builders in Germany.

The Orgelbau-Mühleisen specializes in building new mechanical action (tracker) organs, and in restoring organs from the 19^{th} and 20^{th} century. They wish to build organs that can be "played on". Articulation is an important factor too, achieved by careful planning, good material selection and precise hand work and voicing. Their sound realization does not belong to one particular scheme. However, their sound is often classified as representing the Southern German and Alsace tradition. The 'Mühleisen sound' is created by the intensive interaction between the space and the instrument. Their organs are made to meet the highest expectations of purpose, long life span and aesthetics.

In manufacturing their organs, Orgelbau-Mühleisen tends to combine the best attributes of both old and new crafting and design techniques. Their ideal organ design -- in making the wind chest and the mechanical action – lies in the masterpieces of the baroque master builders; they contend that the space application, the built-in console, the mechanical action, and the classical arrangement of the slide chest is still the best and simplest system, making it possible for artists to play and articulate music sensibly and authentically.

An indispensable condition to this design philosophy is to plan the wind supply and wind movement exactly, and to optimize the leverage of the mechanically moving parts while minimizing friction points. Eloquent testimony to Orgelbau-Mühleisen's design philosophy is to be found in their more than 80 instruments, ranging from the one-manual portatives to the symphonic-style three-manual organs.

In recent years, Konrad Mühleiesen participated in the design of new software which makes it possible to determine with greater accuracy the optimum size of organ for a given venue. With the aid of this powerful tool, they design and build a unique wind supply to each new organ, whatever its size or class. This use of software modeling helps pinpoint ahead of time – and solve – all of the potential areas for mistakes in wind routing, in the acoustic planning stage, and even at the design phase.

7.2.3 Division of labor

The Pécsi Organ-Building Manufacture Ltd was responsible for the following:

- preparing the inner scaffolding, frames, stairs and walking planks
- preparing the slider chests
- preparing the constituents for the wind supply
- preparing the swell boxes
- manufacturing the wooden pipes
- manufacturing a group of inner metal flue pipes
- assembly in the workshop
- installing the high voltage electrical wiring
- making the choir organ

The Werkstatte für Orgelbau Mühleisen GmbH was responsible for

- determining the final measurements
- preparing the whole technical documentation
- making of two consoles
- making of the mechanical action
- supplying certain parts of the reed pipes, front pipes and inner metal pipes
- making of the electrical side wind chests
- providing the electronics

Joint tasks:

- setting up the organ on-site
- installing and regulating the structures
- installing the electrical and electronic devices on-site
- voicing and intonation

7.3 Features of the organ in detail

7.3.1 Disposition

The disposition of the organ defines a 5-manual symphonic organ of 92 stops. The first four manuals, the pedal and their couplers are of mechanical, the fifth manual, the octave couplers and the register trackers are of electrical action.

The organ has 5498 flue pipes (consisting of 5028 tin and 470 wood pipes, made of spruce and maple) and 1214 reed pipes. It has two consoles, one mechanical, the other of electrical action. Manuals II. and III. have swellboxes and there is also a crescendo wheel in each console.

The memory of the organ can store thousands of preset combinations which can also be saved to (and loaded from) an external USB module. The built-in MIDI sequencer can record the performance of the organist, so the artist can listen to his or her own performance. There is also a “sostenuto” function built in, similar to the middle pedal of a piano: the played chord keeps playing even after releasing the keys on the manual.

7.3.2 Dimensions

The dimensions for the arrangement of the new organ were fixed by the dimensions in the hall. A 12.5 meter (41 feet) wide, 13 meter (43 feet) high and 5 meter (16.4 feet) deep niche determined the architectural placement. The front of the organ consists of a wall-to-wall case on the front balcony, and independent display pipes.

7.3.3 Physical Location of Organ Divisions

Mechanical components of the organ are placed in relation to the built-in mechanical console, also known as the upper console:

Located directly above the upper console are the wind chests for the Manual V horizontal Chamade pipes. Above the Chamades are the Grand Orgue and the Récit expressif; above the Grand Orgue pipes are the Solo pipes in the front and the Positif expressif behind.

The pedal pipes flank the two sides of the organ, with the wind chests of the Grand Pedal positioned closest to the stage. In addition, there are two more levels of wind chests for the pedals, positioned to the side of the Grand Orgue and Solo divisions.

The pipes of the organ are manufactured from materials according to the required sounds of the stops. The wooden pipes are made of spruce and maple of excellent quality. The metal pipes are made of cast and machined tin-lead alloys of varying tin content, according to the intended sound. The front pipes are made of 80% tin alloy, with elevated and sealed lips, and a glossy surface finish.

The walls of the pedal pipes are tapered in the 32' ranks and partly in the 16' sections; the largest pipes' bases and bodies are strengthened with zinc plates. The largest front pipes of the organ are actually hung from the ceiling. All reed pipes were manufactured in Göttingen, at Carl Giesecke und Sohn GmbH.

7.3.4 Organ Case Construction

The case of the organ is made mostly of solid cherry, and partially of curved elements with cherry overlay. The pipes in the front consist of the 32' and 16' principal pedal stops and the 16' Principal stop of the Grand Orgue; above the main row of front stops, the next higher row of pipes consist of the 8' Principal stop of the Pedal and the Solo divisions. The chamades are secured in an iron frame, the front of which is hanging from the ceiling on steel wires.

7.3.5 Consoles

The organ can be played from two consoles. Regarding the size of the manuals and the placement of the switches, the two consoles are functionally identical. The bodies of both consoles are made from cherry and cherry-overlaid plates, just like the organ casing. Both consoles have a music stand and a bench also made of cherry.

Gallery Console

The console on the organ gallery, built into the organ case is of mechanical action. The manuals consist of keys made of spruce, with double-armed levers. The natural keys are covered with ivory, the overlay of the black keys is of ebony. The keys are guided by nickel-plated and polished inserts and their bottom is protected by a layer of felt.

The frame of the curved, radial pedalboard is made of cherry. The base of the pedal keys is made of cherry, the overlays are of hornbeam on the natural keys, with ebony on the blacks. The middle D# key of the pedals is positioned directly below the middle D#4 key of the manuals.

On each front side of the gallery console are the two panels of electrical stop switches. The stop switches connect to lathed ebony stop heads, with china inlays. The buttons to configure the electronic registration memory, to store and change the configured combinations are all located on the rail under Manual I..

The preset combinations can be transferred to the gallery console using an USB storage device. In the middle of the vertical board connecting to the foot res is the crescendo wheel; on its right are the two foot-operated swell pedals. There are one preset and three custom (user)-defined programs for the crescendo wheel.

The brass foot-operated pistons are arranged ergonomically in two horizontal rows. The currently selected general combination, crescendo program, and the setting (condition) of the crescendo wheel and the swell pedals' positions are all shown on dedicated LED digital displays.

Lower Console / Stage Console

The free-standing, movable console on the orchestral stage is fully electronic. The manuals have a key pressure simulator, customizable key-by-key. The arrangement (numbering) of the toggle stop switches is the same as on the mechanical console's draw-stops; they are arranged by division in horizontal rows. The console is supported on a cherry stand, reinforced with a welded iron frame with self-adjusting casters. The remote console electrically connects to the "mother organ" through its "umbilical cord" connector on the orchestral podium.

The connection between the stop switches of the organ and the wind chest sliders is fully electric – sliders open and close by means of 24V electromagnets. The drawing power and speed can be set continuously for each magnet using a peripheral electronic device.

7.3.6 Slider Chests

There are twenty-two slider chests in the organ, diatonically organized by organ division; the manual divisions are further divided into bass and descant parts. The valves in the slider chests utilize a double opening system: mechanical (for the gallery console) and electrical (for the stage console). The body of the slider chests is made of oak and plywood, with the valve chests additionally incorporating oak-overlaid plywood. The valves are made of spruce, while their closing surface is covered with special felt and very soft leather. The bases of the manual divisions feature assisting nozzles. The valve chests include compensating blowers with ventils. The sliders are made of the highest quality oak – their sliding contact surfaces covered with graphite for smoother motion. The sliders and the pipe bases are sealed with Schmid rings. The middle layer of the three-layered pipe bases is made of pine, the covers of oak. All flue and reed pipes larger than 4' are arranged on oak hangers. Those of the tin pipes are covered with felt. The largest pipes of the organ and the large frontal pipes stand on auxiliary electrical chests.

7.3.7 Wind System

The wind system of the organ consists of four motors and eight blowers. Two large, slow blower motors work to produce wind for the largest pipes of the I., III. and V. manual divisions as well as the pedal division. The uppermost physical level of the organ houses two more blower motors: one produces wind for two of the upper (II. and IV.) manual works, the other is solely dedicated to the Tuba Mirabilis 8' (380 water mm pressure) stop. The remaining parts of the wind system include the gate valves and wind tunnels. The blowers and wind tunnels, sized according to the wind requirements of the stops, are made of medium density fiberboard (MDF) boards covered with oak.

Actual wind pressure is controlled by blocks at the blowers, and by plate springs at the compensating blowers of the wind chests. By subdividing the five manual divisions into bass and descant parts, it is possible to send different wind pressures required by the different ranks of pipes. Final values were determined after a subjective assessment of the hall acoustics, when setting up the sample pipes.

7.3.8 Internal Organ Case Construction

The main inner bracing of the organ was built of doweled and glued spruce beams. The whole bracing stands on a layer of resin. There are built-in stairs to allow human access to the various levels of the organ, and walking boards and ladders to provide better access to the wind chests, pipes and mechanics.

The swellbox of the II. manual (Positif expressif) is 40 mm thick; that of the III. manual (Récit expressif) 50 mm. They are made of multiple-layered, sandwich-structured leaves and side plates. The leaves are double-horned. Both swellboxes are operated electronically, opening or suppressing the respective divisions' output.

7.4 Statistics of the Organ

Builders	Pécsi Organ-Building Manufacture Ltd. Werkstätte für Orgelbau Mühleisen GmbH
Date of inauguration	May 22, 2006
Voicing Duration	10 months
Total construction hours	28,000
Number of consoles	2
Upper console (organ gallery console)	mechanical action
Lower console (mobile stage console)	electrical action
Number of manuals	5 + Pedal on both consoles
Number of stops	92
Tuning	Equal Temperament
frequency (A4)	442 Hz (continental European concert pitch)
Number of swellboxes	2, (manuals II. and III.)
Crescendo programs	4
Discrete crescendo program frames	61
Dimensions of the organ (meters)	918.3 m^3 (32430 cubic feet)
Total frontal sound emission surface of the organ	155.2 m^2 (1671 square feet)
Height of the organ from the gallery (façade)	12.03 m (40 feet)
Height of the connecting room downwards	3.65 m (12 feet)
Total height	15.68 m (51.4 feet)
Total width	12.90 m (42.3 feet)

Total depth	4.54 m (14.9 feet)
Total weight	38,000 kg (38 tons)
Total number of pipes	6804
wooden pipes	470
tin pipes in the front of the organ façade	92 (equal to the number of stops)
inner tin pipes	5028
reed pipes	1214
Frequency range of the pipes	16 Hz – 25000 Hz
Length of the largest wooden pipe	9.85 m (32 feet speaking length)
Length of the largest front pipe on the façade	9.58 m (32 feet speaking length)
Length of the smallest pipe (without base)	7 mm (0.28 inch speaking length)
Weight of the largest front pipe	485 kg (1067 pounds)
Number of motors (engines)	4
Number of blowers	8
Number of slider chests	22
Number of auxiliary wind chests	22
Wind pressure	85-130 water mm (mbar)
Total length of tracker wires	2307 m (7570 feet)

7.5 Disposition and explanation of the stops

	Name of the stop	Description
Pedal (C-g')		
1	Majorbass 32'	This register is a low-pitched “Contra” Principal.
2	Soubasse 32'	Soubasse is a Bourdon pitched an octave lower.
3	Principalbass 16'	A Principal stop of 16' pitch in the pedal.
4	Contrebasse 16'	An imitative string stop of 16' pitch.
5	Violon 16' (transmission from III. Manual)	A mild string stop of the pedal. Named after the orchestral instrument of the same name, the largest member of the viola da gamba family.
6	Soubasse 16'	Soubasse is a Bourdon pitched an octave lower.
7	Grossquinte 10 2/3'	A stopped rank of pipes made of pine, used to simulate a 32’ “resultant” sound when played simultaneously with a 16’ stop.
8	Octavbass 8'	An open rank of pipes made of 80% tin. Partly featured in the front of the case. These are the widest scaled pipes of the organ.
9	Gedäckt 8'	A covered flute of 8' pitch, similar to Bourdon and Stopped Diapason. It is perhaps the most common covered flute stop. (“Gedäckt” means “covered.)
10	Cello 8'	A string stop imitative of the orchestral instrument of the same name.
11	Octave 4'	An Open Diapason of 4' pitch.
12	Tibia 4'	A stop of conical metal pipes (40% tin). In order to sound well together with Zinck 3x: 5 1/3', the conicity and the mouth of the pipes are exactly the same and have almost the same proportions (Mensur).
13	Tercsept 2x: 6 2/5'	A two-rank compound stop with the following content: 6 2/5' + 4 4/7'

	Name of the stop	Description
14	Zinck 3x: 5 1/3'	This stop imitates a certain type of Renaissance musical instrument, constructed and fingered like a woodwind but blown like a trumpet. A compound stop with the following content: 5 1/3' + 3 1/5' + 2 2/7'
15	Compensum 7x 2 2/3'	A 7- line harmonic stop with the following contents: 2 2/3' + 2' + 1 3/5' + 1 1/3' + 1' + 2/3' + 1/2'
16	Mixtur 4x 2 2/3''	Mixtur is a generic name for compound stops containing mutations, usually with breaks. Here it is a 4-line harmonic stop with the following content: Excerpt from *Compensum (15):* 2 2/3' + 2' + 1 1/3' + 1
17	Bombarde 32'	A powerful chorus reed at 32' pitch, made of pine. Its resonators are inverted pyramidal wood. Its longest pipe is 9 m. Here it is a combined register with Bombarde 16' in the pedal (18).
18	Bombarde 16'	A powerful chorus reed at 16' pitch.
19	Basson 16' *transmission from II. manual (75)*	An imitative reed stop with medium intonation. Its volume is rather set for the positive work (which can be swelled). However, it is loud enough and the placement of the pipes allows using it as a reed in low-volume pedal music.
20	Trompete 8'	A reed stop at 8' pitch, perhaps should more properly be called Orchestral Trumpet.
21	Clairon 4'	A chorus reed of 4' pitch, essentially an octave Trumpet.
22	P+IV m.	A mechanical coupler (the “m” stands for “mechanical”) between the Pedal and the fourth (Solo): it operates the mechanics but the keys are not depressed.
23	P+III m.	mechanical coupler between the pedal and third manual
24	P+II m.	mechanical coupler between the pedal and second manual
25	P+I m.	mechanical coupler between the pedal and first manual

I. Manual, Grande orgue (C-c'''')

30	Montre 16'	Another name of Diapason, Principal, Prestant, etc., the quintessential tone of the pipe organ.
31	Principal 8'	‘Main play’, the major element of the organ sound. Typical metallic, organ-like sound.
32	Flûte harmonique 8'	Harmonic flutes are constructed from open pipes twice the normal speaking length. The pipes are then overblown to speak their first harmonic (the octave). A hole is pierced in each pipe to prevent the formation of an acoustical node at the middle of the pipe’s speaking length.
33	Gamba 8'	A non-imitative string stop of 8' pitch. A common and generally useful string stop.
34	Bourdon 8'	A stopped wooden flute, the name of which is derived from the French word bourdonner, "to buzz". Its sound is similar to Gedäckt and Stopped Diapason.
35	Praestant 4'	An Open Diapason of 4' pitch.
36	Rohrflöte 4'	Pipe flute – medium-wide closed pipes with an extension that yields a brighter sound than the fully closed flute.
37	Quinte 2 2/3'	A harmonic register at the fifth (e.g. when a C is pressed, a G sounds).
38	Superoctave 2'	An alternative name of a Principal at 2' pitch. The pipes are of open metal construction.
39	Cornet 2-5x 8'	The Cornet is a wide-scaled compound stop without breaks, originally also attempting to imitate the Renaissance *cornet* or *zink* (see *Zinck* above), not the modern orchestral cornet.
40	Mixtur 5-7x 2 2/3'	Mixtur is a generic name for compound stops containing mutations, usually with breaks. Here it is an 5-7-line harmonic stop, starting with 2 2/3' + 2' + 1 1/3' + 1' + 2/3'.
41	Cimbel 4-5x 1 1/3'	Highest-pitched, tight, multi-row pipe set. Lots of repetitions, at various harmonics. The brightest-sounding crown of the organ sound.
42	Trompete 16'	These three registers are the “Germanic” trumpets of the organ (as opposed to the “Spanish” Chamades and the remaining “French” Trompettes, Cornet, etc.).

	Name of the stop	Description
43	Trompete 8'	
44	Trompete 4'	
45	I+IV m.	mechanical coupler between the first and fourth manual
46	I+IV e.	electrical coupler between the first and fourth manual
47	I+III m.	mechanical coupler between the first and third manual
48	I+III e.	electrical coupler between the first and third manual
49	I+II m.	mechanical coupler between the first and second manual
50	I+II e.	electrical coupler between the first and second manual

II. Manual, Positif expressif (C-c'''')

60	Quintatön 16'	'Quinter', narrow, closed base pipes sounding the fifth strongly. Quite nasal, somewhat bitter sound.
61	Principal 8'	'Main play', the major element of the organ sound. Typical metallic, organ-like sound.
62	Cor de nuit 8'	A stopped flue rank, the low octave pipes made of pine, the rest of the pipes (from C^0) made of tin.
63	Unda maris 8'	'Wave of the sea' – a soft, flute-like pipe rank deliberately tuned slightly sharp. Together with other stops this causes the sound to 'float' in an undulation reminiscent of massed orchestral strings.
64	Salicional 8'	"Willow" pipe – a tight, cylindrical, somewhat string-like register.
65	Flûte traversière 8'	'Transversal flute', wide blow-through pipes twice the size of normal open pipes. A clear, somewhat veiled flute sound, imitating the orchestral flute.
66	Praestant 4'	An Open Diapason of 4' pitch.
67	Flûte conique 4'	'Conic' flute: the pipes are wider at the top than at the mouth.
68	Quinte 2 2/3'	A harmonic register at the fifth (e.g. when a C is pressed, a G sounds).
69	Doublette 2'	2' principal stop on French organs, a synonym for Super Octave.
70	Terz 1 3/5'	A mutation stop of 1-3/5', supporting the 8' harmonic series. It supports the fifth harmonic, sounding approximately an E when played from a C key, seventeen scale steps higher. It is therefore known as a "third-sounding" rank.
71	Larigot 11/3'	A mutation stop of 1-1/3' pitch, basically a *Nineteenth* (but a flute, not a principal). The name comes from *l'arigot,* a French word denoting a small flute or flageolet.
72	Piccolo 1'	An open flute stop of 1' pitch, closely, but not perfectly imitating the orchestral instrument of the same name.
73	Mixtur 4-6x 2'	A 4-6-line harmonic stop.
74	Septnon 2x 8/9' + 1 1/7'	A 2-line harmonic stop of sevenths.
75	Basson 16'	An imitative reed stop of medium timbre. Its volume is rather set for the positive work (which can be swelled). However, it's inherent output and the placement of the pipes allows using it as a reed in low-volume pedal music.
76	Dulzian 16'	A soft-toned 16' reed stop, built from soft, cylinder-shaped flue pipes.
77	Trompette 8'	Strong reed pipes that resemble the trumpet in sound, usually with a cornet-shaped resonator.
78	Cromorne 8'	One of the oldest organ stops: 'bent horn', reed pipes with natural-length cornets. While it takes its name from the instrument of the same name (a capped reed with a curved body and a muffled, buzzing tone), the organ stop in its most familiar form has a tone resembling that of the Clarinet.
79	Clarinette 8'	Clarinet – medium-pitched pipes that resemble the actual instrument.
80	Tremulant II.	
81	II+III m.	mechanical coupler between the second and third manuals

	Name of the stop	Description
82	II+III e.	electrical coupler between the second and third manuals
83	II+IV m.	mechanical coupler between the second and fourth manuals
84	II+IV e.	electrical coupler between the second and fourth manuals

III. Manual, Récit expressif (C-c'''')

90	Violon 16'	A mild string stop. Named after the orchestral instrument of the same name, the largest member of the viola da gamba family.
91	Gedeckt 16'	A covered flute of 16' pitch, similar to Bourdon and Stopped Diapason. It is perhaps the most common covered flute stop. ("Gedäckt" means "covered.)
92	Geigenprincipal 8'	The Geigen (named after the German geige, meaning "violin") is a common diapason/string hybrid. It blends well, and is often used as the 8' foundation in Swell divisions.
93	Flûte harmonique 8'	Harmonic flutes are constructed from open pipes twice the normal speaking length. The pipes are then overblown to speak their first harmonic (the octave). A hole is pierced in each pipe to prevent the formation of an acoustical node at the middle of the pipe's speaking length.
94	Gamba 8'	A non-imitative string stop of 8' pitch. A common and generally useful string stop.
95	Voix céleste 8'	The ubiquitous Voix Céleste is typically a single rank of pipes yielding a mild string tone, found in Swell divisions and intended for use with a Salicional or Viola da Gamba. The Voix Celeste is tuned slightly sharp, producing that undulating chorus tone reminiscent of massed orchestral strings.
96	Aeoline 8'	The Aeoline is a string stop of very soft tone; the softest string tone in the organ. It is constructed of small scale cylindrical metal pipes.
97	Bourdon à cheminée 8'	'Chimney' bourdon. 'á cheminée' (Rohr in the German) indicates the small extension piece at the end of a closed pipe.
98	Violine 4'	A stop imitating bowed stringed instruments.
99	Flûte octaviante 4'	An open flute of 4' pitch, similar to *Flûte harmonique:* in its perfect form it is said first to touch the ground tone and then leap into the octave.
100	Nasard 2 2/3'	A mutation stop of 2-2/3'. It represents the lowest non-unison pitch that reinforces a harmonic of the fundamental pitch (8' on the manuals, 16' on the pedals). As such, it is the most important mutation pitch.
101	Octavin 2'	Wide, soft blow-through pipes in French organs.
102	Tierce 1 3/5'	A mutation stop of 1-3/5', supporting the 8' harmonic series. It supports the fifth harmonic, sounding approximately an E when played from a C key, seventeen scale steps higher. It is therefore known as a "third-sounding" rank.
103	Progressio 2-4x 2'	A Mixture stop in which the ranks increase in number as the notes progress from bass to treble. Invented by Musikdirektor F. Wilke of Neu-Ruppin, Germany as a means of reinforcing the treble.
104	Cymbale 4x 1'	Highest-pitched, tight, multi-row pipe set. Lots of repetitions, at various harmonics. The brightest-sounding crown of the organ sound.
105	Bombarde 16'	A powerful chorus reed at 16' pitch. Its resonators are inverted conical metal or inverted pyramidal wood, and may be of harmonic (double) length in the treble.
106	Basson-Hautbois 8'	Some schools of organ-building, in particular 18th & 19th century French, consider the Bassoon to be the proper bass of the Oboe. Therefore some organs feature a single rank of reed pipes, split so that the treble and bass are controlled by two separate stops, labeled Oboe and Basson, respectively. When an entire such rank is controlled by a single stop, it is sometimes labeled as here.
107	Trompette harmonique 8'	Double-sized, blow-through trumpet stops with harmonic (double) length resonators, invented by Aristide Cavaillé-Coll. The use of harmonic resonators does not, by itself, result in louder tone. On the contrary, harmonic resonators tend to subdue the tone (, all other things being equal). They also make the tone purer and less dissonant. The

	Name of the stop	Description
		double-length resonators are typically used in the treble part of the compass.
108	Voix humaine 8'	The Vox Humana is one of the oldest organ stops, a reed stop of the Regal class. While it does not really approach the sound suggested by its name (human voice), its beauty depends not so much on the details of its construction, but rather on its acoustical environment. A large, reverberant room, distance from the listener, and enclosure in a swell box all contribute greatly to its effect. A tremulant is also essential, which must be carefully adjusted. The Voix Humaine was a standard voice in the Grand Orgue division of the French Classic organ, where it was always used with the 8' Bourdon and the tremblant doux, and often with the 4' Flute as well.
109	Clairon harmonique 4'	This lingual stop, also invented by Aristide Cavaillé-Coll, is the true Octave of the Harmonic Trumpet, 8', and is, accordingly, of 4' pitch. The pipes are formed in all respects similar to those of the unison stop, being of about double the normal speaking lengths, voiced on high-pressure wind so as to speak the octave pitch.
110	Tremulant III.	
111	III+IV m.	mechanical coupler between the third and fourth manual
112	III+IV e.	electronic coupler between the third and fourth manual

IV. Manual, Solo (C-c'''')

120	Rohrbourdon 16'	A large, 16' Rohrflöte.
121	Principale 8'	The quintessential tone of the pipe organ.
122	Konzertflöte 8'	The widest one of the four blow-through stops on the manuals. Actually, below the small octave this stop shares its pipes with Principale 8' on the Solo work.
123	Voce humana 8'	In Italian organs, the Voce Umana is usually a Diapason Celeste. The term celeste refers to a rank of pipes detuned slightly so as to produce a floating effect when combined with a normally tuned rank. It is also used to refer to a compound stop of two or more ranks in which at the ranks are detuned relative to each other.
124	Nasard 5 1/3'	A mutation stop of 5-1/3'. It represents the lowest non-unison pitch that reinforces a harmonic of the fundamental pitch (8' on the manuals, 16' on the pedals). As such, it is the most important mutation pitch.
125	Octave 4'	An Open Diapason of 4' pitch.
126	Tierce 1 3/5'	A mutation stop of 1-3/5', supporting the 8' harmonic series. It supports the fifth harmonic, sounding approximately an E when played from a C key, seventeen scale steps higher. It is therefore known as a "third-sounding" rank.
127	Septième 2 2/7'	A mutation stop of 1-1/7' or 2-2/7' pitch. The name Septième was introduced by Cavaillé-Coll and it was he who first brought it to prominence in France in the 1860's.
128	Flûte 2'	An open flute stop with no particular distinguishing characteristic.
129	Sesquialtera 2 2/3' + 1 3/5'	A compound flue stop of two unbroken diapason ranks, speaking the 12th and 17th of the 8' harmonic series (thus the ranks at 2-2/3' and 1-3/5' pitch).
130	Plein jeu 3-5x 2 2/3'	The term Plein Jeu ("full chorus") originally designated not a stop but a registration consisting of Principals, Flutes, Fournitures, and Cymbales, rarely containing any 3rd-sounding ranks. Since the end of the French classical period the mixture called Plein Jeu consists of two or more octave and fifth sounding ranks (and never thirds).
131	Cor anglais 8'	The orchestral English Horn is neither English nor a horn; it is essentially a tenor oboe which dates back at least as far as the 18th century. The name "English Horn" is a translation of the French cor anglais which is probably a corruption of cor anglé, meaning "angled horn", referring to an early form of the instrument which was bent in the middle at an angle. The tone of this stop is intended to imitate this woodwind instrument, which has been described as rich, round, plaintive, and somber.
132	Tuba mirabilis 8'	A Tuba of extraordinary power, among the most powerful of all stops.
133	Walze	enables the crescendo wheel
134	Koppeln aus Walze	couplers disabled when using the crescendo wheel

	Name of the stop	Description
135	Mixturen aus Walze	mixtures disabled when using the crescendo wheel
136	Zungen aus Walze	reeds disabled when using the crescendo wheel
137	P+IV e.	electrical coupler between the pedals and the fourth manual
138	P+III e.	electrical coupler between the pedals and the third manual
139	P+II e.	electrical coupler between the pedals and the second manual
140	P+I e.	electronic coupler between the pedals and the first manual

V. Manual, Chamaden (C-c'''')

150	Chamade 16'	During the 20th century, the phrase *en chamade* (meaning "to sound a parley") came to mean a stop (invariably a loud chorus reed) whose pipes were mounted horizontally outside the organ case. When used by itself as a stop name, Chamade indicates some sort of chorus reed mounted *en chamade*. The name here is also used for an entire division. There are a number of reasons for mounting a reed horizontally, or for "hooding" it by mitering its resonators by 90 degrees. The most important reason, arguably, is tonal: by speaking directly into the church or hall, a noticeable number of high harmonics are transferred to the ears of the listener that would otherwise be lost to reflection or absorption. Another important reason is the great visual impact of such externally-, mounted ranks. Other reasons include tuning stability and protection from gravity-borne dust and debris. It should be noted that all of these advantages (except visual impact) can be had by placing the reeds inside the case rather than outside — at considerable savings in cost. Externally mounted reeds are very expensive, because of the required supporting structure, and because the resonators usually employ more expensive materials, and brought to a higher state of finish.
151	Chamade 8'	
152	Chamade 4'	
153	IV+V	electrical coupler between the fourth and fifth manuals
154	III+V	electrical coupler between the third and fourth manuals
155	II+V	electrical coupler between the second and fifth manuals
156	I+V	electrical coupler between the first and fifth manuals
157	P+V	electrical coupler between the pedal and fifth manuals
158	IV+IV 4'	couples a one-octave higher transposed version of the fourth manual to itself
159	IV+IV 16'	couples a one-octave lower transposed version of the fourth manual to itself
160	III+III 4'	couples a one-octave higher transposed version of the third manual to itself
161	III+III 16'	couples a one-octave lower transposed version of the third manual to itself
162	II+III 4'	couples a one-octave higher transposed version of the third manual to the second manual
163	II+III 16'	couples a one-octave lower transposed version of the third manual to the second manual
164	I+IV 4'	couples a one-octave higher transposed version of the fourth manual to the first manual
165	I+IV 16'	couples a one-octave lower transposed version of the fourth manual to the first manual
166	I+III 4'	couples a one-octave higher transposed version of the third manual to the first manual
167	I+III 16'	couples a one-octave lower transposed version of the third manual to the first manual
168	I+II 4'	couples a one-octave higher transposed version of the second manual to the first manual
169	I+II 16'	couples a one-octave lower transposed version of the second manual to the first manual
170	P+IV 4'	couples a one-octave higher transposed version of the fourth manual to the pedal
171	P+III 4'	couples a one-octave higher transposed version of the third manual to the pedal

8 A Guide to Room Acoustics

by Csaba Huszty

This section, designed as an easily readable introduction to the subject of room acoustics, is also intended as an aid to performing with Palace of Arts Budapest Pipe Organ Samples, while (hopefully) proving of general interest.

8.1 Acoustics and sound at a glance

Sound is defined as a mechanical disturbance in a medium – such as air, wood or metal – propagating like a wave and perceived by living creatures through the ability of hearing. Humans usually can perceive sounds in the frequency range of approximately 20 Hz to 20000 Hz (20 kHz) but aging and long exposure to high levels of sound generally limits one's hearing acuity by approximately 2.3 kHz, down from 20 kHz, for every decade after age 20. Sound can travel long distances though no 'material' is actually transported. Acoustics and optics have many similarities but in acoustics, the propagation is mechanical; therefore a propagation medium is also needed.

The disturbance mentioned above is a change in the density of air which happens fast enough so that there is no change in temperature or volume due to this change of density (the process is adiabatic). Sound has two basic descriptor properties, sound pressure and particle velocity. Sound what we perceive can be easily seen as a pressure oscillation that is added onto the constant sound pressure, which is due to the fact that the air above us has finite, quantifiable weight. Consequently, sound pressure is measured as the root-mean-square (RMS) value of the oscillation of the sound pressure in Pa, or Pascal.

$$p = \sqrt{\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} p_{momentary}^2(t)dt} \quad [\text{Pa}]$$

Sound Pressure Level (SPL) is the level that is calculated by the ratio of this RMS sound pressure and of a reference level of $p_{ref} = 20\ \mu Pa$ (micro-Pascal), the hearing threshold of a sine wave with a frequency of 1 kHz. The Sound Pressure Level is measured in decibels (dB). The dB scale, in general is a ratio expressed by using the logarithm of a given and a reference number. For easier reading, the abbreviation of SPL is usually attached after the dB.

$$L_p = 10\log_{10}\frac{p^2}{p_{ref}^2} = 20\log_{10}\frac{p}{p_{ref}} \quad [\text{dBSPL}]$$

The propagation speed of sound in air, c_{air} is a function of many properties such as temperature (T) for example, and can be calculated approximately as follows:

$$c_{air} = 331.3 \cdot \sqrt{1 + \frac{T}{273.16}} \cong 331.3 + 0.606 \cdot T \ [\frac{\mathrm{m}}{\mathrm{s}}]$$

thus the speed of sound is different in cold, as compared to warm air.

In a large, unheated cathedral, this contributes to an actual change of the pipe organ's pitch in the summer and winter months. The tuning of a pipe organ also changes with the ambient temperature, but for a different reason: the pipes and materials of the organ behave differently at different temperatures.

8.2 Sound in a room

Room acoustics is the study of acoustics, noise and vibration in rooms, either fully- or partly-closed enclosures. When sound propagates in an enclosed space, it is usually reflected from the boundary surfaces. An *echo* is a reflected sound that we hear clearly as separate to the original sound source, while reverberation is something that we hear as a process or overall effect, the result of many echoes occurring closely in time. Humans perceive two sounds as distinct if their arrival times are separated by at least 30 to 40 ms; even then a sound level difference is also required (Haas effect).

Sound behavior in a room is governed by two main equations which come from the laws of energy conservation and Newton's Second Law. These equations contain a few simplifications to assume linearity (usually correct when talking about everyday sound levels). The first equation is called the linear Euler-equation:

$$\rho_0 \frac{\partial v}{\partial t} + \frac{\partial p}{\partial x} = 0$$

where ρ_0 denotes the density of air, v denotes particle velocity, p sound pressure level, t time and x displacement. This equation roughly says that the mass of materials propagating through a unity area in a given time, and the gradient of the sound pressure sums to zero. The second equation is the so-called continuity equation, and resembles the Euler-equation above:

$$\rho_0 \frac{\partial v}{\partial x} + \frac{\partial \rho}{\partial t} = 0$$

With the help of these two equations one can find the wave equation describing wave propagation, which is as follows for one dimension:

$$\frac{\partial^2 p}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = 0$$

where c denotes the speed of sound as previously. There is an equation that can be formulated from the wave equation, which has the advantage of not containing the time in it, following the assumption that the sound is a pure sine. This equation is called the Helmholtz-equation:

$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial y^2} + \frac{\partial^2 p}{\partial z^2} + k^2 p = 0$$

or in a shorter form

$$(\nabla^2 + k^2)p = 0$$

where $k = \frac{\omega}{c}$

is the ratio of ω the circular or angular frequency of the pure sine and c the speed of sound; k is called the wave number, and ∇^2 denotes so-called Nabla-operator.

8.2.1 Room modes and its effects on pipe organs

This equation is useful because assuming perfect reflections from walls of a rectangular room, one can find a **room's natural resonance frequencies** called room modes. They are located at certain given frequencies of:

$$\omega_{n_x n_y n_z} = c\sqrt{\left(\frac{n_x \cdot \pi}{l_x}\right)^2 + \left(\frac{n_y \cdot \pi}{l_y}\right)^2 + \left(\frac{n_z \cdot \pi}{l_z}\right)^2} \quad \left[\frac{1}{s}\right]$$

by inserting arbitrary integer numbers of n_x, n_y, n_z to the equation. l_x, l_y, l_z mark the dimensions of a the room in meters.

The number of room modes increases with frequency. In a real room, walls produce imperfect reflections, due to damping, so resonances happen in a frequency range rather than a single frequency. The result is a certain frequency where these ranges overlap in such a way that they can no longer be distinguished separately. This is called the modal overlap crossover frequency or Schröder-frequency and it is defined as:

$$f_{Schröder} = \sqrt{\frac{c^3}{4 \cdot \ln 10} \cdot \frac{T_{60}}{V}} \quad [Hz]$$

T_{60} denotes the reverberation time of the room, the time in seconds for the sound pressure level to drop by 60dB (equivalent to one millionth of its initial value), while V is the volume of the room in cubic meters.

This suggests that rooms of large size and small reverberation times, such as modern concert halls, may have a quite low Schröder-frequency, while very large rooms with long reverberation times, such as cathedrals may have a higher Schröder-frequency. Assuming a perfectly diffuse sound field free of acoustic problems, a Schröder frequency below 20 Hz would lead us to expect a sound not unduly affected by single room modes, with little likelihood of very large or annoying changes or sound resonances that can be only heard in certain parts of a room.

For example, shoebox-shaped large concert halls have a Schröder frequency usually somewhere between 16 and 25 Hz, meaning that for pipe organs, these concert halls shall be treated acoustically using a non-modal approach except for the first few notes of the 32' stops. All this goes to answer the common feeling that deeper pedal notes are typically not so loud in concert halls and why they sound completely different when walking in a cathedral from one location to another. The modal behavior of a room causes great challenges for organ builders, both in design/construction and installation.

8.3 Reverberation time and its effects on organ music

One of the basic room acoustic parameters used to describe or evaluate a room's acoustic conditions in an objective way is the reverberation time. This is the time required for the steady-state sound energy density, or sound pressure level to decrease from its original level to only one-millionth, or in other words, decrease by 60 dB. The term 'reverberation time' usually denotes a band of frequencies, while the term decay time denotes a single frequency.

There are different methods and formulas for calculating reverberation time, including Sabine's empirical formula that takes into account room volume, sound absorption, surface and sound speed, but reverberation time can also be empirically measured.

Reverberation can be considered as a finite process that decays exponentially with time. In a real room, the value is usually different for different frequencies: lower frequencies have longer, higher frequencies have a shorter reverberation time in most cases. Reverberation at very high frequencies in large or absorbent rooms is negligible since air absorbs higher frequency sounds better and in large rooms, such high frequency sounds may not even reach surfaces to reflect from before they are absorbed.

The reverberation time for large concert halls is usually between 1.8 to 2.6 seconds, middle sized churches or smaller cathedrals made of stone usually produce 3 to 4 seconds of overall reverberation while huge cathedrals may have up to 12 seconds or even a bit more. Organists I have met are usually most happy when the cathedral has about 5-6 seconds of reverberation, overall.

While the reverberation time of small rooms such as a living room or a jazz club influences mainly the sound coloration and intelligibility of music, a longer reverberation may be somewhat automatically assigned to traditional organ music as an indispensible ingredient..

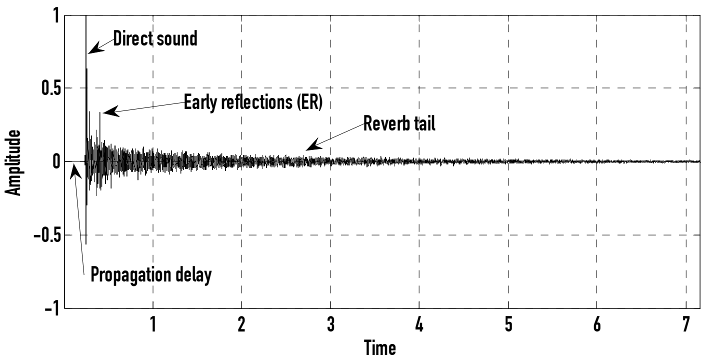
The reverberation time indeed highly influences the manner in which organists play. Longer reverberation times usually require a more staccato (short) style of execution to support the intelligibility and clarity of music when it is needed, with longer pauses between different passages within a piece. Longer reverberation time also boosts the effect to create crescendos just by playing chords of different lengths, since the buildup time of such chords is connected to the reverberation time. The effect can be heard without any reverberation at all, but in the presence of a long reverberation, the effect is easily audible.

Long cathedral reverberation has also influenced composers of organ literature. Several parts, for example in the organ symphonies of Charles-Marie Widor contain fast passages that can only be heard as an overall effect rather than single notes in a reverberant cathedral, and it is very likely that the composer wrote this intentionally, since Widor was resident organist at St. Sulpice cathedral, Paris, blessed with lengthy reverberation. On the other hand, 20th-century and contemporary composers such as Olivier Messiaen, Jean Guillou or Thierry Escaich have composed or improvised pieces that sound gloriously impressive when performed in reverberant spaces.

8.4 The Room Impulse Response

To describe the acoustics of a room, engineers are required to take measurements. There is a nearly 100-year history of room acoustic measurements, but today, these are based on the foundations of System Theory. This theory originally described electrical systems such as circuits, but has now been generalized, providing a good analogy for acoustic and mechanical waves. The system theory helps to find the parameters of an unknown system, which, in this case, is the room itself. The system has an input and an output, and this is generally all we know about it, along with some assumptions on linearity and time invariance. A signal is input (excite a sound in a room), the output examined (record that sound) permitting the determining of that room's parameters. The signal that holds most of the information within the domain of room acoustics is the room impulse response (RIR).

Room impulse responses (RIRs) are time-domain signals measured in a room during room acoustics measurements. RIRs characterize a room between two given physical locations, a source and a receiver, assuming that the room is a stable, causal, linear and time-invariant (LTI) system. The room impulse response can be imagined easily, it is the response of the room to a short impulsive spike (though, in practice, for several technical reasons signals other than spikes are customarily used).



Room impulse responses have the following parts:

- Propagation delay: time taken for sound to travel from the source to the listener
- Direct sound: in the line of sight, the direct sound is a peak corresponding to the shortest travel path
- Early Reflections (ER) part
  - First reflection: usually the reflection from the ground
  - Second and other reflections: subsequent, still clearly distinguishable reflections

- Reverberation Tail part: this is the stochastic part of the reverberation where so many reflections are present that they can no longer be separately identified.

There is an acoustically important parameter, the Initial Time Delay Gap (ITDG), the time between the direct sound and the first reflection. Sometimes it is defined as the time delay between the direct sound and the first reflection that is not a ground reflection, in the room impulse response. In reverberation software, the term Pre-delay is usually equal to this ITDG parameter.

8.4.1 Other representations of the room impulse response

There are many other representations of room impulse responses in use. Since they are always causal, the following representations are all equivalent:

- Time domain
  - **impulse response** (usually abbreviated as IR or RIR)
  - **step response**, obtained by integration of the impulse response
- Frequency-domain
  - **frequency response** function (FRF), obtained by Fourier-transforming the IR
    - Absolute value of the frequency response is the **magnitude response**
    - Angle of the frequency response is the **phase response**
- Complex frequency domain
  - **transfer function** (TF), obtained by taking the Laplace-transform of the IR
- Time-frequency domain (Wigner, Gabor, etc.)
  - Short-term Fourier Transform (STFT) or spectrogram
  - Wavelet transform or scalogram
  - Other time-frequency representations
- Any-to-spatial domain
  - Density plots: some parameter or a multidimensional function plotted as the function of space (physical location).

Usually, the calculation of different room acoustic parameters can be optimized by the use of one or other of these different representations; most of them are used regularly. There are two other forms of time-domain impulse responses used for the calculation of room parameters, but these cannot be transformed back to a RIR once calculated: the Energy Time Curve (ETC) and the Energy Decay Curve (EDC). The ETC is the square of the impulse response and corresponds to the decay of energy, while the EDC curve is a backward-integrated curve that has the advantage of being completely smooth; determination of the reverberation time of a room is usually made using this curve.

Once the impulse response of a room has been recorded between several sources and listener positions, it is possible to thoroughly evaluate the acoustic parameters and, if the measurement quality and post processing are of sufficient precision, the room impulse response can also be used to accurately reverberate sound sources. This is called convolution reverberation.

8.5 Understanding convolution reverberation

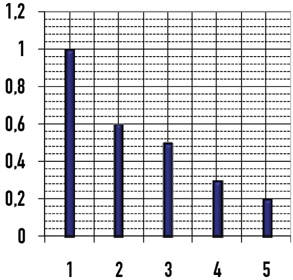
To be able to reverberate a sound (which we will refer to as dry sound from now on), we have to find an algorithm that can calculate the reverberated sound using our original recording and the Room Impulse Response we captured. This algorithm is called convolution. Convolution, in other words, is the way or method to compute the response [result] of a linear time-invariant (LTI) causal system [the acoustical space, e.g. the concert hall] to a known excitation [e.g. our dry sound].

Unlike any other reverberation methods, results of convolution based calculations using impulse responses of real measurements are almost identical (insofar as the equipment and measurement conditions are perfect) to what we would indeed experience or record in that very room.

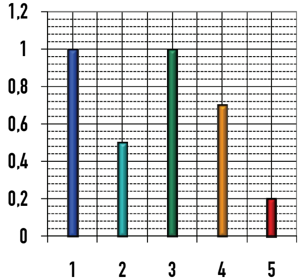
To understand exactly how convolution reverberation works, we will examine the convolution formula (the mathematics), and then visualize all this. We first interpret the sounds with discrete values sampled in time. The sound waves, which are continuous, are converted to discrete amplitude values (quantization) at regular time intervals (sampling rate) by the computer, resulting in a sequence of numbers. A sound source, now in digital form, would look like this: ($0, 3, 15, 512, -241, -235$, etc.. Let us call this sequence $\boldsymbol{e}$ (excitation) and one of its values as $\boldsymbol{e}[\boldsymbol{k}]$, where $\boldsymbol{k}$ means that we are talking about the $\boldsymbol{k}$-th sample value. We start counting $\boldsymbol{k}$ from zero, so for example, $\boldsymbol{e}[\boldsymbol{k} = 0]$ or simply $\boldsymbol{e}[0]$ equals to 0 in our case, while $\boldsymbol{e}[1] = 3$, etc.. Now let us interpret the Room Impulse Response the same way and call it $\boldsymbol{w}$ (from the name 'weight function'). The reverberated result (the response) would be called $\boldsymbol{y}$. Now the convolution formula is the summation of the excitation values multiplied by the shifted values of the impulse response:

$$\boldsymbol{y}[\boldsymbol{k}] = \sum_{\boldsymbol{i}=\boldsymbol{0}}^{\boldsymbol{k}} \boldsymbol{e}[\boldsymbol{i}] \cdot \boldsymbol{w}[\boldsymbol{k} - \boldsymbol{i}]$$

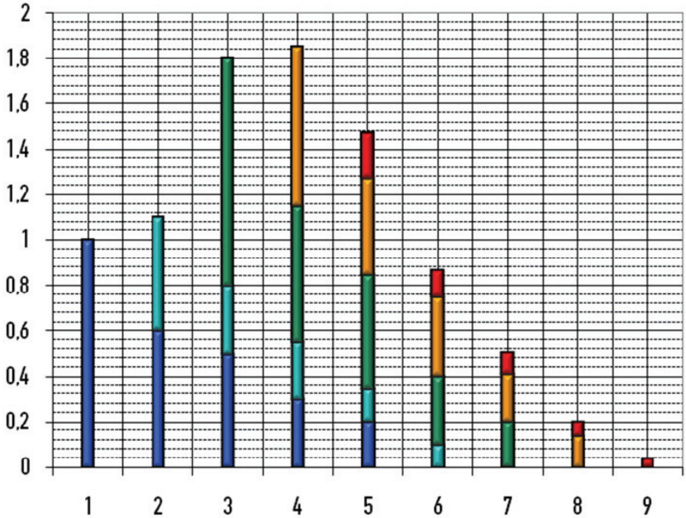
To visualize this, let us look at a sound signal (excitation signal) containing 5 sound samples and an impulse response, again of 5 samples. Imagine these as short excerpts of a concert hall impulse response and a digitally recorded organ sound, respectively. There are no negative values in these examples for ease of view. The excitation signal is colored differently at each time value so that you can follow the convolution algorithms easily. The horizontal axis is time, the vertical is amplitude.



Impulse response



Source signal



Reverberated signal with convolution

Convolution is very resource consuming for the computer – especially in terms of CPU and memory bandwidth usage. Therefore, as is the case for many other algorithms, optimization methods have been introduced to hasten the convolution process, allowing real-time or near real-time calculation for use in audio applications. The discrete convolution formula above in reality simply 'applies' finite length impulse response (FIR) filter to the input, where the filter coefficients are the samples of its impulse response. The term "filter" is used for anything that has an impulse response in system theory. Traditional personal computers nowadays are often not capable of applying very long impulse responses directly as FIR filters, due to the high computational load.

Therefore, optimization is needed, leading to the application of frequency domain convolution; however, transforming a time-domain signal to frequency domain requires all the time-domain samples to exist a-priori, which means a significant latency is introduced, an unavoidable delay caused by collecting the required samples before we can use them for calculations. The transformation to the frequency domain – called the Discrete Fourier Transform (DFT) – can be calculated very fast with its implementation called the Fast Fourier Transform (FFT). Convolution in the frequency domain is simply a multiplication, so after conducting the multiplication, the inverse Fourier Transform (IDFT) is applied to obtain the time-domain signal of the result. Although this is very effective computationally, it cannot be applied successfully to audio in real time because of the latency. A good compromise can be achieved by dividing the incoming signal and the impulse response into parts, applying the processing to these parts separately before combining their outputs. This increases the computational load somewhat, but decreases the latency. This algorithm is usually called 'fast convolution', and is implemented by the partitioned convolution method. Other optimization methods are also known but these are based on dropping away some information in order to make the calculations simpler.

8.6 Acoustical parameters

From the room impulse response and other acoustic measurements, a wide range of acoustical parameters can be calculated, which may be classified into the following categories for easier reading, together with some examples:

- Temporal parameters
    - Initial time-delay gap (ITDG, t1)
    - Early reflections - tail boundary, ER-limit (transition time, t_e)
    - Reverberation time (RT60, T10, T20, T30, etc.)
    - Early decay time (EDT)
    - Bass ratio (BR)
    - Treble ratio (TR)
    - Rise time (TR)
    - Inversion index (II)
    - Steepness (sigma)

- Temporal diffusion (Delta)
- Energetic parameters (energies and energy ratios)
  - Clarity index (C7, C50, C80)
  - Definition (D50, D80)
  - Strength (G, G80, GL)
  - Centre time (Ts)
  - Reverberant to early sound ratio (R)
  - Hallmass, Hallabstand (H)
  - Echo Criterion (EC)
  - Spectral Density (S)
  - Early Energy Balance (EEB)
- Spatial parameters
  - Lateral Strength (GEL, GLL)
  - Inter-Aural Cross-correlation Coefficient (IACC-A, IACC-E, IACC-L, IACC-E3, IACC-L3)
  - Lateral Energy Fraction, Early Lateral Energy Fraction (LF, LFC, ELEF)
  - Lateral Efficiency (LE)
  - Spatial Impression (SI)
  - Subjective Spaciousness (SS)
  - Room Response (RR)
- Stage parameters
  - Support (ST1, ST2, ST-early, ST-late, ST-total)
  - Clarity on Stage (CS)
  - EDT on Podium (EDTP)
  - Early Ensemble Level (EEL)
- Quantitative Speech Intelligibility Parameters
  - Speech Transmission Index (STI, STIr, STIEL, STIPA, RaSTI)
  - Speech Intelligibility Index (SII)
  - Articulation loss of Consonants (AlCons), Privacy Index (PI)
  - Radius of distraction (rd), radius of privacy (rp)

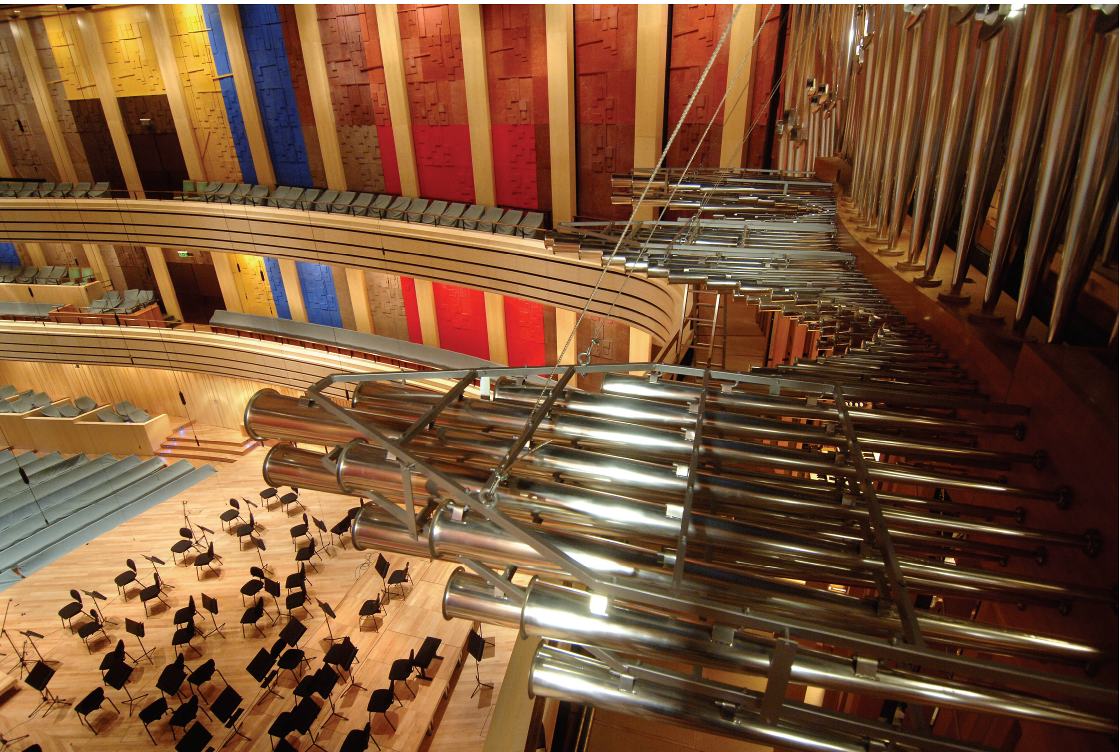
The above mentioned parameters are not fully independent, this means if one changes, others may also change in a reciprocal relationship. Scientists continue to seek independent parameters, so as to avoid the need for so great a range of interactive parameters. Some already established 'orthogonal parameters' are known as:

- Listening level (LL)
- Initial time delay gap (ITDG; Delta t1); without the ground reflection
- Subsequent reverberation time (Tsub)
- Inter-aural cross-correlation coefficient (IACC)

8.7 Objective and subjective pairing

The following list shows the subjective acoustic impression paired to its corresponding objective acoustical parameter, using today's standard terminology.

- Reverberance: early decay time (EDT)
- Liveness: EDT, reverberation time (RT)
- Fullness: RT
- Loudness: strength (G)
- Clarity: clarity index for music (C80)
- Timbre: reverberation time as a function of frequency, RT(f)
- Warmth: bass ratio (BR)
- Brilliance: treble ratio (TR) or high ratio (HR)
- Stage support: ST1
- Hall response: ST-late
- Spaciousness: lateral fraction (LF), early inter-aural cross correlation coefficient IACC-E
- Apparent source width: LF at (500-4000 Hz), IACC-E
- Listener envelopment: late lateral fraction (LLF) at (125-500 Hz), late IACC (IACC-L)
- Intimacy: LF, IACC-E
- Ensemble: clarity on stage (CS), early decay time on podium (EDTP)



9 About the recording process and the library

9.1 Recording

Preparations for this recording included initiation and implementation of a broader cooperation between Entel/Inspired Acoustics and the Palace of Arts – Budapest. Nearly 2 years of preparation, organization and planning took place before the actual recording could start. We were introduced to the instrument from the late phases of its building and voicing. The recording effort itself started in September 2007, more than a year after the official opening of the Palace. The Béla Bartók National Concert Hall has a very busy schedule so we pre-programmed everything before we entered the concert hall to minimize the recording and measurement session time requirements. Even the regular cleaning maintenance of the hall had to be rescheduled to allow us the privilege of continuous recording. Preparations included a custom acoustic setup of the hall, involving repositioning the 40-ton stage canopy and the 10-ton reverberation chamber doors along with all curtains to a location we specifically desired. The first session took about 47 hours, continuously, allowing us to capture a completely consistent spatial image of the organ. All together we recorded a net amount of 66 hours.

9.2 Post production

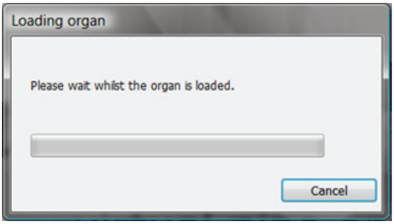
9.3 The recording in numbers

Time of recording	September 2007
Microphone used for this edition	DPA 4035 (a pair)
Microphone setup	AB, hung from the canopy, with a base moderately spaced
Net recording hours (organ only)	66
Sampling frequency	192 kHz/32 bits for all samples
Amount of data recorded	over 640 GB
Room acoustics	optimized for the recording
Total development hours	12,000 hours
Noise filtering performed in	Hungary
Number of continents participating in the post-processing works	4
Number of sound samples in this release	19 508 (Professional Edition), 34136 (Extended Edition)
Multiple loops of the sustained notes in the library	2,712 (55.61%) samples have 3 loops 2,018 (41.38%) samples have 2 loops 116 (2.38%) samples have 1 loop 19 (0.39%) samples have 6 loops 10 (0.21%) samples have 4 loops 1 (0.02%) sample has 5 loops 1 (0.02%) sample has 8 loops

10 Known issues

10.1 Hauptwerk™ loads this organ more slowly than other organs

This is a result of the tremendous number of switch linkages and logic in the organ definition file that describes the PAB Organ. Depending on the speed of your computer, you may need to wait from a few seconds to a few minutes before the Rank Page is displayed in Hauptwerk™ . This is normal, so there is no workaround for this; please wait while Hauptwerk™ finishes processing the organ definition file.



It may take about 30 minutes to load the organ for the first time after the Rank Page was displayed. This is because first Hauptwerk™ generates a cache file to allow faster subsequent loadings. Using the cache, Hauptwerk™ will load the organ in about 3 minutes.

10.2 Limitations in assigning MIDI messages at this time of writing

Although it may be possible in future releases of Hauptwerk™, the current Version 3.11 and earlier, unfortunately, do not support assigning MIDI program change increment and decrement messages to the custom combination frame buttons < and > that increment and decrement PAB's custom combination frames, available on the graphical user interface. You can attach fixed program change messages or other MIDI messages, however.

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Thanks

Gábor Huszty, Gergely Huszty, Norbert Balog, István Baróti, László Fassang, András Csonka, Nikoletta Csapó, Anna Tóth, Tamás Vadas, Péter Kováts, Antal Végh, Attila Budavári, Géza Markovich, Gergely Lakatos, Gábor Zoboki, Dániel Lakos, Bálint Karosi, Dóra Pordán, Zsuzsa Pető, Martin Dyde and Brett Milan

Special thanks

Pécsi Organ-Building Manufacture Ltd, Werkstätte für Orgelbau Mühleisen GmbH, and the staff of the Palace of Arts – Budapest

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13 Appendix

13.1 Tuning information

We would like to provide you with a useful list of widely-used organ tunings in order to allow you to change your instrument's scale to the desired one.

Scale/cent values (distance from C)

	C	C#/Db	D	D#/Eb	E	F	F#/Gb	G	G#/Ab	A	A#/Bb	B/H
Equal	0.00	100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00	900.00	1000.00	1100.00
1/10 Comma Temperament	0.00	99.60	199.20	298.80	398.40	500.40	597.60	699.60	799.20	898.80	998.40	1098.00
1/2 Pythagorean Comma (like Kirnberger 2)	0.00	90.22	203.91	294.13	384.36	498.04	588.27	701.96	792.18	894.13	996.09	1086.31
1/3 Syntonic Comma Meantone	0.00	63.50	189.57	315.64	379.14	505.21	568.72	694.79	758.29	884.36	1010.43	1073.93
1/3rd Comma Mean Tone (Salinas' 31 note Mean Tone)	0.00	63.50	189.50	315.75	379.25	505.25	568.75	694.75	758.25	884.50	1010.50	1074.00
1/4 Comma Modified mean Tone	0.00	88.00	193.00	299.00	386.00	502.50	586.00	696.50	793.00	889.50	1005.00	1084.00
1/4 PC Meantone	0.00	72.63	192.18	311.73	384.36	503.91	576.54	696.09	768.72	888.27	1007.82	1080.45
1/4 SC Meantone with Pyth accidentals	0.00	86.80	193.16	299.51	386.31	503.42	584.85	696.58	788.76	889.74	1001.47	1082.89
1/4 Syntonic Comma Mean-Tone	0.00	75.50	193.00	310.50	386.00	503.50	579.00	696.50	772.00	889.50	1007.00	1082.50
1/4 Syntonic Meantone	0.00	76.05	193.16	310.26	386.31	503.42	579.47	696.58	772.63	889.74	1006.84	1082.89
1/5 Comma Mean Tone	0.00	84.00	195.00	307.00	391.00	502.00	586.00	698.00	781.00	893.00	1005.00	1088.00
1/5 Syntonic Comma Meantone	0.00	83.58	195.31	307.04	390.61	502.35	585.92	697.65	781.23	892.96	1004.69	1088.27
1/5th Comma Well-Temperament	0.00	90.00	194.40	294.00	388.00	498.00	588.00	697.20	792.00	891.60	996.00	1086.00
1/5th Pythagorean Comma Mean-Tone	0.00	80.40	194.40	308.40	388.80	502.80	583.20	697.20	777.60	891.60	1005.60	1086.00
1/6 Comma Modified Meantone	0.00	92.00	196.00	294.00	392.00	502.00	588.00	698.00	796.00	894.00	998.00	1090.00
1/6 Pyth Comma	0.00	86.31	196.09	305.87	392.18	501.96	588.27	698.04	784.36	894.13	1003.91	1090.22
1/6 Pythagorean Comma Mean-Tone	0.00	86.00	196.00	306.00	392.00	502.00	588.00	698.00	784.00	894.00	1004.00	1090.00
1/6 Syntonic Comma	0.00	88.59	196.74	304.89	393.48	501.63	590.22	698.37	786.96	895.11	1003.26	1091.85
1/6th Comma Mean Tone (Silbermann)	0.00	86.00	196.00	306.00	392.00	502.00	588.00	698.00	784.00	894.00	1004.00	1090.00
1/7 Comma Well Temperament	0.00	96.85	197.14	297.43	394.28	501.43	594.85	698.57	797.14	895.71	999.43	1092.85
1/8 Comma Temperament	0.00	99.00	198.00	297.00	396.00	501.00	597.00	699.00	798.00	897.00	999.00	1095.00
1/8th Comma "Well Tempered"	0.00	90.00	196.00	294.00	396.00	498.00	588.00	698.00	792.00	894.00	996.00	1090.00
1/PI Syntonic Comma	0.00	65.77	190.22	314.67	380.44	504.89	570.66	695.11	760.87	885.33	1009.78	1075.55
18th Century English (ord)	0.00	86.00	193.00	290.00	386.00	497.00	586.00	696.50	786.00	889.50	993.00	1086.00
2/7 Syntonic Comma	0.00	70.67	191.62	312.57	383.24	504.19	574.86	695.81	766.48	887.43	1008.38	1079.05
2/9 Comma Mean Tone	0.00	84.00	195.00	307.00	391.00	502.00	586.00	698.00	781.00	893.00	1005.00	1088.00
2/9 Syntonic Comma	0.00	80.23	194.35	308.47	388.70	502.82	583.05	697.18	777.41	891.53	1005.65	1085.88
Alexander Metcalf Fisher's Modified mean Tone Of 1818 In Simplified Form	0.00	85.00	193.00	309.00	386.00	502.00	579.00	696.50	779.50	889.50	1004.50	1082.50
Augustus De Morgan	0.00	100.00	202.50	298.50	403.00	499.00	601.50	701.50	799.00	903.00	998.50	1102.50
Bach 1722 (Lehman)	0.00	98.04	196.09	298.04	392.18	501.96	596.09	698.04	798.04	894.13	998.04	1094.13
Barnes-Bach (1/6 PC starting on F with one skip)	0.00	94.13	196.09	298.04	392.18	501.96	592.18	698.04	796.09	894.13	1000.00	1094.13
Bendeler III	0.00	96.00	192.00	294.00	396.00	498.00	594.00	696.00	798.00	894.00	996.00	1092.00
Broadwood "Best" Tuning (1885)	0.00	95.00	196.00	295.00	392.00	499.00	593.00	698.00	796.00	894.00	997.00	1091.00
French 18th Century Temperament Ordinaire II	0.00	86.00	196.00	292.00	392.00	498.00	588.00	698.00	788.00	894.00	996.00	1092.00
Gioseffo Zarlino's 2/7 Comma Mean Tone (1558)	0.00	71.30	191.80	312.30	383.60	504.10	575.40	695.90	767.20	887.70	1008.20	1079.50

	C	C#/Db	D	D#/Eb	E	F	F#/Gb	G	G#/Ab	A	A#/Bb	B/H
Idealised Well Temperament	0.00	93.00	195.00	297.00	390.00	500.00	591.00	697.50	795.00	892.50	999.00	1090.00
Jean Phillippe Rameau's Modified Mean Tone	0.00	86.50	193.00	296.00	386.00	503.50	584.50	696.50	788.50	889.50	1005.00	1083.00
Jean-Le Rond D'Alembert (1752)	0.00	79.00	193.00	282.50	386.00	494.00	581.00	696.50	776.50	889.50	989.50	1083.50
John Marsh's 4/25ths Comma mean Tone (1809)	0.00	89.50	197.00	304.50	394.00	501.50	591.00	698.50	788.00	895.50	1003.00	1092.50
Just	0.00	111.73	203.91	315.64	386.31	498.04	590.22	701.96	813.69	884.36	1017.60	1088.27
Kirnberger	0.00	91.00	192.00	296.00	387.00	498.00	591.00	696.00	792.00	890.00	996.00	1092.00
Kirnberger II	0.00	90.00	204.00	294.00	386.00	498.00	590.00	702.00	792.00	895.00	996.00	1088.00
Kirnberger II (1/2 Syntonic Comma)	0.00	92.18	203.91	294.13	386.31	498.04	590.22	701.96	794.13	895.11	996.09	1088.27
Kirnberger IIA (Charles Earl Stanhope)	0.00	91.00	197.00	295.00	386.00	498.00	589.00	702.00	793.00	891.50	996.00	1088.00
Kirnberger III	0.00	90.00	193.00	294.00	386.00	498.00	590.00	696.50	792.00	889.50	996.00	1088.00
Kirnberger III (1/4 Syntonic Comma)	0.00	90.22	193.16	294.13	386.31	498.04	588.27	696.58	792.18	889.74	996.09	1088.27
Lucy Tuning	0.00	68.45	190.99	313.52	381.97	504.51	572.96	695.49	763.95	886.48	1009.01	1077.47
Lucy Tuning (From John Harrison's 31 note Mean Tone)	0.00	68.50	191.00	313.50	382.00	504.50	573.00	695.50	764.00	886.50	1009.00	1077.50
Maj3 and Per5 equally beating (1/3,4 Syntonic Comma)	0.00	69.41	191.26	313.11	382.52	504.37	573.78	695.63	765.04	886.89	1008.74	1078.15
Marpurg (1/3 PC skipping)	0.00	98.04	203.91	301.96	400.00	498.04	603.91	701.96	800.00	898.04	1003.91	1101.96
Min3 and Maj3 equally beating (1/3,4545 Syntonic Comma)	0.00	70.11	191.46	312.81	382.92	504.27	574.38	695.73	765.84	887.19	1008.54	1078.65
Modified Mean Tone	0.00	85.00	193.00	309.00	386.00	501.00	585.00	696.50	797.00	889.50	1005.00	1085.00
Neidhardt I (1724)	0.00	94.00	196.00	296.00	392.00	498.00	592.00	698.00	796.00	894.00	996.00	1092.00
Nigel Taylor's Idealised Circulating Temperament	0.00	92.00	194.00	296.00	388.00	498.00	590.00	697.00	794.00	891.00	998.00	1090.00
Ordinaire	0.00	77.00	193.00	290.00	386.00	504.00	580.00	696.00	775.00	890.00	997.00	1083.00
Ordinaire in style of Rameau/Rousseau	0.00	86.80	193.16	296.09	386.31	503.42	584.85	696.58	788.76	889.74	1005.21	1082.89
Pietro Aaron's 1/4 Comma Mean Tone (1523)	0.00	76.00	193.00	310.00	386.00	503.50	586.00	696.50	781.00	889.50	1006.00	1083.00
Pythagorean	0.00	90.22	203.91	294.13	407.82	498.04	588.27	701.96	792.18	905.87	996.09	1109.78
Pythagorean(Arnout Van Zwolle 15c,)	0.00	90.00	204.00	294.00	408.00	498.00	588.00	702.00	792.00	906.00	996.00	1110.00
Skip 1/6 Pythagorean Comma	0.00	98.04	200.00	298.04	400.00	498.04	600.00	698.04	800.00	898.04	1000.00	1098.04
Vallotti (1/6 Comma)	0.00	94.00	196.00	298.00	392.00	502.00	592.00	698.00	796.00	894.00	1000.00	1090.00
Vallotti (1/6 Pyth Comma)	0.00	94.13	196.09	298.04	392.18	501.96	592.18	698.04	796.09	894.13	1000.00	1090.22
Variable Meantone 1: C-G-D-A-E 1/4, others 1/6	0.00	81.43	193.16	304.89	386.31	501.63	583.05	696.58	779.80	889.74	1003.26	1084.68
Variable Meantone 2: C-G-D-A-E 1/4, 1/5-1/6-1/7-1/8 outward both directions	0.00	81.22	193.16	305.09	386.31	502.35	582.34	696.58	780.49	889.74	1003.98	1083.97
Variable Meantone 3: C-G-D-A-E 1/4, 1/6 next, then Pyth	0.00	87.88	193.16	297.72	386.31	501.63	585.92	696.58	789.83	889.74	999.67	1083.97
Variable Meantone 4: 1/4 SC naturals, Pyth acc's	0.00	86.80	193.16	299.51	386.31	503.42	584.85	696.58	788.76	889.74	1001.47	1082.89
Werckmeister (Kellner); Bach's Wohltemperiert; 1/5 Comma Well-Temperament (Dr. Herbert Anton Kellner)	0.00	90.00	194.40	294.00	388.80	498.00	588.00	697.20	792.00	891.60	996.00	1090.80
Werckmeister III	0.00	92.00	193.00	294.00	391.50	498.00	590.00	696.50	793.00	889.50	996.00	1093.50
Werckmeister III	0.00	90.00	192.00	294.00	390.00	498.00	588.00	696.00	792.00	888.00	996.00	1092.00
Werckmeister III (1/4 Pythagorean Comma)	0.00	90.22	192.18	294.13	390.22	498.04	588.27	696.09	792.18	888.27	996.09	1092.18
Werckmeister III(1691)	0.00	90.00	192.00	294.00	390.00	498.00	588.00	696.00	792.00	888.00	996.00	1092.00
William Hawkes Modified Mean Tone (1811)	0.00	84.00	195.00	302.50	391.50	502.00	586.00	697.50	786.00	893.00	1004.50	1088.00
William Hawkes Modified meantone (1807)	0.00	84.00	195.00	295.00	391.00	502.00	586.00	698.00	786.00	893.00	1005.00	1088.00
Young I	0.00	94.00	196.00	298.00	392.00	500.00	592.00	698.00	796.00	894.00	1000.00	1092.00

	C	C#/Db	D	D#/Eb	E	F	F#/Gb	G	G#/Ab	A	A#/Bb	B/H
Young I (Idealised well Temperament) 1799	0.00	94.00	196.00	298.00	392.00	500.00	592.00	698.00	796.00	894.00	1000.00	1092.00
Young II	0.00	90.22	196.09	294.13	392.18	498.04	588.27	698.04	792.18	894.13	996.09	1090.22
Young II (1/6 Comma)	0.00	90.00	196.00	294.00	392.00	498.00	588.00	698.00	792.00	894.00	996.00	1090.00
Young II 1800	0.00	90.00	196.00	294.00	392.00	498.00	588.00	698.00	792.00	894.00	996.00	1090.00
Persian 1	0.00	130.00	-	345.00	-	490.00	630.00	-	850.00	-	1035.00	1137.00
Persian 2	0.00	125.00	-	335.00	-	480.00	625.00	-	835.00	-	1035.00	1115.00
Shrinivas	0.00	133.00	204.00	316.00	394.00	498.00	624.00	702.00	835.00	906.00	1018.00	1096.00
Bhatkhande	0.00	99.00	204.00	316.00	394.00	498.00	597.00	702.00	801.00	906.00	1018.00	1096.00

Deviation from equal temperament in cents

	C+0	C#+0	D+0	Eb+0	E-0	F+0	F#+0	G+0	G#+0	A+0	Bb+0	B+0
Equal Tempered, Perfect Octave	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Equal Tempered, Perfect Fourth	3.52	3.13	2.74	2.35	1.96	1.56	1.17	0.78	0.39	0.00	-0.39	-0.78
Equal Tempered, Perfect Fifth	-2.51	-2.24	-1.96	-1.68	-1.40	-1.12	-0.84	-0.56	-0.28	0.00	0.28	0.56
Equal Tempered, Streched (1,0 Cent)	-0.75	-0.67	-0.58	-0.50	-0.42	-0.33	-0.25	-0.17	-0.08	0.00	0.08	0.17
Equal Tempered, Streched (1,25 Cent)	-0.94	-0.83	-0.73	-0.63	-0.52	-0.42	-0.31	-0.21	-0.11	0.00	0.10	0.21
Equal Tempered, Streched (1,5 Cent)	-1.13	-1.00	-0.88	-0.75	-0.63	-0.50	-0.38	-0.25	-0.13	0.00	0.13	0.25
Just Tempered (Schugk)	15.64	-13.69	19.55	31.28	1.96	13.69	5.86	17.60	29.33	0.00	33.24	3.91
Just Tempered (Barbour)	15.64	-13.69	19.55	31.28	1.96	13.69	5.86	17.60	-11.73	0.00	33.24	3.91
Naturally harmonious (Thirds)	15.64	27.37	19.55	31.28	1.96	13.69	5.86	17.60	29.33	0.00	11.73	3.91
Naturally harmonious	15.64	27.37	19.55	31.28	1.96	13.69	5.86	17.60	29.33	0.00	33.24	3.91
Pythagorean	-5.87	7.82	-1.96	-11.73	1.96	-7.82	5.87	-3.91	9.78	0.00	-9.78	3.91
Pythagorean (Perfect)	15.64	7.82	19.55	11.73	1.96	13.69	5.87	17.60	9.78	0.00	11.73	3.91
Pythagorean (Fifth chain Cb - E)	-5.87	-15.64	-1.96	-11.73	1.96	-7.82	-17.60	-3.91	-13.69	0.00	-9.78	-19.55
Pythagorean (Fifth chain Db - F#)	-5.87	-15.64	-1.96	-11.73	1.96	-7.82	5.87	-3.91	-13.69	0.00	-9.78	3.91
Pythagorean (Fifth chain Ebb - G)	17.60	7.82	-1.96	11.73	1.96	15.64	5.87	19.55	9.78	0.00	13.69	3.91
Pythagorean (Fifth chain Fb - A)	-5.87	-15.64	-1.96	-11.73	-21.51	-7.82	-17.60	-3.91	-13.69	0.00	-9.78	-19.55
Pythagorean (Fifth chain F - A#)	-5.87	7.82	-1.96	11.73	1.96	-7.82	5.87	-3.91	9.78	0.00	13.69	3.91
Pythagorean (Fifth chain Gb - B)	-5.87	-15.64	-1.96	-11.73	1.96	-7.82	-17.60	-3.91	-13.69	0.00	-9.78	3.91
Pythagorean (Fifth chain Ab - C#)	-5.87	7.82	-1.96	-11.73	1.96	-7.82	5.87	-3.91	-13.69	0.00	-9.78	3.91
Pythagorean (Fifth chain Bb - D#)	-5.87	7.82	-1.96	11.73	1.96	-7.82	5.87	-3.91	9.78	0.00	-9.78	3.91
Meantone	8.80	-9.78	2.93	15.64	-2.93	11.73	-7.82	5.87	-10.75	0.00	13.69	-5.86
Meantone # (-1/4)	10.27	-13.69	3.42	-20.53	-3.42	13.69	-10.27	6.84	-17.11	0.00	-23.95	-6.84
Meantone b (-1/4)	10.27	27.37	3.42	20.53	-3.42	13.69	30.79	6.84	23.95	0.00	17.11	-6.84
Meantone (-1/4) (LargeThird)	10.27	-13.69	3.42	20.53	-3.42	13.69	-10.27	6.84	-17.11	0.00	17.11	-6.84
Meantone (Small third)	15.64	-20.86	5.21	31.28	-5.21	20.86	-15.64	10.43	-26.07	0.00	26.07	-10.43
Meantone (Homogeneous)	7.04	-9.38	2.35	14.08	-2.35	9.38	-7.04	4.69	-11.73	0.00	11.73	-4.69
Meantone (Homogeneous third)	12.57	-16.76	4.19	25.14	-4.19	16.76	-12.57	8.38	-20.95	0.00	20.95	-8.38
Meantone (Homogeneous gradated)	4.89	-6.52	1.63	9.78	-1.63	6.52	-4.89	3.26	-8.15	0.00	8.15	-3.26
Comma - Temperament (1/7)	3.35	-4.47	1.12	6.70	-1.12	4.47	-3.35	2.23	-5.59	0.00	5.59	-2.23
Comma - Temperament (1/8)	2.20	-2.93	0.73	4.40	-0.73	2.93	-2.20	1.47	-3.67	0.00	3.67	-1.47
Comma - Temperament (1/9)	1.31	-1.74	0.44	2.61	-0.44	1.74	-1.31	0.87	-2.18	0.00	2.18	-0.87
Comma - Temperament (2/9)	8.47	-11.30	2.82	16.94	-2.82	11.30	-8.47	5.65	-14.12	0.00	14.12	-5.65
Comma - Temperament (1/10)	0.59	-0.78	0.20	1.18	-0.20	0.78	-0.59	0.39	-0.98	0.00	0.98	-0.39
Comma - Temperament (3/11)	11.73	-15.64	3.91	23.46	-3.91	15.64	-11.73	7.82	-19.55	0.00	19.55	-7.82
Pythagorei comma (3-Split)	9.78	0.00	-1.96	3.91	1.96	7.82	-1.96	3.91	1.96	0.00	5.87	3.91
Pythagorei comma (4-Split)	5.87	1.96	-1.96	0.00	1.96	3.91	0.00	1.96	3.91	0.00	1.96	-1.96
Pythagorei comma (5-Split)	8.21	-1.56	2.74	2.35	-2.74	6.26	-3.52	5.47	0.39	0.00	4.30	-5.47
Pythagorei comma (6-Split)	5.87	-3.91	1.96	0.00	-1.96	3.91	-5.87	3.91	-1.96	0.00	1.96	-3.91

	C+0	C#+0	D+0	Eb+0	E-0	F+0	F#+0	G+0	G#+0	A+0	Bb+0	B+0
Pythagorei comma (6 & 12-Split)	5.87	-3.91	1.96	7.82	-1.96	7.82	-3.91	3.91	-3.91	0.00	7.82	-3.91
Syntonic comma (2-Split)	15.64	-13.69	8.80	31.28	1.96	13.69	-4.89	17.60	-11.73	0.00	22.48	3.91
Syntonic comma (4-Split)	10.26	-3.91	3.42	4.40	-3.42	8.31	-10.27	6.84	2.44	0.00	6.35	-6.84
Syntonic comma (5-Split)	7.04	1.17	2.35	3.52	-2.35	5.87	0.00	4.69	2.35	0.00	4.69	-1.17
Diatonic (Chromatic addition)	15.63	-13.70	19.54	31.27	1.95	13.68	5.86	17.59	-11.74	0.00	11.72	3.90
Ammerbach (1571)	5.87	-7.82	3.91	8.80	-1.96	3.91	-3.91	7.82	-9.78	0.00	4.89	-1.96
Ammerbach (1583, Interpretation 1)	6.14	-4.18	4.05	6.27	1.96	4.18	-0.14	8.09	-2.23	0.00	8.23	3.91
Ammerbach (1583, Interpretation 2)	6.14	-8.18	4.05	9.27	-2.05	4.18	-4.14	8.09	-10.23	0.00	5.23	-2.09
Bach (Billeter, Well-Tempered)	4.89	-2.93	4.89	0.98	-4.89	4.89	-4.89	4.89	-0.98	0.00	2.93	-4.89
Bach (Kelletats, 1966)	9.12	-0.65	4.56	3.26	-4.56	7.17	-2.61	9.13	1.30	0.00	5.21	-4.56
Bach (Kellner, Well-Tempered)	9.77	0.00	3.26	3.91	-3.26	7.82	-1.96	6.52	1.95	0.00	5.86	-1.30
Bach (Kellner, 1977)	8.21	-1.56	2.74	2.35	-2.74	6.26	-3.52	5.47	0.39	0.00	4.30	-0.78
Bach (Klais)	7.49	-1.95	3.74	1.85	-4.88	5.65	-3.82	7.51	-0.02	0.00	3.77	-5.70
Barnes (1971)	2.93	-0.98	0.98	0.00	-0.98	3.91	-2.93	1.96	0.98	0.00	1.96	-1.96
Barnes (1977)	5.87	0.00	1.96	3.91	-1.96	7.82	-1.96	3.91	1.96	0.00	5.87	0.00
Bendeler (Fractions)	10.46	0.68	-1.96	4.59	1.96	8.50	-1.27	3.23	2.64	0.00	6.55	3.91
Bendeler III	5.87	1.96	-1.96	0.00	1.96	3.91	0.00	1.96	3.91	0.00	1.96	-1.96
Bermudo (1555)	-1.96	-1.96	-1.96	-7.82	-1.96	-3.91	-3.91	0.00	0.00	0.00	-5.87	0.00
Bossart I	5.87	-3.91	3.91	14.66	-3.91	9.78	-5.87	4.89	0.00	0.00	13.69	-4.89
Bossart II	5.87	0.00	0.98	14.66	0.00	9.78	-1.96	4.89	1.96	0.00	10.75	1.96
Bossart III	5.87	-0.98	3.91	11.73	-3.91	9.78	-2.93	4.89	2.93	0.00	10.75	-4.89
Bruder (1829)	2.93	-1.96	5.87	0.00	-5.87	1.96	-3.42	4.40	-0.98	0.00	0.98	-4.89
Ganassi (1543)	15.64	4.44	-1.96	-3.00	1.96	13.69	12.64	17.60	6.40	0.00	-1.05	3.91
Goebel (1967)	-0.17	0.11	0.21	0.13	0.12	-0.14	0.03	0.02	-0.02	0.00	-0.05	-0.12
Grammateus (1518)	-5.87	-3.91	-1.96	0.00	1.96	-7.82	-5.87	-3.91	-1.96	0.00	-9.78	3.91
Kelletat (1960)	7.82	-1.96	3.91	1.96	-4.89	5.87	-3.91	7.82	0.00	0.00	3.91	-5.87
Kelletat (1966)	7.82	-1.96	3.91	1.96	-3.91	5.87	-3.91	7.82	0.00	0.00	3.91	-5.87
Kellner	8.21	-1.56	2.74	2.35	-2.74	6.26	-3.52	5.47	0.39	0.00	4.30	-0.78
Kircher	15.64	-13.69	19.55	-9.78	1.96	13.69	5.87	17.60	-11.73	0.00	-7.82	3.91
Kirnberger I (1766)	15.64	5.87	19.55	9.78	1.96	13.69	5.87	17.60	7.82	0.00	11.73	3.91
Kirnberger II (1771)	4.89	-4.89	8.80	-0.98	-8.80	2.93	-4.89	6.84	-2.93	0.00	0.98	-6.84
Kirnberger II (1776)	5.87	-3.91	9.78	0.00	-9.78	3.91	-5.87	7.82	-1.96	0.00	1.96	-7.82
Kirnberger III (1779)	10.26	0.49	3.42	4.40	-3.42	8.31	0.49	6.84	2.44	0.00	6.35	-1.47
Lambert (1774)	4.19	-2.23	1.40	1.68	-1.40	5.59	-4.19	2.79	-0.28	0.00	3.63	-2.79
Lublin (1540)	1.09	-13.69	-1.96	2.18	1.96	6.09	5.87	3.05	-11.73	0.00	4.14	3.91
Malcolm (Alexander, 1721)	15.64	20.60	19.55	13.15	1.96	13.69	18.64	17.60	11.20	0.00	4.96	3.91
Marpurg I	15.64	5.87	19.55	9.78	1.96	13.69	5.87	17.60	7.82	0.00	11.73	3.91
Marpurg II	-5.87	3.91	-1.96	7.82	1.96	-7.82	1.96	-3.91	5.87	0.00	9.78	0.00
Marpurg III	-5.87	-9.78	-1.96	-5.87	1.96	-7.82	-11.73	-3.91	-7.82	0.00	-9.78	-13.69
Marpurg IV	-5.87	-7.82	-1.96	-11.73	1.96	-7.82	-9.78	-3.91	-5.87	0.00	-9.78	-11.73
Marpurg V	-5.87	-1.96	-1.96	1.96	1.96	-7.82	-3.91	-3.91	0.00	0.00	3.91	-5.87
Marpurg VI	-5.87	-3.91	-1.96	0.00	1.96	-7.82	-5.87	-3.91	-1.96	0.00	1.96	3.91
Marpurg VII	1.96	0.00	-1.96	-3.91	1.96	0.00	-1.96	-3.91	1.96	0.00	-1.96	-3.91
Marpurg VIII	0.00	1.96	-1.96	0.00	1.96	-1.96	0.00	-3.91	-1.96	0.00	1.96	-1.96
Marpurg IX	-5.87	-3.91	-1.96	0.00	1.96	-1.96	0.00	-3.91	-1.96	0.00	1.96	3.91
Marpurg X	1.96	0.00	1.96	0.00	1.96	0.00	1.96	0.00	1.96	0.00	1.96	0.00
Marpurg XI	-5.87	0.00	-1.96	-3.91	1.96	-7.82	1.96	-3.91	-1.96	0.00	-5.87	3.91
Marpurg XII	-7.82	3.91	-1.96	-11.73	-1.96	-7.82	1.96	-3.91	5.87	0.00	-9.78	0.00
Meister	4.89	16.62	3.42	20.53	-3.42	2.93	14.66	6.84	18.57	0.00	0.98	-6.84
Mersenne (Fractions)	15.64	-13.69	19.55	31.28	1.96	13.69	-15.64	17.60	29.33	0.00	11.73	3.91
Mersenne (Marin, 1636)	5.13	1.71	-1.71	-5.13	-8.55	-6.84	-5.13	-3.42	-1.71	0.00	1.71	3.42
Neidhardt (1724, Grosse Stadt)	5.87	1.96	1.96	3.91	0.00	3.91	1.96	1.96	1.96	0.00	3.91	1.96

	C+0	C#+0	D+0	Eb+0	E-0	F+0	F#+0	G+0	G#+0	A+0	Bb+0	B+0
Neidhardt (1732, Dorf)	5.87	0.00	3.91	1.96	-3.91	3.91	-1.96	5.87	0.00	0.00	3.91	-1.96
Neidthardt I	5.87	0.00	1.96	1.96	-1.96	3.91	-1.96	3.91	1.96	0.00	1.96	-1.96
Neidthardt II	5.87	1.96	1.96	3.91	0.00	5.87	1.96	3.91	1.96	0.00	5.87	1.96
Neidthardt III	5.87	1.96	1.96	3.91	0.00	3.91	1.96	3.91	1.96	0.00	3.91	1.96
Rameau	11.73	-3.91	3.91	0.00	-3.91	15.64	-5.87	7.82	-1.96	0.00	7.82	-7.82
Rameau (-1/4)	10.27	-2.93	3.42	-4.56	-3.42	13.69	-4.89	6.84	-0.98	0.00	4.56	-6.84
Ramis de Pareia (1482)	15.64	7.82	-1.96	9.78	1.96	13.69	5.87	17.60	7.82	0.00	11.73	3.91
Reinhard (Andreas, 1604)	15.64	14.60	19.55	8.35	1.96	13.69	12.64	17.60	6.40	0.00	-1.05	3.91
Rossi (-1/5)	7.04	-9.39	2.35	14.08	-2.35	9.39	-7.04	4.69	-11.73	0.00	11.73	-4.69
Rossi (-2/9)	8.47	-11.30	2.82	16.95	-2.82	11.30	-8.47	5.65	-14.12	0.00	14.12	-5.65
Salinas (-1/3)	15.64	-20.85	5.21	31.28	-5.21	20.86	-15.64	10.43	-26.07	0.00	26.07	-10.43
Schlick (Barbour)	5.87	-3.91	1.96	7.82	-1.96	7.82	-3.91	3.91	1.96	0.00	7.82	-3.91
Schlick (Dupont)	10.27	-13.69	3.42	20.53	-3.42	13.69	-10.27	6.84	3.42	0.00	17.11	-6.84
Schlick (Lange)	6.23	-8.31	2.08	12.46	-2.08	8.31	-6.23	4.15	6.48	0.00	10.39	-4.15
Schlick (Ratte)	5.87	-5.87	1.96	9.78	-1.96	7.82	-3.91	3.91	5.87	0.00	7.82	-3.91
Schlick (Schugk)	8.21	-10.95	2.74	16.42	-2.74	10.95	-8.21	5.47	19.16	0.00	13.69	-5.47
Schlick (Tessmer)	7.33	-4.89	2.44	9.78	-2.44	9.78	-4.89	4.89	5.87	0.00	9.78	-4.89
Schlick (Vogel)	8.21	-6.26	2.74	2.35	-2.74	10.95	-8.21	5.47	-4.30	0.00	8.99	-5.47
Schneegass I (1590)	10.34	-13.79	3.45	20.68	-3.45	13.79	-10.34	6.89	-17.23	0.00	17.23	-6.89
Schneegass II (1590)	10.34	-10.66	3.45	20.68	-0.31	13.79	-7.21	6.89	-14.10	0.00	17.24	-3.76
Schneegass III (1590)	10.20	-9.02	4.27	18.31	-1.45	11.11	-8.58	6.16	-14.46	0.00	15.66	-4.32
Silbermann (-1/6)	4.89	-6.52	1.63	9.78	-1.63	6.52	-4.89	3.26	-8.15	0.00	8.15	-3.26
Silbermann (1/6)	5.87	-7.82	1.96	11.73	-1.96	7.82	-5.87	3.91	-9.78	0.00	9.78	-3.91
Sorge	5.87	1.96	1.96	3.91	0.00	3.91	1.96	3.91	3.91	0.00	3.91	1.96
Stanhope (1801)	9.78	0.00	5.87	3.91	-5.87	7.82	-1.96	11.73	1.96	0.00	5.87	-3.91
Trost (Johann Caspar, 1677)	-3.42	-6.84	3.42	-6.84	-3.42	0.00	-3.42	-6.84	-10.26	0.00	3.42	-13.69
Valotti (1754)	5.87	0.00	1.96	3.91	-1.96	7.82	-1.96	3.91	1.96	0.00	5.87	-3.91
Van Zwolle	-5.87	-15.64	-1.96	-11.73	1.96	-7.82	-17.60	-3.91	-13.69	0.00	-9.78	3.91
Veroli (Ordinaire)	10.27	-8.80	3.42	-1.46	-3.42	8.31	-8.80	6.84	-6.84	0.00	4.40	-6.84
Werckmeister I	11.73	1.96	3.91	5.87	1.96	9.78	0.00	7.82	3.91	0.00	7.82	3.91
Werckmeister II	9.78	-7.82	5.87	3.91	1.96	7.82	-1.96	3.91	-5.87	0.00	13.69	-3.91
Werckmeister III	0.00	-3.91	3.91	0.00	-3.91	3.91	0.00	1.96	-7.82	0.00	1.96	-1.96
Werckmeister IV	7.54	-2.24	-5.31	5.03	1.96	5.58	2.51	6.09	-0.28	0.00	6.98	3.91
Wiegleb	5.87	-1.96	1.96	1.96	0.00	5.87	-3.91	3.91	0.00	0.00	3.91	-1.96
Wiegleb (1790)	8.80	0.00	2.93	3.91	0.00	7.82	-1.96	5.87	1.96	0.00	5.87	-0.98
Young I	5.87	0.00	1.96	3.91	-1.96	5.87	-1.96	3.91	1.96	0.00	5.87	-1.96
Young II	5.87	-3.91	1.96	0.00	-1.96	3.91	-5.87	3.91	-1.96	0.00	1.96	-3.91
Zarlino (-2/7)	12.57	-16.76	4.19	25.14	-4.19	16.76	-12.57	8.38	-20.95	0.00	20.95	-8.38

If you wish to calculate frequencies from the table above, here is a useful formula to do this.

$$f_{Hz} = 2^{\frac{C}{1200}+O+\frac{N}{12}} \cdot f_{REF} \ \ [\mathrm{Hz}]$$

or the other way:

$$C = 1200 \cdot \left(\log_2\left(\frac{f_{Hz}}{f_{REF}}\right) - O - \frac{N}{12}\right) \ \ [\mathrm{cent}]$$

where

- C is the value to be calculated or converted in cents
- f_{Hz} is the value to be calculated or converted in Hertz
- O is the value of the octave transposed from the reference 'a' note, where the desired note is located (e.g. if 'a1' is the reference, 0 for a 'c1', +1 for a 'd2', -1 for a 'g#0', etc.)
- N is the number of half-notes from the reference note ('a') in the interval of one octave (values from -9 to 2: e.g. -9 for a 'c', -8 for a 'c#', etc., 0 for an 'a', 1 for an 'a#' and 2 for a 'b' regardless of its octave)
- f_{REF} is the frequency in Hertz of the reference 'a1' note of the scale (e.g. 440 Hz, 415 Hz, 442 Hz, etc.)

13.2 MIDI-assignable switches (Professional Edition)

Should you have a real organ console or a MIDI-capable control surface, please use this list as a reference to assign MIDI messages to the different controls of the virtual pipe organ.

Switch name	Meaning
Button_Reeds_Off_-Z	All reeds off button (-Z) button
Cancel_0_PEDALI	Turns off all stops and couplers on Pedal
Cancel_1_GO	Turns off all stops and couplers on Grand Orgue (Manual #1)
Cancel_2_POS	Turns off all stops and couplers on Positive (Manual #2)
Cancel_3_REC	Turns off all stops and couplers on Récit (Manual #3)
Cancel_4_SOLO	Turns off all stops and couplers on Solo (Manual #4)
Cancel_5_CHAM	Turns off all stops and couplers on Chamade (Manual #5)
Comb_0	Combination selector "0", wooden button
Comb_1	Combination selector "1", wooden button
Comb_2	Combination selector "2", wooden button
Comb_3	Combination selector "3", wooden button
Comb_4	Combination selector "4", wooden button
Comb_5	Combination selector "5", wooden button
Comb_6	Combination selector "6", wooden button
Comb_7	Combination selector "7", wooden button
Comb_8	Combination selector "8", wooden button
Comb_9	Combination selector "9", wooden button
Comb_Decr	Combination Decrement button
Comb_Decr_CHAM	Combination Decrement button below the 5th Manual (small black button)
Comb_Decr_Left	Combination Decrement button marked with < on the left side
Comb_Decr_POS	Combination Decrement button below the 2nd Manual (small black button)
Comb_Decr_REC	Combination Decrement button below the 3rd Manual (small black button)
Comb_Decr_Right	Combination Decrement button marked with < on the right side
Comb_Decr_SOLO	Combination Decrement button below the 4th Manual (small black button)
Comb_Down	Combination navigator "Down", wooden button
Comb_Incr	Combination Increment button
Comb_Incr_CHAM	Combination Increment button below the 5th Manual (small black button)
Comb_Incr_Left	Combination Increment button marked with > on the left side
Comb_Incr_POS	Combination Increment button below the 2nd Manual (small black button)
Comb_Incr_REC	Combination Increment button below the 3rd Manual (small black button)
Comb_Incr_Right	Combination Increment button marked with > on the right side
Comb_Incr_SOLO	Combination Increment button below the 4th Manual (small black button)
Comb_Seq_Enable	Button to enable small black buttons below the manuals
Comb_Up	Combination navigator "Up", wooden button

Switch name	Meaning
Crescendo_Program_A	Selector of crescendo program #1 on the Crescendo Page
Crescendo_Program_B	Selector of crescendo program #2 on the Crescendo Page
Crescendo_Program_Increment	Selector for the next Crescendo program
Foot_Piston_I-II	Foot piston for the coupler I+II
Foot_Piston_II-III	Foot piston for the coupler II+III
Foot_Piston_III-IV	Foot piston for the coupler III+IV
Foot_Piston_III-IV_left	Foot piston for the coupler III+IV
Foot_Piston_II-IV	Foot piston for the coupler II+IV
Foot_Piston_I-IV	Foot piston for the coupler I+IV
Foot_Piston_Incr-Decr: Decr	Direction button for unlabelled foot piston, select decrement
Foot_Piston_Incr-Decr: Incr	Direction button for unlabelled foot piston, select increment
Foot_Piston_P-I	Foot piston for the coupler P+I
Foot_Piston_P-II	Foot piston for the coupler P+II
Foot_Piston_P-III	Foot piston for the coupler P+III
Foot_Piston_P-IV	Foot piston for the coupler P+IV
Foot_Piston_P-V	Foot piston for the coupler P+V
Foot_Piston_Reeds_Off_-Z	Foot piston for the -Z (reeds off) button
Foot_Piston_Seq.-Incr	Large foot piston for incrementing the Combination Action
Foot_Piston_Seq.-Incr-Decr	Large unlabelled foot piston that can be set either to work as a Combination Increment or Decrement
GO-30 Montre 16'	Stop
GO-31 Principal 8'	Stop
GO-32 Flute harmonique	Stop
GO-33 Gamba 8'	Stop
GO-34 Bourdon 8'	Stop
GO-35 Praestant 4'	Stop
GO-36 Rohrflöte 4'	Stop
GO-37 Quinte 2 2/3'	Stop
GO-38 Superoctave 2'	Stop
GO-39 Cornet 2-5x 8'	Stop
GO-40 Mixtur 5-7x 2 2/3'	Stop
GO-41 Cimbel 4-5x 1 1/3'	Stop
GO-42 Trompete 16'	Stop
GO-43 Trompete 8'	Stop
GO-44 Trompete 4'	Stop
Master_Cancel	Turn off all stops and couplers, wooden button
Master_Capture	
Motor	Turn on the Motor (organ engine)

Switch name	Meaning
Pedal-1 Majorbass 32'	Stop
Pedal-10 Cello 8'	Stop
Pedal-11 Octave 4'	Stop
Pedal-12 Tibia 4'	Stop
Pedal-13 Tercsept 2x 6 2/5'	Stop
Pedal-14 Zinck 3x 5 1/3'	Stop
Pedal-15 Compensum 7x 2 2/3'	Stop
Pedal-16 Mixtur 4x 2 2/3'	Stop
Pedal-17 Bombarde 32'	Stop
Pedal-18 Bombarde 16'	Stop
Pedal-19 Basson 16'	Stop
Pedal-2 Soubasse 32'	Stop
Pedal-20 Trompete 8'	Stop
Pedal-21 Clairon 4'	Stop
Pedal-3 Principalbass 16'	Stop
Pedal-4 Contrebasse 16'	Stop
Pedal-5 Violon 16'	Stop
Pedal-6 Soubasse 16'	Stop
Pedal-7 Grossquinte 10 2/3'	Stop
Pedal-8 Octavbass 8'	Stop
Pedal-9 Gedackt 8'	Stop
Plenum_PL	Turn on the pre-programmed Plenum combination
POS-60 Quintatön 16'	Stop
POS-61 Principal 8'	Stop
POS-62 Cor de nuit 8'	Stop
POS-63 Flűte travers	Stop
POS-64 Salicional 8'	Stop
POS-65 Unda maris 8'	Stop
POS-66 Praestant 4'	Stop
POS-67 Flűte conique 4'	Stop
POS-68 Quinte 2 2/3'	Stop
POS-69 Doublette 2'	Stop
POS-70 Terz 1 3/5'	Stop
POS-71 Larigot 1 1/3'	Stop
POS-72 Piccolo 1'	Stop
POS-73 Mixtur 4-6x 2'	Stop
POS-74 Septnone 2x 8/9' + 1	Stop
POS-75 Basson 16'	Stop

Switch name	Meaning
POS-76 Dulzian 16'	Stop
POS-77 Trompette 8'	Stop
POS-78 Cromorne 8'	Stop
POS-79 Clarinette 8'	Stop
POS-80 Tremulant II.	Stop
Power-Keyswitch	Enables the controls of this virtual organ (turn the organ “on”)
REC-100 Nasard 2 2/3'	Stop
REC-101 Octavin 2'	Stop
REC-102 Tierce 1 3/5'	Stop
REC-103 Progressio 2-4x 2'	Stop
REC-104 Cymbale 4x 1'	Stop
REC-105 Bombarde 16'	Stop
REC-106 Trompette harmonique	Stop
REC-107 Basson-Hautbois 8'	Stop
REC-108 Voix humaine 8'	Stop
REC-109 Clairon harmonique 4	Stop
REC-110 Tremulant III.	Stop
REC-90 Violon 16'	Stop
REC-91 Gedeckt 16'	Stop
REC-92 Geigenprincipal 8'	Stop
REC-93 Flűte harmonique	Stop
REC-94 Gamba 8'	Stop
REC-95 Voix céleste 8'	Stop
REC-96 Aeoline 8'	Stop
REC-97 Bourdon á cheminč	Stop
REC-98 Violine 4'	Stop
REC-99 Flűte octaviante	Stop
SOLO-120 Rohrbourdon 16'	Stop
SOLO-121 Principale 8'	Stop
SOLO-122 Konzertflöte 8	Stop
SOLO-123 Voce humana 8'	Stop
SOLO-124 Nasard 5 1/3'	Stop
SOLO-125 Octave 4'	Stop
SOLO-126 Tierce 3 1/5'	Stop
SOLO-127 Septiéme 2 2/7	Stop
SOLO-128 Flöte 2'	Stop
SOLO-129 Sesquialtera 2 2/3'	Stop
SOLO-130 Plein jeu 3-5x 2 2/	Stop

Switch name	Meaning
SOLO-131 Cor anglais 8'	Stop
SOLO-132 Tuba m	Stop
Tuba	Turn on the Tuba (organ engine)
Tutti_TT	Turn on the pre-programmed Tutti combination
Walze_An	Crescendo wheel is enabled when this is turned on
Walze_Koppeln_Aus	Couplers are disabled from the crescendo program when turned on
Walze_Mixturen_Aus	Mixtures are disabled from the crescendo program when turned on
Walze_Zungen_Aus	Reeds are disabled from the crescendo program when this is turned on

Additionally, the Extended Edition contains the following switches

Switch name	Meaning
Sostenuto-Chamade	Turns on the Sostenuto on the 5th manual
Sostenuto-Great	Turns on the Sostenuto on the 1st manual
Sostenuto-Pedal	Turns on the Sostenuto on the pedal
Sostenuto-Positiv	Turns on the Sostenuto on the 2nd manual
Sostenuto-Recit	Turns on the Sostenuto on the 3rd manual
Sostenuto-Solo	Turns on the Sostenuto on the 4th manual
Split_Set	Engaged the learn functionality to set the pedal split (division) point
SwellDirection	Changes the operation direction of the sweller pedal
Up100	Combination navigation for the 100's digits, upwards
Dn100	Combination navigation for the 100's digits, downwards
Foot_Piston_Pedal-Split	Turns on the pedal split functionality
Coupler I+P e	Couples the pedal to the 1st manual electronically
Coupler II+P e	Couples the pedal to the 2nd manual electronically
Coupler III+P e	Couples the pedal to the 3rd manual electronically
Coupler IV+P e	Couples the pedal to the 4th manual electronically
Coupler V+P e	Couples the pedal to the 5th manual electronically
Coupler P/I	Splits the 1st manual so that the lower part will play the pedal
Coupler P/II	Splits the 2nd manual so that the lower part will play the pedal
Coupler P/III	Splits the 3rd manual so that the lower part will play the pedal
Coupler P/IV	Splits the 4th manual so that the lower part will play the pedal
Coupler P/V	Splits the 5th manual so that the lower part will play the pedal
Comb-Direct-00	Direct combination access buttons from 000
…	to
Comb-Direct-99	099