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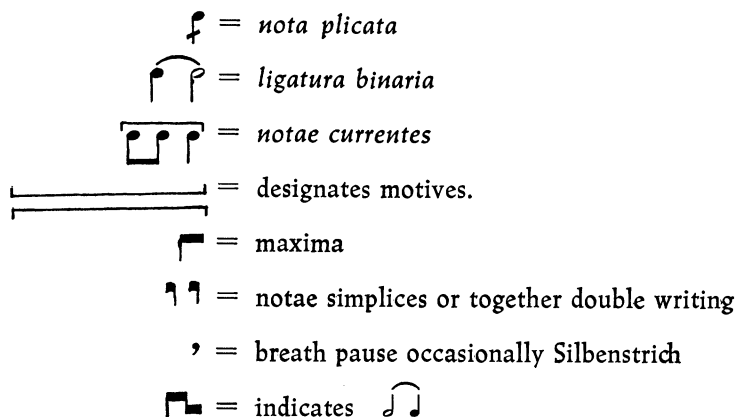
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Explanation of Symbols



The Technique of the Monochord

CECIL ADKINS (DENTON/TEXAS)

The relation of the monochord to musical theory and practice is often referred to by writers on music but seldom explained. There is almost no detailed information concerning the monochord and its techniques available outside the original sources. As a result, the interested reader is often confused or misled by the multiplicity of terms applied to the instrument, as well as the many methods used in dividing the string. The following remarks on the construction and techniques of the monochord are offered as a means of clarifying and standardizing some of the more obscure aspects of its theory and practice.

The monochord in its early form, and in the form utilized throughout the Middle Ages (Diagram 1), was a table or plank (AC) upon which were erected two fixed bridges (EB and FD). The string was stretched across the bridges (EF) and securely fastened at the ends (AC). A movable bridge (K) was then placed underneath the string, dividing it into two sections (EK and KF). The marks indicating the placement of the movable bridge were then inscribed on the table underneath the string, between the two end bridges (B and D). The resonating box, generally considered an integral part of the instrument, is not mentioned in the treatises of the Middle Ages, but is depicted in miniatures after the twelfth century. It was probably a late medieval addition directed at increasing the portability of the instrument as well as enhancing its tone.

Diagram 1. Medieval diagram of the monochord.¹

These factors seem to suggest that the basic pitch varied considerably between instruments and was influenced more by the physical characteristics of the individual instruments and the vocal range of the user than by a given standard of pitch.

Later writers describe the construction of monochords of a variety of sizes and shapes, many of which are equipped with more than one string. Technically, these multi-stringed instruments should not be called monochords, but the consensus was that, if the strings were tuned in unison, the designation was to be retained. In the instances of multi-stringed monochords tuned in octaves or other intervals the use of the instrument like an ordinary monochord accounted for the retention of the name.⁵

The primary purpose or use of the monochord was to sound intervals or scales whose pitch relationships had been predetermined by means of mathematical calculation. Traditionally, any kind of determination of the notes of a scale, whether a mathematical or an aural determination, has been called a monochord division. This custom is nevertheless misleading because, although the mathematical determination of the pitch relationships is necessary for the correct production of the desired sounds, these determinations are not usable for practical musical purposes unless they can be applied directly to a monochord without further calculation. It is perhaps preferable to use the term *manual division* to designate any set of calculations that may be applied directly to a string under tension, that is, the mathematical formulas which will produce the desired sounds when applied directly to the monochord. The manual division of the monochord is the only kind of division to attain any practical significance before the early twentieth century.⁶

ACOUSTICAL SYSTEMS APPLIED TO THE MONOCHORD

The divisions of the monochord are usually presented in musical literature in terms of proportions, string lengths, or cents. The first two methods have a tradition almost as old as the monochord itself and are both directly applicable to the instrument. The third is greatly favored by most contemporary writers on tem-

⁵ In all of the Greek and in many of the Latin sources dealing with the monochord one encounters the word *canon*. In many of these sources it is used synonymously with the word monochord. In its strictest sense, however, it seems reserved for instructions on dividing the string, or for the diagram that is to be placed under the string to facilitate the exact placement of the bridge, just as the word monochord, in its strictest sense, is reserved for reference to the instrument.

⁶ The appearance of so many tunings and temperaments in the eighteenth and nineteenth centuries that are not physically applicable to the monochord brings up a point that is of great importance in the study of the scale variations of this period: that tunings before the early twentieth century which did not employ the monochord were virtually worthless from a practical musical standpoint. The application of such impractical tunings, produced mainly by mathematicians whose interest in scale division was intellectual and as much a matter of scientific as of musical interest, had to be done by ear according to a set of verbal directions.

The practicing musicians, on the other hand, who were interested in actual tunings, used the monochord in order to give their theories some practical realization. Because of the limitations of the instrument and of the ear, however, tuning by means of a monochord may be presumed to be as difficult and inaccurate as a tuning determined by ear, but at least a tuning that was applicable to the monochord was heard by its inventor in the most accurate way available and was not just a series of numbers.

peraments and tunings, but because of its nonproportional nature it needs to be reduced either to string lengths or to proportions, before it can be used to produce pitches aurally.⁷

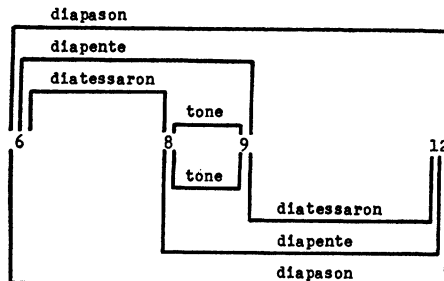
Proportions

The Pythagorean concept of monochord division by proportions is based on two means: the arithmetic mean and the harmonic mean. The four main intervals of the system are derived by relating, in pairs, the smallest whole integers that can be used to show the relationships of these two means. These numbers are 6, 8, 9, and 12. The ratio 12:6 produces the diapason (octave); 9:6 and 12:8, the diapente (fifth); 8:6 and 12:9, the diatessaron (fourth); and 9:8, the tone (major second).

From right to left in Diagram 2 these numbers produce multiplex and superparticular proportions (2:1, dupla; 3:2, sesquialtera; 4:3, sesquitercia; 9:8, sesquiocava). From left to right these numbers are transposed into submultiplex and subsuperparticular proportions (1:2, subdupla; 2:3, subsesquialtera; 3:4, subsesquitercia; 8:9, subsesquiocava). Other multiplex and submultiplex proportions used on the monochord are tripla (3:1), subtrippla (1:3), quadrupla (4:1), and subquadrupla (1:4).

Whether an octave, for example, is expressed as dupla (i. e., by doubling a given length of string) or as subdupla (i. e., by halving a given length of string) and whether the other proportions are expressed with their larger terms first or last (e. g., 3:2 or 2:3 or 3/2 or 2/3), may seem of small import at this time; but a clear

Diagram 2. The basic Pythagorean intervals.



understanding of the relationships of both kinds of proportions to interval production is necessary for understanding all kinds of monochord divisions and their influence on medieval pedagogy.⁸

⁷ A fourth method, that of expressing string lengths by means of logarithms, appears not infrequently in the literature of the eighteenth century. This system, from which the cents were later derived, is also not directly applicable to the monochord.

⁸ This aspect of the division of the monochord is apparent in all of the medieval treatises that discuss the elements of music. As such it plays a vital part in the medieval retention of the Pythagorean tuning and the Greek genera as well as in the expansion of the scale system, the use of letter notation and the development of didactic techniques. Cf. C. ADKINS, *The Theory and Practice of the Monochord*, unpublished dissertation, State University of Iowa, 1963, pp. 68–190. The reader is also referred to the monochord studies of SIGFRID WANTZLOEBEN (*Das Monochord als Instrument und als System*, Halle, Karras, 1911), K. W. GÜMPPEL (*Das Tasten-Monochord Conrads von Zabern*, in: *Archiv für Musikwissenschaft*, XII, 1955, pp. 143–66), and the brief but excellent article *Monochord* by HANS HEINZ DRÄGER, in: *Die Musik in Geschichte und Gegenwart* (IX, 1957, col. 474–75).

System of String Lengths

The cumbersomeness of the proportional system and the difficulty encountered in manually dividing a monochord by means of a compass caused some investigators to adopt the system of string lengths. If, for example, a string is assigned a length of 10,000 units of measurement, its upper octave would be regarded as having a length of 5,000 units. This system is an accurate and simple method of abstract pitch representation, but it is difficult to reproduce aurally on a monochord because of the size of the numbers involved. A case in point is the set of string lengths for equal temperament devised by Johann Neidhardt in 1706.⁹ The string length specified for the second scale step of this system was 1781.82 units. There were many like Marpurg, however, who believed that a temperament could be more easily reproduced by reducing the number of digits representing the total length of the string to as few as three—a compromise rarely confessed to by the users of string lengths in an era when the system was at its height of popularity.¹⁰

System of Cents

The system of cents, introduced by Alexander Ellis in the late nineteenth century, has been widely adopted as a uniform basis for the comparison of intervals. The application of this kind of abstract representation to an intervallic series originally determined by other means (i. e., proportions or string lengths) is of doubtful value for two reasons. First, the nonproportional nature of the cents renders them incapable of direct mechanical reproduction;¹¹ and second, the end result of a monochord division is often not so important or interesting from the historical point of view as the means by which it is attained.

With regard to the method of dividing the monochord, one should be aware that the technique used in working out a specific monochord division was often selected with a view to its intended usage. For example, in the Middle Ages the monochord divisions all achieve the same end result and all utilize the same four proportions (dupla, sesquialtera, sesquitercia, sesquioctava), yet the techniques of division vary according to whether the division was made for use in a speculative or practical musical treatise. There are also significant trends toward simplification of the division of the instrument that appear to have directly influenced not only the expansion of the whole medieval musical concept but also the eventual discontinuance of the Pythagorean tuning system in the early Renaissance.¹²

⁹ J. G. NEIDHARDT, *Sectio canonis harmonici*, Königsberg, Eckart, 1724, p. 7.

¹⁰ F. W. MARPURG, *Anfangsgründe der theoretischen Musik*, Leipzig, J. G. I. Breitkopf, 1757, pp. 172–75.

¹¹ See Ellis's own description of this attempt in his annotations to the English translation of HERMANN VON HELMHOLTZ, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, 5th ed., London, Longmans, Green, and Co., 1930, p. 523.

¹² See ADKINS, *op. cit.*, pp. 29–30, 68–284.

THE MANUAL TECHNIQUE OF THE MONOCHORD

The technique of the manual division of the monochord is divided into three categories: the first contains diatonic divisions based on superparticular proportions; the second includes the various methods of adding chromatic semitones to a diatonic division; the third comprises divisions whose notes are determined mathematically in terms of string lengths. Of these classifications, the first represents practically all of the monochord divisions of the Greek, medieval and early Renaissance periods. The second was used mainly in the Renaissance era and the third is the main method of the post-Renaissance period (after 1600). Since the manner of dividing the monochord by means of the system of string lengths and a ruler is self-explanatory it will not be dealt with further. The techniques of the other categories are presented, not as specific divisions of a particular tuning, but as general concepts necessary to an understanding of the instrument.

The Manual Division of Diatonic Superparticular Tunings

The manual divisions of the monochord in the Greek and medieval eras are based upon an extension of the relationships of the superparticular proportions. A given division is usually based on a preponderance of either superparticular or subsuperparticular proportions. The initial note of a division based on a plurality of superparticular proportions is found as a part of the total length of the string, and the remaining notes are determined, not in relation to the length of the entire string, but in relation to the string length of the initial note. Divisions using mainly subsuperparticular proportions usually have the total length of the string as the initial note and the succeeding notes are related to this length. For example, if a given portion of a length of string is divided into eight parts, a tone may be produced by adding the length of one of these parts to the original portion, making nine. Conversely, if the string length is divided into nine parts, one part must be subtracted in order to produce the tone. The first of these divisions, using a superparticular proportion (sesquioctava), proceeds from a higher to a lower pitch; the second using a subsuperparticular division (subsesquioctava), proceeds from a lower pitch to a higher.

A division containing predominantly superparticular proportions progresses in a descending manner, that is, from the higher sounding pitches to the lower through the use of longer and longer portions of the string, and many be called a *descending division*. The use of subsuperparticular proportions produces an *ascending division* that utilizes shorter and shorter portions of the string. A division using both kinds of proportions may be said to be an *alternating division*, and, depending on the primary sesquioctaval division of the string, it may be classed as an *alternating-descending* or an *alternating-ascending* division.

As a means of clarification, the two following divisions for determining the notes of a tetrachord are offered. It will be noticed that the semitone of the descending division is between the lower two pitches, whereas that of the ascending division

appears between the upper two pitches. This arrangement of the tetrachord is a result of the simplest mechanical method of finding the Pythagorean semitone, which is to subtract two whole tones from the diatessaron.¹³

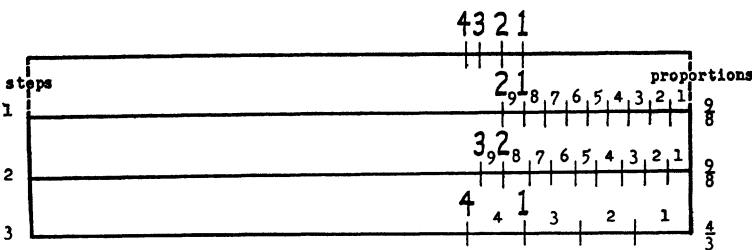
The descending division for determining the tetrachord.

(For this demonstration a point 25 cm. from the end of a one meter string has been selected.) The first note will have a sounding length of 25 cm. The second pitch, a whole tone lower, is determined by taking a sesquiocitava proportion to the first pitch. The string length of the second pitch will be 28.125 cm. The logical completion of these divisions results in a tetrachord that may be summarized as follows:

Pitch	4	3	2	1
String length	33.333 cm.	31.641 cm.	28.125 cm.	25.00 cm.
Proportion	$\frac{256}{243}$	$\frac{9}{8}$	$\frac{9}{8}$	
Interval	semitone	tone	tone	

A visual representation of this division is shown in Diagram 3.¹⁴

Diagram 3. A sample descending monochord division.



¹³ The ratio of the Pythagorean semitone (256:243) is not directly applicable to the manual division, since any mechanical division of the string into 243 and 256 units would be grossly impractical. This ratio is found as a sort of by-product by subtracting the sum of the two whole tones ($\frac{9}{8} \times \frac{9}{8} = \frac{81}{64}$) from the fourth ($\frac{4}{3} : \frac{81}{64} = \frac{256}{243}$). Procedures such as this illustrate a cardinal principle of monochord division: complex ratios are determined by calculation with simple ratios. The corollary to this principle is that in most theoretical writings all ratios, both simple and complex, are basically associated with mathematical calculation rather than measurement.

¹⁴ By using a series of parallel lines to represent successive measurements, one can show the relation of these measurements to the whole string. The measurements of the superparticular division are numbered from right to left (see steps 1 and 2 of Diagram 3); subsuperparticular divisions are numbered from left to right (steps 1 and 2 of Diagram 4). The linear representation of the complete division is presented on the top line of the diagram. The particular measurement of each step is listed under "proportions" at the right end of each line.

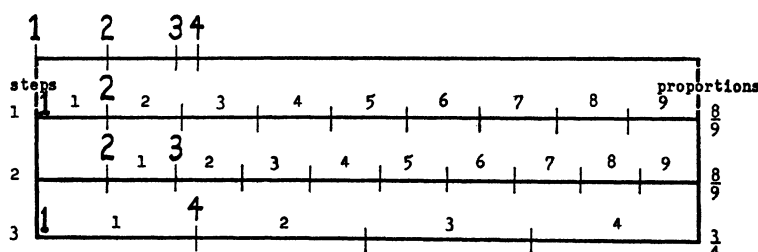
The ascending division for determining the tetrachord.

For this division the entire sounding length of the monochord's string (one meter) may be used for the first pitch. The second pitch, found by means of a subsestiquioctava proportion has a length of 88.889 cm. The completion of the division results in the following tetrachord.

Pitch	1	2	3	4
String length	100.00 cm.	88.889 cm.	79.023 cm.	75.00 cm.
Proportion	$\frac{8}{9}$	$\frac{8}{9}$	$\frac{243}{256}$	
Interval	tone	tone	semitone	

Diagram 4 visually represents the above procedure.

Diagram 4. A sample ascending monochord division.



The completion of either of the above divisions in the manner of the Middle Ages would result in a two-octave scale in the Pythagorean tuning whose lowest note would be obtained from the entire length of the string. These two kinds of division, ascending and descending, exerted great influence upon the development of Western music. In general it may be said that the Greek writers up to A. D. 500 utilized the descending division; medieval scholars used both ascending and descending divisions; and later writers (Renaissance and post-Renaissance) preferred the ascending division.¹⁵

The Manual Division of the Chromatic Scale

There are three methods of determining semitones by means of the manual division of the monochord: an extension of the superparticular ratios, an arithmetical division of the tone, and a mean-proportional division of the tone.

In superparticular tunings one has the option of dividing to produce either of two complete and different (different even for notes which are "enharmonic equivalents") sets of chromatic notes. These may be obtained by the successive application of the sesquialtera proportion (beginning with B-natural) or of the subsestiquialtera

¹⁵ The specific reasons for these usages are discussed in detail in ADKINS, *op. cit.*, pp. 35–337.

proportion (beginning with the note F). The resultant intervals will be a series of perfect fifths in descending order (sesquialtera) or ascending order (subsesquialtera).¹⁶ The descending semitones may be called *sharp semitones* and the ascending semitones, *flat semitones*.

Arithmetic semitones are determined by an equal division of the difference between the string lengths of two notes a step apart. Even though the resulting semitones are of unequal size, this method was frequently used in the post-medieval period.

Equal semitones are determined from mean proportional string lengths and are usually found by means of the *Euclidean construction*. This geometric construction is effective for finding one mean proportional, but in order to determine more than one proportional string length, one needs to resort to more complicated mechanical devices such as the mesolabium¹⁷ or to the kind of geometric figures used by Lemme Rossi in his *Sistema musico* of 1666.¹⁸ While the mesolabium and other geometrical methods of determining mean proportionals are not frequently encountered in connection with the monochord, they are often used in placing the frets on stringed instruments.¹⁹

SOME OBSERVATIONS CONCERNING THE MONOCHORD

Information about the construction and technique of dividing the monochord as discussed in the preceding pages is readily obtainable from the original sources. Once a working knowledge of the instrument has been acquired, however, other less easily understood, but more intriguing aspects present themselves. Some of these facets of the monochord and its relation to musical practice are: the efficiency and accuracy of the division; the kind of scale tuning or temperament produced; and the uses of the completed monochord division.

Because the monochord of the Greek and medieval periods was almost always employed as a didactic device, its users attempted to make the division as efficient and as accurate possible. The efficiency of a monochord division depends on the relation between the number of separate measurements made and the number of notes produced. For example, a division that will produce fifteen pitches in seven measurements is much more efficient than a division that needs seventeen measurements to produce the same number of pitches.

The results of these efforts are particularly noticeable after 1450, since, after this date, each new division often produced a new variation of a given tuning. Often the

¹⁶ This phenomenon is due to the idiosyncracies of the superparticular tunings. For a detailed explanation, see *Ibid.*, Chapters III and IV.

¹⁷ Clearly described in J. Gow, *A Short History of Greek Mathematics*, London, Cambridge University Press, 1884, pp. 245–6.

¹⁸ Besides Rossi (*Sistema musico*, Perugia, Laurenzi, 1666, pp. 62, 82), KIRCHER (*Op. cit.*, I, p. 207) was apparently the only other author to use anything other than the mesolabium in connection with the monochord.

¹⁹ See J. M. BARBOUR, *Tuning and Temperament*, East Lansing, Michigan State College Press, 1951, pp. 51 ff.

musician wished to change the tuning but not infrequently he was only seeking a simpler method of division. It would seem that the appearance of an altered tuning bothered the Renaissance musician little, for in view of the inaccuracy of the monochord, a variation of a few cents (in some cases as much as 22 cents) was a small sacrifice to pay for a more efficient division. A case in point is the division of Ramos de Pareia whose monochord tuning varied widely from the accepted Pythagorean standard. Ramos, however, was apparently not bothered by the pitch deviation as long as he was able to simplify the division of the instrument. To this end he stated: "So therefore we have made all of our division very easy, because the fractions are common and not difficult."²⁰ In many cases this desire is not stated expressly, as it was by Ramos, but it may be suspected that it served as the underlying cause of many of the new tunings of the Renaissance and succeeding periods.

Therefore, in addition to the efficiency of a division (the relationship of the number of measurements to the number of pitches produced), a second criterion of a good division is how closely it approximates the musical or acoustical result desired by its inventor. In other words, does a given division achieve accuracy as well as efficiency, or is one sacrificed for the other?

Although the origins of the instrument are shrouded in the haze of antiquity, its usage can be definitely traced to about 300 B. C., when, according to Greek writings, the monochord seems to have been most often a tool of the mathematician. In the hands of the mathematicians the monochord was used as a device to provide both visual and aural representation of the mathematical ratios of the intervals. There is also evidence that the monochord may have found, among the Greeks, some small favor as a performing instrument.²¹

In the Middle Ages the monochord not only fulfilled the basic functions allotted to it by the Greeks, but it also served as the principal method of expounding details of music theory—that is, it was employed frequently in explanation of the mathematical manner of determining intervals and scales, and also as a pitch-producing device for the teaching of singing. The Renaissance and later periods utilized the instrument to a great extent as a practical means of experimenting with scalar variants, and to a lesser extent as a pitch-producing medium for the tuning of keyboard instruments. A system of acoustical representation expressed in the form of string lengths, which was derived from the monochord, also found great favor with theorists, composers, and mathematicians in this latter era.

Symbolic use was made of the monochord in the Renaissance to illustrate the unity that existed between man and his environment—both physical and spiritual. As more accurate devices for pitch experimentation became available, the monochord fell into disuse, surviving in the twentieth century only as a laboratory instrument.

²⁰ BARTOLOMÉ RAMOS DE PAREIA, *Musica Practica* (1482), ed. J. Wolf, Leipzig, Breitkopf und Härtel, 1901, p. 60.

²¹ ADKINS, *op. cit.*, pp. 361—5.