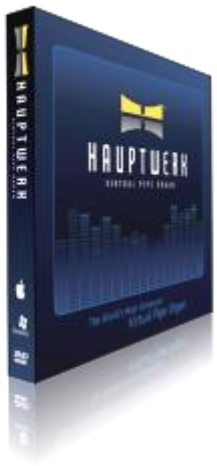
HAUPTWERK
VIRTUAL PIPE ORGAN

Technical Data



Technical information on hardware for Hauptwerk

Part 1: polyphony

When you engage several stops on an organ and play a chord, a lot of pipes sound simultaneously. For example, suppose you have 10 stops drawn and you play a 10-note chord (5 keys with each hand). Usually 10 x 10 = 100 pipes will be sounding simultaneously. Since Hauptwerk uses one sample per pipe, playing and holding such a chord in Hauptwerk means that Hauptwerk must play 100 samples simultaneously, and thus consume 100 voices of polyphony.

Since Hauptwerk uses release samples to reproduce the natural decay of the pipes and, optionally, also the acoustic (reverberation) of the room, those samples must continue to play after you release the keys. If the reverberation tails are long, perhaps 2 seconds, then that chord will continue to consume 100 voices of polyphony for an extra 2 seconds after you release the keys. So if you play a fast piece of music, the polyphony demands may be very high. For example, suppose you play chords of 4 notes with 10 stops drawn, at a rate of 5 chords per second, and the average length of the release samples is 2 seconds. You then need a polyphony of 4 x 10 x 5 x 2 = 400 voices.

However, if the samples are 'dry', with no reverberation recorded into the release samples then the release samples will be much shorter - perhaps 0.5 seconds, and you would need a polyphony of only 4 x 10 x 5 x 0.5 = 100 voices to play the same piece. So dry samples require much less polyphony than 'wet' samples. However, wet samples capture the natural acoustic of the room, which is often much more realistic for listening at home, especially with historic organs where the acoustic is an integral part of the sound.

Hauptwerk has an advanced 'polyphony management' system, which allows you to specify the maximum polyphony that your computer hardware can achieve after testing it initially. When Hauptwerk reaches that limit, no more pipes are allowed to sound, preventing the system becoming overloaded and the audio breaking up (very important for live recitals!). A little before the limit is reached, Hauptwerk attempts to fade out some of the most inconspicuous release samples, so that even reaching the polyphony limit is extremely rare. In practice this means that you can choose your computer hardware to support the polyphony that you will need for average playing, and let Hauptwerk's polyphony management system handle extreme loads safely, usually with no audible loss of quality.

The limit can be fine-tuned separately for each instrument, and processor-intensive features can be enabled or disabled separately for each instrument, so that you can get the best balance of performance and realism that your computer hardware can handle for the instrument.

If, for example, you expect to play a instrument with 2 second reverberation, and anticipate that you would normally not use more than about 10 stops with 3-note chords in each hand (6 keys), at a rate of 3 chords per second, then, as above, you would need a true polyphony of 6 x 10 x 3 x 2 = 360. As a rule of thumb, we would recommending choosing your computer hardware to be able to handle 3 times that polyphony, which would give optimal performance for the vast majority of the time, while Hauptwerk's polyphony management system will handle extreme loads unobtrusively and safely. Hence, with this example, you should choose a computer that you would expect to be able to handle about 1000 simultaneous pipes.

As a very, very rough guide, we would recommend that for average use you might choose the overall maximum polyphony required as follows:

- 500+ voices of polyphony for medium-sized organs (30 ranks or less) with dry samples.
- 1000+ voices of polyphony for large organs (30-60 ranks) with dry samples.
- 1000+ voices of polyphony for medium-sized organs (30 ranks or less) with wet samples.
- 2000+ voices of polyphony for large organs (30-50 ranks) with wet samples.
- 4000+ voices of polyphony for extremely large organs (50 or more ranks) with very long reverberation (the largest cathedral organs).

The polyphony is the main factor that determines the processing power you need. In summary it depends on:

- How 'wet' the most reverberant instrument you plan to use will be (average decay time).
- The maximum number of stops you will engage at once (more stops tend to be drawn simultaneously on larger organs).
- The type of music you will play - speed and number of simultaneous notes.

Part 2: memory

The amount of memory your computer has primarily determines the maximum size instrument that can be loaded in Hauptwerk.

In order to achieve the very high polyphony necessary to model organs effectively, Hauptwerk needs to keep all of the samples in memory. Hard-drives are very slow compared to memory, and many drives would be required in parallel to achieve an equivalent polyphony by streaming samples from the hard-disk. Thus it usually works out considerably cheaper in terms of computer hardware to keep the samples in memory, particularly because computer memory is very cheap now.

Since Hauptwerk keeps all samples in memory, ***you must have sufficient physical memory free to load the largest instrument you intend to use entirely into memory***. If you don't have enough memory, you be warned when loading the instrument and some of the samples might be 'paged' temporarily to disk by the operating system, in which case it will probably not be possible to access them quickly enough when they are required, causing glitches in the audio output.

The amount of free memory required for a given instrument is usually stated as a prerequisite by the creator of the instrument. We also try to give a basic guide figure for each Hauptwerk instrument in our list of third-party virtual instruments. Very roughly speaking, it depends upon:

- The number of samples.
- The average length of the samples. Dry samples usually require less memory because the release samples are shorter.
- The channel format of the samples – surround, stereo or mono. Stereo requires twice as much memory as mono and four-channel surround twice as much again.
- The sample rate – 44.1, 48 or 96 kHz. Higher rates require more memory.
- The sample resolution – 16 or 24-bit.
- Whether the instrument has multiple release or attack samples per pipe.

When you load an instrument in Hauptwerk you can choose not to load some of the ranks of pipes, so that you can fit a subset of an instrument into the memory available.

You can also choose to load 24-bit samples in 16-bit (the default) or 20-bit, very significantly reducing the memory requirement for 24-bit samples. The audible quality loss will be small since Hauptwerk performs all mixing and signal processing in 32-bit and produces output in the highest resolution supported by the audio interface, so the effective resolution is usually much higher than 16-bit even if the samples are loaded in 16-bit.

Various further per-rank memory saving options are available, such as loading only the first loop in a sample, loading a stereo sample in mono, loading at most one release sample per pipe, or truncating its release samples, although they come at the expense of some realism.

The following is a very, very rough guide to the types of instruments that might typically be usable in full within a given amount of memory:

- 2 GB: dry, mono organs <80 ranks; dry, stereo organs <50 ranks; wet, stereo organs <30 ranks.
- 4 or 8 GB: large and/or very wet, stereo organs and almost all dry organs.
- 16 GB: very large wet surround organs.

However, please look at the requirements given by the instrument creators for the specific instruments that are of interest to you. The St. Anne's, Moseley organ instrument included with Hauptwerk requires at least 2 GB of installed memory to be loaded fully.

The maximum amount of memory that can be installed in a computer is determined by its hardware (motherboard) and the operating system. Older computers are commonly limited to 4 or 8 GB while newer models of Apple Macs and PCs can handle 16 GB or more.

To use more than about 3.2 GB (Mac OS X) or 2-2.7 GB (Windows PCs) for Hauptwerk you need a 64-bit capable computer with a 64-bit capable operating system and you need to use 64-bit Hauptwerk.

All recent Macs are 64-bit capable. Mac OS X 10.6 Snow Leopard and 10.5 Leopard are both natively simultaneously 64-bit and 32-bit capable. Hauptwerk is natively 64-bit on modern 64-bit capable Intel Macs, but only 32-bit Hauptwerk is available for older (pre-2006) PowerPC-based Macs, such as the G4 and G5 models.

All recent PCs are 64-bit capable but you need to install 64-bit Windows specifically (64-bit Windows 7 is recommended) , rather than 32-bit if you want to use more than about 2 GB of memory for Hauptwerk.

The clock rate of the memory can make a significant difference to the performance of Hauptwerk. If your computer supports several different memory clock rates reliably then use the fastest memory for best performance. In general on PCs, we recommend using ECC memory if your motherboard supports it, since ECC memory should lead to improved system stability. All computer memory will have very occasional data errors which can lead to crashes or other unexpected results. ECC memory attempts to detect and correct such errors automatically.

For computers that support dual or triple-channel memory, ensure that all memory channels have separate but matching memory boards, which can also give a significant performance improvement. For example, if you have a single processor that supports dual-channel memory, and you require 4 GB of memory in total, install two 2 GB memory boards - one into a slot for each memory channel, rather than a single 4 GB board. All available memory channels and processors should be loaded equally for best performance (Hauptwerk is optimised for NUMA, and can take advantage of such memory configurations), and memory boards should be matched for maximum reliability.

When buying a computer it is also a good idea to consider allowing room for expanding the memory at a later date, i.e. buying a system with more memory slots than you need initially.

Part 3: processors

The performance of the processor(s) primarily determines the polyphony that can be achieved in Hauptwerk.

Hauptwerk's basic static polyphony is defined and measured for mono samples, panned into stereo in real-time, and for unenclosed pipes (those not in swell boxes), with all of Hauptwerk's realism features enabled. There are several additional factors within Hauptwerk that affect the polyphony that can be achieved on a given system:

- Using true stereo instruments decreases the polyphony that can be achieved by about 20 percent.
- Using pipes enclosed in a virtual swell box decreases the polyphony by about 30 percent due to the additional overheads of the digital filters used in Hauptwerk's swell box model, which are applied to each pipe individually. (Note that the swell box model filters can be disabled, leaving just volume adjustment by the virtual swell box.)
- Hauptwerk also applies 'harmonic shaping' filters to control the tone of each pipe individually for voicing, tremulants and flow modeling. These can also be disabled, giving approximately a further 30 percent gain in polyphony, although the realism of tremulants will be particularly impaired, and we recommend this only as a last resort.
- You can disable interpolation entirely, giving fixed pitch sample play-back and a loss of some realism, but typically doubling or even tripling the polyphony that can be achieved, and allowing even very large instruments to be used on older or low-cost computers.

Hauptwerk is specially optimized to be able to take advantage of multi-core processors, multi-processor systems, 64-bit processors and NUMA (non-uniform memory access). 64-bit processors are also required if you want to use more than about 3.2 GB (Mac OS X) or 2-2.7 GB (Windows PCs) of memory with Hauptwerk.

The total number of processor cores, memory bandwidth, processor level 2 cache size and the processor core clock speed are the main factors that determine the polyphony that can be achieved with Hauptwerk.

On Windows PCs the audio interface and its drivers can also have a large effect on polyphony. In particular, note that a good basic 'semi-pro' or 'pro' audio interface and driver (such as an M-Audio 2496) can as much as double polyphony over a budget sound card in a PC. This is not usually the case

on Apple Macs because high-performance audio is built into Mac OS X and there is much less dependency on audio drivers.

Generally speaking, recent processors will usually significantly out-perform older processors of the same clock speed, since processor technology advances rapidly. If buying a new computer to run Hauptwerk we would recommend buying one with at least four CPU cores (quad-core) and plenty of processor cache. On Windows PCs, both the recent Intel and AMD processors should work well with Hauptwerk, but, at the time of writing, the higher-specification Intel processors out-perform the higher-specification AMD models with Hauptwerk by a significant margin.

The Apple Mac Pro range in particular offer probably the highest performance of any current desktop computer, and the MacBook Pro range probably the highest performance of any current notebook computer, both with very robust audio and MIDI performance, and we particularly recommend them if you're looking for the ultimate computer to run Hauptwerk.

However, once again we wish to stress that ***these recommendations are only intended as a guide if you are buying a new computer***. Hauptwerk will perform very well indeed with even quite moderately-sized instruments (30 ranks or so) on existing computers with a single 2 GHz processor or faster and all realism features enabled, provided that you have sufficient memory for the instrument you wish to use.

You can still easily use Hauptwerk on older computers (such as 2 GHz Pentium 4 PC or 1.25 GHz G4 Mac) with fairly large organs and with excellent results and incredible performance by simply disabling some of the audio realism features such as interpolation and per-pipe filters, of course, at the expense of some realism. With interpolation, per-pipe filters and multiple sample loop playback disabled, Hauptwerk will typically be able to achieve about three times the polyphony than with all features enabled.

As a very, very rough rule-of-thumb guide to the approximate static polyphony in simultaneous pipes that can normally be expected with recent multi-core Intel processors with a good-quality audio interface, a 64-bit operating system and 64-bit Hauptwerk, subtract one from the number of CPU cores then multiply the result by 1200-2500.

Part 4: audio interface

Functionally, the computer's audio interface determines:

- The maximum number of audio output channels to which pipe ranks can be routed from Hauptwerk.
- The sample resolution in which Hauptwerk will produce output (16, 24 or 32-bit). Hauptwerk automatically uses the highest resolution supported by the interface.
- The instruments that can be used, by way of its maximum sample rate. Hauptwerk will only allow an instrument to be used if the audio interface supports the sample rate used for its samples (technically speaking, that is in order to avoid the overheads of real-time anti-aliasing filters).
- On Windows platforms: the types of audio drivers that can be used by Hauptwerk. Hauptwerk supports both ASIO and DirectSound on Windows, with ASIO usually giving lower

latency (delay from pressing a key to hearing the sound). Generally only professional audio interfaces and high-end consumer sound cards support ASIO natively.

- On Windows platforms: the minimum latency that can be achieved reliably. Usually professional audio interface ASIO drivers are better, but the results still vary greatly between individual interfaces and their drivers, from as little as 5 milliseconds to more than 50 milliseconds.
- On Windows platforms: the maximum polyphony that can be achieved reliably (number of simultaneous pipes). The interface's drivers can have a large effect on polyphony, as much as doubling or halving it between different interfaces and drivers.

Mac OS X has high-performance professional-grade audio built in ('Core Audio'), so there's much less dependence on driver quality on OS X, and latency (delay from pressing a key to hearing the sound) and polyphony should not be affected significantly by the choice of audio interface.

On Windows PCs: the audio interface and the quality of its drivers (either ASIO or DirectSound) are the biggest factors determining the lowest latency that can be achieved, and also have a huge effect on polyphony. ASIO drivers will usually give a much lower latency than DirectSound drivers, and tend to be much more resilient. If you want high polyphony and low latency, please ***buy a good basic professional/semi-pro audio interface, rather than economizing on the most important part of the whole system***! A low-cost sound card or emulated/third-party drivers will not usually give especially high performance.

The quality of the audio interface itself (and its digital-to-analog converters) makes an enormous difference to the audio quality you will hear from Hauptwerk. We would strongly recommend using professional audio interfaces that support at least 24-bit, 96 kHz audio with good quality drivers.

Any audio interface you use must natively support the sample rates used by the organs you wish to load into Hauptwerk (typically 44.1 kHz, 48 kHz and 96 kHz). Note that the default built-in sound output found on many PCs only supports 44.1 kHz and so cannot be used with instruments requiring other sample rates, such as 48 kHz. The sound quality from most computers' built-in audio outputs is also not usually especially high.

The number of audio outputs required depends on how you wish to amplify the output; for use in churches and reverberant spaces, where dry instruments would normally be preferred, using many audio channels with separate amplifiers and speakers gives a much better spatial effect, and allows the sound to mix more naturally within the room acoustic. However, for listening at home to instruments recorded in their original acoustic, a single stereo pair is often more appropriate. Multi-channel audio output facilities are only available in the Advanced Edition of Hauptwerk.

Part 5: MIDI interface

If you want to play or control Hauptwerk in real-time then you need some form of MIDI interface (or USB music keyboard) for the computer. Hauptwerk receives MIDI input to control its keys and console controls, and optionally produces MIDI output to drive external MIDI console hardware, such as solenoid-actuated or illuminated draw-knobs or tabs, or real external ranks of pipes.

Many audio interfaces, such as the Echo Audiofire range have one or more MIDI input and MIDI output ports built in. Many consumer PC sound cards also have such a such a facility by attaching a MIDI-gameport adapter lead.

However, if you want to connect several MIDI input devices to Hauptwerk, such as several MIDI keyboards and MIDI draw-knob encoders, then you will usually need either a multi-port MIDI interface or a MIDI merge box. Multi-port MIDI interfaces are preferable because their timing is usually more accurate and they are less easily overloaded ('flooded') by rapid MIDI data. You need to buy an interface that has at least as many MIDI input ports as you have MIDI input devices to connect.

MIDI output is simpler because most MIDI devices allow the MIDI connections to be 'chained', but a MIDI interface with multiple output ports will still usually provide better timing and error-resilience.

Any MIDI interface supported by the manufacturer on your system should work with Hauptwerk. For maximum compatibility with our testing we would recommend using one of the following. Please note that we do not recommend very small 'micro' USB-MIDI interface, such as the M-Audio MIDISPORT UNO, since we have found some such interfaces to have insufficient hardware buffering and to lose occasional MIDI messages when the computer's process or is heavily loaded, causing stuck notes in Hauptwerk. That should never occur if using a good quality MIDI interface with plenty of buffering.

If you only intend to use Hauptwerk with a MIDI sequencer, or by clicking on its virtual keys on the screen, then you don't necessarily need any hardware MIDI interface.

Part 6: disk drives

The speed of your hard disk(s) only determines the time it will take Hauptwerk to load a sample set; real-time performance should not be affected once the sample set is loaded into memory. SSD drives or RAID 5 disk arrays can be used if you want sample sets to load quickly (RAID 5, RAID 1 or RAID 0+1 can also make your system more resilient to the failure of a hard disk).

If you consider loading times to be important, then we recommend you use the fastest disks available for your hardware, such as 7,200 or 10,000 RPM SATA drives with 16 MB or more of cache memory, or (fastest of all) SSD drives.

For live installation in an environment where fault-tolerance is critical, such as for public performance, two or more matching disks in a RAID 5, RAID 1, or RAID 0+1 array are recommended.

On Apple Macs that support multiple disk drives, such as the Mac Pro range, Mac OS X includes a tool called Disk Utility which can be used to set up a software-based RAID array. A (software) RAID 1 array on a Mac Pro gives good performance.

Hauptwerk requires a large amount of disk space to allow for installation of instruments, and its cached instrument data. The cached data are used to speed up loading of instruments, and occupy very approximately an additional two-thirds of the amount of disk space occupied by the raw instrument data alone. Hence almost twice as much disk space is required as that for the raw

instrument data alone. In general, we would recommend allowing 50-400 GB of disk space if you intend to use a number of different instruments.