

Luigi Swich

Further thoughts on Bach's 1722 temperament

THE importance of Bach's drawing at the top of title-page of his *Das wohltemperirte Clavier* of 1722 was first noted by Andreas Sparschuh in 1999 and further acknowledged in Bradley Lehman's detailed 2005 exegesis.¹ In 2007, Graziano Interbartolo suggested a different interpretation of Bach's drawing,² reading it without turning the page upside-down, but instead from left to right, and emphasizing the difference between the first three small double loops (from the inside to the outside, i.e. slightly wide 5ths) and the five bigger multiple loops (from the outside to the inside, i.e. very narrow 5ths). Unfortunately, as Lehman pointed out,³ Interbartolo's formula of using 1/4-syntonic-comma 5ths on F–C–G–D–A–E, pure 5ths on E–B–F#–C# and Bb–F, and 1/12-comma wide fifths on C#–G#–Eb–Bb does not work, because it does not take into account the schisma: the difference that all temperaments must consider in order to reconcile the syntonic comma with the Pythagorean comma.

However, neither Lehman's objections to this formula nor Interbartolo's corrected layout, with the F#–C# 5th not exactly pure, but diminished by the schism,⁴ are completely convincing. Emile Jobin's almost identical reading of the drawing,⁵ on the other hand, instead of starting from F, begins from C, thus transposing the whole system by a 5th.

First of all, let us examine Bach's drawing (illus.1, which also includes an indication of the proposed note relative to the calligraphic loops):

1. No one has noticed that the drawing shows an intersection between the two single loops above the letter 'w' of 'wohltemperirte'. This would lead to four, not three, kinds of loops and consequently of 5ths: five very narrow on the right; one pure, one slightly narrow and one pure in the centre; three slightly wide on the left and another pure on the far left.⁶

2. The letter 'C' of the word 'Clavier' is close to the C loops and inside the letter 'D' of the word 'Das' there are the letters 'Es' (Eb in German) written in the style of the old German organ-builders and touching the Eb loop, and a straight line with two dots touching the G# loop.
3. The first sign on the left is nothing other than a stylized, old-fashioned 'f', again in the German organ-builders' style.

The result is a temperament beginning on F and ending on the G#–Eb 5th—the old 'wolf 5th', and now the true closing point of the circle.

The Preludes and Fugues no.8 BWV853 (Eb minor prelude with D# minor fugue), no.17 in Ab major BWV862 and no.18 in G# minor BWV863 clearly emphasize the double purpose of the black keys between D and E and between G and A.

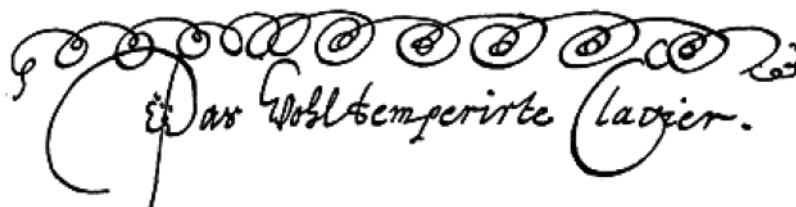
My system is shown in illus.2 (bold letters indicate the beginning and the end of the system).

As far as the width of the 5ths is concerned, the sum of three pure, three slightly wide, one slightly narrow and five very narrow 5ths apparently gives various solutions. But not so many if we—like early keyboard players and instrument-makers—have to lay any temperament without an electronic tuning device. We must look for a temperament having control intervals, or for a means of comparing beat frequency, in order to help determine the tuning easily, but precisely.⁷

The tuning with five 1/4-syntonic-comma 5ths would be the first candidate, because of its mean-tone origin and the two pure 3rds produced at C–E and F–A. Nevertheless, it results in three major 3rds that are too large: B–D#, F#–A# and C#–E#, the last two particularly unusable as they result from the sum of one pure 5th and three over-wide 5ths.

However, Lehman's solution with 1/6-comma 5ths, *inter alia*, does not allow for three wide 5ths, as clearly required by the knots on the left of the

F B $\flat$ E $\flat$ G $\sharp$ C $\sharp$ F $\sharp$ B E A D G C F



1 Calligraphic title of *Das wohltemperirte Clavier* (1722) in Bach's hand, including indication of the note relative to the calligraphic loops

drawing. I have therefore taken into account the $1/5$ -comma division, with the use of slightly sharpened major 3rds.

Five 5ths reduced by a $1/5$ -Pythagorean comma allow a tuning: (i) close to Bach's drawing; (ii) checkable by ear; (iii) circulating, and, at the same time, (iv) with an unequal, mean-tone character making the keys different from one another.

The synchronicity, or equal beating, between the 5th F–C and the 3rd F–A (respectively 161 and 157 beats per minute corresponding approximately to three beats per second in the central octave of the keyboard at A415) and between the 5th C–G and the 3rd C–E (121 and 118 beats per minute corresponding approximately to two beats per second) (at A440:

171 and 167; 128 and 125 beats per minute) allows this tuning to be laid easily by ear.

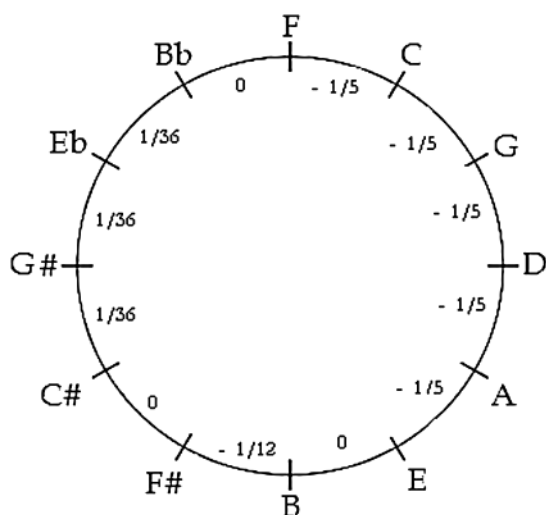
Regarding the three slightly wide 5ths, one must consider the following points:

1. The three 5ths C $\sharp$ –G $\sharp$ –E $\flat$ –B $\flat$ are residual, since they are tuned at the end of the circle of 5ths.
2. The remainder, amounting to $3/36$ of the Pythagorean comma, is therefore to be distributed between them so that only two notes (G $\sharp$ and E $\flat$) are to be tuned, the others resulting from the previous tuning procedure: C $\sharp$ has been tuned as a pure 5th on F $\sharp$ while B $\flat$ has been tuned as a pure 5th down from F.
3. Though we must not overlook the fact that the knots inside these three loops are much smaller than any other in the drawing (i.e. slightly wide 5ths) and, if we ignore them, their loops would actually look like the simple loops of the pure 5ths. It is as though the author of the drawing wished to underline that these last closing 5ths are nearly pure or rather a little bit wide.

Given that there are just two notes to be tuned, this temperament works effortlessly and can be done by ear.

The result is a tuning having neither 'wolf 5ths' nor 3rds exceeding the Pythagorean value (408 cents), except those on F $\sharp$ –A $\sharp$ and on C $\sharp$ –E $\sharp$. Nevertheless, these do so by an amount so small (409.8 cents) that they do not sound intolerable to the ear and do not prevent the system from being 'circular'.

As for the enharmonic dimension, this cannot be assessed in itself, regardless of temperament. Once we have verified that there are no unplayable major 3rds and that the scheme does circulate, any consideration of greater or lesser quality of a given enharmonic sound would be subjective speculation with no scientific basis.



2 Representation of the tuning circle for Bach's temperament

Bach's 1722 temperament produces the formula shown in illus.2.

Given a starting point of F, as in many classic tuning processes,⁸ the practical procedure is as follows:

1. Tune upwards five 1/5-Pythagorean-comma diminished 5ths.
2. Tune the 5th E–B pure, then the B–F# 5th 1/12-Pythagorean-comma diminished and the 5th F#–C# pure.
3. Tune downwards the 5th F–Bb pure.
4. Share out the remaining 3/36-Pythagorean comma between the last three slightly wide 5ths, actually tuning G# and Eb only.

We must consider that the aim of such a system, as it was designed by Bach, is to distinguish all the keys to varying degrees and not to follow the flat homogeneity of equal temperament (Table 2), where the value of all the major 3rds is invariably 400 cents.

Moreover, with the exception of the aforementioned two distant 3rds, no other major 3rd is Pythagorean, the others being more or less smaller than 408 cents, as shown in Tables 3a and b.

All this, as a result of the greater or lesser width of the major 3rds, creates a tonal palette that is subtly varied—a rainbow of 24 keys differing from each other, which I personally find richer, more interesting and more expressive than those of any other comparable temperament. It is, indeed, a good balance: maximizing the differentiation and at the same time achieving circulation throughout all 24 keys.

This can be especially appreciated when all *The well-tempered clavier* preludes and fugues are played systematically, semitone by semitone, from C major to B minor. The range reaches from the almost pure C–E and F–A (i.e. 389 cents against the mean-tone pure value of 386.4 cents) through the more strongly beating 3rds on E–G# (406.6 cents) and on



3 The 1688 Arp Schnitger organ in St Ludgeri, Norden, Germany

B–D# (407.2 cents) to the spicy 3rds on F#–A# and C#–E# (409.8 cents). The result is a circulating tuning that has at the same time a slight mean-tone character, which makes it possible to play and modulate through 24 keys without unpleasant intervals, but with varying degrees of difference—the temperament being unequal, and the keys not all sounding the same.

Such a system is reminiscent of Herbert Anton Kellner's 1977 temperament and, even more, the temperament worked out by Harald Vogel and Jürgen Ahrend for the 1688 Arp Schnitger organ in Norden, St Ludgeri (Germany) (illus.3) during its restoration (1981–5) (Table 4).⁹ This last, based on various documents concerning Schnitger's tuning method and on organs built at the same time in the same locality, is based on 1/5-Pythagorean comma, with seven 5ths 1/5-Pythagorean-comma-diminished

Table 1 Bach's 1722 temperament with detailed frequencies and measures (A415 Hz), (software by Giancarlo Bardelli, 1996)

SCALE	C	C#	D	Eb	E	F	F#	G	G#	A	Bb	B
Hertz frequencies	247.9	261.6	277.4	294.5	310.4	331.4	348.8	370.8	392.5	415.0	441.9	465.6
FIFTHS	C–G	C#–G#	D–A	Eb–Bb	E–B	F–C	F#–C#	G–D	G#–D#	A–E	Bb–F	B–F#
beats/minute	121	18	135	20	0	161	0	181	27	202	0	95
MAJOR THIRDS	C–E	C#–E#	D–F#	Eb–G	E–G#	F–A	F#–A#	G–B	Ab–C	A–C#	Bb–D	B–D#
beats/minute	118	1071	490	654	1093	157	1428	479	1239	1073	570	1693

Table 2 Differences in cents between Bach's 1722 temperament and equal temperament

F	F#	G	G#	A	Bb	B	C	C#	D	Eb	E
0	-11.7	-5.5	-7.2	-10.9	-2	-11.7	-2.7	-9.8	-8.2	-4.6	-13.7

Table 3a Measurements of major 3rds in Bach's 1722 temperament, with the purest (i.e. the narrowest) in bold and the least pure (i.e. the widest) in italic

C-E	389	F#-A#	409.8
C#-E#	409.8	G-B	393.7
D-F#	396.5	G#-B#	404.4
Eb-G	399.1	A-C#	401.2
E-G#	406.6	Bb-D	393.7
F-A	389	B-D#	407.2

from F to F#, three pure 5ths from F# to G# and on Bb-F and the remaining two 5ths G#-Eb-Bb being 1/5-Pythagorean comma wide (Table 3b).

As Table 4 shows, the Norden tuning has strong similarities with Bach's system. It is a modified mean-tone temperament, with sharpened major 3rds and no 'wolf 5th', which nevertheless remains within the framework of 19 keys (nine major 3rds from Eb to B and ten minor 3rds from F to G#). With the significant quantity of three major 3rds substantially exceeding the Pythagorean value (F# and C# = 414 cents; G# = 410 cents), it deliberately does not circulate but allows one to play the marginal chords of B major and F minor. Importantly, it reveals the significance of the relationship of beats in tempered triads and the special nature of 1/5-comma temperament, with a few sharpened major 3rds and flattened 5ths beating at the same speed, as discussed above. However, it is a transitional form between strict mean-tone and 'well-tempered' schemes.¹⁰

Bach's well-tempered system does more—it enables circulation through as many as 24 keys. We cannot enjoy some of the slight peripheral roughness of Bach's tuning method if we do not reconsider our point of view and realize that his aim was to alleviate the severe hardness of some mean-tone intervals and not simply to diversify the monotony of equal temperament. It is important to remember that the modern ear has been accustomed to equal tem-

perament for at least a century, while in Bach's time mean-tone temperament and its variants were the standard for every musician, their ears being accustomed to significant differences between the ten most common keys and all the others (which were more or less unplayable, according to the type of mean-tone).

Every temperament is a give-and-take situation: there is no such thing as the perfect solution. Therefore our aim should be, according to Bach's learned, as well as practical mind (as shown by the remarkably simple way he conveyed his own tuning method), to seek the best compromise. He intentionally wrote 'well-tempered' and not 'perfectly tempered'. Nevertheless, Bach succeeds in making the unusable keys in mean-tone usable, without destroying the greater beauty of the ten most used keys.

With this in mind, it is useful to re-read Forkel's valuable statement:

*Seinen Flügel konnte ihm Niemand zu Danck bekielen; er that es stets selbst. Auch stimmte er so wohl den Flügel als sein Clavichord selbst, und war so geübt in dieser Arbeit, daß sie ihm nie mehr als eine Viertelstunde kostete. Dann waren aber auch, wenn er fantasirte, alle 24 Tonarten sein; er machte mit ihnen was er wollte. Er verband die entferntesten so leicht und so natürlich mit einander, wie die nächsten; man glaubte, er habe nur im innern Kreise einer einzigen Tonart modulirt.*¹¹

No one would be thanked for quilling his harpsichord for him, as he always did it himself. Moreover, the tuning of his harpsichord and clavichord was his own job, and he was so competent in this work that it did not take him more than a quarter of an hour. Yet, when he improvised, all 24 keys were his; he could do what he wanted with them. He connected the most remote keys together as easily and naturally as the nearest; one could even believe he was only modulating in the inner circle of a single key.

There are also other examples of tuning slightly wide 5ths: Andreas Werckmeister, in his *Die nothwendigsten Anmerkungen* (1698), described an unequal temperament with the 5ths on G#-Eb-Bb 1/16- or 1/24-comma wide.¹² Seventy-eight years after Bach, Carlo Gervasoni described—in an impressive and so far neglected analogy with Bach—a system with the 5ths from C to E less than 1/4-syntonic comma narrow:

Table 3b Major 3rds in Bach's 1722 temperament, and how they differ from the pure major 3rd value (386.4 cents)

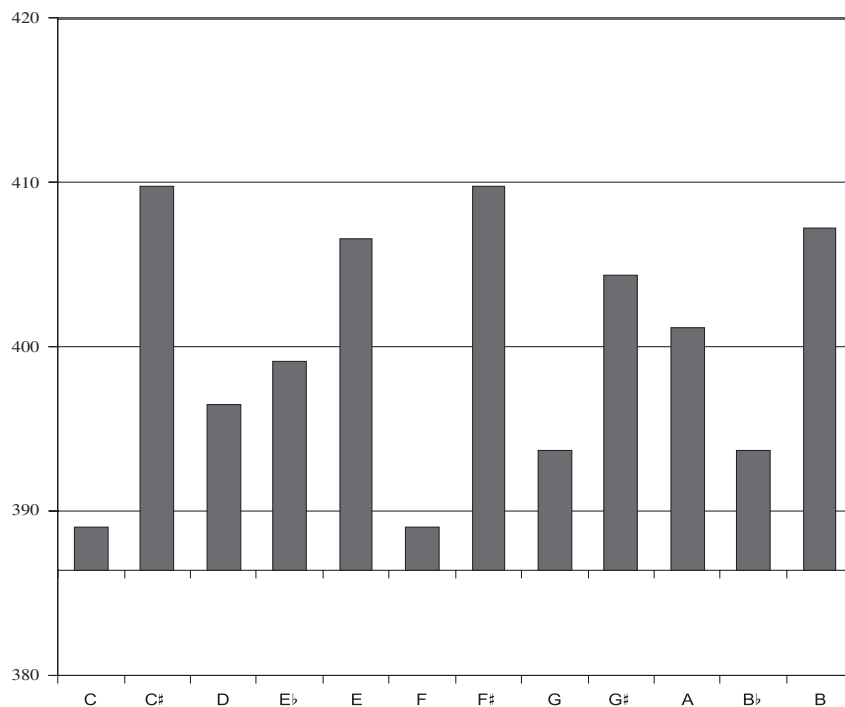
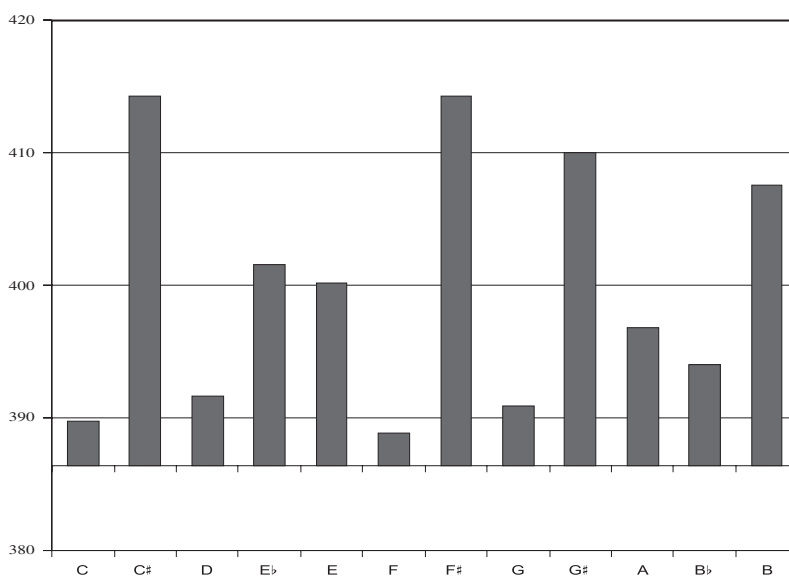


Table 4 Major 3rds in the temperament of the 1688 Arp Schnitger organ in Norden



L'alterazione . . . esser dee però tanto leggiera, che a riconoscere non s'abbia siffatta quinta distante dal giusto intervallo nè anche per un quarto di comma in calare.

The alteration of the 5ths from C to E must be so narrow that these 5ths should differ from their pure value less than $\frac{1}{4}$ syntonic comma.

and the others wide:

*fa d'uopo inoltre di far crescere qualche poco alcune quinte; quelle cioè che si trovano ne' suoni cromatici ne' quali si convengono le maggiori alterazioni, per essere questi meno degli altri usati.*¹³

It is moreover necessary to make some 5ths a little wide; i.e. those on chromatic notes, where the most of sharps and flats can be found, as they are the least-used notes.

The 5th on G $\sharp$ –E $\flat$ is clearly said to be the closing point of the circle and the proof of the temperament with E $\flat$ sounding at the same time as D $\sharp$:

Finalmente coll'E la fa lasciato s'accordi la sua ottava in ascendere; ed allora quando si riconoscerà che quest'ultimo suono potrà servire opportunamente anche per quinta di A la fa, ossia del G sol re ut diesis, che si è accordato per ultimo nell'accordo per diesis: sarà questa la piena prova dell'ottimo riparto.

Finally, tune the E $\flat$ in such a way that it serves at the same time as a 5th on the G $\sharp$ last tuned in the sharp sequence—this will be the full proof of the excellent temperament.

Temperaments with more or less wide 5ths downwards from C or F were commonly used in France (*temperament ordinaire*, Mersenne 1637, Chautmont 1695, Vincent 1712, Rameau 1726, D'Alembert 1752, Corrette 1753, *Méthode pour accorder le piano-forte*—Paris, first quarter of the 19th century) and in Italy (Corri 1787, anonymous from Bologna before 1788),¹⁴ while the tuning of the 5ths from F or C upwards $\frac{1}{5}$ -Pythagorean-comma narrow with the other 5ths pure was used by German organ-builders (Gottfried Silbermann, Freiberg Dom 1714), and is nowadays adopted by organ restorers.¹⁵

The existence of a temperament with all its major 3rds more or less sharp is confirmed by Marpurg's famous report about the way Kirnberger was taught to tune in his lessons with Bach.¹⁶ It is worth studying the original text in full:

Der Hr. Kirnberger selbst hat mir und andern mehrmahl erzählt, wie der berühmte Joh. Seb. Bach ihm, während der

Zeit seines von demselben genoßnen musikalischen Unterrichts, die Stimmung seines Claviers übertragen, und wie dieser Meister ausdrücklich von ihm verlangt, alle großen Terzen scharf zu machen. In einer Temperatur, wo alle große Terzen etwas scharf, d.i. wo sie alle über sich schweben sollen, kann unmöglich eine reine große Terz statt finden, und sobald keine reine große Terz statt findet, so ist auch keine um 81:80 erhöhte große Terz möglich. Der Hr. Capellmeister Joh. Seb. Bach, welcher nicht ein durch einen bösen Calcul verdorbnes Ohr hatte, mußte also empfunden haben, daß eine um 81:80 erhöhte große Terz ein abscheuliches Intervall ist. Warum hatte derselbe wohl seine aus allen 24 Tönen gesetzte Präludien und Fugen die Kunst der Temperatur betitelt?

Several times Kirnberger himself told me and others how the famous J. S. Bach, during the former's music lessons with the latter, made him tune his keyboard, and how the master expressly asked him to make all major 3rds sharp. In a tuning with all major 3rds sharp, i.e. with all beating 3rds, no pure major 3rd can occur; and there are neither pure major 3rds nor major 3rd a syntonic comma sharp. J. S. Bach, whose hearing was not impaired by bad arithmetic, must have heard that a major 3rd a syntonic comma sharp is an unpleasant interval. Why ever else would he entitle his collection of preludes and fugues in all 24 keys, the *Art of Temperament*?

Marpurg was criticizing, not for the first time,¹⁷ Kirnberger and his tuning methods, testifying that Bach's tuning was quite different to his pupil's temperaments with pure 3rds.¹⁸ Kirnberger, who was Bach's private student from 1739 to 1741, never contradicted the statement. This last fact is worth considering, because it recalls the principle that pure major 3rds leave too much error for the other two major 3rds in the octave, and prevent a circulating temperament.

Like the German harpsichord school and its skilful fusion of French and Italian styles, Bach's well-tempered system shows similarities with other earlier and later tuning methods from the same countries, thus putting its author at the centre of the long-standing debate in Europe on the best temperament. His temperament is a rational and practical unequal system, with the more distant keys gradually becoming slightly harsh while allowing it to circulate throughout 24 keys.

Luigi Swich is viceprefetto of the Italian Ministry of the Interior. He obtained degrees in both organ and harpsichord at the Conservatory of Parma with Stefano Innocenti and at the Conservatory of Milan with Danilo Costantini. He published the Italian text of Christopher Hogwood's Handel biography (1991) as well as studies on Renaissance Italian organs and organ-builders. luigi.swich@alice.it

I dedicate this article to my mother and to the memory of my father, who both transmitted their love of beauty to me. My thanks go to Giovanna Bonomo, Caterina Ciufferi, Daniela Codarin and Lorenzo Lentini, who kindly checked the English translation of this article. I am indebted to the harpsichord-maker Augusto Bonza (Milan) and to the organ-builder Giovanni Pradella (Sondrio) for testing my experiments about Bach's temperament and for the fruitful exchange of ideas on the matter.

- 1 A. Sparschuh, 'Stimm-Arithmetik des wohltemperierten Klaviers', in *Deutsche Mathematiker Vereinigung Jahrestagung 1999* (Mainz, 1999), pp.154–5; B. Lehman, 'Bach's extraordinary temperament: our Rosetta Stone 1-2', *Early Music*, xxxiii/1-2 (2005), pp.3–23 and 211–31, with Appendix material on the *Early Music* website (including J. S. Bach's 1722 autograph title-page of *Das wohltemperirte Clavier*; comparison of Bach's method with other temperaments; data charts; major 3rd comparisons).
- 2 G. Interbartolo, P. Venturino and G. Bof, *Bach 1722: Il temperamento di Dio* (Finale Ligure, 2007).
- 3 B. Lehman, *Other 'Bach' temperaments*, on his website: <http://www.larips.com>, p.36.
- 4 Lehman, *Other 'Bach' temperaments*, pp.40–1.
- 5 Lehman, *Other 'Bach' temperaments*, pp.26–7.
- 6 No wonder if only one of those two 5ths is made narrow while the other is left pure. While the drawing was obviously done by writing from left to right, when tuning it must be followed from right to left. Consequently, the 5th on E–B is pure (the first loop is simple) while the following 5th on B–F# is narrow because of the intersection of the second loop on the first one. This is an important feature because it gives the tuner a safe point of reference (i.e. the pure 5th) and at the same time it avoids any Pythagorean value on the widely used E–G# and B–D# major 3rds. It would not be so if the three 5ths from E to C# were made pure.
- 7 K. Wegscheider, 'Das "Geheimnis" der Stimmungsarten im Orgelbau des 17. und 18. Jahrhunderts', *ISO Journal*, xx (July 2004), pp.14–53.

- 8 Costanzo Antegnati, *L'arte organica* (Brescia, 1608); Michel Corrette, *Le maître de clavecin pour l'accompagnement* (Paris, 1753); L. F. Tagliavini, 'Note introduttive alla storia del temperamento in Italia', in *L'Organo* (Bologna, 1980).
- 9 H. A. Kellner, 'Eine Rekonstruktion der wohltemperierten Stimmung von Johann Sebastian Bach', *Das Musikinstrument*, xxvii (Frankfurt, 1977). 5ths from C to E and B–F# 1/5-Pythagorean-comma diminished, the others pure.
- 10 H. Vogel, 'Die Interpretation der Orgelwerke Bachs auf Orgeln in der norddeutschen Bauweise des späten 17. Jahrhunderts', *Informazione organistica*, iii (1991). *Das goldene Zeitalter der Norddeutschen Orgelkunst*, liner notes to CD Organa 3207.
- 11 Johann Nikolaus Forkel, *Ueber Johann Sebastian Bachs Leben, Kunst und Kunstwerke* (Leipzig, 1802), p.17, in *Bach-Dokumente VII* (Kassel, 2008), p.30 (English translation by the author).
- 12 R. Rasch, 'Does "well-tempered" mean "equal-tempered"?', *Bach–Handel–Scarlatti Tercentenary Essays* (Cambridge, 1985), pp.297–8.
- 13 Carlo Gervasoni, *La scuola della musica* (Piacenza, 1800), pp.125–8.
- 14 P. Barbieri, *Acustica accordatura e temperamento nell'illuminismo veneto* (Rome, 1987).
- 15 Wegscheider, 'Das "Geheimnis" der Stimmungsarten im Orgelbau'.
- 16 Friedrich Wilhelm Marpurg, *Versuch über die musikalische Temperatur* (Berlin, 1776), p.213, in *Bach-Dokumente III—Dokumente zur Nachwirken Johann Sebastian Bachs 1750–1800* (Kassel, 1984), p.304 (English translation by the author).
- 17 See *Bach-Dokumente III*, n.701; Marpurg, *Polemik gegen Kirnbergers Analysen*, Berlin 1.12.1759 bis 24.5.1760, p.134.
- 18 The so-called 'Kirnberger II' from *Die Kunst des reinen Satzes in der Musik*, (1771): all the 5ths are pure, except those on D–A–E (–1/2) and that on F#–C# (–1/11), with good pure 3rds on C–E, G–B and D–F#. The so-called 'Kirnberger III' (from a letter to J. N. Forkel of c.1779): 5ths from C to E 1/4- syntonic-comma diminished, the others pure except the 5th F#–C# 1/11-syntonic-comma diminished, with one pure 3rd on C–E.

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