

Gottfried Silbermann's Fluework

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Posted: 1 March 2008

Last revised: 16 August 2014

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Abstract

Gottfried Silbermann's organs have always been famed for their “silvery sounds”. This article reports the results of research which focused on some characteristics of his fluework in an attempt to see what this might mean and how his results were achieved.

Using acoustic measurements made on a surviving Silbermann organ, details of how his Principals and Flutes were probably regulated are presented. They demonstrate how the acoustic power output of individual Principal and Flute stops varied across the compass, and how it compared with the other ranks comprising these two varieties of chorus work.

These data are original, detailed and made available in the public domain for the first time. Suggestions are made as to how the results might be used in practice when voicing organs which are intended to have Silbermann-like tonal characteristics.

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Introduction

Since the time he built them in the first half of the 18th century, Gottfried Silbermann's organs have been famous for their “silvery sounds”. This is no mere play on words, because it is only necessary to listen to pieces such as Bach’s Pastorale in F (*BWV 590*) played on one of the surviving instruments to appreciate what is meant. Given the high wind pressure he used (*typically 95 mm/3.7 in water gauge*) and the consequential power of his Principal choruses, it is all the more extraordinary that he managed to achieve such astonishing tonal contrasts within a single instrument.

This article presents the results of research which has occupied several years. It has focused on some detailed characteristics of his fluework in an attempt to discover something of how these results were achieved. However, it first looks at Silbermann’s life and times, and briefly compares his organs with those of his illustrious near-contemporary Arp Schnitger because of the importance of these builders in the lives of the composers and organists of the day. The difficulties in trying to draw conclusions about the work of an organ builder who died over 250 years ago are then discussed, in view of the apparently widely held but probably mistaken belief that today’s so-called “Silbermann organs” are much as he left them.

Detailed results of how his Principals and Flutes were probably regulated are then presented. Based on acoustic measurements made on a surviving Silbermann organ, they demonstrate how the acoustic power output of individual Principal and Flute stops varies both across the compass, and relative to the other ranks comprising these two varieties of chorus work. These data are original and made available in the public domain for the first time.

Finally, some suggestions are made as to how the results might be used in practice when voicing organs which are intended to have Silbermann-like tonal characteristics.

History and Geography

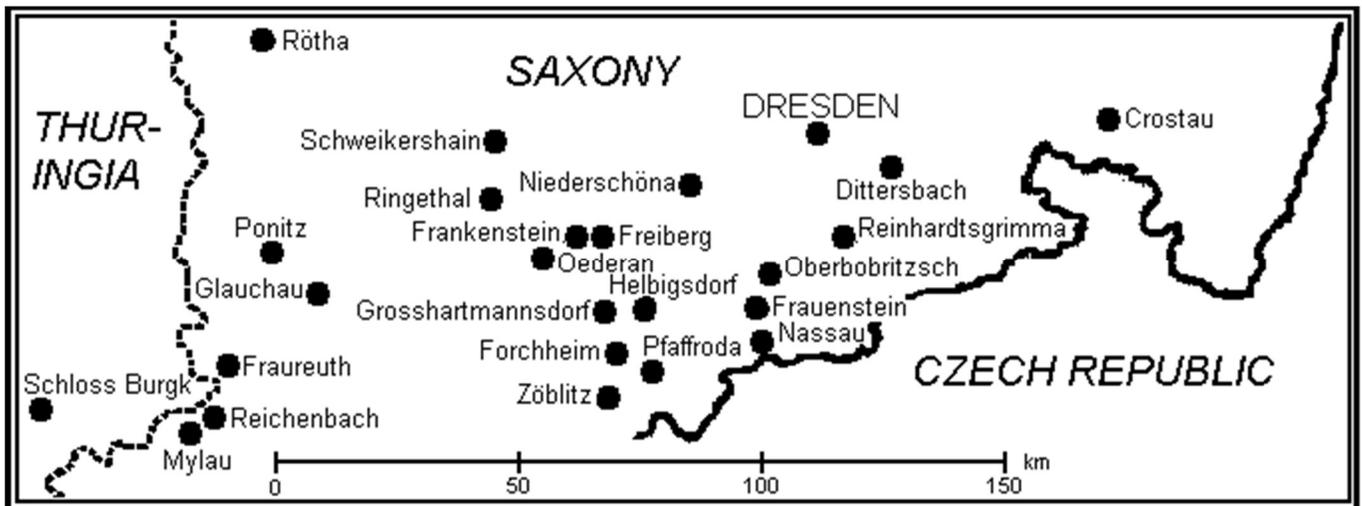


Figure 1. Saxony - the area in which Gottfried Silbermann lived and worked

During this study I found it helpful to relate Silbermann’s work to the context of his times and where he spent his life. He was born in 1683, just over two years before J S Bach, near Frauenstein, which is marked on the map of Saxony in Figure 1, that area of Germany in which Dresden is the chief city. In those days Germany was not the unified nation of today, instead it consisted of a number of independent principalities. Gottfried's older brother, Andreas, also became an organ builder who lived and worked mainly in what is now eastern France, around the Strasbourg area and close to the border with modern

Germany. Gottfried worked with Andreas for some years before setting up on his own back in Saxony in 1710. He established his workshop in Freiberg and remained there until his death in 1753, just over three years after that of Bach. At the start of his career, he built the organ in Freiberg cathedral, and when he died, he was building a large one at Dresden (*the Katholische Hofkirche*). Between these landmark instruments he built more than 40 others.



Figure 2. Modern day Germany showing Saxony

(courtesy World Sites Atlas <http://www.sitesatlas.com>)

The main towns and villages where he endowed the churches with organs are sketched in Figure 1, and the relation of this small area to modern day Germany can be judged from Figure 2 where it is delineated by the blue rectangle. Thus, it was some 500 km (300 miles) south east of the area where Arp Schnitger (1648-1719) was active, in the north of the country around Hamburg and in the Netherlands to its west. This geographical separation between what were then separate countries was

comparable to the distance between London and Carlisle, and it was huge by the standards of those days given the difficulty of travelling. It was partly responsible for the considerable differences in the styles of the organs of the two builders even though they somewhat overlapped in time.

Silbermann's organs in the 18th century

A hallmark of Silbermann's organs was that he adopted a uniform style of design as far as possible. Many of his two manual village organs, such as those at Reinhardtsgrimma, Fraureuth and Helbigsdorf (*see Figure 1 for their locations*), had similar stop lists. For this reason, he is sometimes credited with having invented the concept of the factory organ, taken up so enthusiastically thereafter by those with more interest in profit than artistry. This does not imply that Silbermann himself made little profit from his work because he apparently became wealthy, though this was probably more the result of his connections with well-heeled patrons than anything else. Also – and sensibly - he did not have all his business eggs in the one basket, in view of his equal fame as a builder of pianos, harpsichords and other keyboard instruments, besides the organ.

To assist in setting the scene for what follows, it is relevant to compare Silbermann's organs with those built by Arp Schnitger, touching on only a few basic facts for reasons of brevity and to retain objectivity.

Aural Effect – Voicing and Wind Pressures

In contrast to Schnitger, Silbermann used quite high wind pressures. Even in his smallest instruments a pressure around 95 mm water gauge (*nearly 4 inches*) was typical, and therefore his organs must have been, quite simply, rather loud and powerful. An article elsewhere on this website contrasts the Principal stops of the two builders and contains aural examples to listen to [5]. At the same time much was made both then and now of the “silvery sound” of his organs, and this seems to be more than just the famous pun based on his name (*"Silverman" in English*). I shall return to what the description might have meant later in this article as it was one of the pointers which led to the work to be described presently.

Pipe Scales

Knowledge of Schnitger's pipe scales is somewhat uncertain. Although writers continue to discuss them, one problem is that they were usually specific to a particular instrument, many of which incorporated re-used pipework from earlier organs by other builders. Thus deriving data at a more generic level is difficult, and it completely defeated Ralph Downes who was desperate to base his pipe scales at the Royal Festival Hall in London on Schnitger's practices [2].

Silbermann's scales were better based in that we know more about them and moreover they appeared to conform to rules we recognise today, indeed he contributed to the establishment of those rules. Rule and rote is another reflection of his desire to streamline the process of organ building. Thus, he arrived at the method of routinely halving the pipe diameters every 16th or 17th note, at least over part of the compass of a given stop. Later endowed with a somewhat dubious theoretical basis by Töpfer in the 19th century, this recipe was adopted as the so-called Normal Scaling by the Organ Reform Movement of the 20th century and still widely used today.

A more detailed discussion of Schnitger's and Silbermann's pipe scales appears in [Appendix 1](#).

Stop Lists

Other differences between the organs of Schnitger and Silbermann include the paucity of Silbermann's pedal organs, at least in his smaller instruments. While Schnitger typically provided at least as many stops on the pedals as on any of the manuals, Silbermann commonly restricted them to two or three stops in his small organs. However, he usually threw in a coupler (*sometimes permanently in action*) to the chief manual whereas Schnitger did not – nor did he need to. Nevertheless, this is one

reason why it is more difficult to sensibly render much of Bach on a Silbermann organ, in particular many of the chorale preludes and trios, thereby confirming the belief that he composed with a Schnitger-style instrument in mind [9]. (*How can you play an independent melodic line on the pedals when a suitable stop is unavailable?*). Nor did Silbermann include reed stops as frequently as did Schnitger, and it is possible that in his view his Cornet mixtures would have made up for their absence, at least when used in a solo role.

The stop list of Silbermann's village organ at Helbigsdorf is shown below:



(courtesy Baroque Music Club www.baroque-music-club.com)

Hauptwerk		Oberwerk		Pedal	
Principal	8	Gedackt	8	Subbass	16
Rohrflöte	8	Rohrflöte	4	Posaunenbass	16
Quintadena	8	Nassat	3		
Octave	4	Octave	2	Hw - Ped	
Spitzflöte	4	Terzia	1 ³ / ₅		
Quinta	3	Sufflet	1	Tremulant	
Octave	2	Cimbeln	3 fach		
Mixtur	4 fach				

Silbermann's organ at Helbigsdorf, 1731

Temperament

Curiously, both builders tuned their organs to much the same temperaments based on variants of meantone tuning. This would have considerably restricted the range of keys that could be used. It is curious in Silbermann's case because of his progressive outlook in other respects. However, in Schnitger's it was understandable – he was active largely before Werckmeister's various well-tempered tuning systems, based on the earlier notions of Mersenne and the still earlier ones of Galileo, had become well known and popular. In fact, Schnitger and Werckmeister were contemporaries. Thus the young Schnitger learnt his art on the basis of the early 17th century Praetorius school of organ building which

knew nothing of Werckmeister's later ideas, thus he continued with its precepts virtually throughout his life.

Silbermann, on the other hand, worked some 35 years after Schnitger and was therefore more exposed to the somewhat later classical rather than high-Baroque musical influences. Based as it was more on homophony and melody rather than polyphonic contrapuntal writing, it is therefore surprising that he did not incline more in the direction of the well-tempered tunings that these composers were demanding. There is a number of instances where the exasperation of composers has come down to us, and Bach was apparently one of them. Simultaneously Silbermann is on record as disliking what he called the "sharp tuning" of equal (*or near-equal*) temperament in which all the thirds are indeed sharp, and unpleasantly so to an ear brought up on the purity of strongly unequal temperaments – though pure only in certain keys of course. (*In the other keys the thirds are even sharper than in ET!*) The uniformly sharpened thirds in equal temperament would have made a nonsense of Silbermann's apparent reliance on the third-sounding intervals in his mutations and Cornet mixtures for injecting the strong 5th harmonic necessary for synthetic reed tones, for example. Such ranks produce hideous beats when used for additive synthesis in equal temperament. Some remarks about how one of Bach's important works would have sounded on a Silbermann organ - the "great" prelude and fugue in C (BWV 547) - are at reference [4]. It would have been most unpleasant to play or listen to.

In all this we hear a lingering echo of strongly held opinions on both sides, confirming other evidence that Silbermann was of a somewhat stubborn disposition in any case. With his death in the mid-18th century, it is probably no coincidence that the battle to retain strongly unequal temperaments was finally lost.

Silbermann organs today

It is often claimed that this or that Silbermann organ remains in its original state. If by "original state" is meant an organ which is just as the builder left it and which still sounds today just as it did then, then I find it difficult to believe. After two and a half centuries of cone tuning, repairs, cleanings and rebuilds, alterations of pitch, temperament and wind pressures, plus the almost perpetual state of warfare and oppression which the rulers of Europe (*including Britain*) have inflicted on their long-suffering populations, can it really be that the preservation of a few church organs remained at the top of the list of priorities over this period? This question has special relevance in a region which has suffered deliberate attempts to destroy it. Is it also really credible that the succession of organ builders who have variously intervened in the affairs of these instruments were never tempted to indulge in a bit of tweaking to suit the fashions of the day? That has never happened anywhere else, so why here?

Some writers now maintain (*see [3] for an example*) that the half century of the Cold War was actually a good thing from the point of view of these instruments because it prevented anything major being done to them. Even if one accepts the curious view that deliberate neglect is advantageous (*something which does not pertain in other aspects of life*), that still does not account for what might have happened during the largely undocumented two hundred years prior to 1945, and surely this significantly weakens the argument. To my mind the sound and the appearance of many so-called Silbermann organs today is just a bit too chocolate-boxy to be true, especially given the frantic attempts to attract tourists (*including organ tourists*) to the area. Just take a look at the Internet to see what I mean.

As far as I have been able to ascertain, Silbermann's village organ at Fraureuth is now tuned close to today's standard pitch where the A above middle C speaks at 440 Hz. His similar one at Reinhardtsgrimm is tuned almost a semitone higher. Is this not rather odd? Two virtually identical organs by the same builder from almost the same time and only a few miles apart? If they really still are in original condition, one must ask oneself why their pitch standards are not the same

Currently, both these organs are also tuned in equal temperament or something close to it. This is incompatible with those authors who maintain that an “historical Silbermann-like tuning system” was introduced in the recent post-Cold War rebuilds. If true, this would presumably imply some variant of meantone tuning, although it is for them to say more exactly what they mean, not for me to guess at it. But more to the point, one only has to listen to these organs today for a few minutes to realise that a tuning which departs strongly from equal temperament is almost certainly not in use. For example, Bach’s “great” prelude and fugue in C (*BWV 547*) played on these organs shows no evidence of a strongly unequal temperament which this work would otherwise reveal [4].

It is more useful to look at what has actually happened to these organs, and a more detailed inventory of events can be inferred by studying examples. As an outline of the sort of tempestuous history to which these organs have been subjected one need only look at the Reinhardtsgrimma instrument, for which some milestones are as follows. Built in 1729-31, it was converted to equal temperament in 1852 when it was also revoiced. In 1953 the wind pressure was reduced from Silbermann's usual high value of 95 mm to 75mm, with yet another drastic revoicing of necessity to suit the reduced pressure. In 1997 the pressure was returned to 95 mm, the pipes revoiced yet again, and the temperament meddled with in some manner as mentioned above (even though it still sounds like ET to me!).

This sort of history means that every single original pipe in the organ will have been subjected to numerous interventions. Therefore, I can only conclude that anyone who claims that these organs are “untouched” can only be living on a different planet to myself. And of course, many Silbermann organs were destroyed beyond recovery in the second world war, yet even these in their totally re-created state are still referred to as “Silbermann organs”!

What can we infer from today’s Silbermann organs?

Despite the iconoclastic remarks above and whatever the truth might be, I have no difficulty in agreeing that most of today’s so-called Silbermann organs are extremely beautiful in their own right. Although they might not sound exactly like they once did – and who can possibly say unless they possess a talent for time travel? – a good number of them probably retain sufficient of the characteristics from Silbermann’s day to make them worthy of study. For example, even if they have been completely rebuilt, there exists sufficient information about his pipe scales, wind pressures and voicing practices to enable them to be regarded as reasonable Silbermann clones, at least in favourable circumstances.

In particular, to my mind some of today’s Silbermann organs do have something of the “silvery sound” that was made much of in the 18th century. But what on earth does this term actually mean? Too much vagueness and subjectivity is useless, so it is necessary to tie it down rather more objectively. I believe there are two important factors – there may well be others.

The first factor is that the Principal choruses of these instruments are clear, loud and ringing. Even the 8’ Principal, when used on its own usually has these characteristics. The loudness is largely because of the high wind pressure – simple. But the other attributes need to be looked at rather more closely. Clearness means transparency – the sound is transparent in that every note of every chord, or every note moving in a polyphonic composition such as a fugue, can be heard clearly. Muddiness and opaqueness are generally not apparent in a Silbermann organ. In turn, this usually means that the middle registers of these stops, in the two octaves or so centred on the middle of the keyboard, are regulated in power so they do not mask the sounds both above and below them. Although this desirable state of optimum regulation can be achieved largely by a skilful voicer with almost any rank of pipes if he is allowed enough time, it is probable that Silbermann’s pipe scales contributed to the effect. A well chosen scale assists the voicer to achieve these goals more rapidly and with greater certainty. [Appendix 1](#) contains more details of Silbermann's pipe scales.

The second factor relating to “silvery sound” concerns the Flute choruses on a subsidiary manual (*such as the Oberwerk, Hinterwerk, etc*) in my opinion. The transparency of the Principals discussed

above relates mainly to the chief manual (*the Hauptwerk*). By properly choosing the Flute stops used on a subsidiary keyboard, it is possible on a Silbermann organ to get an exquisite, bell-like sound which entirely deserves the “silvery” epithet. One has to choose the stops carefully however. Sometimes there will be no 2’ Flute in a chorus which goes up to 1’ pitch, the 2’ stop being a Principal in this case. Some of the mutations might also be Principals rather than Flutes. One has to become aware of which stops are which, in the organ one is faced with. Adding high pitched Principals to a Flute chorus can sometimes, though not always, detract from the subtlety of an effect which depends to some extent on the music being played.

Thus, it seems obvious that the regulation of the organ in terms of the acoustic power of the various Flute ranks is critical if they are to blend in the desired manner. A factor strongly dependent on regulation is that one can often play quite low in the keyboard with a collection of Silbermann’s Flute stops without the sound becoming unpleasant. The fifth-sounding mutations do not become too dominant as they do on so many organs – their additive synthesis effect does not disintegrate low in the keyboard on a Silbermann organ.

It will be observed that both of the factors mentioned relate to the *regulation* of the stops, both within each rank and between ranks. Obviously, timbre (*tone quality*) must also play a part, but in my view, regulation is at least as important as timbre. For this reason, I have investigated the regulation of Silbermann organs and some interesting features emerged. This work will now be described.

The regulation of Silbermann’s fluework

The study described here was experimental and based on the sounds of existing Silbermann pipework, regardless of how much or how little original material was included. Therefore, the results relate only to the instruments we have today, and they might not necessarily correspond in detail with the instruments of over 250 years ago. However, this is something one has to accept – one has no choice.

The study goes beyond an examination of Silbermann’s wind pressures, pipe scales and voicing practices to analyse the actual sounds of individual pipes. When all is said and done, it is ultimately the sound waves impinging on the ear that matter, not the measurements of this or that pipe or how many nicks there happen to be in its languid. Considering for a moment a thought experiment, it would be possible to build from scratch two identical “Silbermann” organs using the best available data relating to his practices and place them next to each other in the same building, yet they would still sound different provided each was voiced independently. By this I mean that no artificial attempt was made to *force* them to sound the same by voicing each pipe in one instrument to match exactly the sound of the corresponding one in the other. The differences in sound would then arise largely from the differences in regulation, because a voicer regulates the power of a pipe by ear mainly through adjustments to the size of its foot hole or its flue. This affects the quantity of air admitted to the mouth, and therefore controls the acoustic power of the pipe.

Silbermann’s original regulation data at such a detailed level have been almost completely, if not totally, lost to us. It is surely inconceivable that any organ several centuries old, no matter how strongly people insist that it is “untouched”, can retain sufficient of these vital regulation characteristics for each and every pipe. Each time an organ is tuned there will be small changes in its regulation and these will accumulate over time, and cone tuning is particularly bad in this regard in view of the brutality inflicted on the pipes. More major interventions, such as revoicing to suit changed wind pressures or when a new temperament was imposed, imply major changes to the regulation as well. Nor should one forget the effects of corrosion of metal pipes over such a long period, which will often disguise details of how they were first voiced and regulated. Some pipes of this age even have accumulations of moss or fungus growing around their mouths! Many of them are covered inside and out with bat droppings which itself is corrosive. Removing detritus such as this can damage the pipes. Or pipes may have been transposed, the lazy organ builder’s way of implementing a change of pitch. Regulation data are immediately lost

in the process, particularly if documentary evidence of the changes does not exist. All these things have happened to Silbermann's organs.

But provided the organ still sounds sufficiently Silbermann-like, whatever that might mean, this may not be a major problem. If it still sounds attractive, with characteristics such as a "silvery sound" in terms of the (*admittedly rather vague*) definitions of the term above, it is still probably worth analysing those sounds. But again, whatever the problems, we have no choice. We either do that or nothing at all. Thus, it is on this basis that the following analysis is offered.

Experimental technique

I analysed the regulation of the major flue choruses (*Principal and Flute*) of a single Silbermann organ, but do not wish to say which one it was. This craven reticence is born of an apprehension of otherwise having to cope with an impractical amount of correspondence about the instrument! It might be argued that I should have analysed more than one organ, but in this case, I disagree - one can definitely have too much data in a study like this one, as will become clear. Using more than one organ would have necessitated more or less dubious means of normalising the results on a stop-for-stop basis. Also, the interesting results obtained might have been swamped by the need to average too much data.

The sound of the organ was captured by making digital stereophonic recordings of individual pipes of each stop, the two microphones remaining in the same positions throughout.

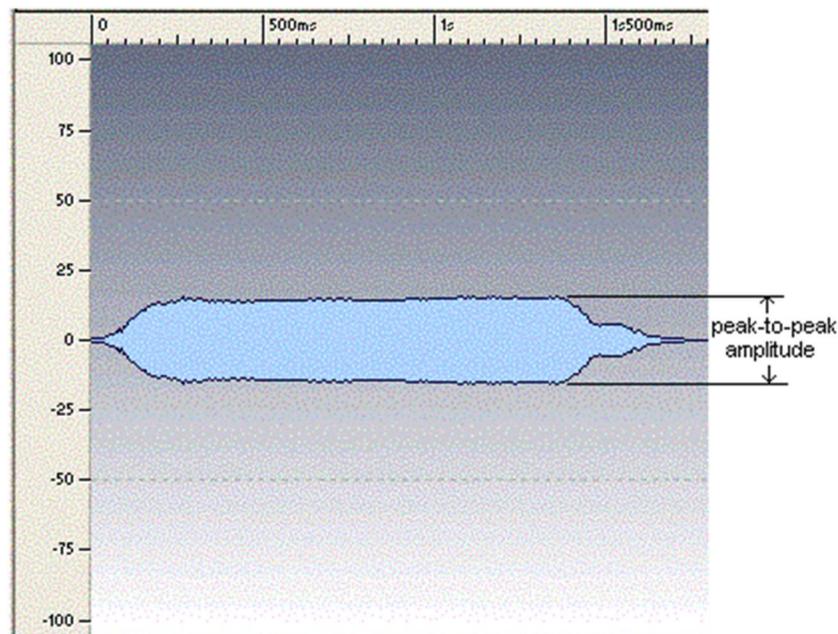


Figure 3. Illustrating how the peak-to-peak amplitudes were measured

The regulation of each stop was then investigated by measuring with a waveform editor the peak-to-peak voltage amplitude of the waveforms across the compass as shown in Figure 3, which shows a typical envelope of the acoustic waveform of a single pipe which sounded for about 1 ½ seconds. The attack and release transients at the beginning and end of the sound can be seen, and to some extent these represent the reverberant characteristics of the auditorium as well as the transients of the pipe itself. Between the transients is the region where the pipe sounded fairly steadily, and the peak-to-peak amplitude of the waveform measured in this region is shown in the diagram. This measurement has the virtue of simplicity, and because an analysis of the data revealed sufficiently interesting results, I did not find it necessary to convert the measurements to SPL (*sound pressure level*), loudness or any other form.

For each note, the two peak-to-peak voltage amplitude values corresponding to the two microphone channels were averaged and then expressed logarithmically as decibels (*dB*) [1]. The reason for taking the mean (*average*) amplitude of each note was mainly to reduce the effects of standing waves due to reflections within the building, which affect the amplitudes of sounds at any given position – they can either be reinforced or attenuated depending on the phases of the direct and reflected waves. The standing wave pattern at each microphone location would in general have been different, therefore taking the mean will have reduced the worst effects in most, but not necessarily all, cases.

The reason for then converting the mean amplitude to decibels was to compress the number range of the large amplitude changes which occur across any organ stop from the bass (*where the amplitudes are greatest*) to the treble [6].

Another advantage also accrues when using decibels. If the measurements made as shown in Figure 3 were to be plotted directly as a graph, the acoustic amplitudes across the compass of an organ stop would lie on a rather steeply descending curve with the numbers decreasing rapidly in value from the bass to the treble. The curve would have some qualitative similarities to the shape traced out by the heights of a rank of pipes, and it is an inconvenient shape to manipulate and inspect. In the case of acoustic amplitudes, the shape arises because the acoustic output of a pipe is related to the size of its mouth, and this in turn is related to its diameter. The diameters vary across the rank according to how the stop has been scaled, in which the diameters might halve every 17th note for example. Therefore, the acoustic output across the rank will vary (*to some extent*) in a similar way to the pipe scale. For mathematical reasons, converting the amplitudes to decibels converts the steeply descending amplitude *curve* to one which is more nearly a *straight line*, which may or may not have a slope away from the horizontal.

These two changes introduced by using a decibel scale – compressing the number range, and converting a curve to a straight line – make it easier for the eye to spot interesting features in data of this sort when plotted as a graph. This is an important factor when doing experimental science of any sort.

Results – Principals

This section describes the results obtained for the Principal stops on the chief manual (*the Hauptwerk*) of the organ.

Principal 8ft

The most important stop on any organ is the 8' Principal (*or Diapason*) on the chief department and thus it merits discussion in some detail.

The variation of the amplitudes of this stop across the keyboard is shown in Figure 4 by the blue curve, where the numbers are represented in dB for the reasons already explained. The physical notes of the keyboard are indicated on the horizontal axis, beginning with bottom C (denoted C1) and ending with the C four octaves above (denoted C5). Thus, middle C is C3. This representation was convenient for this study because it was important to relate stops of any pitch to their note positions on the keyboard, but it can easily be converted to other conventions if desired.

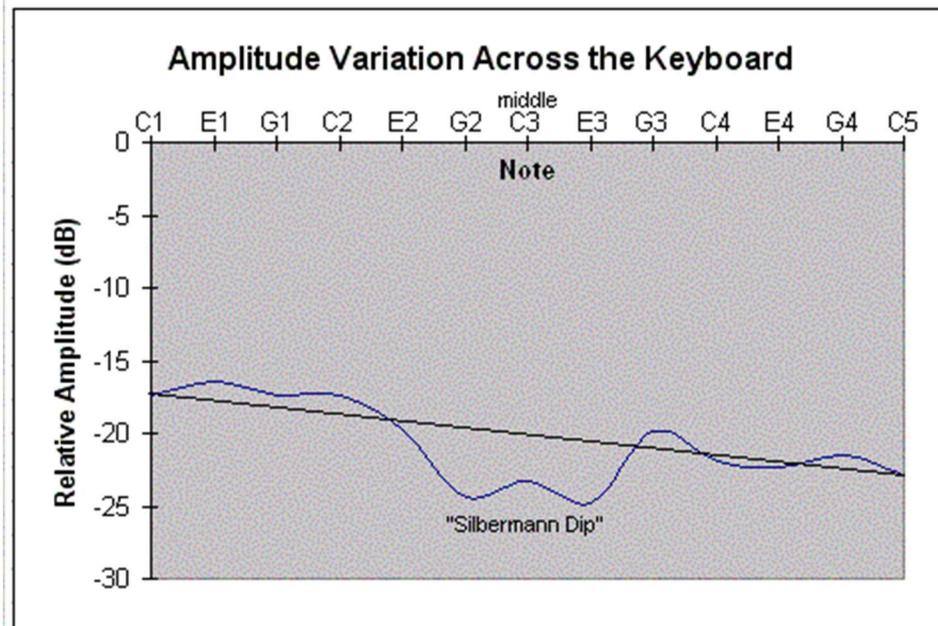


Figure 4. Regulation characteristic of the 8' Silbermann Principal

Neglecting for the moment the dip in the middle of the blue curve, the remainder of the data lie fairly close to a straight line joining its beginning and end – this line is drawn in black. This confirms the statement above that the use of decibels brings the data points closer to a straight line. If decibels had not been used, the data points would have swooped steeply down from the left-hand side in a curvy fashion. The black line starts at -17 dB and ends at -23 dB, thus on average there is a gradual reduction in amplitude of 6 dB (a factor of two) across the rank.

However, we cannot actually ignore the dip in the middle of the blue curve. Although the measured data would be expected to exhibit some degree of fluctuation, this dip is noticeable and almost certainly not random. This probably means it was imposed – presumably deliberately – either by the organ builder through his choice of pipe scale, or by the voicer through the way he regulated the power across the rank. Most likely it was a combination of both. It shows that the sound amplitude drops by about 5 dB (*a factor of about 1.8*) over the region of the keyboard between tenor D and middle F, a range of somewhat more than an octave encompassing middle C. Because acoustic power is proportional to the square of amplitude, this means the sound power drops by more than a factor of 3 over this region, and it is the power of the sound waves which matters because it is the vibrational power of the air molecules which actuates the hearing mechanism in our ears.

This amount of power reduction is significant, it seems to be systematic rather than random, and therefore it cannot be discounted lightly. It might explain, at least in part, the subjective transparency of Silbermann's Principals already discussed. In a stop with this characteristic, notes in the middle of the keyboard will tend not overpower those above and below. In particular the trebles will sing out rather than being drowned, compared to a stop which does not have this dip and whose amplitudes would therefore lie closer to the black line throughout its compass.

This was an intriguing feature, so I investigated it further by comparing the amplitude plot of this Silbermann Principal with those for two other types. One was a Cavaillé-Coll Montre (c. 1870) and the other was a typical British “large” Open Diapason of about 1900. The results for all three are in Figure 5.

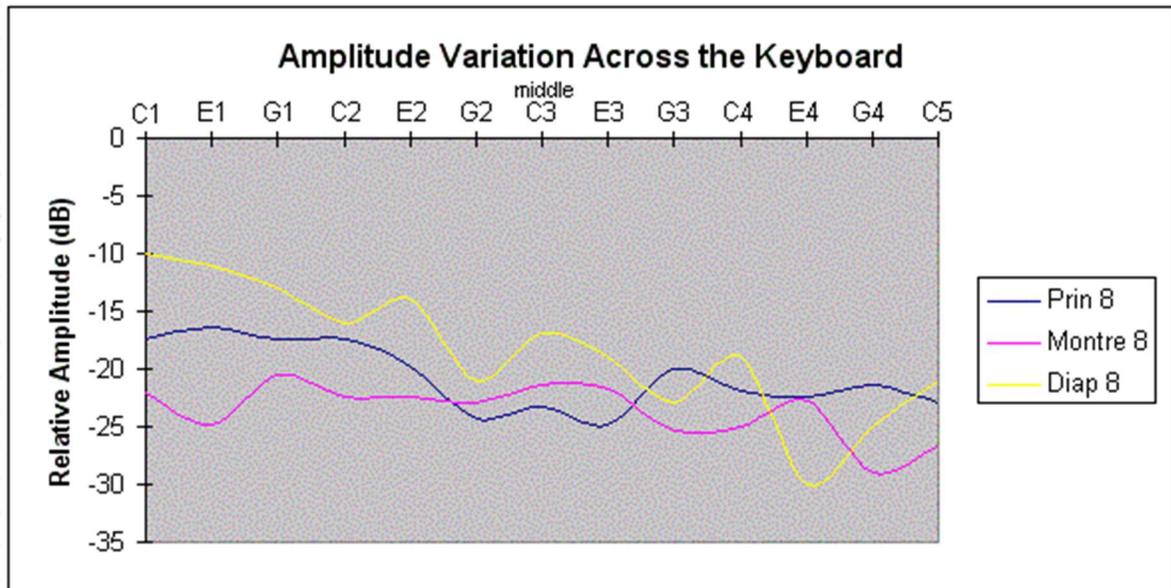


Figure 5. Regulation characteristics of a Silbermann Principal, a Cavallé-Coll Montre and a "large" British Open Diapason

The blue curve is the Silbermann data repeated, and the red one represents the Montre. Again, neglecting random fluctuations which can probably be discounted, this lies close to a straight line which is almost horizontal rather than having the gentle slope of the Silbermann Principal. Nor is there any evidence of a systematic dip in the middle of the keyboard with this stop. From this we can infer that the bass notes of this Montre would not have been particularly prominent, but nor would the trebles sing out above the middle register to the extent they do with the Silbermann Principal.

Interestingly, this is exactly what one experiences when playing on these two stops – the Silbermann Principal is indeed transparent across the entire compass and quite feisty and perky in its upper register as already noted, whereas the Montre is less so. Nevertheless, the Montre still sings in its own way just as these stops always do, and it is not particularly heavy or opaque owing to the relatively lightweight scaling and regulation treatment towards the bass. This characteristic of approximately equal power across the compass also probably relates to the ability of Cavallé-Coll’s Montres to blend so successfully with other fluework at unison pitch, rather than contributing to an imprecise and muddy effect.

The Open Diapason (*yellow curve*) is different again. Although there is quite a lot of fluctuation across the compass, one can see how prominent the bass register is compared to either of the other stops, and that the treble progressively falls off in power. This occurs because the graph for this stop slopes more steeply than the Silbermann Principal. Again, this is precisely what one experiences subjectively with this (*and most other*) British Open Diapasons of this vintage – they sound ponderous and fat, bass heavy, and the trebles easily get drowned out by notes in the middle of the compass. Such stops are heavy and opaque, and personally I find them most unpleasant when trying to play Bach and similar music on a British organ with this sort of Diapason. They are the antithesis of a Silbermann Principal.

From the foregoing I feel there is little doubt that the differences in the subjective playing characteristics of these three different types of Principal can be related to the way their acoustic amplitudes (*and therefore their powers*) vary across the keyboard. I could not resist the temptation to call the drop in power of the Silbermann Principal in the middle of the keyboard the “Silbermann Dip”! (*Interestingly, Silbermann's Principal pipe scales can also be analysed in terms of the same three distinct regions of the keyboard (bass, middle and treble) which Figure 4 demonstrates for the regulation - this is discussed further in [Appendix 1](#)*).

Principal 4 ft

The data for this stop in the Silbermann organ are plotted as the red line in Figure 6. For comparison purposes the 8' Principal has again been included.

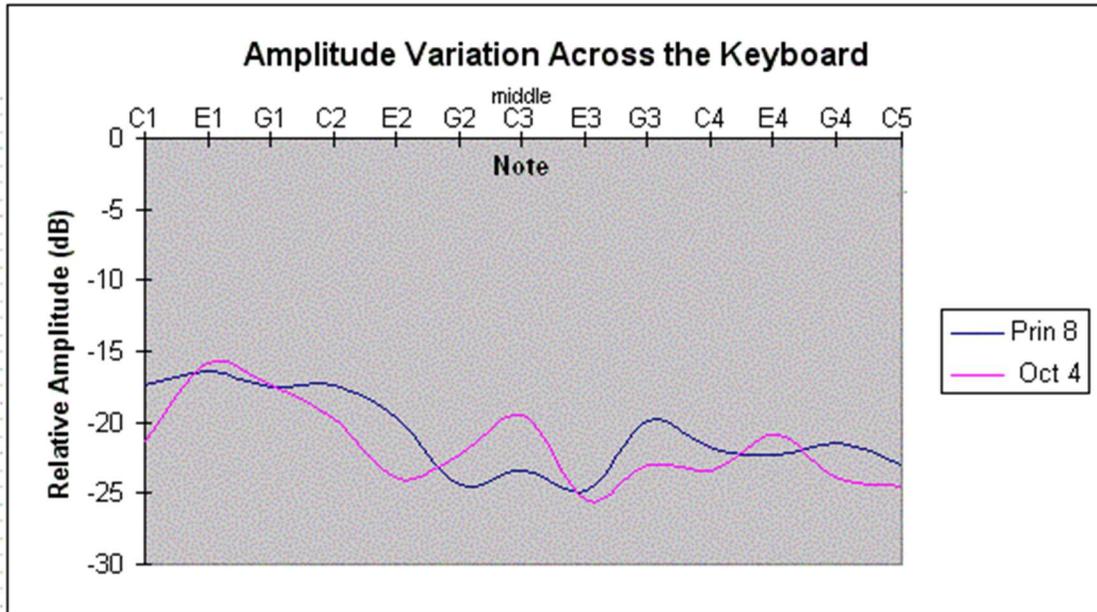


Figure 6. Regulation characteristics of the 8 and 4 foot Silbermann Principals

There are two features of interest. Firstly, there is still some sort of “dip” in the middle register, though it would have been more convincing if there was not also a hump near middle C. Apart from this, the acoustic amplitudes start to decrease a few notes before those of the 8' Principal as one ascends the keyboard from the bass, and they start to rise again a few notes after the Principal amplitudes rise. Whether one can therefore ascribe a “Silbermann Dip” to the data in this case is left to the judgement of the reader, as the hump near middle C renders the data less compelling if one is honest. The organ builder might well have intended to regulate the rank to have a dip in the middle register, but if so, the fluctuations inherent in the measurement process – no doubt partly due to standing waves in the building - have somewhat masked it.

The second feature of interest is that the slope of the “best fit” straight line (*not drawn in this diagram*) is about the same as that of the 8' Principal, which means that the average acoustic power across both ranks varies in a similar manner from bass to treble. Therefore, the pipe scales of the two ranks on the organ used for the measurements probably followed a similar law, which would be no surprise.

Principal Chorus

It is best at this juncture to look now at the complete Principal chorus on the Hauptwerk of this organ, rather than continuing to analyse each stop in isolation. The chorus comprised Principals at pitches of 8, 4, 2 2/3 and 2', together with two mixtures: a quint Mixture and a Cornet.

The graphs for all these stops are in Figure 7.

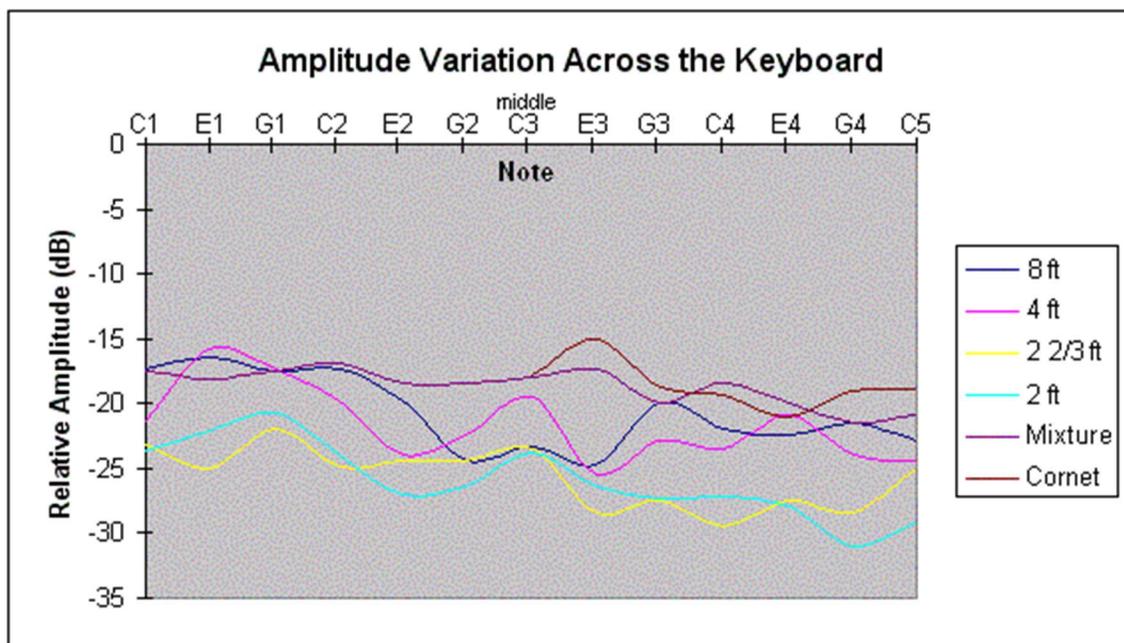


Figure 7. Regulation characteristics of a Silbermann Principal chorus

At first sight one might be forgiven for concluding it is just a chaotic muddle, and when faced with data like this a lifetime in research tells me to just stand back and think leisurely about it for a while with the help of lots of coffee. One can also turn it over if awake in the small hours, allow one's subconscious to pick at it while asleep, or reflect on it whilst out walking. Having gone through this process, several features then became clearer:

1. The two mixtures begin (*in the bass*) and end (*in the treble*) with about the same amplitudes as the 8 and 4' Principals. (Although the Cornet did not go below the middle of the keyboard on this organ, it follows much the same curve as the Mixture thereafter). No "Silbermann Dip" can be seen in either case.

2. The twelfth and fifteenth Principals begin and end about 6 dB (a factor of two) lower than the 8 and 4' Principals. This is a significant amount – a *systematic* difference of this magnitude can never be ignored. Again no "Silbermann Dip" can be seen.

3. The slopes of the "best fit" straight lines of all the stops are about the same, in which there is a gentle shading of amplitude across the keyboard from bass to treble amounting to about 6 dB (*a factor of two*).

Therefore, it is reasonable to conclude that, on average, Silbermann's mixtures are as powerful across the keyboard as the 8 and 4' Principals except in the region of the "Silbermann Dip", where their relative power is greater because the mixtures have no dip. Again, this confirms one's subjective impressions of a Silbermann organ in which the mixtures are dominant and powerful. In particular it helps to explain the first of the two factors contributing to Silbermann's "silvery sounds" discussed earlier, where I conjectured that the term means that "*the middle registers of these stops, in the two octaves or so centred on the middle of the keyboard, are carefully regulated in power so they do not mask the sounds both above and below them*". This has been demonstrated by the measurements.

On the other hand, the twelfth and fifteenth both have significantly lower amplitudes across the whole compass than the other stops making up the chorus, which explains why they add brightness and colour rather than excessive loudness to the 8 and 4' Principals in all regions of the keyboard. Only when the mixtures are added to the Principal chorus in a Silbermann organ do we get a major increase in loudness,

and when that happens it is indeed arresting in its effect. The data in Figure 7 help us to understand why these effects occur.

Results- Flutes

Turning to the Flute stops, the results to be discussed here relate to the Flute chorus on a subsidiary manual of this organ. Six stops at pitches of 8, 4, 2 2/3, 1 3/5, 1 1/3 and 1' were analysed in the same way as before. It was not entirely clear whether all of these were Flutes because although their names implied that they were, some of them partook of a Principal flavour over part of their compass. Nevertheless, they were all treated as Flutes here, and the results are plotted in Figure 8.

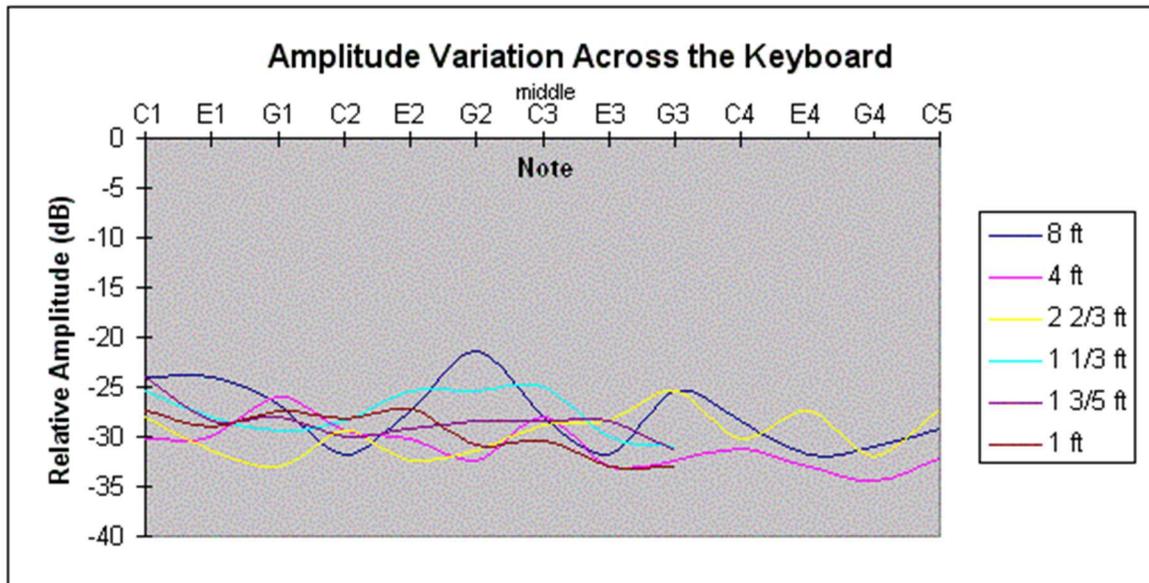


Figure 8. Regulation characteristics of a Silbermann Flute chorus

Only the 2' stop on this department was omitted from this analysis because it was definitely a Principal. Note that the three highest-pitched stops did not, of course, go up to the top of the keyboard because of the decreasing size of the tiny pipes, and this is reflected in their respective graphs.

As with the Principal chorus, I decided to back off for a while and let the coffee do its work on this rather jumbled plot also. After due reflection, the following features then stood out rather more clearly:

1. The data for the 8' Flute formed a curve (*the dark blue one*) unlike any other seen in this analysis. It is likely that its pronounced periodic wave-like character was an artefact due to standing waves in the auditorium while the sounds were being recorded. While the technique of averaging the signals from two microphones will usually reduce standing wave effects, there will be a few occasions when this will be less effective. The formation of standing waves at the locations occupied by the microphones is sensitive to their positions and particularly their separation, to the positions of the pipes which are radiating the sounds, and to the spatial geometry in three dimensions of all the myriad reflecting surfaces in the building. The wave-like character of this curve strongly suggests that what we see here was simply due to the standing waves in the building at the microphone positions as the frequency varied across the compass. Thus, it is unlikely that one can draw any conclusions from this curve about this Flute stop itself other than, on average, it appears to oscillate about a straight line with a slope similar to that observed for the Principal stops.

2. Similar behaviour is also observed to some extent with the 4 foot and 2 2/3' Flutes (*red and yellow curves respectively*), though the effects are less pronounced in these cases.

3. While most of the remaining data have little or no singular characteristics, there appears to be an amplitude hump just below the middle of the keyboard for the 1 1/3' Flute (*light blue curve*). Whether this is an inverse "Silbermann Dip" is difficult to say. However, it might suggest that the voicer was concerned to ensure that the tiny pipes towards the top of this rank did not lose power insofar as he was able to do anything about it. This is of course relevant to the way the Flute stops blend together in chorus.

4. Taken together, all these curves straddle an average "best fit" straight line which starts at -27 dB at the bass end and ends at -32 dB at the treble end. The difference, 5 dB, is for all practical purposes the same as the difference (*6 dB*) observed for the Principals. Therefore the average slopes of these two sets of curves are essentially the same for both the Principal and Flute stops.

5. The average amplitude of the Flutes on this subsidiary manual is significantly lower than the average amplitude of the Principals on the Hauptwerk by about 6 dB. If one compares them to the 8 foot Principal alone, the Flutes are on average quieter by about 10 dB. 10 dB is a significant amount, equating to a factor of more than 3 in amplitude and thus a factor of 10 in power.

When attempting earlier to tie down what the term "silvery sound" might mean when applied to the Flutes, I said "*one can often play quite low in the keyboard with a collection of Flute stops without the sound becoming unpleasant. The fifth-sounding mutations do not become too dominant as they do on so many organs – their additive synthesis effect does not disintegrate low in the keyboard on a Silbermann organ*".

If the data in Figure 8 are to have any practical value and meaning when set against these remarks, there are probably two characteristics which predominate. The first is that all the Flutes have broadly similar power which falls off gradually across the compass by about 5 or 6 dB (*i.e. as for the Principals*). In other words, no single stop has a behaviour departing in a major way from this "rule", save for the 1 1/3' Flute whose amplitude might rise towards the top end. The second is that the tiniest pipes at the top end of the highest pitched stops are not allowed to fall off in power, as far as is possible. If these characteristics are adopted when voicing and regulating a chorus of Flutes, it might then have a sporting chance of sounding "silvery" in the Silbermann sense.

Summary

The quantitative results of this analysis of the acoustic amplitudes of Silbermann's flue stops, that is to say, their regulation characteristics, can be summarised as follows:

1. When expressed logarithmically in decibels, the acoustic amplitudes of all the flue stops (*both Principals and Flutes*) on the organ used for the measurements were approximated by "best fit" straight lines which decreased by 5 – 6 dB across the keyboard from bass to treble.

2. The 8' Principal exhibited a pronounced dip (*called the "Silbermann Dip" in this study*) where its amplitude dropped sharply by about 5 dB over the region of the keyboard between tenor D and middle F (*i.e. the D below middle C and the F above it*). This artefact was not seen for a Cavallé-Coll Montre and a typical British Open Diapason when analysed in the same way.

3. Less compelling evidence suggested the 4' Principal might also have a similar "dip".

4. The 8' Principal, 4' Principal and the Mixtures all had comparable amplitudes (*neglecting the "dip"*), and they were the most powerful of all the flue stops.

5. The twelfth and fifteenth Principals were comparable in amplitude among themselves across the keyboard, but about 6 dB lower than the 8' Principal.

6. The amplitudes of the smallest pipes of the highest pitched Flute stops might rise towards the top of their compass, suggesting an attempt by the voicer to maintain their power as far as practical. Apart from this, all the Flute stops were of comparable power.

7. The average amplitude of the Flute stops was about 6 dB lower than the average amplitude of the Principals. More specifically, the average amplitude of the Flutes was about 10 dB lower than the 8 foot Principal.

Conclusions

This article has described research undertaken over a number of years, in the course of which I have attempted to capture something of the flavour of the sound of one of today's Silbermann organs and express it in numbers. This concluding section contains some practical suggestions for organ builders who might want to use the numbers to capture "Silbermann" sounds for themselves.

An attempt was made to define more precisely what is meant by the "silvery sound" of a Silbermann organ in terms of its Principal and Flute choruses. The most important conclusion was that the regulation of the fluework is probably rather critical, and at least as important as the timbres (*tone qualities*) of the ranks. That is to say, the way that the acoustic power varies across a given rank of Principal or Flute pipes, and the way these powers relate to all the others, evolved to become the main focus of the work. Making the pipes according to what is known of Silbermann's practices (*scales, shapes, mouth dimensions, etc*) and using his wind pressures will go a long way towards capturing the essence of the sounds, but it does little to assist a voicer when tonally finishing an organ in respect of how he regulates it. It is well known that the effect of a potentially fine organ can be ruined simply by poor regulation. The data presented here might therefore be useful at that point in the process.

But how would the results in this article be used in practice? Are decibels really of much use to a voicer? To answer these questions, the first point is that the acoustic amplitude values given here relate directly to the sound pressure level (SPL) figures that one can measure merely by using a commercial sound level meter when regulating pipework [7]. Therefore, using such a meter might help a voicer to realise the regulation characteristics presented in this article. However, the meter must have a "Z-weighting" option, which means no filtering is used to cut out parts of the audio spectrum. This would otherwise happen if "A-weighting" or other types was used.

Secondly, in using such a meter its microphone would need to be placed some distance from the pipes, and a distance of at least 5 metres should be used. The microphone should then be left in the same position throughout the regulating process. Clearly, therefore, it would be advantageous to use a meter with a detachable microphone so that the voicer could observe the meter readings himself while he was adjusting the pipes.

Thirdly, although such a meter measures sound levels on a decibel scale, it would not indicate anything like the numerical values presented here and indeed they would be very different [8]. This is because a sound level meter measures sound pressure levels relative to the average threshold of human hearing, not relative to the arbitrary level used in this article. This is not a problem, because what matters are not absolute values but the *differences* between dB measurements. As an example, the relative amplitude of the CC pipe of the 8 foot Principal was -17 dB in Figure 4, and that of the pipe 4 octaves above was -23 dB, which is 6 dB lower. If the sound level meter actually read +50 dB, say, for the CC pipe (a typical figure), then one would try to regulate the smallest pipe to indicate something in the region of 44 dB (6 dB lower). The pipes in-between would therefore be regulated to lie approximately within this range. Another way of saying the same thing is that, in this example, 67 dB would need to be added to all the dB values in this article (*because* $67 + (-17) = 50$).

Thus, a similar procedure would be used to relate all other sound level meter readings to the data presented here. Therefore, it might be asked why I have not adjusted all the numbers myself in the first

place. The answer is that the actual dB levels indicated by a meter will depend on several factors of which I have no knowledge and over which I have no control. One is simply the distance that the meter would be placed away from the pipes, because the further away from a sound source it is, the lower the reading it will indicate and vice versa. Another is that nominally identical organ pipes will emit SPL readings which vary considerably. There are many other factors as well.

The sound level meter method would be most effective in a building with a relatively dry acoustic. If there was a prolonged reverberation time, this would mean that reflections from the surfaces in the building were subject to low attenuation, and this is exactly the situation which gives rise to pronounced standing waves as well as to reverberation. Their presence would make the interpretation of the SPL measurements from a sound level meter more difficult, although its use would by no means be ruled out completely.

Notes and References

1. Decibels (dB) are not an absolute measure – they express an amplitude measurement as a *ratio* relative to some datum value. In this case the value adopted for the datum was simply the maximum possible amplitude which was defined as ± 100 units, as can be seen from the graph of the waveform in Figure 3. In other words, the peak-to-peak amplitudes were expressed as a fraction relative to a value of 200. For present purposes any datum number could have been chosen, though it would have affected the dB value of course. This does not matter in the present study where only relative differences, rather than absolute values, were of interest. An advantage of using decibels is that the *difference* in dB between two measurements is unaffected by the datum number chosen provided it is the same for both, even though the absolute dB values themselves will change.

Thus the relative amplitude value in decibels of each mean amplitude value (derived from averaging pairs of measurements made as per Figure 3) was given by the formula:

$$20\log(\text{mean peak-peak amplitude}/200)$$

2. “Baroque Tricks”, Ralph Downes, Oxford 1983.

Despite a phenomenal amount of research into pipe scales, Downes unconsciously succeeded in demonstrating in this book that it mattered less than he thought. Apart from anything else, the scales used by Arp Schnitger on which he tried to model much pipework of his organ at the RFH “... *exhibited such variety that ... I despaired of getting much further on any such basis ...*” (his words). And he either knew nothing about the scales used by Silbermann or he ignored them, because not one example is presented.

3. Editorial, *BIOS Reporter*, April 2005 (British Institute of Organ Studies, anonymous).

4. Specifically, the two sets of three bars in BWV 547 starting (a) 12 bars from the end of the prelude, and (b) 10 bars from the end of the fugue modulate rapidly through various keys. Even a “good” temperament like Werckmeister III comes somewhat unstuck here on certain of the chords, and a more extreme one such as quarter or sixth comma mean tone even more so. Silbermann is said to have used sixth comma tuning, in which A flat major is virtually unusable, yet this key appears as an essential part of the harmonic texture in this piece.

The unpleasant effects are obvious when using just a single unison 8’ Principal stop, where the beats are relatively slow. When played using high pitched mixtures as well, which this composition calls for, the effect can be excruciating. This is because beat rates between notes are proportional to absolute pitch and thus to the footage of stops, and it is beat rates which tell the ear whether notes are out of tune or not. One wonders whether Bach was trying to make the point here rather more succinctly than in his “48”! However, temperament is largely a subjective matter, so whether one likes the effects or not, this

piece is nevertheless a good one for detecting the presence of an unequal temperament, and that is the only point I am making here.

If BWV 547 sounds OK on a Silbermann organ it is *definitely* not tuned to sixth comma mean tone, the so-called "Silbermann Temperament"!

5. The Tonal Structure of Organ Principals”, currently on this website ([read](#)).

6. The relation between a few amplitude ratios expressed as dB and the ratios themselves is demonstrated in the following table, which shows how an amplitude range of 1000 : 1 is compressed into a dB range of only 60:

Amplitude Ratio (as a decimal)	Amplitude Ratio (as a fraction)	dB value
1	1	0
0.707	$1/\sqrt{2}$	-3
0.5	$1/2$	-6
0.1	$1/10$	-20
0.0333	$1/30$	-30
0.01	$1/100$	-40
0.001	$1/1000$	-60

In terms of subjective effect, a change of 1 dB is almost undetectable to the ear. 3 dB either way (increase or decrease) is noticeable if you are listening for it, but otherwise it would often pass unnoticed. A change of 6 dB or more is easily detected. In general, anything above ± 3 dB had to be looked at carefully, particularly if the change related to a contiguous range of notes rather than the odd one or two. These and similar criteria were used in this article to help determine which fluctuations in the data were significant and which were not.

7. Sound pressure level (SPL) measured by a sound level meter is a root mean square (rms) measurement of the voltage from its microphone, whereas I used peak-to-peak amplitude measurements here. However the two are simply related by the factor $2\sqrt{2}$ (i.e.2.8). In other words, one divides a peak-to-peak amplitude by 2.8 to get the root mean square value – this refers to the values before converting them to dB, not the dB values themselves.

Strictly this conversion factor is only applicable to a pure sine wave, whereas the sound of a Principal pipe contains significant contributions from harmonics which cause the shape of its waveform to depart from sinusoidal. The shape of a wave is expressed by what is known as its Form Factor. But since the amplitude of the fundamental (first harmonic) of a Principal pipe is usually the strongest, or among the strongest, the error introduced will not be great – the first (or any) harmonic in isolation is of course simply a sine wave. Moreover, such errors will be of little consequence when set against those due to standing waves for example, which also characterised the results presented here. In the case of Flutes with fewer and weaker harmonics than Principals, Form Factor errors will be even smaller.

Therefore, comparative measurements of the sound levels from organ pipes using a commercial sound level meter, provided it has a Z-weighting option, could be used when regulating an organ on the basis of the regulation data presented in this article.

8. A sound level meter would indicate typically around 50 - 70 dB when a single organ pipe was sounding a few metres away from the meter in a quiet building.

9. Bach familiarised himself with the north European school of music and organ building before he was 20 even though he lived far away from it. It is well known that the fame of players and composers such as Buxtehude, together with Schnitger's organs, lured him north as a young man to visit the area which was also the birthplace of Lutheran Protestantism. It is unnecessary to dwell here on the importance of the Lutheran chorale in his musical thinking, nor of its spread together with Protestantism as a whole into the southern German principalities where he spent the rest of his life. Thus it is no surprise that he composed for an organ with a complete and independent pedal organ, even though he did not always have access to such instruments himself and though his personal acquaintance with Schnitger's organs must have been limited. The sometimes curious dispositions of the organs he knew in and around Thuringia and Saxony, such as the one by Wender at Arnstadt, must surely have fallen well below what he would have liked. The same might well be said of many of Silbermann's organs. Against this background it seems reasonable to say, as I do in the main body of this article, that he composed with a Schnitger-style instrument in mind.

Appendix 1- Schnitger and Silbermann's Pipe Scales

Although this is not really the place for a detailed discussion of the pipe scales used by Arp Schnitger and Gottfried Silbermann, a few remarks might help to fill out some details in the historical sketch given in the main body of the article.

Three 8 foot Principal stops are plotted below on a standard scaling chart, two of them from organs by Schnitger and the other by Silbermann. One of the Schnitger organs is that now at Cappel, west of Hamburg.

The chart shows how the pipes of the first four C's across the keyboard deviate in diameter from Normal Scaling (NS), in which bottom C has an internal diameter of 155.5 mm and this then halves every successive 17th note (inclusive). The deviations from NS are expressed on the vertical axis in terms of semitones. Note that none of the curves has been corrected for pitch - NS assumes a pitch of A = 440 Hz whereas the pitch of the Silbermann rank was about a semitone higher. This probably applied to the Schnitger organs also.

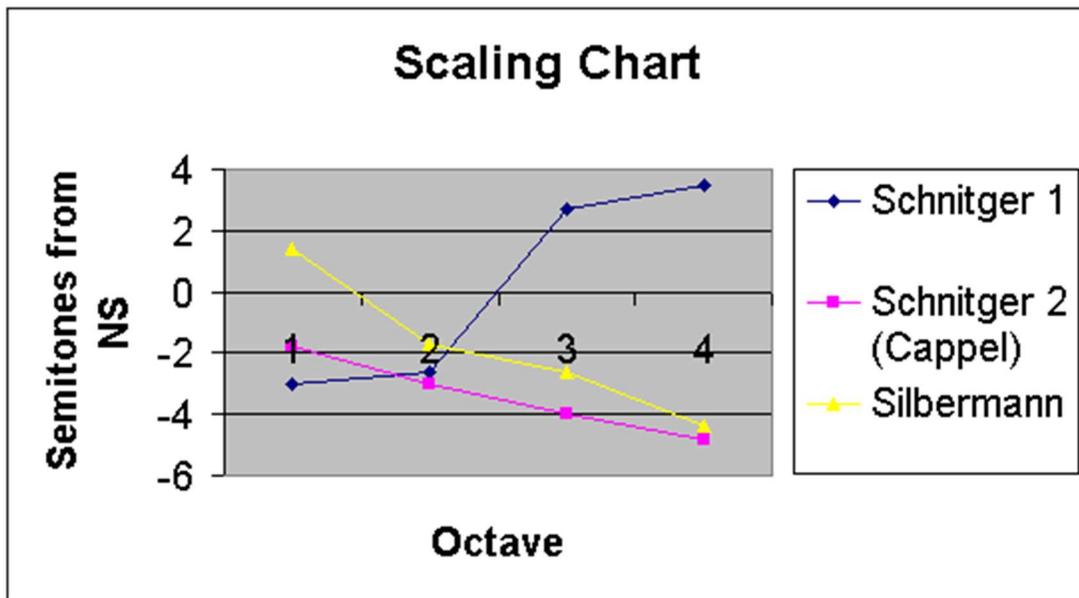


Figure A1. Some Schnitger and Silbermann pipe scales.

The first point to note is the enormous difference between the two Schnitger scales, confirming the difficulties encountered by Ralph Downes (see reference [2]). The differences are so great that it is pretty much a waste of time trying to account for them at this remove in time - three centuries. They probably arose because Schnitger often re-used a lot of old pipework when rebuilding an organ, whereas Silbermann seldom or never did. However in practice Schnitger overcame the consequential problems because of his (or his voicer's) consummate skill in getting any rank of pipes to sound as he wanted in terms of tone quality and power. A pipe scale is only a starting point, because of the many other adjustments available to a voicer which enable him to compensate for a less than optimum scale if he has enough skill, experience and time at his disposal. This example of Schnitger's disparate scales also illustrates perfectly the utter pointlessness of spending too much time getting bogged down in scales as so many organ writers do today.

Nevertheless, one can extract other information from these graphs which is of interest here. One is that the slopes of the Schnitger (Cappel) and Silbermann curves are similar over the middle of the compass, indicating that the halving intervals were much the same in this region. Specifically, measurements of the gradients show the pipe diameters appear to halve on the 16th note between tenor C and middle C, thus slightly faster than in NS though not by a significant amount. One has to bear in mind that the data used for graphs such as these often contain errors, a common one being that some writers measure the outside rather than the inside diameters of pipes, or their approach is just slapdash anyway. Consequently this is another reason why one cannot take the subject of scale too far if one is to remain rooted in reality.

Below tenor C the Silbermann stop halves even more quickly, ending up nearly $1\frac{1}{2}$ notes wider at bottom C than if it had been a NS rank. This would have made the stop sound relatively fluty towards the bass, assuming the voicer wanted to encourage such behaviour. Above middle C it again halves more quickly than in the middle octave, suggesting a desire to push up the level of the higher harmonics towards the top of the keyboard but, again, only if the voicer chose to allow this to happen.

Although one must not try to draw conclusions beyond what the data can reasonably be expected to furnish, these scaling data are of a piece with the regulation characteristics of a Silbermann 8' Principal discussed in the main article. The drop in power in the region of the keyboard around middle C (the "Silbermann dip" - Figure 4) also approximately coincides with the slowest rate of change of pipe diameters (Figure A1). Outside this region, both towards the bass and the treble, the power of the rank increases at the same time as the halving interval decreases. This accords with the subjective playing experience that the treble of a Silbermann Principal sings out well, it is not drowned by the middle range, and the stop becomes subdued and fluty towards the bass.