Modes of internal symmetry - taking a closer look at Messiaen's modes of limited transposition

Stefaan.Himpe@gmail.com

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1 Introduction

Before we start, make sure to get the latest version of this document from https://github.com/shimpe/mints . If you are unsure what to do on that page, click "Download ZIP". It will download an archive containing all the files required to recreate this document. In the *out* folder is a document.pdf file which corresponds to the article itself. In the *output* folder are .pdf and .midi files of the modes listed in sections 8, 9, 10, 11, 12, 13 and 14. Feel free to send your questions and remarks with respect to this document to stefaan.himpe@gmail.com. Feel free to report errors, or corrections, additions, to https://github.com/shimpe/mints/issues

After reading Olivier Messiaen's book "The technique of my Musical Language" I started wondering how exactly his "modes of limited transposition" create the sound they create. Major questions for me became:

- What is so special about the property of *limited transposition* that makes the music derived from it work so well?
- Is music derived from a random subset of a chromatic scale on some sense "crippled" compared to music written based on Messiaen's modes? Can we find some kind of intuitive explanation why Messiaen's modes work well, arguably better than other non-diatonic modes? Can we use this insight to propose other modes that perhaps do not have limited transposition, but still might result in an interesting, fresh, sound?

I set out to do a series of experiments and came up with some insights that I intend to explain here. I apologize in advance if what I'm about to describe is already well-known and obvious to more informed readers. Please accept that I'm writing this down only to further my own understanding of the matter. I do not claim to have found something new.

2 Symmetry? What symmetry?

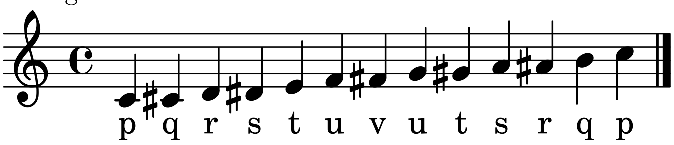
Messiaen himself explains how his modes can be thought of as consisting of *symmetrical* groups of notes. The exact nature of this symmetry was not entirely clear to me. In fact, at first sight it seemed more like repeating patterns than symmetry, and this is what I wanted to clarify.

As a starting point I set out to systematically enumerate all modes derived from a chromatic scale that have intervals symmetrically distributed around the f# (the middle note of the chromatic scale starting on c). Note that during the experiments I don't directly take into account any property of *limited transposition* but I will find back many of Messiaen's modes by considering only symmetry arguments anyway.

2.1 Systematic enumeration

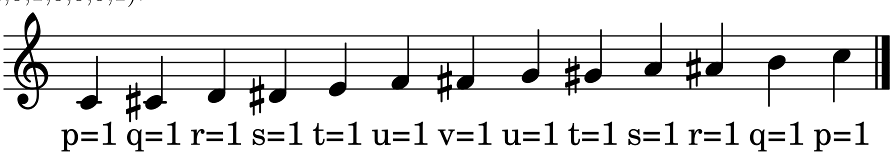
The first thing to explain is how the modes with intervals symmetrically distributed around f# can be systematically enumerated.

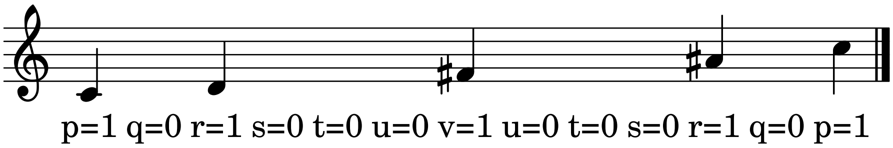
I started from a chromatic scale. On that scale I added symbols under each note. Note how the symbols that occur left of f# return later on to the right of f#. This is important to keep symmetry of the intervals around f#, as will hopefully become clearer in the next step. For now, remember that the symbols under the complete chromatic scale form a *palindrome*, i.e. if you read them left-to-right you get exactly the same sequence of symbols as when you read them right-to-left.



In what follows we will now construct modes by assigning values 0 or 1 to each of the symbols p,q,r,s,t,u,v. A value of 0 indicates that the note to which the symbol is attached is not to be selected from the chromatic scale while constructing a mode. A value of 1 indicates that the notes to which the symbol is attached are to be selected from the chromatic scale.

E.g. if we set p=1, q=1, r=1, s=1, t=1, u=1, v=1 we retain all the notes from the chromatic scale and end up with the chromatic scale itself. We can say that the chromatic scale is characterized by a "key" (p,q,r,s,t,u,v) = (1,1,1,1,1,1,1). If we set p=1, q=0, r=1, s=0, t=0, u=0, v=1, we end up with a mode that contains the notes c, d, f#, a#, c'. This mode is characterized by a key (p,q,r,s,t,u,v) = (1,0,1,0,0,0,1).





This method for constructing modes has some properties:

- Any combination of values 0,1 assigned to all of p, q, r, s, t, u, v results in a mode derived from the chromatic scale with intervals distributed symmetrically around f#.
- A different combination of values 0,1 assigned to p, q, r, s, t, u, v results in a different mode. In other words, there are no two different keys

(p,q,r,s,t,u,v) that result in the same set of notes selected from the chromatic scale.

- If we look at all possible ways that we can assign 0, 1 to p, q, r, s, t, u, v, we construct all possible subsets of the chromatic scale with intervals distributed symmetrically around f#. In other words, we don't skip any modes symmetrical around f# by using this method.
- All in all, this means that any (p,q,r,s,t,u,v) key uniquely defines one mode with intervals symmetrically distributed around f#.
- There are $2^7 = 128$ different ways to assign the values 0, 1 to the variables p, q, r, s, t, u, v. This means that there are 128 unique modes with symmetrical distribution of intervals around f#. One of those modes is mode 0, which has no notes at all. We don't consider it further.

2.2 Intermezzo: binary numbers

In computer science a key like (0,1,1,0,0,1,0) can be interpreted as a binary number. Each number 1 or 0 is called a "bit". For every binary number, there's an equivalent decimal number and vice versa. In the systematic enumeration of modes in the appendices of this explanation, I use decimal equivalents of binary numbers, because they take much less typesetting space. If you want to make sense of the explanations that follow, it's useful to understand how binary numbers relate to decimal numbers, as explained now:

2.2.1 Conversion from binary number to decimal number

In order to convert from a binary number to a decimal number, one writes powers of two underneath the binary number and then multiplies and adds the results. As an example, consider conversion of number (0,1,1,0,0,1,0) to decimal:

0	1	1	0	0	1	0	$\leftarrow$ write binary digits	
64	32	16	8	4	2	1	$\leftarrow$ write powers of 2	
$*\downarrow$	$*\downarrow$	$*\downarrow$	$*\downarrow$	$*\downarrow$	$*\downarrow$	$*\downarrow$	$\downarrow$ multiply one by one	
0	32	16	0	0	2	0	$\rightarrow$ sum to get:	$32 + 16 + 2 = 50$

Note that if I add extra 0's to the left of a binary number, its value doesn't change. The same is true for a decimal number: if you write 6 or you write 06 you really have the same number.

2.2.2 Conversion from a decimal number to a binary number

In order to convert a decimal number back to a binary number one keeps on dividing the number by 2, and notes down the rest after division. As an example, consider converting 50 back to binary representation:

- We start from 50
- divide 50 by 2 to get 25, with rest after division=0
- divide 25 by 2 to get 12, with rest after division=1

- divide 12 by 2 to get 06, with rest after division=0
- divide 06 by 2 to get 03, with rest after division=0
- divide 03 by 2 to get 01, with rest after division=1
- divide 01 by 2 to get 00, with rest after division=1

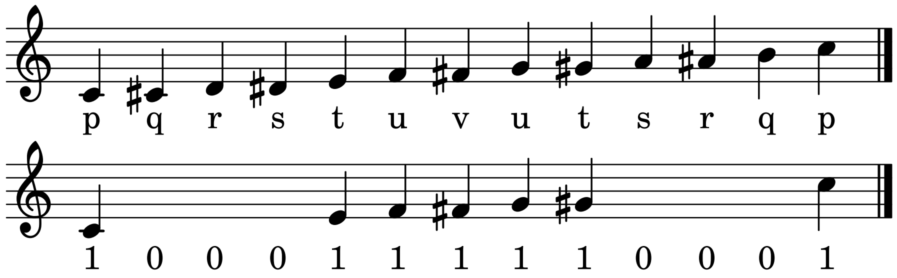
If you now look at the rests after division from bottom to top, you get (1,1,0,0,1,0). Remember from section 2.2.1 that one can add zeros to the left of any number without changing its value. Since we prefer to work with binary numbers (keys) of length 7 (i.e. the number of symbols p,q,...,v) we turn the binary number into key (0, 1, 1, 0, 0, 1, 0).

2.2.3 Tip about binary/decimal conversion

Practically all operating systems nowadays have some built-in calculator application that knows how to convert between binary and decimal should you ever need to do so.

3 What's the point? How do these binary numbers help us analyze music?

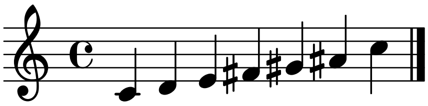
Using this enumeration method, I listed all the 127 non-empty modes that are symmetrical around f# as can be seen in section 8. I've sorted the modes by length. Mode 0 with zero notes was left out. Each mode is annotated with a few numbers, e.g. 74:(2)7-71. The number 74 means it's the 74th mode in the list of modes sorted by length. The number (2) means that we're looking at modes wity binary symmetry (the mode is divided in two symmetrical parts). The number 7 means that the mode consists of 7 notes, distributed symmetrically around f#. The number 71 is the decimal number that corresponds to the binary key (p,q,r,s,t,u,v) = (1,0,0,0,1,1,1) that uniquely defines the mode:



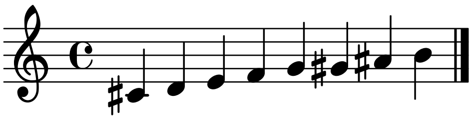
3.1 The symmetry of Messiaen's modes around f#

A first thing that struck me as interesting is that all of Messiaen's modes can be found back in the list of 127 modes enumerated in section 8 (albeit not always in first transposition, which is caused by our restriction to only look at modes symmetrical around f#, and not to look at modes symmetrical around – say – g.):

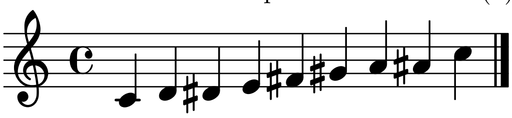
- Messiaen's mode 1 corresponds to our mode (2)85 (p,q,r,s,t,u,v) = (1,0,1,0,1,0,1)



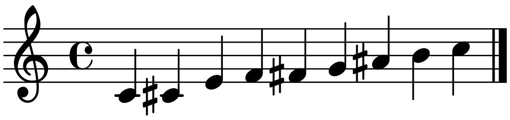
- Messiaen's mode 2 corresponds to our mode (2)54 (p,q,r,s,t,u,v) = (0,1,1,0,1,1,0)



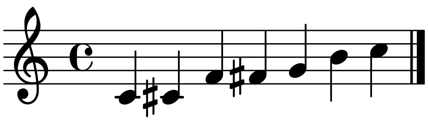
- Messiaen's mode 3 corresponds to our mode (2)93 (p,q,r,s,t,u,v) = (1,0,1,1,1,0,1)



- Messiaen's mode 4 corresponds to our mode (2)103 (p,q,r,s,t,u,v) = (1,1,0,0,1,1,1)

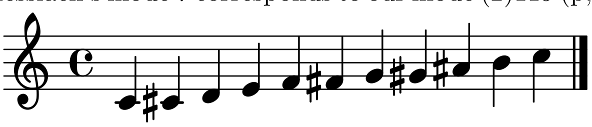


- Messiaen's mode 5 corresponds to our mode (2)99 (p,q,r,s,t,u,v) = (1,1,0,0,0,1,1)



- Messiaen's mode 6 corresponds to our mode (2)107 (p,q,r,s,t,u,v) = (1,1,0,1,0,1,1)

- Messiaen's mode 7 corresponds to our mode (2)119 (p,q,r,s,t,u,v) = (1,1,1,0,1,1,1)



3.2 More symmetry in Messiaen's modes

Now take a close look at the binary keys for Messiaen's modes. *In all but one of his modes, the binary keys are themselves palindromes*, indicating that not only are the modes symmetrical around f#, but they also have extra internal symmetry around d# (left-hand side of f#) and around a (right-hand side of f#). Having a palindromic key thus implies that there's a second level of symmetrical interval distribution inside the upper and lower halves of the modes.

It would not be correct to say that only modes with palindromic binary keys sound good. Look e.g. at mode of binary internal symmetry number (2)90 (1,0,1,1,0,1,0), which is better known as "c dorian". The binary key is not palindromic but it does show other extra symmetries in its structure (observe how its binary key becomes a palindrome if you leave out the last 0). Similarly, Messiaen's fourth mode of limited transposition also becomes a palindrome if you leave out the last 1 in its binary key, indicating that it has significant internal symmetries beyond the always present symmetry around f#.

I'd like to speculate here that additional internal symmetries play an important role in making modes (and their "modes") sound good. The human brain is optimized for pattern matching. It is sensitive to symmetries and the listener probably subconsciously picks up the patterns and hears the symmetries present in the intervals that make up the mode. (If that were true, we might even nominate the "Dorian" mode as the most natural of modes based on a diatonic scale.) Modes with extra internal symmetries look like good candidates for harmony and melody experiments.

3.3 Are there any modes with similar internal symmetries that are not Messiaen modes?

3.3.1 Perfect internal symmetry

In section 9 all modes are listed that have palindromic binary keys. Note that almost all of Messiaen's modes appear here in one form or another, and that some modes appear that are not part of Messiaen's musical language. This is because we used *internal symmetry* instead of *limited transposition* as criterion. From these results, it's quite clear that there's a close connection between the two criteria. It's also interesting that a number of (shorter) modes appear which, to the best of my knowledge, were not used directly by Messiaen, but which may be interesting for further harmonic and melodic experiments.

In what follows, remember that the notation "mode (2)x-y" means "a mode with binary symmetry, x notes and key y, where y should be converted to binary to see which notes are present in the mode. Compare the descriptions given here to the modes as listed in section 9.

- Mode (2)02-008 (0,0,0,1,0,0,0) is a ditonic mode. Two notes may be a bit limited for a composition. Interesting though that it is a tritone, which is one of the basic building blocks for Messiaen's musical language.
- Mode (2)04-020 (0,0,1,0,1,0,0) is a tetratonic mode.
- Mode (2)06-028 (0,0,1,1,1,0,0) is a hexatonic mode.
- Mode (2)04-034 (0,1,0,0,0,1,0) is a tetratonic mode. Interesting about this mode is that there's even more symmetry present in the lower and upper half of the binary key. This is a third level of symmetry in the mode.
- Mode (2)06-042 (0,1,0,1,0,1,0) is a hexatonic mode. Interesting about this mode is that there's even more symmetry present in the lower and upper half of the binary key. This is a third level of symmetry in the mode.
- Mode (2)08-054 (0,1,1,0,1,1,0) is an octotonic mode. It's also known as Messiaen's second mode of limited transposition.

- Mode (2)10-062 (0,1,1,1,1,1,0) is a decatonic mode. This mode is not listed by Messiaen. However, if we extend this mode with a c# at the right, we get a "mode" of Messiaen's seventh mode of limited transposition built on note d.
- Mode (2)03-065 (1,0,0,0,0,0,1) is a tritonic mode. It consists of 2 tritones.
- Mode (2)05-073 (1,0,0,1,0,0,1) is a pentatonic mode.
- Mode (2)07-085 (1,0,1,0,1,0,1) is a heptatonic mode. It's also known as Messiaen's first mode of limited transposition, or as the whole-tone scale. Interesting about this mode is that there's even more symmetry present in the lower and upper half of the binary key. This is a third level of symmetry in the mode.
- Mode (2)09-093 (1,0,1,1,1,0,1) is a nonatonic mode. This is Messiaen's third mode of limited transposition. Interesting about this mode is that there's even more symmetry present in the lower and upper half of the binary key. This is a third level of symmetry in the mode.
- Mode (2)07-099 (1,1,0,0,0,1,1) is a heptatonic mode. This is Messiaen's fifth mode of limited transposition.
- Mode (2)09-107 (1,1,0,1,0,1,1) is a nonatonic mode. This is a "mode" of Messiaen's sixth mode of limited transposition built on note c#.
- Mode (2)11-119 (1,1,1,0,1,1,1) is an undecatonic mode. This is a "mode" of Messiaen's seventh mode of limited transposition built on note b. Interesting about this mode is that there's even more symmetry present in the lower and upper half of the binary key. This is a third level of symmetry in the mode.
- Mode (2)13-127 (1,1,1,1,1,1,1) is the chromatic scale itself. This mode also has a third and even fourth level of symmetry.

3.3.2 Partial internal symmetry

Now follows a list of modes that are partially palindromic as follows: the binary keys of the modes listed here become palindromic if you leave out either the first or last bit. They are listed in musical form in section 10. These form another subset of modes (slightly less "perfect" than the modes in the previous section). Probably some of these modes are better known under other names, but my knowledge of existing scales is not large enough to recognize all of them.

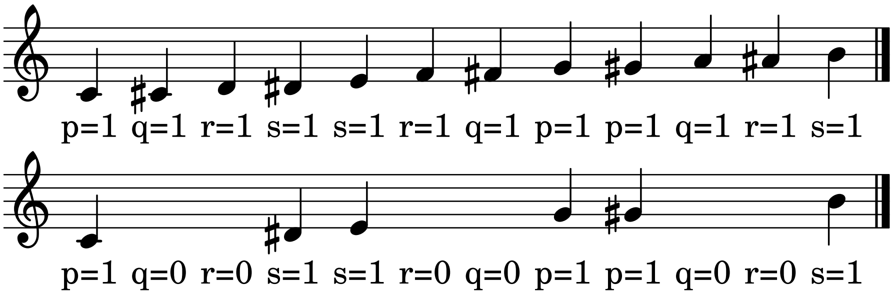
By reducing the constraints on symmetry also other interesting modes can be selected (e.g. modes that are a palindromic if you leave out 2 outer bits), but listing those is left as an exercise to the interested reader.

- (2)001 (0,0,0,0,0,0,1) is a mode consisting of a single note f#. This is a bit limited to compose with :)
- (2)012 (0,0,0,1,1,0,0) tetratonic
- (2)018 (0,0,1,0,0,1,0) tetratonic

- (2)024 (0,0,1,1,0,0,0) tetratonic
- (2)025 (0,0,1,1,0,0,1) tetratonic. Sounds quite exotic (arabic?).
- (2)030 (0,0,1,1,1,1,0) octatonic
- (2)033 (0,1,0,0,0,0,1) tritonic
- (2)036 (0,1,0,0,1,0,0) tetratonic
- (2)037 (0,1,0,0,1,0,1) pentatonic
- (2)045 (0,1,0,1,1,0,1) heptatonic. This is c# aeolian mode (natural minor diatonic scale).
- (2)051 (0,1,1,0,0,1,1) heptatonic. Sounds quite exotic (arabic?)
- (2)060 (0,1,1,1,1,0,0) octatonic
- (2)061 (0,1,1,1,1,0,1) nonatonic
- (2)063 (0,1,1,1,1,1,1) undecatonic. Like a chromatic scale but without note c.
- (2)064 (1,0,0,0,0,0,0) ditonic. Consists of only notes c.
- (2)066 (1,0,0,0,0,1,0) tetratonic. Consists of the notes of a sus4 chord built on c.
- (2)067 (1,0,0,0,0,1,1) pentatonic.
- (2)076 (1,0,0,1,1,0,0) hexatonic.
- (2)082 (1,0,1,0,0,1,0) hexatonic.
- (2)090 (1,0,1,1,0,1,0) octatonic. This is really just the dorian mode of c.
- (2)091 (1,0,1,1,0,1,1) nonatonic. Like the dorian mode of c but with f# added.
- (2)094 (1,0,1,1,1,1,0) decatonic.
- (2)097 (1,1,0,0,0,0,1) pentatonic.
- (2)102 (1,1,0,0,1,1,0) octatonic. Sounds quite exotic (arabic?).
- (2)103 (1,1,0,0,1,1,1) is the fourth mode of limited transposition of Messiaen.
- (2)109 (1,1,0,1,1,0,1) nonatonic. Left halve sounds darker than right halve.
- (2)115 (1,1,1,0,0,1,1) nonatonic.
- (2)126 (1,1,1,1,1,1,0) dodecatonic. Like a chromatic scale, but with f# left out.
- (2)127 (1,1,1,1,1,1,1) is the chromatic scale. This is the only key that also appears in the fully palindromic modes.

4 Ternary symmetries

So far we've only considered symmetries that divide the chromatic scale in a symmetrical left half and a right half. But a chromatic scale consists of 12 half tones, and therefore it can also be divided in groups of 3. The way of working remains more or less the same. First we propose an enumeration scheme. Note that to find ternary symmetries, we leave out the repeated tonic at the end of the mode. We then need a 4-bit binary key. Note how the mode now is divided in three parts $p, q, r, s \rightarrow s, r, q, p \rightarrow p, q, r, s$. This unfolded key (p,q,r,s,s,r,q,p,p,q,r,s) is not a palindrome anymore. This is a fundamentally different form of symmetry, namely between d#,e and between g,g#.



We can now reuse the knowledge we gathered before: given that we use 4-bit binary keys, there must be $2^4 = 16$ such modes (of course mode 0 has no notes, so we don't consider it further). As before we can translate the binary keys to decimal numbers, but the decimal denote a different mode than the same decimal numbers we used while examining binary symmetries. The difference lies in the structure of the unfolded key. In the binary symmetry case we had a key (p,q,r,s,t,u,v) that after unfolding becomes (p,q,r,s,t,u,v,u,t,s,r,q,p). Now in the ternary case we have a key (p,q,r,s) that after unfolding becomes (p,q,r,s,s,r,q,p,p,q,r,s). To distinguish the decimal numbers for modes with binary symmetry from the decimal numbers for modes with ternary symmetry, we preceded the former ones with (2) and we precede the latter ones with (3).

Sections 15, 16, 17, 18, 19 list all 16 modes with ternary symmetry.

5 Deriving harmonies from modes of internal symmetry

Another question I was struggling with was why Messiaen chose to build chords based on the interval of a fourth. During my investigation I think I saw a possible explanation as follows:

- Sections 11, 12, 13, 14 systematically list the chords built on the modes of binary internal symmetry by taking notes from consecutive mode (scale) degrees, every third mode degree, every fourth mode degree, every fifth mode degree respectively. Sections 16, 17, 18 and 19 do the same for modes of ternary internal symmetry.

- As is clearly visible, the fewer notes are in a mode that is symmetrical around f#, the more widely spaced those notes are (on average).

- In wider spaced modes (many 0's in the binary key), it makes sense to build chords from mode degrees that are close enough to each other.
- In more dense modes (many 1's in the binary key), it makes sense to build chords from mode degrees that are spaced further apart. If we use notes too close together, every chord sounds very dissonant and there's not much room for creating harmonic contrasts.
- Since Messiaen's modes are relatively dense compared to - say - a diatonic scale (Messiaen's modes all have 8 or more notes, whereas a diatonic scale has 7 notes), my guess is that the harmonies as built using every third note sound a bit too harsh, and Messiaen therefore decided to to use fourths.

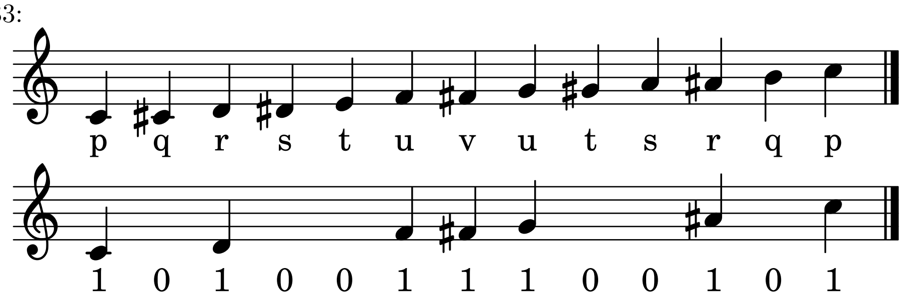
It would seem that when deriving harmonies from a set of notes we want to avoid uneven spreading of intervals over the mode, to avoid ending up with a series of very closely spaced chords, followed by a series of much more widely spaced chords. In other words: a mode that consists of a left part with many half tones, and a right part with many whole tones will tend to result in much more dissonant chords derived from that left part, and much more open sounding chords derived from the right part. Can the binary keys can help us see in which modes the intervals are better spread out than in other modes?

5.1 From binary key to intervals in symmetric modes

First we can convert the binary keys back to intervals between successive notes in the mode. Doing so is simple once we think back of what the binary keys really mean: each 1 or 0 is an inclusion respectively exclusion of a particular note from the chromatic scale built on c. We can find back the intervals in the mode as follows:

- Write down the binary key (p,q,r,s,t,u,v) and unfold it to from the complete mode: (p,q,r,s,t,u,v,u,t,s,r,q,p). Or in the case of a ternary symmetrical mode, take the key (p,q,r,s) and unfold it to (p,q,r,s,s,r,q,p,p,q,r,s).
- Now each time count the number of 0's between successive 1's. Each count is one less than the number of half steps in the interval.

An abstract description like the above begs for an example. Let's take mode 83:



Number (2)83 in binary is (1,0,1,0,0,1,1). After unfolding we get (1,0,1,0,0,1,1,1,0,0,1,0,1) (see music example). Now we count zeros between successive 1's. We find 1 zero, 2 zeros, 0 zeros, 0 zeros, 2 zeros, 1 zero:

If we count zero 0's, then the interval between successive notes is 1/2 tone. If we count one 0, the interval is 1 tone. In general, if z is the number of zeros

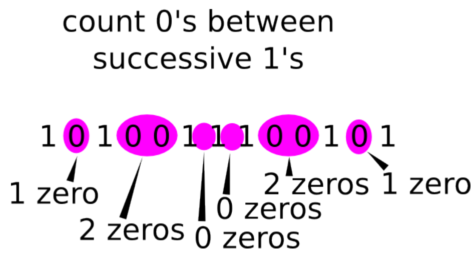


Figure 1: Turning binary keys back into intervals

we counted, the number of half tones in the interval is $h = (z+1)$. And then the number of tones in the interval is $t = h/2 = (z+1)/2$. In the case of mode (2)83, we apply this formula as follows:

- we counted 0's between successive 1's: (1,2,0,0,2,1).
- we apply the formula: ((1+1)/2, (2+1)/2, (0+1)/2, (0+1)/2, (2+1)/2, (1+1)/2) = (1, 1.5, 0.5, 0.5, 1.5, 1).
- so we have a mode with intervals 1 tone, 1.5 tones, 0.5 tones, 0.5 tones, 1.5 tones, 1 tone
- we double check with the musical example and see indeed that $c \to d = 1$ tone, $d \to f = 1.5$ tones, $f \to f\# = 0.5$ tones, $f\# \to g = 0.5$ tones, $g \to a\# = 1.5$ tones, $a\# \to c = 1$ tone

5.2 Ideal interval size. Avoiding clusters and gaps

Intuitively, when one wants to derive harmonies by stacking notes from every n-th scale degree, one could decide to avoid too small intervals (clusters) and too large intervals (gaps), e.g. to avoid a concentration of too dissonant chords on one side of the scale. For this reason it's useful to think about what intervals one reasonably can expect to occur in a mode.

Suppose you create a mode of only 2 different notes. These 2 notes have to span an octave, i.e. 12 half tones. To have maximal spreading of the notes over the mode one should have intervals between the notes of 6 half tones ($c \to f\#$). The interval ($f\# \to c$) closes the construction by repeating the first note c, so this second "c" it is not a "third note" in our mode. More general, for n notes spanning an octave (12 half tones), the ideal interval has $12/n$ half tones.

Suppose this assumption makes sense, then in an octotonic scale (8 distinct notes) the ideal interval between notes is $12/8 = 1.5$ half tones. There's one problem with this: 1.5 half tones leads to microtonal music. If we don't want to go there, we need to do the next best thing: round to multiples of 1. We can't round all 1.5 half tone intervals to 2 half tone intervals because then we end up with way too many half tones to fit in an octave. Similarly we can't round all 1.5 intervals down to 1 because then we end up with too few half tones to span the octave. We can however approximate this 1.5 by alternating between rounding 1.5 up to 2 and rounding 1.5 down to 1 to get the following configuration of half tone intervals: (1,2,1,2,1,2,1,2) which nicely adds up to

$1+2+1+2+1+2+1+2=12$ half tones over 8 notes. But now look closely at what we really constructed...

We find Messiaen's second mode of limited transpostion! Even though I didn't present a rigorous mathematical proof here, I hope it is clear that Messiaen's second mode of limited transposition is a best possible approximation of evenly spread intervals in an octotonic scale (best possible if we don't allow microtonal intervals).[1]

When we select modes for our own compositions, we may want to pay some attention to avoiding clusters and gaps in the intervals that lie between the notes in the modes we select. An interval G can be named a "gap" if it has more half tones than the ideal interval rounded up, and an interval C can be named a "cluster" if it has less half tones than the ideal interval rounded down. In all this, the ideal interval is itself a function of the number of notes in the mode. Summarizing:

- The ideal interval I(n) in a mode is $I(n) = 12/n$ where n is the number of distinct notes in the mode.
- An interval G is a gap if $B > \lceil I(n) \rceil$. (The symbols $\lceil$ and $\rceil$ should be read as "round up")
- An interval C is a cluster if $S < \lfloor I(n) \rfloor$. (The symbols $\lfloor$ and $\rfloor$ should be read as "round down")

6 Conclusions

To summarize:

- First we systematically listed all modes with internal symmetry around f# derived from a chromatic scale. We found that there are 127 non-empty such modes.
- Then, we saw how all of Messiaen's modes are part of this list of 127 modes, meaning that they at least have some symmetry in interval distribution.
- After that, we noticed how all but one of the Messiaen modes contain extra symmetries in the lower half and upper half of the mode (palindromic keys). We listed all modes that have both symmetry around f# and the extra symmetries in the lower half and upper half of the mode, and discovered some potentially interesting modes not directly used by Messiaen (with fewer notes). Even though we didn't care about the property of *limited transposition*, by just considering symmetry arguments we arrived at a very similar set of modes.
- While doing so, we also formulated a possible explanation for why Messiaen may have chosen to build his chords using fourths, and we speculated about how internal symmetry and even spreading of intervals may contribute to make Messiaen's modes work better than other, randomly chosen, modes.

[1] This makes me wonder how octotonic scales sound if we do allow microtonal intervals.

7 Some resources

While investigating I made extensive use of Jackson Hardaker's Messiaen mode visualizer: http://messiaen.jacksonhardaker.com/

The complete code required to reproduce the experiments and the text in this document (together with midi files for the listed modes and chords in the following sections) can be found online at https://github.com/shimpe/mints. To recreate this document you need at the very least the following free software:

- python 2.x
- lilypond
- LaTeX
- a .pdf viewer (I used okular, but any viewer should do).

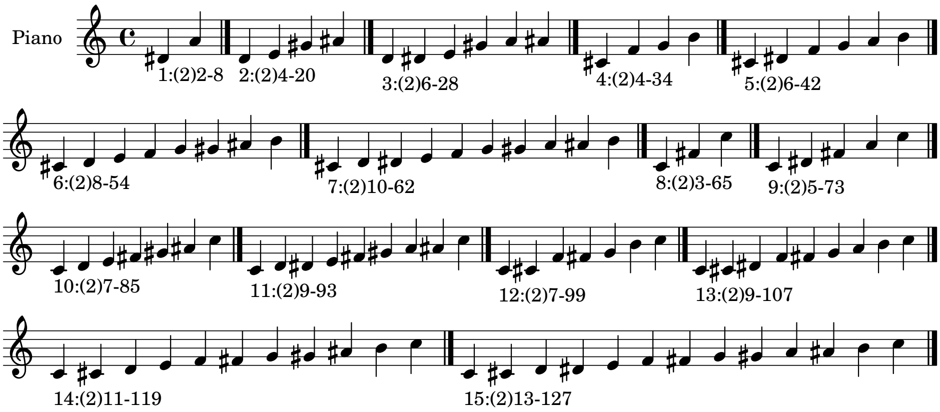
The provided build script is written in bash. For windows or other systems, you may need to translate to an appropriate format.

Feel free to send your questions and remarks with respect to this document to stefaan.himpe@gmail.com. Feel free to report errors, or corrections, additions, to https://github.com/shimpe/mints/issues

8 All modes with binary internal symmetry around f#, ordered by length

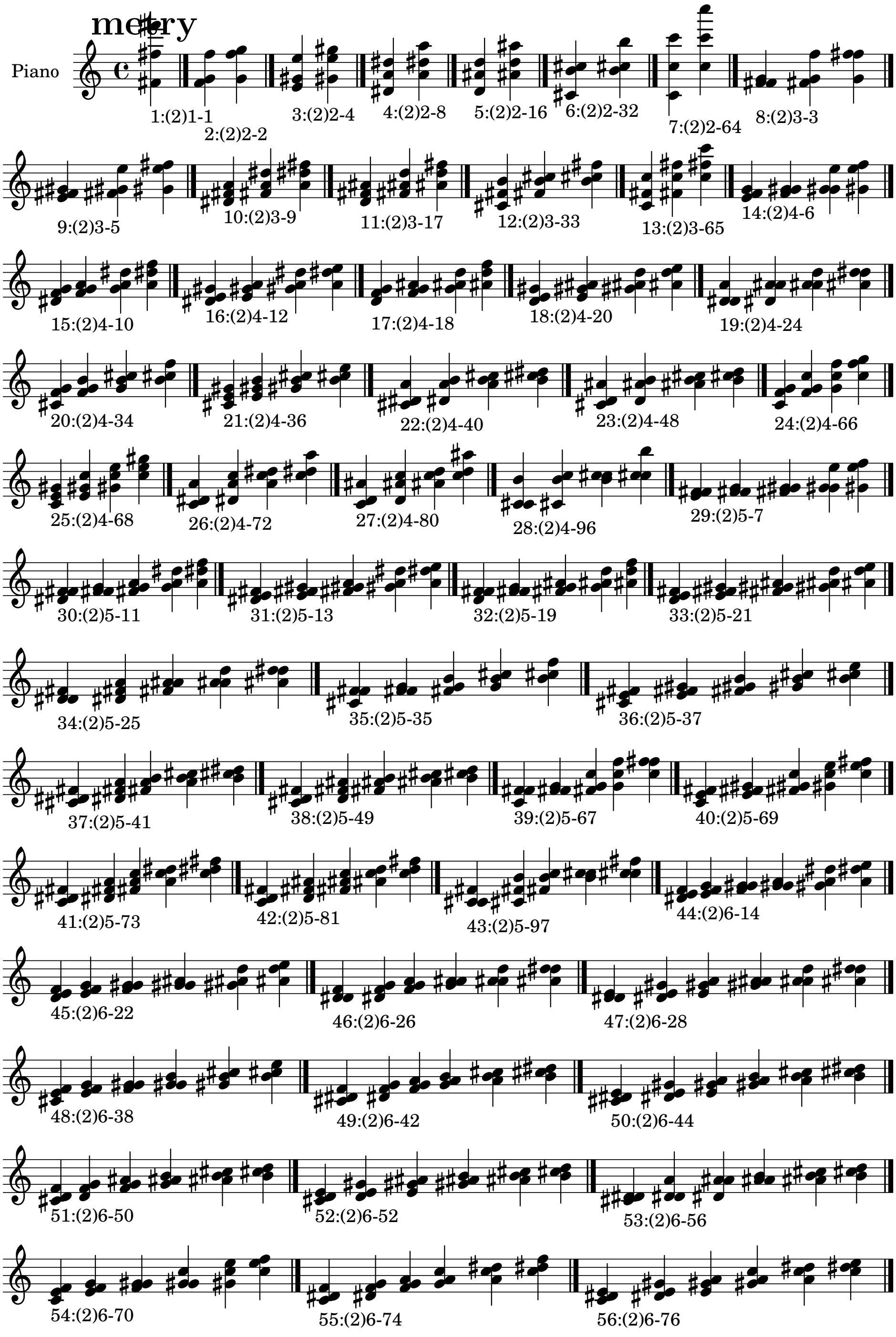

80:(2)7-99
81:(2)7-101
82:(2)7-105
83:(2)7-113
84:(2)8-30
85:(2)8-46
86:(2)8-54
87:(2)8-58
88:(2)8-60
89:(2)8-78
90:(2)8-86
91:(2)8-90
92:(2)8-92
93:(2)8-102
94:(2)8-106
95:(2)8-108
96:(2)8-114
97:(2)8-116
98:(2)8-120
99:(2)9-31
100:(2)9-47
101:(2)9-55
102:(2)9-59
103:(2)9-61
104:(2)9-79
105:(2)9-87
106:(2)9-91
107:(2)9-93
108:(2)9-103
109:(2)9-107
110:(2)9-109
111:(2)9-115
112:(2)9-117
113:(2)9-121
114:(2)10-62
115:(2)10-94
116:(2)10-110
117:(2)10-118
118:(2)10-122
119:(2)10-124
120:(2)11-63
121:(2)11-95
122:(2)11-111
123:(2)11-119
124:(2)11-123
125:(2)11-125
126:(2)12-126
127:(2)13-127

9 All modes of binary internal symmetry with palindromic keys



10 All modes of binary internal symmetry with partially palindromic keys

11 All chords built by stacking every second note from the modes of internal binary symmetry




57:(2)6-82
58:(2)6-84
59:(2)6-88
60:(2)6-98
61:(2)6-100
62:(2)6-104
63:(2)6-112
64:(2)7-15
65:(2)7-23
66:(2)7-27
67:(2)7-29
68:(2)7-39
69:(2)7-43
70:(2)7-45
71:(2)7-51
72:(2)7-53
73:(2)7-57
74:(2)7-71
75:(2)7-75
76:(2)7-77
77:(2)7-83
78:(2)7-85
79:(2)7-89
80:(2)7-99
81:(2)7-101
82:(2)7-105
83:(2)7-113
84:(2)8-30
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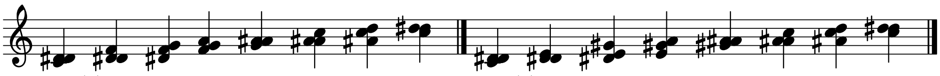
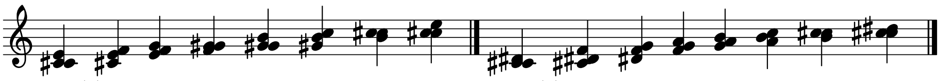
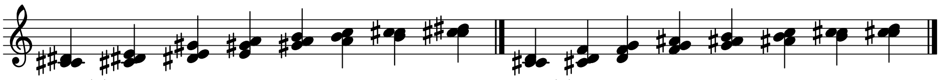
86:(2)8-54
87:(2)8-58
88:(2)8-60
89:(2)8-78
90:(2)8-86



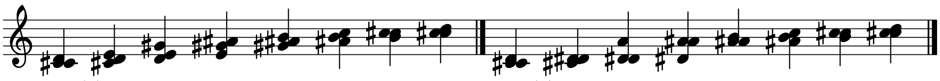
91:(2)8-90 92:(2)8-92



93:(2)8-102 94:(2)8-106

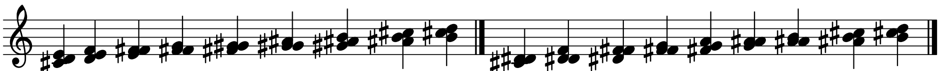


95:(2)8-108 96:(2)8-114

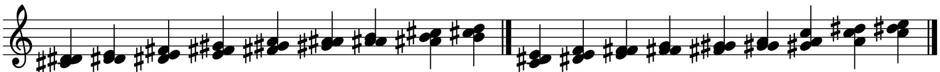


97:(2)8-116 98:(2)8-120

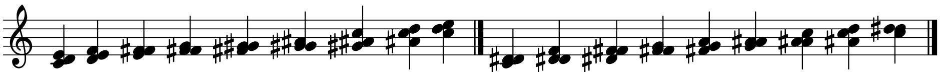
99:(2)9-31 100:(2)9-47



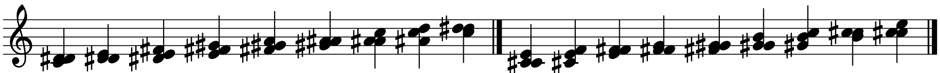
101:(2)9-55 102:(2)9-59



103:(2)9-61 104:(2)9-79



105:(2)9-87 106:(2)9-91



107:(2)9-93 108:(2)9-103

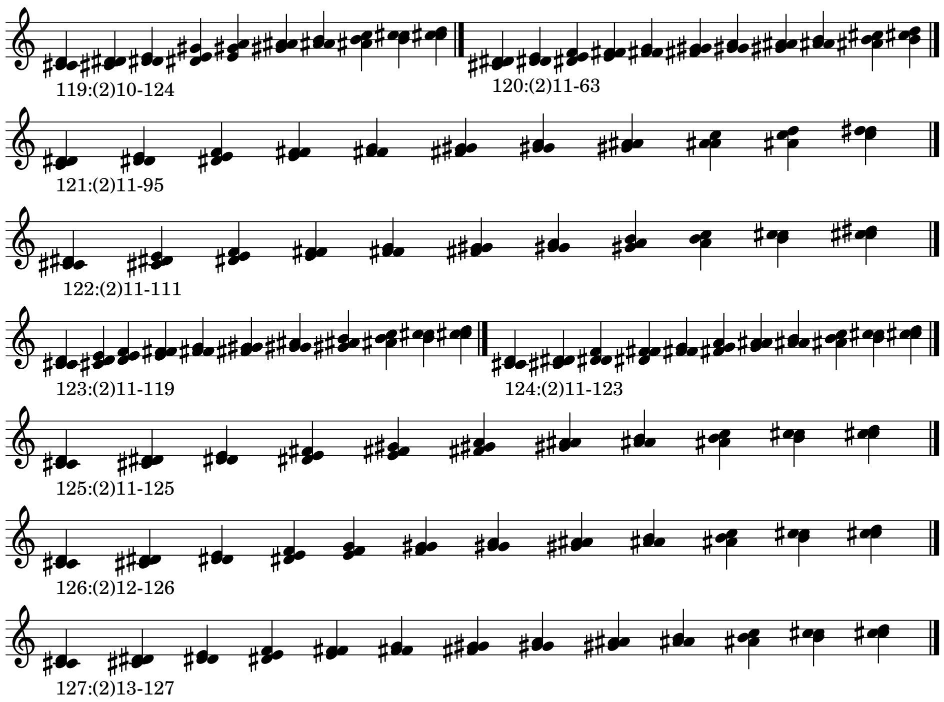
109:(2)9-107 110:(2)9-109

111:(2)9-115 112:(2)9-117

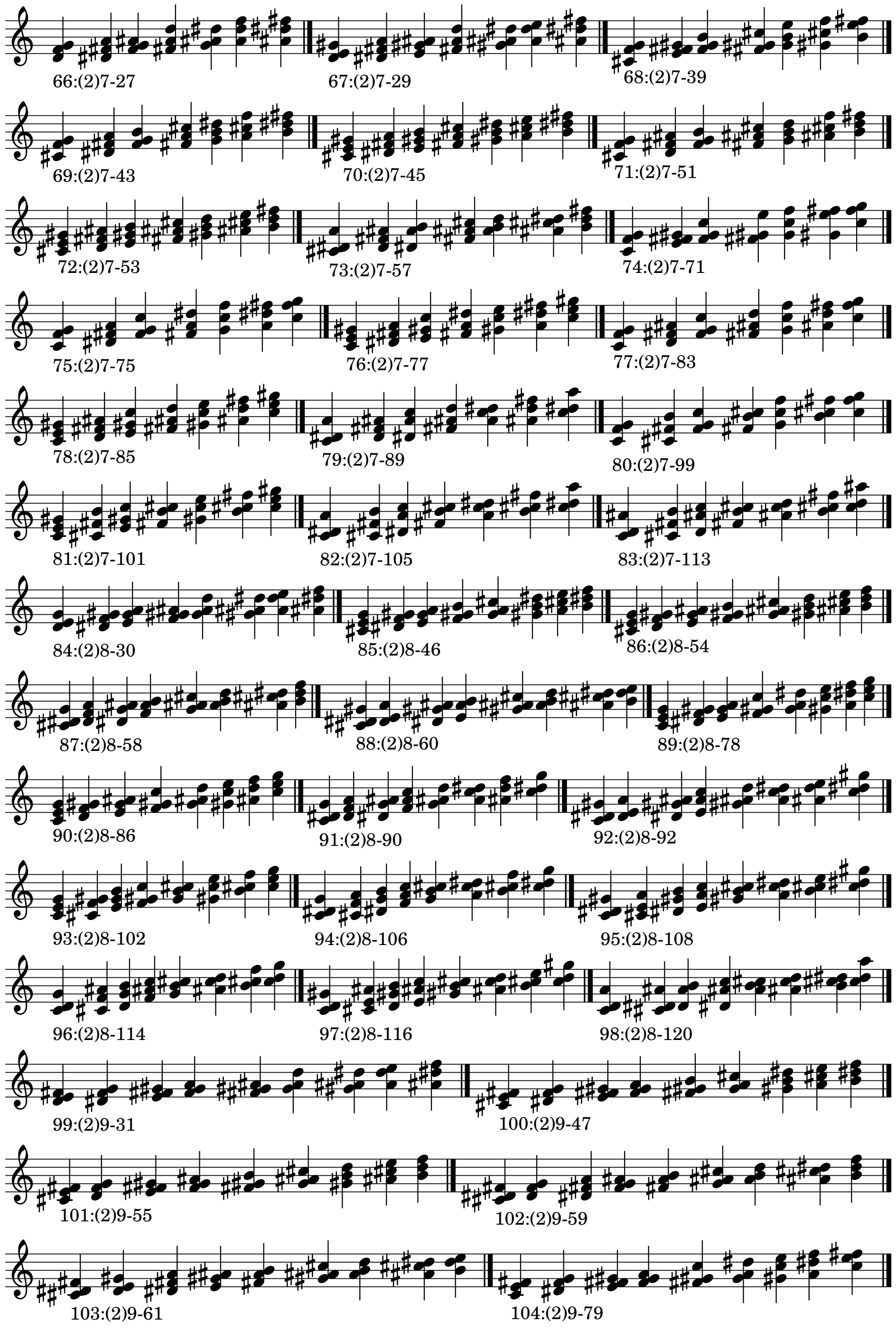
113:(2)9-121 114:(2)10-62

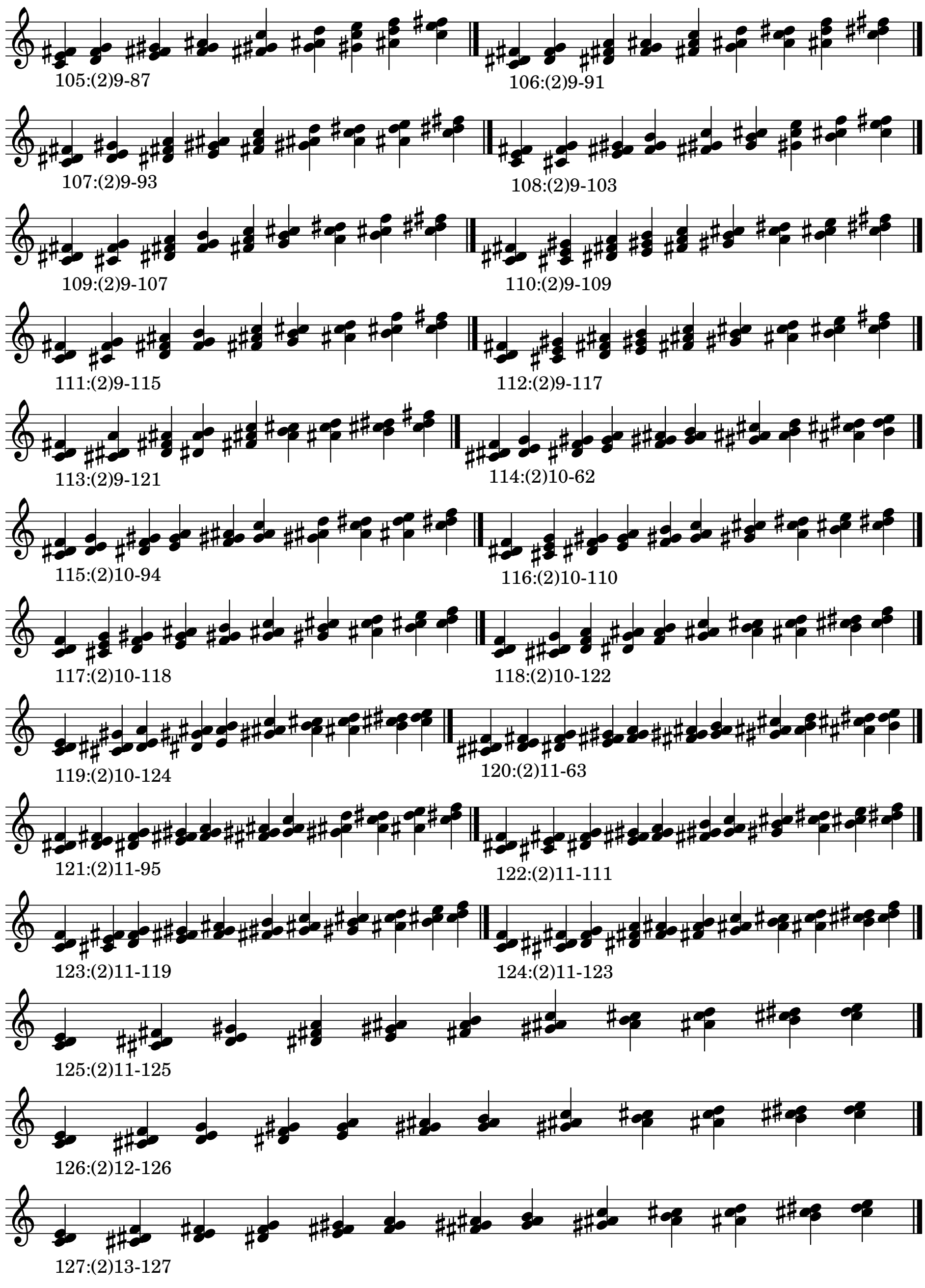
115:(2)10-94 116:(2)10-110

117:(2)10-118 118:(2)10-122

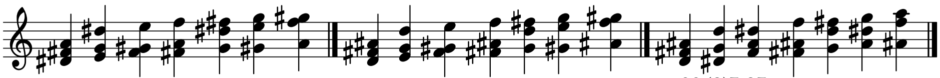

119:(2)10-124
120:(2)11-63
121:(2)11-95
122:(2)11-111
123:(2)11-119
124:(2)11-123
125:(2)11-125
126:(2)12-126
127:(2)13-127

12 All chords built by stacking every third note from the modes of internal binary symmetry


66:(2)7-27
67:(2)7-29
68:(2)7-39
69:(2)7-43
70:(2)7-45
71:(2)7-51
72:(2)7-53
73:(2)7-57
74:(2)7-71
75:(2)7-75
76:(2)7-77
77:(2)7-83
78:(2)7-85
79:(2)7-89
80:(2)7-99
81:(2)7-101
82:(2)7-105
83:(2)7-113
84:(2)8-30
85:(2)8-46
86:(2)8-54
87:(2)8-58
88:(2)8-60
89:(2)8-78
90:(2)8-86
91:(2)8-90
92:(2)8-92
93:(2)8-102
94:(2)8-106
95:(2)8-108
96:(2)8-114
97:(2)8-116
98:(2)8-120
99:(2)9-31
100:(2)9-47
101:(2)9-55
102:(2)9-59
103:(2)9-61
104:(2)9-79


105:(2)9-87
106:(2)9-91
107:(2)9-93
108:(2)9-103
109:(2)9-107
110:(2)9-109
111:(2)9-115
112:(2)9-117
113:(2)9-121
114:(2)10-62
115:(2)10-94
116:(2)10-110
117:(2)10-118
118:(2)10-122
119:(2)10-124
120:(2)11-63
121:(2)11-95
122:(2)11-111
123:(2)11-119
124:(2)11-123
125:(2)11-125
126:(2)12-126
127:(2)13-127

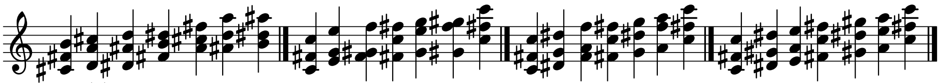
13 All chords built by stacking every fourth note from the modes of internal binary symmetry



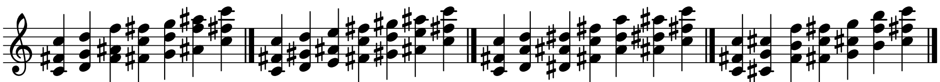
64:(2)7-15 65:(2)7-23 66:(2)7-27

67:(2)7-29 68:(2)7-39 69:(2)7-43

70:(2)7-45 71:(2)7-51 72:(2)7-53



73:(2)7-57 74:(2)7-71 75:(2)7-75 76:(2)7-77



77:(2)7-83 78:(2)7-85 79:(2)7-89 80:(2)7-99

81:(2)7-101 82:(2)7-105 83:(2)7-113 84:(2)8-30

85:(2)8-46 86:(2)8-54 87:(2)8-58

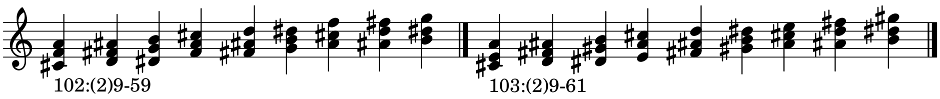
88:(2)8-60 89:(2)8-78 90:(2)8-86

91:(2)8-90 92:(2)8-92 93:(2)8-102

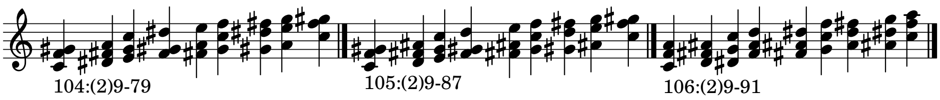
94:(2)8-106 95:(2)8-108 96:(2)8-114

97:(2)8-116 98:(2)8-120 99:(2)9-31

100:(2)9-47 101:(2)9-55



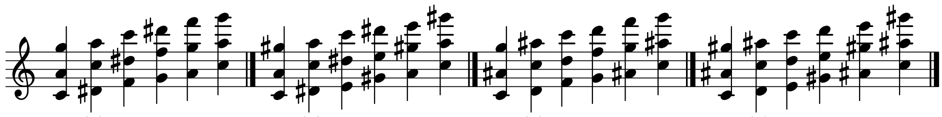
102:(2)9-59 103:(2)9-61



104:(2)9-79 105:(2)9-87 106:(2)9-91


107:(2)9-93
108:(2)9-103
109:(2)9-107
110:(2)9-109
111:(2)9-115
112:(2)9-117
113:(2)9-121
114:(2)10-62
115:(2)10-94
116:(2)10-110
117:(2)10-118
118:(2)10-122
119:(2)10-124
120:(2)11-63
121:(2)11-95
122:(2)11-111
123:(2)11-119
124:(2)11-123
125:(2)11-125
126:(2)12-126
127:(2)13-127

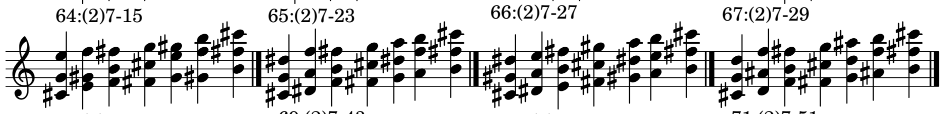
14 All chords built by stacking every fifth note from the modes of internal binary symmetry



55:(2)6-74 56:(2)6-76 57:(2)6-82 58:(2)6-84

59:(2)6-88 60:(2)6-98 61:(2)6-100 62:(2)6-104 63:(2)6-112

64:(2)7-15 65:(2)7-23 66:(2)7-27 67:(2)7-29



68:(2)7-39 69:(2)7-43 70:(2)7-45 71:(2)7-51

72:(2)7-53 73:(2)7-57 74:(2)7-71 75:(2)7-75

76:(2)7-77 77:(2)7-83 78:(2)7-85 79:(2)7-89

80:(2)7-99 81:(2)7-101 82:(2)7-105 83:(2)7-113

84:(2)8-30 85:(2)8-46 86:(2)8-54

87:(2)8-58 88:(2)8-60 89:(2)8-78

90:(2)8-86 91:(2)8-90 92:(2)8-92

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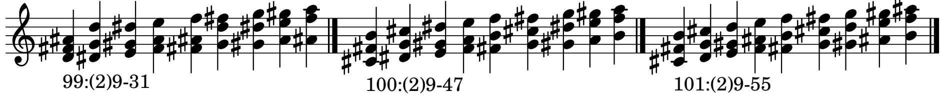
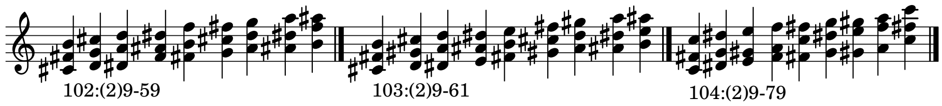
96:(2)8-114 97:(2)8-116 98:(2)8-120



99:(2)9-31 100:(2)9-47 101:(2)9-55

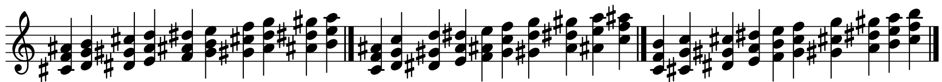


102:(2)9-59 103:(2)9-61 104:(2)9-79

105:(2)9-87 106:(2)9-91 107:(2)9-93

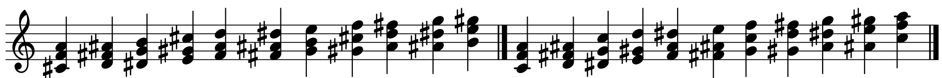
108:(2)9-103 109:(2)9-107 110:(2)9-109

111:(2)9-115 112:(2)9-117 113:(2)9-121



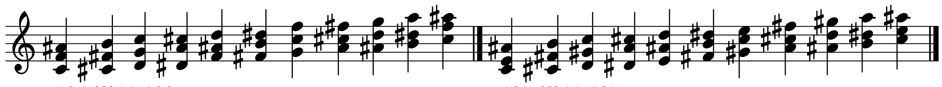
114:(2)10-62 115:(2)10-94 116:(2)10-110

117:(2)10-118 118:(2)10-122 119:(2)10-124



120:(2)11-63 121:(2)11-95

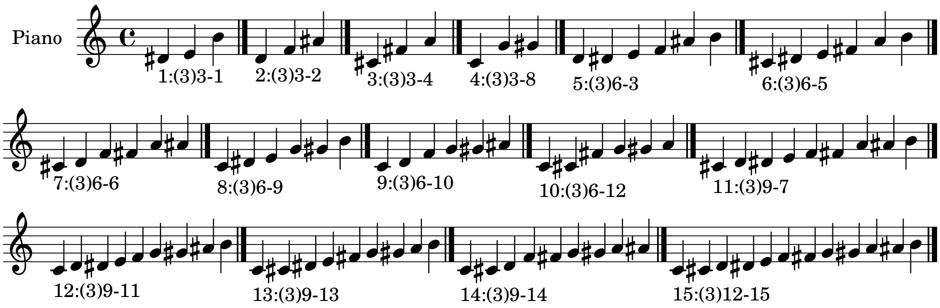
122:(2)11-111 123:(2)11-119



124:(2)11-123 125:(2)11-125

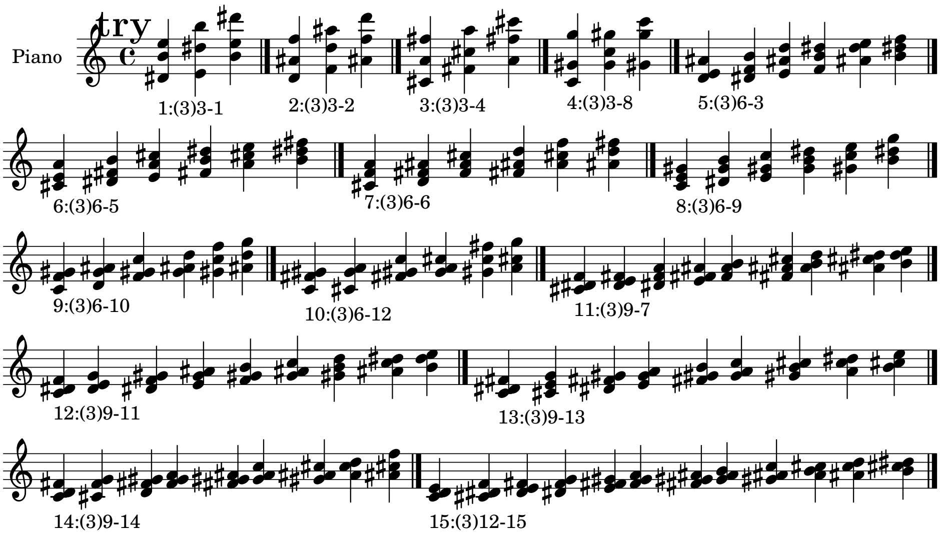
126:(2)12-126 127:(2)13-127

15 All modes with ternary internal symmetry ordered by length

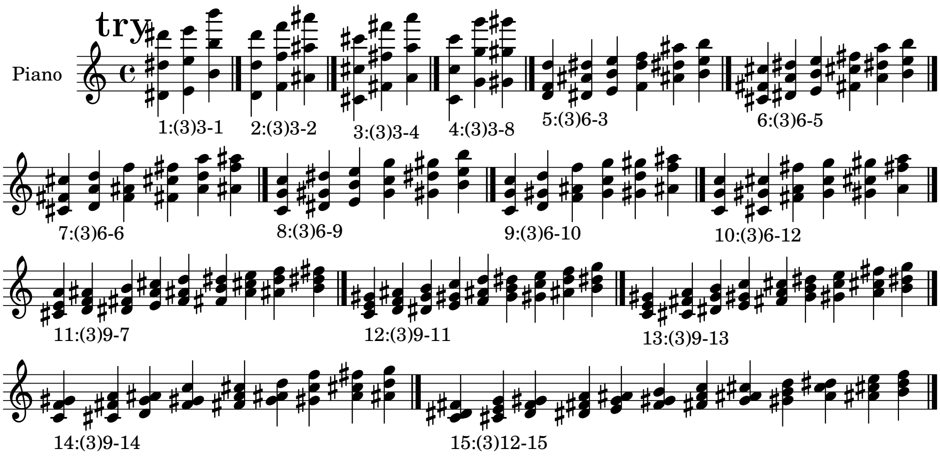


16 All chords built by stacking every second note from the modes of ternary internal symmetry

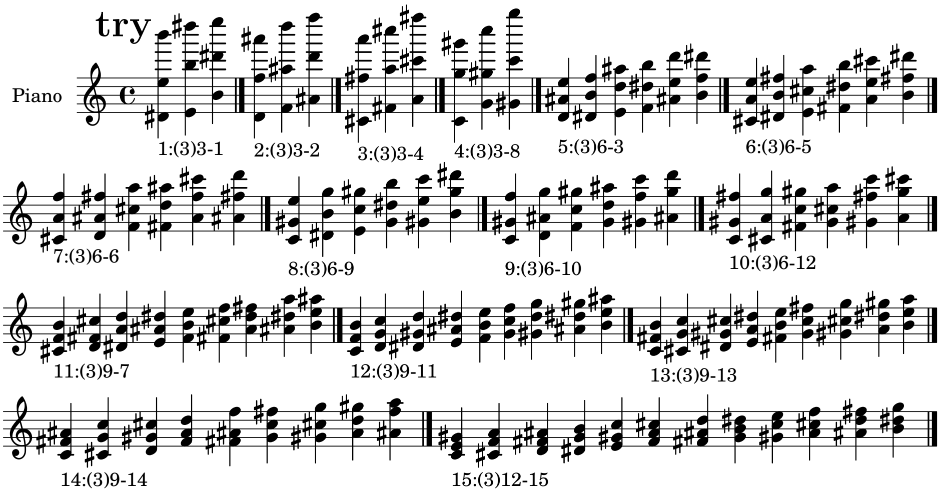
17 All chords built by stacking every third note from the modes of ternary internal symmetry



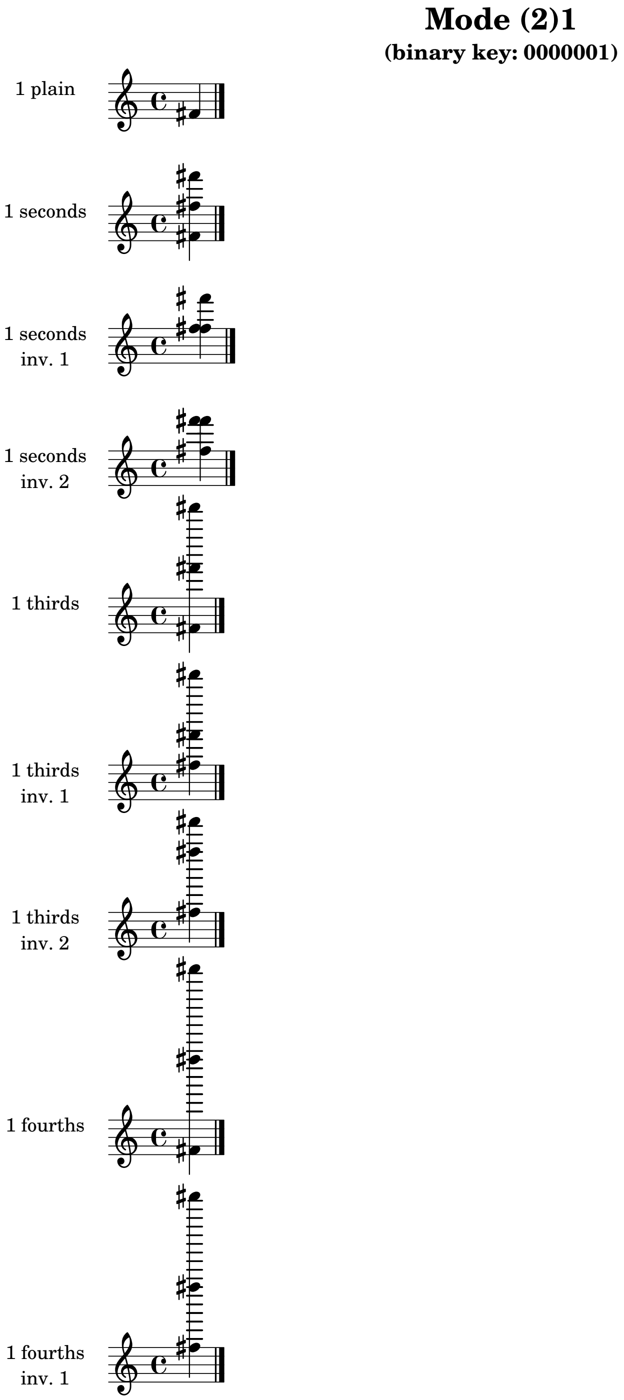
18 All chords built by stacking every fourth note from the modes of ternary internal symmetry

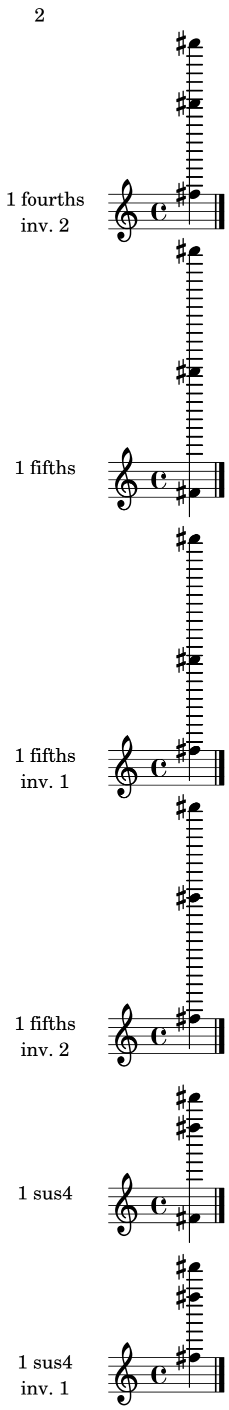


19 All chords built by stacking every fifth note from the modes of ternary internal symmetry

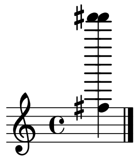


20 Characterizing mode (2)1

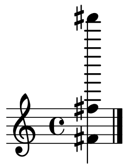



2
1 fourths
inv. 2
1 fifths
1 fifths
inv. 1
1 fifths
inv. 2
1 sus4
1 sus4
inv. 1

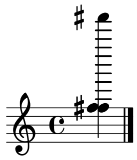
1 sus4
inv. 2



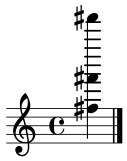
1 sus2



1 sus2
inv. 1



1 sus2
inv. 2

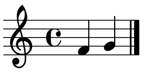


21 Characterizing mode (2)2

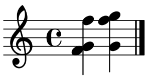
Mode (2)2

(binary key: 0000010)

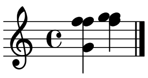
2 plain



2 seconds



2 seconds inv. 1



2 seconds inv. 2

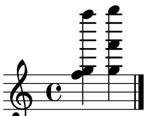
2 thirds

2 thirds inv. 1

2 thirds inv. 2

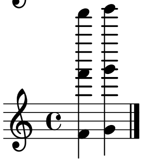
2 fourths

2 fourths inv. 1

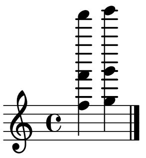


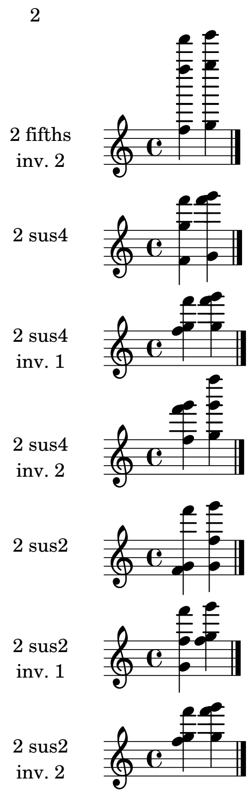
2 fourths inv. 2

2 fifths



2 fifths inv. 1




2
2 fifths
inv. 2
2 sus4
2 sus4
inv. 1
2 sus4
inv. 2
2 sus2
2 sus2
inv. 1
2 sus2
inv. 2

22 Characterizing mode (2)3

Mode (2)3

(binary key: 0000011)

3 plain

3 seconds

3 seconds
inv. 1

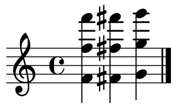
3 seconds
inv. 2

3 thirds

3 thirds
inv. 1

3 thirds
inv. 2

3 fourths



3 fourths
inv. 1

3 fourths
inv. 2

3 fifths

3 fifths
inv. 1

3 fifths
inv. 2

2

3 sus4

3 sus4
inv. 1

3 sus4
inv. 2

3 sus2

3 sus2
inv. 1

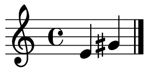
3 sus2
inv. 2

23 Characterizing mode (2)4

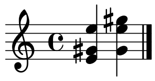
Mode (2)4

(binary key: 0000100)

4 plain



4 seconds



4 seconds inv. 1

4 seconds inv. 2

4 thirds

4 thirds inv. 1

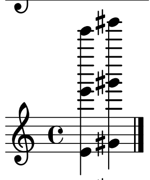
4 thirds inv. 2

4 fourths

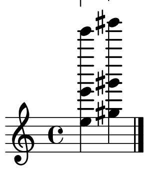
4 fourths inv. 1

4 fourths inv. 2

4 fifths

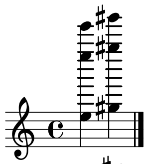


4 fifths inv. 1



2

4 fifths
inv. 2



4 sus4

4 sus4
inv. 1

4 sus4
inv. 2

4 sus2

4 sus2
inv. 1

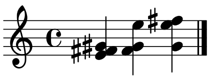
4 sus2
inv. 2

24 Characterizing mode (2)5

Mode (2)5
(binary key: 0000101)

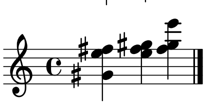
5 plain

5 seconds



5 seconds
inv. 1

5 seconds
inv. 2



5 thirds

5 thirds
inv. 1

5 thirds
inv. 2

5 fourths

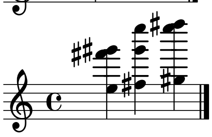
5 fourths
inv. 1

5 fourths
inv. 2

5 fifths

5 fifths
inv. 1

5 fifths
inv. 2



2

5 sus4

5 sus4
inv. 1

5 sus4
inv. 2

5 sus2

5 sus2
inv. 1

5 sus2
inv. 2

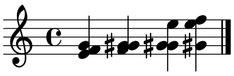
25 Characterizing mode (2)6

Mode (2)6

(binary key: 0000110)

6 plain

6 seconds

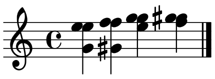


6 seconds inv. 1

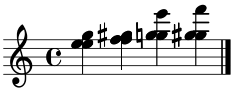
6 seconds inv. 2

6 thirds

6 thirds inv. 1



6 thirds inv. 2

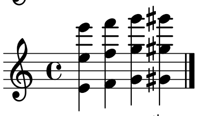


6 fourths

6 fourths inv. 1

6 fourths inv. 2

6 fifths



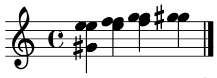
6 fifths inv. 1

6 fifths inv. 2

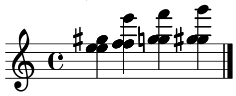
6 sus4

2

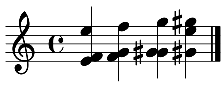
6 sus4
inv. 1



6 sus4
inv. 2

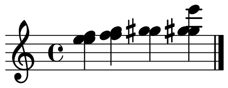


6 sus2



6 sus2
inv. 1

6 sus2
inv. 2



26 Characterizing mode (2)7

Mode (2)7
(binary key: 0000111)

2

7 sus4

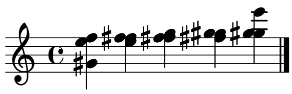
7 sus4
inv. 1

7 sus4
inv. 2

7 sus2

7 sus2
inv. 1

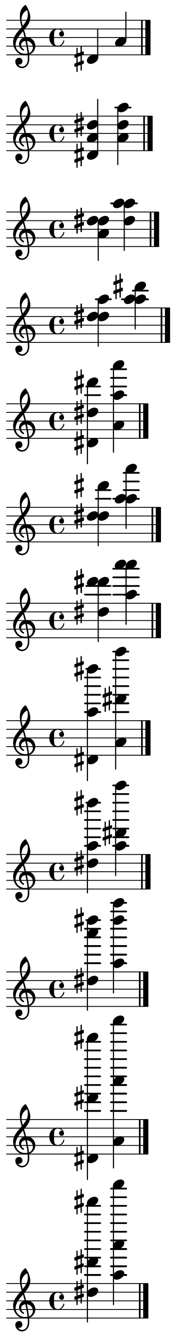
7 sus2
inv. 2



27 Characterizing mode (2)8

Mode (2)8

(binary key: 0001000)



8 plain

8 seconds

8 seconds inv. 1

8 seconds inv. 2

8 thirds

8 thirds inv. 1

8 thirds inv. 2

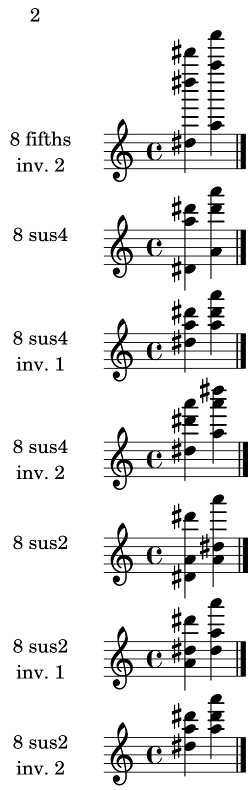
8 fourths

8 fourths inv. 1

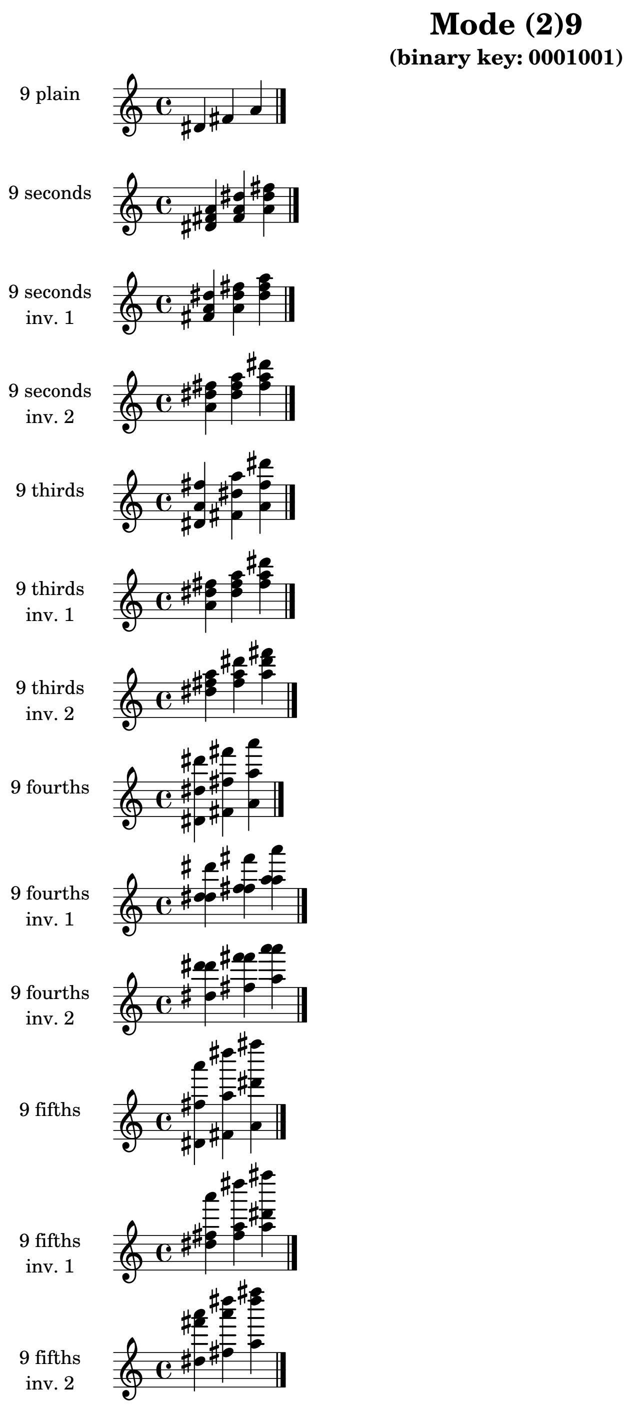
8 fourths inv. 2

8 fifths

8 fifths inv. 1


2
8 fifths
inv. 2
8 sus4
8 sus4
inv. 1
8 sus4
inv. 2
8 sus2
8 sus2
inv. 1
8 sus2
inv. 2

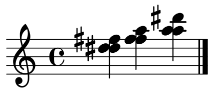
28 Characterizing mode (2)9



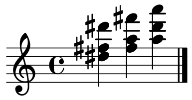
2

9 sus4

9 sus4
inv. 1



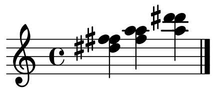
9 sus4
inv. 2



9 sus2

9 sus2
inv. 1

9 sus2
inv. 2



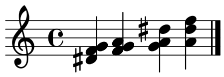
29 Characterizing mode (2)10

Mode (2)10

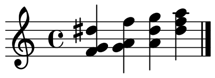
(binary key: 0001010)

10 plain

10 seconds

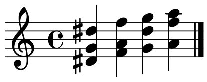


10 seconds
inv. 1

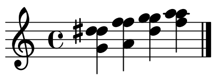


10 seconds
inv. 2

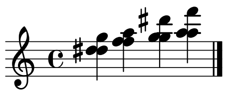
10 thirds



10 thirds
inv. 1



10 thirds
inv. 2



10 fourths

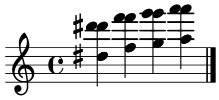
10 fourths
inv. 1

10 fourths
inv. 2

10 fifths

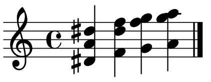
10 fifths
inv. 1

10 fifths
inv. 2

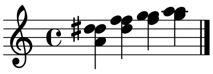


2

10 sus4

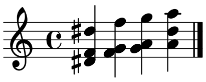


10 sus4
inv. 1

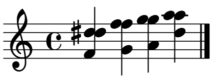


10 sus4
inv. 2

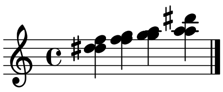
10 sus2



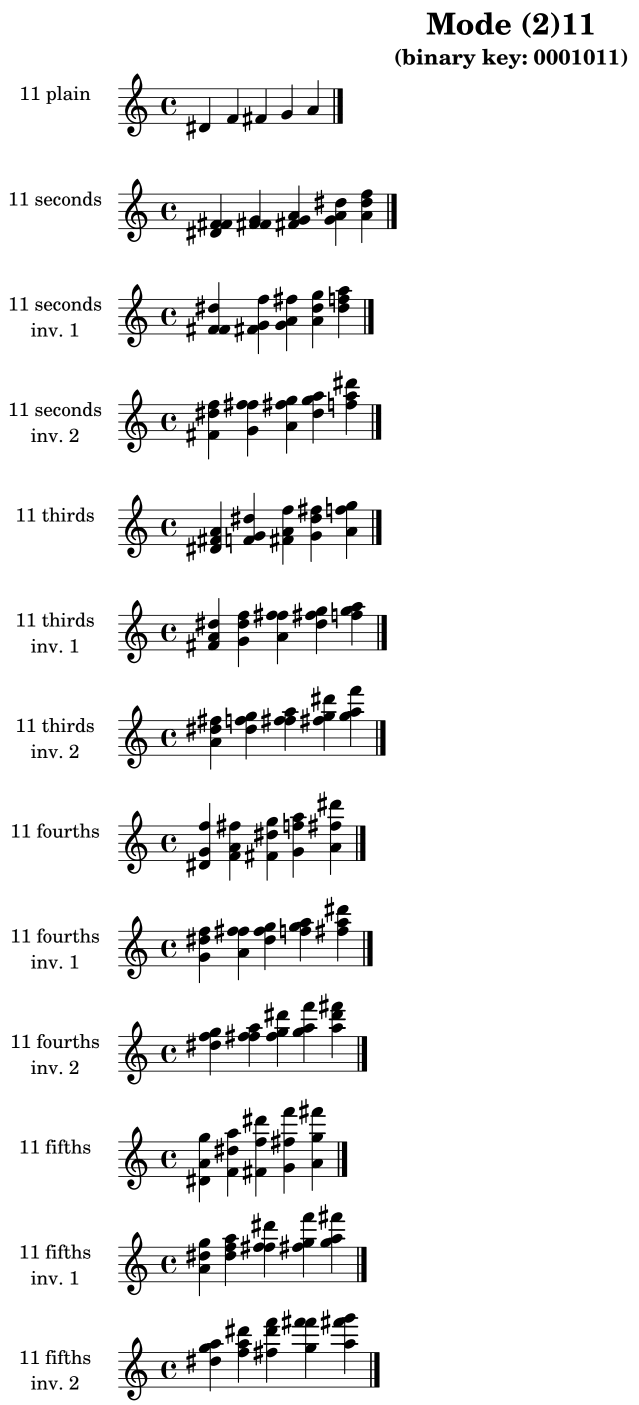
10 sus2
inv. 1



10 sus2
inv. 2



30 Characterizing mode (2)11

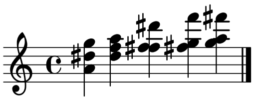


2

11 sus4

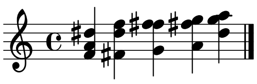
11 sus4
inv. 1

11 sus4
inv. 2

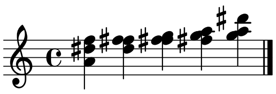


11 sus2

11 sus2
inv. 1



11 sus2
inv. 2



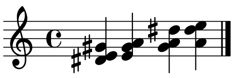
31 Characterizing mode (2)12

Mode (2)12

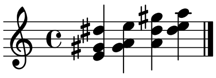
(binary key: 0001100)

12 plain

12 seconds

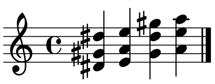


12 seconds inv. 1

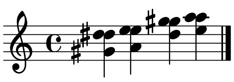


12 seconds inv. 2

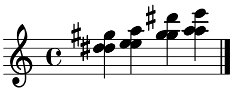
12 thirds



12 thirds inv. 1



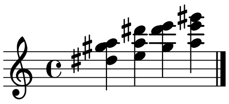
12 thirds inv. 2



12 fourths

12 fourths inv. 1

12 fourths inv. 2



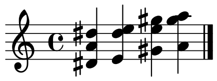
12 fifths

12 fifths inv. 1

12 fifths inv. 2

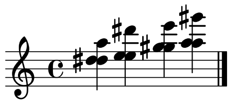
2

12 sus4

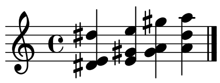


12 sus4
inv. 1

12 sus4
inv. 2

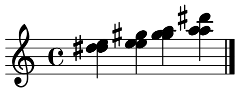


12 sus2

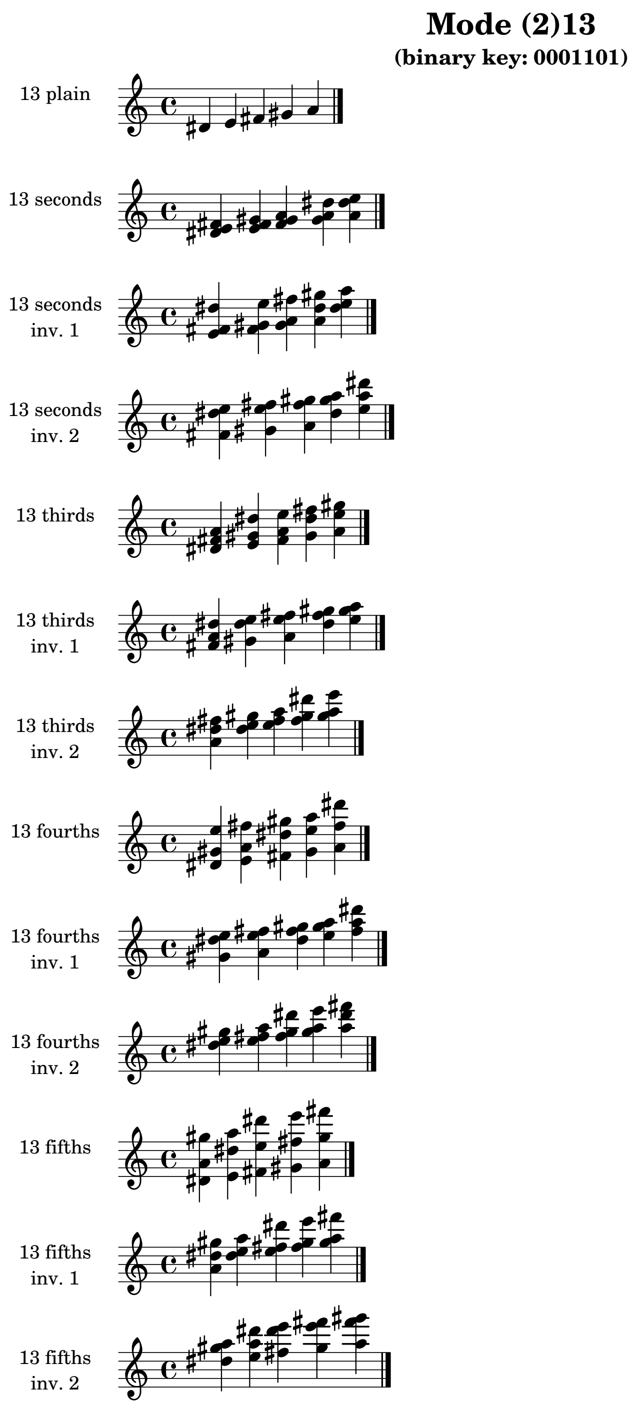


12 sus2
inv. 1

12 sus2
inv. 2

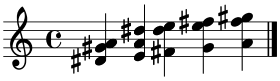


32 Characterizing mode (2)13



2

13 sus4



13 sus4
inv. 1

13 sus4
inv. 2

13 sus2

13 sus2
inv. 1

13 sus2
inv. 2

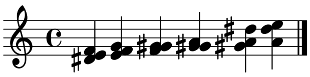
33 Characterizing mode (2)14

Mode (2)14

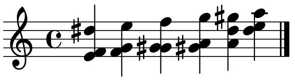
(binary key: 0001110)

14 plain

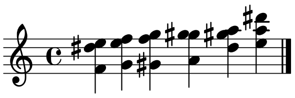
14 seconds



14 seconds
inv. 1



14 seconds
inv. 2



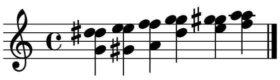
14 thirds

14 thirds
inv. 1

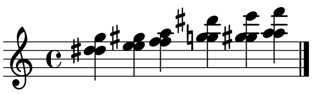
14 thirds
inv. 2

14 fourths

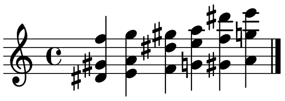
14 fourths
inv. 1



14 fourths
inv. 2

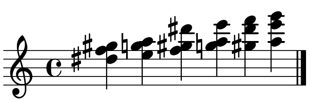


14 fifths



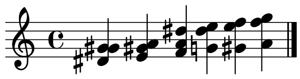
14 fifths
inv. 1

14 fifths
inv. 2

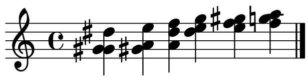


2

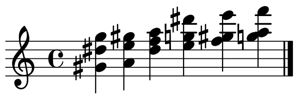
14 sus4



14 sus4
inv. 1



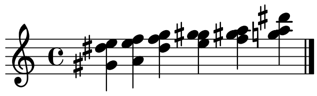
14 sus4
inv. 2



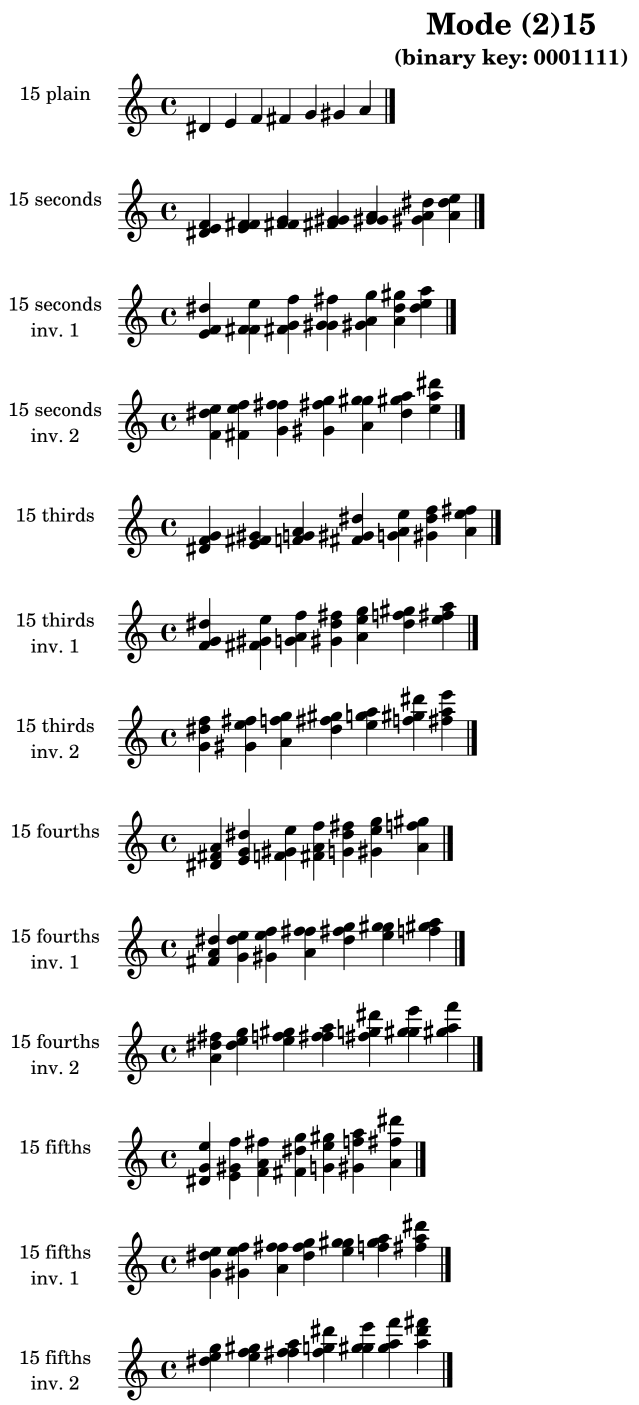
14 sus2

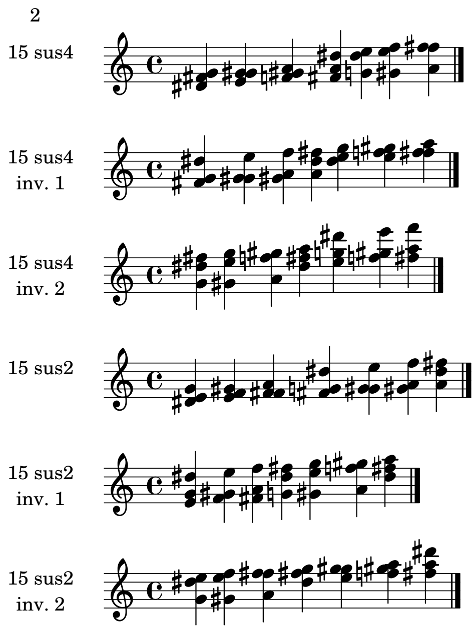
14 sus2
inv. 1

14 sus2
inv. 2



34 Characterizing mode (2)15




2
15 sus4
15 sus4
inv. 1
15 sus4
inv. 2
15 sus2
15 sus2
inv. 1
15 sus2
inv. 2

35 Characterizing mode (2)16

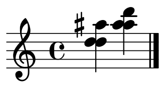
Mode (2)16
(binary key: 0010000)

16 plain

16 seconds

16 seconds
inv. 1

16 seconds
inv. 2



16 thirds

16 thirds
inv. 1

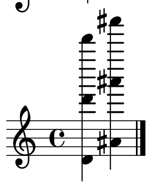
16 thirds
inv. 2

16 fourths

16 fourths
inv. 1

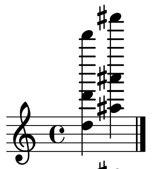
16 fourths
inv. 2

16 fifths

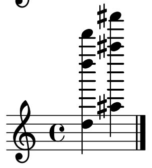


2

16 fifths
inv. 1



16 fifths
inv. 2



16 sus4

16 sus4
inv. 1

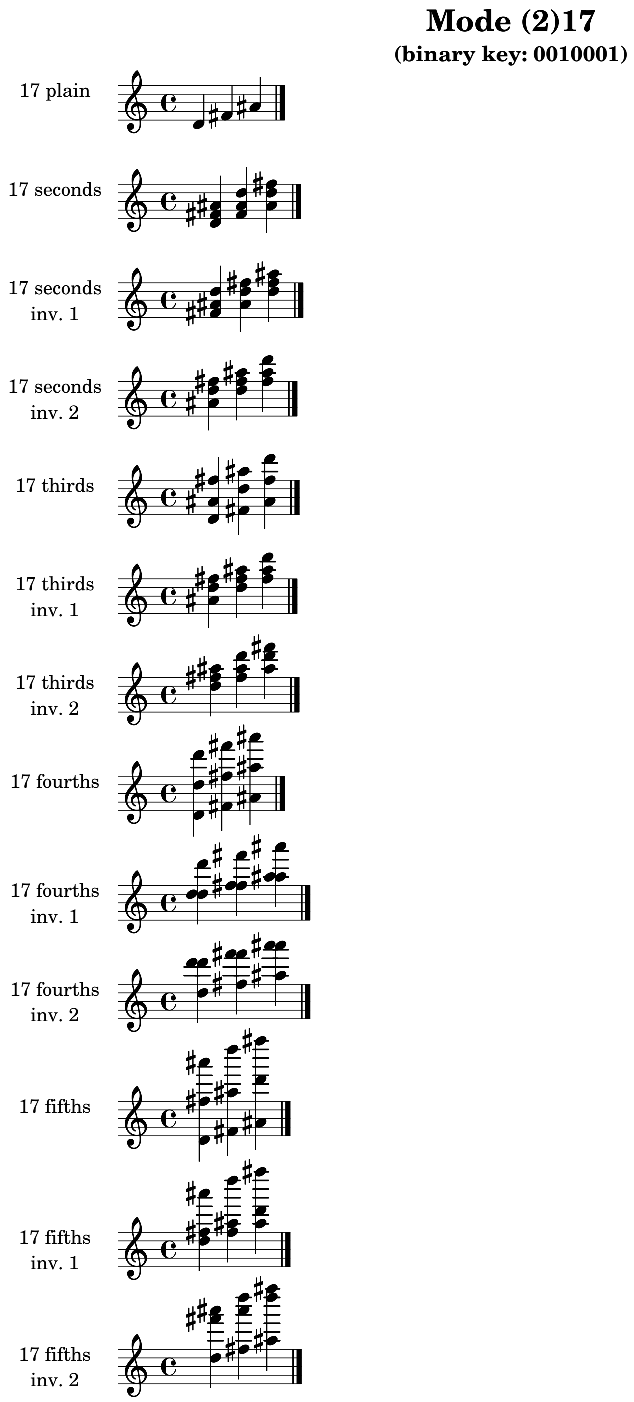
16 sus4
inv. 2

16 sus2

16 sus2
inv. 1

16 sus2
inv. 2

36 Characterizing mode (2)17

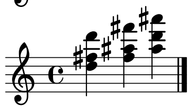


2

17 sus4

17 sus4
inv. 1

17 sus4
inv. 2



17 sus2

17 sus2
inv. 1

17 sus2
inv. 2

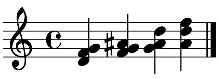
37 Characterizing mode (2)18

Mode (2)18

(binary key: 0010010)

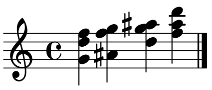
18 plain

18 seconds

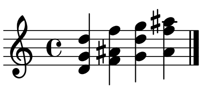


18 seconds inv. 1

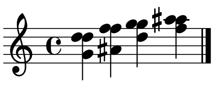
18 seconds inv. 2



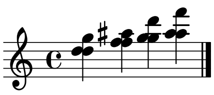
18 thirds



18 thirds inv. 1



18 thirds inv. 2



18 fourths

18 fourths inv. 1

18 fourths inv. 2

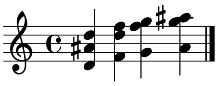
18 fifths

18 fifths inv. 1

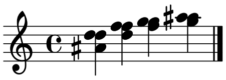
18 fifths inv. 2

2

18 sus4

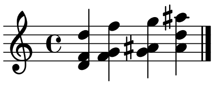


18 sus4
inv. 1

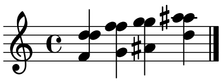


18 sus4
inv. 2

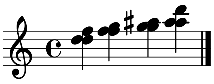
18 sus2



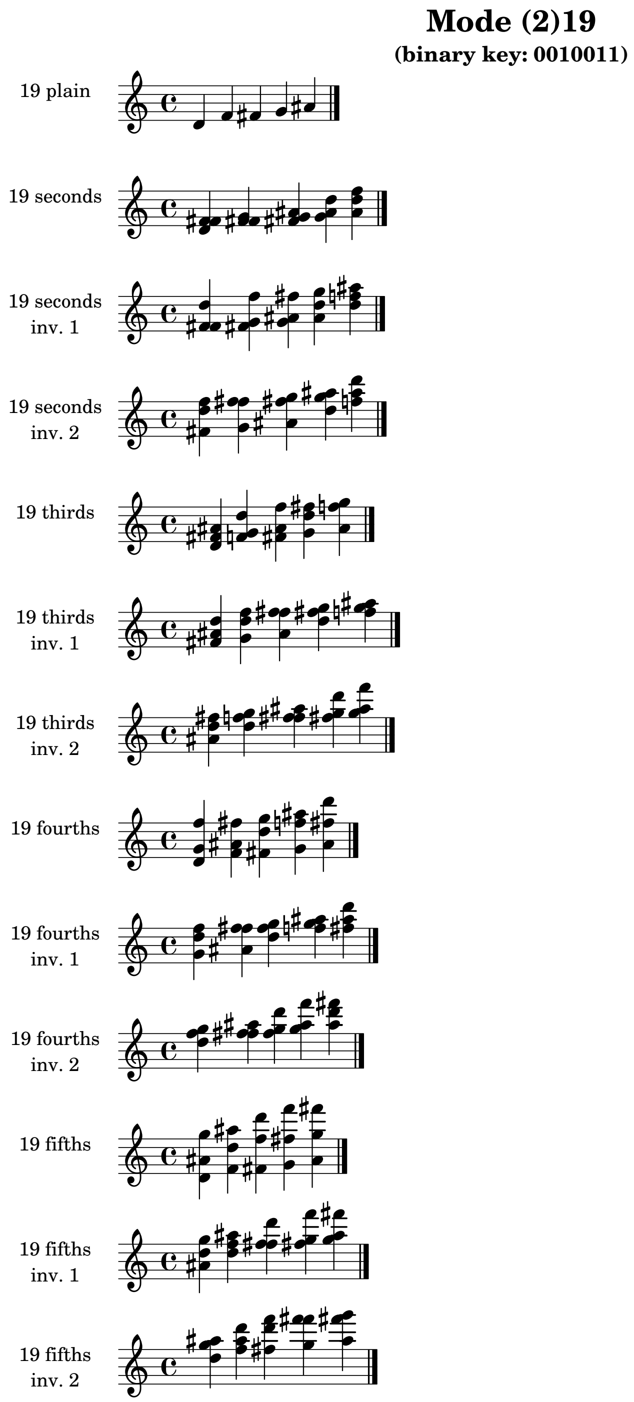
18 sus2
inv. 1



18 sus2
inv. 2

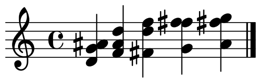


38 Characterizing mode (2)19

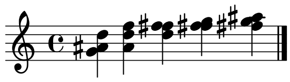


2

19 sus4



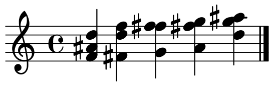
19 sus4
inv. 1



19 sus4
inv. 2

19 sus2

19 sus2
inv. 1



19 sus2
inv. 2

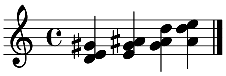
39 Characterizing mode (2)20

Mode (2)20

(binary key: 0010100)

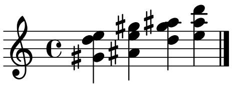
20 plain

20 seconds

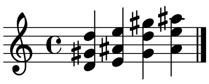


20 seconds inv. 1

20 seconds inv. 2



20 thirds



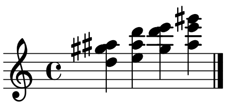
20 thirds inv. 1

20 thirds inv. 2

20 fourths

20 fourths inv. 1

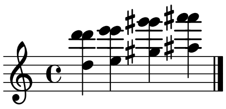
20 fourths inv. 2



20 fifths

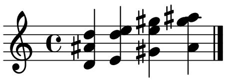
20 fifths inv. 1

20 fifths inv. 2

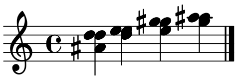


2

20 sus4



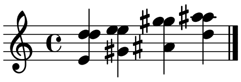
20 sus4
inv. 1



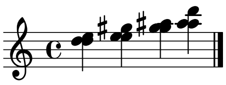
20 sus4
inv. 2

20 sus2

20 sus2
inv. 1



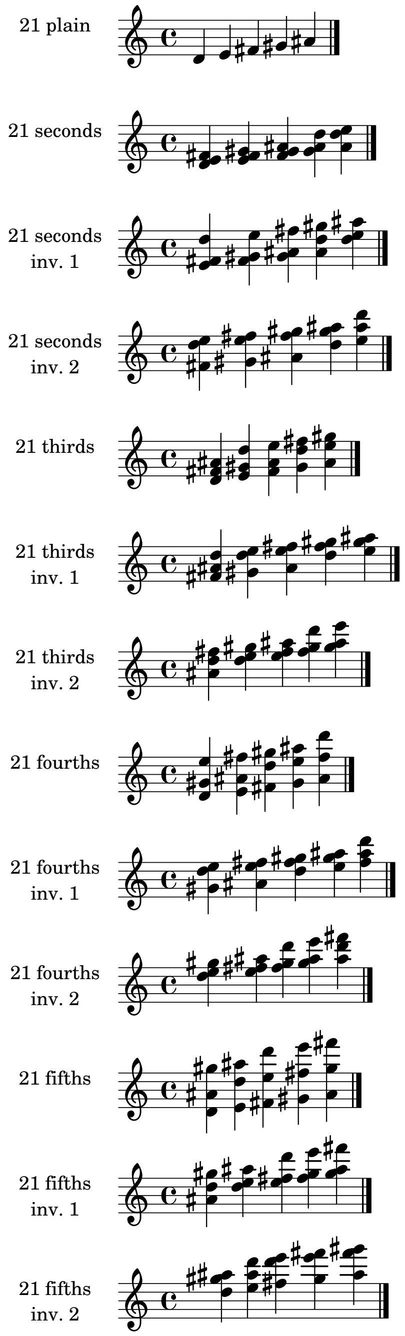
20 sus2
inv. 2



40 Characterizing mode (2)21

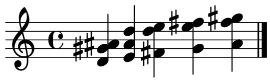
Mode (2)21

(binary key: 0010101)



2

21 sus4

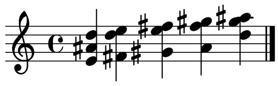


21 sus4
inv. 1

21 sus4
inv. 2

21 sus2

21 sus2
inv. 1



21 sus2
inv. 2

41 Characterizing mode (2)22

Mode (2)22

(binary key: 0010110)

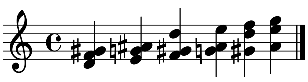
22 plain

22 seconds

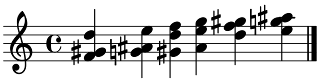
22 seconds inv. 1

22 seconds inv. 2

22 thirds



22 thirds inv. 1

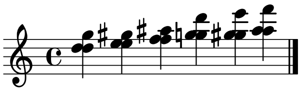


22 thirds inv. 2

22 fourths

22 fourths inv. 1

22 fourths inv. 2



22 fifths

22 fifths inv. 1

22 fifths inv. 2

22 sus4

2

22 sus4
inv. 1

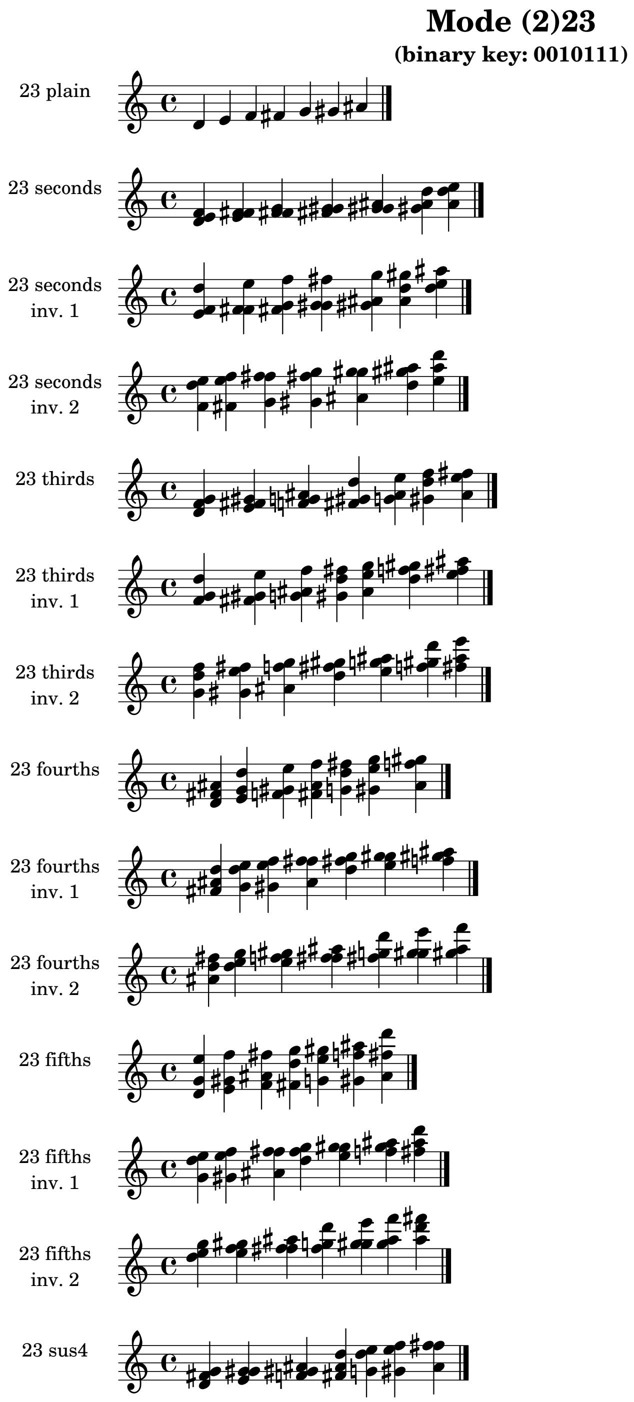
22 sus4
inv. 2

22 sus2

22 sus2
inv. 1

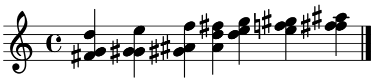
22 sus2
inv. 2

42 Characterizing mode (2)23



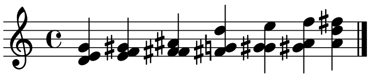
2

23 sus4
inv. 1



23 sus4
inv. 2

23 sus2



23 sus2
inv. 1

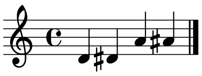
23 sus2
inv. 2

43 Characterizing mode (2)24

Mode (2)24

(binary key: 0011000)

24 plain



24 seconds

24 seconds inv. 1

24 seconds inv. 2

24 thirds

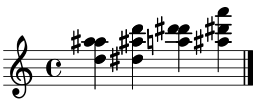
24 thirds inv. 1

24 thirds inv. 2

24 fourths

24 fourths inv. 1

24 fourths inv. 2



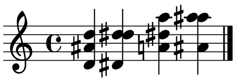
24 fifths

24 fifths inv. 1

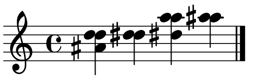
24 fifths inv. 2

2

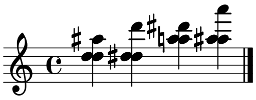
24 sus4



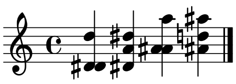
24 sus4
inv. 1



24 sus4
inv. 2

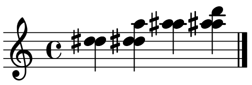


24 sus2

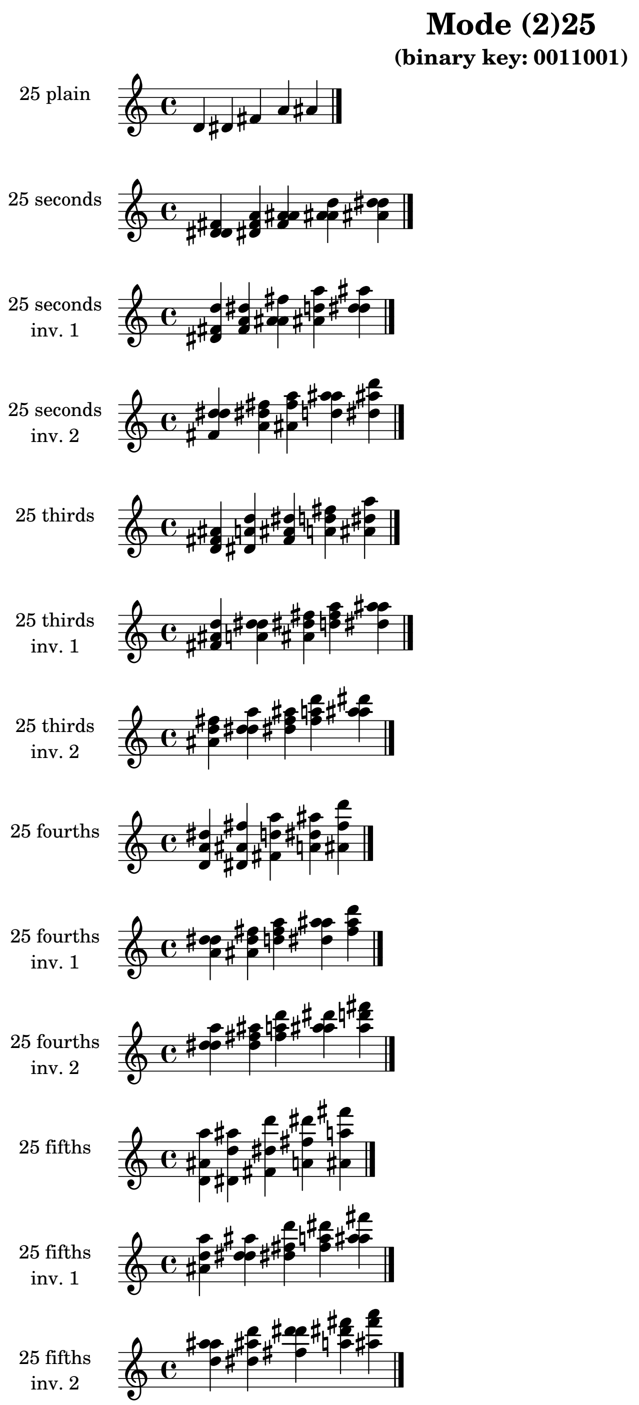


24 sus2
inv. 1

24 sus2
inv. 2



44 Characterizing mode (2)25



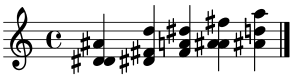
2

25 sus4

25 sus4
inv. 1

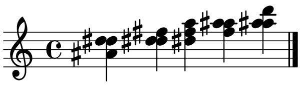
25 sus4
inv. 2

25 sus2



25 sus2
inv. 1

25 sus2
inv. 2



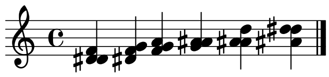
45 Characterizing mode (2)26

Mode (2)26

(binary key: 0011010)

26 plain

26 seconds



26 seconds inv. 1

26 seconds inv. 2

26 thirds

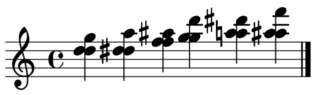
26 thirds inv. 1

26 thirds inv. 2

26 fourths

26 fourths inv. 1

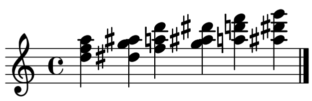
26 fourths inv. 2



26 fifths

26 fifths inv. 1

26 fifths inv. 2



2

26 sus4

26 sus4
inv. 1

26 sus4
inv. 2

26 sus2

26 sus2
inv. 1

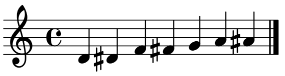
26 sus2
inv. 2

46 Characterizing mode (2)27

Mode (2)27

(binary key: 0011011)

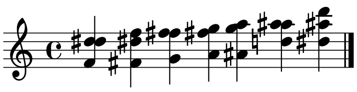
27 plain



27 seconds

27 seconds inv. 1

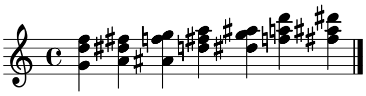
27 seconds inv. 2



27 thirds

27 thirds inv. 1

27 thirds inv. 2



27 fourths

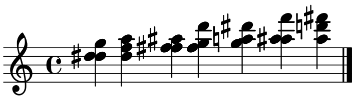
27 fourths inv. 1

27 fourths inv. 2

27 fifths

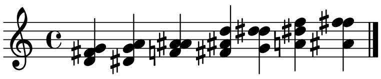
27 fifths inv. 1

27 fifths inv. 2



2

27 sus4



27 sus4
inv. 1

27 sus4
inv. 2

27 sus2

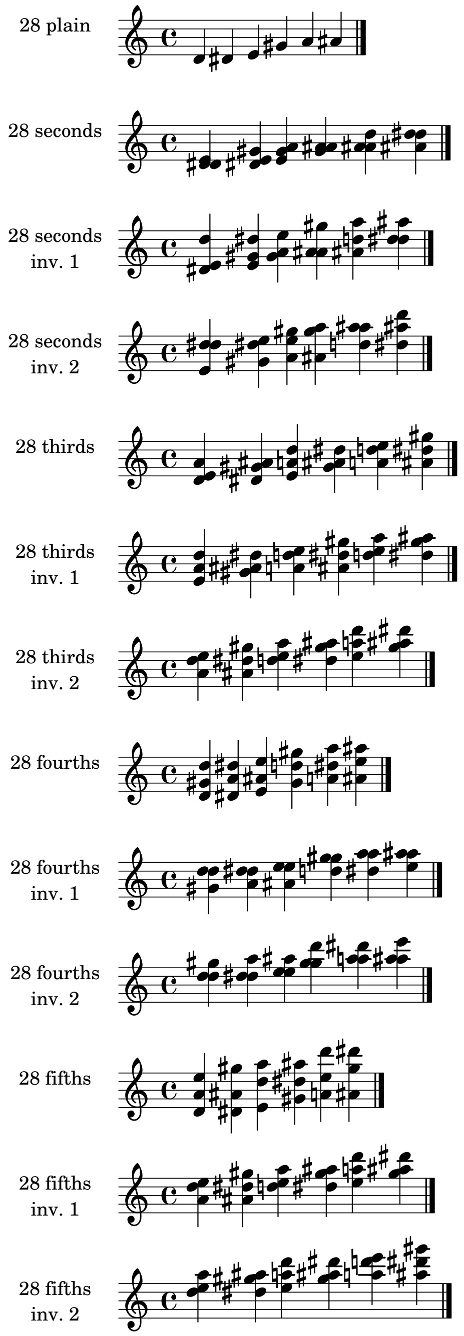
27 sus2
inv. 1

27 sus2
inv. 2

47 Characterizing mode (2)28

Mode (2)28

(binary key: 0011100)



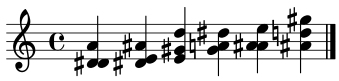
2

28 sus4

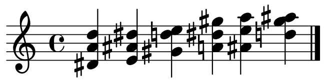
28 sus4
inv. 1

28 sus4
inv. 2

28 sus2

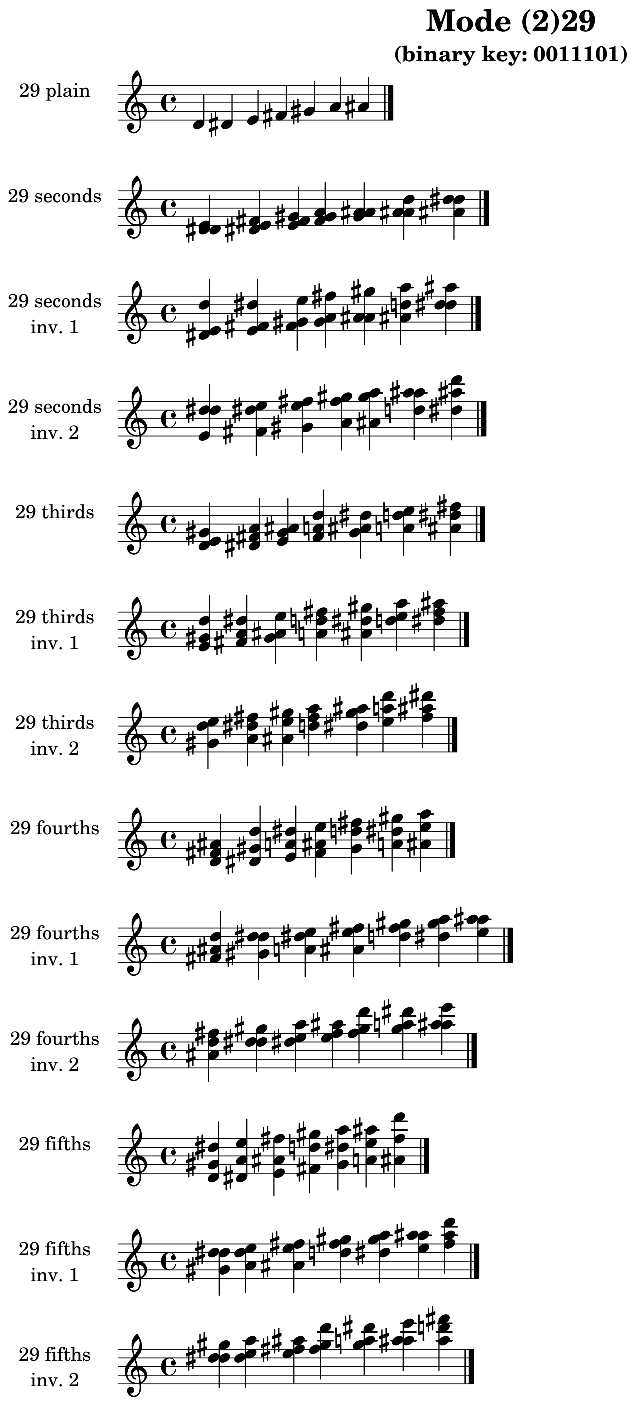


28 sus2
inv. 1



28 sus2
inv. 2

48 Characterizing mode (2)29



2

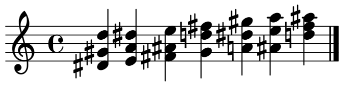
29 sus4

29 sus4
inv. 1

29 sus4
inv. 2

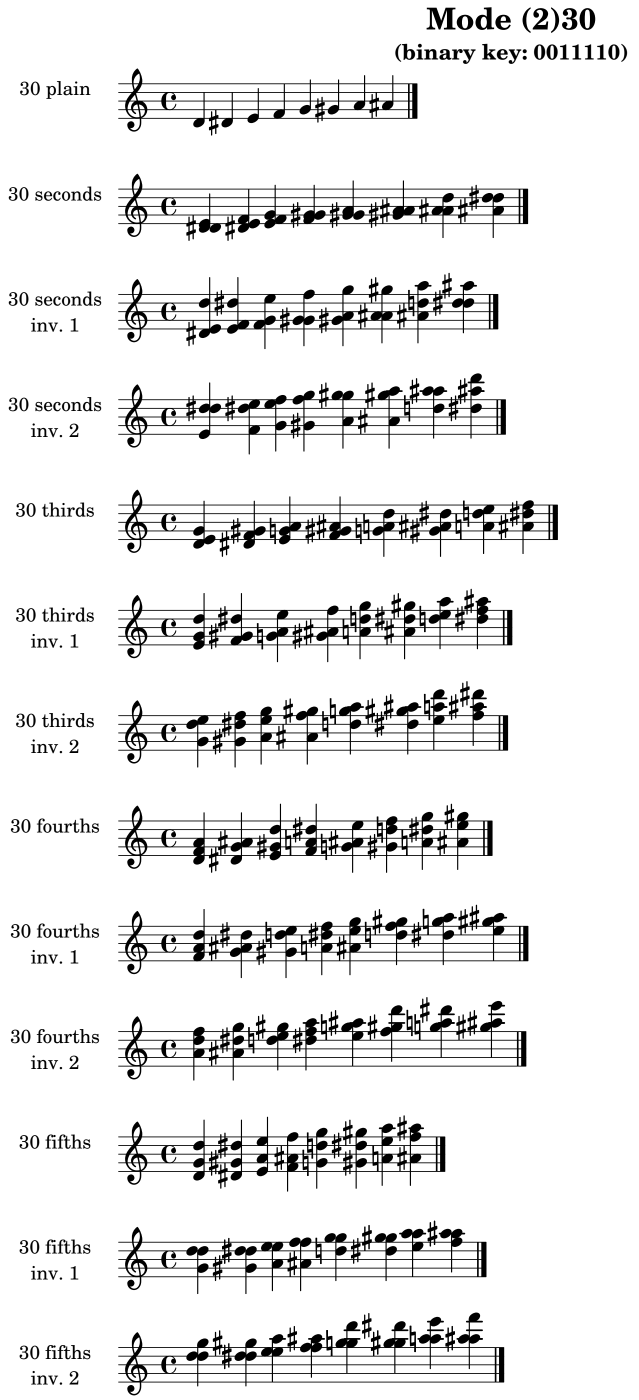
29 sus2

29 sus2
inv. 1



29 sus2
inv. 2

49 Characterizing mode (2)30



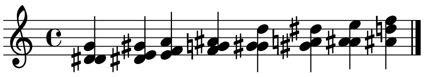
2

30 sus4

30 sus4
inv. 1

30 sus4
inv. 2

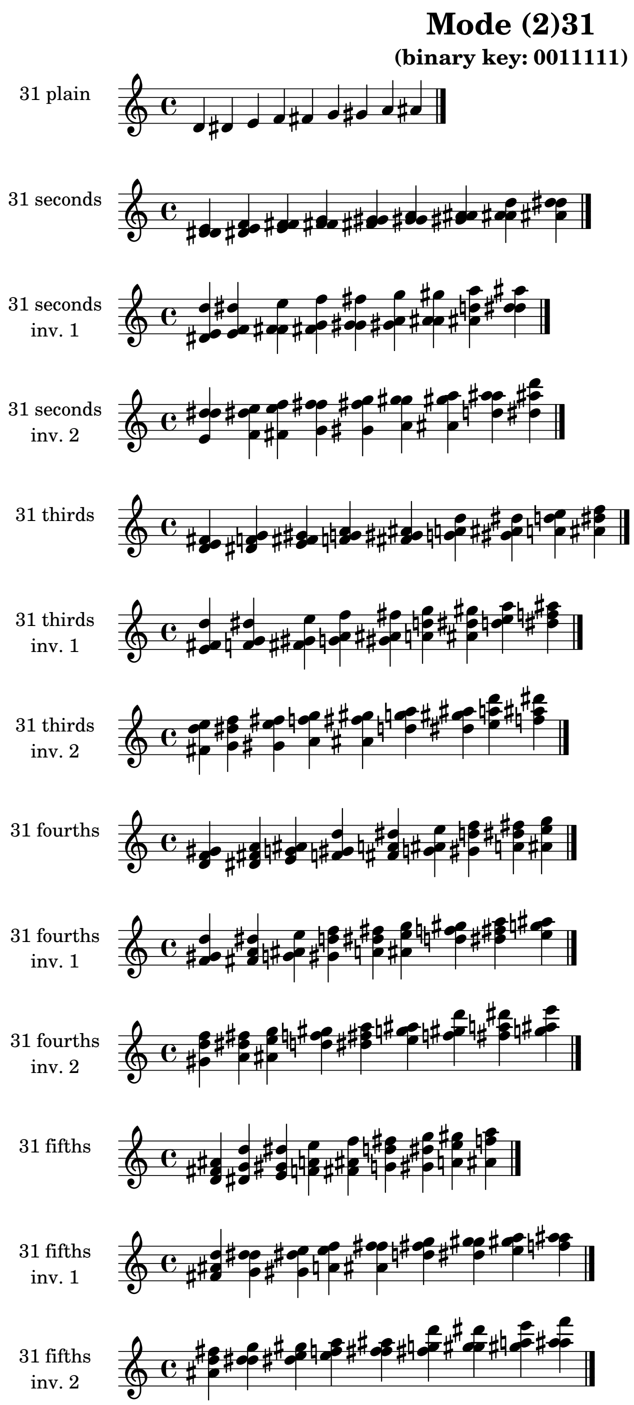
30 sus2



30 sus2
inv. 1

30 sus2
inv. 2

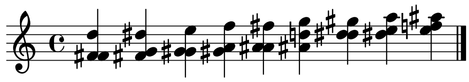
50 Characterizing mode (2)31



2

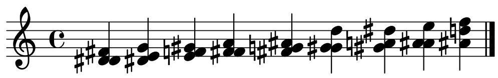
31 sus4

31 sus4
inv. 1



31 sus4
inv. 2

31 sus2



31 sus2
inv. 1

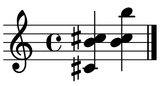
31 sus2
inv. 2

51 Characterizing mode (2)32

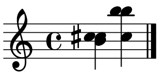
Mode (2)32
(binary key: 0100000)

32 plain

32 seconds



32 seconds
inv. 1



32 seconds
inv. 2

32 thirds

32 thirds
inv. 1

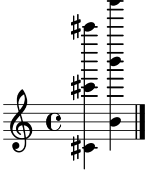
32 thirds
inv. 2

32 fourths

32 fourths
inv. 1

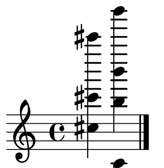
32 fourths
inv. 2

32 fifths

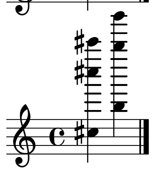


2

32 fifths
inv. 1



32 fifths
inv. 2



32 sus4

32 sus4
inv. 1

32 sus4
inv. 2

32 sus2

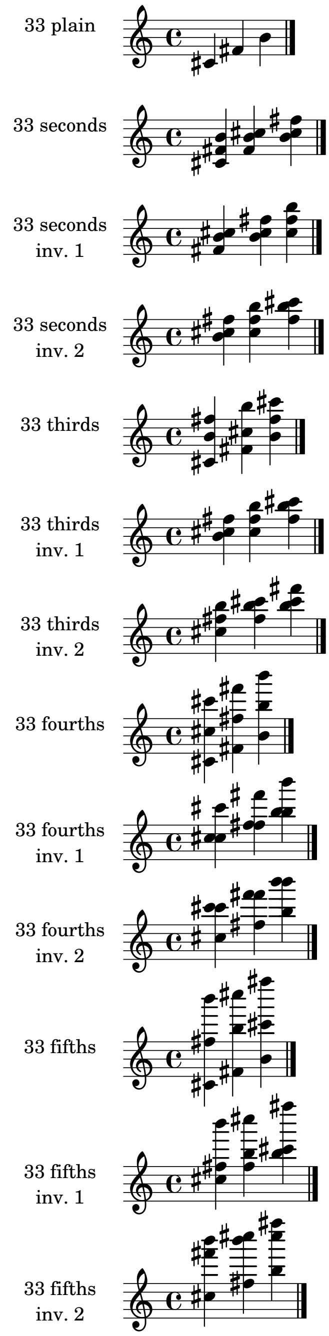
32 sus2
inv. 1

32 sus2
inv. 2

52 Characterizing mode (2)33

Mode (2)33

(binary key: 0100001)



2

33 sus4

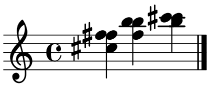
33 sus4
inv. 1

33 sus4
inv. 2

33 sus2

33 sus2
inv. 1

33 sus2
inv. 2

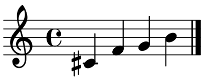


53 Characterizing mode (2)34

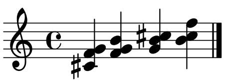
Mode (2)34

(binary key: 0100010)

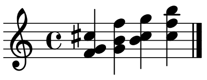
34 plain



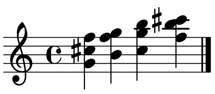
34 seconds



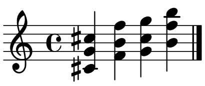
34 seconds inv. 1



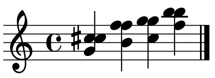
34 seconds inv. 2



34 thirds



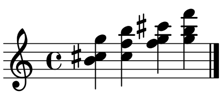
34 thirds inv. 1



34 thirds inv. 2

34 fourths

34 fourths inv. 1



34 fourths inv. 2

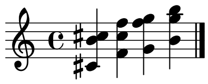
34 fifths

34 fifths inv. 1

34 fifths inv. 2

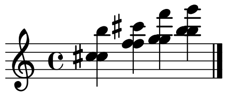
2

34 sus4

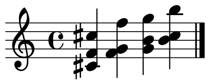


34 sus4
inv. 1

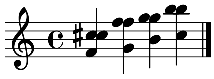
34 sus4
inv. 2



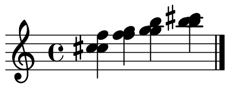
34 sus2



34 sus2
inv. 1



34 sus2
inv. 2



54 Characterizing mode (2)35

Mode (2)35

(binary key: 0100011)

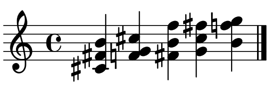
35 plain

35 seconds

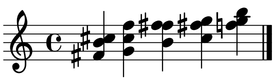
35 seconds
inv. 1

35 seconds
inv. 2

35 thirds

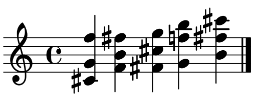


35 thirds
inv. 1



35 thirds
inv. 2

35 fourths



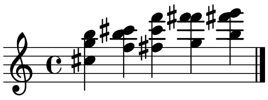
35 fourths
inv. 1

35 fourths
inv. 2

35 fifths

35 fifths
inv. 1

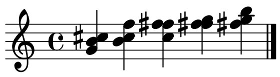
35 fifths
inv. 2



2

35 sus4

35 sus4
inv. 1



35 sus4
inv. 2

35 sus2

35 sus2
inv. 1

35 sus2
inv. 2

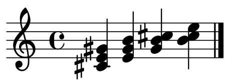
55 Characterizing mode (2)36

Mode (2)36

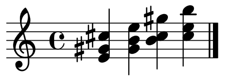
(binary key: 0100100)

36 plain

36 seconds

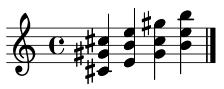


36 seconds inv. 1

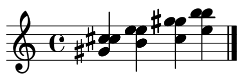


36 seconds inv. 2

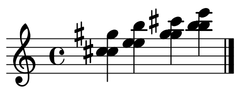
36 thirds



36 thirds inv. 1



36 thirds inv. 2



36 fourths

36 fourths inv. 1

36 fourths inv. 2

36 fifths

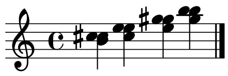
36 fifths inv. 1

36 fifths inv. 2

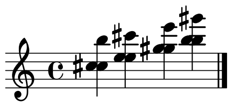
2

36 sus4

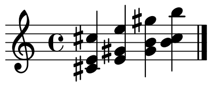
36 sus4
inv. 1



36 sus4
inv. 2

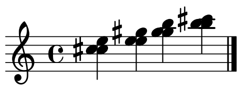


36 sus2



36 sus2
inv. 1

36 sus2
inv. 2



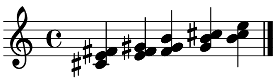
56 Characterizing mode (2)37

Mode (2)37

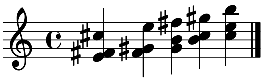
(binary key: 0100101)

37 plain

37 seconds

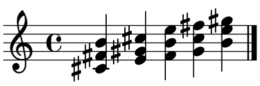


37 seconds
inv. 1

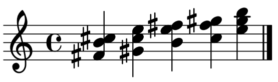


37 seconds
inv. 2

37 thirds



37 thirds
inv. 1



37 thirds
inv. 2

37 fourths

37 fourths
inv. 1

37 fourths
inv. 2

37 fifths

37 fifths
inv. 1

37 fifths
inv. 2

2

37 sus4

37 sus4
inv. 1

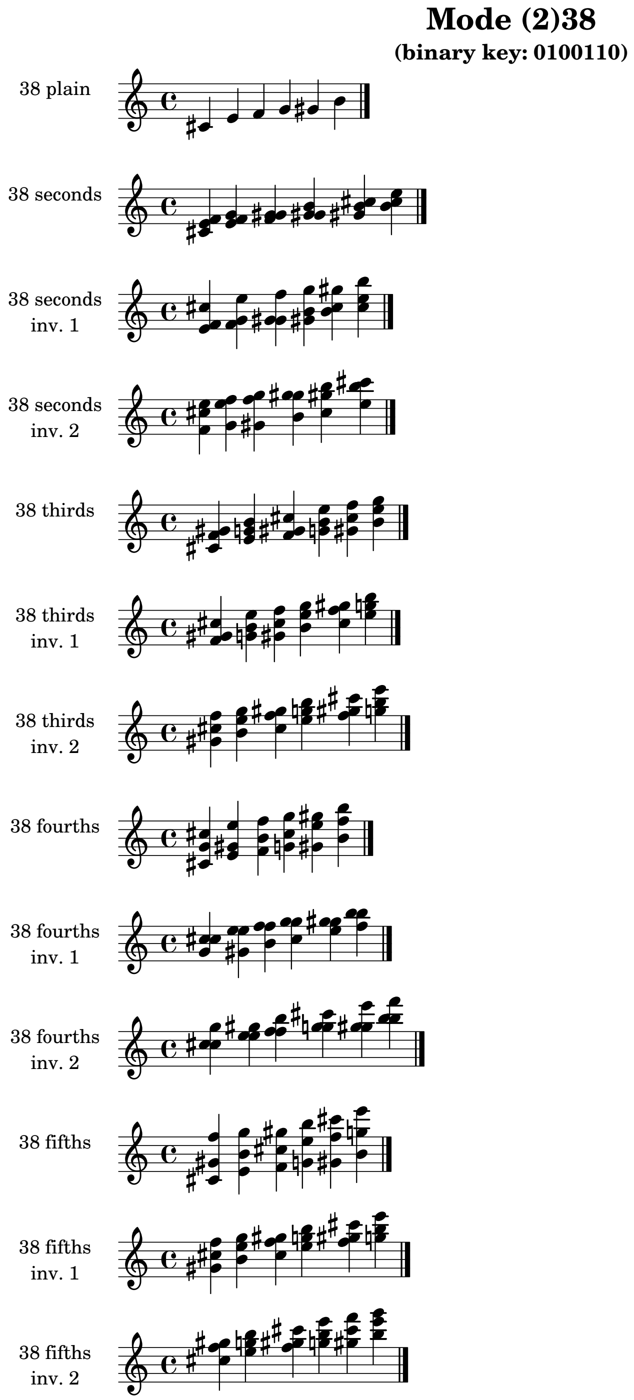
37 sus4
inv. 2

37 sus2

37 sus2
inv. 1

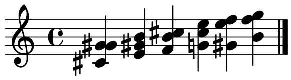
37 sus2
inv. 2

57 Characterizing mode (2)38



2

38 sus4



38 sus4
inv. 1

38 sus4
inv. 2

38 sus2

38 sus2
inv. 1

38 sus2
inv. 2

58 Characterizing mode (2)39

Mode (2)39
(binary key: 0100111)

39 plain

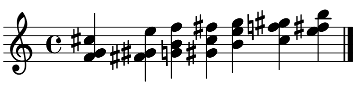
39 seconds

39 seconds inv. 1

39 seconds inv. 2

39 thirds

39 thirds inv. 1

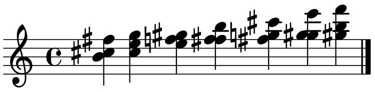


39 thirds inv. 2

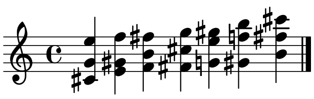
39 fourths

39 fourths inv. 1

39 fourths inv. 2

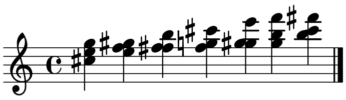


39 fifths



39 fifths inv. 1

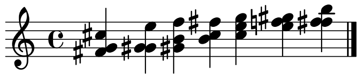
39 fifths inv. 2



2

39 sus4

39 sus4
inv. 1



39 sus4
inv. 2

39 sus2

39 sus2
inv. 1

39 sus2
inv. 2

59 Characterizing mode (2)40

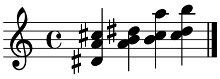
Mode (2)40

(binary key: 0101000)

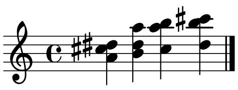
40 plain

40 seconds

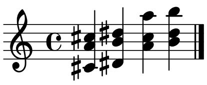
40 seconds inv. 1



40 seconds inv. 2



40 thirds



40 thirds inv. 1

40 thirds inv. 2

40 fourths

40 fourths inv. 1

40 fourths inv. 2

40 fifths

40 fifths inv. 1

40 fifths inv. 2

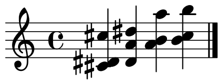
2

40 sus4

40 sus4
inv. 1

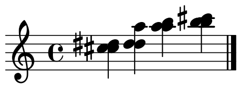
40 sus4
inv. 2

40 sus2

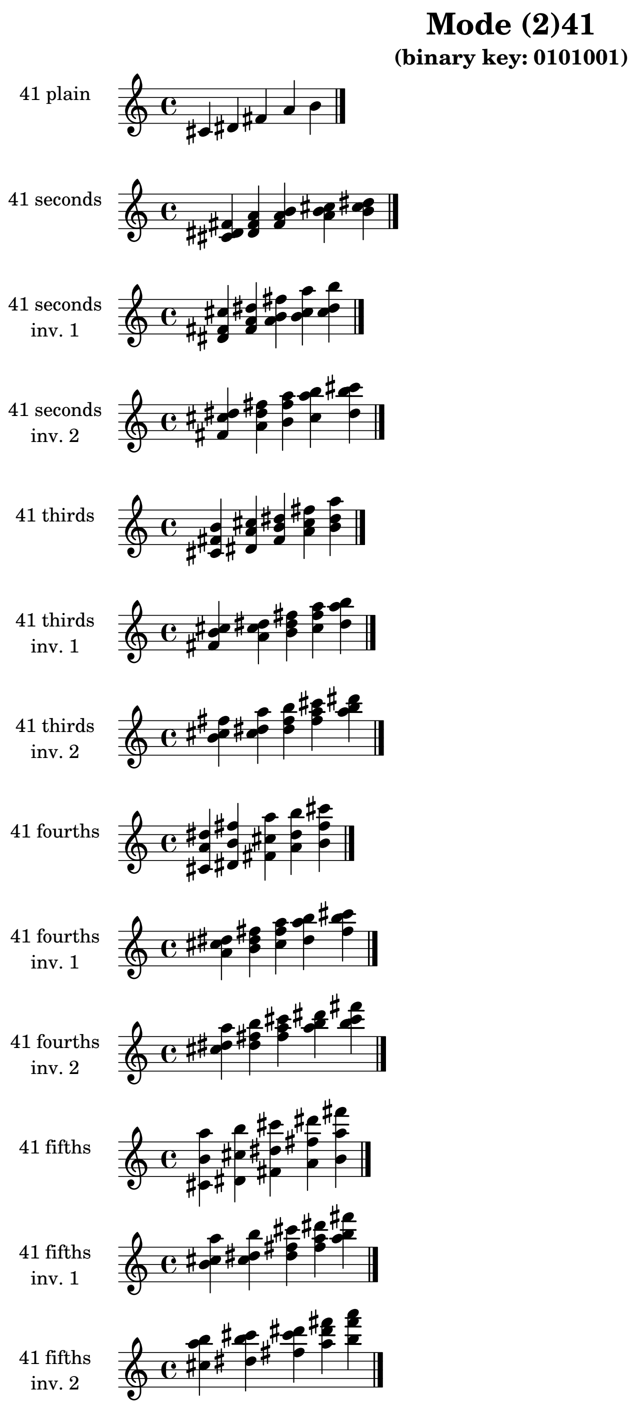


40 sus2
inv. 1

40 sus2
inv. 2



60 Characterizing mode (2)41

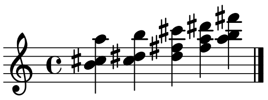


2

41 sus4

41 sus4
inv. 1

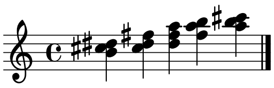
41 sus4
inv. 2



41 sus2

41 sus2
inv. 1

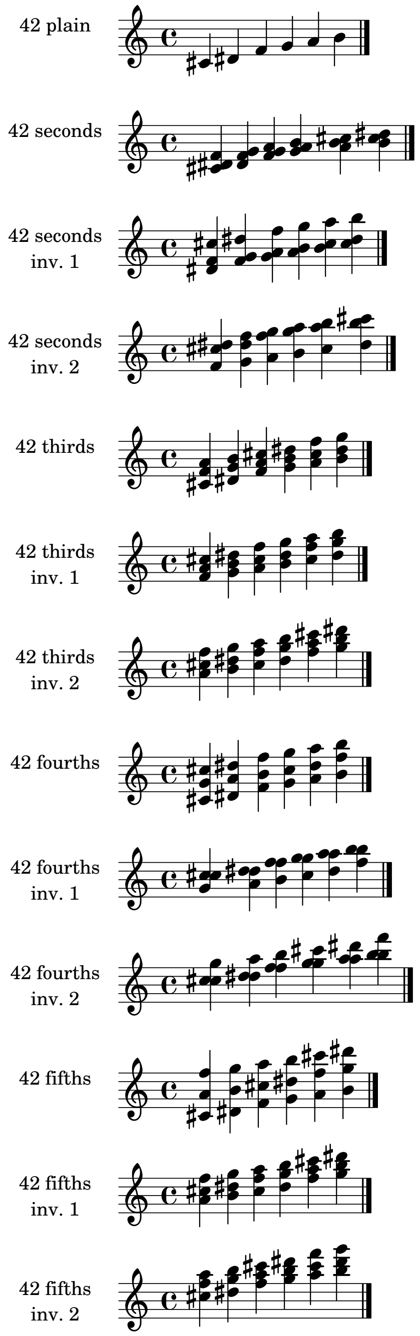
41 sus2
inv. 2



61 Characterizing mode (2)42

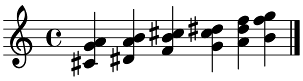
Mode (2)42

(binary key: 0101010)

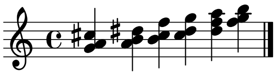


2

42 sus4



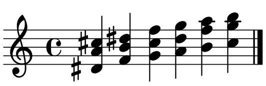
42 sus4
inv. 1



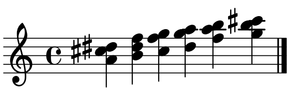
42 sus4
inv. 2

42 sus2

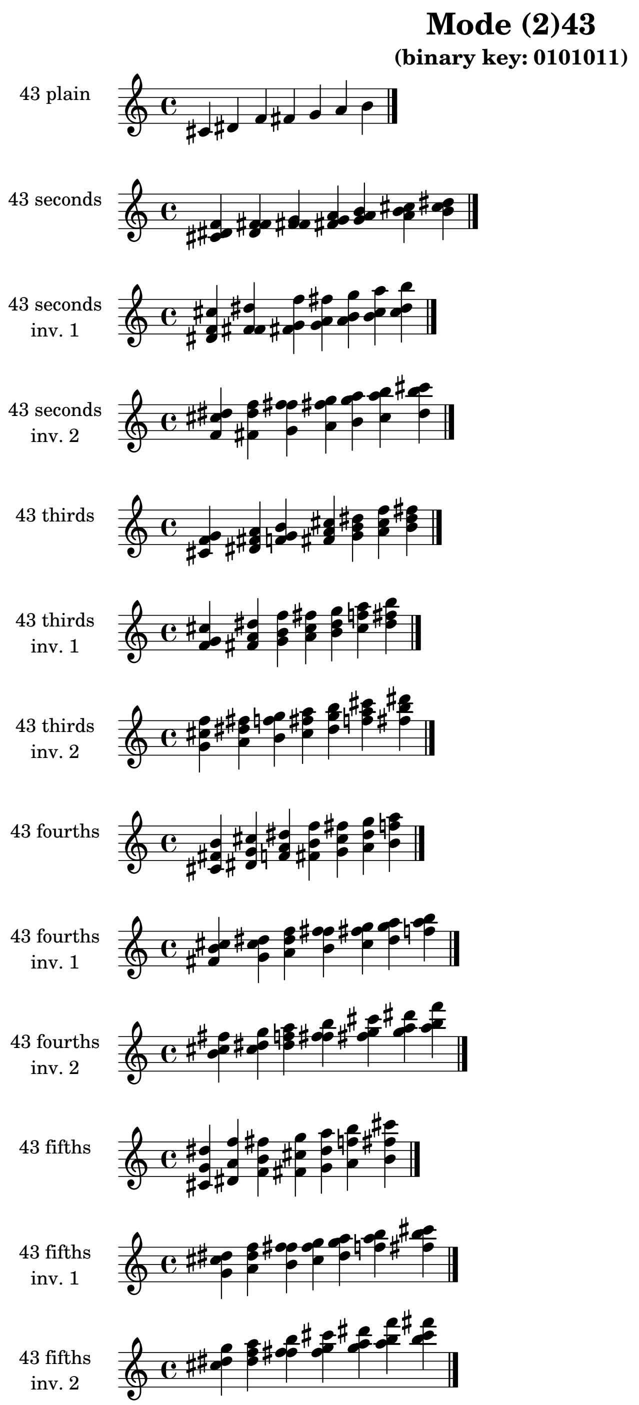
42 sus2
inv. 1



42 sus2
inv. 2

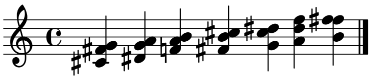


62 Characterizing mode (2)43



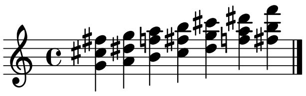
2

43 sus4

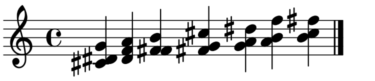


43 sus4
inv. 1

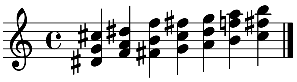
43 sus4
inv. 2



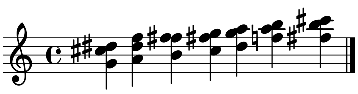
43 sus2



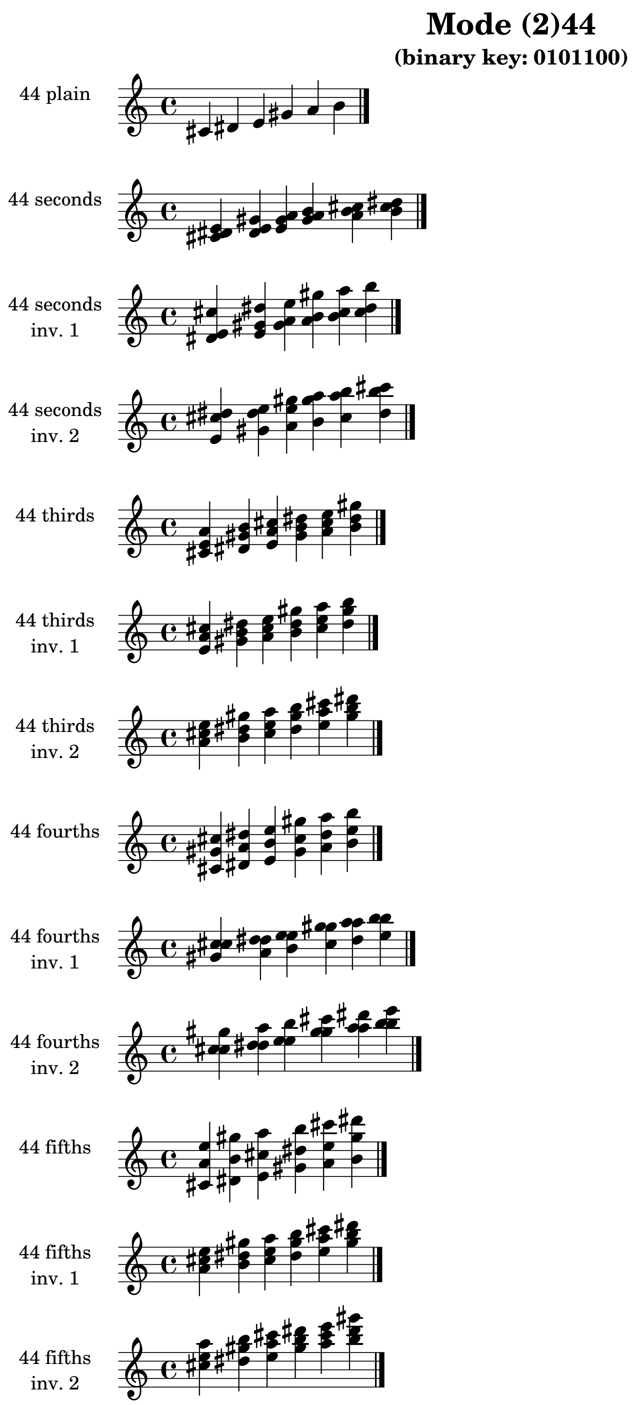
43 sus2
inv. 1



43 sus2
inv. 2



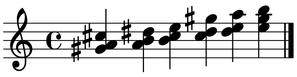
63 Characterizing mode (2)44



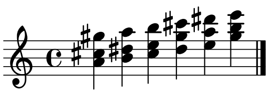
2

44 sus4

44 sus4
inv. 1

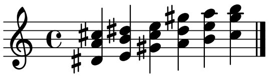


44 sus4
inv. 2



44 sus2

44 sus2
inv. 1

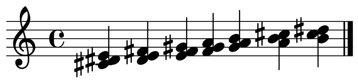


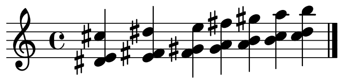
44 sus2
inv. 2

64 Characterizing mode (2)45

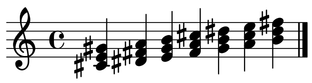
Mode (2)45
(binary key: 0101101)

45 plain


45 seconds


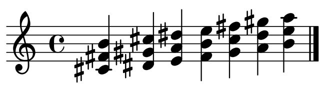
45 seconds inv. 1


45 seconds inv. 2


45 thirds


45 thirds inv. 1


45 thirds inv. 2

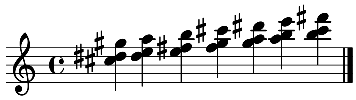

45 fourths


45 fourths inv. 1


45 fourths inv. 2


45 fifths

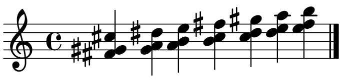

45 fifths inv. 1


45 fifths inv. 2


2

45 sus4

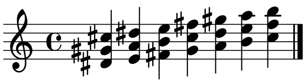
45 sus4
inv. 1



45 sus4
inv. 2

45 sus2

45 sus2
inv. 1



45 sus2
inv. 2

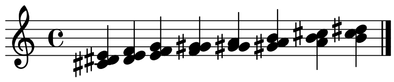
65 Characterizing mode (2)46

Mode (2)46

(binary key: 0101110)

46 plain

46 seconds



46 seconds inv. 1

46 seconds inv. 2

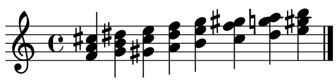
46 thirds

46 thirds inv. 1

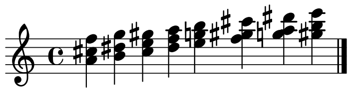
46 thirds inv. 2

46 fourths

46 fourths inv. 1

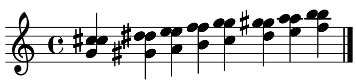


46 fourths inv. 2

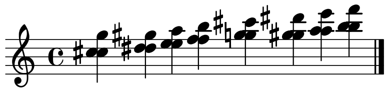


46 fifths

46 fifths inv. 1



46 fifths inv. 2



2

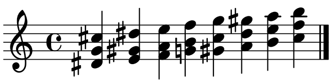
46 sus4

46 sus4
inv. 1

46 sus4
inv. 2

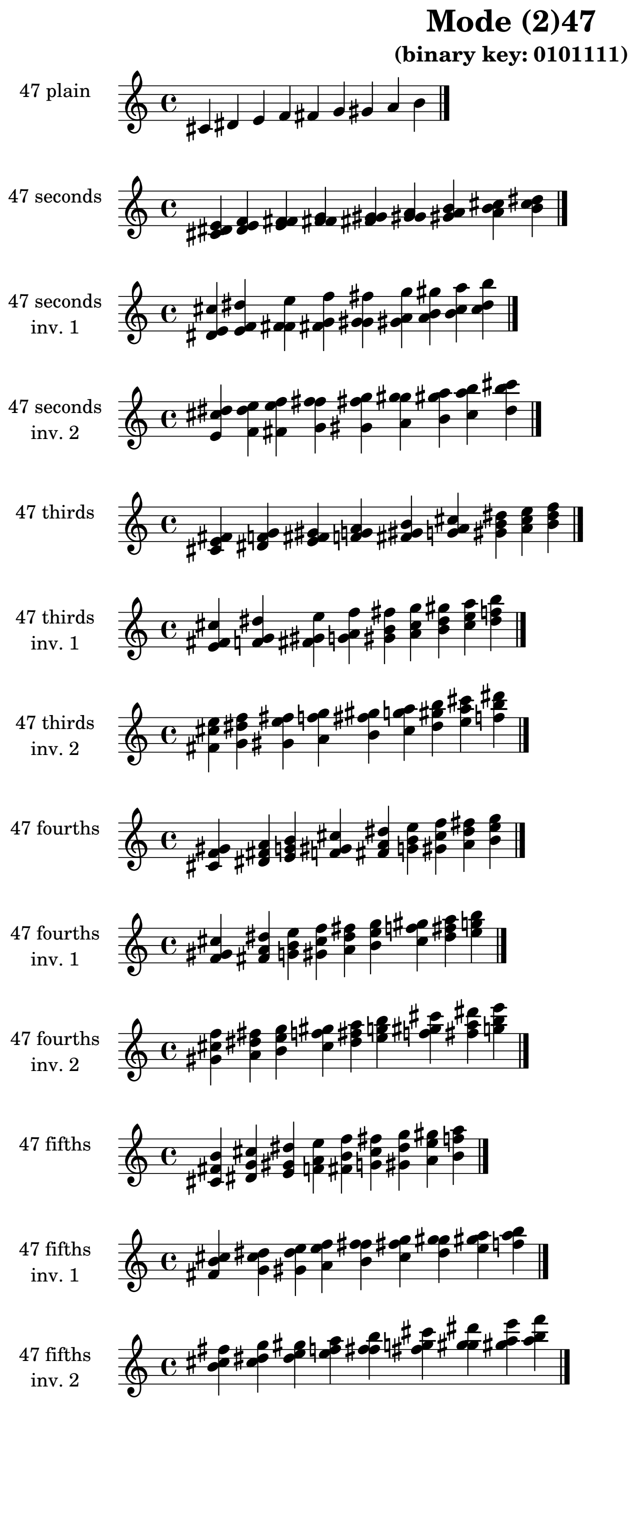
46 sus2

46 sus2
inv. 1



46 sus2
inv. 2

66 Characterizing mode (2)47



2

47 sus4

47 sus4
inv. 1

47 sus4
inv. 2

47 sus2

47 sus2
inv. 1

47 sus2
inv. 2

67 Characterizing mode (2)48

Mode (2)48

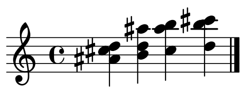
(binary key: 0110000)

48 plain

48 seconds

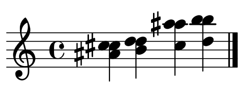
48 seconds inv. 1

48 seconds inv. 2

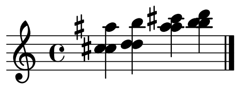


48 thirds

48 thirds inv. 1



48 thirds inv. 2



48 fourths

48 fourths inv. 1

48 fourths inv. 2

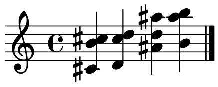
48 fifths

48 fifths inv. 1

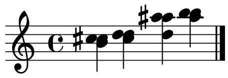
48 fifths inv. 2

2

48 sus4



48 sus4
inv. 1

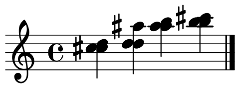


48 sus4
inv. 2

48 sus2

48 sus2
inv. 1

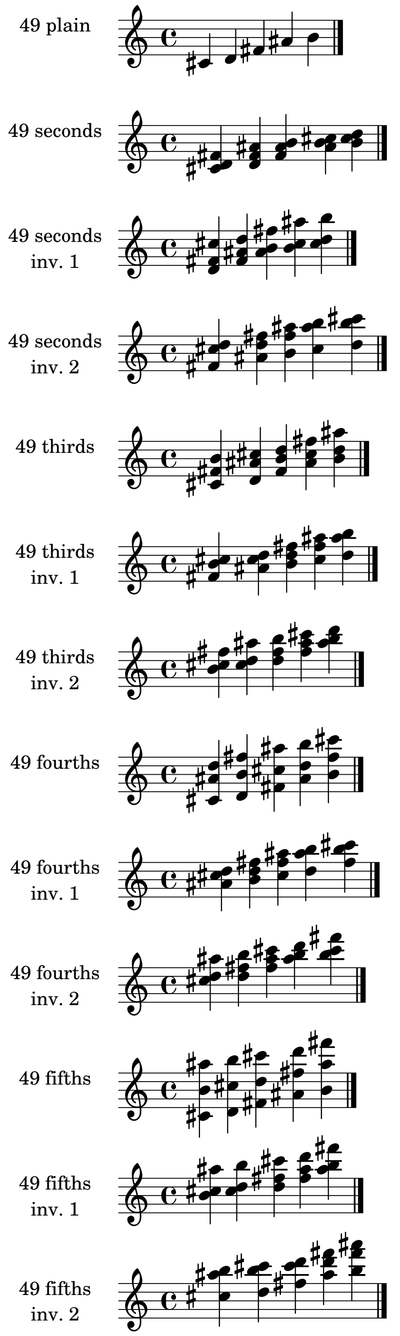
48 sus2
inv. 2



68 Characterizing mode (2)49

Mode (2)49

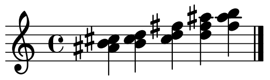
(binary key: 0110001)



2

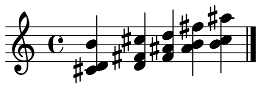
49 sus4

49 sus4
inv. 1

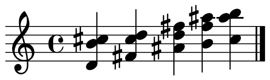


49 sus4
inv. 2

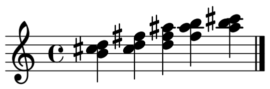
49 sus2



49 sus2
inv. 1



49 sus2
inv. 2



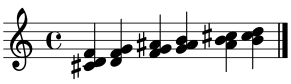
69 Characterizing mode (2)50

Mode (2)50

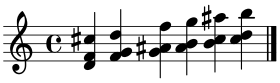
(binary key: 0110010)

50 plain

50 seconds

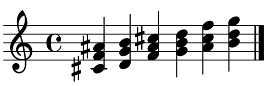


50 seconds
inv. 1

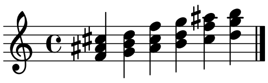


50 seconds
inv. 2

50 thirds

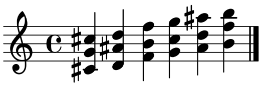


50 thirds
inv. 1

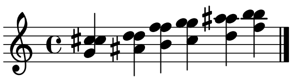


50 thirds
inv. 2

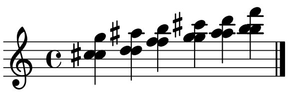
50 fourths



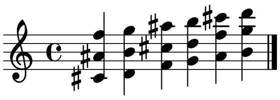
50 fourths
inv. 1



50 fourths
inv. 2

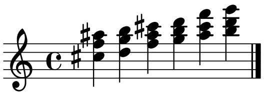


50 fifths



50 fifths
inv. 1

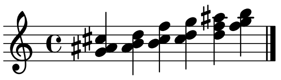
50 fifths
inv. 2



2

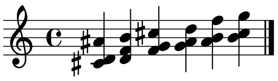
50 sus4

50 sus4
inv. 1

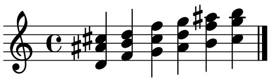


50 sus4
inv. 2

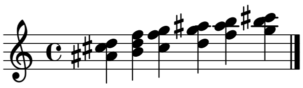
50 sus2



50 sus2
inv. 1



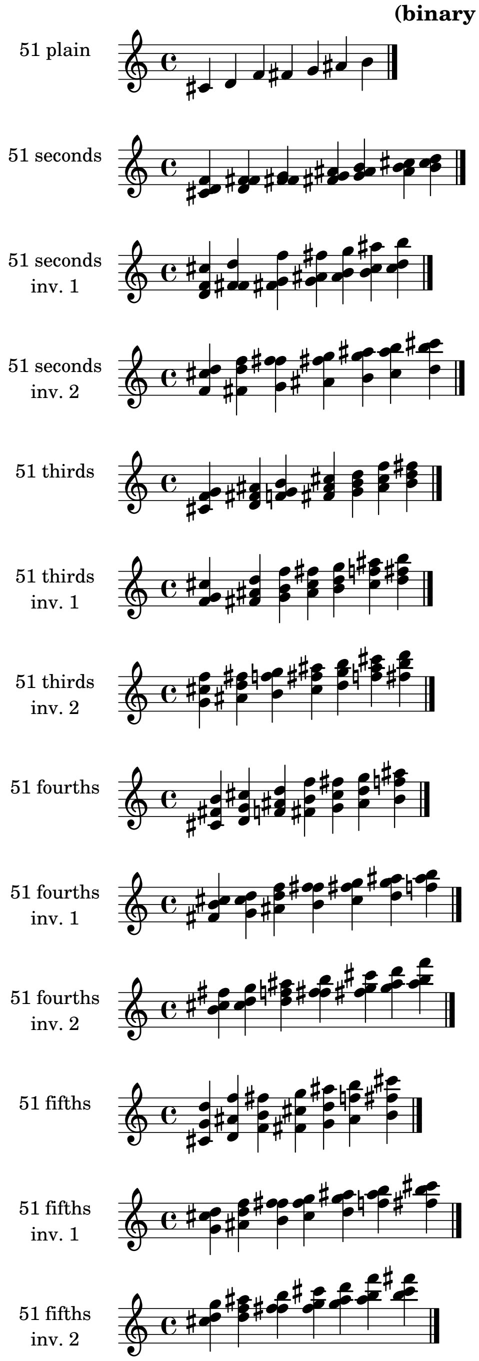
50 sus2
inv. 2



70 Characterizing mode (2)51

Mode (2)51

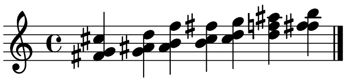
(binary key: 0110011)



2

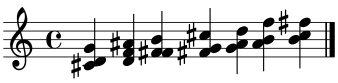
51 sus4

51 sus4
inv. 1

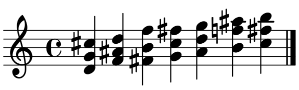


51 sus4
inv. 2

51 sus2

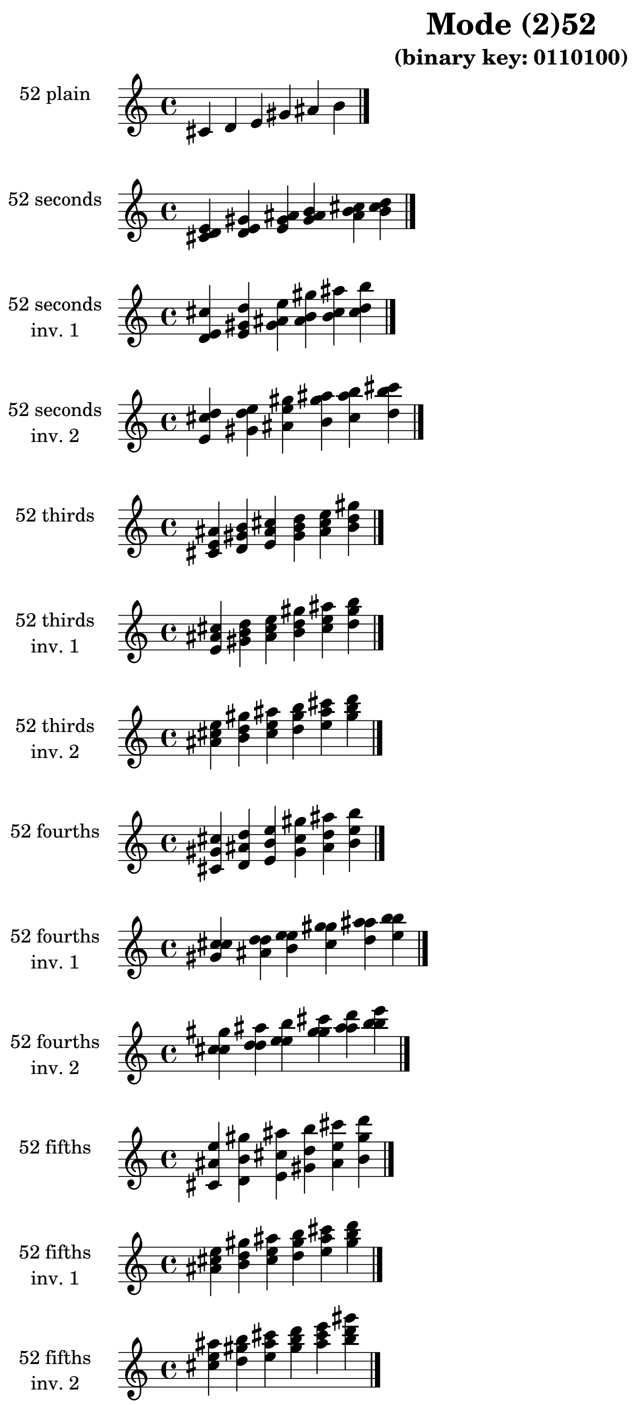


51 sus2
inv. 1



51 sus2
inv. 2

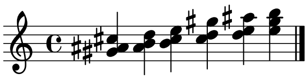
71 Characterizing mode (2)52



2

52 sus4

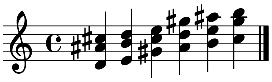
52 sus4
inv. 1



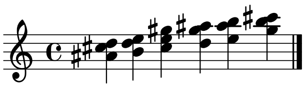
52 sus4
inv. 2

52 sus2

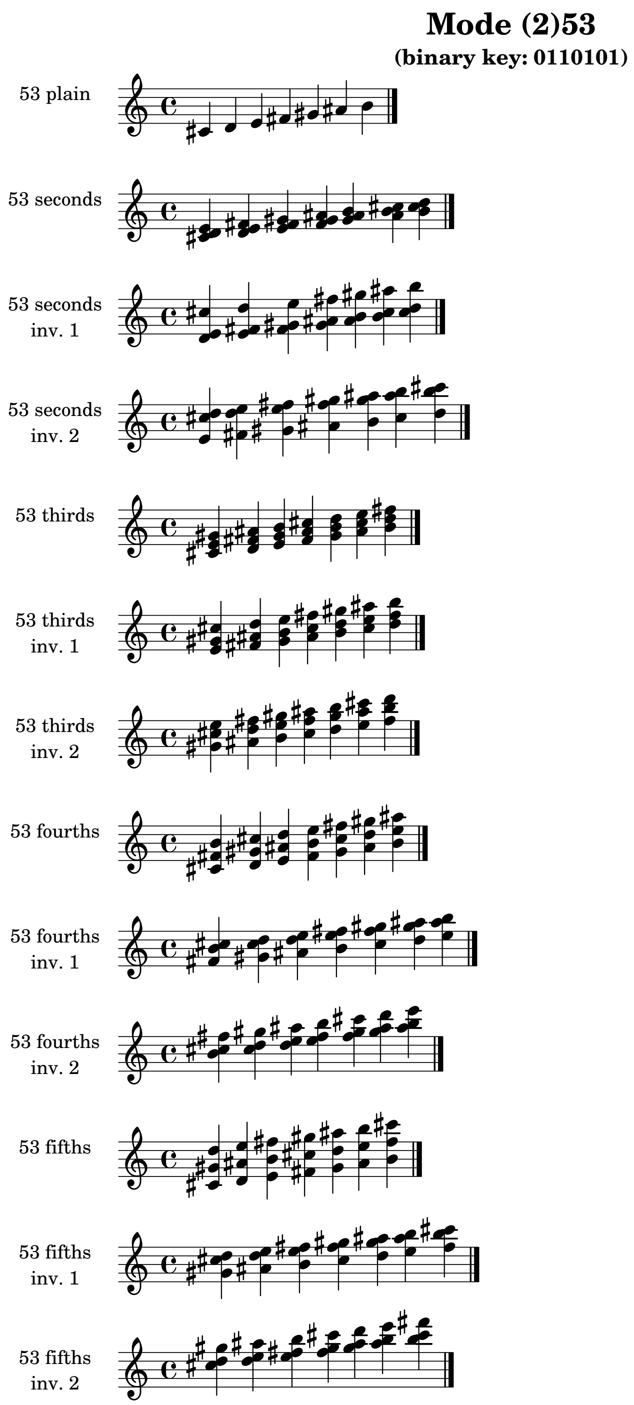
52 sus2
inv. 1



52 sus2
inv. 2



72 Characterizing mode (2)53



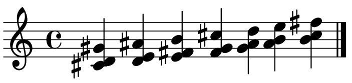
2

53 sus4

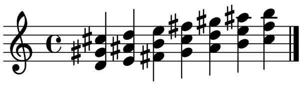
53 sus4
inv. 1

53 sus4
inv. 2

53 sus2

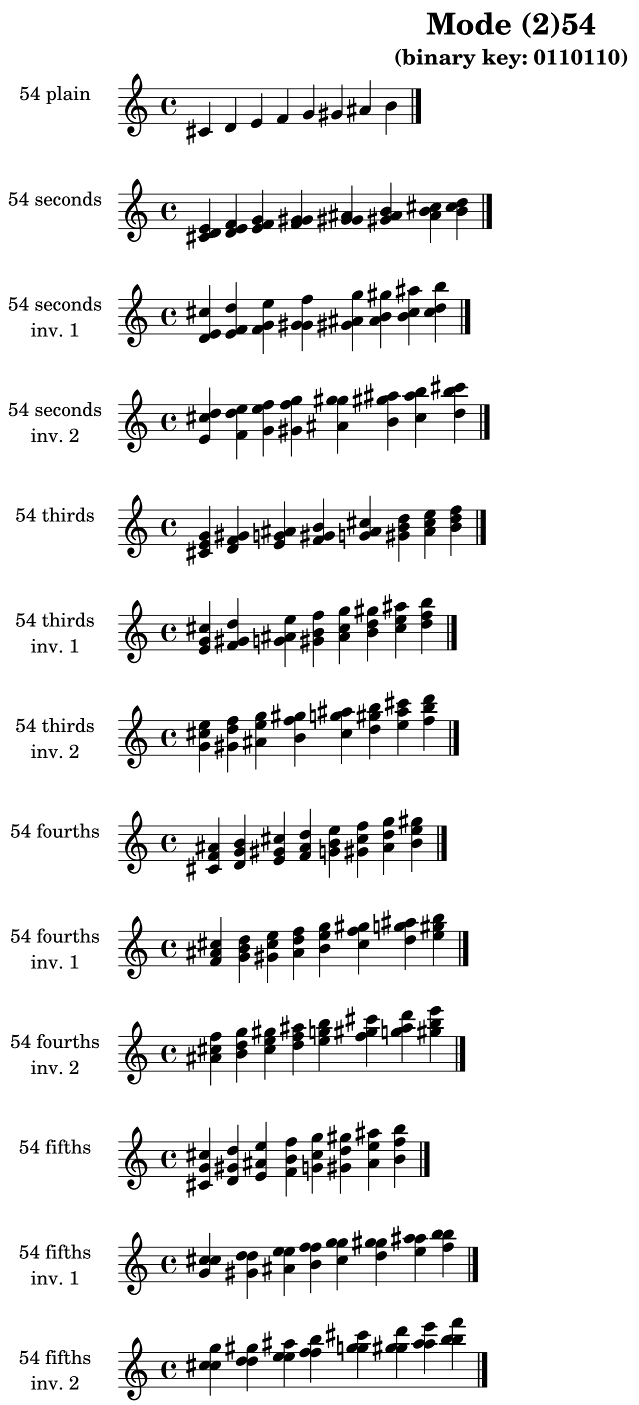


53 sus2
inv. 1



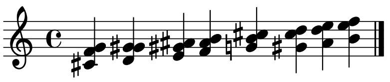
53 sus2
inv. 2

73 Characterizing mode (2)54

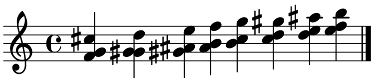


2

54 sus4



54 sus4
inv. 1



54 sus4
inv. 2

54 sus2

54 sus2
inv. 1

54 sus2
inv. 2

74 Characterizing mode (2)55

Mode (2)55

(binary key: 0110111)

55 plain

55 seconds

55 seconds inv. 1

55 seconds inv. 2

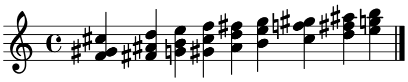
55 thirds

55 thirds inv. 1

55 thirds inv. 2

55 fourths

55 fourths inv. 1



55 fourths inv. 2

55 fifths

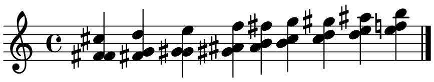
55 fifths inv. 1

55 fifths inv. 2

2

55 sus4

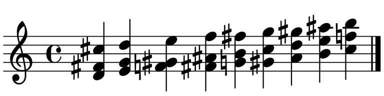
55 sus4
inv. 1



55 sus4
inv. 2

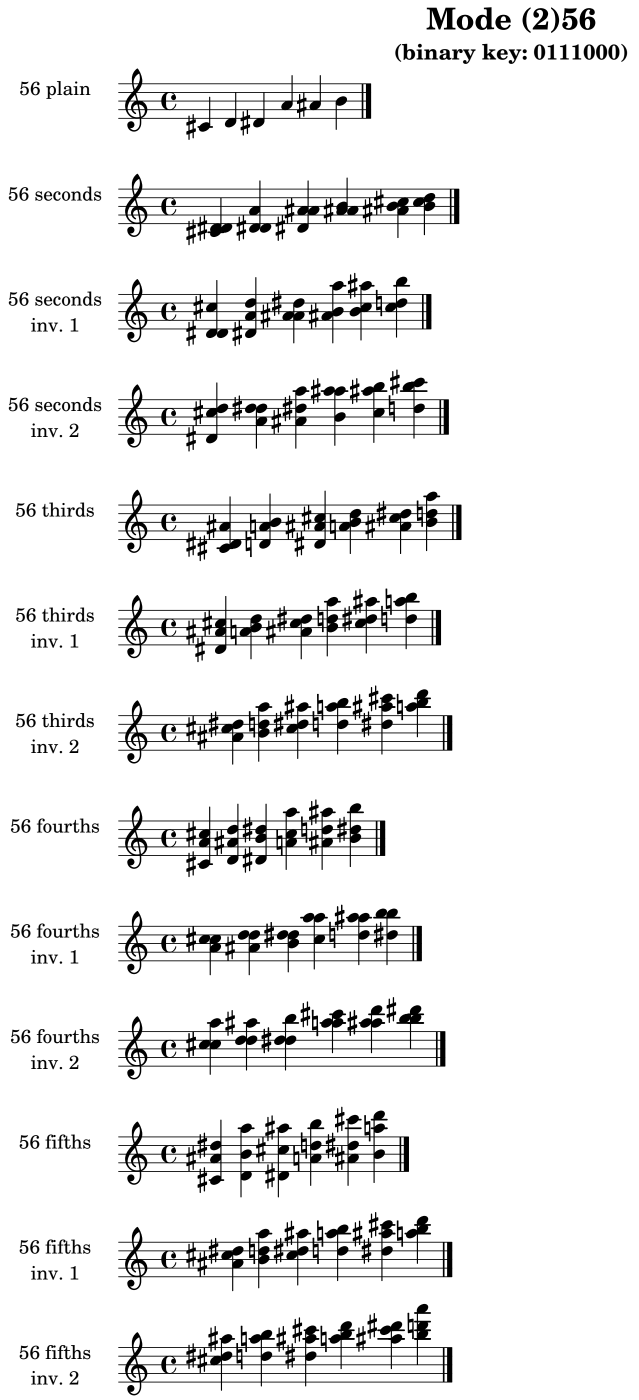
55 sus2

55 sus2
inv. 1



55 sus2
inv. 2

75 Characterizing mode (2)56



2

56 sus4

56 sus4
inv. 1

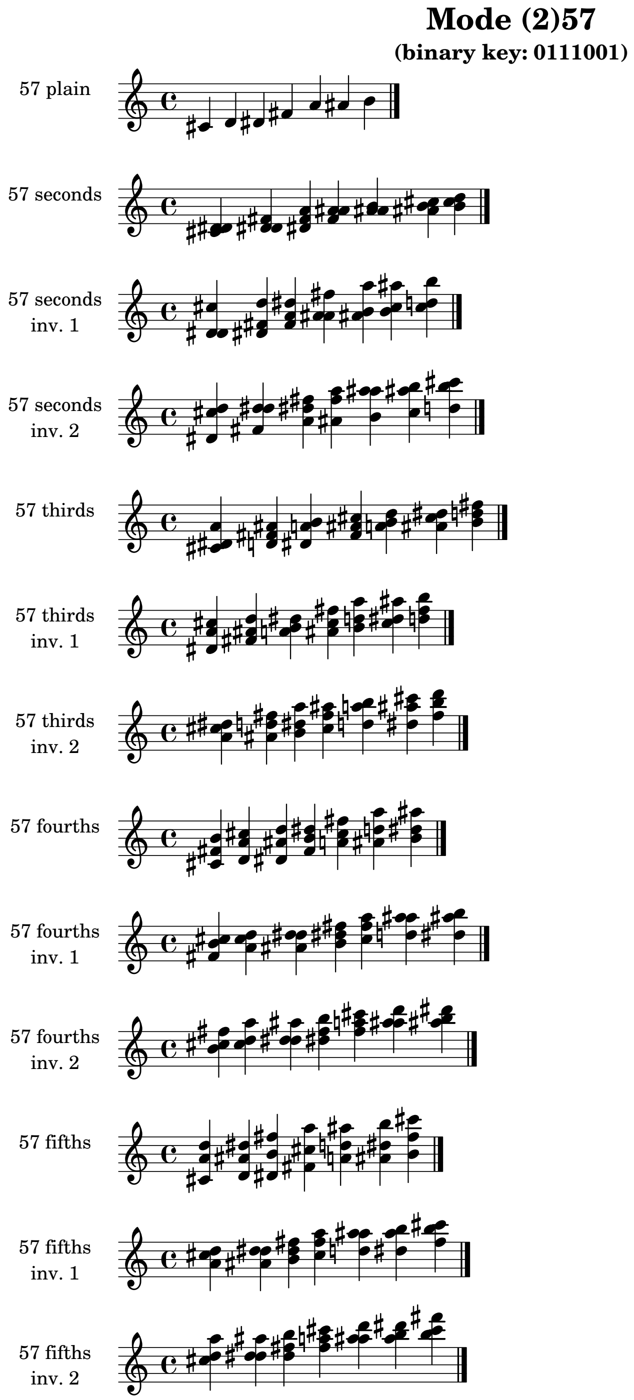
56 sus4
inv. 2

56 sus2

56 sus2
inv. 1

56 sus2
inv. 2

76 Characterizing mode (2)57



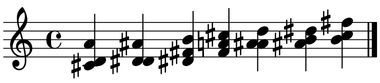
2

57 sus4

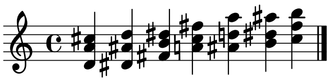
57 sus4
inv. 1

57 sus4
inv. 2

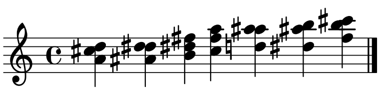
57 sus2



57 sus2
inv. 1



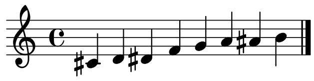
57 sus2
inv. 2

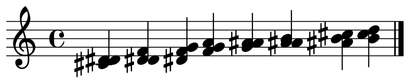


77 Characterizing mode (2)58

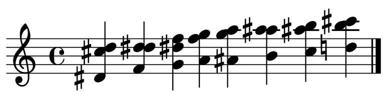
Mode (2)58

(binary key: 0111010)

58 plain


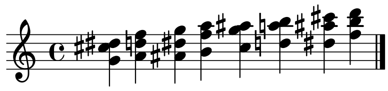
58 seconds


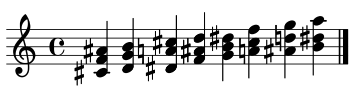
58 seconds inv. 1

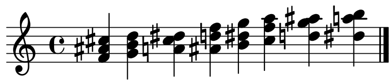

58 seconds inv. 2


58 thirds


58 thirds inv. 1

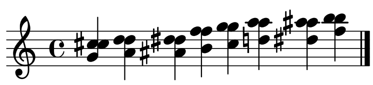

58 thirds inv. 2


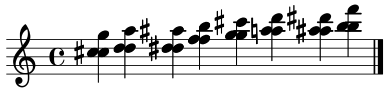
58 fourths


58 fourths inv. 1


58 fourths inv. 2

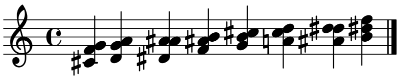

58 fifths


58 fifths inv. 1


58 fifths inv. 2


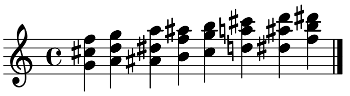
2

58 sus4

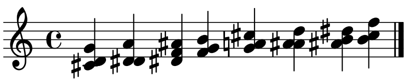


58 sus4
inv. 1

58 sus4
inv. 2

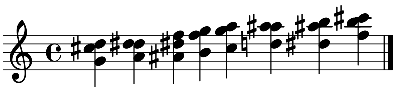


58 sus2

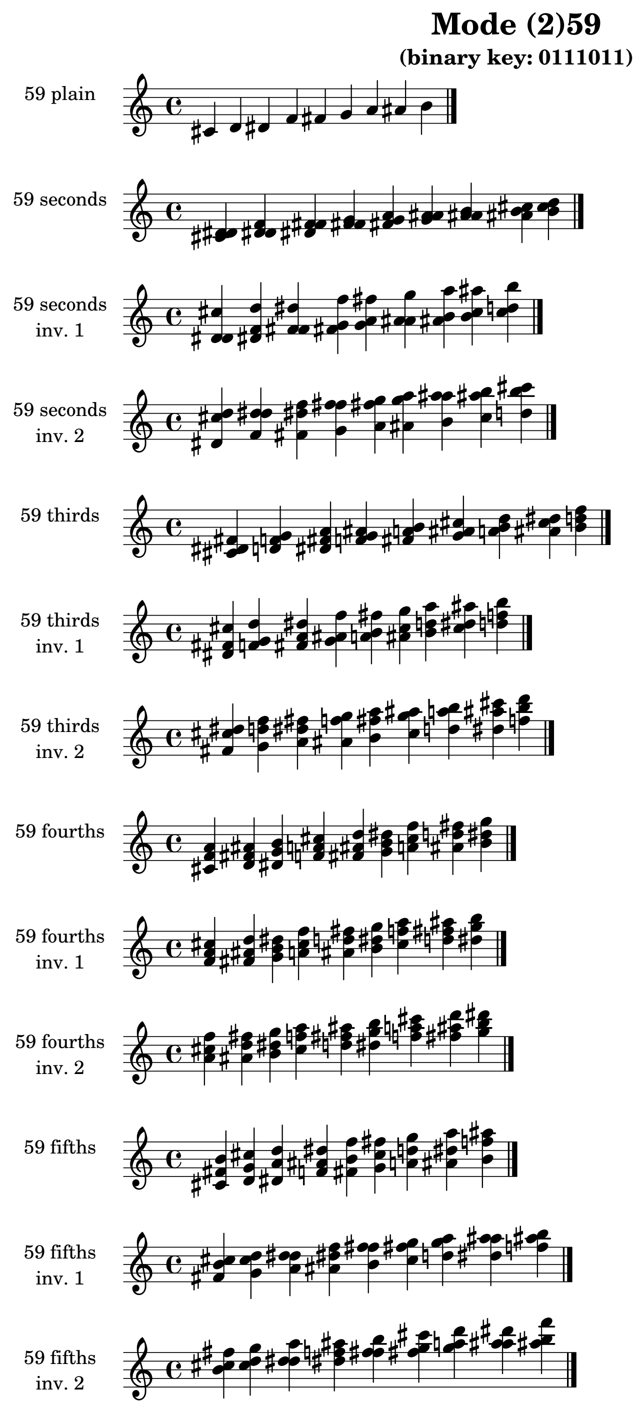


58 sus2
inv. 1

58 sus2
inv. 2

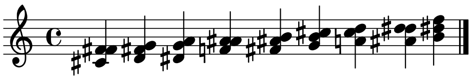


78 Characterizing mode (2)59



2

59 sus4

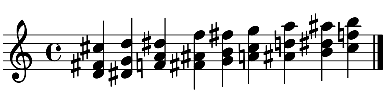


59 sus4
inv. 1

59 sus4
inv. 2

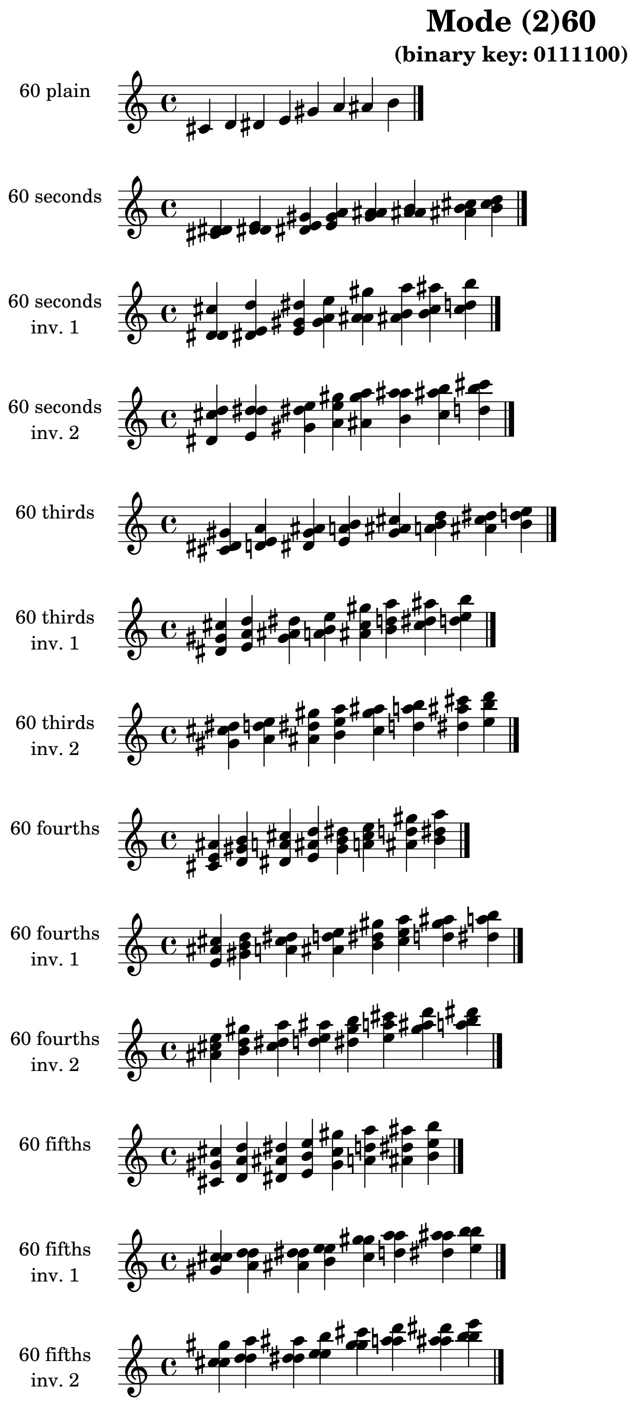
59 sus2

59 sus2
inv. 1



59 sus2
inv. 2

79 Characterizing mode (2)60



2

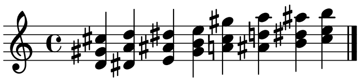
60 sus4

60 sus4
inv. 1

60 sus4
inv. 2

60 sus2

60 sus2
inv. 1

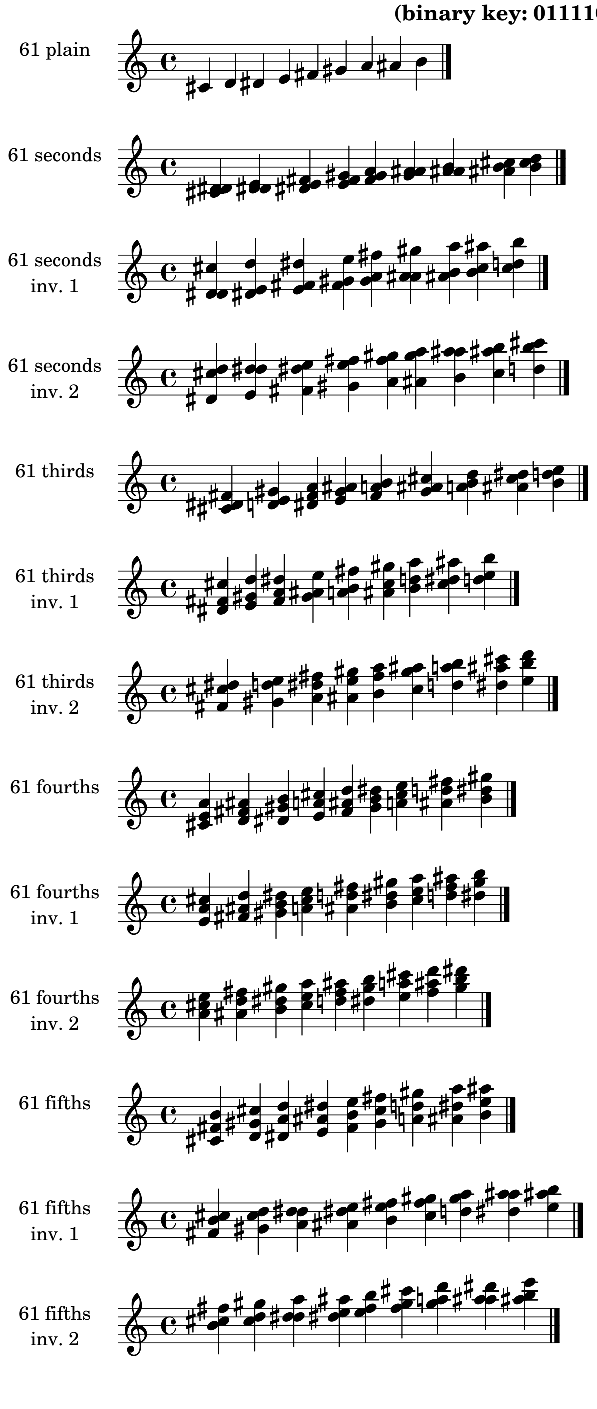


60 sus2
inv. 2

80 Characterizing mode (2)61

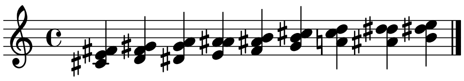
Mode (2)61

(binary key: 0111101)



2

61 sus4

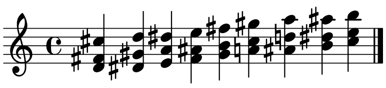


61 sus4
inv. 1

61 sus4
inv. 2

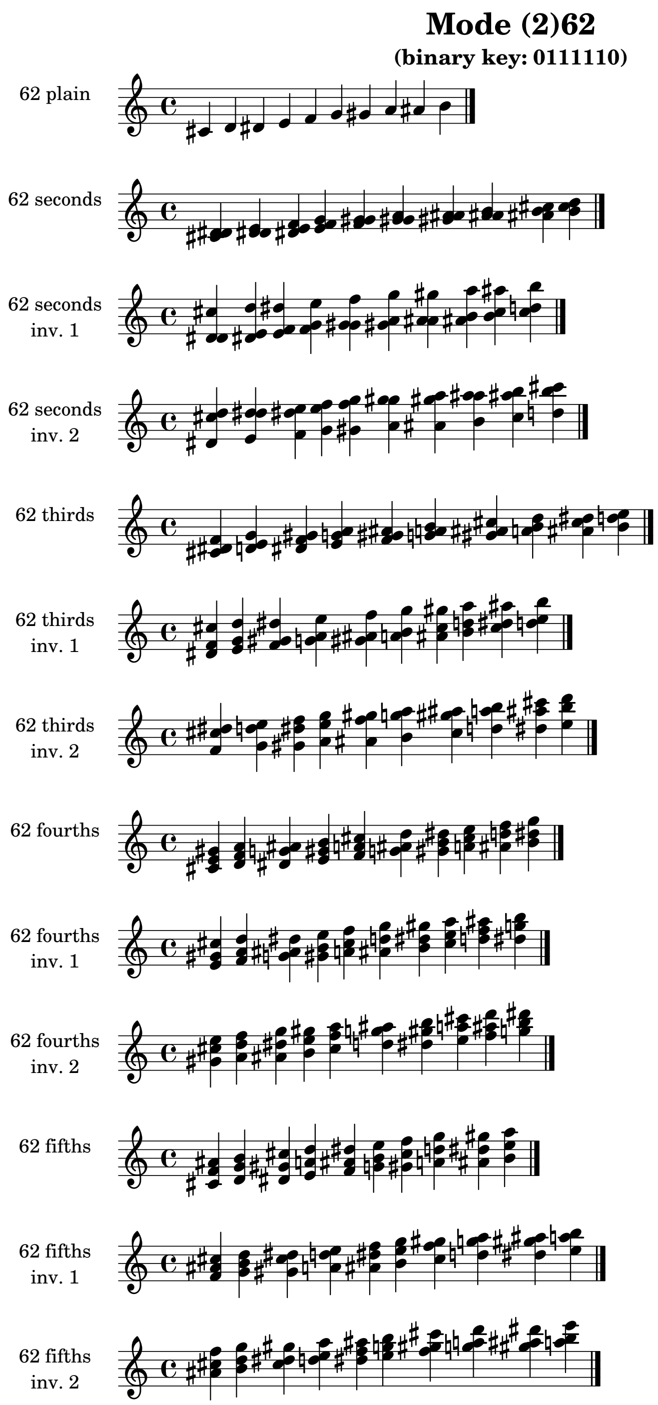
61 sus2

61 sus2
inv. 1



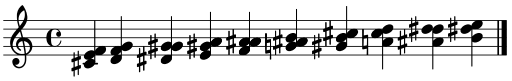
61 sus2
inv. 2

81 Characterizing mode (2)62



2

62 sus4



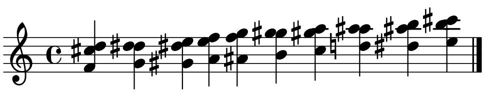
62 sus4
inv. 1

62 sus4
inv. 2

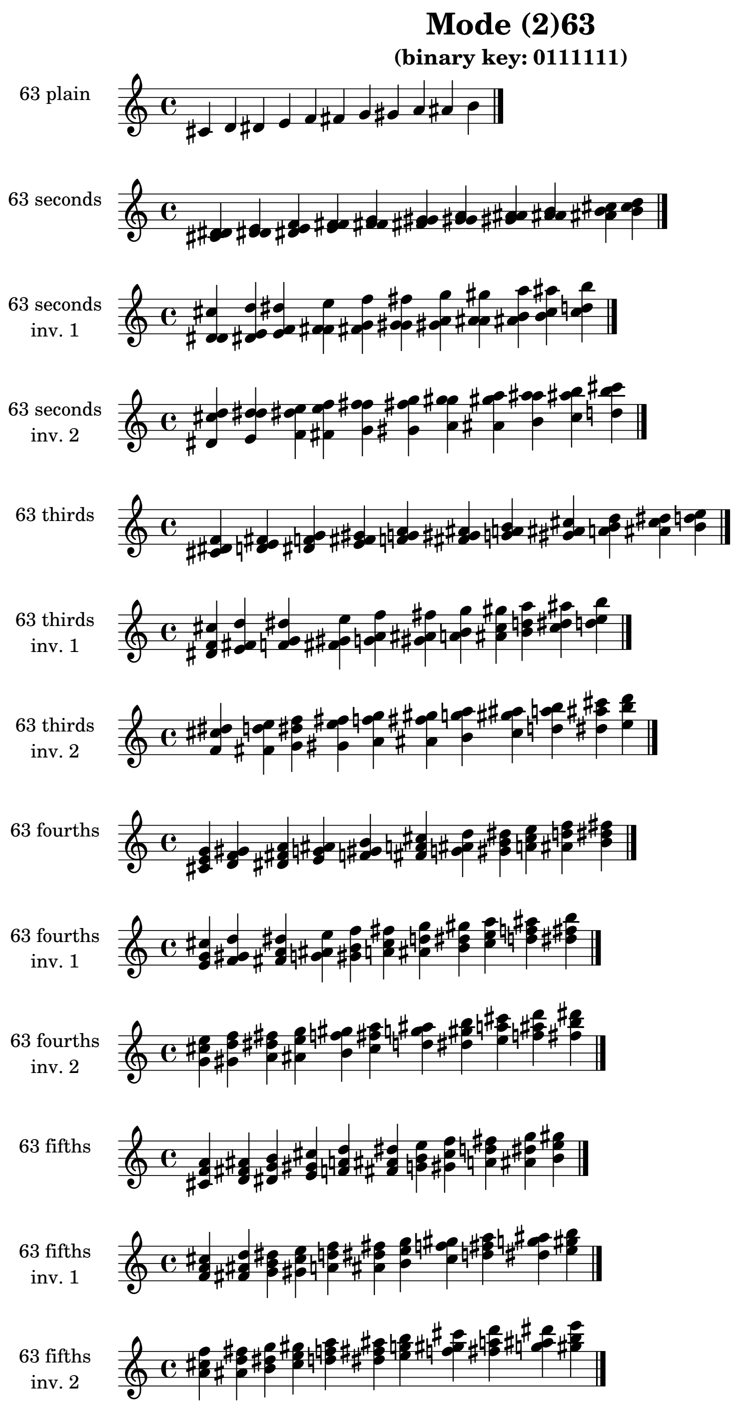
62 sus2

62 sus2
inv. 1

62 sus2
inv. 2

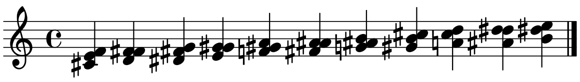


82 Characterizing mode (2)63



2

63 sus4



63 sus4
inv. 1

63 sus4
inv. 2

63 sus2

63 sus2
inv. 1

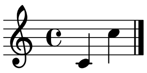
63 sus2
inv. 2

83 Characterizing mode (2)64

Mode (2)64

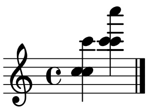
(binary key: 1000000)

64 plain



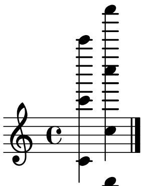
64 seconds

64 seconds
inv. 1

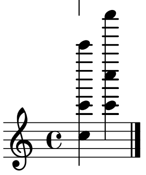


64 seconds
inv. 2

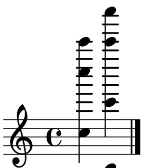
64 thirds



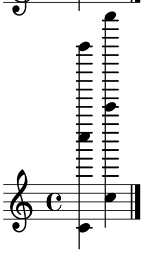
64 thirds
inv. 1



64 thirds
inv. 2

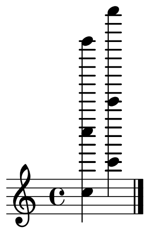


64 fourths

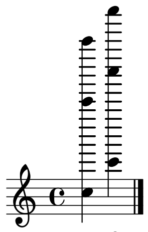


2

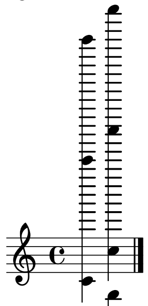
64 fourths
inv. 1



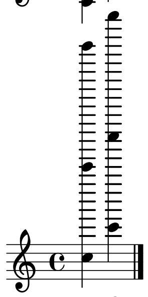
64 fourths
inv. 2



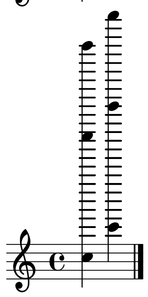
64 fifths



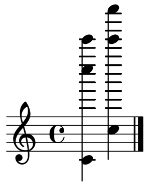
64 fifths
inv. 1



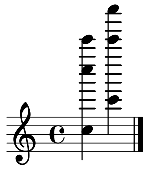
64 fifths
inv. 2



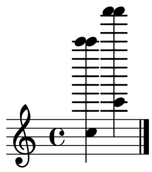
64 sus4



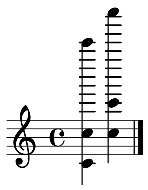
64 sus4
inv. 1



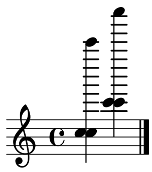
64 sus4
inv. 2



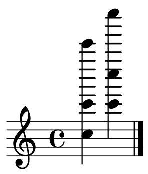
64 sus2



64 sus2
inv. 1



64 sus2
inv. 2



84 Characterizing mode (2)65

Mode (2)65

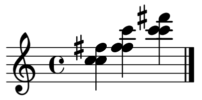
(binary key: 1000001)

65 plain

65 seconds

65 seconds inv. 1

65 seconds inv. 2



65 thirds

65 thirds inv. 1

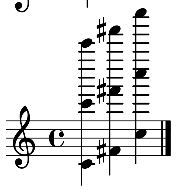
65 thirds inv. 2

65 fourths

65 fourths inv. 1

65 fourths inv. 2

65 fifths



2

65 fifths
inv. 1

65 fifths
inv. 2

65 sus4

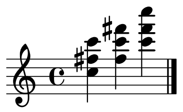
65 sus4
inv. 1

65 sus4
inv. 2

65 sus2

65 sus2
inv. 1

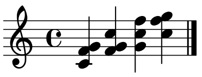
65 sus2
inv. 2



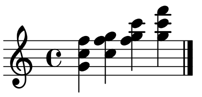
85 Characterizing mode (2)66

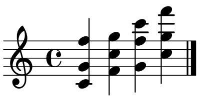
Mode (2)66
(binary key: 1000010)

66 plain


66 seconds


66 seconds inv. 1


66 seconds inv. 2


66 thirds


66 thirds inv. 1


66 thirds inv. 2


66 fourths


66 fourths inv. 1


66 fourths inv. 2

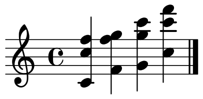

66 fifths


66 fifths inv. 1


66 fifths inv. 2


2

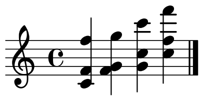
66 sus4



66 sus4
inv. 1

66 sus4
inv. 2

66 sus2



66 sus2
inv. 1

66 sus2
inv. 2

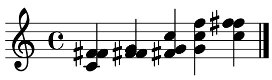
86 Characterizing mode (2)67

Mode (2)67

(binary key: 1000011)

67 plain

67 seconds



67 seconds
inv. 1

67 seconds
inv. 2

67 thirds

67 thirds
inv. 1

67 thirds
inv. 2

67 fourths

67 fourths
inv. 1

67 fourths
inv. 2

67 fifths

67 fifths
inv. 1

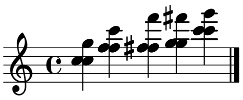
67 fifths
inv. 2

2

67 sus4

67 sus4
inv. 1

67 sus4
inv. 2



67 sus2

67 sus2
inv. 1

67 sus2
inv. 2

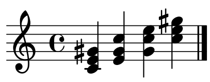
87 Characterizing mode (2)68

Mode (2)68

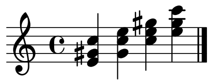
(binary key: 1000100)

68 plain

68 seconds



68 seconds inv. 1



68 seconds inv. 2

68 thirds

68 thirds inv. 1

68 thirds inv. 2

68 fourths

68 fourths inv. 1

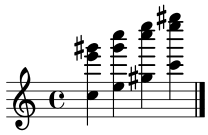
68 fourths inv. 2

68 fifths

68 fifths inv. 1

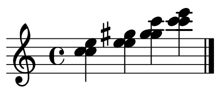
2

68 fifths
inv. 2



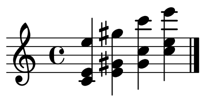
68 sus4

68 sus4
inv. 1



68 sus4
inv. 2

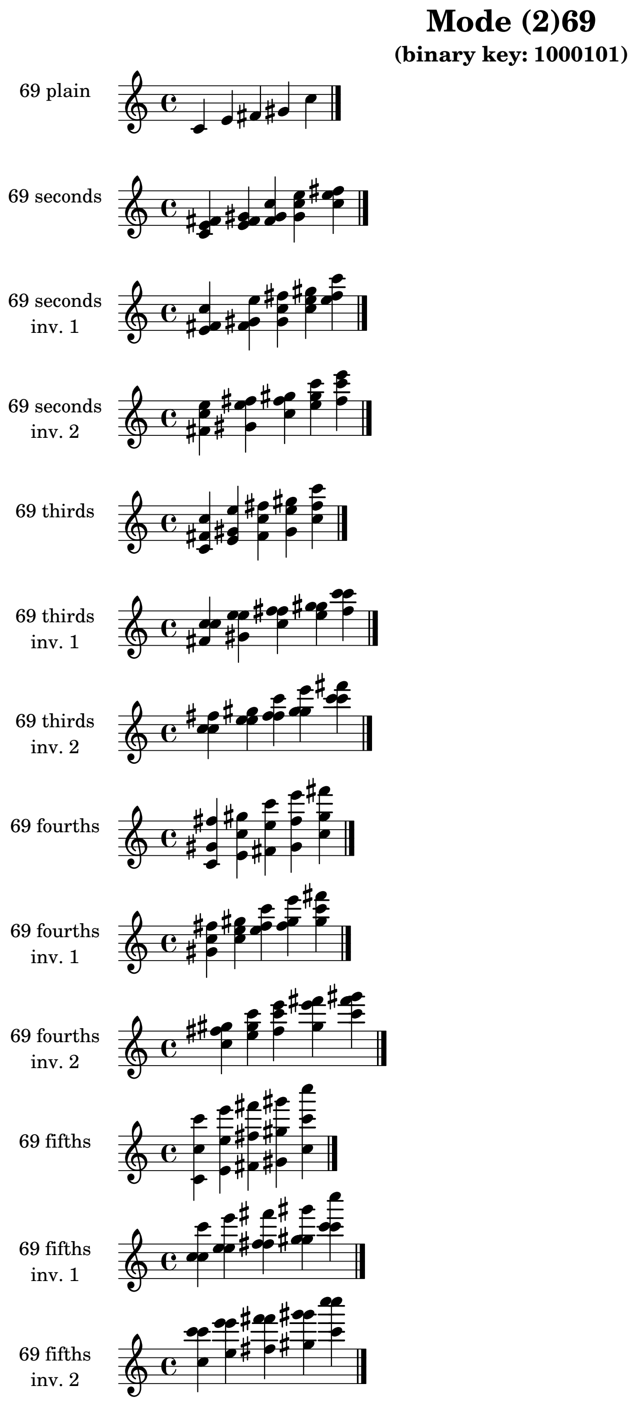
68 sus2



68 sus2
inv. 1

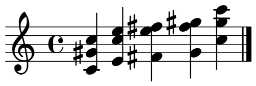
68 sus2
inv. 2

88 Characterizing mode (2)69



2

69 sus4

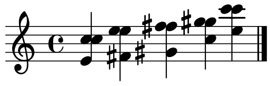


69 sus4
inv. 1

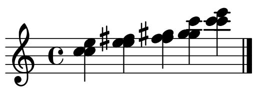
69 sus4
inv. 2

69 sus2

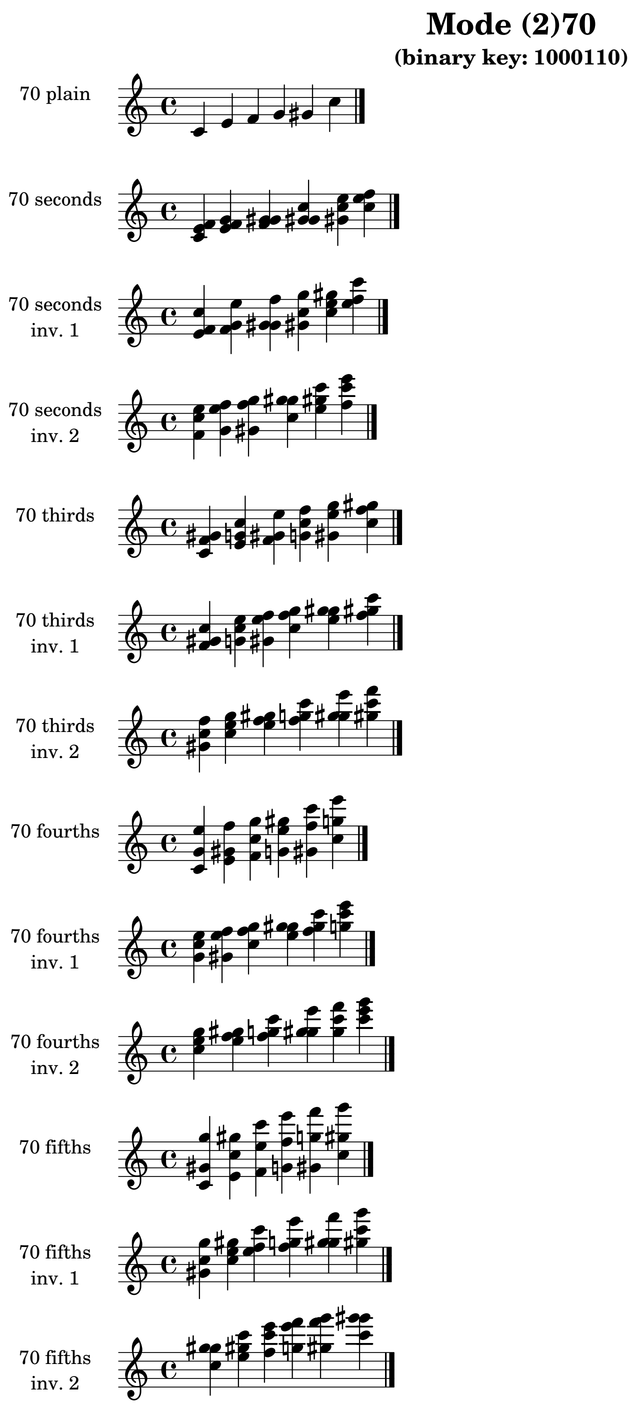
69 sus2
inv. 1



69 sus2
inv. 2

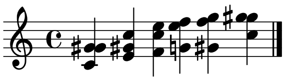


89 Characterizing mode (2)70

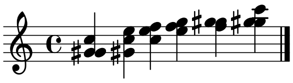


2

70 sus4



70 sus4
inv. 1

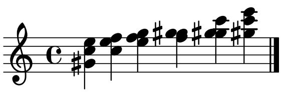


70 sus4
inv. 2

70 sus2

70 sus2
inv. 1

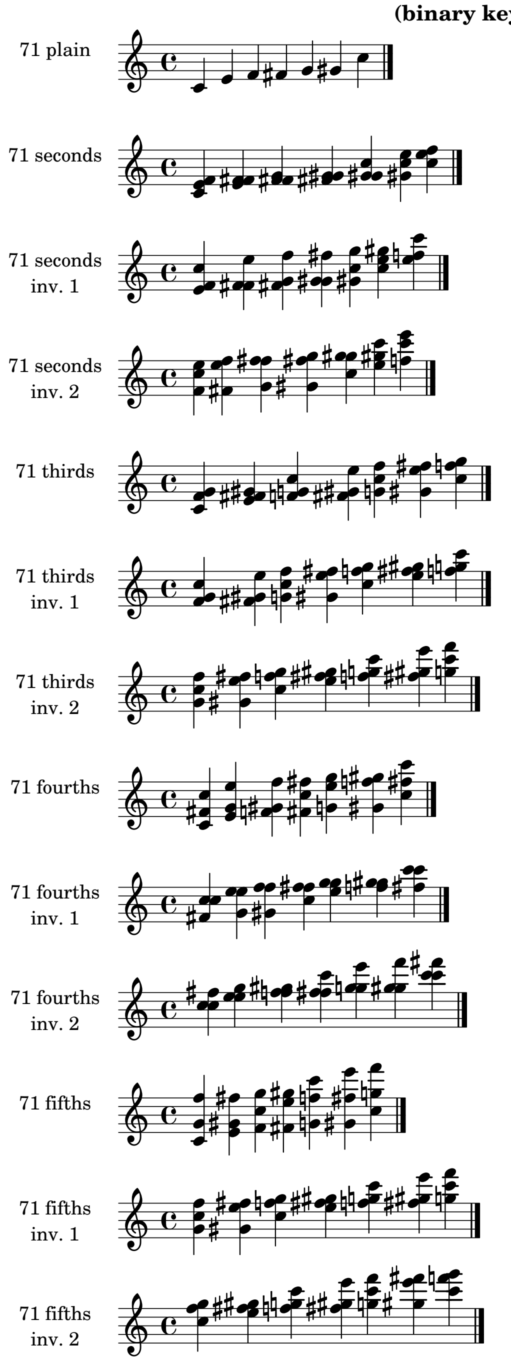
70 sus2
inv. 2



90 Characterizing mode (2)71

Mode (2)71

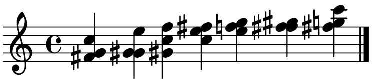
(binary key: 1000111)



2

71 sus4

71 sus4
inv. 1



71 sus4
inv. 2

71 sus2

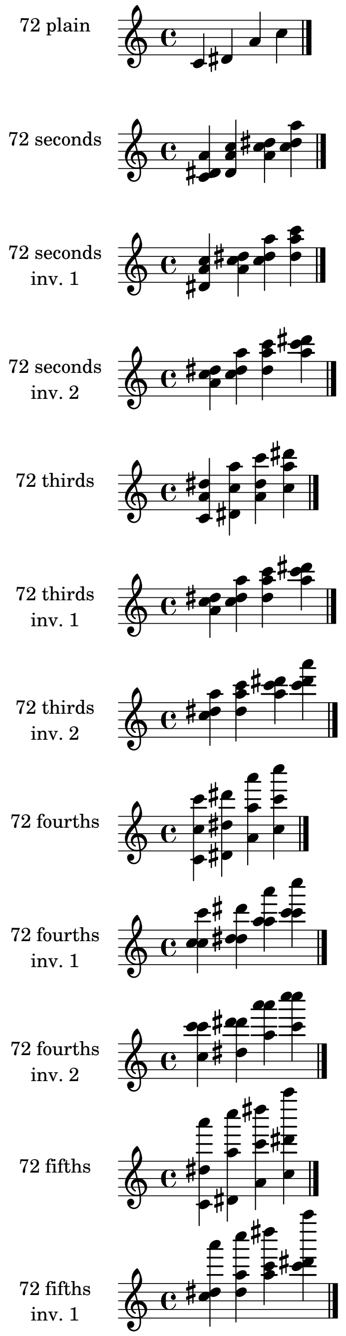
71 sus2
inv. 1

71 sus2
inv. 2

91 Characterizing mode (2)72

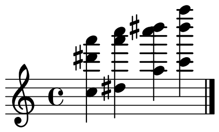
Mode (2)72

(binary key: 1001000)



2

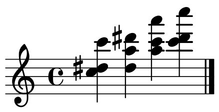
72 fifths
inv. 2



72 sus4

72 sus4
inv. 1

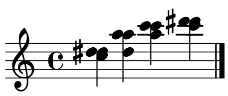
72 sus4
inv. 2



72 sus2

72 sus2
inv. 1

72 sus2
inv. 2

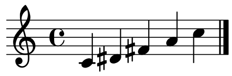


92 Characterizing mode (2)73

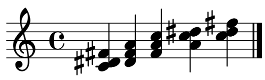
Mode (2)73

(binary key: 1001001)

73 plain



73 seconds



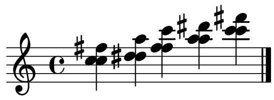
73 seconds inv. 1

73 seconds inv. 2

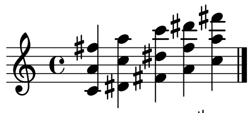
73 thirds

73 thirds inv. 1

73 thirds inv. 2

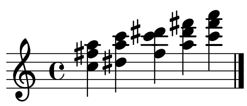


73 fourths



73 fourths inv. 1

73 fourths inv. 2



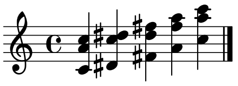
73 fifths

73 fifths inv. 1

73 fifths inv. 2

2

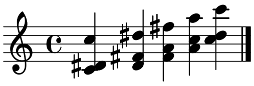
73 sus4



73 sus4
inv. 1

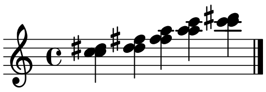
73 sus4
inv. 2

73 sus2



73 sus2
inv. 1

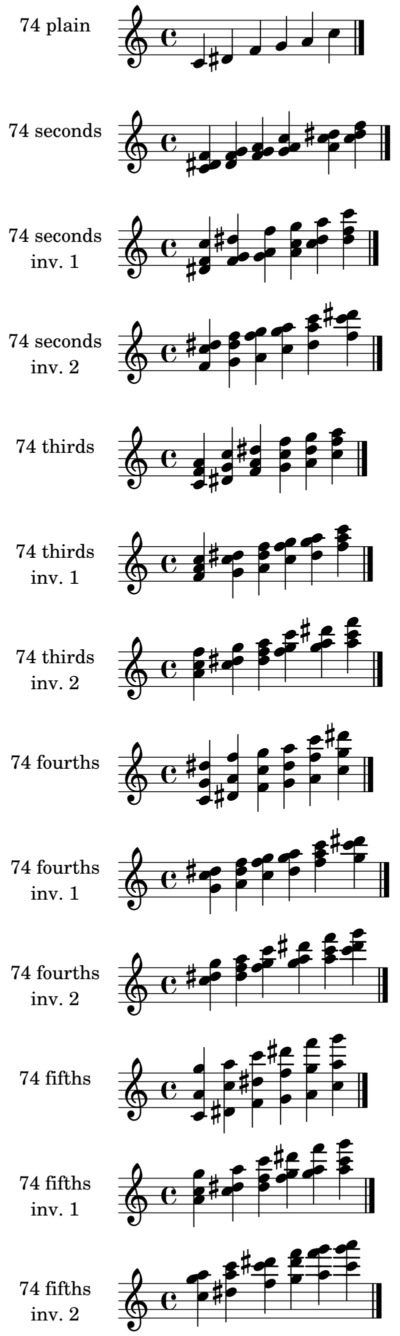
73 sus2
inv. 2



93 Characterizing mode (2)74

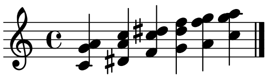
Mode (2)74

(binary key: 1001010)

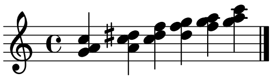


2

74 sus4



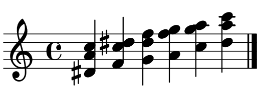
74 sus4
inv. 1



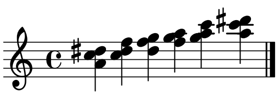
74 sus4
inv. 2

74 sus2

74 sus2
inv. 1



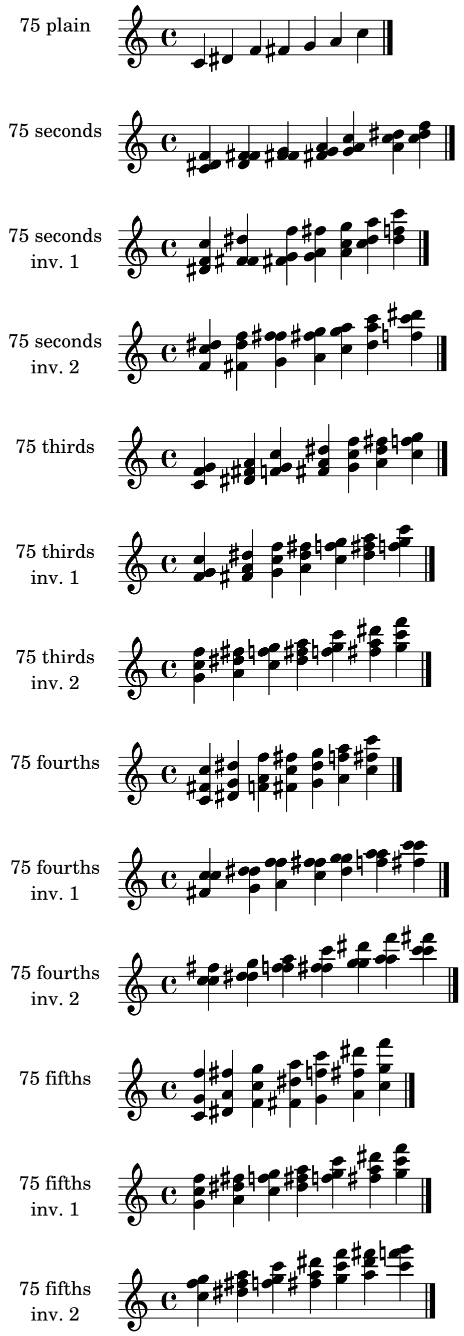
74 sus2
inv. 2



94 Characterizing mode (2)75

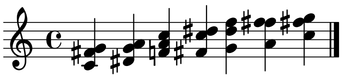
Mode (2)75

(binary key: 1001011)

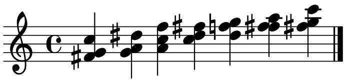


2

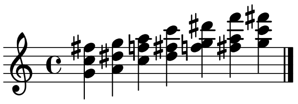
75 sus4



75 sus4
inv. 1



75 sus4
inv. 2

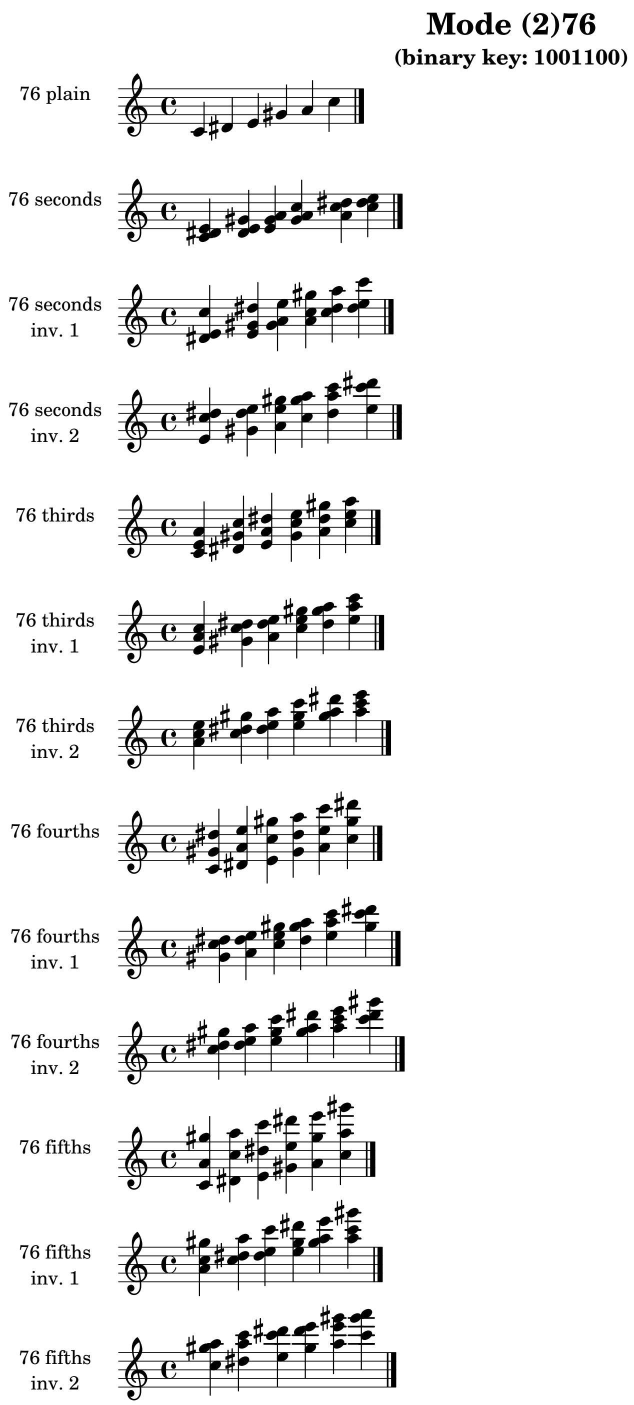


75 sus2

75 sus2
inv. 1

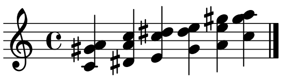
75 sus2
inv. 2

95 Characterizing mode (2)76

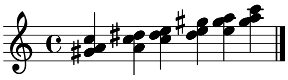


2

76 sus4

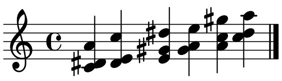


76 sus4
inv. 1

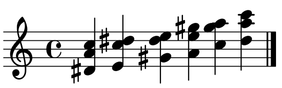


76 sus4
inv. 2

76 sus2



76 sus2
inv. 1

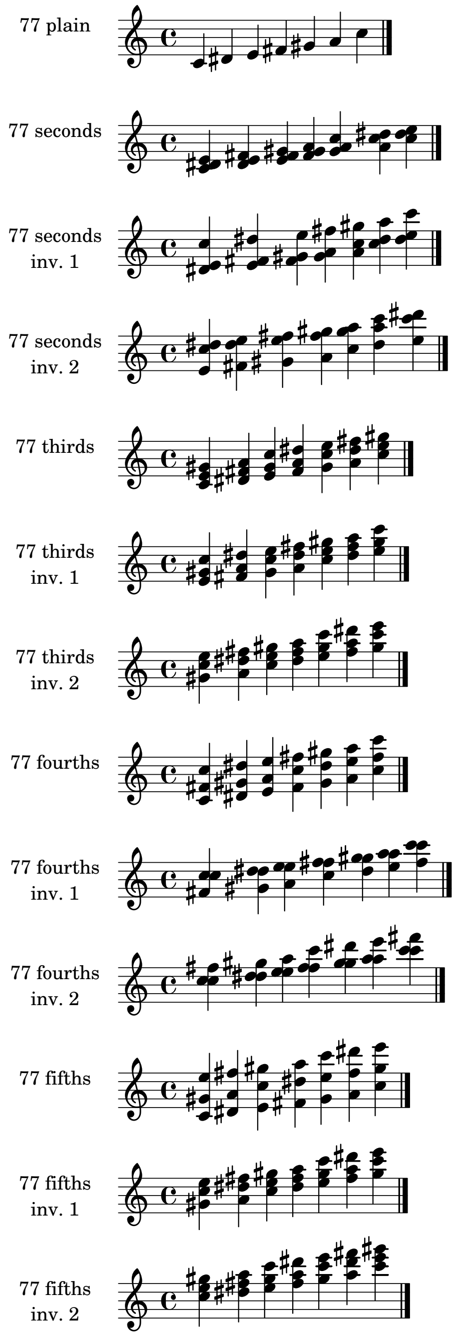


76 sus2
inv. 2

96 Characterizing mode (2)77

Mode (2)77

(binary key: 1001101)



2

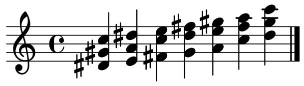
77 sus4

77 sus4
inv. 1

77 sus4
inv. 2

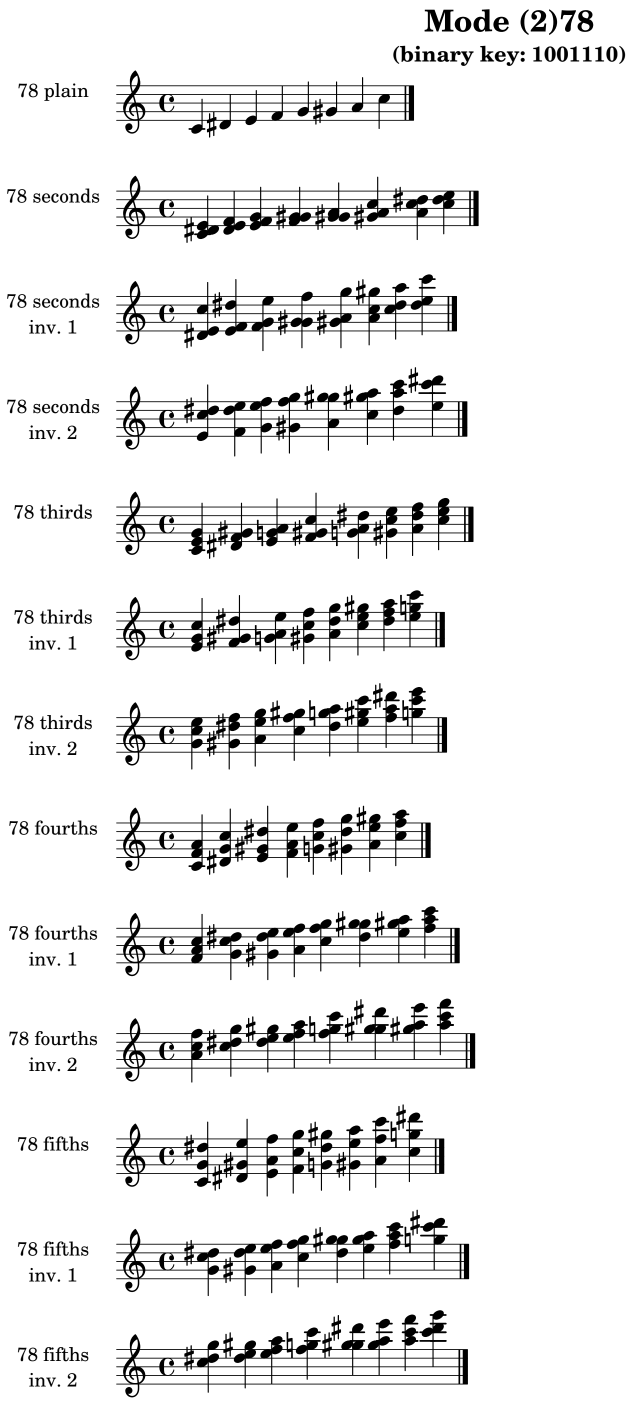
77 sus2

77 sus2
inv. 1



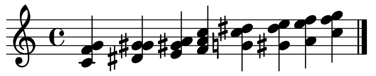
77 sus2
inv. 2

97 Characterizing mode (2)78



2

78 sus4

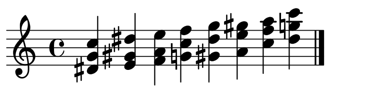


78 sus4
inv. 1

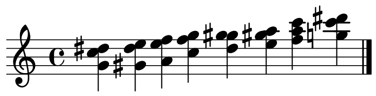
78 sus4
inv. 2

78 sus2

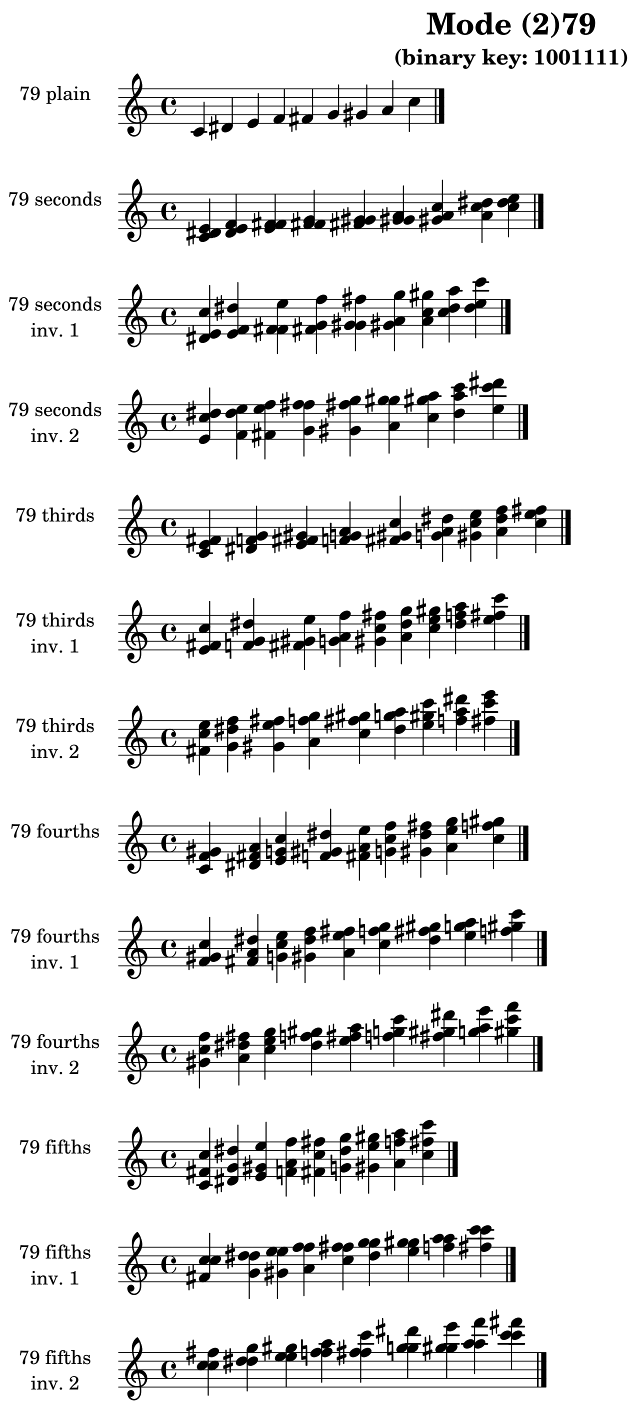
78 sus2
inv. 1



78 sus2
inv. 2



98 Characterizing mode (2)79



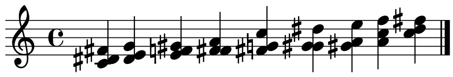
2

79 sus4

79 sus4
inv. 1

79 sus4
inv. 2

79 sus2



79 sus2
inv. 1

79 sus2
inv. 2

99 Characterizing mode (2)80

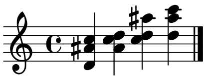
Mode (2)80

(binary key: 1010000)

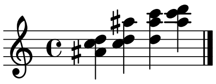
80 plain

80 seconds

80 seconds
inv. 1

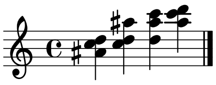


80 seconds
inv. 2



80 thirds

80 thirds
inv. 1

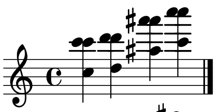


80 thirds
inv. 2

80 fourths

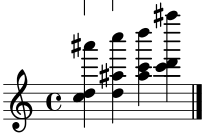
80 fourths
inv. 1

80 fourths
inv. 2



80 fifths

80 fifths
inv. 1

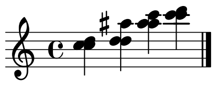


2

80 fifths
inv. 2

80 sus4

80 sus4
inv. 1

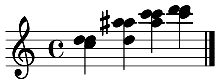


80 sus4
inv. 2

80 sus2

80 sus2
inv. 1

80 sus2
inv. 2



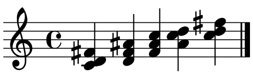
100 Characterizing mode (2)81

Mode (2)81

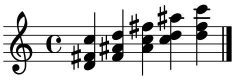
(binary key: 1010001)

81 plain

81 seconds



81 seconds inv. 1



81 seconds inv. 2

81 thirds

81 thirds inv. 1

81 thirds inv. 2

81 fourths

81 fourths inv. 1

81 fourths inv. 2

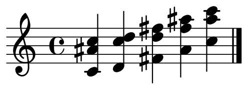
81 fifths

81 fifths inv. 1

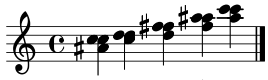
81 fifths inv. 2

2

81 sus4

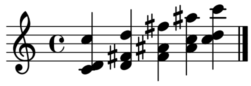


81 sus4
inv. 1



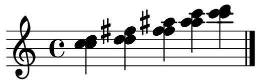
81 sus4
inv. 2

81 sus2



81 sus2
inv. 1

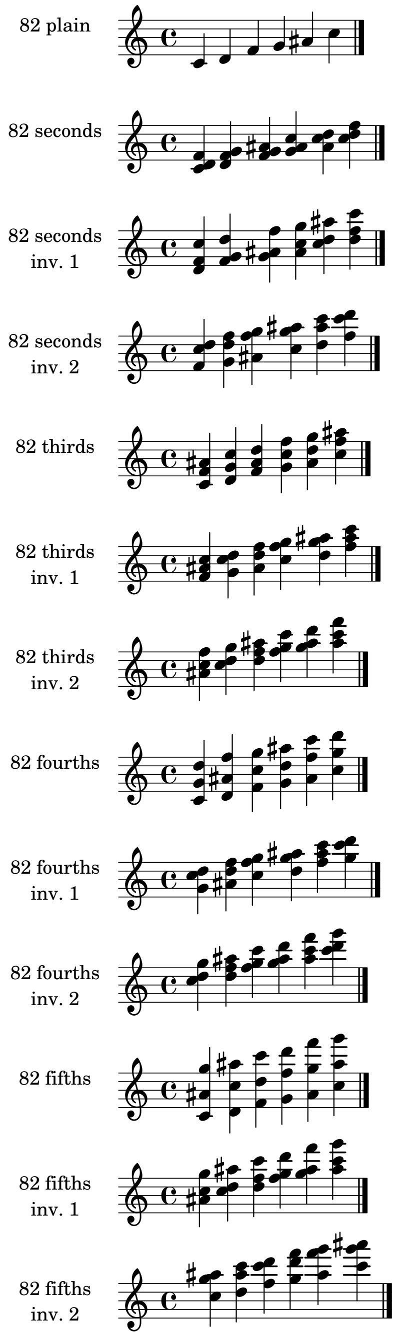
81 sus2
inv. 2



101 Characterizing mode (2)82

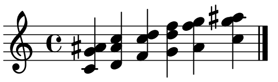
Mode (2)82

(binary key: 1010010)

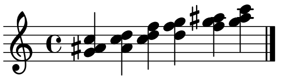


2

82 sus4

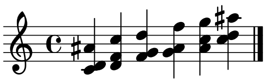


82 sus4
inv. 1

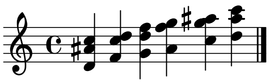


82 sus4
inv. 2

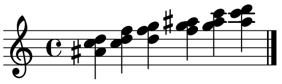
82 sus2



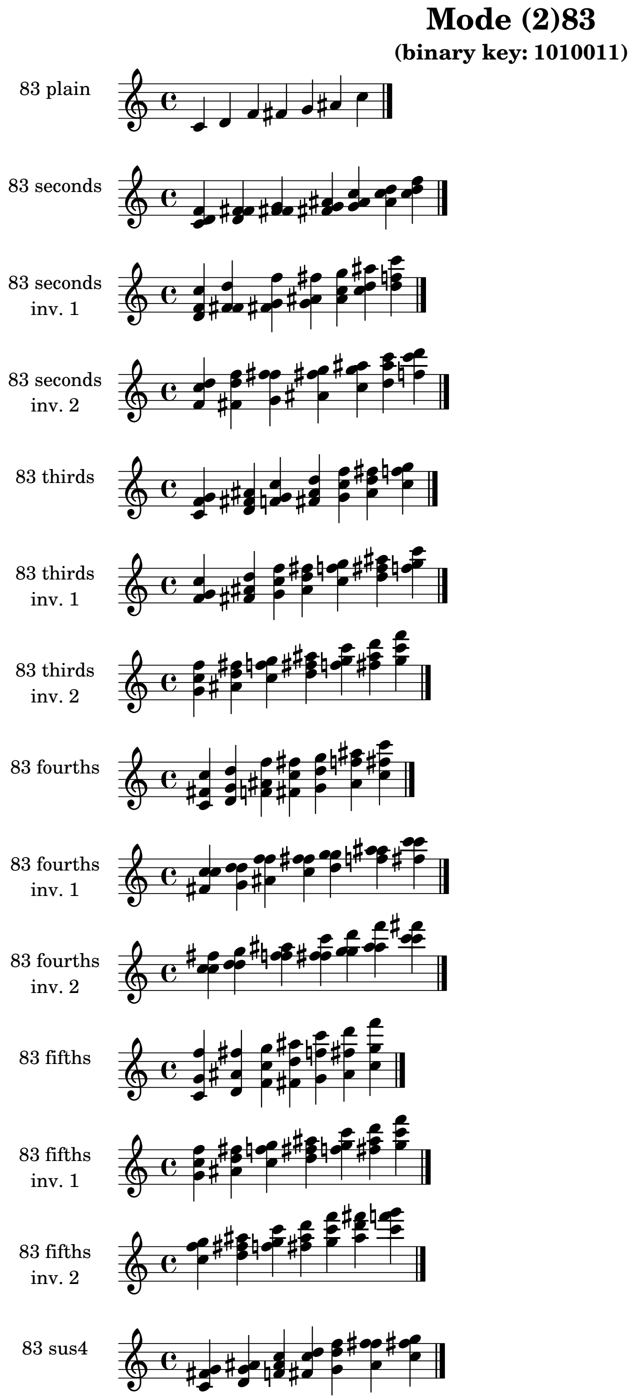
82 sus2
inv. 1



82 sus2
inv. 2

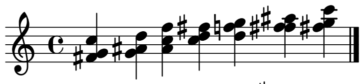


102 Characterizing mode (2)83



2

83 sus4
inv. 1



83 sus4
inv. 2

83 sus2

83 sus2
inv. 1

83 sus2
inv. 2

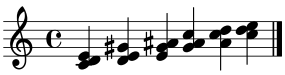
103 Characterizing mode (2)84

Mode (2)84

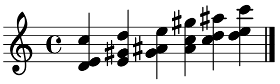
(binary key: 1010100)

84 plain

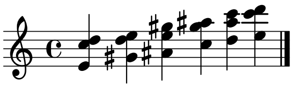
84 seconds



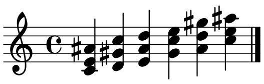
84 seconds
inv. 1



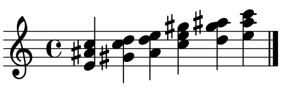
84 seconds
inv. 2



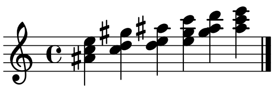
84 thirds



84 thirds
inv. 1

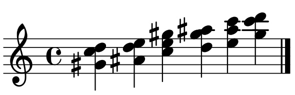


84 thirds
inv. 2



84 fourths

84 fourths
inv. 1

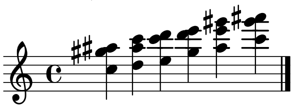


84 fourths
inv. 2

84 fifths

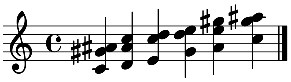
84 fifths
inv. 1

84 fifths
inv. 2

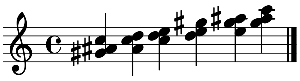


2

84 sus4

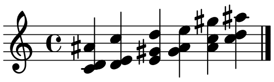


84 sus4
inv. 1

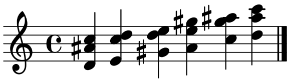


84 sus4
inv. 2

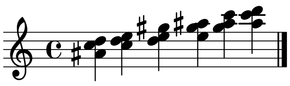
84 sus2



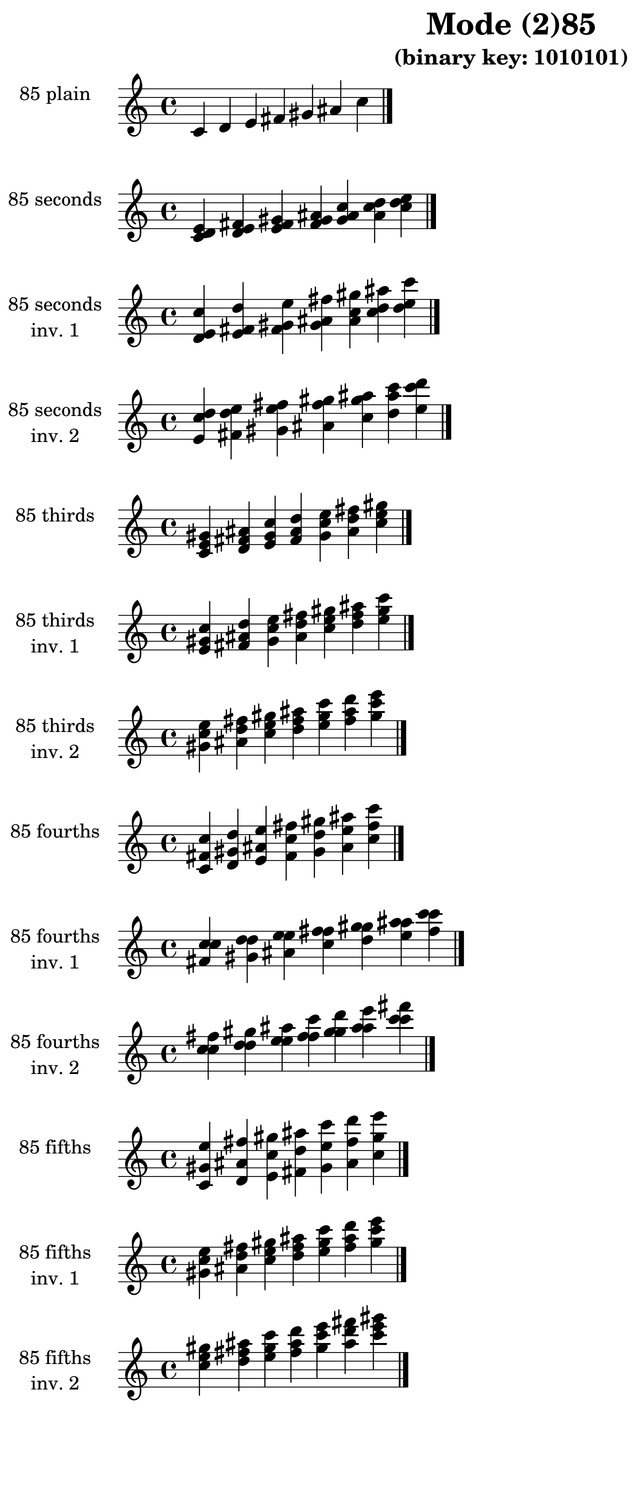
84 sus2
inv. 1



84 sus2
inv. 2

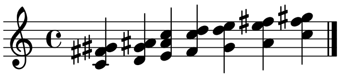


104 Characterizing mode (2)85

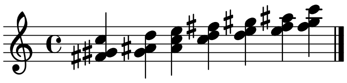


2

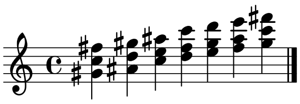
85 sus4



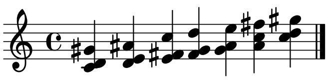
85 sus4
inv. 1



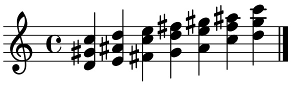
85 sus4
inv. 2



85 sus2

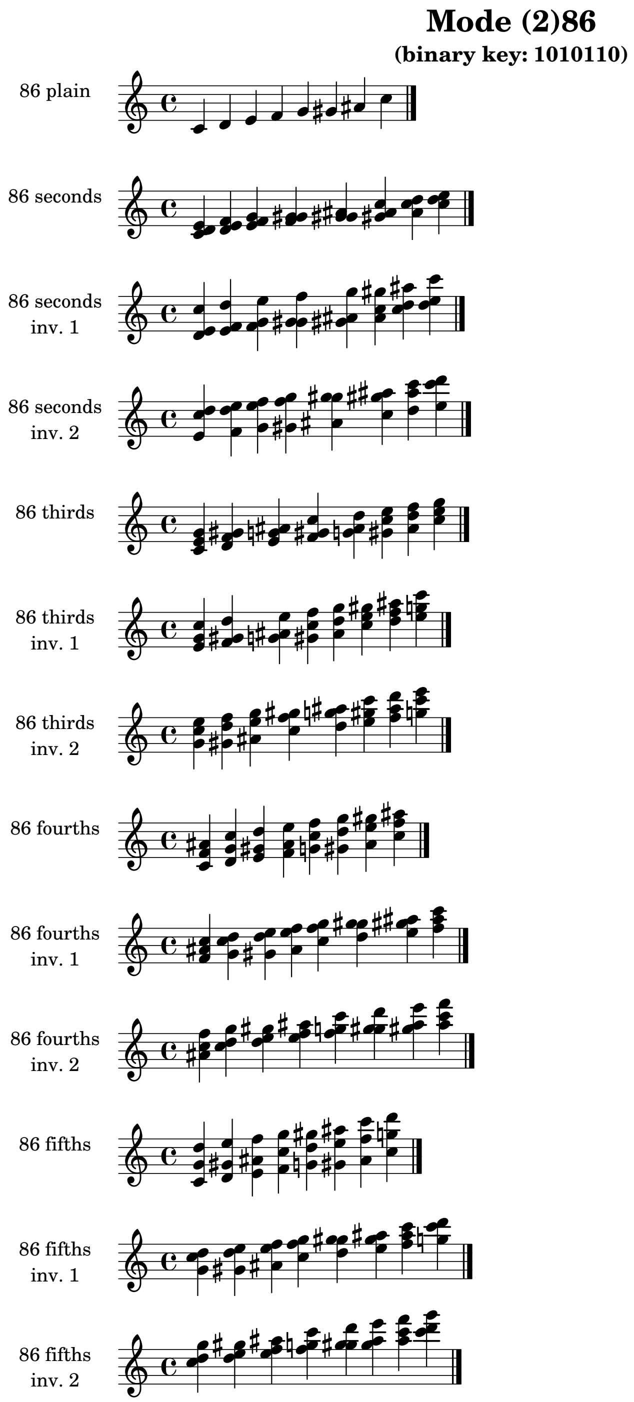


85 sus2
inv. 1



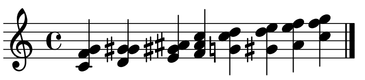
85 sus2
inv. 2

105 Characterizing mode (2)86

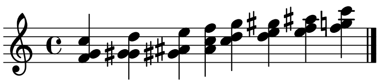


2

86 sus4



86 sus4
inv. 1



86 sus4
inv. 2

86 sus2

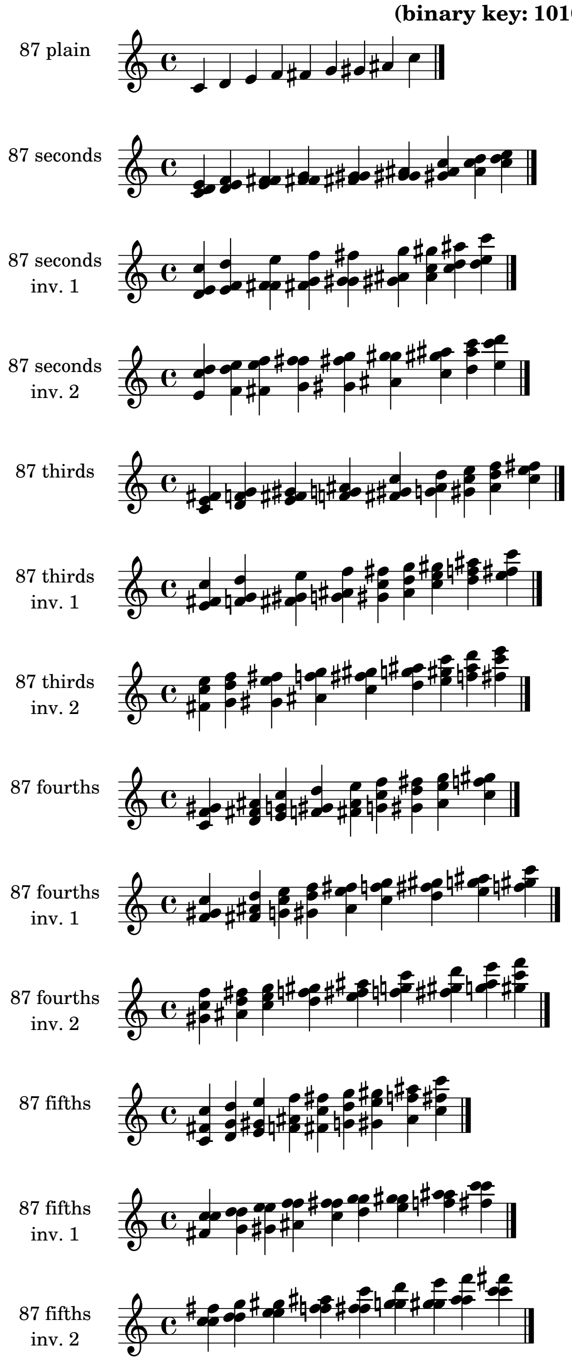
86 sus2
inv. 1

86 sus2
inv. 2

106 Characterizing mode (2)87

Mode (2)87

(binary key: 1010111)



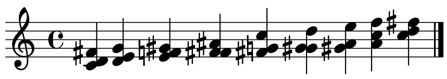
2

87 sus4

87 sus4
inv. 1

87 sus4
inv. 2

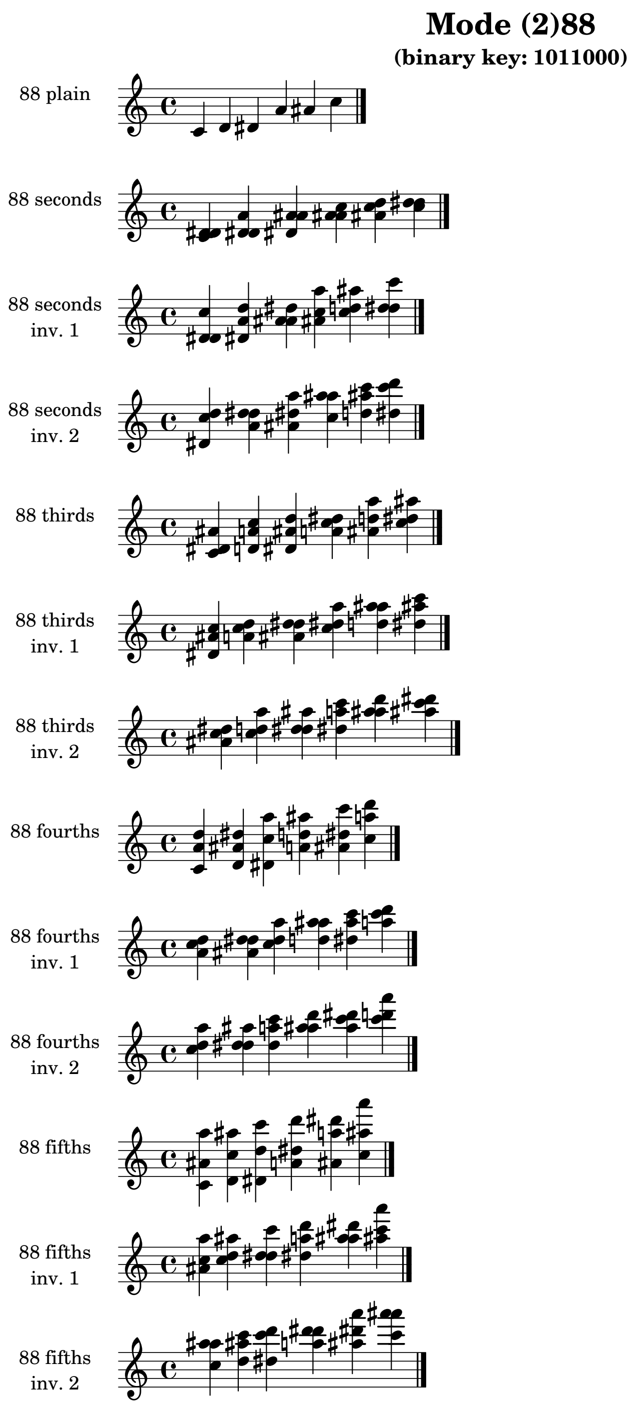
87 sus2



87 sus2
inv. 1

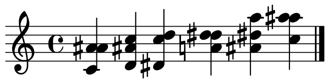
87 sus2
inv. 2

107 Characterizing mode (2)88



2

88 sus4



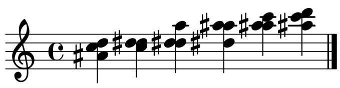
88 sus4
inv. 1

88 sus4
inv. 2

88 sus2

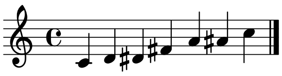
88 sus2
inv. 1

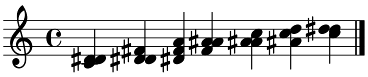
88 sus2
inv. 2

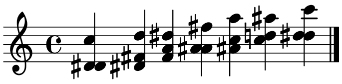


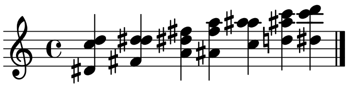
108 Characterizing mode (2)89

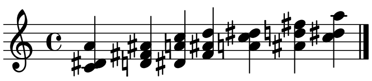
Mode (2)89
(binary key: 1011001)

89 plain


89 seconds


89 seconds inv. 1


89 seconds inv. 2


89 thirds


89 thirds inv. 1


89 thirds inv. 2

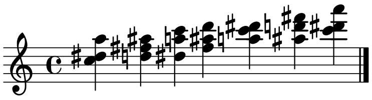

89 fourths


89 fourths inv. 1


89 fourths inv. 2

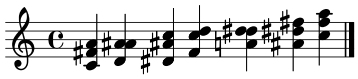

89 fifths


89 fifths inv. 1


89 fifths inv. 2


2

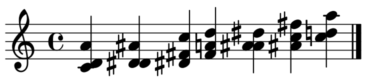
89 sus4



89 sus4
inv. 1

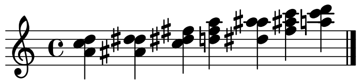
89 sus4
inv. 2

89 sus2

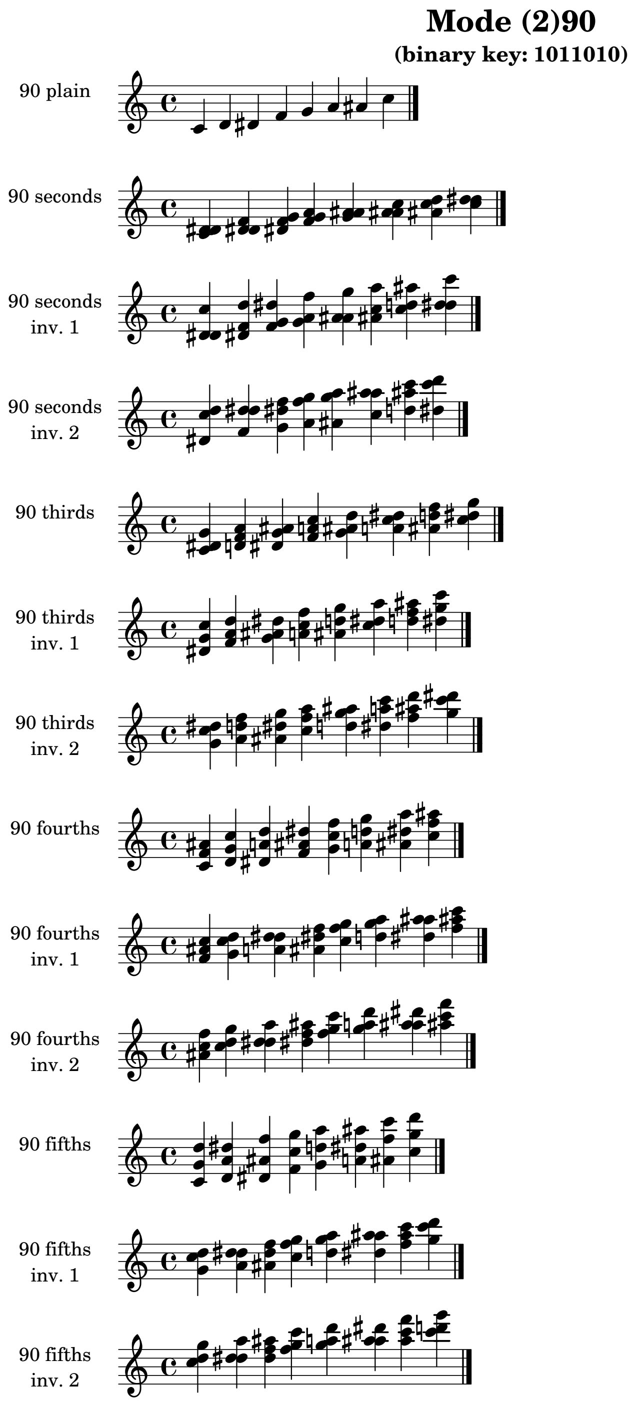


89 sus2
inv. 1

89 sus2
inv. 2

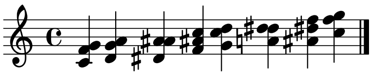


109 Characterizing mode (2)90



2

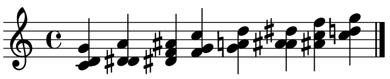
90 sus4



90 sus4
inv. 1

90 sus4
inv. 2

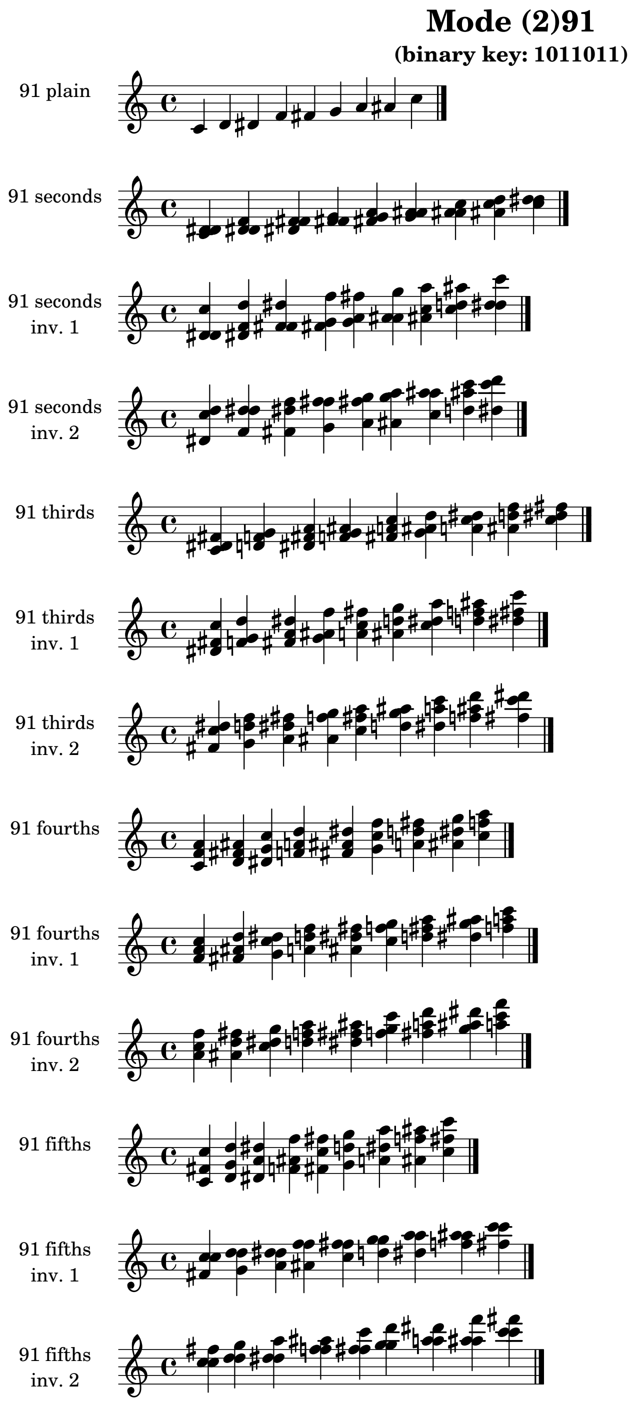
90 sus2



90 sus2
inv. 1

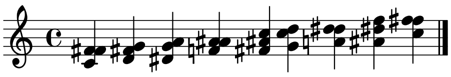
90 sus2
inv. 2

110 Characterizing mode (2)91



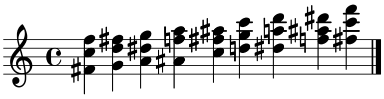
2

91 sus4

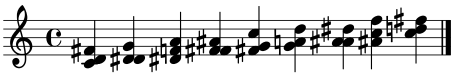


91 sus4
inv. 1

91 sus4
inv. 2



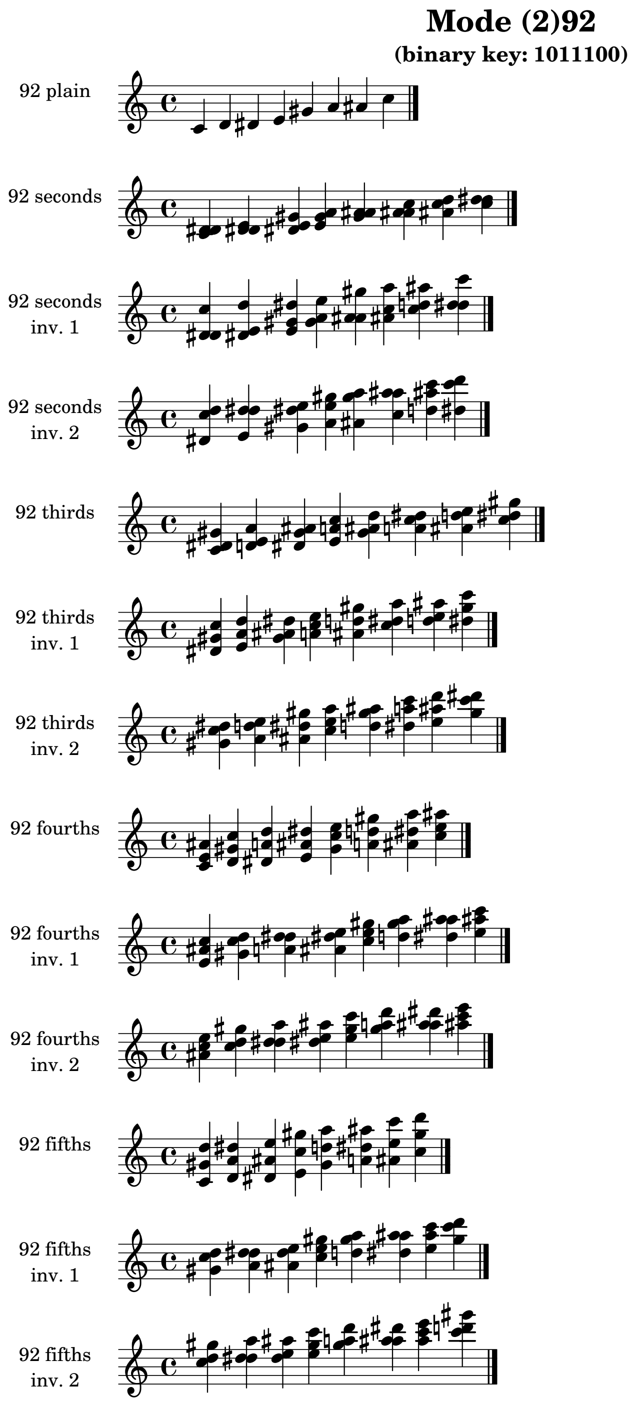
91 sus2



91 sus2
inv. 1

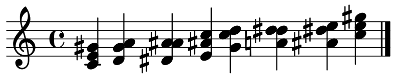
91 sus2
inv. 2

111 Characterizing mode (2)92

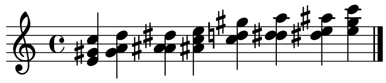


2

92 sus4



92 sus4
inv. 1



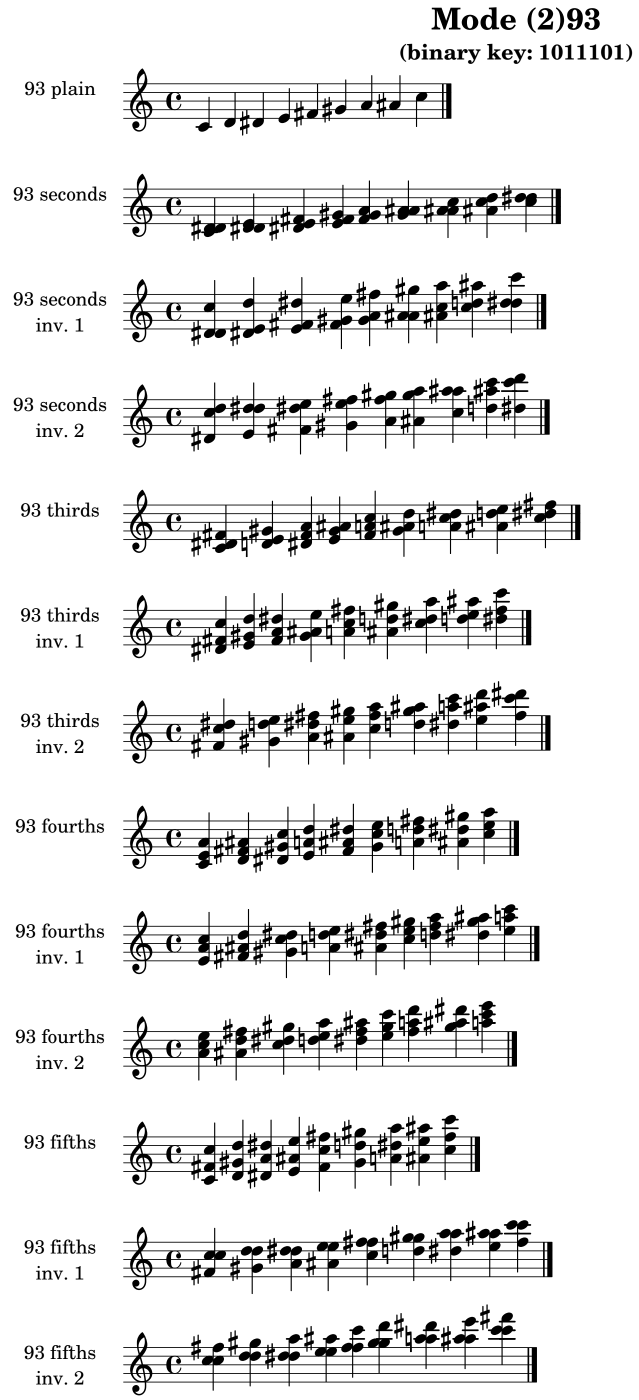
92 sus4
inv. 2

92 sus2

92 sus2
inv. 1

92 sus2
inv. 2

112 Characterizing mode (2)93



2

93 sus4

93 sus4
inv. 1

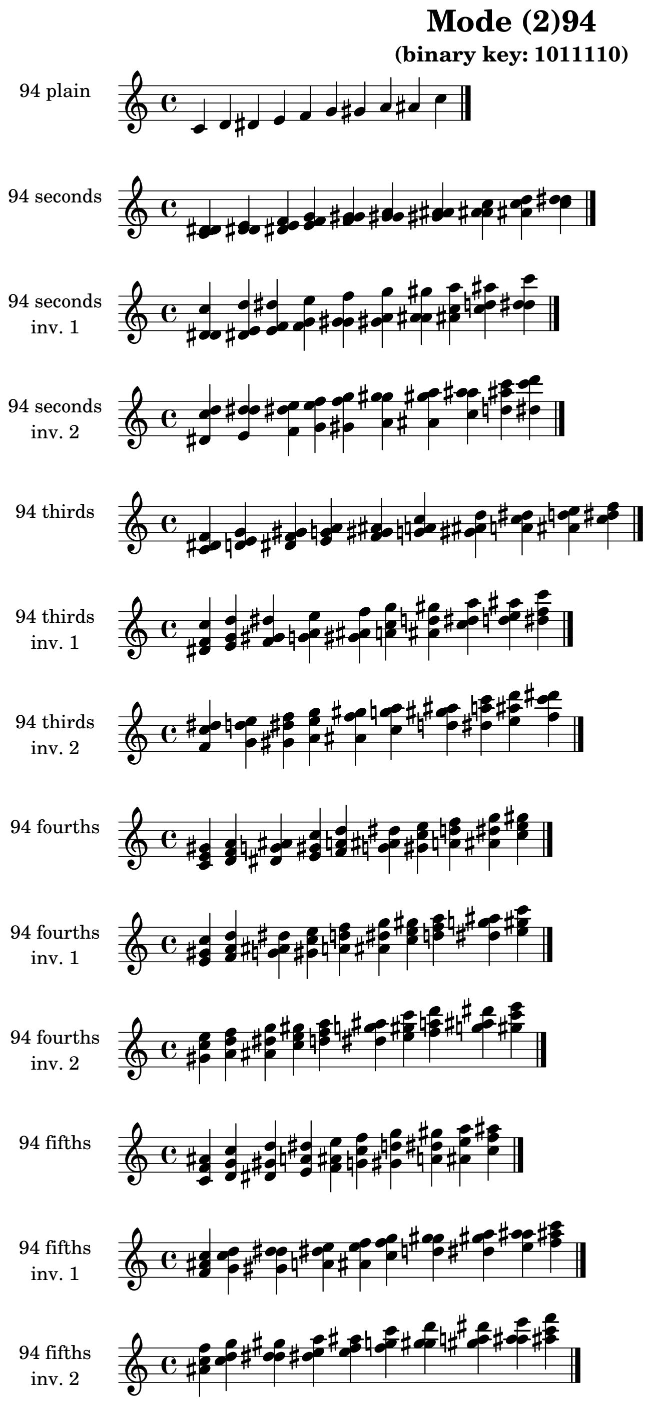
93 sus4
inv. 2

93 sus2

93 sus2
inv. 1

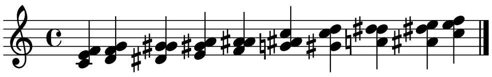
93 sus2
inv. 2

113 Characterizing mode (2)94



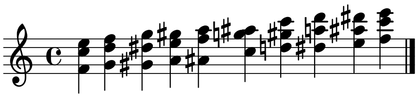
2

94 sus4



94 sus4
inv. 1

94 sus4
inv. 2



94 sus2

94 sus2
inv. 1

94 sus2
inv. 2

114 Characterizing mode (2)95

Mode (2)95

(binary key: 1011111)

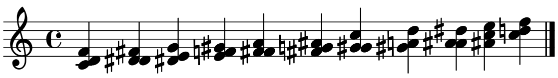
2

95 sus4

95 sus4
inv. 1

95 sus4
inv. 2

95 sus2



95 sus2
inv. 1

95 sus2
inv. 2

115 Characterizing mode (2)96

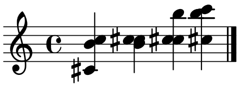
Mode (2)96

(binary key: 1100000)

96 plain

96 seconds

96 seconds
inv. 1

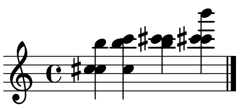


96 seconds
inv. 2

96 thirds

96 thirds
inv. 1

96 thirds
inv. 2

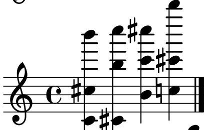


96 fourths

96 fourths
inv. 1

96 fourths
inv. 2

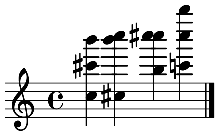
96 fifths



96 fifths
inv. 1

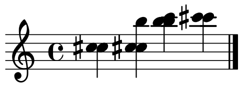
2

96 fifths
inv. 2



96 sus4

96 sus4
inv. 1

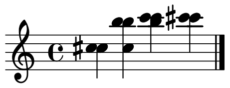


96 sus4
inv. 2

96 sus2

96 sus2
inv. 1

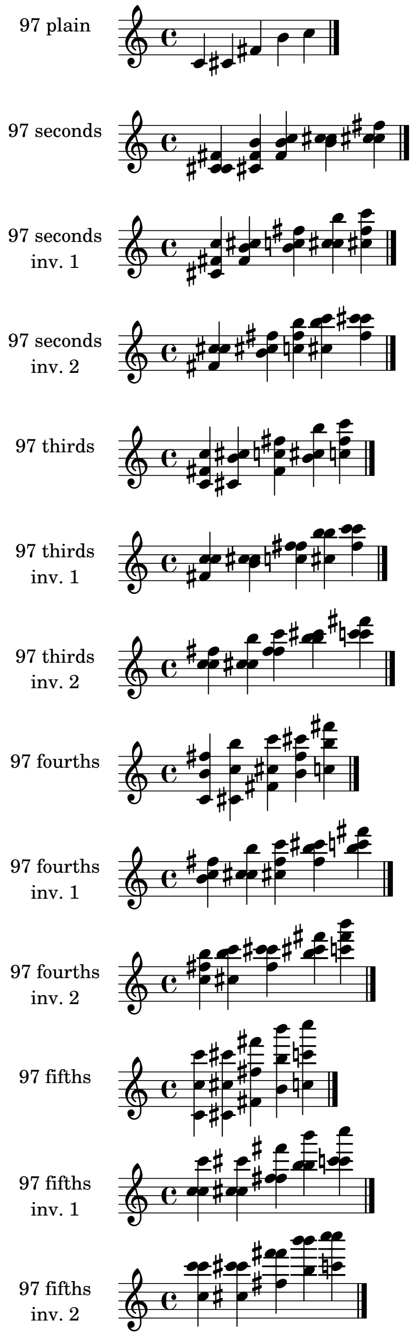
96 sus2
inv. 2



116 Characterizing mode (2)97

Mode (2)97

(binary key: 1100001)



2

97 sus4

97 sus4
inv. 1

97 sus4
inv. 2

97 sus2

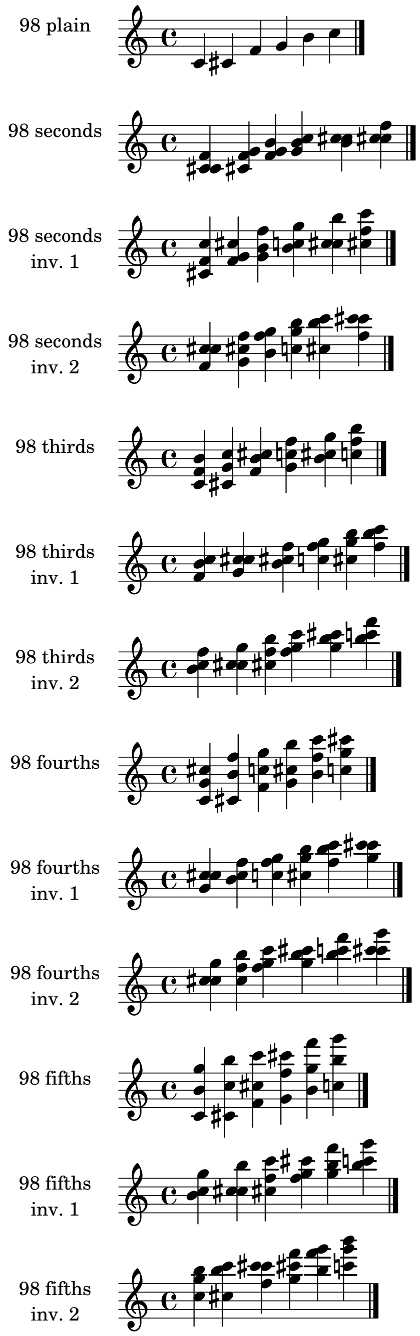
97 sus2
inv. 1

97 sus2
inv. 2

117 Characterizing mode (2)98

Mode (2)98

(binary key: 1100010)



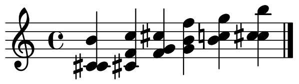
2

98 sus4

98 sus4
inv. 1

98 sus4
inv. 2

98 sus2



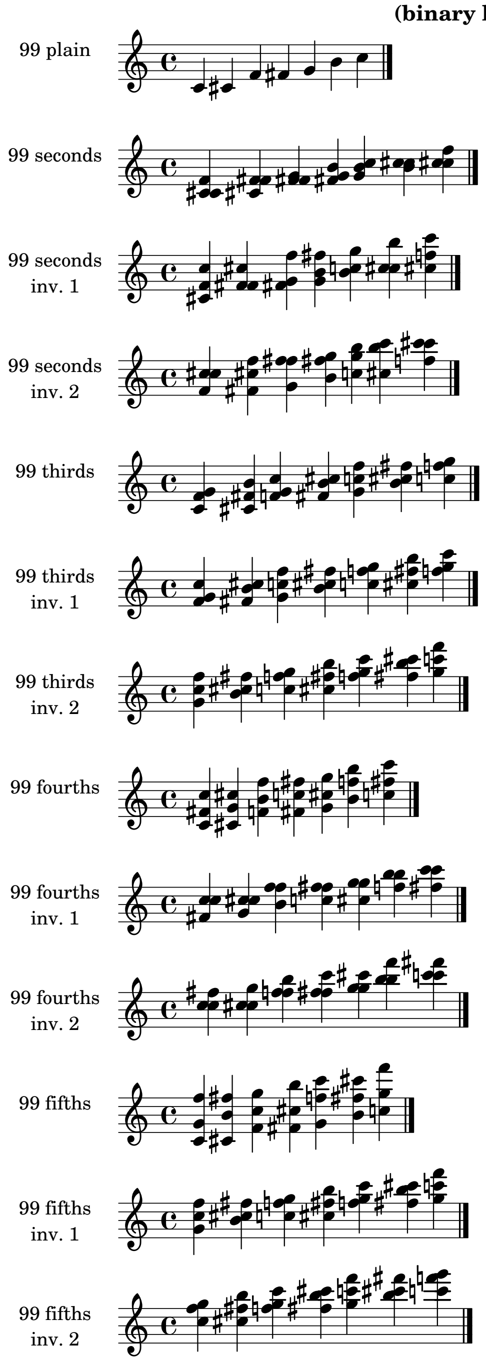
98 sus2
inv. 1

98 sus2
inv. 2

118 Characterizing mode (2)99

Mode (2)99

(binary key: 1100011)



2

99 sus4

99 sus4
inv. 1

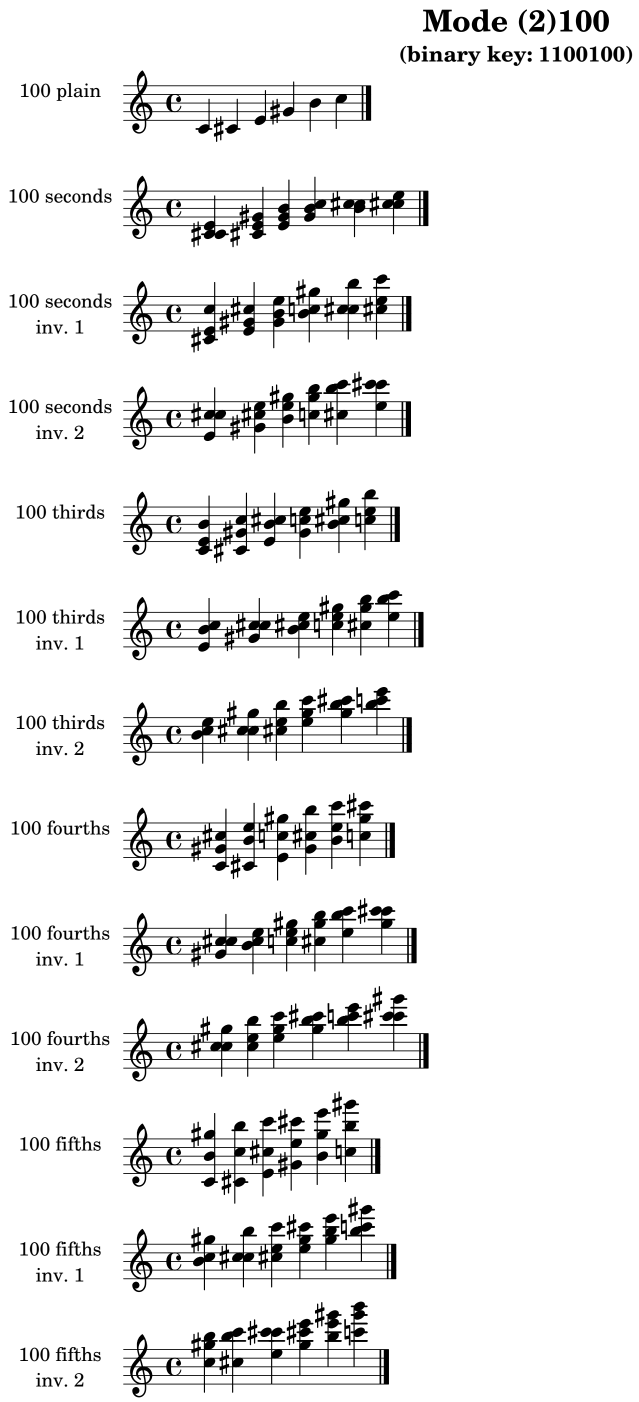
99 sus4
inv. 2

99 sus2

99 sus2
inv. 1

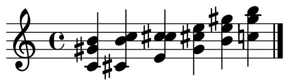
99 sus2
inv. 2

119 Characterizing mode (2)100



2

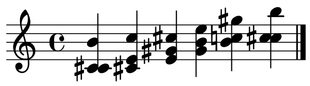
100 sus4



100 sus4
inv. 1

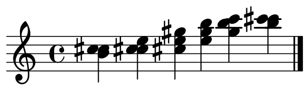
100 sus4
inv. 2

100 sus2

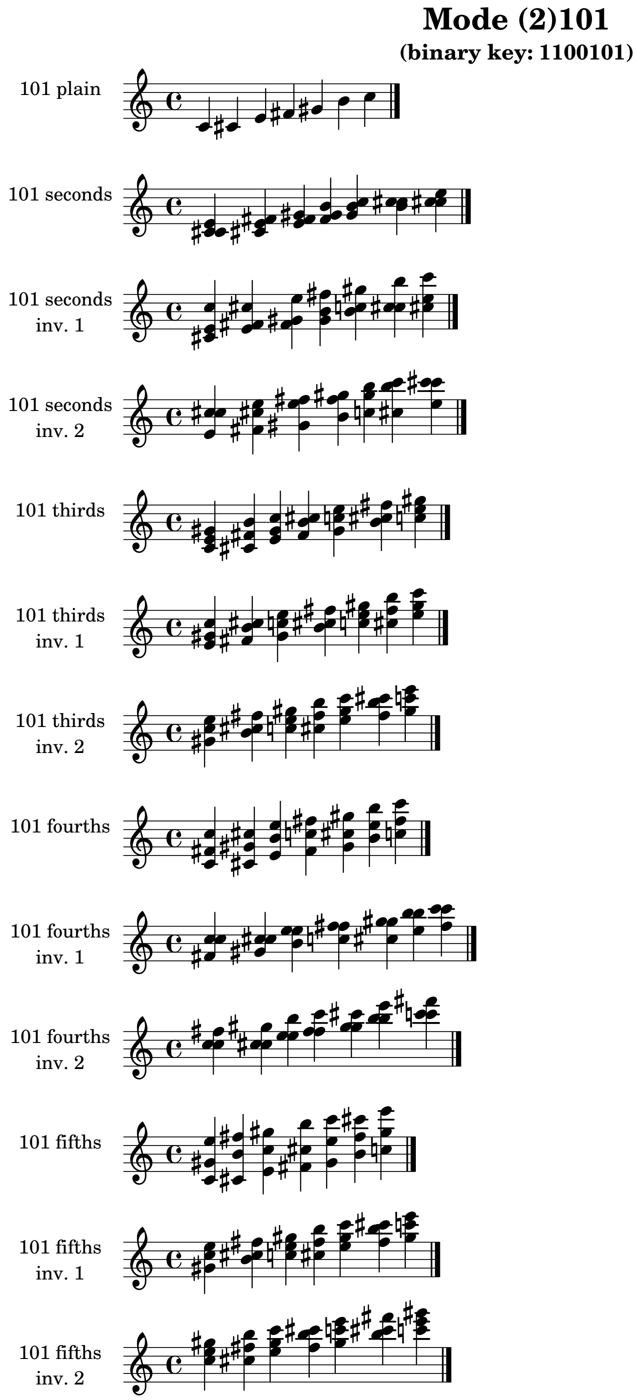


100 sus2
inv. 1

100 sus2
inv. 2



120 Characterizing mode (2)101



2

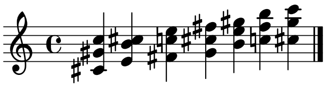
101 sus4

101 sus4
inv. 1

101 sus4
inv. 2

101 sus2

101 sus2
inv. 1

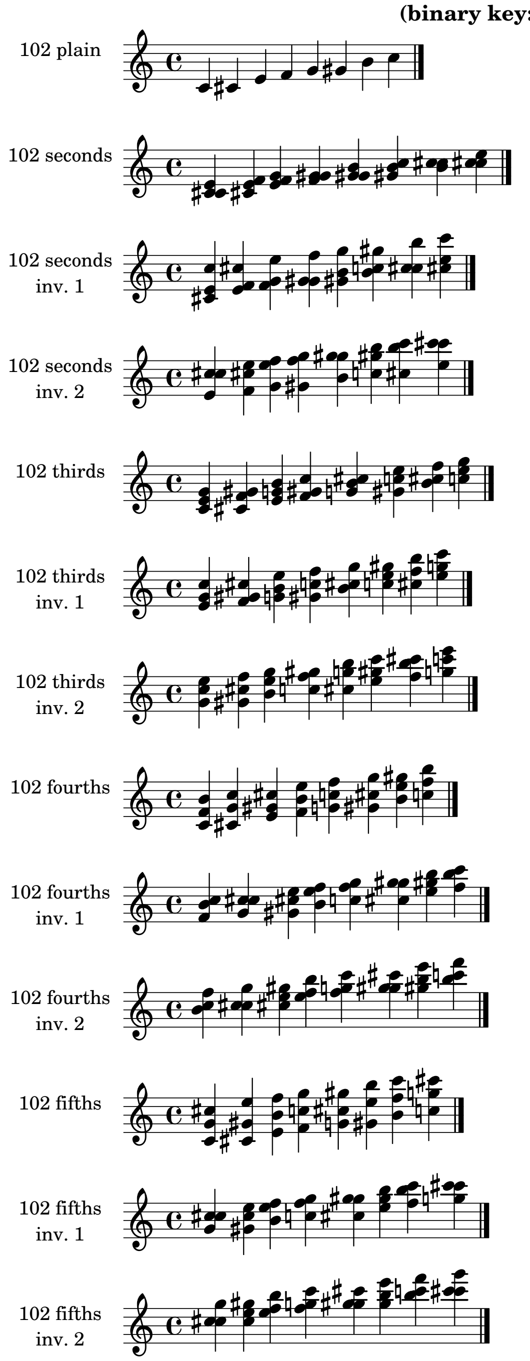


101 sus2
inv. 2

121 Characterizing mode (2)102

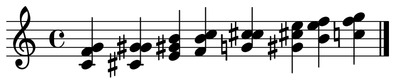
Mode (2)102

(binary key: 1100110)

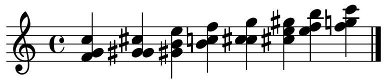


2

102 sus4



102 sus4
inv. 1



102 sus4
inv. 2

102 sus2

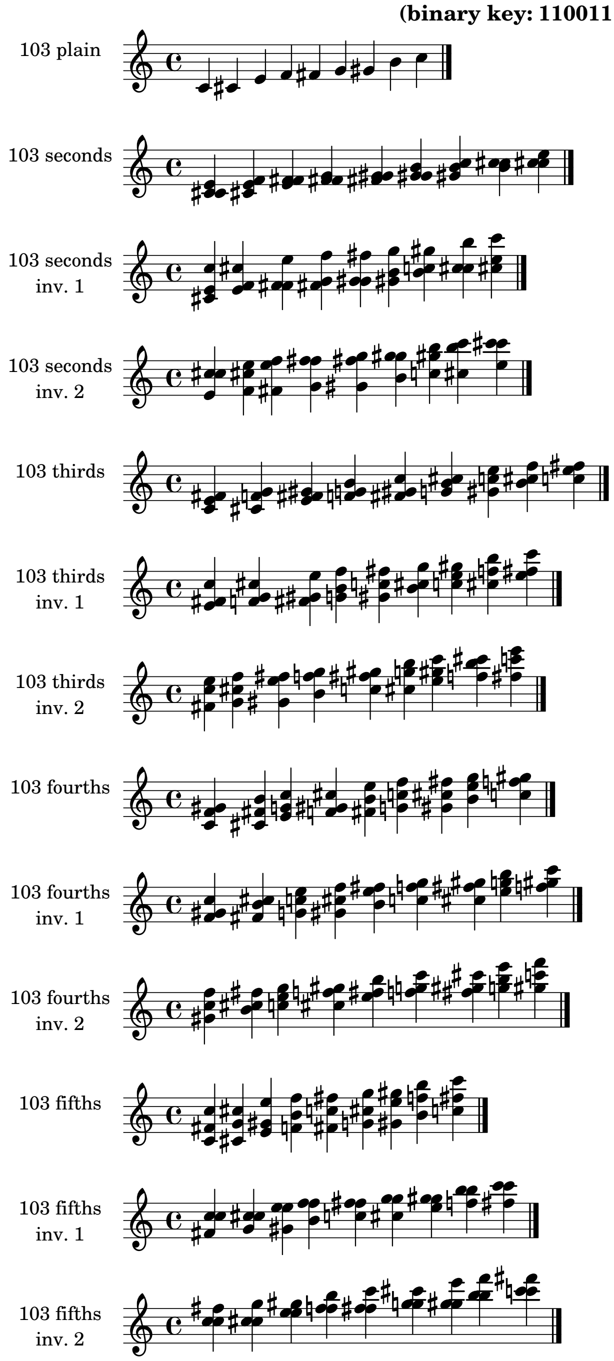
102 sus2
inv. 1

102 sus2
inv. 2

122 Characterizing mode (2)103

Mode (2)103

(binary key: 1100111)

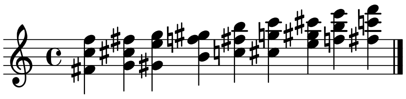


2

103 sus4

103 sus4
inv. 1

103 sus4
inv. 2

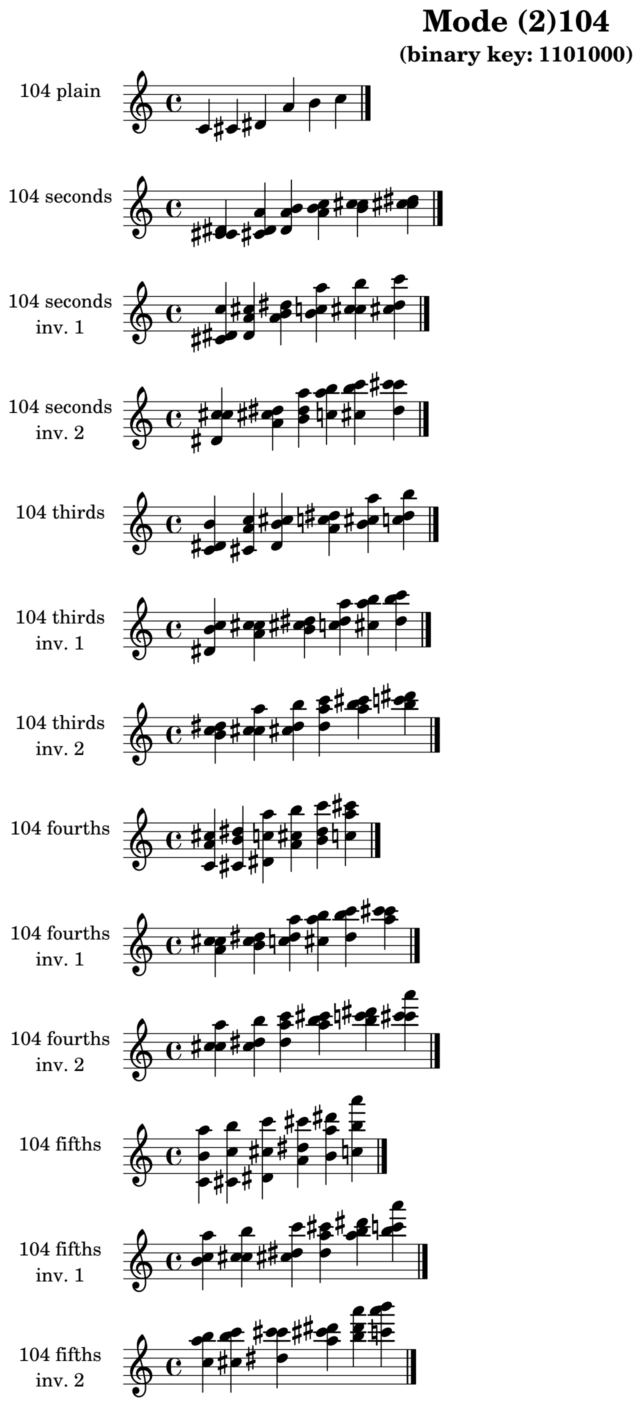


103 sus2

103 sus2
inv. 1

103 sus2
inv. 2

123 Characterizing mode (2)104



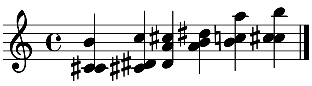
2

104 sus4

104 sus4
inv. 1

104 sus4
inv. 2

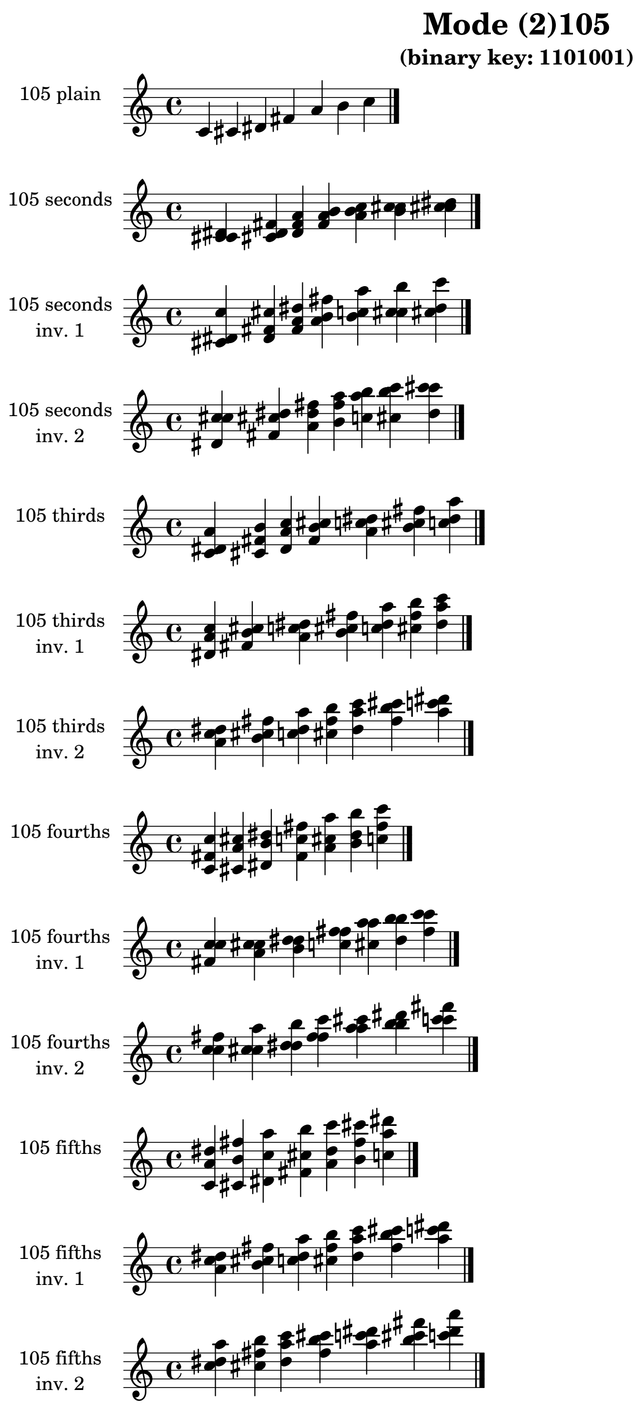
104 sus2



104 sus2
inv. 1

104 sus2
inv. 2

124 Characterizing mode (2)105



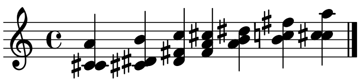
2

105 sus4

105 sus4
inv. 1

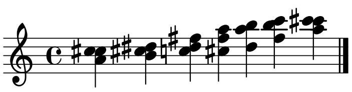
105 sus4
inv. 2

105 sus2

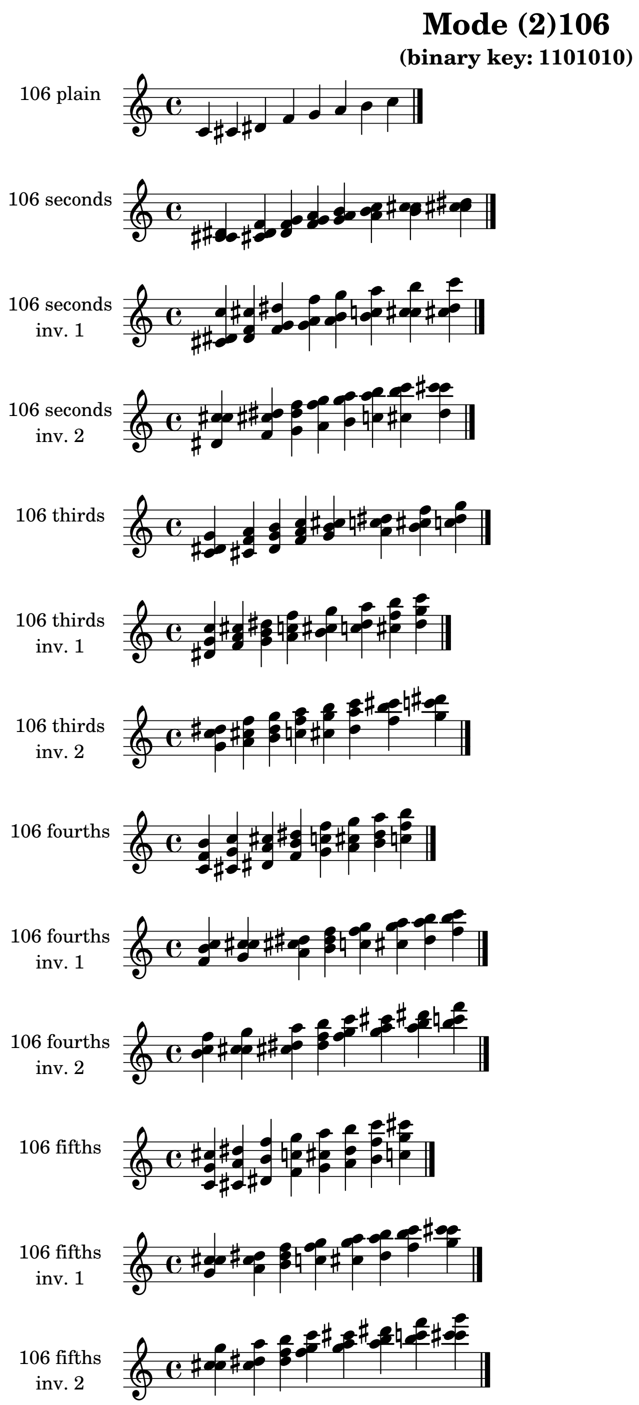


105 sus2
inv. 1

105 sus2
inv. 2



125 Characterizing mode (2)106



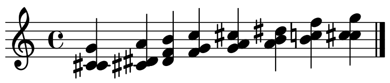
2

106 sus4

106 sus4
inv. 1

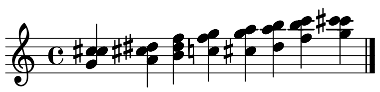
106 sus4
inv. 2

106 sus2



106 sus2
inv. 1

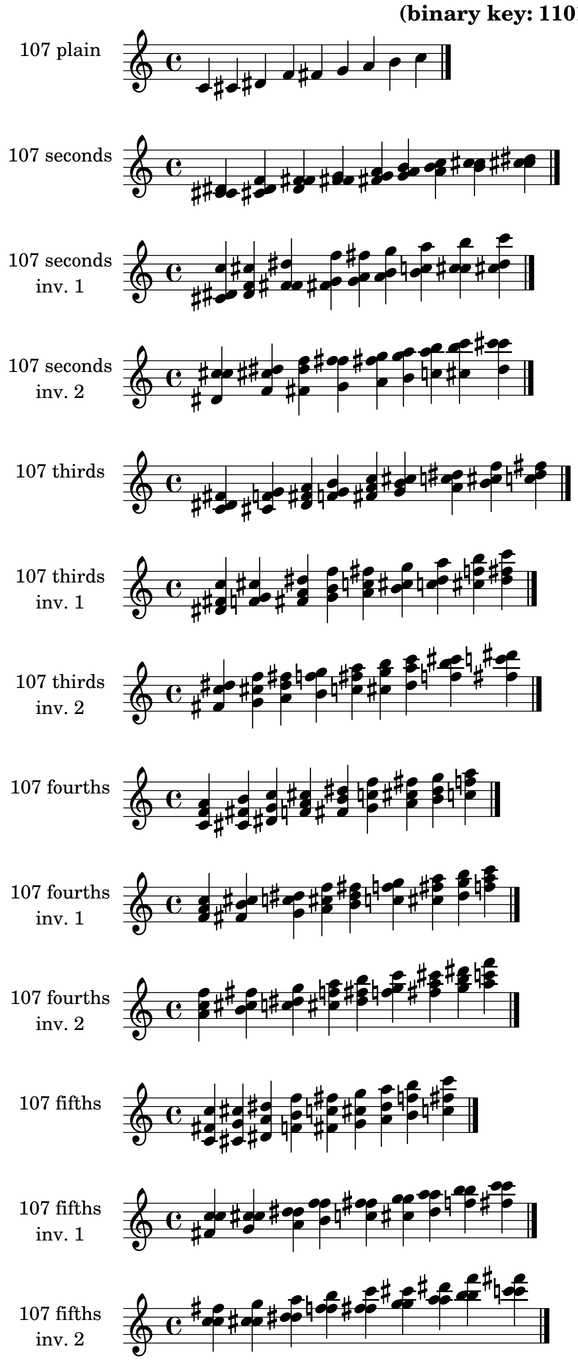
106 sus2
inv. 2



126 Characterizing mode (2)107

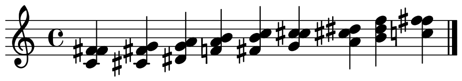
Mode (2)107

(binary key: 1101011)



2

107 sus4



107 sus4
inv. 1

107 sus4
inv. 2

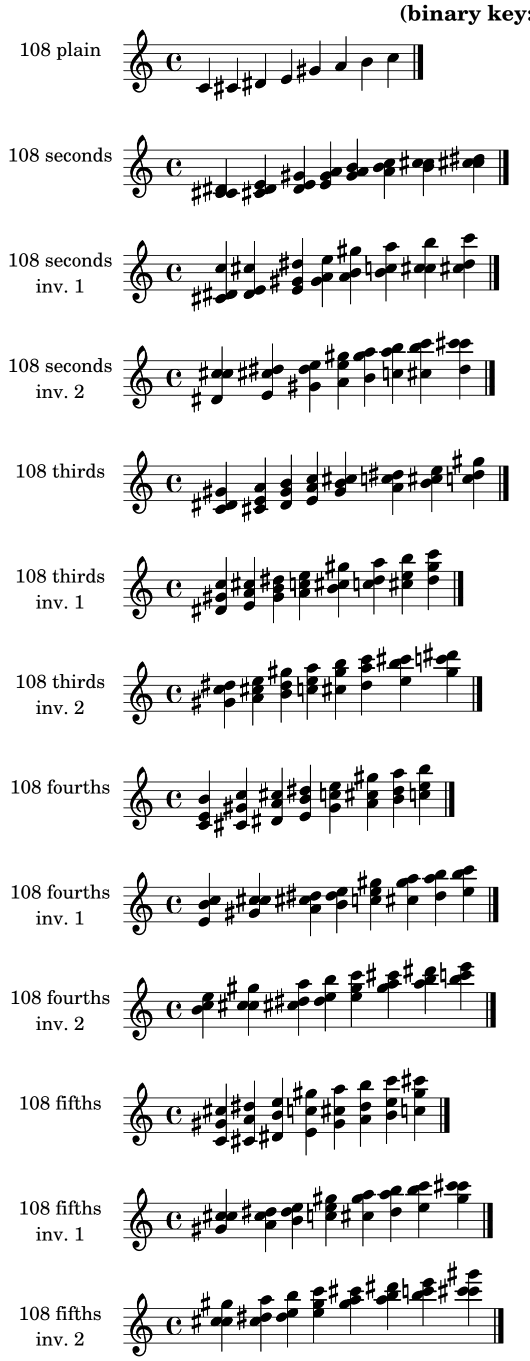
107 sus2

107 sus2
inv. 1

107 sus2
inv. 2

127 Characterizing mode (2)108

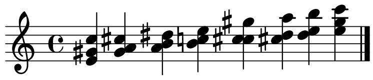
Mode (2)108
(binary key: 1101100)



2

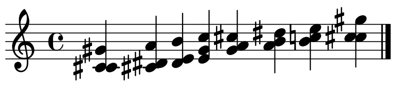
108 sus4

108 sus4
inv. 1



108 sus4
inv. 2

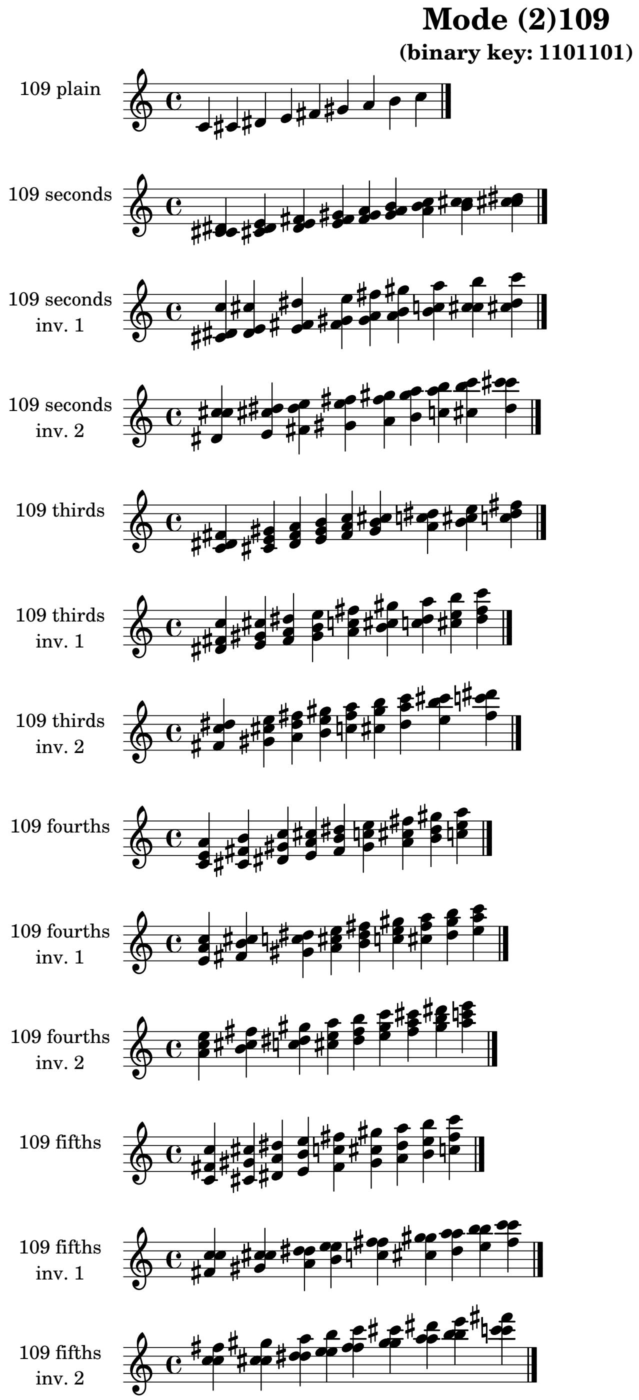
108 sus2



108 sus2
inv. 1

108 sus2
inv. 2

128 Characterizing mode (2)109

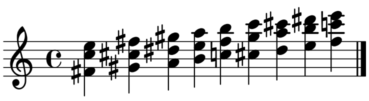


2

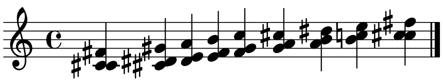
109 sus4

109 sus4
inv. 1

109 sus4
inv. 2



109 sus2



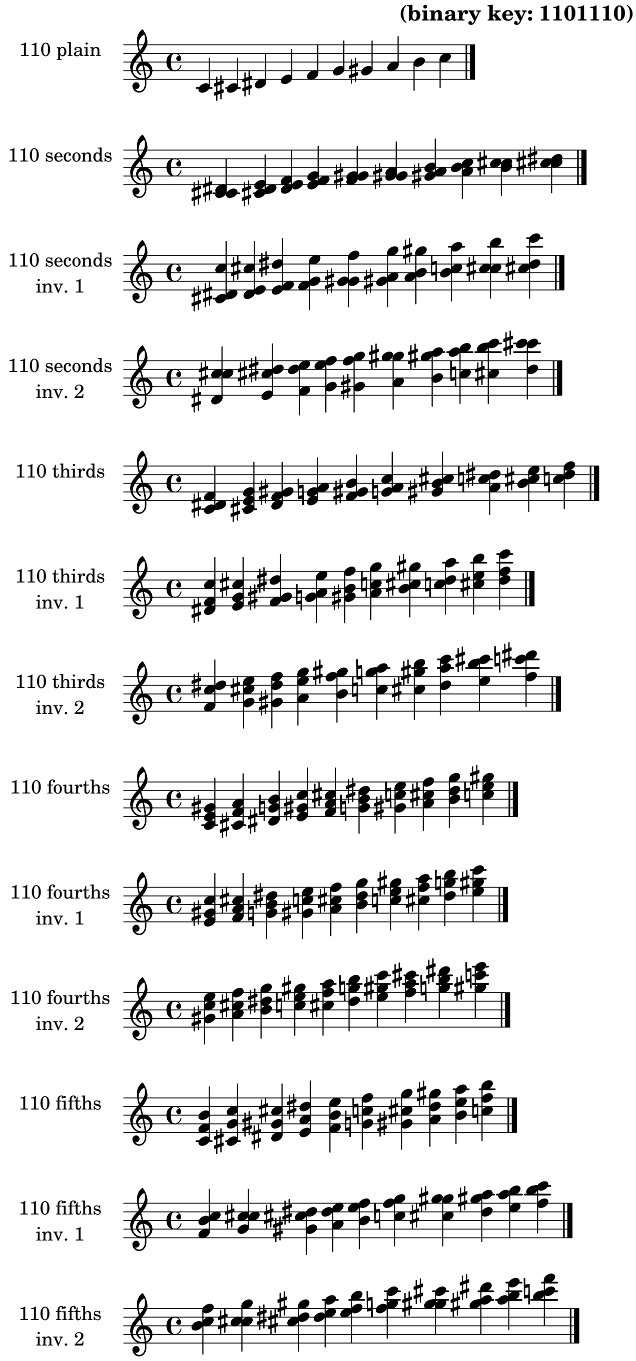
109 sus2
inv. 1

109 sus2
inv. 2

129 Characterizing mode (2)110

Mode (2)110

(binary key: 1101110)



2

110 sus4

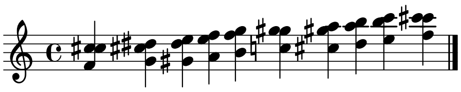
110 sus4
inv. 1

110 sus4
inv. 2

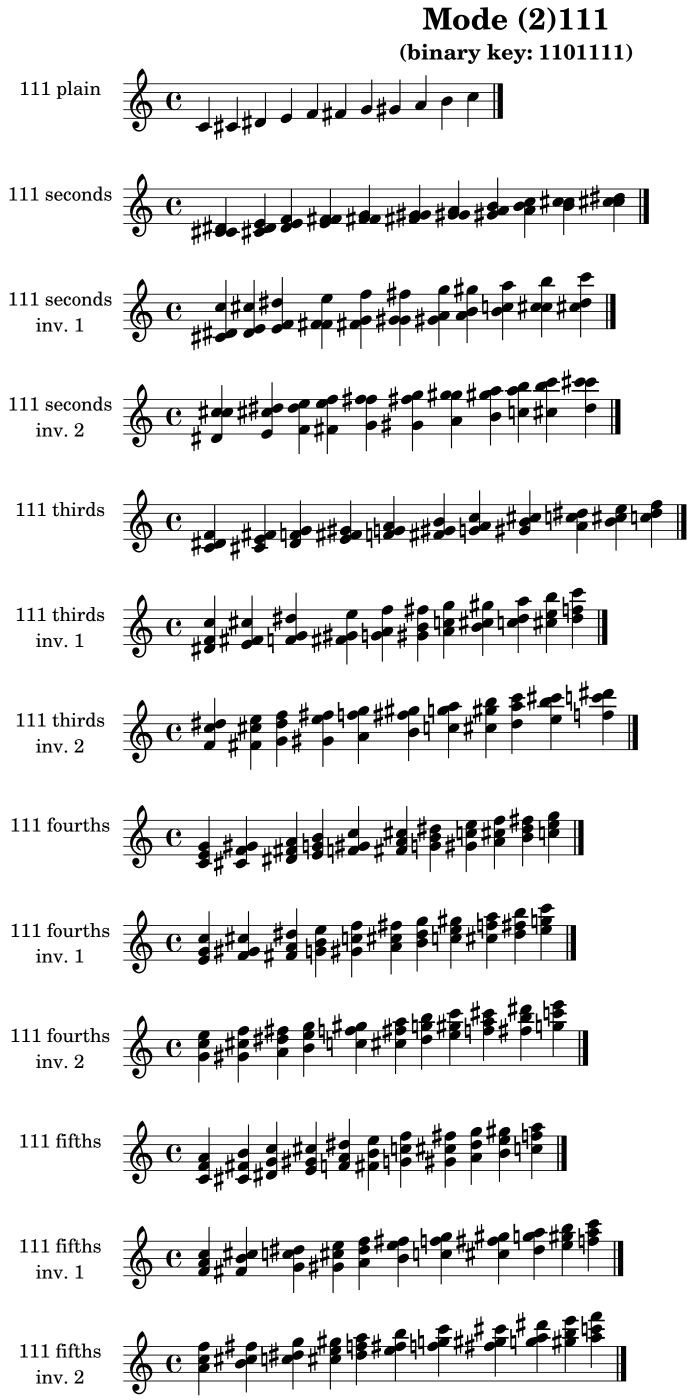
110 sus2

110 sus2
inv. 1

110 sus2
inv. 2



130 Characterizing mode (2)111



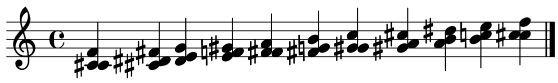
2

111 sus4

111 sus4
inv. 1

111 sus4
inv. 2

111 sus2

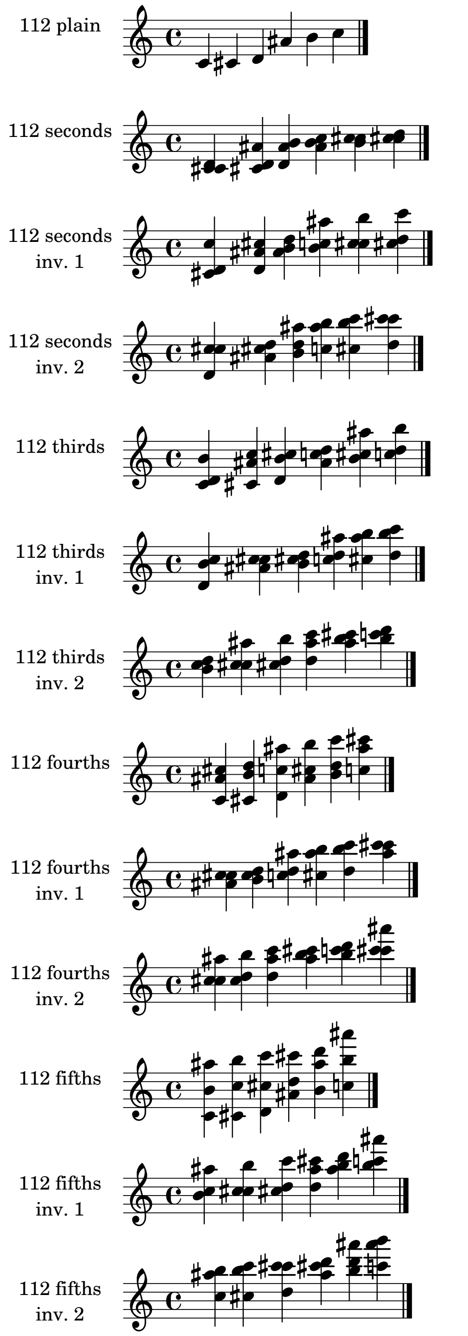


111 sus2
inv. 1

111 sus2
inv. 2

131 Characterizing mode (2)112

Mode (2)112
(binary key: 1110000)



2

112 sus4

112 sus4
inv. 1

112 sus4
inv. 2

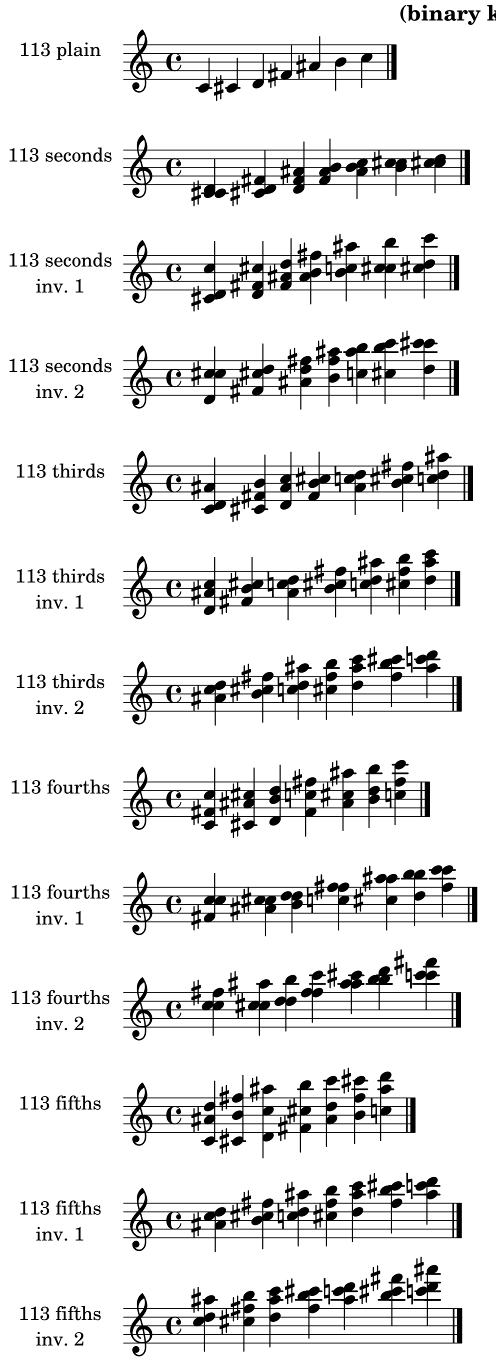
112 sus2

112 sus2
inv. 1

112 sus2
inv. 2

132 Characterizing mode (2)113

Mode (2)113
(binary key: 1110001)



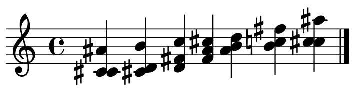
2

113 sus4

113 sus4
inv. 1

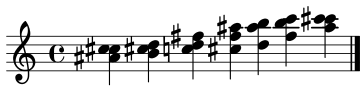
113 sus4
inv. 2

113 sus2

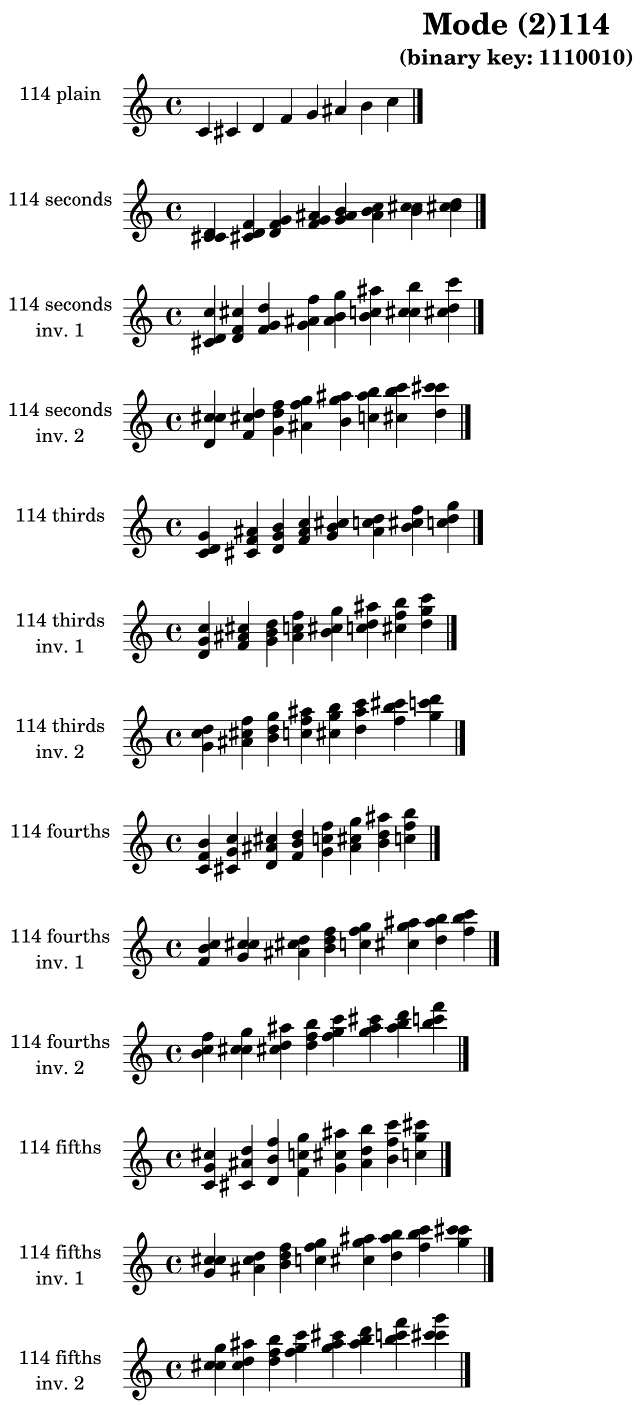


113 sus2
inv. 1

113 sus2
inv. 2



133 Characterizing mode (2)114



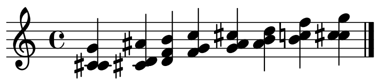
2

114 sus4

114 sus4
inv. 1

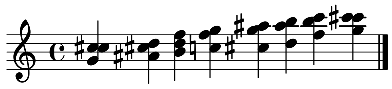
114 sus4
inv. 2

114 sus2

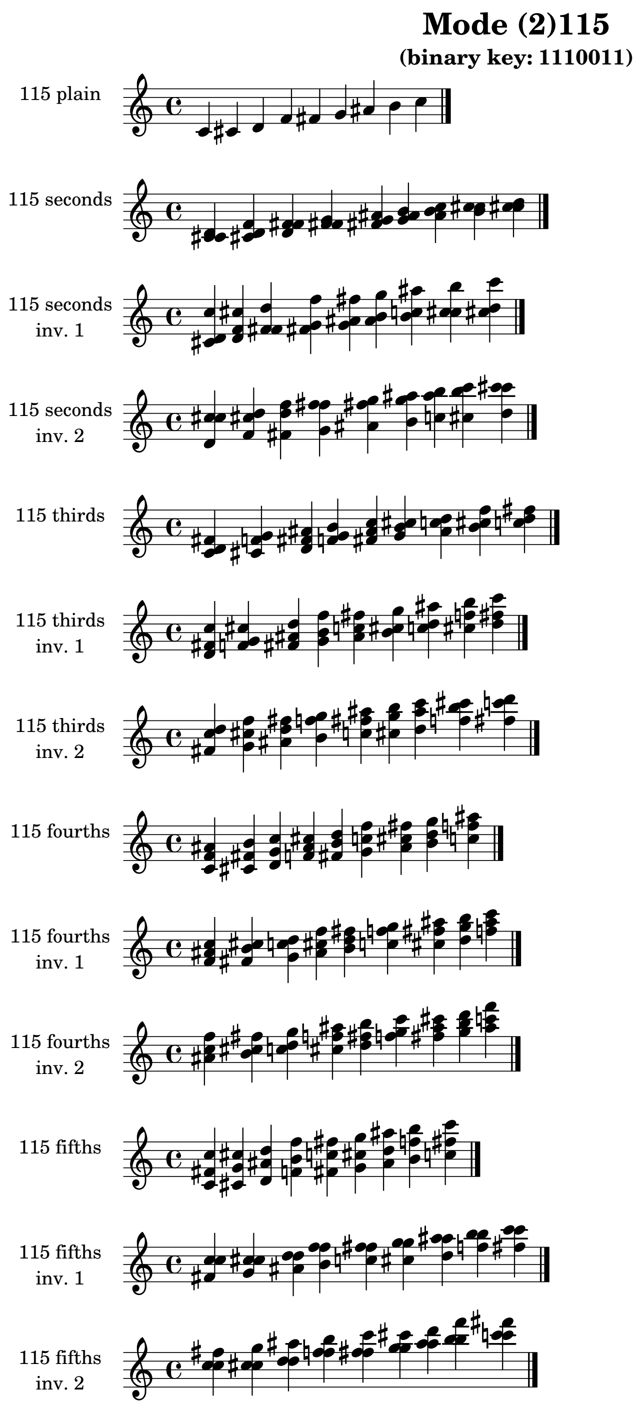


114 sus2
inv. 1

114 sus2
inv. 2



134 Characterizing mode (2)115

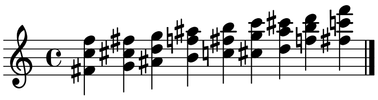


2

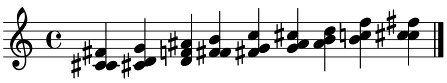
115 sus4

115 sus4
inv. 1

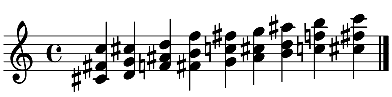
115 sus4
inv. 2



115 sus2

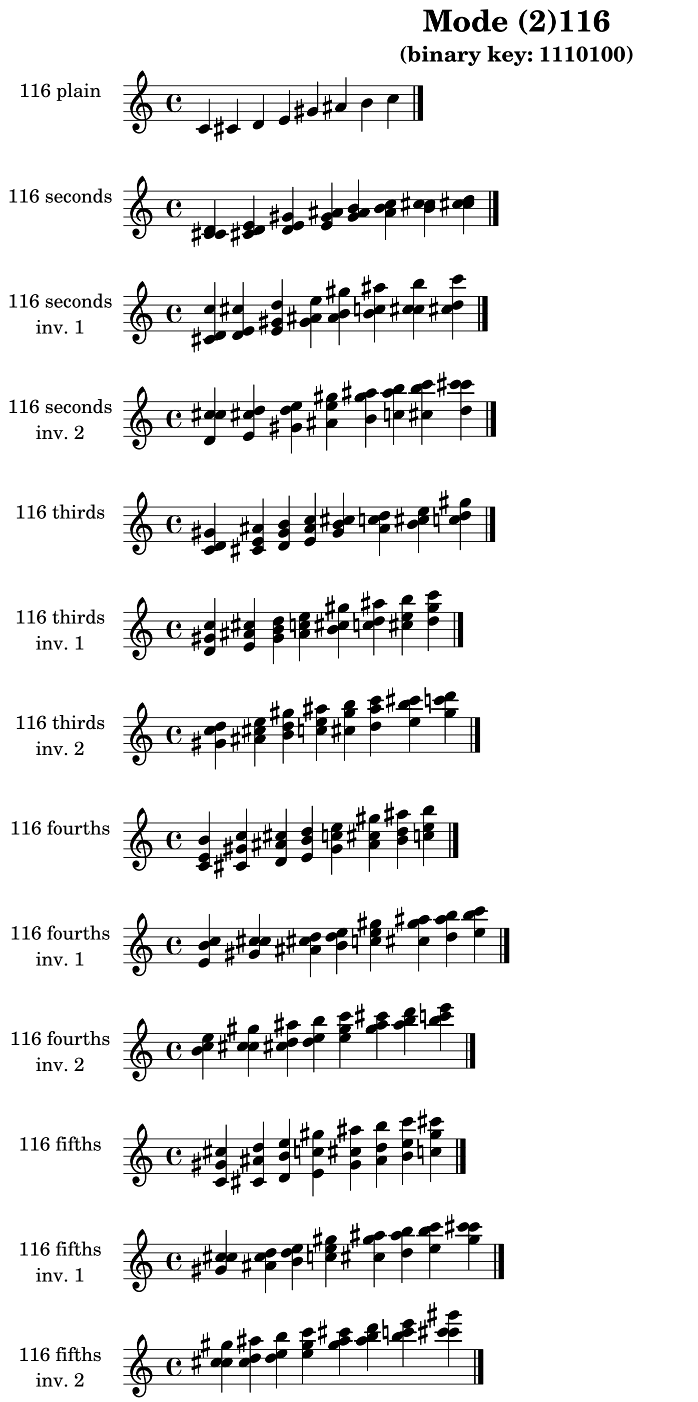


115 sus2
inv. 1



115 sus2
inv. 2

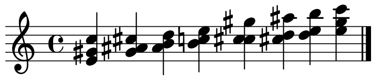
135 Characterizing mode (2)116



2

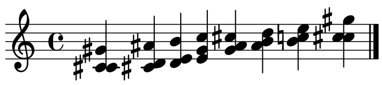
116 sus4

116 sus4
inv. 1

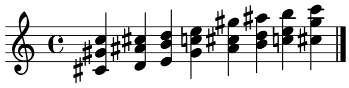


116 sus4
inv. 2

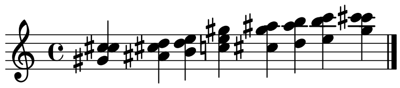
116 sus2



116 sus2
inv. 1



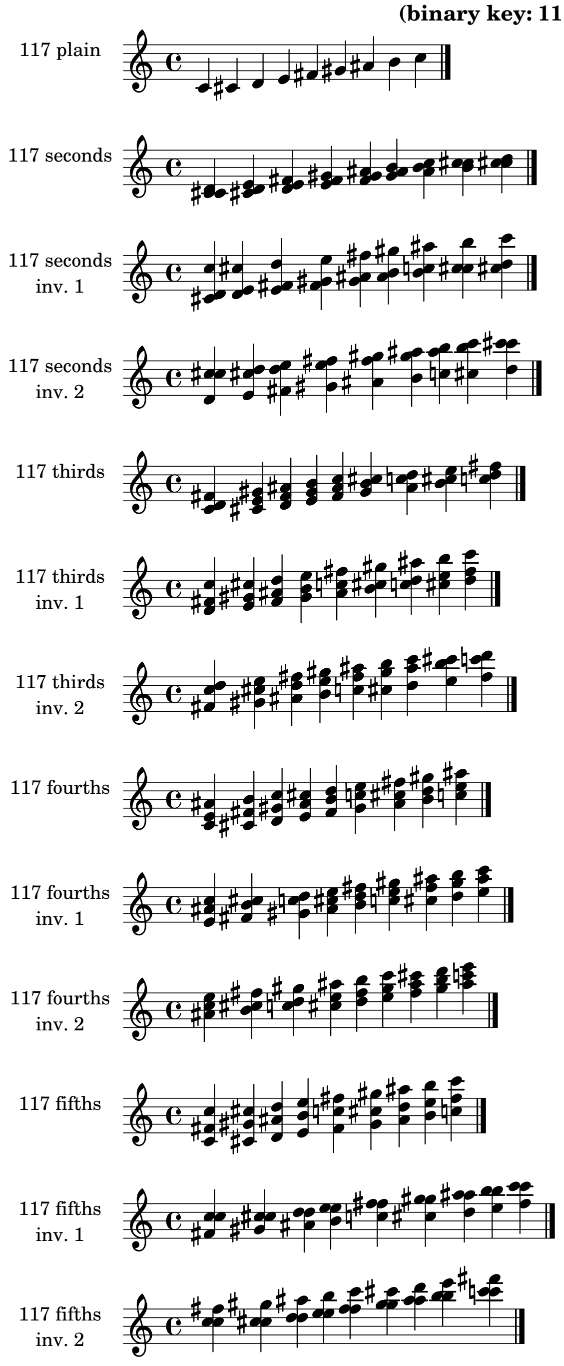
116 sus2
inv. 2



136 Characterizing mode (2)117

Mode (2)117

(binary key: 1110101)



2

117 sus4

117 sus4
inv. 1

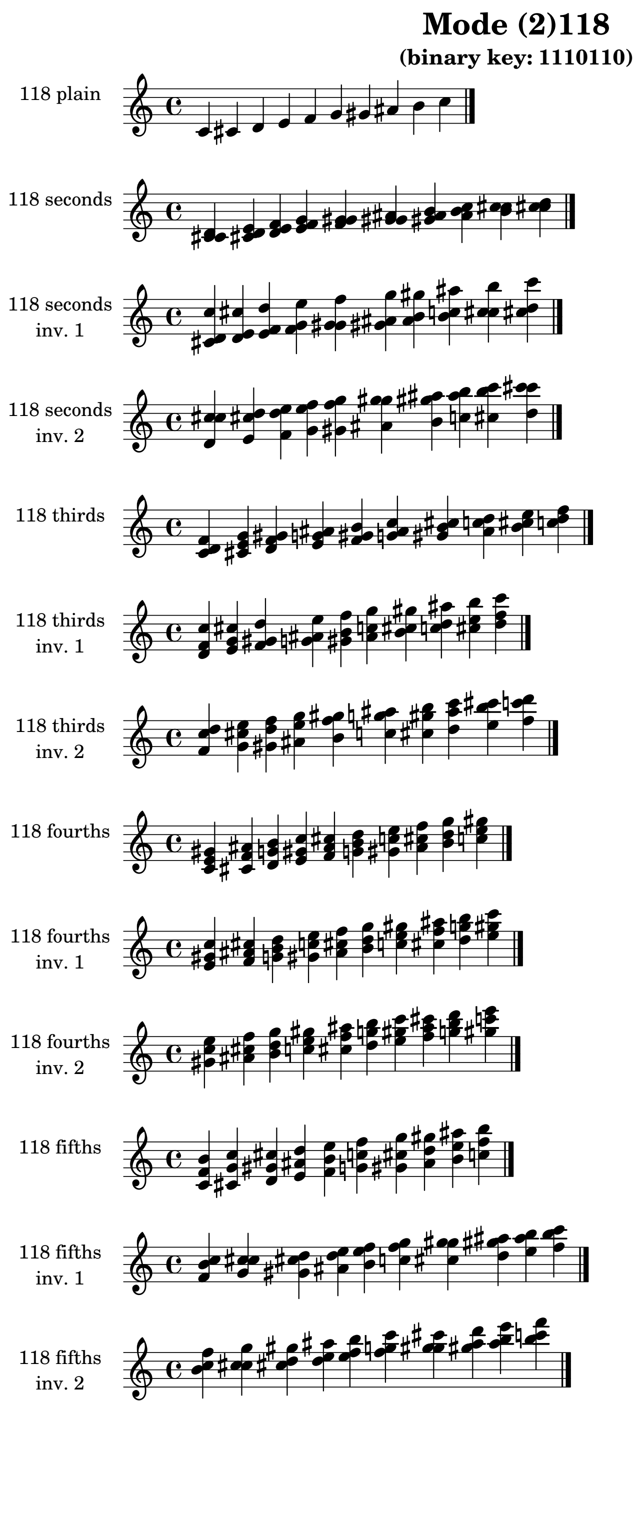
117 sus4
inv. 2

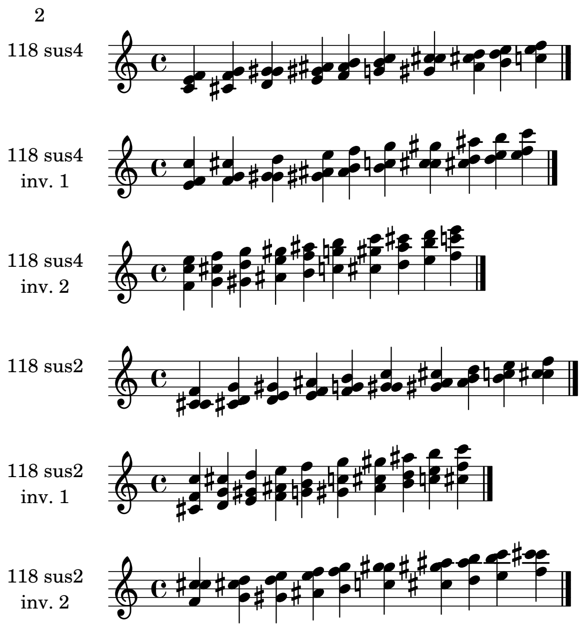
117 sus2

117 sus2
inv. 1

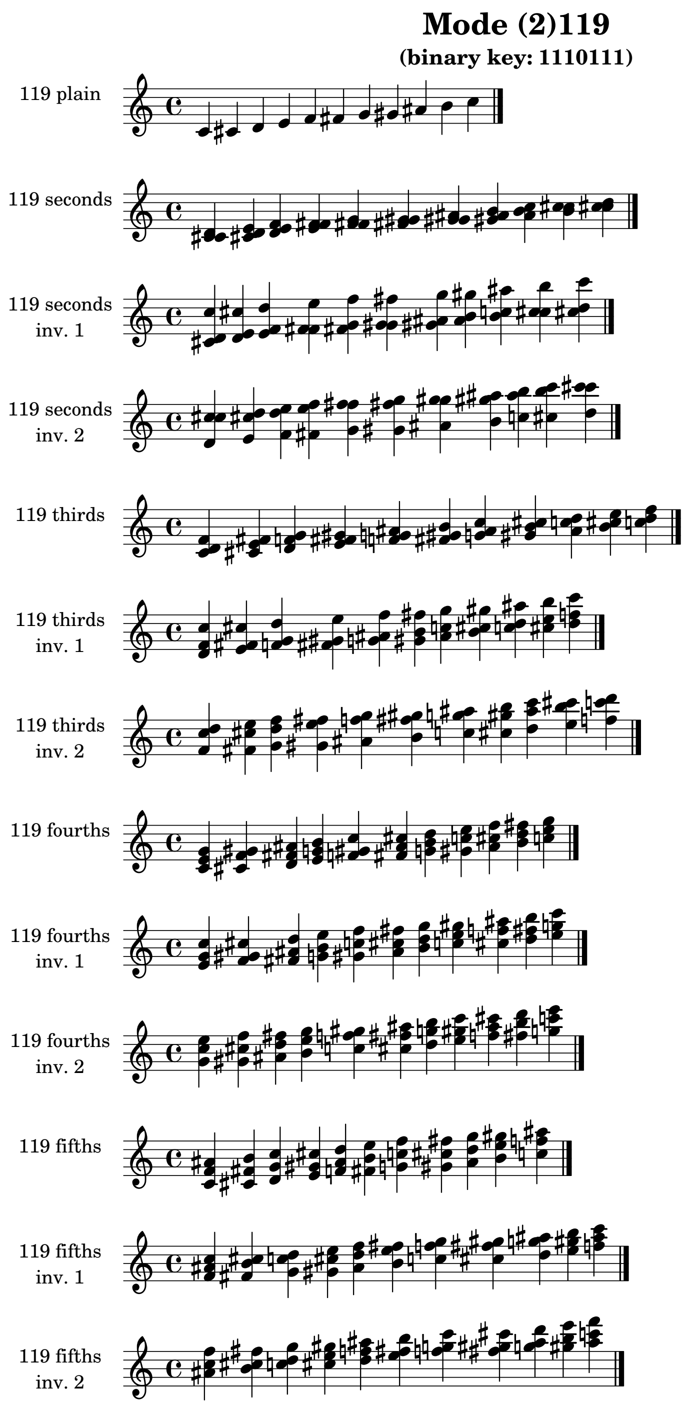
117 sus2
inv. 2

137 Characterizing mode (2)118




2
118 sus4
118 sus4 inv. 1
118 sus4 inv. 2
118 sus2
118 sus2 inv. 1
118 sus2 inv. 2

138 Characterizing mode (2)119



2

119 sus4

119 sus4
inv. 1

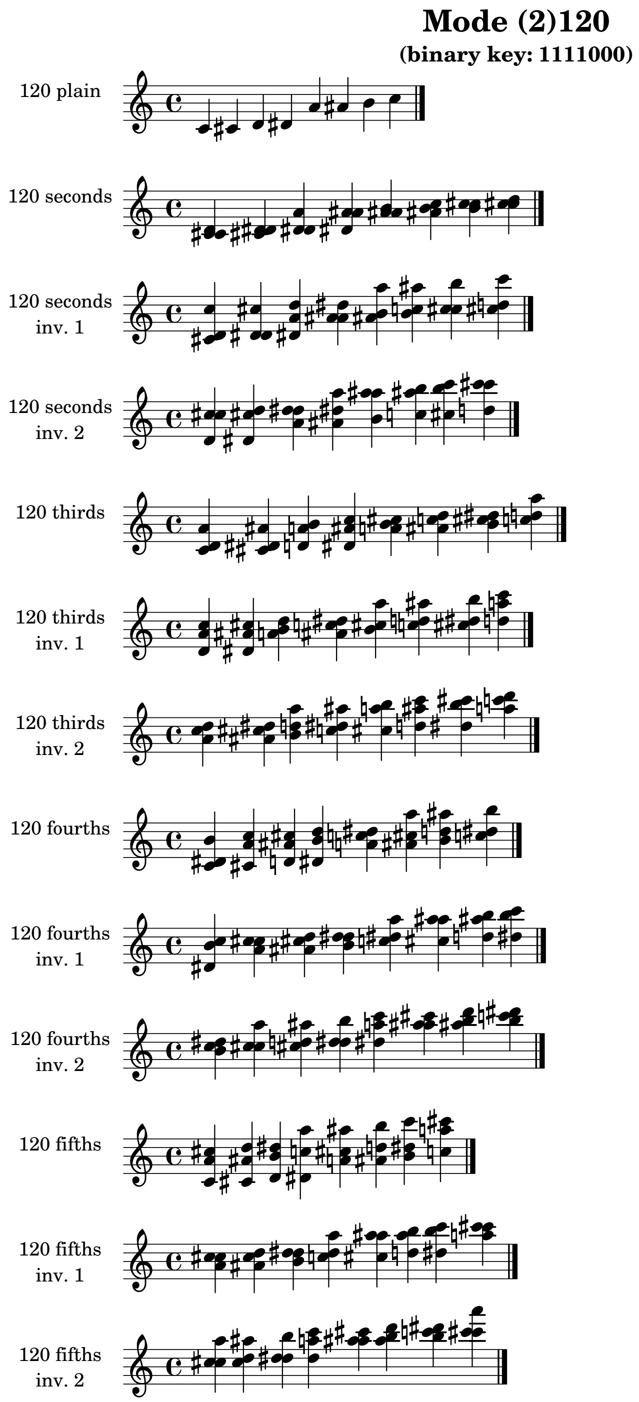
119 sus4
inv. 2

119 sus2

119 sus2
inv. 1

119 sus2
inv. 2

139 Characterizing mode (2)120



2

120 sus4

120 sus4
inv. 1

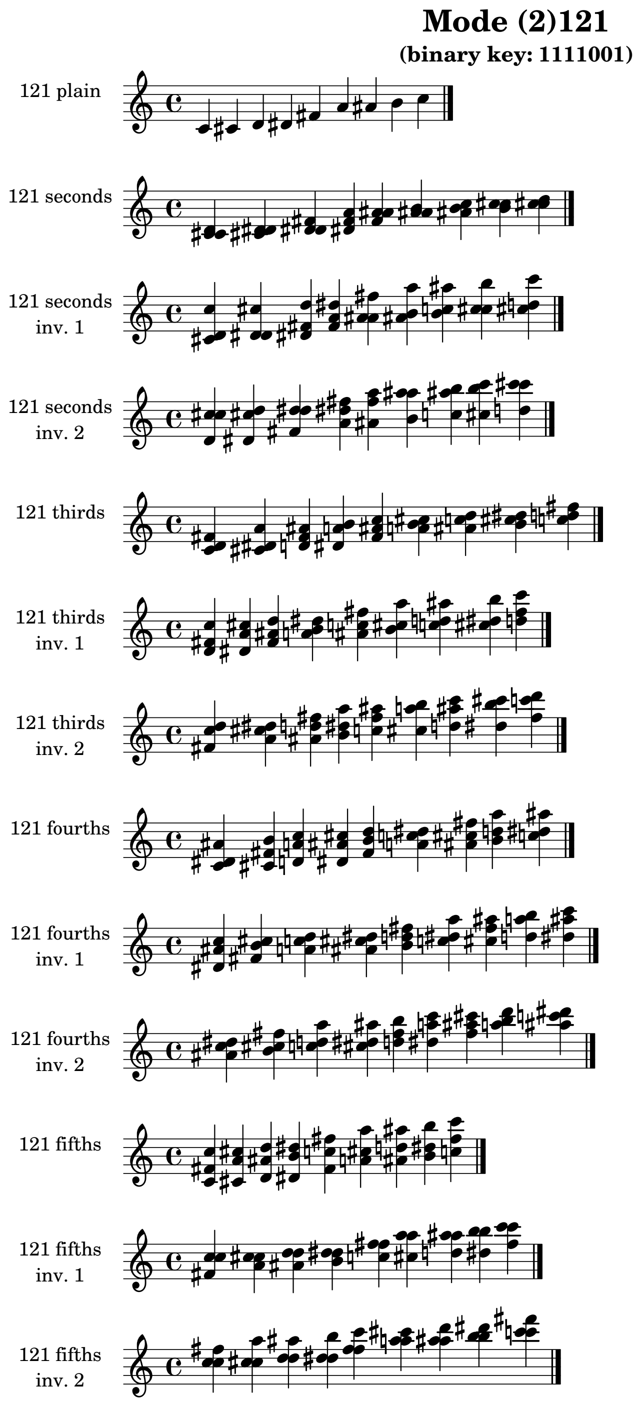
120 sus4
inv. 2

120 sus2

120 sus2
inv. 1

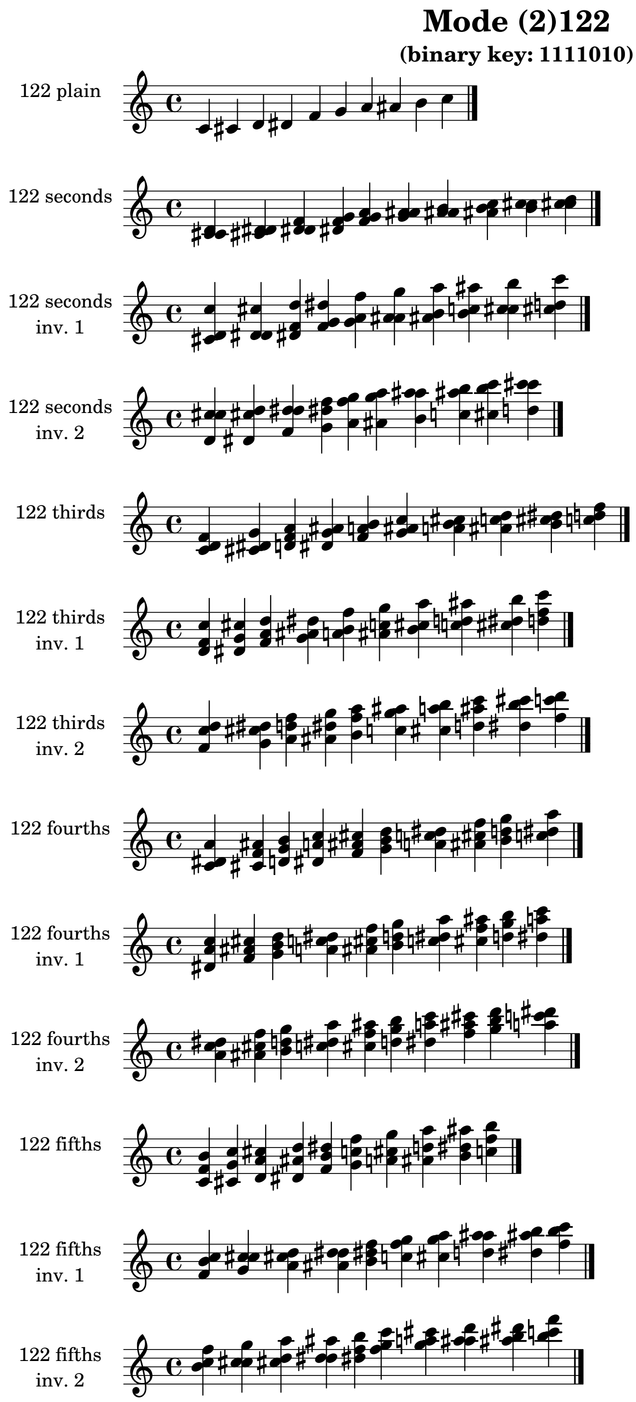
120 sus2
inv. 2

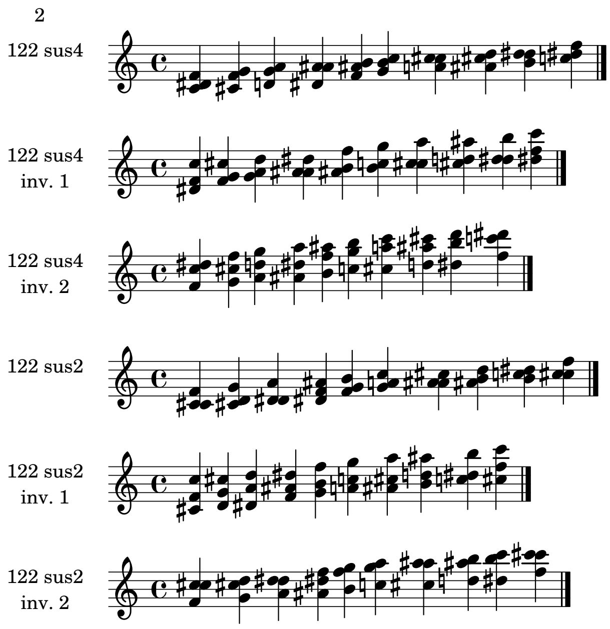
140 Characterizing mode (2)121



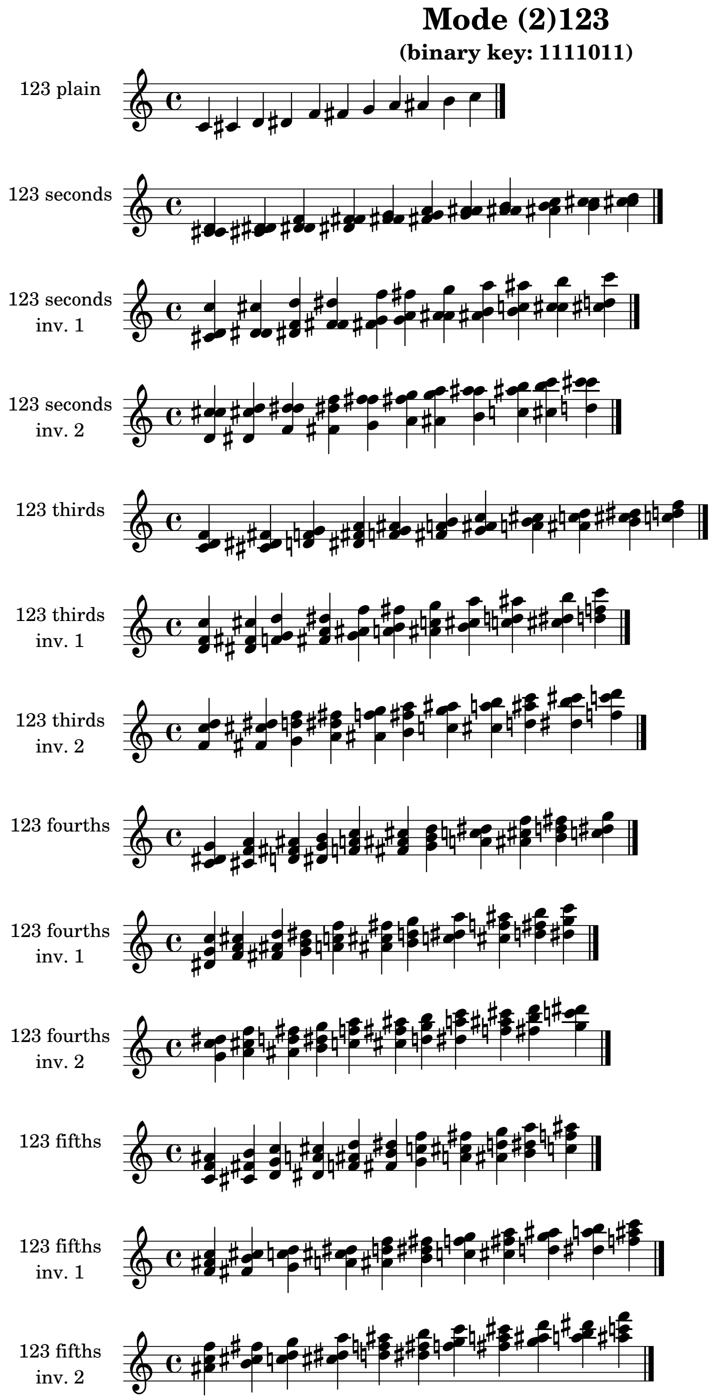

2
121 sus4
121 sus4
inv. 1
121 sus4
inv. 2
121 sus2
121 sus2
inv. 1
121 sus2
inv. 2

141 Characterizing mode (2)122




2
122 sus4
122 sus4 inv. 1
122 sus4 inv. 2
122 sus2
122 sus2 inv. 1
122 sus2 inv. 2

142 Characterizing mode (2)123



2

123 sus4

123 sus4
inv. 1

123 sus4
inv. 2

123 sus2

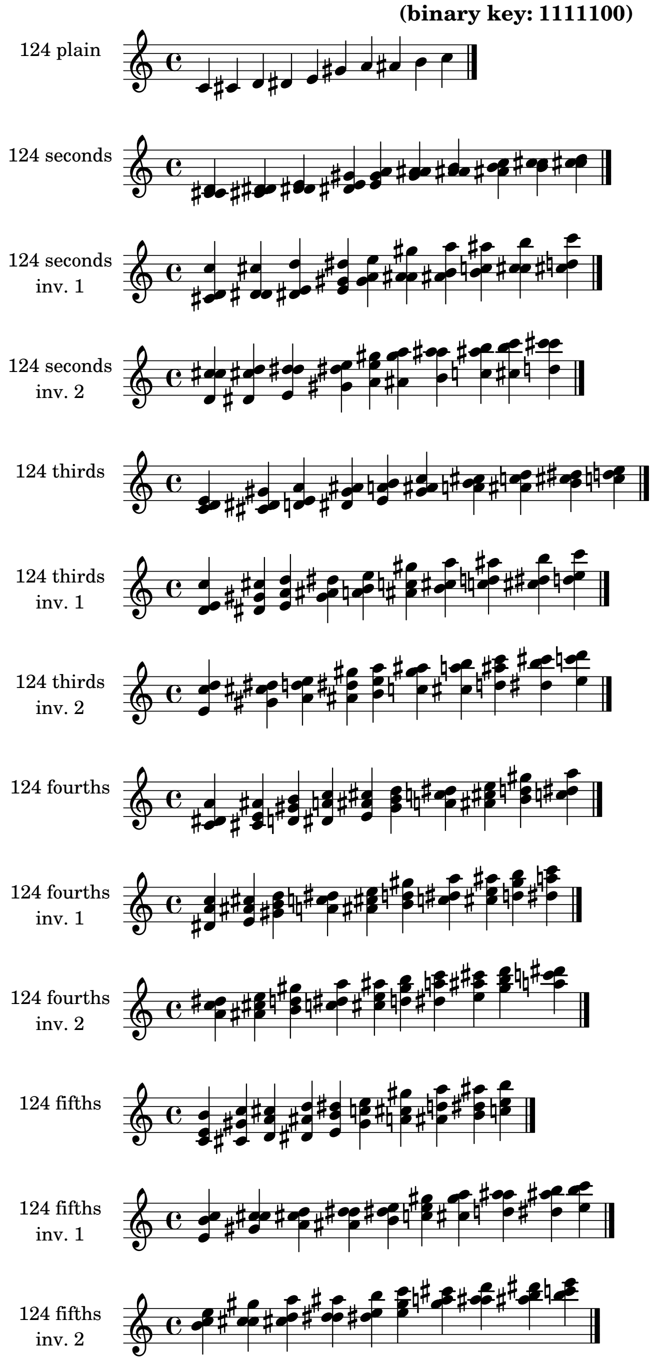
123 sus2
inv. 1

123 sus2
inv. 2

143 Characterizing mode (2)124

Mode (2)124

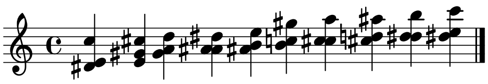
(binary key: 1111100)



2

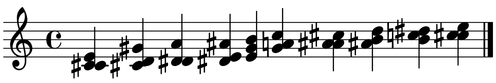
124 sus4

124 sus4
inv. 1



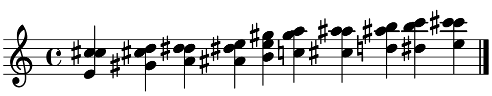
124 sus4
inv. 2

124 sus2



124 sus2
inv. 1

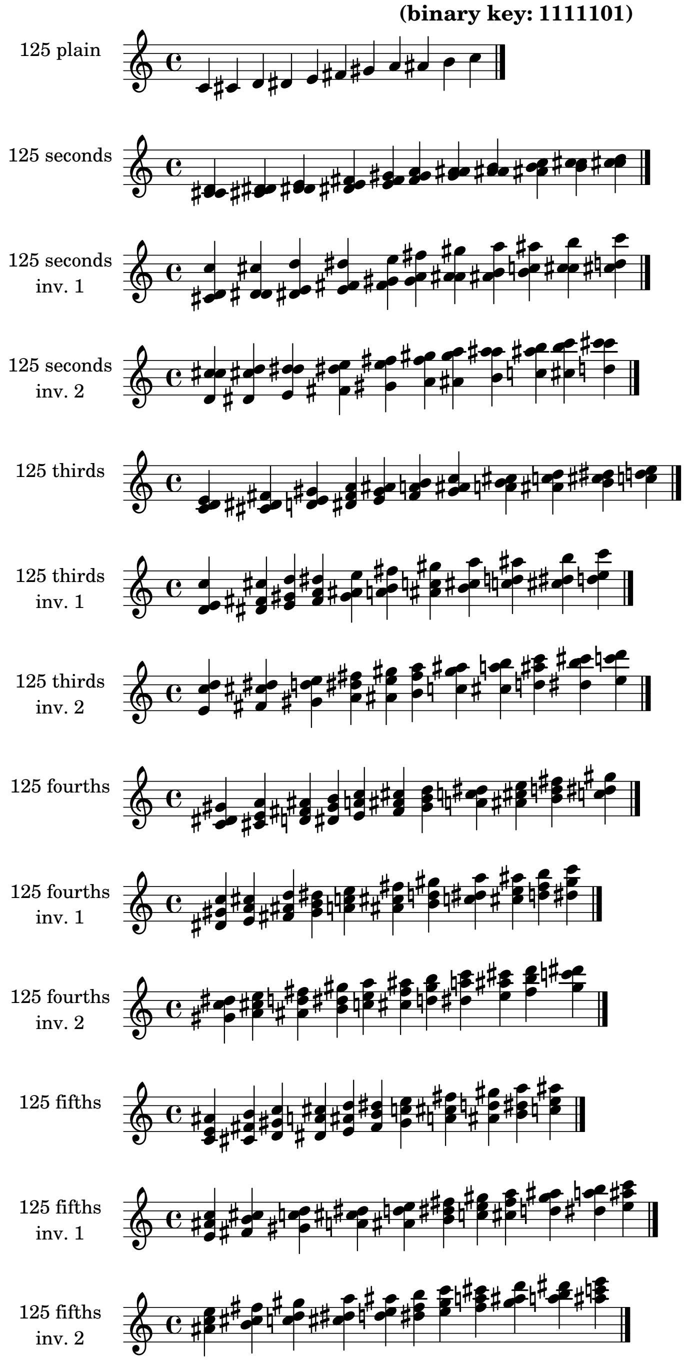
124 sus2
inv. 2



144 Characterizing mode (2)125

Mode (2)125

(binary key: 1111101)



2

125 sus4

125 sus4
inv. 1

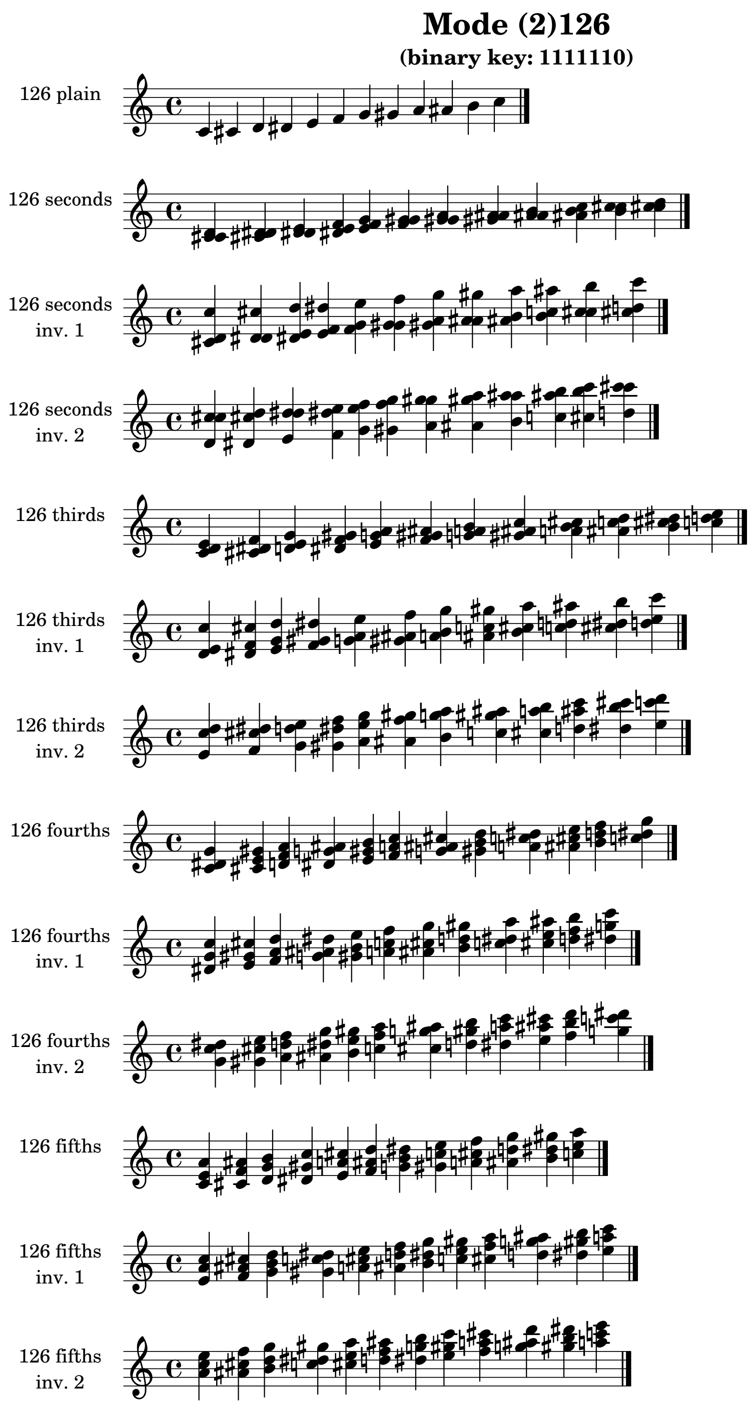
125 sus4
inv. 2

125 sus2

125 sus2
inv. 1

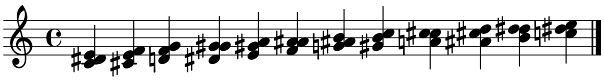
125 sus2
inv. 2

145 Characterizing mode (2)126



2

126 sus4



126 sus4
inv. 1

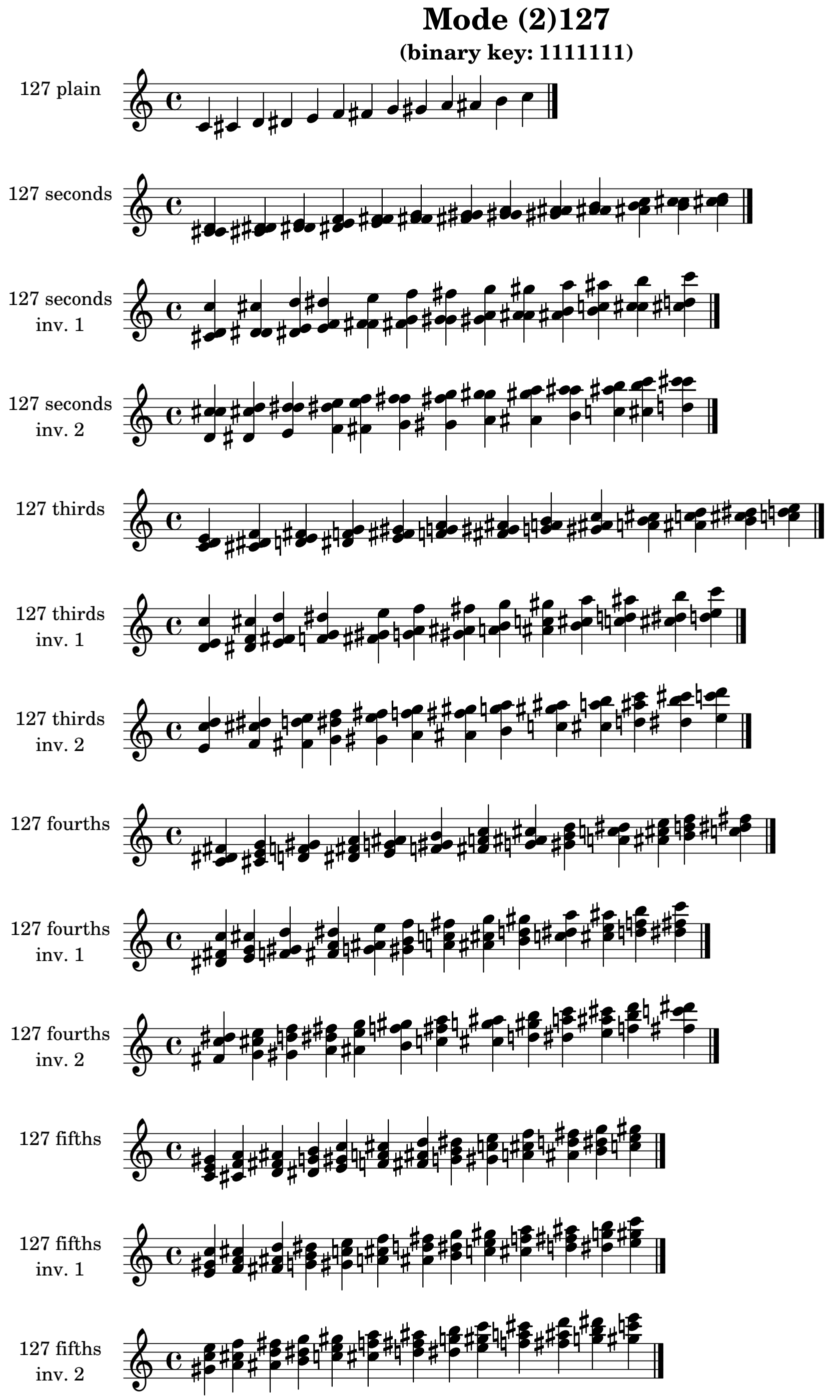
126 sus4
inv. 2

126 sus2

126 sus2
inv. 1

126 sus2
inv. 2

146 Characterizing mode (2)127



2

127 sus4

127 sus4
inv. 1

127 sus4
inv. 2

127 sus2

127 sus2
inv. 1

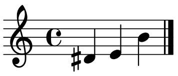
127 sus2
inv. 2

147 Characterizing mode (3)1

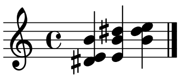
Mode (3)1

(binary key: 0001)

1 plain

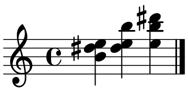


1 seconds

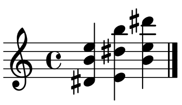


1 seconds inv. 1

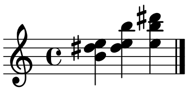
1 seconds inv. 2



1 thirds



1 thirds inv. 1



1 thirds inv. 2

1 fourths

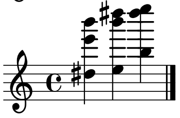
1 fourths inv. 1

1 fourths inv. 2

1 fifths

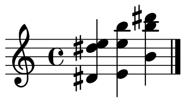
1 fifths inv. 1

1 fifths inv. 2



2

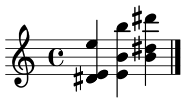
1 sus4



1 sus4
inv. 1

1 sus4
inv. 2

1 sus2



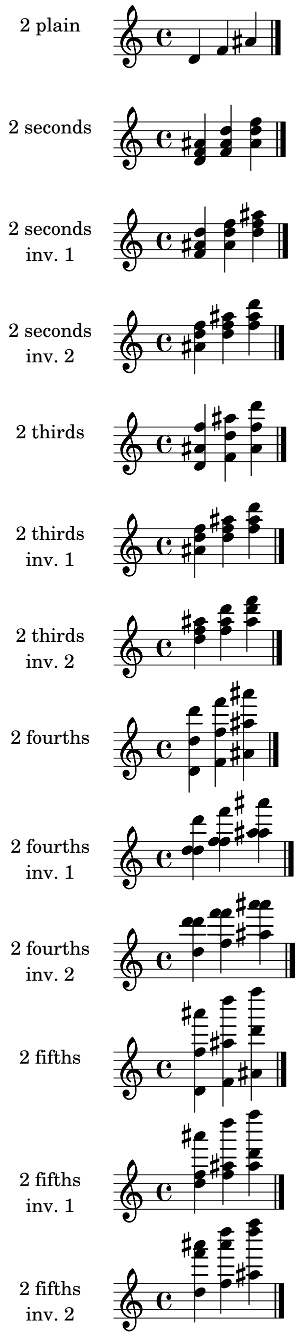
1 sus2
inv. 1

1 sus2
inv. 2

148 Characterizing mode (3)2

Mode (3)2

(binary key: 0010)



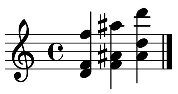
2

2 sus4

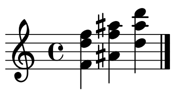
2 sus4
inv. 1

2 sus4
inv. 2

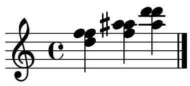
2 sus2



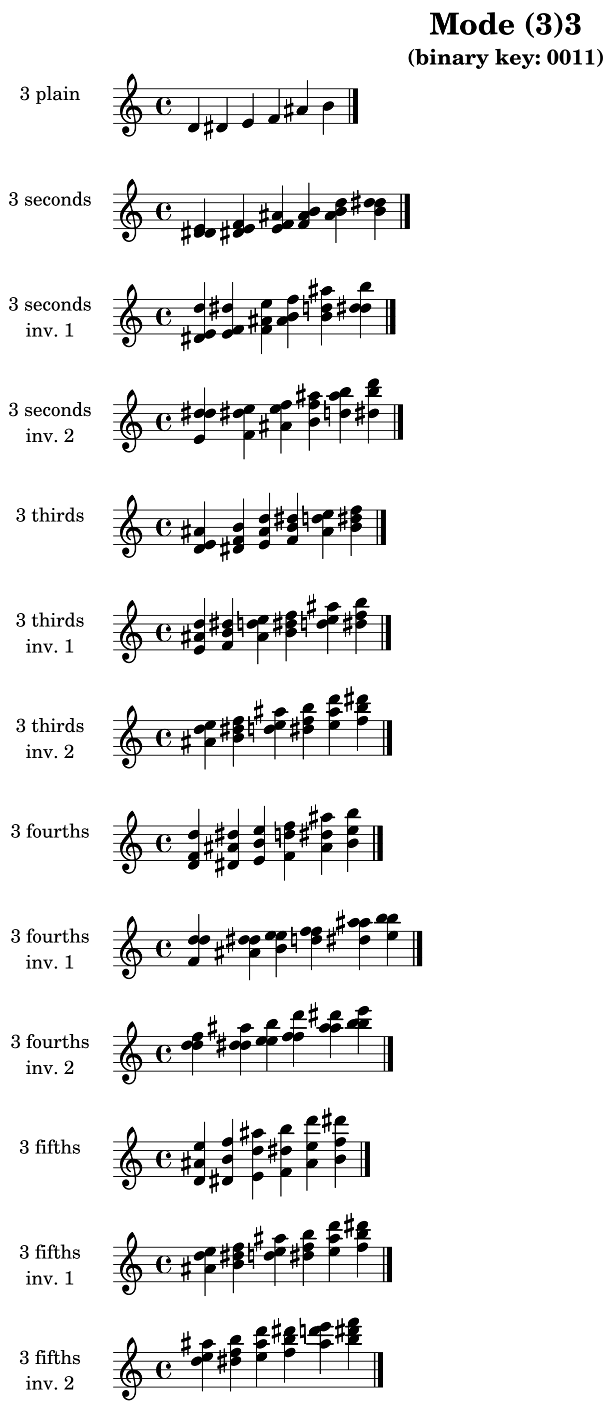
2 sus2
inv. 1



2 sus2
inv. 2

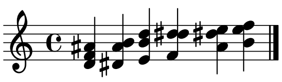


149 Characterizing mode (3)3



2

3 sus4



3 sus4
inv. 1

3 sus4
inv. 2

3 sus2

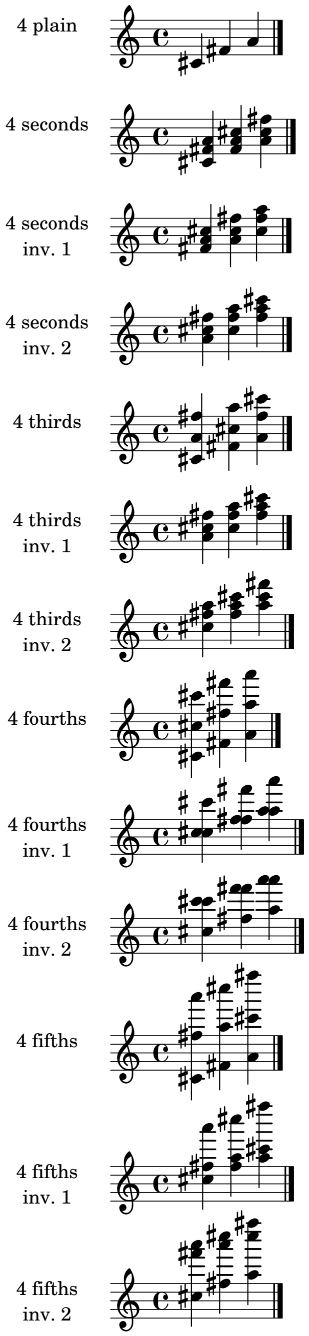
3 sus2
inv. 1

3 sus2
inv. 2

150 Characterizing mode (3)4

Mode (3)4

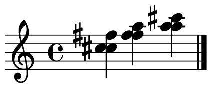
(binary key: 0100)



2

4 sus4

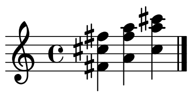
4 sus4
inv. 1



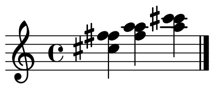
4 sus4
inv. 2

4 sus2

4 sus2
inv. 1



4 sus2
inv. 2



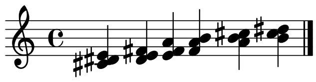
151 Characterizing mode (3)5

Mode (3)5

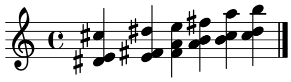
(binary key: 0101)

5 plain

5 seconds



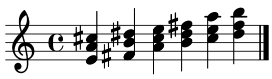
5 seconds inv. 1



5 seconds inv. 2

5 thirds

5 thirds inv. 1

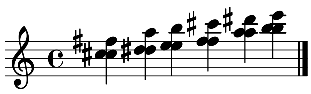


5 thirds inv. 2

5 fourths

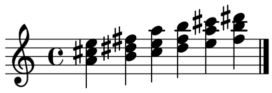
5 fourths inv. 1

5 fourths inv. 2

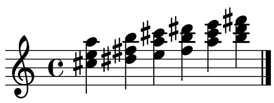


5 fifths

5 fifths inv. 1



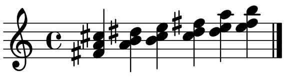
5 fifths inv. 2



2

5 sus4

5 sus4
inv. 1



5 sus4
inv. 2

5 sus2

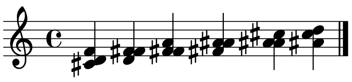
5 sus2
inv. 1

5 sus2
inv. 2

152 Characterizing mode (3)6

Mode (3)6
(binary key: 0110)

6 plain

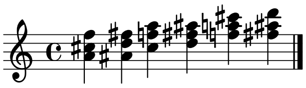

6 seconds


6 seconds inv. 1


6 seconds inv. 2

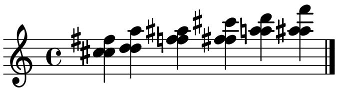

6 thirds


6 thirds inv. 1


6 thirds inv. 2


6 fourths


6 fourths inv. 1


6 fourths inv. 2


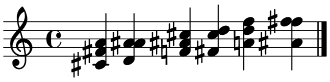
6 fifths


6 fifths inv. 1


6 fifths inv. 2

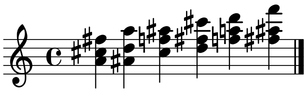

2

6 sus4



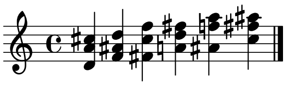
6 sus4
inv. 1

6 sus4
inv. 2



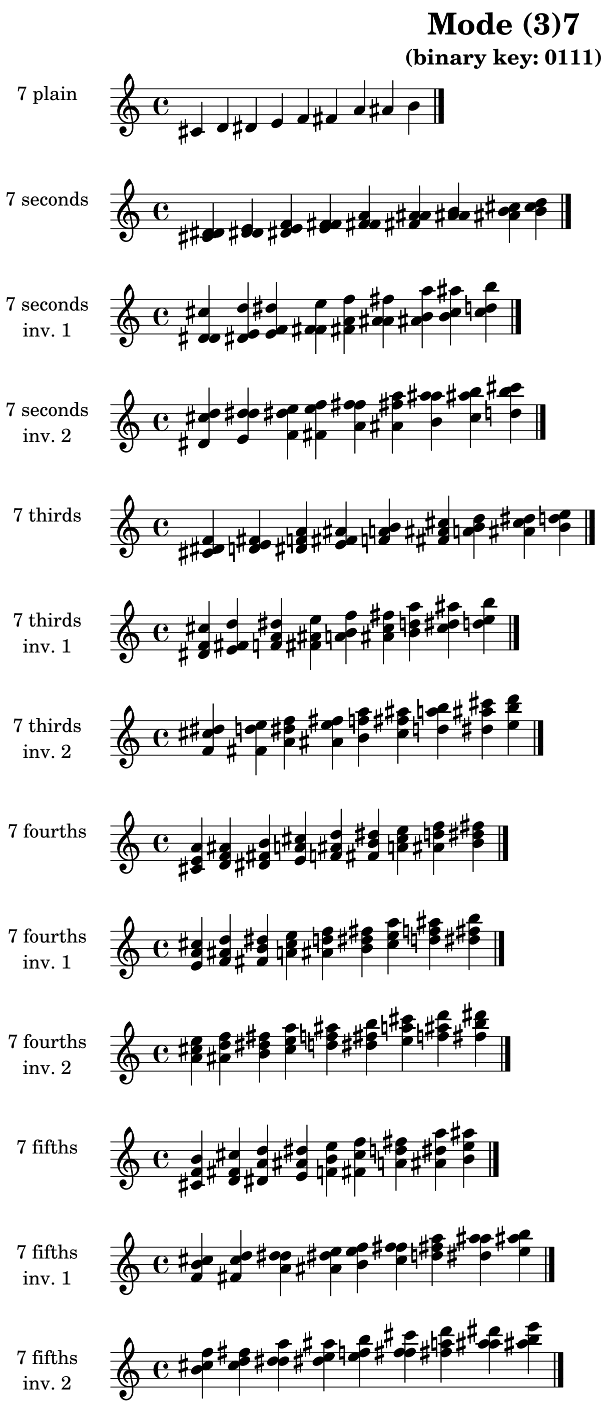
6 sus2

6 sus2
inv. 1



6 sus2
inv. 2

153 Characterizing mode (3)7



2

7 sus4

7 sus4
inv. 1

7 sus4
inv. 2

7 sus2

7 sus2
inv. 1

7 sus2
inv. 2

154 Characterizing mode (3)8

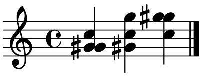
Mode (3)8

(binary key: 1000)

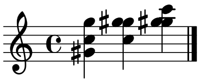
8 plain

8 seconds

8 seconds inv. 1



8 seconds inv. 2



8 thirds

8 thirds inv. 1

8 thirds inv. 2

8 fourths

8 fourths inv. 1

8 fourths inv. 2

8 fifths

8 fifths inv. 1

8 fifths inv. 2

2

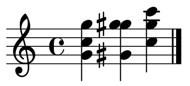
8 sus4

8 sus4
inv. 1

8 sus4
inv. 2

8 sus2

8 sus2
inv. 1



8 sus2
inv. 2

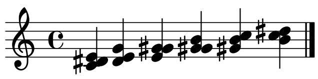
155 Characterizing mode (3)9

Mode (3)9

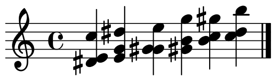
(binary key: 1001)

9 plain

9 seconds



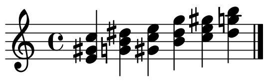
9 seconds inv. 1



9 seconds inv. 2

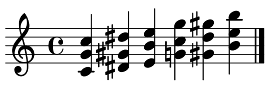
9 thirds

9 thirds inv. 1

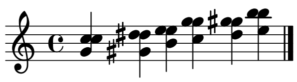


9 thirds inv. 2

9 fourths



9 fourths inv. 1

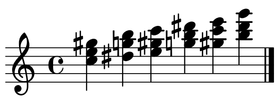


9 fourths inv. 2

9 fifths

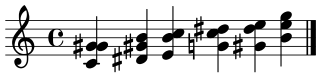
9 fifths inv. 1

9 fifths inv. 2

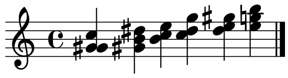


2

9 sus4



9 sus4
inv. 1

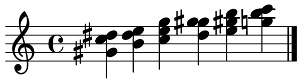


9 sus4
inv. 2

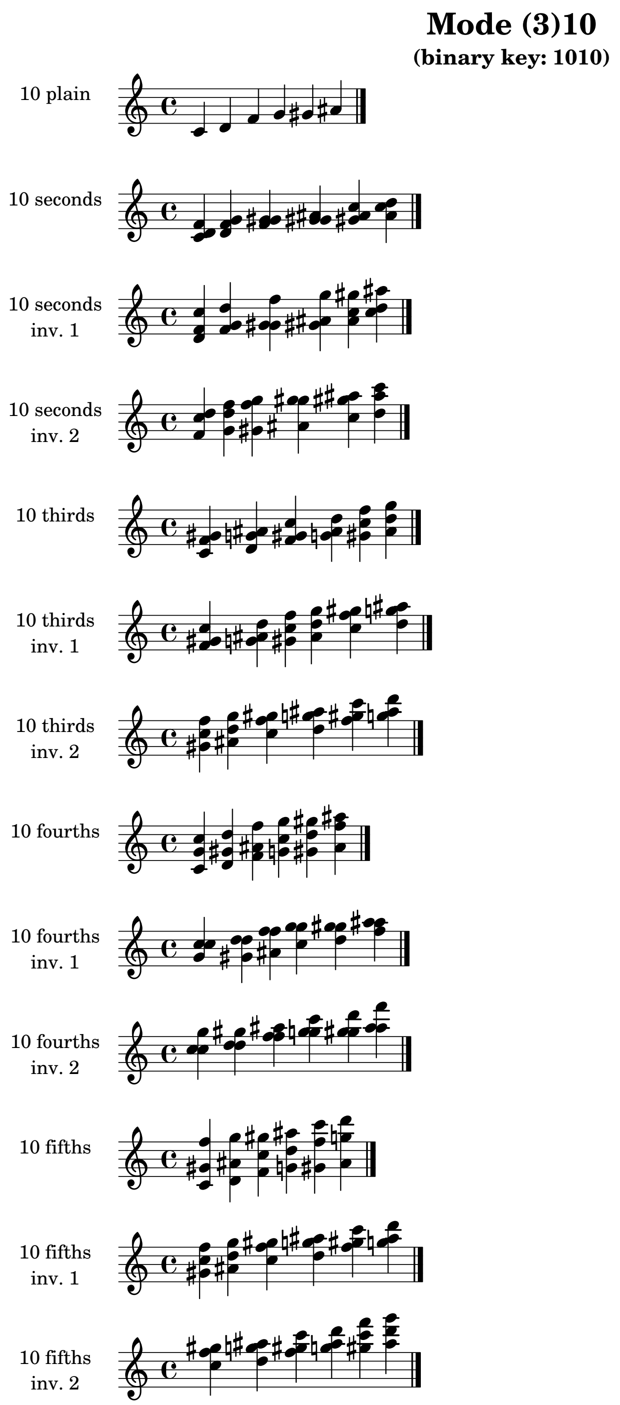
9 sus2

9 sus2
inv. 1

9 sus2
inv. 2



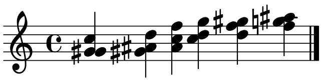
156 Characterizing mode (3)10



2

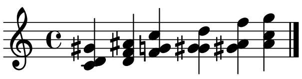
10 sus4

10 sus4
inv. 1

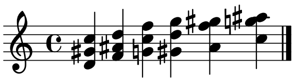


10 sus4
inv. 2

10 sus2



10 sus2
inv. 1



10 sus2
inv. 2

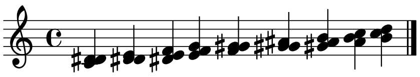
157 Characterizing mode (3)11

Mode (3)11

(binary key: 1011)

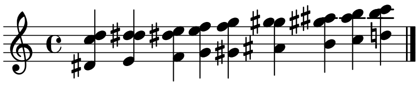
11 plain

11 seconds



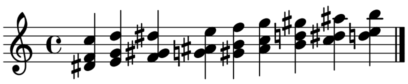
11 seconds
inv. 1

11 seconds
inv. 2



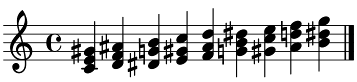
11 thirds

11 thirds
inv. 1

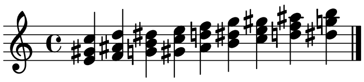


11 thirds
inv. 2

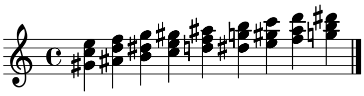
11 fourths



11 fourths
inv. 1



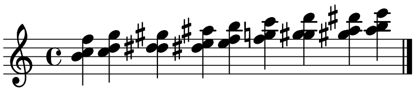
11 fourths
inv. 2



11 fifths

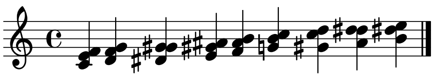
11 fifths
inv. 1

11 fifths
inv. 2



2

11 sus4



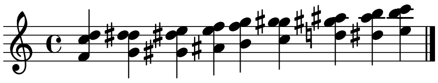
11 sus4
inv. 1

11 sus4
inv. 2

11 sus2

11 sus2
inv. 1

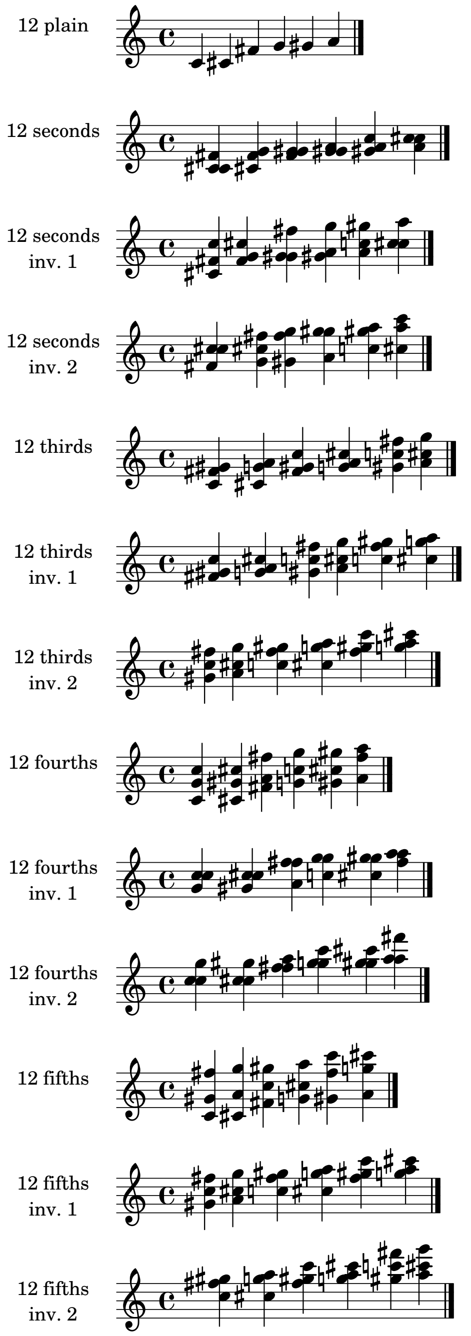
11 sus2
inv. 2



158 Characterizing mode (3)12

Mode (3)12

(binary key: 1100)



2

12 sus4

12 sus4
inv. 1

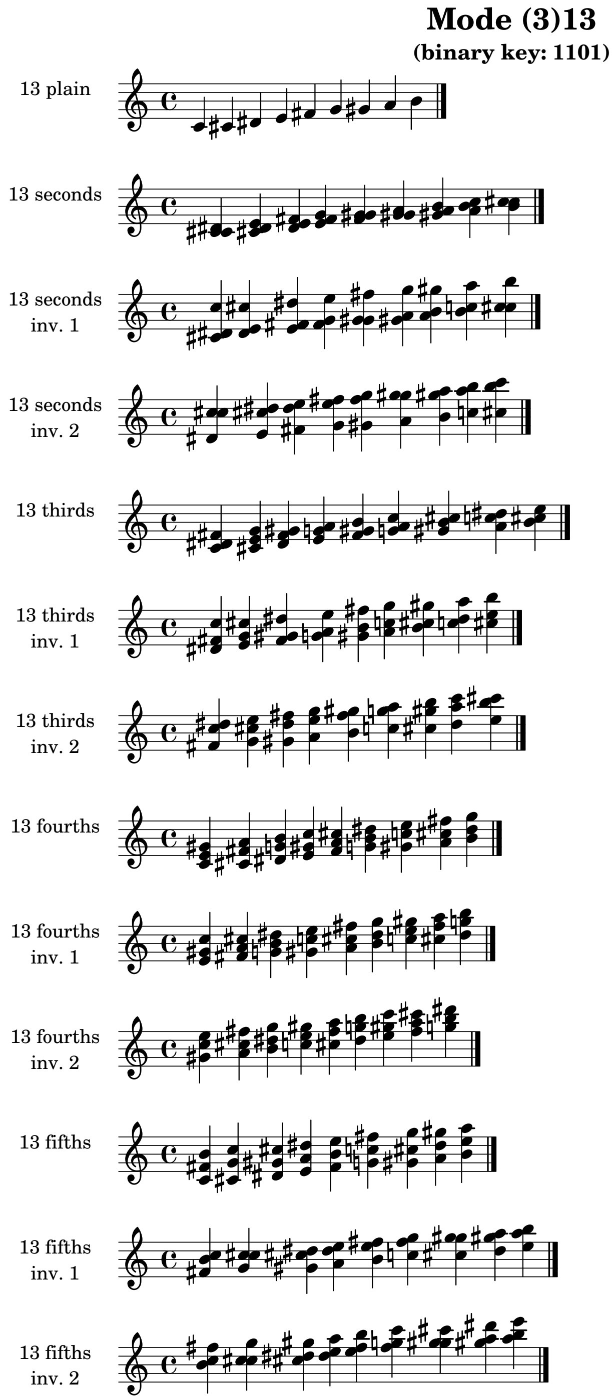
12 sus4
inv. 2

12 sus2

12 sus2
inv. 1

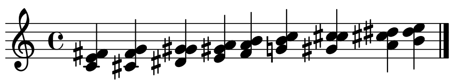
12 sus2
inv. 2

159 Characterizing mode (3)13



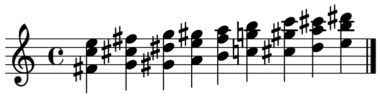
2

13 sus4

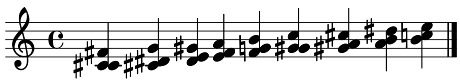


13 sus4
inv. 1

13 sus4
inv. 2



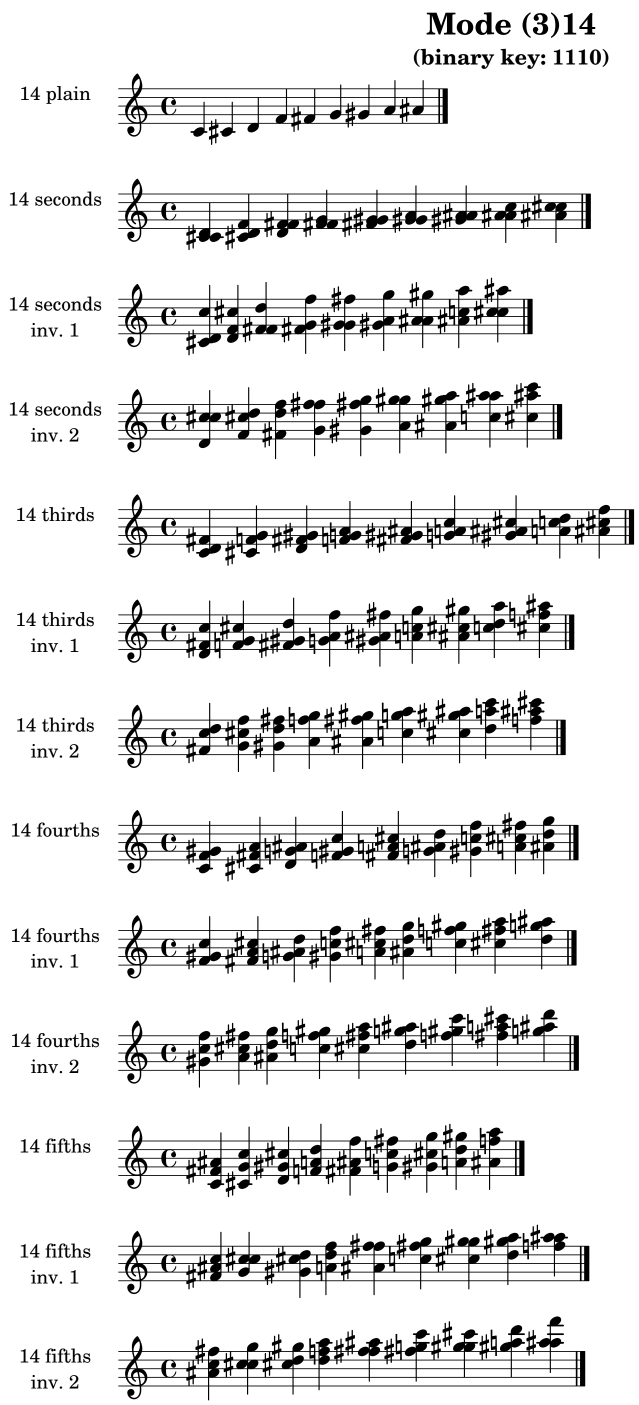
13 sus2



13 sus2
inv. 1

13 sus2
inv. 2

160 Characterizing mode (3)14



2

14 sus4

14 sus4
inv. 1

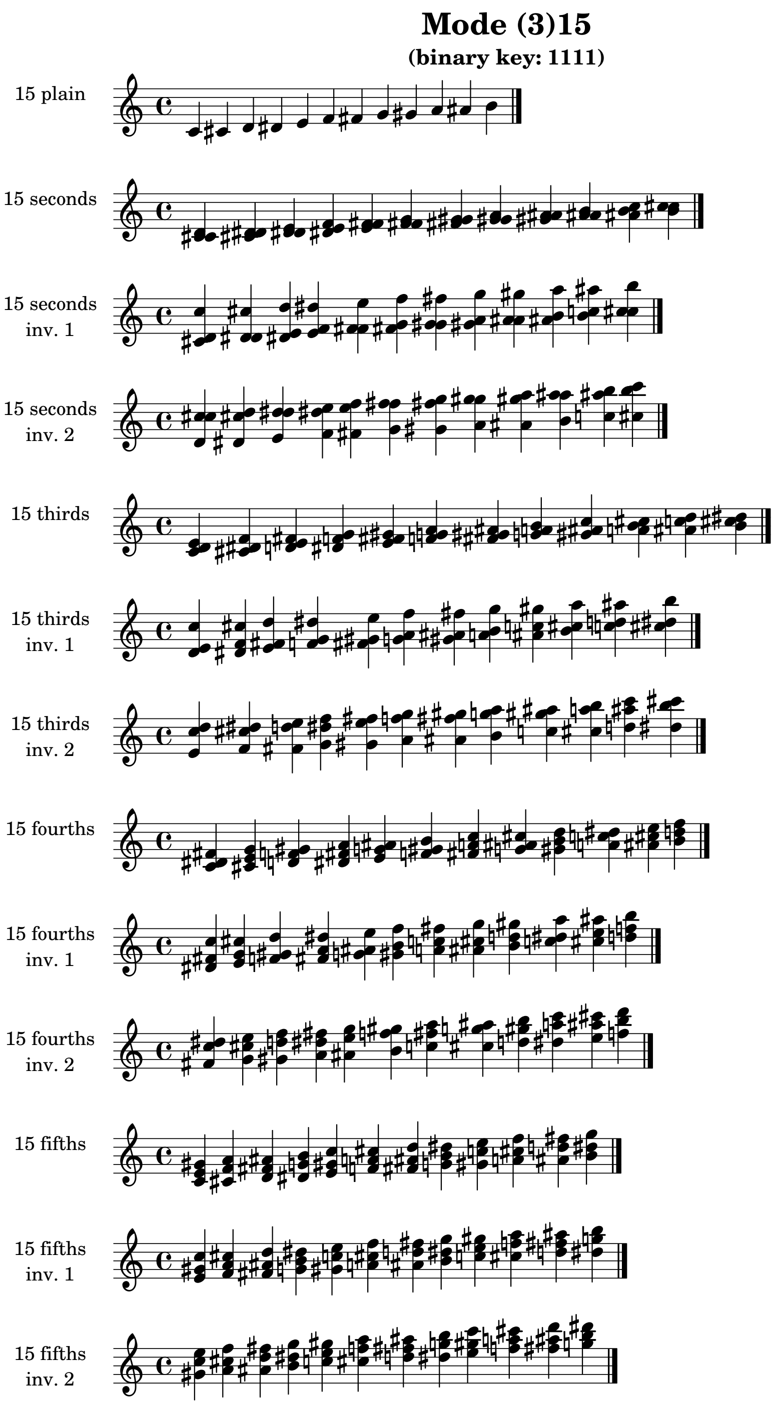
14 sus4
inv. 2

14 sus2

14 sus2
inv. 1

14 sus2
inv. 2

161 Characterizing mode (3)15



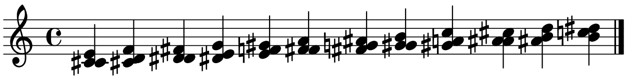
2

15 sus4

15 sus4
inv. 1

15 sus4
inv. 2

15 sus2



15 sus2
inv. 1

15 sus2
inv. 2