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# Why were enharmonic keyboards built? – From Nicola Vicentino (1555) to Michael Bulyowsky (1699)[1]

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The 12-note diatonic-chromatic keyboard may be called one of the success stories in the history of Western music. Ever since its invention at some point in the fifteenth century, its design has remained basically unchanged. It has been the basic playing device for traditional keyboard instruments such as the organ, the harpsichord, the pianoforte, and the clavichord, all of them used abundantly in historical and present-day times, often as the ‹leading instruments› of the time. In addition the design has, for many centuries already, been applied to instruments of other categories such as the carillon, the accordion, keyed percussion, and electronic instruments of various designs.

From its early history, however, theorists and builders have thought it necessary to improve this seemingly perfect design by drafting or constructing keyboards with a larger number of keys and therefore pitches per octave, from just a few more than the traditional twelve to a real proliferation, up to fifty or even more. It is difficult to give an exact estimate of the number of keyboard designs proposed in history as extensions of the simple 12-note model. Instruments with raised keys split into two keys were built from the late fifteenth century onwards. The earliest instruments with a number of keys that is substantially larger than twelve, say, 19 or more, were built around the middle of the sixteenth century. A continuous stream of later examples followed them, through all the succeeding centuries. In all, hundreds of them may have been built and presumably new designs are still being developed today. This contribution will deal primarily with the enharmonic keyboards developed during the first one and half centuries of its existence. The designs that are easily available from this period such as the ones described by Nicola Vicentino, Gioseffo Zarlino, Martino Pesenti, Michael Praetorius, Joan Albert

1 I want to thank Denzil Wraight (Cölbe, Germany) for the discussions concerning various details of this contribution; they have been essential for solving a number of problems in a satisfactory manner. Thanks also go to Bob van Asperen (Bennebroek, Netherlands) and Martin Kirnbauer (Basel, Switzerland) for their careful reading of the final draft and for their helpful remarks on several details.

Ban, Giovanni Battista Doni, Marin Mersenne, Athanasius Kircher, etc. present already a range that may be taken as representative for the variety of enharmonic keyboards in general.

The more keys are added on top of the basic 12-note design, the more complicated they are to play on or to compose music for them that is to be played. Keyboards with just a few extra keys resemble in general the 12-note design fairly closely. This resemblance applies more or less to keyboards with no more than 19 notes per octave. In general, keyboards with 12 to 19 notes per octave may be called *chromatic keyboards*.[2] Keyboards with 19 or more notes, however, look so different from than their 12-note precursors that they cannot be played without special training. They are the genuine enharmonic keyboards and they will be the primary concern of this article. Note that the 19-tone keyboard is counted in both the categories of chromatic and enharmonic keyboards. This is done intentionally since it shares some characteristics with the keyboard designs having fewer notes per octave and other features with designs having more than 19 notes.[3] In a few cases, however, attention will also be paid to keyboard designs with fewer then 19 keys per octave, such as Zarlino's 17-note and René Descartes's 18-note design.

It is then a valid question to ask what the reasons were why people occupied themselves with such complicated matters as enharmonic keyboards, because it must have been obvious to everybody that the simple 12-note standard solution served the needs of so many musicians already so well.

Musical instruments are always built to satisfy the specific needs of their builders or users. Therefore, if we want to understand the why of enharmonic keyboards we should look at the motivation or motivations of the designers and builders of such instruments. Since musical needs and the corresponding musical preoccupations have changed throughout the entire history of music, one should not be surprised to find behind the history of enharmonic keyboards not a single motivation but rather a number of motivations, which developed over time, in connection with the preoccupations of the time's musical practice, thought, and theory.

Evidence of several kinds is available for writing the history of the enharmonic keyboard in general. Surviving enharmonic instruments and written texts describing, and sometimes depicting such instruments are the most

2 About these keyboards see especially Denzil Wraight & Christopher Stembridge, «Italian Split-Keyed Instruments with Fewer than Nineteen Divisions to the Octave», in: *Performance Practice Review* 7/2 (1994), pp. 150–181.

3 See my contribution «On Terminology for Diatonic, Chromatic, and Enharmonic Keyboards» in this volume.

important sources for our knowledge of the enharmonic instruments. Additional information may be derived from archival documents and musical scores. In this contribution, which rather deals with the «why» of the enharmonic instruments than the «how», most use will be made from written information. There the designer perhaps tell us the reason why the pursued such a complicated art, an art, after all, that induced Zarlino to quote the following lines from Alciato's *Emblemata*:[4]

> «Difficile est, nisi docto homini tot tendere chordas.»
> Difficult it is, except for a learned man to play on so many strings.

The present article is organized in six sections, each of which takes an author and his main publication dealing with enharmonic keyboards as its point of departure. The earliest source examined in such a way is Nicola Vicentino's *L'antica musica ridotta all moderna pratica*, published in Rome in 1555, the latest Michael Bulyowsky's *Neu-erfundenes vollkommenes fünff-faches Clavier* published in Stuttgart in 1699. The present overview will not discuss every single case of an enharmonic keyboard proposed or built in the one and half centuries from about 1550 to about 1700. An exhaustive treatment of the topic is not to be expected. To begin with, we will refrain of a detailed discussion of the various multi-note keyboards proposed in the writings of Giovanni Battista Doni, notably his *Compendio del trattato* (Rome 1635) and his *Annotazioni sopra il compendio* (Rome 1640), despite the interest they have regarding the subject matter of the present article. The attentive reader undoubtly will notice more examples missing. It must be said also that in a number of cases enharmonic keyboards are described without an explicit or implicit motivation being given for it. They are just presented as the only way to build an instrument.

## Nicola Vicentino: *L'antica musica ridotta all moderna pratica (Rome 1555)*

The earliest enharmonic keyboards date, as far as we know, from the middle years of the sixteenth century. The first elaborate description of such an instrument was published by the somewhat wayward Italian composer and theorist Nicola Vicentino in his remarkable treatise entitled *L'antica musica ridotta alla moderna pratica* (Ancient music brought back to modern

4 Gioseffo Zarlino, *Le istitutioni harmoniche*, Venice: (no publisher) 1558, p. 143 (see also Figure 1 below).

practice) and published in Rome in 1555.[5] Vicentino called his instrument the *archicembalo*, which can be literally translated as ‹arch-harpsichord›. Ever since its first description Vicentino's archicembalo has functioned as a kind of archetypal enharmonic instrument. No discussion of the subject can forgo mentioning the archicembalo.

Presumably the archicembalo was already built in 1555.[6] But unfortunately Vicentino does not tell us who built the instrument, or when or where, as Zarlino did for example concerning his instrument in *Le istitutioni harmoniche* of 1558 (see below) and half a century later Fabio Colonna in *La sambuca lincea* of 1620 (see below). Vicentino provided, however, in his *L'antica musica*, detailed descriptions and drawings that give us a clear picture of what the instrument looked like, how it was constructed and what it intended to make possible. By 1561 the archicembalo was supplemented with an *arciorgano* of similar construction, as far as the keyboards were concerned.[7] The basic design of the archicembalo and the arciorgano is that of a harpsichord with two manuals, each of which had three rows of keys: one row of lower keys, and two rows of raised keys.

Vicentino's *L'antica musica* is an entirely verbal (and often verbose) book, without any figure or formula. This certainly makes for ease of reading but leaves open a certain number of questions, one of which is the tuning of the archicembalo. From what is indeed clear it may be concluded that the three rows of keys of the lower manual and the lower two rows of the upper formed together a 31-note keyboard, with 31 pitches per octave, which can be ordered

5 Nicola Vicentino, *L'antica musica ridotta alla moderna pratica* (Rome: Antonio Barre, 1555). Facsimile edition, ed. by Edward E. Lowinsky, Kassel 1959 (= Documenta Musicologica Erste Reihe 17). English translation with introduction and notes by Maria Rika Maniates as *Ancient Music Adapted to Modern Practice*, New Haven 1996 (= Music Theory Translation Series). The classical introduction to Vicentino's life and work is Henry W. Kaufmann, *The Life and Works of Nicola Vicentino (1511-c.1576)*, [Rome] 1966 (= Musical Studies and Documents 11). About the tuning of the archicembalo see also Henry W. Kaufmann, «More on the Tuning of the Archicembalo», in: *Journal of the American Musicological Society* 23 (1970), pp. 84–94; Peter Niedermüller, «La musica cromatica ridotta all pratica vicentiniana: Genus, Kontrapunkt und Musikalische Temperatur bei Nicola Vicentino», in: *Neues Musikwissenschaftliches Jahrbuch* 6 (1997), pp. 59–90, and Denzil Wraight's contribution «The *cimbalo cromatico* and other Italian string keyboard instruments with divided accidentals» to the present volume.

6 See Wraight, «*The cimbalo cromatico*», in this volume.

7 Described by Vicentino in his *Descrizione dell'arciorgano* (Venice: Nicolo Bevilacqua, 1561), translated in Johannes Wolf, «Das Arciorgano des Nicola Vicentino (1561)», in: *Der deutsche Instrumentenbau. Zeitschrift für Instrumentenbau und Instrumentenkunde* 35 (1900), pp. 299–302, and in Henry W. Kaufmann, «Vicentino's Arciorgano: An Annotated Translation», in: *Journal of Music Theory* 5 (1961), pp. 32–53.

in a scale of 31 steps of equal size. The tuning of the uppermost row of the upper keyboard is not entirely clear, but seems to stand apart from the tuning of the five lower rows; we will not occupy ourselves with it. So Vicentino's archicembalo may be seen as a 31-note keyboard.[8]

The 31-note system is not so far removed from the ordinary 12-note system as it may look like at first sight. Most pitches of the 12-note system have an easy and satisfactory counterpart in the 31-note system. The 7-note diatonic scale is represented by pitch with the numbers 0, 5, 10, 13, 18, 23, 28, and 31, if the 31 pitches are just given a sequential number, starting with zero for C. An important difference between the 12-note and 31-note systems is that the 31-note system has different keys for the sharps and flats that are played with the same key on a 12-note keyboard. In the 31-note system the chromatic semitone covers two steps, the diatonic semitone three. That gives C♯ key 2, D♭ key 3, D♯ key 7, E♭ key 8, etc. The 31-note system provides new pitches in the middle of every chromatic semitone, that is, one between C and C♯ (namely, key 1), between D♭ and D (key 4), between D and D♯ (key 6), between E♭ and E (key 9), etc.

How did come Vicentino to construct and tune a 31-note keyboard? The answer lies in the imitation of the ancient enharmonic genus. Theorists of the fifteenth and sixteenth centuries had remarked that the Greek enharmonic genus did not have a role in the contemporary tonal system, but in this humanistic time many music theorists, Vicentino among them, could not withstand the lure of the enharmonic genus. The theory of the enharmonic genus was an extension of that of the diatonic and chromatic genera.

The diatonic genus could simply be represented by a tetrachord such as

B - C - D - E

The chromatic tetrachord came into being by lowering the second highest note from D to C♯:

B - C - C♯ - E

To make an enharmonic tetrachord, the second highest note was lowered again, now to C, which led to a lowering of the third highest note to a position between C and B, a position that we will call B+ for the moment:

B - B+ - C - E

8 See also Patrizio Barbieri, «I temperamenti ciclici da Vicentino (1555) a Buliowski (1699): Teoria e pratica ‹Archicembalistica›», *L'Organo* 21 (1983), pp. 129–208, especially pp. 160–166.

How can exact pitch values given to these notes? The answer to this question is far from easy. As easy as it is to propose the diatonic, chromatic, and enharmonic genera, so is it difficult to provide exact pitches for the notes involved in them. Of course, the pitches chosen depend on the tuning system adopted. But this very observation is the beginning of all the difficulties. Should one adopt the tuning system(s) from Greek music theory or one of those in contemporary (sixteenth-century) theory or practice? Vicentino choose a solution that was in agreement with the mainstream of contemporary (sixteenth-century) music theory.

Sixteenth-century interval theory is dominated by a system that is called *just intonation* today. Its starting points are the octave with the frequency ratio 1:2, a fifth with 2:3, and a major third with 4:5. From this it is easily derived that the fourth represents a ratio of 3:4, the minor third of 5:6, the major sixth of 3:5, the minor sixth of 5:8. One of the peculiarities of the system is that for the dissonant intervals several ratios are always in use, depending on how the interval was derived as the summation and subtraction of consonant intervals. For the major second or whole tone the ratios 8:9 (major whole tone; 204 cents) and 9:10 (minor whole tone; 182 cents) are in use. For the minor second or diatonic semitone the ratio 15:16 (112 cents) is the basic one, for the chromatic semitone the ratio 24:25 (71 cents).

Which interval ratios should be chosen for the various tetrachords as sketched above? The fourth 3:4 (B-E), the major third 4:5 (C-E), and the minor third 5:6 (C♯-E) are not difficult to decide upon. The problems arrive with the whole tones and smaller intervals. The whole tones in the diatonic tetrachord are usually taken as one major whole tone (8:9; D-E) and one minor whole tone (9:10; C-D), the semitones in the chromatic tetrachord as the diatonic semitone 15:16 (B-C) and the chromatic semitone 24:25 (C-C♯). So far, so good. But what to do with the enharmonic intervals, or the position of B+ between B and C? A solution here is particularly difficult since any traditionally available way failed here to divide an interval into two smaller intervals of comparable rank. The major third could be divided into two whole tones (one major, one minor), the (major) whole tone could be divided into two semitones, one diatonic, one chromatic. For the major (diatonic) semitone no such obvious division was available.

Instead, it was unavoidable that the difference in size between the two types of semitones, the diatonic and the chromatic, would play a part. The major whole tone (204 cents) and the minor whole tone (182 cents) differ between them by a syntonic comma, which is with its 22 cents by no means negligible, but in size small (about one tenth) in comparison with the two types of whole tones themselves. The difference in size between the chromatic and diatonic semitones is, however, of a much more drastic nature. The smaller of the two semitones is the chromatic, which, with its ratio 24:25, equals 71 cents. The diatonic or major semitone has a ratio of 15:16, which equals 112 cents and which prevents the two semitones being seen as more or less of the same size. It is better to say that the sizes of the chromatic and the diatonic semitones are more or less in the proportion of 2:3. We have demonstrated this ratio with the help of cents, but the sixteenth-century scientist may have done the same with arithmetical methods.

The large difference between the chromatic and diatonic semitones made it possible to use the chromatic semitone as an interval to divide the diatonic semitone. After all, what remained when the diatonic semitone (112 cents) was diminished by a chromatic semitone (71 cents), was still an interval of substantial size, namely 41 cents. This interval has a ratio of 125:128 and is commonly known as the minor diesis or, in short, the *diesis*.[9] If indeed the chromatic semitone is used to divide the diatonic semitone into two parts, this can be done in two ways. First, the lower interval can be the chromatic semitone, the higher one the diesis:

B - chromatic semitone - B♯ - diesis - C

The ‹B+› has now been named B♯, because is it a chromatic semitone higher than B. A second way to divide the diatonic semitone is to have the chromatic semitone as the higher interval. In that case the intervening note ‹B+› can be called C♭, since it is a chromatic semitone lower than C:

B - diesis - C♭ - chromatic semitone - C

Since the diesis and the chromatic semitone are roughly in the proportion of 1:2, combining both types of division leads to a division of the diatonic semitone into three more or less equal intervals:

B - diesis - C♭ - [....] - B♯ - diesis - C

The consequences of the double division of the diatonic semitones are enormous, since it makes the generalization over the entire keyboard possible. A diatonic semitone now equals three small «parts», a chromatic semitone two. If all diatonic and chromatic semitones are constituted of these «parts», the entire octave has 7x3 + 5x2 = 31 «parts». If the «parts» are, for practical purposes, considered to be of equal size, the entire keyboard is now one with 31 pitches per octaves, more or less laid out in a regular series of ascending (or descending) pitches. In other words, it tranforms the 12-note keyboard into a 31-note keyboard. Vicentino calls the 31 parts that make up an octave dieses. By doing this he gives the term diesis a slightly different meaning than

9 The major diesis is the difference between four minor thirds and an octave, and has the ratio 625:648 (63 cents).

it had in traditional theory. In the latter it strictly has the size of 125:128 (or 41 cents); it arises as the difference between an octave and the sum of three just major thirds. For Vicentino a diesis was a small step, 31 of which formed an octave. If the steps are all taken as having equal sizes, this diesis has the size of 39 cents (or 38.710 cents to be more exact), a little less than the traditional diesis (which has the size of 41.059 cents if the same order of exactness is applied).

This is what Vicentino must have done, although one looks in vain in his book to find an explicit derivation. Where it comes to the enharmonic tetrachord, Vicentino applies only the division of the diatonic semitone with the smaller interval (the diesis) on the lower position.[10]

Vicentino notated the enharmonic pitches by adding dots over notes. A note with a dot above it is one diesis higher than the corresponding note without diesis. The dot is placed on top of all natural notes and sharps and flats. This simple addition suffices to provide a full notation for the 31-note scale, as is clear from the following example, where the succesive pitches or keys have been numbered from zero onwards (the dots have been placed behind the note names instead of on top of them):

0: C 1: C· 2: C♯ 3:D♭ 4: D♭· 5: D 6: D· 7: D♯ 8: E♭ 9: E♭· 10: E

Looking back at the reasoning given above, it will be clear that the construction of Vicentino's keyboard resulted from a coincidence not foreseen by the Greek theorists who had launched the enharmonic tetrachord about one thousand years before. For them the semitone of the enharmonic tetrachord was to be divided into two parts that were in principle equal and could be called dieses. The division of an interval strictly in equal parts is carried out by the so-called geometrical division. If realized in numerical terms, the method requires a root extraction, a procedure not yet readily available in the sixteenth century. Vicentino followed sixteenth-century principles of interval construction out of just-intonation ratios, which implied the use of ratios with small integers. This way of working does not allow the division of an interval into two equal parts. Therefore, all interval divisions in sixteenth-century music theory are unequal divisions, such as the division of the octave in the fifth and the fourth, the division of the fifth in the major and minor thirds, the division of the major third in the major and minor whole tones, and the division of the whole tone in the diatonic and chromatic semitones. This principle was now extented to the division of the diatonic semitone into two unequal parts, the chromatic semitone (also called the chromatic diesis) and the diesis (or enharmonic diesis).

10 Vicentino, *L'antica musica*, fol. 15.

Vicentino's treatise is interesting because it not only describes the enharmonic genus and the 31-note scale as theoretical concepts, but puts them into practice as well. On the one hand he designed the archicembalo to produce enharmonic pitches as sound, on the other he composed music in the enharmonic genus, which was printed in *L'antica musica*. In all there are four such pieces, all for four voices: «Musica prisca caput» (with phrases in the diatonic, chromatic and enharmonic genera respectively, 48 *brevis* measures), «Soav'e dolc'ardore» (a 14-measure fragment entirely enharmonic), «Dolce mio ben» (a 26-measure fragment entirely enharmonic), and «Madonna il poco dolce» (a 44-measure fragment entirely enharmonic).[11] In these compositions the enharmonic tetrachord is not used as a melodic figure. Instead, the enharmonic pitches are used to raise certain major and minor chords by a diesis that as a whole sound ‹normal› internally. This creates melodic intervals in the various voices that are one diesis larger or smaller than the ‹normal› melodic interval. When this is done to the ‹dominant chord› before a ‹tonic chord› a ‹sharp› leading-note is created, one that is a minor semitone removed from the tonic (instead of a major semitone).

Appendix 1 of this article contains a transcription in keyboard notation of «Soav'e dolc'ardore». It is clearly seen in it that there is an alternation of chordal blocks of *brevis* or semibreve length that are shifted upward by a diesis and blocks which are not shifted, again of *brevis* or semibreve length. It is not as difficult to play this or Vicentino's other compositions on the archicembalo as it may look at first sight. The non enharmonic passages may be played on the lower manual in a fairly normal way: one has only to distinguish carefully between sharps and flats that are served by the same key on 12-note instruments. The enharmonic passages are played on the upper manual again simply as usual because the fourth rank is a diesis-raised repetition of the first rank. The fifth rank provides the flats for the naturals of the fourth rank. Only there are no diesis-raised sharps on the upper manual. Vicentino has thought of this and has replaced them in his compositions by ordinary flats of the next higher natural, to be played on the third rank of keys, of the lower manual.

So Vicentino's motivation for building the archicembalo may be summarized in the following succinct phrase: the archicembalo was constructed in order to make audible the enharmonic pitches of Greek music theory.

11 These pieces are edited in Kaufmann, *Life and Works*, pp. 140–146; in Barbieri, «I temperamenti», pp. 170–173; in Alexander Silbiger (ed.), *Nicola Vicentino: Four enharmonic madrigals for four voices (Rome, 1555)*, Utrecht 1990 (= Corpus Microtonale 33); and in Maniates, *Ancient Music*, pp. 209–222.

## Gioseffo Zarlino: *Le istitutioni harmoniche* (Venice 1558)

The Venetian music theorist Gioseffo Zarlino has earned his place in the early history of the enharmonic keyboard from an instrument that he had made by Dominico da Pesaro in 1548. If it is difficult to say whether Zarlino's instrument is older than that of Vicentino; at least it is the earliest enharmonic instrument for which a date is known. It is described and pictured in *Le istitutioni harmoniche* (first published in 1558) in the section that follows the description of the enharmonic tetrachord so that it may nearly be taken for granted that the purpose of the instrument was – as Vicentino's – to illustrate the enharmonic tetrachord or the enharmonic genus in general.

The chapter in which the enharmonic keyboard is discussed is Capitolo 47 of the Seconda Parte of *Le istitutioni harmoniche*. It is towards the end of the *Seconda Parte*, which is devoted to the pitch systems of music. First the antique system is described including the various tetrachords and genera; they have been constructed according to the principles of Pythagorean tuning, with the just fifth (with ratio 2:3) as the basis of everything. Thereafter modern elements are included, such as just intonation intervals and Zarlino's keyboard temperament based on fifths that are tempered by 2/7 of a syntonic comma. Finally, Zarlino returns to the tetrachords and describes how the notes of the chromatic and the enharmonic tetrachords may be inserted in a just-intonation framework.

The chromatic tetrachord is ‹solved› in Chapter 46 in the following way:[12]

| | | |
|---|---|---|
| 60 E | | Hypate meson |
| | Trihemituono [= minor third: 60:72 or 5:6] | |
| 72 [C]♯ | | Lychanos hypaton |
| | Semituono minore [= minor or chromatic semitone 72:75 or 24:25] | |
| 75 C | | Parhypate hypaton |
| | Semituono maggiore [= major or diatonic semitone 75:80 or 15:16] | |
| 80 H | | Hypate hypaton |

The enharmonic tetrachord is similarly treated in the next chapter (47) and is solved in this way:[13]

| | | |
|---|---|---|
| 300 a | | Mese |
| | Sesquiquarta [= major third: 300:375 or 4:5] | |
| 375 F | | Lychanos meson |
| | Supertripartiente 125 [= minor diesis 375:384 or 125:128] | |
| 384 [E] V | | Parhypate meson |
| | Sequiventesima quarta [= minor or chromatic semitone 72:75 or 24:25] | |
| 400 E | | Hypate meson |

12 Zarlino, *Le istitutioni harmoniche* (1558), p. 138.
13 Zarlino, *Le istitutioni harmoniche*, p. 140.

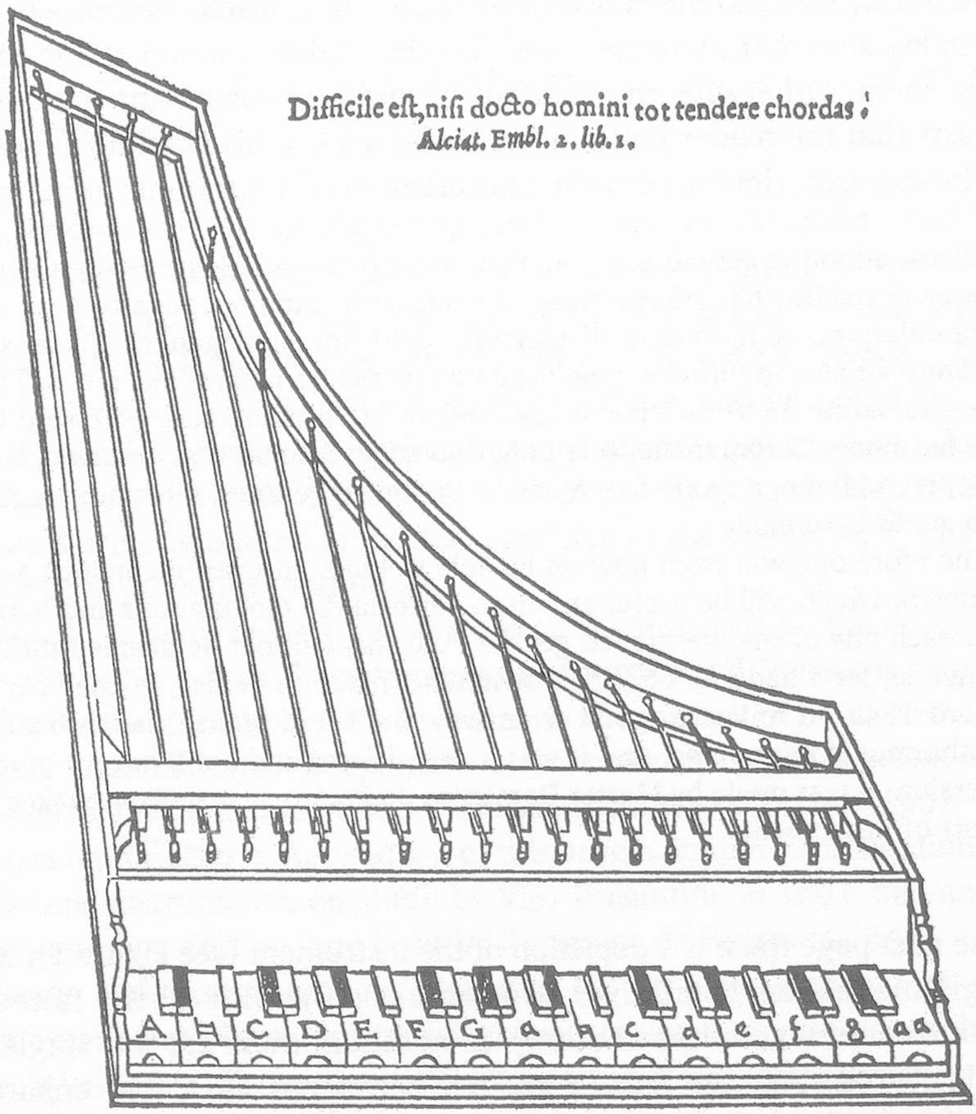



Figure 1. Zarlino's enharmonic harpsichord, as depicted on p. 143 of *Le istitutioni harmoniche* (Venice 1558).

These notes, Zarlino continues, are suitable on a musical instrument if only one makes sure that there are fifths, fourths, major or minor thirds above or below them. Otherwise they cannot be used as consonant intervals. He suggests that the reader has built an instrument to his (Zarlino's) design so that he can experiment with the chromatic and enharmonic genera:[14]

> «Potrà adunque ciascuno per lo avenire fabricare uno istrumento alla simiglianza di quello ch'io hò mostrato; il quale sarà commodo, & atto a servire alle modulationi, & harmonie di ciascuno delli nominati generi; Et questo non parerà ad alcuno difficile: percioche uno de tali istrumenti feci fare io l'anno di nostra salute 1548. in Vinegia, per vedere, in qual maniera potessero riuscire le harmonie Chromatiche, & le Enharmoniche; & fu un Clavicembalo, & è anco appresso di me, il quale fece Maestro Dominico Pesarese fabricatore eccellente di simili istrumenti.»
> Therefore one will from now on be able to build an instrument such as I have shown, which will be useful and fit to perform the modulations and harmonies of each one of the mentioned genere. And this will not be deemed difficult by anyone, for I had one of such instruments made in Venice, in the year of our Lord 1548, in order to see in what way one could realize the chromatic and enharmonic harmonies. And it was a harpsichord and I still have it in my possession; it was made by Master Domenico da Pesaro, an excellent maker of that sort of instruments.

On the next page there is a depiction of the instrument (see Figure 1). It gives a single-manual keyboard over two octaves only, with all the raised keys split into two (next to one another). In addition, there are two single extra raised keys, one between E and F and one between B and C. The enharmonic keys (that is, the ones missing in 12-note keyboards) are supposed to be red. All together it is a 19-note keyboard.

Until relatively recently it has been generally assumed (also by me) that the picture of the keyboard matched the information about the Dominico da Pesaro harpsichord given by Zarlino in his text one page earlier. Christopher Stembridge first established convincingly that the instrument referred to in the text did not fit the picture and could instead better be viewed as an instrument having a keyboard with 24 pitches per octave.[15] There are several reasons for this. First, Zarlino states in his text also that on the instrument[16]

14 Zarlino, *Le istitutioni harmoniche*, p. 140.

15 Christopher Stembridge, «The *Cimbalo cromatico* and Other Italian Keyboard Instruments with Nineteen or More Divisions to the Octave (Surviving Specimens and Documentary Evidence)», in: *Performance Practice Review* 6/1 (1993), pp. 33–59, especially pp. 43–54; see also Wraight, «The cimbalo cromatico», in this volume.

16 Zarlino, *Le istitutioni harmoniche*, p. 140.

> «non solamente li Semituoni maggiori sono divisi in due parti, ma anche tutti li minori.»
> not only the major semitones are divided into two parts, but also all the minor semitones.

The latter division is certainly not applied to the instrument depicted. If we interpret ‹all the minor semitones› as ‹all the minor semitones of a 12-note keyboard›, the instrument must have, in addition to the ones depicted, keys between C and C♯, between E♭ and E, between F and F♯, between G and G♯, and between B♭ and B. The resulting pitches could be called D♭♭, D♯♯, G♭♭, A♭♭, and A♯♯. It would require all the whole tones of the diatonic scale (of C major), namely C-D, D-E, F-G, G-A, and A-B, to be divided into four parts, as Zarlino remarked in the 1573 revision of the *Istitutioni*.[17] The total number of keys would then be 24.

That there were indeed five extra keys is confirmed by the description of the instrument that the seventeenth-century blind Venetian composer Martino Pesenti (*c*1600-*c*1648) provided in the preface of his *Correnti, gagliardi, e balletti diatonici, trasportati parte cromatici, e parte henarmonici … Libro quarto, Opera decimaquinta* (Venice: Alessandro Vincenti 1645).[18] The preface is reproduced in Appendix 2 of this article. In it Pesenti mentions two enharmonic instruments, one built by Vito Trasuntino in 1601, and another one ‹invented by Zarlino, and built by Dominico da Pesaro in 1548›. Pesenti had known both instruments and played on both of them. Neither instrument has survived, but obviously the latter instrument is the one described in Zarlino's *Istitutioni*. Trasuntino has become particularly well known because he is the builder of one of the few surviving enharmonic harpsichords of the decades around 1600, the *Clavemusicum omnitonum* that survives in the Museo Civico, Bologna.[19]

After reciting the histories of the instruments, he goes on to describe them both, comparing them, key by key. As said before, Pesenti's description provides five keys that are not present in the picture in Zarlino's *Istitutioni*, which he gives the names of C♯♯, D♯♯, F♯♯, G♯♯, and A♯♯. Their pitches do divide chromatic semitones into two parts, but not always the same as mentioned above, when interpreting Zarlino's phrase about them on face value. The pitch names given by Pesenti would point to the chromatic semi-

17 Gioseffo Zarlino, *Istitutioni harmoniche*, Venice: Francesco dei Franceschi 1573, p. 164: «ma anche li minori, di maniera che ogni Tuono viene ad essere diviso in quattro parti.»

18 See Carl Morey, «The Diatonic, Chromatic, and Enharmonic Pieces by Martino Pesenti», in: *Acta Musicologica* 38 (1966), pp. 185–189.

19 Inv.-no. 1766; a playable copy is in the Germanisches Nationalmuseum, Nuremberg, MI 533.

tones D♭-D, E♭-E, G♭-G, A♭-A, and B♭-B as the ones to be divided. It is difficult to decide whether our guess was the choice of pitches meant by Zarlino, or Pesenti's listing. After all, when Pesenti first played on the instrument, it was out of tune, while, being blind, he could not see which keys were red. In favor of Pesenti's interpretation is that the pitches in it can be ordered into a single line of fifths: after E♯ and B♯ follow F♯♯, C♯♯, G♯♯, D♯♯, and A♯♯. When Charles Burney saw the instrument in Venice in 1771, in the house of the widow of the composer Giovanni Battista Pescetti, there Zarlino's handwritten tuning instructions pasted to the back of the nameboard.[20] One must assume that the instructions were there also when Pesenti investigated the instrument and that someone has read them for him. So for the moment Pesenti's description should be accepted as the best one available.

After having compared both instruments, Pesenti stated his preference for Zarlino's, because it is ‹il più regolato del tutto› (of all the most conforming to the rules). He quotes the passage from the 1573 revision of the *Istitutioni harmoniche* where the instrument is described and which we have quoted above. The final lines of Pesenti's preface are remarkable. First he apologizes that he has not composed a toccata that would pass from the diatonic via the chromatic to the enharmonic genus and would then return via the chromatic back to the diatonic. He has not done so ‹because it is difficult to find oneself a harpsichord with all the three afore-mentioned genera.› Nevertheless, he continues, he has presented the various *correnti, gagliarde* and *balletti* in the chromatic and enharmonic genera since these can be played on lutes and viols, instruments encompassing (in his opinion) the chromatic and enharmonic genera. Unfortunately he did not start a discussion of how the enharmonic (or even the chromatic) pitches should be realized on these instruments. It does not seem very sensible to perform them on lutes or viols fretted in 12-note equal temperament, which leaves only the alternative that Pesenti must have thought of lutes and viols fretted in 31-note equal temperament. One could wish for a confirmation for this thought.[21]

20 Burney copied the instructions, but he did not publish them, as he intended to do. Neither the original instructions nor Burney's copy has survived. See Percy A. Scholes (ed.), *Dr. Burney's Musical Tours in Europe, Volume I: An Eighteenth Century Musical Tour in France and Italy*, London 1959, p. 189.

21 See about possible additional frets on the viol for enharmonic music Martin Kirnbauer, «‹Wherein the Most Compleat Harmony was heard›: The Viola da Gamba in Chromatic and Enharmonic Music in Seventeenth-Century Rome», in: Susan Orlando (ed.), *The Italian Viola da Gamba. Proceedings of the International Symposium on the Italian Viola da Gamba, Magnano 29 April – 1 May 2000*, Solignac & Turin 2002, pp. 34–51.

Finally there is a music example ‹after Zarlino› with the enharmonic tetrachords on B, e, b, e1, and a, on a single staff with seven lines. The enharmonic pitches use the simple cross ‹x› as accidental. I assume that the music example is based on Zarlino's enharmonic monochord depicted on p. 116 of *Le istitutioni harmoniche*.[22] The pitches in Pesenti's example are exactly those in Zarlino's monochord. Looking at that picture, for example, makes clear why the a-d1 tetrachord has been put at the rightmost end of Pesenti's example. Pesenti may have taken the sign ‹x› (which is missing in Zarlino's monochord, which has no musical notation at all) from other illustrations of the *Istitutioni*.

Although we now know by Pesenti's description that Zarlino's keyboard had 24 keys per octave, this raises more questions that it answers. The big question especially is that of why Zarlino needed a 24-note instrument to let him hear the enharmonic genus. A 19-note keyboard as depicted would have served this aim very well, since it provides enharmonic tetrachords of the kind described by Zarlino on all the seven degrees of the diatonic scale:

B - B♯ - C - E
C - C♯ - D♭ - F
D - D♯ - E♭ - G
E - E♯ - F - A
F - F♯ - G♭ - B♭
G - G♯ - A♭ - C
A - A♯ - B♭ - D

The 19-note design that is depicted in *Le istitutioni harmoniche* is much more regular than the actual 24-note design of the instrument. At least some instruments with 19 keys per octave have been built during the decades around 1600, of which the *Clavicymbalum universale*, described by Michael Praetorius in his *Syntagmatis musicum tomus secundus* (Wolfenbüttel 1619) is the most famous.[23]

But one looks in vain for a motivation Zarlino's addition of the five keys added to the 19-note design. All Zarlino mentions is that the keyboard may illustrate the enharmonic genus and that it splits diatonic and chromatic semitones into two parts. Whereas he is comprehensive and verbose every-

22 That is, page 116 in the first edition, of 1558. Pesenti almost certainly used the revision of the *Istitutioni* issued in 1573.

23 According to Praetorius the *Clavicymbalum universale* was built in Vienna around 1590 and in 1619 in the possession of Carolus Luython in Prague. See *Syntagmatis musici Tomus secundus*, Wolfenbüttel: Elias Holwein 1619, chapter 40, pp. 63–66. For further 19-note harpsichords, see Wraight, «*The cimbalo cromatico*», in this volume.

where else in his writings, he is sketchy and indirect here. On the near 350 pages of the *Istitutioni* one or two pages more to explain the keyboard would not have made much difference. The only reason that I can think of for Zarlino's vagueness is his wish not to be associated with Vicentino and the latter's *archicembalo*. This may also be implied in the words that follow the description and praise of his instrument:[24]

> «Et ancora che se ne potessero fare degli altri con diverse divisioni; nondimeno io credo, che da loro si possa cavare poca utilità: percioche in loro senza alcuna necessità sono moltiplicate le chorde; le quali (oltra le mostrate) non sono atte ad esprimere altri concenti, più dilettevoli, che quelli che fanno udire quelle, che sono collocate nel mostrato istrumento; i quali veramente sono Diatonici, over Chromatici, o pure Enharmonici.»
> And although it would be possible to make other instruments with several divisions, they would prove, none the less, of little purpose, for in them the strings are multiplied without necessity, which [strings] (except the ones shown [in my instrument]) are not fit to express other consorts of sounds more delightful than those which the strings render audible that are placed together in the instrument shown, which really are in the diatonic, chromatic, or enharmonic genera.

What is striking is that Zarlino mentions compositions using enharmonic pitches in one breath with those having chromatic and diatonic pitches, as if enharmonic compositions were to be found abundantly. Perhaps these sentences must be seen as an indirect criticism of Vicentino, who is never mentioned by Zarlino, let alone his ideas discussed.

An advantage of a 24-note keyboard over a 19-note one is that the 24-note keyboard does not only provide enharmonic tetrachords based on the natural notes, but also such tetrachords on the raised keys:

C♯ - C♯♯ - D - F♯
D♯ - D♯♯ - E - G♯
F♯ - F♯♯ - G - B
G♯ - G♯♯ - A - C♯
A♯ - A♯♯ - B - D♯

But it is difficult to see what use Zarlino could have made of this. True, it allows full major scales on all ordinary sharps and on E♯ and B♯. But on the flats's side D♭ is the furthest out with a full major scale. The scale of G♭ is prevented by the absence of a C♭.

Trasuntino's instrument of 1601, as described by Pesenti, allowed of course a few more enharmonic tetrachords, namely those on E♯, B♯, B♭, and E♭, and an equal number of extra major scales. His keyboard falls only three

24 Zarlino, *Le istitutioni harmoniche* (1558), pp. 140–141.

keys short of Vicentino's 31-note keyboard, on which, of course, enharmonic tetrachords are possible on all degrees, including the ‹enharmonic notes› themselves. That Trasuntino's instrument was to be tuned in meantone temperament can be derived from a remark by Pesenti that is puzzling at first sight. After having described Trasuntino's instrument he says that there are two keys between B and C, namely B♯♯ and C♭, that make up a major, that is, diatonic semitone. Strictly speaking the interval B♯♯-C♭ is not a diatonic semitone. But if is taken as three steps (C♭-B♯-C-B♯♯) in a 31-note octave it is a diatonic semitone in a 31-note tuning, and therefore in meantone tuning.

Pesenti's preface was to introduce a set of thirty pieces, all of them first presented in the diatonic genus, using such normal keys as F, C, and G major and G, D, and A minor, just the standard keys of meantone temperament. Each piece is followed by a transposition into the chromatic genus (eleven times) or enharmonic genus (19 times). Most of the ‹chromatic keys› are remote keys with flats; most of the ‹enharmonic keys› are remote keys with sharps. It is not clear why the keys with the flats are called chromatic, the ones with sharps enharmonic.

If one lists all the tonic keys of Pesenti's chromatic and enharmonic pieces, there are 19. Except C♭ and F♭, all pitches that are either naturals or sharps or flats have been used as tonic, for both a major and a minor key. This set of tonic pitches corresponds with the set of pitches normally present in a 19-note keyboard of the time, that is, with E♯ and B♯, but without C♭ and F♭. The question now is whether all of Pesenti's pieces would be playable on Zarlino's keyboard. The elaborate description of the keyboard suggests that they would indeed, but this is too simple an answer. A closer look of Pesenti's pieces tells us, namely, that they can be played on Zarlino's harpsichord if one is willing to retune one or both of the E♯ and B♯ keys into F♭ and C♭ when needed. (On Trasuntino's harpsichord they could be played without this retuning.) Some pieces would require a rather far-out key signature (if notated), frequently of more than seven sharps. This is the case for A♯ major (10 sharps), B♯ minor (9 sharps), B♯ major (12 sharps), D♯ major (9 sharps), E♯ minor (8 sharps), E♯ major (11 sharps), and G♯ major (8 sharps). An example of a diatonic composition turned into a chromatic is given in Appendix 3; the conversion of a diatonic composition into an enharmonic is illustrated in Appendix 4.

There is a missed chance in Pesenti's *Correnti, gagliardi, e balletti*. Having major and minor keys on 19 pitches in the octave results in a set of 38 keys or tonalities, 19 major and 19 minor. Pesenti's six diatonic keys and the 30 chromatic plus enharmonic keys add up to 36 at most, leaving two keys unused. Which keys are missing? In fact, three keys are missing, since one key is present twice: A major, which is to be found among the chromatic *and* the enharmonic pieces. The placement of an A major piece among the chromatic pieces seems to be a mistake: it is the only piece there with a scale having sharps and no key signature. All other chromatic pieces have scales with at least two flats and a key signature of two flats. Missing is D major as far as keys with sharps are concerned, and D♭ minor and G♭ minor of the keys with flats. With these keys included Pesenti would have created a complete ‹well-tempered enharmonic clavier›. None the less Pesenti's set is remarkable and it is an important testimony in the history of the enharmonic genus.

Let us return to Zarlino. In the *Sopplimenti musicali,* published in 1588, in Chapter XI of the *Libro quarto*, Zarlino presented another multi-note keyboard.[25] It shows an entirely different design and serves an entirely different aim than the 24-note keyboard described in the *Istitutioni* of thirty years earlier. Perhaps the new keyboard should be rather called a chromatic keyboard, since it differs from normal keyboards only in the doubled D key and three split raised keys, the ones between D and E, F and G, and A and B.

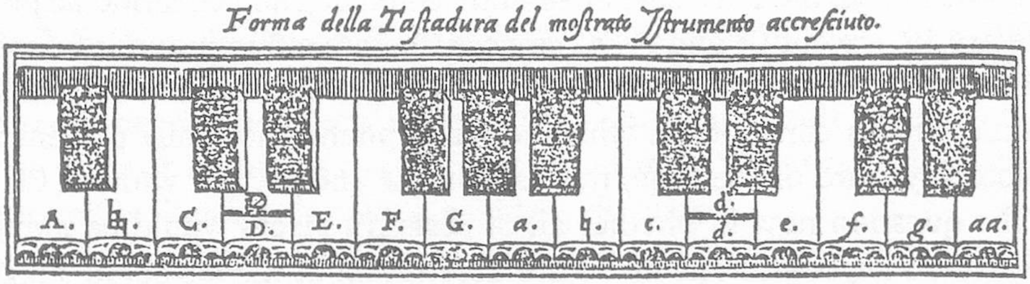



Figure 2. Zarlino's *Istrumento accresciuto*, a multi-note just-intonation keyboard, as depicted in the *Sopplimenti musicali* (Venice 1588), p. 156.

Zarlino himself called it his *Istromento accresciuto* (increased instrument). A table lists monochord string lengths and from these it is clear the instrument is to be tuned in just intonation, with just or untempered fifth and major thirds.[26] This is all in opposition to the tempered tunings described by Zarlino from 1558. An analysis of the figures given by Zarlino for his just intonation keyboard reveals the following scheme of just fifths and major thirds (note names are modern):[27]

25 Gioseffo Zarlino, *Sopplimenti musicali*, Venice: De' Franceschi 1588, p. 156.

26 Zarlino, *Sopplimenti*, p. 155.

27 Zarlino gives 13834 instead of 13824 for C♯.

| | | | | | |
|---|---|---|---|---|---|
| | F♯ 10368 | C♯ 13824 | G♯ 9216 | | |
| | D 12960 | A 8640 | E 11520 | B 7680 | F♯ 10240 |
| E♭ 12150 | B♭ 8100 | F 10800 | C 14400 | G 9600 | D 12800 |
| | | | | E♭ 12000 | B♭ 8000 |

This not a very efficient system of just intonation, but it has several important characteristics. There are just fifths between all of the twelve scale pitches, and there are just major thirds upon all notes except B, F♯, C♯, and G♯. To achieve this a number of notes must be present twice, namely E♭, B♭, D, and F♯. But the system is inefficient by the double E♭: nothing is gained by it, while now a true D♯ is missing. With the design, however, Zarlino introduced a new class of enharmonic keyboards, if we may call them so, namely the class of multi-note just intonation keyboards. They are characterized by the extra keys over the normal keyboard (such as the double E♭, B♭, D, and F♯) to provide just consonant intervals, keys to replace other keys, not to form small intervals with them (they do of course, but that is not their purpose). An essential difference with the archicembalo-like instruments is therefore that they have multiple keys that address essentially only one note in the musical scale. This type of keyboard will be met again when the enharmonic keyboards of Mersenne are being discussed.

## *Francisco Salinas: De musica libri septem (Salamanca 1577)*

Early discussions of the archicembalo are relatively rare. It looks as if Vicentino was somewhat frowned upon as a theorist, which is not so difficult to understand in view of the rather eccentric positions he took. Francisco Salinas, in his *De musica libri septem* of 1577 was one of the few who paid attention to Vicentino's archicembalo, although he was clearly opposed to the ideas behind its tuning.[28] In Liber III the various genera are discussed, including the enharmonic. Tonal systems are constructed which have up to and including 24 notes per octave (all in just ratios, with many pairs a comma or diesis apart) and tuning with fifths tempered by 1/3, 1/4, or 2/7 of a comma. In Chapter XXVII of Liber III the archicembalo is discussed.[29] The chapter is ominously headed ‹De prava constitutione cuiusdam instrumenti, quod in Italia citra quadraginta annos fabricari coeptum est, in quo reperitur omnis tonus in quinque partes divisus› (About the wrong constitution

28 Francisco Salinas, *De musica libri septem*, Salamanca: Gastius 1577. Facsimile ed. by Macario Santiago Kastner, Kassel 1958 (= Documenta Musicologica Erste Reihe 13).

29 Salinas, *De musica*, pp. 164–166.

of a certain instrument that was begun to be built in Italy fewer than forty years ago, in which every tone is found divided into five parts). In the first sentence of the chapter it is remarked that the instrument was called *archicymbalum*, but Vicentino is nowhere mentioned. The question also is what is exactly meant by ‹fabricari coeptum est› or ‹has begun to be built›. If this phrase is taken literally, it may mean either that the instrument was unfinished or that the first specimen was built less than forty years before and that later examples were built since. The second alternative seems to be the more plausible of the two, and that would mean that Salinas spoke about the archicembalo as a kind of instrument, not as just one specific example.

Salinas had a rather good idea about what the archicembalo was like. He lucidly described the circular nature of the tuning. Some well-known musicians held the instrument in esteem:[30]

> «Eò quod omnis in eo sonus habet omnia intervalla, atque omnes consonantiae (ut sibi videntur) infernè, & supernè, & post certam periodum ad eundem, aut aequivalentem sibi sonum post 31 intervalla reditur. Si sint dieses in diapason; si semitonia minora, in disdiapason; si majora, in trisdiapason: & sic in tot diapason, quot diesibus intervallum constabit tricies, & semel repetitum.»
> Because every note of it has all intervals, and all consonances (as they appear) below and above, and after a certain time every note returns to the same, or to an equivalent one, after 31 intervals. If it concerns dieses, [31 of them make up] the octave; if minor semitones, the double octave; if major semitones, the triple octave, and so will an interval that is repeated 31 times make up so many octaves as it contains dieses.

He nevertheless rejected the idea of having an octave divided in 31 dieses of equal size. He observed that two dieses could never form a minor semitone, neither in just intonation nor in any type of tempered tuning, which is true if no other interval is accepted as a diesis than the one with the ratio 125:128. He remarked that the diesis of the 31-note system was smaller than the diesis of 125:128 (which is true) and also smaller than the corresponding interval in any of the tempered tunings he described. To begin, the interval C♯-D♭ is exactly 125:128 in meantone temperament, where the fifth is tempered by one fourth of a comma. In the ‹Zarlino temperament› (with the fifths tempered by 2/7 of a comma) the interval C♯-D♭ equals the diesis of 125:128 plus 3/7 of a syntonic comma (or 41+9=50 cents), in the ‹Salinas temperament› (with the fifths tempered by one third of comma) the diesis plus a syntonic comma (or 41+22=63 cents). Systems with fifths tempered less than one quarter of a comma could produce a ‹diesis› smaller than that of 125:128, but Salinas did not consider these. Salinas admitted

30 Salinas, *De musica*, p. 164.

that a whole tone could be divided in five equal intervals by a geometrical division, but such a fifth part of a whole tone was, at least in his eyes, not a diesis.

From his denial of the possibility of the division of an octave in 31 equal parts, Salinas gradually shifted to a comparison of the 31-note equal division with the intervals on a multi-note keyboard of his own. He had already mentioned the instrument earlier in the Liber III of his *De musica*:[31]

> «Sed omnium perfectissimum est, quod ego Romae faciendum curavi, et hic habeo Salmanticae, in quo utrumque reperitur instrumentum, tam perfectum, quam id, quo utimur, imperfectum, et alterius alterum potest fieri collatio, et in utroque tria melodiarum genera maxima cura, atque diligentia perfectissimè demonstrantur.»
> But the most perfect [instrument] of all is the one that I had made in Rome and that I have here in Salamanca. In it both kinds of instruments are found, both the perfect one, and the imperfect one (which is the one used), and one can compare the one with the other, and in both of them the three melodic genera can be demonstrated perfectly and with care and diligence.

The quotation seems to point to some kind of double instrument, one contraption that houses two more or less independent keyboards. That this is indeed the case, becomes clear when the instrument is mentioned again, in the discussion of the relative merits of the 31-note equal division versus just or tempered systems:[32]

> «Nam in tribus primis ordinibus accomodavi temperamentum instrumenti participati, et in tribus supremis perfecti; sonis C litera signatis fixis manentibus, et ad unisonantiam temperatis, quo ex utriusque collatione possit (ut Ptolemaeus ait) legitimum ab spurium, et imperfectum a perfecto discerni.»
> For in the three lower rows I have accomodated the tempered instrument, and in the three upper rows the perfect, while the notes called C remained fixed, and tuned as unisons, so that from their mutual comparison one can (as Ptolemy said) distinguish between the genuine and the false, or between the imperfect and the perfect.

So Salinas's instrument was a kind of ‹archicembalo›, with the three lowermost rows tuned in some kind of temperament and the three uppermost in just intonation. Both three-row manuals were in a sense complete keyboards by themselves. How many keys per octave had these manuals? Three rows of keys can in principle accommodate 21 keys per octave, but there are reasons to believe that both three-row manuals of Salinas's instrument had 19 keys per octave. When discussing the tuning of the archicembalo, Salinas stated

31 Salinas, *De musica*, p. 127.
32 Salinas, *De musica*, p. 166.

that he could not add a fifth above ‹♮ Enharmonicum› (=B♯), because that note (‹inter G molle enharmonicum et G diatonicum›: between G♭ and G, that is, F♯♯) did not have any consonance. In the other direction his series of fifths stopped at G♭, ‹ubi terminatur genus enharmonicum› (where the enharmonic genus ends). Adding a further fifth, C♭, would have to take place on the fourth row of in instrument, as would F♭, but it would give the same imperfection as the F♯♯. This seems to confirm that Salinas's instrument had two manuals with three rows of keys and 19 keys per octave on each manual, an arrangement that, strikingly, is similar to the layout of the keyboard of Vicentino's archicembalo.[33]

Another argument that can be used to support the notion that Salinas adhered to keyboards of not more than 19 keys per octave is the observation that with a tempering of the fifth by one third of a comma, the one seemingly preferred by Salinas, it does not make sense to have more than 19 keys. If one were to expand the row of fifths after B♯, the next pitch, F♯♯, would be undistinguishable from G♭, C♯♯ from D♭, and so on. On the flats' side, C♭ would be practically equal to B♯, F♭ to E♯, and so on. Finally, it may be mentioned that Salinas's enharmonic genus in just intonation has 19 notes per octave if the comma pairs are considered as the same note, something necessary in a tempered system.[34]

The observation that the double 19-note design is thus common to both Vicentino's and Salinas's keyboards makes one wonder if perhaps one was constructed after the example of the other. The time frames usually adopted for the contruction of the instruments overlap completely: Salinas's is said to have been built in Rome between 1538 and 1553, Vicentino's in Rome before 1549, but perhaps already in the decade 1538–1547.[35] Perhaps Salinas's instrument was first meant to be a copy of Vicentino's. It was the archicembalo ‹that was begun to be built fewer than forty years ago›. Salinas tried to tune his instrument according to the opinion of the inventor of the archicembalo.[36] Doing so he found the disquieting imperfection of the fourth and fifth rows as a consequence of the extension of the row of fifths beyond B♯ or G♭. Then he changed his mind and tuned the two manuals as two separate keyboards, with the C as common tone. Now just and tempered tuning could be compared as easily as wished. These observations seem to point to a precedence of the 31-note archicembalo.

33 It may be remarked that the C♭ and F♭ are on the fourth row of Vicentino's archicembalo, as B and E raised by a diesis.

34 See Salinas, *De musica*, p. 122.

35 See Wraight, «The *cimbalo cromatico*», in this volume.

36 Salinas, *De musica*, p. 165: «quoties illud iuxta eius autoris positionem temperare volebam.»

Salinas realized that not all instrumentalists could afford having enharmonic keyboards built. He concludes his discussion of the archicembalo with a plea for at least adding D♯ and A♭ to keyboards that were as usual for the rest, especially in the middle octaves, the ones below and above middle C.[37] His arguments for that was not the expansion of the tonal space of the instrument, but the opportunity it gave to transpose the ordinary church modes. With these four extra keys, he said, the first mode can be played from F (with the A♭) or E (with the D♯), the fourth mode from G, etc.

## *Fabio Colonna: La sambuca lincea (Naples 1618)*

Despite Zarlino's implicit and Salinas's explicit criticisms and despite the complexity of its construction, as a musical instrument the archicembalo, understood as a keyboard with, let us say, at least 24 keys to an octave (to distinguish it from the 19-note design), was some sort of a success. Apart from the ones built for Vicentino and Zarlino, there are the Trasuntino instruments, the ones for Scipione Stella and Fabio Colonna, and several more Italian examples from the first half of the seventeenth century. During the later seventeenth century and the eighteenth century similar instruments were built outside Italy, in the Germanic countries. The Stella and Colonna instruments have been extensively described in a booklet by Fabio Colonna entitled *La sambuca lincea*, published in Naples in 1618.[38] In the book Colonna provides drawings of the keyboards of the instrument. Let us see how Colonna defends the design of his instrument:[39]

> «Habbiamo anco detto Istromento Musico perfetto, poiche vi si ritrova la divisione del Tuono in più minute parti del Semituono minore, & differenti dalla divisione de gli altri, dalla quale dipende la cognitione delle Terze maggiori, & minori; non dichiarate, ne tenute per consonanti dagli Antichi, con tutto che da quelle certamente si dimostri la varietà delli tre gen[er]i di Musica, & particolarmente il Chromatico, & Enarmonico altrimente dolcissimo, & come riferisce Vitruvio, molto grave & di eccellente autorità: che da Moderni Musici è stato stimato incantabile, & però disusato. Il che nel progresso si vedrà essere non meno cantabile del Chromatico, & da quello nella dolcezza, & gravità differire: & questo per beneficio del nostro Istromento, & sua divisione nelli Tuoni, & et parti di quelli.»

37 Salinas, *De musica*, p. 166.

38 Fabio Colonna, *La sambuca lincea, overo Dell'istromento musico perfetto Libri III*, Naples: Constantino Vitale, 1618. Facsimile reprint Sala Bolognese 1980 (= Bibliotheca Musica Bononiensis II 152). Facsimile reprint «con annotazioni critiche manoscritte di Scipione Stella (1618–22)» and an introduction by Patrizio Barbieri, Lucca 1991 (= Musurgiana 24).

39 Colonna, *La sambuca lincea*, pp. 2–3.

> We have called this a perfect musical instrument too, because you find there the division of the whole tone in smaller parts than the minor semitone, different from the divisions of the other [instruments], from which [division] depends the realization of the major and minor thirds, which the Ancients neither mentioned nor held as consonances, in spite of the fact that they certainly determine the variety of the three musical genera, and in particular the chromatic and the enharmonic, [the last of which is] sweet in a different way, and – as Vitruvius has written – very solemn and most majestic; which [however] Modern Musicians have considered unsingable and is therefore not used. Henceforth it will be seen to be no less singable than the chromatic genus, and not to differ from it in both sweetness and gravity, and that thanks to our instrument, and its division of the tones, and the parts thereof.[40]

Colonna brings together here two elements of different origin: the major and minor thirds that could be constructed on every note of the scale (and that were not yet part of ancient music theory) and the diatonic, chromatic and enharmonic genera (rejected by the contemporary musicians) that are possible on his instruments. Just major and minor thirds were part of contemporary music theory, but not of ancient. The enharmonic genus was part of ancient music theory, but not of contemporary thinking. By combining the two elements Colonna took the best of both worlds.

The construction of the keyboards of Colonna's «Sambuca Lincea» with six rows of keys and of Padre Scipione Stella's harpsichord with eight rows of keys has been discussed in the literature already several times.[41] No further discussion is needed here. It may only be remarked that Stella's design is clearly based on the double 19-note design as used by Vicentino and Salinas. Only the two manuals have each been enlarged by a fourth rank of keys that mostly has keys that are four dieses higher (a distance corresponding to the double sharp in a 31-note environment) than the left-adjacent natural key. Colonna's design is a double 21-note design.

It is interesting, however, to spend a few words on Colonna's use of the enharmonic tetrachord, which deviates in several respects from his predecessors. We have seen above that in sixteenth-century interval theory the

40 This translation has benefited from a prior translation by Riccardo Pergolis (Battaglia Terme, Italy).

41 See for example Lynn Wood Martin, «The Colonna-Stella *Sambuca Lincea*: An enharmonic instrument», in: *Journal of the American Musical Instrument Society* 10 (1984), pp. 5–21; Patrizio Barbieri, «La sambuca lincea di Fabio Colonna e il tricembalo di Scipione Stella: Con notizie sugli strumenti enarmonici del Domenichin», in: *Atti del Convegno Internazionale di Studi Napoli, 11–14 aprile 1985*, ed. by Domenico D'Alessandro & Agostino Ziino, Rome 1987 (= Miscellanea Musicologia 2), pp. 167–216; and Barbieri's introduction to the facsimile edition.

division of an interval into two equal parts does not play a role. The means, both conceptual and arithmetical, were lacking for that operation. Intervals were always divided unequally. If an interval was split into two parts, there were therefore always two arrangements of intervals and pitches: one with the smaller interval below and the larger above, and one with the larger interval below, and the smaller above.

Zarlino typically made use of interval divisions that place the larger interval below. The chromatic tetrachord starts from below with the diatonic semitone, followed by the chromatic semitone (and by a minor third). The enharmonic tetrachord starts from below with the diatonic semitone, followed by the diesis (and the major third). Vicentino let his chromatic tetrachord start from below with a diesis. Colonna deviated from this principle by describing two variants for both the chromatic and the enharmonic tetrachord: one with the smaller interval below and the larger above, and one with the larger interval below and the smaller above. Tetrachords of the first type are called *molle* (which we will translate by ‹low›), tetrachords of the second type *intenso* (‹high›). Colonna also provided numerical values (monochord string lengths) for the pitches of the chromatic and enharmonic tetrachords. The diatonic tetrachord, for example, has the following pitches:

B 2000 - C 1882 6/17 - D 1666 2/3 - E 1500

Colonna's string-length values are not derived from certain choices for the size of semitones, whole tones, etc., but were determined by his wish to use only string lengths that satisfy a certain arithmetical condition, namely, that the length for the note and that of the remainder of the string formed some kind of consonant ratio between them, an unfounded and in fact dubious principle, which nevertheless provided a set of ratios that sufficed to produce a scale of some 30-odd pitches per octave.[42] The values for D and E as shown above conform the just-intonation ratios 5:6 and 3:4. The value for C has the ratio of 16:17 if compared with B.

The string lengths and cents values for the first pitches of his scale are, for example:

| | | | | |
|---|---|---|---|---|
| C | 1:1 | 2000 | | 0 cents |
| Cx | 192:197 | 1949 47/197 = | 1949.239 | 45 cents |
| C♯ | 24:25 | 1920 | | 71 cents |
| D♭ | 16:17 | 1882 6/17 = | 1882.353 | 104 cents |
| D♮ | 10:11 | 1818 2/11 = | 1818.182 | 165 cents |
| D | 8:9 | 1777 7/9 = | 1777.778 | 203 cents |

42 For an explanation of Colonna's method see Barbieri's introduction to the facsimile, pp. xii-xviii and xxxvii-xliv.

In a perfectly equal 31-note scale the cents vaules would have been 39, 77, 116, 155, and 194 cents. Colonna's choices show deviations up to about 10 cents, in either direction. This is considerable in view of the about 40 cents unit of the system.

Colonna's two chromatic tetrachords are realized on the following ways:

molle: B 2000 - B♯ 1920 - C♯ 1777 7/9 - E 1500
intenso: B 2000 - C 1882 6/17 - C♯ 1777 7/9 - E 1500

The two enharmonic tetrachord are described as follows:

molle: B 2000 - Bx 1949 47/197 - C 1882 6/17 - E 1500
intenso: B 2000 - B♯ 1920 - C 1882 6/17 - E 1500

Although Colonna's intervals are not an equal division of the octave in 31 parts, the steps in the sequence B - Bx - B♯ - C - Cx - C♯ - D♭ - D♮ [C♯♯] D and so on are treated virtually as steps of equal size. (Colonna uses the cancellation sign ♮ for the lowering of a pitch of a natural by one step.)

At the end of his book Colonna gives examples of short four-part compositions that illustrate the low and high chromatic and enharmonic tetrachords. The well-known composer Ascanio Mayone had provided him with them, without having seen the instrument. The examples illustrating the enharmonic tetrachords are brief four-part settings in score notation. They differ both from Vicentino's and Pesenti's compositions in that the enharmonic tetrachord appears in the melodic lines of the four voices.[43] The examples for the enharmonic genus are transcribed in the contribution of Bob van Asperen in this volume.

In addition, there is a somewhat longer *Esempio della circulatione*, a kind of prelude beginning with a G major chord and then proceeding by cadences via C major, F major, B♭ major, and so on through the entire circle of 31 until the final G major cadence is reached.[44] Although Colonna nowhere mentions let alone describes meantone temperament in any explicit way, the *Esempio* makes it clear that Colonna's tuning and therefore his instrument could be very well used for the generalization of meantone temperament.

43 Mayone's compositions are reproduced in two-staff keyboard notation in Barbieri's introduction to the facsimile, pp. lxii–lxvii. See also the contribution by Bob van Asperen, «Consonant or dissonant? – Reflections at the keyboards of a Clavemusicum Omnitonum, cimbalo cromatico, and cembalo naturale», in this volume.

44 Colonna, *La sambuca lincea*, pp. 103–110. Modern edition by Rudolf Rasch in *Fabio Colonna: Esempio della circolatione, for 31-tone keyboard (1618)*, Utrecht 1985 (= Corpus Microtonale 3), and in Barbieri's introduction to the facsimile, pp. lvii-lxii.

## *Marin Mersenne: Harmonie universelle (Paris 1636)*

The universal scholar Marin Mersenne discussed, in his *Harmonie universelle*, keyboards with more than twelve keys per octave both in connection with the organ and the harpsichord. *Proposition V* of the *Livre troisiesme des Instrumens à cordes* begins with the remark that:[45]

> «Il est certain que l'on peut faire une aussi grande diversité de Claviers, comme il y a de differens Systemes.»
> It is certain that one can make as many different keyboards as there are different systems.

Which is certainly true. He then presents a 12-tone keyboard tuned in just intonation that can be analyzed as the following grid of just fifths and just major thirds (note names are ours):

| | | | |
|---|---|---|---|
| D 3240 | A 2160 | E 2880 | B 1920 |
| B♭ 2025 | F 2700 | C 3600 | G 2400 |
| G♭ 2631¼ | D♭ 3374 | A♭ 2250 | E♭ 3000 |

This survey tells us that all the raised keys have been interpreted as just major thirds below a natural, or, in other word, as flats. After this a second keyboard is shown in which the raised keys are interpreted as sharps (except the B♭).[46] A just-intonation analysis results in the following diagram:

| | | | | |
|---|---|---|---|---|
| F♯ 2592 | C♯ 3456 | G♯ 2304 | D♯ 3072 | |
| | A 2160 | E 2880 | B 1920 | |
| B♭ 2025 | F 2700 | C 3600 | G 2400 | D 3200 |

This scheme has, as is easily seen, an irregularity in that the F♯ (2592) is chosen as a just major third above the D from the first keyboard (3240), whereas in the second keyboard another D has been chosen (3200). The reason for the substitution of the D is not difficult to see: in just intonation it is impossible to have all naturals in one row of just fifths. In the first keyboard there is a ‹jump› from G 2400 to D 3240 which is a fifth diminished by a syntonic comma. If a just fifth between G and D is desired, the D must be 3200, but this shifts the comma-diminished fifth to the position D-A. Many just-intonation schemes therefore have a double D. Obviously Mersenne

45 Marin Mersenne, *Harmonie universelle, contenant La théorie et la pratique de la musique*, Paris: Sébastien Cramoisy 1636–1637. Facsimile edition of Mersenne's own copy with introduction by François Lesure, Paris 1975; *Livre troisiesme des Instrumens à cordes*, p. 117.

46 Mersenne, *Livre troisiesme des Instrumens à cordes*, p. 117.

wanted to use the second keyboard to show the second D. Strangely enough the key between A and B is still a B♭ with string length 2025, which would be a just major third with the missing D 3240. The two keyboards both have twelve keys; five of them have different pitches. Mersenne would not have been himself without combining the two keyboards into one, which has, however, only sixteen keys.[47] There is only one D, that of the first keyboard.

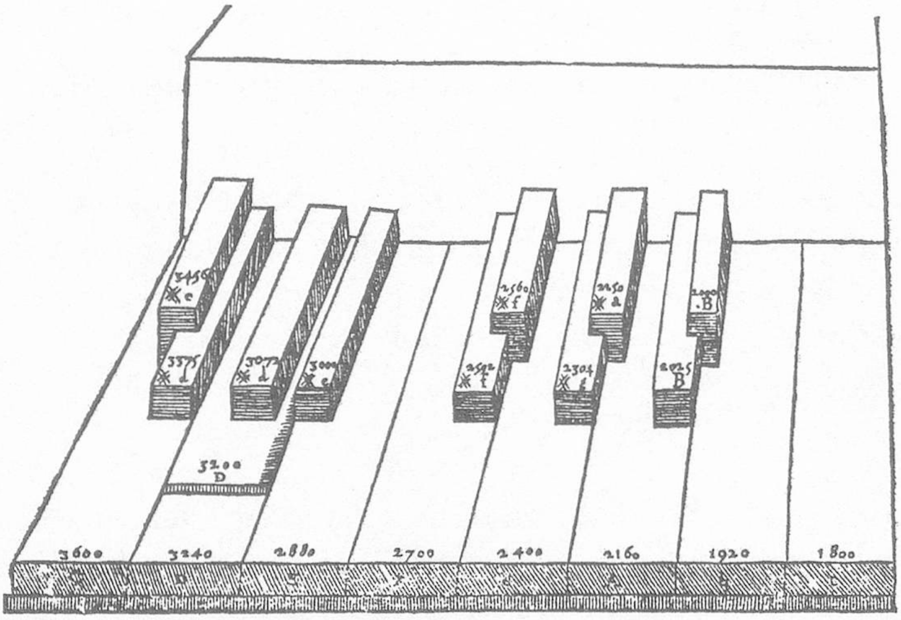



Figure 3. Marin Mersenne's ‹Clavier Harmonique, Parfait de 19 marches sur l'Octave, commençant par C sol ut› (Harmonic keyboard, perfect, in 18 steps in the octave, beginning with C) in his *Harmonie universelle* (Paris 1636), Livre sixiesme des Orgues, p. 352. Mersenne included the conluding octave key in his count, so that the picture actually shows an 18-note keyboard.

Mersenne resumes the discussion of keyboards with more than twelve keys in *Proposition XXII* of the *Livre sixiesme des Orgues*.[48] If we are to believe the caption of this proposition, these multi-note keyboards help us ‹understand the perfection of the diatonic, chromatic and enharmonic genera›. First the three keyboards discussed for the harpsichord are repeated, the first two in reversed order, but now Mersenne expanded the keyboard slightly by omitting the G♭ of the system and adding comma-lowered D, F♯, and B♭. The result is a keyboard with 18 pitches per octave, to be arranged in the following grid of just fifths and major thirds (see Figure 3):

47 Mersenne, *Livre troisiesme des Instrumens à cordes*, p. 118.
48 Mersenne, *Livre sixiesme des Orgues*, p. 349.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| F♯ | 2592 | C♯ | 3456 | G♯ | 2304 | D♯ | 3072 | | |
| D | 3240 | A | 2160 | E | 2880 | B | 1920 | F♯ | 2560 |
| B♭ | 2025 | F | 2700 | C | 3600 | G | 2400 | D | 3200 |
| | | D♭ | 3375 | A♭ | 2250 | E♭ | 3000 | B♭ | 2000 |

The design resembles that of Zarlino's just intonation keyboard, but is more regular and therefore more efficient. With only two notes more than Zarlino's sixteen it has a row of fourteen just fifths. Thirteen notes have just major thirds above them. Mersenne defends this design with the following words:[49]

> «C'est pourquoy je veux adjouster un Clavier avec les marches nécessaires pour faire toutes les consonances dans leur justesse, car encore que les dix-neuf marches de son octave soient, ce semble, plus difficiles à toucher que les treize des autres Claviers, néantmoins la perfection de l'harmonie, et la facilité qu'il y a à accorder les Orgues qui usent de ce quatriesme Clavier, recompense abondamment la difficulté du toucher, que les Organistes pourront surmonter dans l'espace de huit jours, ou dans for peu de temps.»
> This is why I want to add a keyboard with the keys needed to produce all the consonances in their justness, for, although eighteen[50] keys per octave seemingly are more difficult to play on than the twelve of other keyboards, none the less the perfection of the harmony and the ease with wich organs can be tuned that use this fourth keyboard abundantly compensate the difficulty in playing, which the organist can overcome in a week or in a very short time.

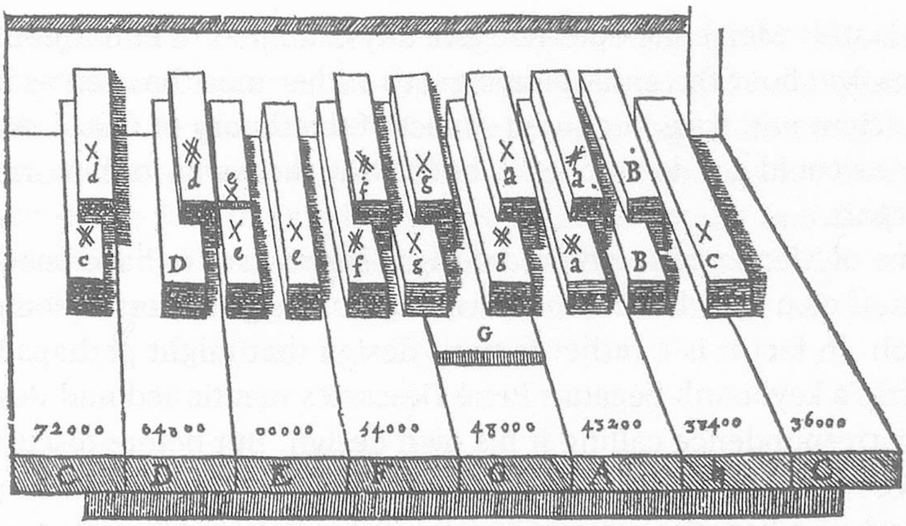



Figure 4. Mersenne's ‹Clavier parfait de vingt-sept marches sur l'Octave› (Perfect keyboard with 27 steps in the octave) as depicted in the *Harmonie universelle* (Paris 1636), Livre sixiesme des Orgues, p. 356. In the present article this is called a 26-note keyboard.

49 Mersenne, *Livre sixiesme des Orgues*, pp. 351–352.
50 Mersenne writes ‹dix-neuf› (19) here, but he always includes the completing octave note in the count of how many keys there are in an octave.

Mersenne did not stop at the 18 keys per octave. In the next proposition (Proposition XXIII) the keyboard design is extended first to 26 and eventually to 31 keys per octave.[51] The following motivation is given for the developments of the 26-tone keyboard (see Figure 4):[52]

> «Quant à l'utilité que l'on peut tirer de ce Clavier, elle est fort grande, car il fait voir très-exactement les intervalles des trois genres de Musique, & donne une plus grande lumière à l'harmonie, que tout ce que les Grecs & le Latin en ont escrit: de sorte que si l'on enseigne la Musique, ils pourront comprendre les plus subtiles raisons de toutes sortes de compositions, & de concerts dans fort peu de temps, & chanter des airs Enharmoniques aussi aysément que les Chromatiques & les Diatoniques. Je laisse plusieurs autres utilitez dont se pourront adviser les Organistes, s'ils usent de ce Clavier, sur lequel ils feront quantité de beaux passages & de gentillesses, qu'il ne peuvent trouver sur les Claviers ordinaires.»
> Regarding the use one may have of this keyboard: this is quite ample, for it shows exactly the intervals of the three musical genera, and illuminates better the harmony than everything that the Greek and Latin authors have written about it, so that, if one is teaching music, they [the pupils] will be able to understand all the subtle proportions of all sorts of compositions and ensemble pieces in a very short time, and sing enharmonic airs as easily as chromatic and diatonic. I pass over several other uses that the organist will be able to think of, if they use this keyboard, on which they will produce many fine and gracious passages that they cannot find on the ordinary keyboards.

Unfortunately Mersenne does not give any examples of enharmonic music. His remarks about the enharmonic genus rather must be seen as lipservice to an ancient and time-honoured aspect of the theory of music. As a music theorist he could not do without it, but clearly there was for him no practical counterpart.

None of Mersenne's keyboard designs seems ever to have been realized by himself or on his behalf, but the 18-note design deserves some further attention. In fact it is a rather famous design that might perhaps be called ‹Descartes's keyboard› because René Descartes mentioned and described it in his correspondence calling it his own design. But before discussing that letter we must pay attention to a practical realization of it (which preceded the letter) on a harpsichord made on the order of Joan Albert Ban, a Catholic priest and amateur musician living in Haarlem (Netherlands). Ban had constructed a theory of musical rhetoric in which every minute detail of the text had to be expressed in the music.[53] He conveyed his theories to friends like

51 Mersenne, *Livre sixiesme des Orgues, Proposition XXIII*, pp. 353–358.

52 Mersenne, *Livre sixiesme des Orgues*, p. 357.

53 Daniel Pickering Walker, «Joan Albert Ban and Mersenne's Musical Competition of 1640», in: *Music and Letters* 57 (1976), pp. 233–255.

Constantijn Huygens in The Hague, René Descartes who was at that time living in various places in Holland, and later in correspondence with Marin Mersenne in Paris. Because Ban's theories were far too extreme to be practical, he usually met with responses ranging from reluctance to rejection, but his dealing with music left behind a few interesting experiments. In order to express the musical rhetoric rightly, a strict just tuning was required. For Ban all the intervals had specific affective bearings, but only when they were exactly in tune. In a letter written to Constantijn Huygens on 18 August 1636 he wrote:[54]

> «Gradus sonituum sunt semitonia, ac toni. Blandimentum omne in apotome, semitonio majori, est. Ferocitas seu animositas in diesi seu semitonio minori. Utrumque κατ'ἐξοχὴν chromatico ac diatonico modulamine. Tonus major durior, minor tonus mitior est. Hinc intervalla sonituum nascuntur. Ditonus, ob binos tonos, est durus ac incitativus. Semiditonus seu tertia minor, ob adjunctum tono semitonium, lenis. Quarta omnino dura ac tetrica, aspera, mordax est.»
> The steps of the sounds are semitones and whole tones. All sweetness is in the apotome or major semitone. There is ferocity and animosity in the diesis or minor semitone. Both are essential in chromatic and diatonic composition. The major whole tone is harder, the minor whole tone softer. From this the [larger] intervals between notes arise. The major third is stern and inciting, because of the two whole tones. The minor third is flexible, because of the semitone added to the whole tone. The fourth is quite hard and harsh, and rough and biting.

Descartes suggested to Ban to have a harpsichord constructed with a multinote keyboard representing all the desired pitches and intervals in just intonation. Ban acted in accordance with Descartes's suggestion and had an 18-note just-intonation built in 1639.[55] It is described and depicted in a brief treatise written by Ban in Dutch and published in Amsterdam in 1643 as *Kort sangh-bericht*.[56] The description makes it clear that Ban's keyboard had the same design and tuning as Mersenne's 18-note keyboard (see Figure 5).

54 Letter in Leiden, University Library, Codex Huygenianus 37.

55 See Ban's letter to Constantijn Huygens of 16 October 1639, partly edited in Willem Jozef Andreas Jonckbloet & Jan Pieter Nicolaas Land, *Musique et musiciens au XVII$^{e}$ siècle: Correspondance et oeuvre musicales de Constantin Huygens*, Leiden 1882 (= Maatschapij tot bevordering der Toonkunst, Uitgave 11), pp. lxvii-lxviii; and Cornelis de Waard (ed.), *Correspondance de P. Marin Mersenne, réligieux minime VIII* , Paris 1963, pp. 536–538.

56 Joan Albert Ban, *Kort sangh-bericht*, Amsterdam: Lodewijk Elsevier 1643. Reproduced in facsimile in Joan Albert Ban, *Zangh-Bloemzel (theoretical part) & Kort sangh-bericht*, with an introduction by Frits Noske, Amsterdam 1969 (= Early Music Theory in the Low Countries 1).

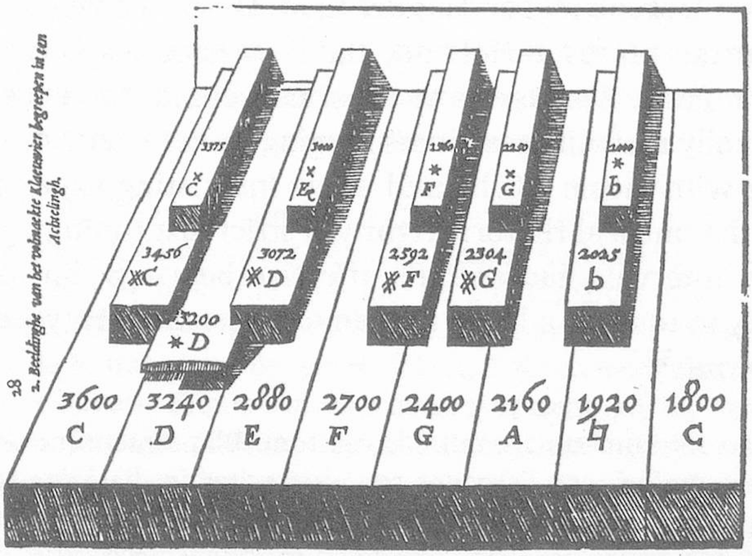



Figure 5. Joan Albert Ban's 18-note keyboard as depicted in his *Kort sangh-bericht* (Amsterdam 1643), p. 28.

Ban not only had a just-intonation keyboard built, he also composed music using the specific just-intonation pitches, a volume with three part settings for soprano, tenor, and bass (and figured bass) of Dutch poetic texts. The music was printed as *Zangh-bloemzel* in 1642, before the treatise; unfortunately only the alto and bass voices have survived.[57] A few fragments of the soprano part can be found in the *Kort sangh-bericht*. If the three-part setting of these fragments is reconstructed, it appears that the vertical sonorities are kept just but the melodic intervals within the voices repeatedly are a comma too large or too small.[58] That means that in *composing* the music the specific tuning scheme of the instrument was not observed. *Afterwards* a number of B♭s, Ds, and F♯s were changed to provide just chords. Actually, the procedure could not repair the occasional situations where a single B♭, D, or F♯ had to sound successively against notes that required a different intonation of the respective B♭, D, or F♯.

Descartes wrote about his keyboard design in a letter, of which it has been unknown for a long time to whom it was addressed or when it was written. The original letter, probably written in Latin, has not survived. The text of the

57 Joan Albert Ban, *Zangh-bloemzel*, Amsterdam: Lodewijk Elsevier, 1642. The lengthy theoretical introduction is included in the facsimile edition mentioned in the previous note. Ban's correspondence with Constantijn Huygens makes clear that the *Zangh-bloemzel* was not disseminated before the spring of 1643; the *Kort sangh-bericht* may have not been issued before Ban's death on 27 July 1644.

58 See Rudolf Rasch, «Ban's Intonation», in: *Tijdschrift van de Vereniging voor Nederlandse Muziekgeschiedenis* 33 (1983), pp. 75–99.

letter is known through the French translation that Claude Clerselier published in 1667 in the third volume of his edition of the letters of Descartes.[59] Clerselier provided neither an addressee nor a date. The editor of the later *Œuvres* by Descartes, Charles Adam, considered Constantijn Huygens as the addressee of the letter and 1646 as the year of writing.[60] But the letter does not fit into the exchange of letters between Huygens and Descartes of that year. It was Cornelis de Waard who showed that the letter was written to Andreas Colvius, a Dutch-reformed minister in the city of Dordrecht in Holland, and it had to be dated 6 July 1643.[61] De Waard had found a transcription by Colvius that overlapped the letter as edited by Clerselier.[62] It seems as if Colvius had transcribed just the technical information in the letter, and that Clerselier translated just those sections that he deemed interesting for a general readership. Both versions, Colvius's and Clerselier's, are included with English translations in Appendix 5.

Colvius's extract begins by describing the diatonic, chromatic, and enharmonic tetrachords. Descartes shows his independence from traditional music theory by defining the chromatic and enharmonic tetrachords with the smaller intervals as adjacent to the *upper* note of the tetrachord, not the lower note as was usual before him. So his chromatic tetrachords are D-F-F♯-A and E-G-G♯-A, the enharmonic tetrachord is given as C-E-E♯-F. The diesis of 125:128 is given as the typical interval for the enharmonic tetrachord. There is, however, barely any relation between the theory of the tetrachord and the design of his keyboard. The latter was, in his view, restricted to the diatonic and chromatic genera and made use of major and minor whole tones, major and minor semitones, the enharmonic diesis [=125:128] and the comma [=80:81]. These intervals are indeed the ones found between adjacent keys, either naturals or raised keys. No arrangements of notes in tetrachord structures are provided.

Clerselier's edition included a sketch of the keyboard, while Colvius's extract contains a listing of the string lengths for the various notes. Both the drawing and the listing correspond to the depictions of the 18-note just-intonation keyboard as given by Mersenne (Figure 3) and Ban (Figure 5). There is no doubt that the three men (Mersenne, Ban, Descartes) discussed

59 Claude Clerselier, *Lettres de Mr Descartes*, Paris: Charles Angot 1667, pp. 587–588 (no. 104).

60 Charles Adam & Paul Tannery (eds.), *Oeuvres de Descartes IV: Correspondance IV*, Paris 1901, pp. 678–679 (no. 476bis).

61 Cornelis de Waard, «Sur le destinataire et la date à attribuer à une lettre de Descartes sur une épinette parfaite», in: *Revue d'Histoire des Science* 3 (1950), pp. 251–255.

62 Colvius's transcription is in Leiden, University Library, Codex Latinus 284 (Adversaria Andreae Colvii), fols. 76v–77v.

the same design. In both versions of Descartes's letter it is explained which key to choose in order to make sure that the resulting sonority would conform to a just-intonation ratio. The lower D had to be used in combination with F or A, the higher D with G or B♭, the C♯ with A or E, the D♭ with F, etc.

The method of designating keys requires some explanation. Capital letters denote naturals, in the sequence C, D, D·, E, F, G, A, ♮. Raised keys are designated by lower-case letters c, d, f, g, and b (or ♭) for the keys right of C, D, F, G, and A respectively. The raised keys always occur in pairs; the higher one is identified by the addition of a dot. For the pairs f-f· (F♯) and ♭-♭· (B♭) the difference between the two notes is a comma, for the pairs c-c·, d-d·, and g-g· it is a diesis, so that c = c♯, c· = D♭, d = D♯, d· = E♭, g = G♯, and g· = A♭.

Colvius's transcription is concluded with a rather unusual suggestion how to tune the lute, namely by just major thirds. Since three just major thirds together are short of an octave by one diesis, the third major third has to be enlarged by a diesis. The proposal, however, makes sense if the pitches of the keyboard are to be transferred to the lute since by following it the comma pairs would be on the same positions on the various strings. Tuning the strings with major thirds would mean to have them as B♭-D-F♯. It is to be doubted, however, if this was ever tried on a lute.

The lesson to learn from the discussion of these multi-note just-intonation keyboard designs is that music theory and musical practice clearly began to diverge here. Just intonation was the basis of contemporary interval theory (which it had been since the sixteenth century and would remain until well into the eighteenth), but it could not be put into practice. A just diatonic scale can only be constructed if one accepts either at least one clearly imperfect fifth or a double realization of, for example, the D. Both options were untenable for musical practice. Mersenne, Ban, and Descartes worked out the second option for their keyboards, which they successively connected with the concept of the enharmonic genus, but essentially to no avail.

## *Michael Bulyowsky: Neu-erfundenes vollkommenes fünff-faches Clavier (Stuttgart 1699)*

The Slowak nobleman Michael Bulyowsky (*c*1650–1713) is perhaps the least known of the various theorists and authors discussed in this article. He left his native country as a youth and spent the rest of his life in the South Western part of the German area, in places like Strasbourg, Durlach (now part of Karlsruhe), Oehringen, Pforzheim, and Stuttgart. He left three notable traces in the history in music. In 1675 he started the compilation of a manuscript that eventually contained the largest number of keyboard suites of Johann Jacob Froberger ever found in a single source; the same manuscript also includes a suite for harpsichord of his own composition.[63] The second feat is that he published in 1681 a brief treatise defending the use of keyboards with 19 notes per octave for the organ.[64] And the third is that he designed and had constructed a harpsichord with 31 notes per octave. The instrument is described in several publications, all of them rather short. The first of these is a pamphlet published in Stuttgart in 1699 under the title *Neu-erfundenes vollkommenes fünff-faches Clavier* (Newly invented perfect fivefold keyboard).[65] It describes a harpsichord with a keyboard including five rows of keys, one row of ordinary lower keys and four rows of raised keys the one behind the other and all together between every adjacent pair of the lower keys. Already from the title it is clear that it is a keyboard with 31 pitches per octave, which have to be tuned to a regularly ascending series of pitches. (Bulyowsky speaks of 32 pitches per octave, by including the completing octave pitch in the count.) Two steps in such a series constitute a chromatic semitone, three a diatonic semitone. The size of the step is called a *comma* but nowhere exact sizes of the intervals as ratios or string lengths are provided. But for a 31-note keyboard with equal division there is no other choice than a very close approximation of meantone tuning when expanded beyond the 12-note range as far as possible.

Browsing through his pamphlet, Bulyowsky's goal for building this instrument becomes immediately clear. It is meant to make it possible to play all sharps and flats, and all double sharps and double flats without having to resort to wolf intervals. In a generalized meantone tuning only the major thirds are just consonant intervals, but it is certainly true that in a 31-note keyboard all intervals sound indiscernably close to their correct meantone size. To illustrate his point, Bulyowsky presents two musical compositions, apparently scored for two violins and figured bass. The first one is in F minor and illustrates the ample use of flats that is possible with the

63 Now Dresden, Sächsische Landesbibliothek, Ms. 1-T-595. See Rudolf Rasch & Pieter Dirksen, «Eine neue Quelle zu Johann Jacob Frobergers Claviersuiten: Michael Bulywoskys Handschrift», in: *Musik in Baden-Württemberg* 8 (2001), pp. 133–153. Complete modern edition by Rudolf Rasch in: *Vingt en une suites pour le clavecin de Johann Jacob Froberger et d'autres auteurs*, Stuttgart 2000 (= Convivium Musicum 5).

64 Michael Bulyowsky, *Brevis de emendatione organi musici tractatio – Kurtze Vorstellung von Verbesserung des Orgelwercks*, Straßburg: Johann Eberhard Zetzner 1680.

65 Michael Bulyowsky, *Neu-erfundenes fünff-faches Clavier, bestehend aus fünff Reyhen der Palmulen, und so genandten Clavium, dessen eine gantze Octav XXXII. Commata begreifft, so alle in geometrischer continuen und ungetrennten Progression aufeinander gehen*, Stuttgart: Paul Treu, 1699. See also Barbieri, «I temperamenti», pp. 185–189.

new keyboard, the second one is in E major, to illustrate the use of sharps. Appendix 6 transcribes the two pieces into modern notation.[66]

In the final section of his 1699 pamphet Bulyowsky discusses the defects of ordinary keyboards, certainly having in mind harpsichords tuned in meantone temperament. These defects, presented against the background of the perfection of his instrument, are the main topic in two pamphlets that appeared in 1711 in Durlach entitled *Fünfffaches vollständiges Transponier-Clavier, in einigen seinen Tugenden vorgestellt* and *Tastatura quinqueformis panarmonico-metathetica, suis quibusdam virtutibus adumbrata* respectively.[67] In fact, these two pamphlets are translations of one another. The texts consist of little more than the explanation of seven defects of the ordinary keyboards followed by no fewer than eighteen advantages of his own 31-note keyboard. In general, the defects and advantages are rightly described, but it must be remarked that many of them are nothing else than saying the same thing again in a different way or viewed from a different angle. The defects of the ordinary, 12-note meantone keyboards may be summarized as follows:

1. On many keys no chromatic or diatonic semitones, whole tones, major or minor thirds, and so on, are available.
2. There are many wolf intervals.
3. No circulation of keys through a circle of fiths is possible.
4. The intervals cannot be tuned equally.
5. On the raised keys one cannot play a theme without wolf intervals.
6. One cannot start a piece on an arbitrary degree.
7. The calculation of the intervals is entirely wrong, except for the just octave.

Bulyowsky needed no fewer then eighteen virtues to praise his own instrument:

1. There is a single progression of commas through the keyboard.
2. The ‹fivefold transposing keyboard› can be used on all occasions.
3. There are no wolves in the keyboard.
4. A theme can be presented through all keys.
5. Music can be transposed with every interval.
6. It is easy to learn to play on the transposing keyboard.
7. The usual interval nomenclature can be used for it.
8. The usual notation (with single and double sharps and flats) can be used.
9. The usual bass figuring can be used.

66 Earlier transcriptions are to be found in Barbieri, «I temperamenti», pp. 188–189.
67 Both printed and published in Durlach by Theodorus Hecht, 1711.

10. The usual interval definitions can be used.
11. It is easy to tune the instrument.
12. The calculation of interval sizes is easy.
13. All theorists so far have failed to recognize the simplicity of the design.
14. With help of monochord string lengths one can calculate the lengths of organ pipes.
15. Whoever can play on an ordinary keyboard, can also play on the 31-note keyboard.
16. The 31-note keyboard is the only one with a full progression of pitches.
17. Keyboards with less than 31 notes are incomplete and imperfect.
18. Keyboards with 31 notes but not in equal progression are imperfect as well.

Most modern performers and scholars will agree with the advantages of a 31-note keyboard as far as it is an expansion of a meantone keyboard: there are no wolves and one can transpose without limit. But unfortunately the disadvantages when it comes to building such instruments or playing on it outweigh by far the advantages and can be seen as prohibitive. In the eighteenth century ordinary twelve-note equal temperament became more and more common because it equally had no wolves and allowed unlimited transposition. The just major third was easily sacrificed.

In closing this section about Bulyowsky's 31-note harpsichord it must be mentioned that the instrument inspired a later composer, Friedrich Suppig, to write a piece for it. It is titled «Appendix» since in its sole source it concludes a large keyboard piece entitled *Fantasia* and progressing through all 24 major and minor keys. That source is a dedication manuscript dated 24 June 1722 and offered to the government of the city of Dresden.[68] The author seems to have been an amateur musician; nothing more is known about him that that he was bookkeeper at a mirror factory in Costebrau (near Klettwitz) and that he was the father of the later famous theatre actor Sebastian Friedrich Suppig (who died in 1750).[69] The «Appendix» is a kind of prelude that explores a number of chord sequences that make use in a clever way of the

68 Now Paris, Bibliothèque du Conservatoire, Ms. Rés. F 211. See the facsimile edition Friedrich Suppig, *Labyrinthus musicus – Calculus musicus – Facsimile of the manuscripts Paris, Bibliothèque du Conservatoire, Rés. F 211–212 (Dated Dresden, 24 June 1722)*, edited by Rudolf Rasch, Utrecht 1990 (= Tuning and Temperament Library 3). See also Rudolf A. Rasch, «The musical circle: From Alfonso to Beethoven, (I-II)», in: *Tijdschrift voor Muziektheorie* 2 (1997), pp. 1--17 and 110–133, pp. 111–114.

69 See the introduction to the facsimile edition of Suppig's *Labyrinthus musicus*.

circulating possibilities of the 31-note keyboard. Musically, it is, however, of little value. As far as we know Suppig knew of Bulyowsky's instrument through the latter's publications and has never had the possibility to play on it.

## *Conclusion*

Reading the preceding sections will have made several things clear. First of all, the design of enharmonic keyboards has always been closely connected with the theory of music, more than with musical practice. The various designs have given rise to lengthy discussions in writing by their inventors (and in modern literature), but to very few musical compositions. The musical compositions that can be connected with enharmonic keyboard design, such as Vicentino's enharmonic madrigals, Mayone's examples for Colonna's instruments, Pesenti's dances, Ban's three-part Dutch songs, and the compositions for Bulyowsky's keyboard, are very diverse in nature and have never become the prototypes of ensuing traditions. All of them have remained isolated examples, experiments with little follow-up, if any. The inventors' first examples were seldom followed by further attemps by other composers. Even theorists rarely developed a scheme presented by a precursor. In general every proposal for an enharmonic keyboard instrument was a singular proposal, with a theoretical framework of its own. Only Pesenti's use of Zarlino's design, Ban's and Descartes's uses of Mersenne's 18-note design (if it was not invented by Descartes), and Suppig's composition for Bulyowsky's instrument show that sometimes theorists or composers did follow the leads of their predecessors.

One thing that occurs again and again in all discussions of enharmonic keyboard design, at least through the first century of it, from about the the middle of the sixteenth century until the middle of the seventeenth, is the *enharmonic tetrachord*. The weight of ancient music theory pressed hard on the minds of the sixteenth-century music theorist, and the latter would do his utmost best to incorporate as many elements of ancient music theory as possible into their own contemporary concepts. At first sight the enharmonic tetrachord seems to resist inclusion in sixteenth-century music theory, but on a closer look the enharmonic tetrachord is not such an alien element at all. For the sixteenth-century music theorist, the diatonic tetrachord of Greek music theory could be easily recognized in the system of natural notes (including the B♭) as codified in the hexachord system. Sixteenth-century polyphony contains many C♯s, F♯s, and G♯s as leading notes to the finals D, G, and A. Together with the E♭, all these notes figured on the standard keyboard of the time, probably already tuned in meantone tuning. The standard keyboard included many chromatic tetrachords, such as B-C-C♯-E, D-E♭-E-G, E-F-F♯-A, and so on. This all made the Greek chromatic tetrachord an easy part of sixteenth-century music theory.

The enharmonic tetrachord comes into the play when and where one needed an extra raised key between two naturals, for example a flat, where the regular key would produce the sharp. This process is nicely formulated by Francisco Salinas. At the end of his discussion of the enharmonic notes, he remarks that there are pieces that require three flats, while the ordinary keyboard only provides two (B♭, E♭).[70] The third flat required would be the A♭. To create this pitch (and a key for it), one has to divide the diatonic semitone from G♯ to A into two parts, one part (A♭-A) being a chromatic semitone, or chromatic diesis as Salinas calls it, the other part an enharmonic diesis (G♯-A♭). This action creates the enharmonic tetrachord G♯-A♭-A-C♯. Splitting other raised keys adds more enharmonic pitches and enharmonic tetrachords to the keyboard. The splitting created two smaller intervals that were unequal in size, even rather unequal in size. In Greek music theory the small intervals of the enharmonic keyboard may also be of unequal size, but the procedures adopted in the sixteenth century are not to be found there.

At this stage the sixteenth-century theorist must have realized that there was a strange parallellism between these enharmonic intervals and the intervals of meantone tuning. Music theory preferably worked with intervals tuning according to just intonation, and this led to a major third of 4:5 (386 cents), a minor third of 5:6 (316 cents), a whole tone in two sizes (a major one of 8:9 or cents 204 cents, a minor of 9:10 or 182 cents), a diatonic semitone of 15:16 (112 cents) and a chromatic semitone of 24:25 (71 cents). The diesis, the interval that was the result of the enharmonic division, equals 125:128 (or 41 cents).

Meantone tuning is based on the just major third of 4:5 (386 cents). That makes the whole tone (the true ‹mean tone›, the geometric mean between the major and minor whole tones) equal to 193 cents, the diatonic semitone equal to 117 cents, and the chromatic semitone equal to 76 cents. It is easily seen that especially the semitones differ very little in size from those of just intonation. Meantone tuning has, exactly as just intonation, a diesis with the ratio 125:128 (41 cents) as the interval between, for example, C♯ and D♭. Although it is nowhere formulated explicitly, it cannot have escaped the sixteenth-century theorist that many intervals of meantone tuning corresponded relatively closely to those of just intonation, not only regarding the major third – which was just – but also regarding the smaller intervals, especially the diatonic and chromatic semitones and the diesis.

70 Salinas, *De musica*, pp. 126–127.

One further coincidence helped the sixteenth-century theorist. The diesis, the chromatic semitone, and the diatonic have sizes that can roughly be compared to one another as 1 (diesis, 41 cents) to 2 (chromatic semitone, 71 cents) to 3 (diatonic semitone, 112 cents), if the unit is defined as something just below 40 cents. These proportions made it possible to incorporate these intervals and all larger intervals (which were nothing but sums of these smaller intervals) into one system with, as the smallest unit, a not-exactly-defined diesis having a size somewhat less than 40 cents. At least, this is what Vicentino did. The approximative character of this approach could be hidden by the clever abstinence from all figures and from all calculation or further arithmetic or mathematics. His approach is ‹informal› as far as strict interval size is concerned. The price he had to pay was that it had become impossible to speak about just ratios because that would involve the introduction of figures, ratios, and so on. Salinas was not willing to sacrifice his arithmetical foundations and could therefore give no place to the 31-note equal division.

The success of meantone tuning on simple 12-note keyboards was thus readily extended to its expansion in the domain of the equal divisions, thanks to the possibility of incorporating the enharmonic tetrachord in it. That meant that the 31-note archicembalo could develop into some kind of standard design. In order to play diatonic music in the sixteenth and early seventeenth centuries, a 12-note keyboard in meantone tuning sufficed, with the raised keys tuned to C♯, E♭, F♯, G♯, and B♭. For chromatic music an extension of the keyboard with a number of raised keys split into two would be helpful.[71] Diatonic music could, of course, also be played on these instruments. For enharmonic music keyboards were required with at least 19 keys per octave; optimal would be a keyboard with a 31-note octave, in other words, a true archicembalo. Such an instrument was:

> «Modulis diatonicis, cromaticis, et enarmonicis a docta manu tactum»
> for playing diatonic, chromatic, and enharmonic music, by a learned hand,

as the nameboard of Trasuntino's Clavemusicum omnitonum of 1606 proudly tells us. Unfortunately, enharmonic repertoire is so extremely scarce. Note the use of the word ‹doctus› (learned) that reminds us of the quotation from Alciatus that Zarlino appended to the picture of his enharmonic harpsichord and that was reproduced in the introducion of this article.

71 See Christopher Stembridge, «Music for the *Cimbalo Cromatico* and Other Split-Keyed Instruments in Seventeenth-Century Italy», in: *Performance Practice Review* 5/1 (1992), pp. 5–43.

In fact, the 31-note archicembalo would outlive the enharmonic tetrachord. In the discussions of their just-intonation keyboards by Mersenne, Ban, and Descartes the enharmonic tetrachord is still mentioned from time to time, to add authority to their arguments. But it does not serve a real purpose any more. In their just-intonation structures there are no repeating tetrachords. The development of just-intonation keyboards seems to have stopped after the middle of the seventeenth century and with it the connection between the enharmonic tetrachord and enharmonic keyboard design. Not so the 31-note keyboard design.

Even if the building of archicembali in Italy stopped largely after the middle of the seventeenth century, several comparable instruments were built on the other side of the Alps.[72] Especially through Christiaan Huygens's work the relation between meantone tuning and 31-note equal tuning received a sound theoretical foundation.[73] Bulyowsky's *Transponir-Clavir* was built in Stuttgart by the end of the seventeenth century, a pianoforte with six rows of seven keys in 31-note tuning about a century later.[74] These instruments served the generalization of meantone tuning, without the burden of the enharmonic tetrachord.

72 Fritz Zobeley, *Rudolf Franz Erwein Graf von Schönborn (1677–1754) und seine Musikpflege*, Würzburg 1949 (= Neujahrsblätter der Gesellschaft dür Fränkische Geschichte 21), p. 25, relates that at some point around 1700 Elector Palatine Johann Wilhelm, residing in Düsseldorf, donated three 31-note keyboards to the Emperor, to the Grand Duke of Toscana, and to *Musikdirektor* Fekler respectively. I have this information from Martin Kirnbauer (Basel).

73 See Christiaan Huygens, «Lettre touchant le cycle harmonique», in: *Histoire des Ouvrages des Sçavans* (October 1691), pp. 78–88. Reproduction in facsimile with introduction as *Le cycle harmonique (Rotterdam 1691), Novus cyclus harmonicus (Leiden 1724)*, edited by Rudolf Rasch, Utrecht 1986 (= Tuning and Temperament Library 6). Huygens's ideas about the relation between meantone tuning and the 31-note equal division had already been worked out in manuscript thirty years before, in 1661.

74 See Martin Vogel, *Die Lehre von den Tonbeziehungen*, Bonn 1975 (= Orpheus-Schriftenreihe zu Grundfragen der Musik 16), pp. 304–308.

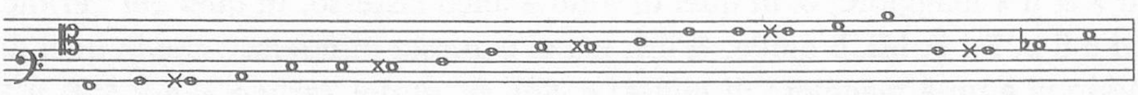
Appendix 1

*Soav'e dolc'ardore*, from Nicola Vicentino's *L'antica musica ridotta alla moderna prattica* (Rome 1555), p. 67. Dots above or below the notes indicate an upward pitch shift of a diesis. Since the upper half of his keyboard, with the diesis raised pitches, does not provide diesis-raised sharps, Vicentino consistently writes flats of the next higher natural for diesis-raised sharps. We have transcribed these flats as diesis-raised sharps, to make the chordal structure clearer. This applies to measures 9, 10, and 14 of the soprano, measure 12 of the alto, and measures 9 and 13 of the tenor.

Appendix 2
The preface of Martino Pesenti's *Correnti, gagliarde, e balletti diatonici, trasportati parte cromatici, e parte henarmonici … Libro quarto, Opera decimaquinta* (Venice 1645). The text has been previously edited in G. Gaspari [and others], *Catalogo della biblioteca del Liceo Musicale di Bologna*, Volume IV, Bologna 1905, pp. 136–137; Claudio Sartori, *Bibliografia della musica strumentale italiana stampata in Italia fino al 1700*, Florence 1952, pp. 392–393, and (partly, until the Zarlino quotation, but with English translation) in Stembridge, «The *cimbalo cromatico*», pp. 47–49. For better readability the text has been slightly edited here, as regards punctuation, use of capitals, accents, and u/v spelling.

*«A professori di musica, per maggior intelligenza.*

Si ritrovava l'anno 1621 appresso l'Illustrissimo Sig. Nicolò de Rossi all'hora Residente di sua Maestà Cesarea in Venetia un Clavicembalo di mano di Vido Trasentino [sic] fabricato l'anno 1601, il quale era Diatonico, Cromatico, & Henarmonico, e perchè con occasione d'haver io servitù con quell'Illustrissimo Sig. mi commandò à dover tasteggiare detto Clavicembalo, se bene fosse mal acconcio, per non haver mai potuto trovare (doppo la morte dell'Autore) chi gli[e] lo cordasse; mi risolsi, eccittato da sommo desiderio di servire un tanto mio Padrone, di accordarlo, se bene fuori di mia professione, e nell'oprar ritrovai, che dall'A, La, mi, re, ascendendo sino al G, Sol, re, ut era ogni corda col B molle, & il ♯, & anco il ♯ maggiore; Continuai à tenerlo accordato sino l'anno 1634, che passò all'altra vita il detto Illustrissimo Residente. Il che causò, che il detto Clavicembalo fù mandato all'Imperatore, se bene per certo accidente rimase à Trieste, dove credo si ritrovi anco al presente. Il che mi fu di grandissimo ramarico vedendomi privo dell'essercitio di Stromento così stravagante, e degno. Pure bisognò haver patienza sino l'anno 1641, quando mi capitò alle mani il Clavicembalo inventato dal Zerlino, e fabricato da Domenico da Pesaro l'anno 1548, il quale fu il primo Clavicembalo, che fosse mai fabricato col Diatonico, Cromatico, & Henarmonico. Si può parangonare [sic] quel di Vido à quel del Zerlino. Prima nell'A, La, mi, re vi è il b molle, il ♯ & il ♯ maggiore, & in quel di Vido è anco l'istesso. In quel del Zerlino vi è il b, Fa, b, Mi, b molle, & il ♯, ma vi è questa differenza, che in quel di Vido vi è un ♯ maggiore di più. Al c, Sol, fa, ut del Zerlino vi è il ♯, & il ♯ maggiore. In quel di Vido vi è il b molle, il ♯, & il ♯ maggiore. In D, La, sol, re del Zerlino, vi è il b molle, il ♯ & il ♯ maggiore, & in quel di Vido vi è l'istesso. In E, La, mi del Zerlino vi è il b molle, & il ♯, in quel di Vido vi è il b molle, il ♯, & il ♯ maggiore. Nel F, Fa, ut del Zerlino vi è il ♯, & il ♯ maggiore, in quel di Vido vi è il b molle, il ♯ & il ♯ maggore. In G, Sol, re, ut del Zerlino vi è il b molle, il ♯, & il ♯ maggiore, & anco in quel di Vido è l'istesso. Di maniera che nascono in quel di Vido doi corde fra il b, Fa, b, Mi & il c, Sol, fa, ut, cioè il ♯ maggiore, di b, Fa, b, Mi, & il b molle di c, Sol, fa, ut che è semituono maggiore. Nascono anco in quel di Vido doi corde tra E, La, mi & F, Fa, ut il ♯ maggiore d'E, La, mi & il b molle di F, Fa, ut, semituono parimente maggiore. hò parangonato [sic] li doi detti Clavicembali, accio possino vedere i Musici, che intendono più di me, la differenza, che vi è tra l'uno, e l'altro. A mio senso ellegerei [sic] più tosto il Clavicembalo del Zerlino come il più regolato del tutto, e qui sotto riportarò le sue formali parole. Dove tratta dell› Institutioni Henarmoniche libro 2, Capitolo 47:[75] ‹Potrà adunque [ciascuno][76] per l'avenire fabricare un stromento alla simiglianza di quello che io hò mostrato, il quale sarà commodo, & atto à servire alle modulationi, & harmonie di ciascuno delli nominati tre generi, & questo non sarà ad alcun difficile, percioche uno de tali Stromenti feci fare io l'anno di nostra salute 1548, in Venetia, per vedere in qual maniera potessero riuscir le Harmonie Cromatiche, & le Henarmoniche, & fù un Clavicembalo, & è anco appresso di me. Il quale fabricò maestro Domenico Pesarese, raro et eccellente Fabricatore di simili stromenti, nel quale non solo li semituoni maggiori sono divisi in doi parti, ma anco li minori, di maniera che ogni tuono viene ad esser diviso in quattro parti & ancor che se ne potessero fare de gli altri con diverse divisioni, nondimeno da loro si haverebbe poca utilità.› Questo sono le parole che hà detto il Zerlino. Mà veniamo alla conclusione. hò composto le Correnti, Gagliarde, e Balletti, & le hò fatte Diatoniche trasportate parte Cromatiche, e parte Henarmoniche, acciò ogn'uno possi vedere tutti tre li generi. Dovevo fare una Toccata passando gentilmente dal Diatonico, al Cromaticho, & all'Henarmonico, ritornando in dietro [d]all'Henarmonico, al Cromatico & al Diatonico, che unendo insieme tutti tre li generi sarebbero stati soavi da sentirsi; ma non l'hò composta, perche è difficile il ritrovarsi un Clavicembalo con tutti tre li predetti generi, ma è ben vero, che le Correnti, Gagliarde, e Balletti si possono sonare sopra i Liuti, & Viole, havendo tali stromenti il Cromatico & l'Henarmonico. hò messo per ordine il Cromatico, & l'Henarmonico uno dietro l'altra, acciò possi vedere ciascuno la differenza che tra l'uno, e l'altro si trova. Hà posto il Zerlino questo segno dell'H[en]armonico.



75 Pesenti quotes from Zarlino, *Istitutioni harmoniche* (1573 edition), pp. 163–164. The quotation entirely follows Zarlino's text except spelling details.

76 The word «ciascuno», which occurs at this place in Zarlino's text, is missing in Pesenti's quotation.

Et io in veci dell'Henarmonicho posto il ♯ ordinario, perche li stampatori non si ritrovano havere il detto segno. Martino Pesenti»

English translation:[77]

*To the professors of music, for a better understanding.*

In 1621 there was in the house of the Illustrious Signor Nicolò de Rossi, at that time Ambassador of his Imperial Majesty in Venice, a harpsichord made by Vido Trasuntino in 1601, which was diatonic, chromatic, and enharmonic. And, as I was at the service of that most illustrious noble Lord, he ordered that I should play the said harpsichord, although it was in bad condition, because it had never been possible to find (after the death of the maker) someone who would tune it. Moved by the strongest wish to serve such a master as mine, I decided to tune it, although that was not my profession, and in so doing I discovered that from A upwards until G every note had its flat, its sharp, and it double sharp. I kept it in tune until 1634, when the illustrious Ambassador passed away. Because of this, the said harpsichord was sent to the Emperor, although, owing to a certain accident it remained in Trieste, where I believe it still is. And for this reason I was greatly distressed as I saw myself deprived of the practice on so extraordinary and worthwile an instrument. And yet I had to bear the situation until 1641 when I happened to lay my hands upon the harpsichord invented by Zarlino and made by Domenico da Pesaro in 1548, which was the first harpsichord ever made with the diatonic, chromatic, and enharmonic genera. Vido's instrument may be compared to Zarlino's. First, concerning the A, there are the flat [A♭], the sharp [A♯], and the double sharp [A♯♯], and in Vido's instrument it is the same. In Zarlino's there are the B, the flat [B♭], and the sharp [B♯], but here there is a difference, because Vido's instrument also has the double sharp [B♯♯]. Regarding the C, Zarlino's instrument has the sharp [C♯] and the double sharp [C♯♯]. In Vido's instrument, there are the flat [C♭], the sharp [C♯], and the double sharp [C♯♯]. Regarding the D, Zarlino's instrument has the flat [D♭], the sharp [D♯] and the double sharp [D♯♯], and Vido's is the same in this respect. For the E, Zarlino's instrument has the flat [E♭] and the sharp [E♯]; in Vido's there are the flat [E♭], the sharp [E♯], and the double sharp [E♯♯]. For the F, Zarlino's instrument has the sharp [F♯] and the double sharp [F♯♯]; in Vido's there are the flat [F♭], the sharp [F♯], and the double sharp [F♯♯]. For the G, Zarlino's instrument has the flat [G♭],

77 This translation greatly benefited from remarks and comments made by Riccardo Pergolis (Battaglia Terme, Italy) in response to the author's earlier version.

the sharp [G♯], and the double sharp [G♯♯]; Vido's is the same here. So that in Vido's instrument there are two strings between B and C, namely the double sharp of B [B♯♯] and the flat of C [C♭], that form between them a major semitone. Also in Vido's instrument there are two strings between E and F, namely the double sharp of E [E♯♯] and the flat of F [F♭], that form a major semitone as well. I have compared the two above-said harpsichords so that the musicians – who understand more than I do – may see the difference between the one and and the other instrument. For my part, I would rather choose Zarlino's harpsichord as the more perfectly contrived, and I will here quote his very words from the Second Book of his *Institutioni Henarmoniche* [sic!], Chapter 47: «Therefore [everybody] will from now one be able to built an instrument such as I have shown, which will be easy and fit to serve the modulations and harmonies of all the mentioned genera. And this will not be deemed by anyone. For I had one of such an instrument made in Venice, in the year of our Lord 1548, in order to see in what way it could realize the chromatic and enharmonic harmonies. And it was a harpsichord, and I still have it in my possession; it was constructed by Master Domenico da Pesaro, extraordinary and excellent maker of that sort of instruments, in which instrument not only the major semitones are divided into two parts, but also all the minor semitones, so that each tone is divided into four parts. And although it would be possible to make other instruments provided with several divisions, they would prove, none the less, of little purpose.» This is what Zarlino said. But let us draw a conclusion. I have composed these *correnti*, *gagliarde*, and *balletti*, and I have them made diatonic, and [then] transposed partly chromatically and partly enharmonically, so that anyone could see all the three genera. I intended to compose a Toccata that proceeded gently from the diatonic genus to the chromatic and to the enharmonic genus, returning from the enharmonic into the chromatic and diatonic genera, so that by uniting them the three genera would sound sweet together. But I did not compose it since it is difficult to find a harpsichord with all the three mentioned genera. Nevertheless the *correnti*, *gagliarde*, and *balletti* can be played on lutes and viols as such instruments have the chromatic and enharmonic genera. I have placed the chromatic and the enharmonic genera one after the other so as to enable any person to hear the difference between the one and the other. Zarlino has given this sign for the enharmonic pitches:

But I have used the ordinary ♯, instead of this enharmonic [sign], since no printer is supplied with such type. Martino Pesenti

Appendix 3

Diatonic and chromatic versions of Pesenti's *Corrente Prima*, from his *Correnti, gagliarde, e balletti … Libro quarto, Opera decimaquinta* (Venice 1645)

*Corrente Diatonica Prima* (p.4):

Appendix 3 (sequ.)

*L'Istessa Corrente Cromatica* (p. 5):

Appendix 4
Diatonic and enharmonic versions of Pesenti's *Corrente duodecima*.

*Corrente Diatonica Decima Terza* (p. 28):

*L'Istessa Corrente Henarmonica* (p. 29):

Appendix 5
René Descartes's letter to Andreas Colvius, 6 July 1643, about his just-intonation keyboard. The letter survives in two rather divergent readings. One is an excerpt in Latin made by Andreas Colvius in Dordrecht, presumably not long after receipt of the letter, now in Leiden, University Library, Codex Latinus 284, fols. 76v–77v. The other is a (partial?) French translation by Claude Clerselier, published in his *Lettres de Mr Descartes … Tome troisiesme et dernier* (Paris: Charles Angot, 1667), no. 104, pp. 587–588. Colvius's version has been edited previously by Cornelis de Waard in «Sur le destinataire et la date à attribuer à une lettre de Descartes sur une épinette parfaite», in: *Revue d'Histoire des Sciences* 3 (1950), pp. 251–255, Clerselier's version in Charles Adam & Paul Tannery (eds.), *Œuvres de Descartes IV: Correspondance IV* (Paris 1901), pp. 678–679 (no. 476bis).

Colvius's transcription:

*Musica est triplex: Diatonica, Chromatica, Enharmonica.*

*Diatonica* procedit per tonos et semitonia, qualia reperiuntur in scalâ vulgari: *ut, re, mi, fa, sol, la*; ubi *mi* et *fa* est semitonium majus; cætera sunt integri toni.

*Chromatica*, ut intelligitur ex Ptolomæo, procedit per tertiam minorem et per duo semitonia, unum majus et alterum minus, quæ simul faciunt quartam: *re, fa, ♯[fa], sol*; vel: *mi, sol, ♯sol, la.*

*Enharmonica* procedit per tertiam majorem et semitonium minus et *diæsin*, quæ vocatur *enharmonica*, quæ est ut 125:128, id est, si fides sit 128 partium et inde 125$^{am}$ premas, facies diæsin enharmonicam. Itaque sic procedit verbi gratiâ: *ut, mi, ♯mi, fa.*

Intervalla quibus utuntur diatonica et chromatica sunt: 1. Tonus major et minor, 2. Semitonium majus et minus, 3. Diœsis enharmonica et comma. Hæc intervalla sunt paulatim minora et majora.

In instrumentis musicis, ut perfecta sint et accurata, octava ex meâ sententiâ dividi debet in 18 intervalla, quæ sunt 4 semitonia majora, 8 minora, 3 diœses enharmonicæ et tria commata, quæque disponantur modo sequenti:

| | | | | | |
|---|---|---|---|---|---|
| F | C | 1800 | ♮ | f | 2592 |
| E | ♮ | 1920 | B | F | 2700 |
| | ♭[.] | 2000 | A | E | 2700 |
| | comma | | | d[.] | 3000 |
| | ♭ | 2025 | | d | 3072 |
| D | A | 2160 | G[.] | D[.] | 3200 |
| | g[.] | 2250 | | comma | |
| | g | 2304 | G | D | 3240 |
| C | G | 2400 | | c[.] | 3375 |
| ♮[.] | f[.] | 2560 | | c | 3456 |
| | comma | | F | C | 3600 |

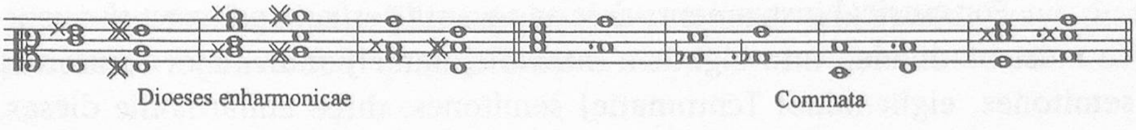
Nempe in monochordo, si totus nervus exhibeat sonum C, sitque partium 3600, ejusdem partes 3456 exhibebunt sonum c, et sic de cæteris.

Notandum autem est ex his divisionibus sive chordis, illas quæ pertinent ad genus diatonicum nempe: C, D, E et G, A et ♮, esse præcipuas, et reliquas omnes ad ipsas ita referri, ut nulla planè sit admittenda, nisi cum aliquâ ex illis consonantiam efficiat.

Item notandum duas quasque quas eodem charactere notavimus, pro unis quodammodo esse sumendas vel simul usurpandas. Sed utendum esse D superiori si velimus ut consonet cum G, vel ♮, D verò inferiori ut consonet cum A vel F, item ♭ superiori ut consonet cum G, ♭ inferiori ut consonet cum F, c cum E vel A, d. cum G, d cum ♮, f. cum ♮, f cum A, g. cum F vel C, g cum E. Ex quibus per enumerationem facile cognoscitur nullum intervallum in musicâ posse optari, quod non in tali instrumento reperiatur.

Hæc autem intelligenda de cantilenis quæ canuntur per [♮]. Pro iis autem quæ canuntur per b molle, oportet tantum substituere F in locum C, et reliquos characteres consequenter immutare.

Intervallum diœseos enharmonicæ, itemque intervallum commatum, videntur posse cantari in locis sequentibus. Oportet autem ut notæ præcedentes vel subsequentes præparent auditum ad illa dignoscenda vocemque ad illa canenda; quod videtur fieri posse his et similis modis qui à practicis melius poterunt inveniri.




Porrò, ad testudinem bene ordinandam, vellem incipere divisionem à commate, et efficere ut primus nervus à 2° distaret 3â majori, 2us à 3° 3â majori, tertius à 4° tertiâ majori unâ cum diœsi enharmonicâ. Tres enim tertiæ majores simul junctæ, differunt ab 8â hac unâ diœsi enharmonicâ, seu unâ cum illâ diœsi complent octavam. Ideo autem à commate divisio testudinis et monochordi et cujuscunque instrumenti incipitur commodius, quia hâc ratione in subtilissimam chordarum (quæ et maximè pulsatur et per cujus longitudinem longissimè decurritur) inciderent omnia tria commata. Incipere autem divisionem instrumenti à commate, est ponere primum intervallum ita, ut digitus in eo positus, faciat comma cum chorda liberè tactâ. Est autem comma dimidium toni majoris et minoris. Nec unquam rite canendo aut instrumento ludendo, licet continuatâ serie ascendere per duos tonos majores, sed alternatim q[uidem] per majorem et minorem.

Hæc sunt Domini de Cartes.

English translation:

Music is in three genera: the diatonic, chromatic, and enharmonic.

The diatonic genus has whole and half steps, as in the usual scale: C, D, E, F, G, A, where between E and F there is a semitone (or half step); the other steps are whole tones.

The chromatic genus, after Ptolemy, consists of a minor third, followed by two semitones, the one large, the other small, which together make up a fourth: D, F, F♯, G, or E, G, G♯, A.

The enharmonic genus has a major third, a small semitone and a diesis, which is called the enharmonic diesis, which it has the ratio 125:128, that is, when a string is divided into 128 parts and one presses on the 125th part of it, the resulting sound in an enharmonic diesis. For example in the sequence C, E, E♯, F.

Intervals that are found in the diatonic and chromatic genera are: 1. the major and minor whole tones; 2. the major and minor semitones; and 3. the enharmonic diesis and the comma. These intervals are sometimes smaller, sometimes larger.

For musical instruments that one wants perfect and exact the octave must be divided into eighteen intervals, namely four major [diatonic] semitones, eight minor [chromatic] semitones, three enharmonic dieses, and three commas, in the following order:

| | | | | | |
|---|---|---|---|---|---|
| F | C | 1800 | B | F♯ | 2592 |
| E | B | 1920 | B | F | 2700 |
| | B♭· | 2000 | A | E | 2700 |
| | comma | | | E♭ | 3000 |
| | B♭ | 2025 | | D♯ | 3072 |
| D | A | 2160 | G· | D· | 3200 |
| | A♭ | 2250 | | comma | |
| | G♯ | 2304 | G | D | 3240 |
| C | G | 2400 | | D♭· | 3375 |
| B· | F♯· | 2560 | | C♯ | 3456 |
| | comma | | F | C | 3600 |

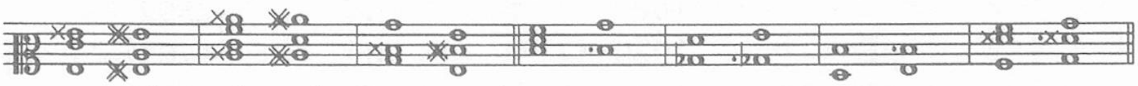
For, if on a monochord the whole string of 3600 parts produces the note C, 3456 parts will prodcue the C♯, and so on with the other ones.

It must be remarked that from these notes the ones that concern the diatonic genus (namely C, D, E, and G, A, B) are the most important, and all notes must be connected to these in such a way there will always be a consonance.

It be also remarked that everywhere where there are two notes with the same letter these notes refer to the same note in a certain sense,' as if they can freely be interchanged. But we must use the high D when there is a consonance with G or B, whereas the low D forms a consonance with A or F. Similarly the high B♭ forms a consonance with G, the low B♭ with F, the C♯ with E or A, the E♭ with G, the D♯ with B, the [high] F♯ with B, the [low] F♯ with A, the A♭ with F or C, the G♯ with E. From this enumeration it appears clearly that there is no interval wanted in music that is not to be found on such an instrument.

These things must be kept in mind for melodies that are sung without a flat in the key signature. For melodies with the key signature of a flat one must put the F on the place of the C, and change all the note names accordingly.

The interval of the enharmonic diesis, and also that of the comma, can be sung at various places as shown below. It must be done in such a way that the preceding or subsequent notes prepare the ear to distinguish them, and the voice to sing them. This can be done in these and similar ways that can better be invented by musicians:





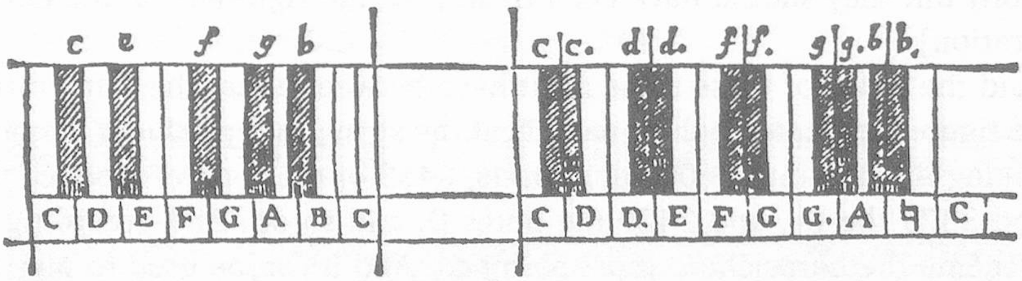
In addition, in order to tune a lute well, I would like to start the division with a comma, and go on in such a way that the first string differs from the second one by a major third, and the second one from the third [also] by a major third, and the third one from the fourth by a major third plus an enharmonic diesis. For three major thirds in succession differ by this enharmonic diesis from the octave, or, in other words, with that enharmonic diesis they make the octave complete. And therefore the division of the lute, or a monochord, or whichever instrument, may be set up more easily from the comma, since by this procedure the three commas are placed on the most sensitive part of the string, which is plucked the strongest and sounds the longest by its length. To begin the division of the instrument with the comma means that the first interval is set in such a way that the string, when the finger is placed upon it, creates the interval of a comma with the open string. A comma is the difference between the major and minor whole tone. In no manner of singing or playing on an instrument is it permitted to ascend over two major whole tones, but one has to alternate between major and minor whole tones. Written this way by Descartes.

Clerselier's edition:

Monsieur,

Je ne receus vostre dernière que Lundy matin, une heure après avoir envoyé celle que je vous écrivis Dimanche au soir, ce qui est cause que je n'y adjoutay point mon système pour faire un instrument de musique qui soit parfait; car je ne pensois pas que vous le voulussiez encore voir, et je sçay bien que vous n'en avez aucun besoin pour l'espinette que vous voulez faire faire à Mademoiselle vostre fille, car, pour l'âge où elle est, il ne faut chercher que les choses les plus faciles, et ce système est beaucoup plus difficile que le vulgaire. Mais vous en pourrez aisément juger, car le voicy:

A sçavoir, au lieu qu'on a coustume de diviser l'octave en douze parties, pour les instrumens ordinaires, il faut icy la diviser en dix-huit. Comme, par exemple, aux espinettes les marches d'une octave sont ainsi disposées, etc., et elles le devroient estre ainsi, etc..




Et les sons de ces marches doivent avoir entr'eux mesme proportion que les nombres icy mis; en sorte que, si la corde qui fait le son C estoit divisée en 3600 parties égales, 3456 de ses parties donneroient le son *c*, et 3375 le son *c*., et 3240 le son D, et ainsi des autres. Et c'est suivant cela qu'il faut accorder cette espinette. Et on s'en peut servir pour jouer toutes les mesmes pièces qu'on joue sur les autres, sans qu'il soit besoin d'y rien changer, sinon qu'il faut prendre garde que, quand on veut se servir de la feinte c avec A ou E, il faut prendre le premier c, et que, quand on s'en sert avec F, il faut toucher le second *c*., et qu'il faut toucher le premier D avec A ou F, et D· avec G ou ♮, et *d* avec ♮, et *d* avec G, et *f* avec A, et *f*· avec ♮, et g avec E, et g· avec F ou C, et enfin ♭ avec F, et ♭· avec G, ce qui s'entend pour les pièces qu'on joue en B quarré. Et pour celles qu'on joue en B mol, il ne faut que mettre F au lieu de C, G et G·, au lieu de D et D·, et ainsi de suitte. Et ce que j'ay dit icy d'une octave, se doit entendre de tout le clavier, dans lequel toutes les octaves doivent estre divisées l'une comme l'autre.

Je suis, [etc.]

English translation:

Dear Sir,

I received your last letter only Monday morning, an hour after I had sent the letter that I wrote Sunday night, which is the reason that I have not added my system for a perfect musical instrument, for I thought you did not want to see it any more, and I am sure you do not need it at all for the keyboard you want to have made for your daughter [Agneta Colvius], for whom one must, considering her age, only select the most easy things, and this system is much more complicated than the usual one. You can readily form an opinion about it on account of the following:

Namely, instead of dividing the octave into twelve parts, as in ordinary instruments, one has to divide it into eighteen parts. For on the harpsichords the steps in an octave are laid out as follows: [See the left part of the above illustration] But they should have been thus: [See the right part of the above illustration]

And the notes of these steps must have between them the same ratios as the figured indicated below, namely, if the string that produces the note C is being divided into 3600 equal parts, 3456 of these parts produce the C♯ and 3375 the D♭, and 3420 the notes D, and so on. And according to this scheme the harpsichord must be tuned. And it can be used to play all the pieces that one can play on [ordinary] instruments, without having to change anything. Only one has to take into account that, if one wants to use a C♯ or D♭ with A or E, one has to use the first raised key after the C, and if one wants to make a combination with F one must play the D♭, which is the second raised key. And also that one must use the low D together with the A or the F and the high D with the G or the B, and the D♯ with B, and E♭ with G, and the [low] F♯ with A and the [high] F♯ with B, and the G♯ with E, and the A♭ with F or C, and finally the [low] B♭ with F and the [high] B♭ with G, which applies to pieces that are played without key signature. For the pieces with the key signature of one flat the F may take the place of C, and low and high G those of low and high D, and so on. And everything I have explained for a single octave, must be extended over the entire keyboard, where all the octaves have to be divided in the same way.

I am, [etc.]

Appendix 6

Michael Bulyowsky's compositions for his 31-note keyboard, included in his *Neu-erfundenes vollkommenes fünff-faches Clavier* (Stuttgart 1699)

*Und zwar erstlich in Cantu Molli* (pp. 13–16):

*So dann in Cantu duro* (pp. 16–17):

## *Abstract*

This article deals with the motivation that 16th- and 17th-century designers and builders of enharmonic keyboards had in constructing their instruments. Discussed are instruments, or descriptions of instruments, by Nicola Vicentino, Gioseffo Zarlino, Martino Pesenti, Francisco Salinas, Fabio Colonna, Marin Mersenne, Joan Albert Ban, René Descartes, and Michael Bulyowsky. Several of the instruments can be classified as «archicembali» by reason of their having 31 pitches per octave, the number which Vicentino's famous archicembalo had. Other instruments had 19 or 24 pitches per octave. The earliest examples were built to demonstrate the Greek enharmonic tetrachord, or «enharmonic music» in general (Vicentino, Zarlino, Pesenti, Colonna). A 31-note division could also function as an expansion of meantone tuning and as a result of this feature the division remained in use after the connection with the enharmonic tetrachord had become obsolete in music and music theory, by the mid 17th century. Multi-note, just-intonation keyboards such as described by Zarlino, Mersenne, Ban, and Descartes, basically served the rendering of consonant intervals in their just form. Appendices to the article present enharmonic compositions by Vicentino, Pesenti, and Bulyowsky, as well as texts about enharmonic keyboards by Pesenti and Descartes.

## *Zusammenfassung*

Der Beitrag beschäftigt sich mit den Motivationen, die hinter den enharmonischen Instrumenten stehen, die im 16. und 17. Jahrhundert erdacht und gebaut wurden. Diskutiert werden Instrumente bzw. deren Beschreibungen von Nicola Vicentino, Gioseffo Zarlino, Martino Pesenti, Francisco Salinas, Fabio Colonna, Marin Mersenne, Joan Albert Ban, René Descartes und Michael Bulyowsky. Einige dieser Instrumente können als «archicembali» bezeichnet werden, da sie – genau wie Vicentinos berühmtes Archicembalo – 31 Tonstufen pro Oktave aufweisen, andere Instrumente hingegen haben 19 oder 24 Töne pro Oktave. Die frühesten Exemplare wurden gebaut, um das griechische enharmonische Tetrachord darstellen oder generell «enharmonische Musik» darauf spielen zu können (Vicentino, Zarlino, Pesenti, Colonna). Eine 31-tönige Unterteilung konnte zugleich als Erweiterung der mitteltönigen Stimmung dienen und, als Ergebnis davon, blieb diese Unterteilung auch noch in Gebrauch, als die Verbindung mit dem enharmonischen Tetrachord in Musik und Musiktheorie im 17. Jahrhundert obsolet wurde. Vieltönige Instrumente mit reiner Stimmung, wie sie etwa von Zarlino, Mersenne, Ban, und Descartes beschrieben wurden, dienten hauptsächlich zur Darstellung von konsonanten Intervallen in reiner Form. Anhänge zu dem Beitrag bieten enharmonische Kompositionen von Vicentino, Pesenti, und Bulyowsky, sowie Dokumente für die enharmonischen Tasteninstrumente von Pesenti und Descartes.