Canonical Combining Classes of Znamenny Notation Characters (revised)

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1. Background

In the original version of the proposal to encode Znamenny musical symbols (L2/19-053, Andreev and Simmons), the various combining marks used as part of the notation system were proposed with non-zero CCC values corresponding to their placement on and around base characters. This was later revised to make all such marks non-reorderable instead.

I propose reconsidering that decision.

2. Rationale

Canonical reordering is an important and powerful tool to allow Unicode-compliant applications to recognise and treat visually and semantically identical, but codepoint-wise different strings as being equivalent. As such, many scripts make generous use of this feature, with two main exceptions: Brahmic-type scripts, where all combining marks save for nuktas and viramas must be input in a strictly phonetic/linguistic order, and Sutton SignWriting, whose complex interplay of components and modifiers would have made designing a sensible encoding model built around non-zero CCCs next to impossible.

Making an entire writing system non-reorderable has its advantages; processing text becomes easier because all characters can always be assumed to be in canonical order even before it has been normalised. The downside is, however, that the normalisation algorithm can no longer fold "equivalent" sequences of combining characters into a common, canonical form, because such canonical form does not exist.

As a result, the UTC must decide in these cases which of these "equivalent" forms is the *actual*, canonical representation for any given sequence of characters – something the normalisation algorithm would have taken care of automatically otherwise – and implementations must be taught to reject all other "improper" representations, as having two non-equivalent forms of the same underlying message would be a catastrophe for security and searching purposes.

This manifests the most prominently in fonts for Indic scripts, where an incorrect order of combining marks causes ligatures to break and dotted circles to be displayed, signalling to the user that they have entered the text in the wrong order. The user simply has to learn what the one correct order expected by the Unicode Standard is, which isn't always obvious. This is different from, say, applying diacritical marks to Latin letters, where non-interacting diacritics can be input in any order without causing the string to become semantically malformed.

In Znamenny notation, combining marks are used on base neumes to represent properties like pitch, note length or other musical qualities. These properties form an unordered set and it would be

nonsensical to ascribe any kind of "priority" to each possible modifier – it cannot be said that, for example, the pitch of a note applies "before" or "after" its duration.

From an encoding perspective, this aspect of Znamenny notation is therefore comparable to the various stems, flags, dots, and diacritics of articulation in the Musical Symbols block. Consider this complex note:

Figure 1

In Unicode, this is represented as the following sequence:

- U+1D158 MUSICAL SYMBOL NOTEHEAD BLACK
- U+1D167 MUSICAL SYMBOL COMBINING TREMOLO-1 (CCC = Overlay)
- U+1D165 MUSICAL SYMBOL COMBINING STEM (CCC = Attached_Above_Right)
- U+1D17B MUSICAL SYMBOL COMBINING ACCENT (CCC = Below)
- U+1D16D MUSICAL SYMBOL COMBINING AUGMENTATION DOT (CCC = Right)

Because the four combining marks do not interact typographically with each other, they were rightfully assigned distinct CCC values. They can therefore be input in any order and normalisation will take care of the rest. The user does not need to remember that the tremolo must be entered before the stem – which is very unintuitive given the note's glyphic representation – or that the accent must necessarily precede the augmentation dot to form a valid sequence. Instead, all possible arrangements of these four marks are equally valid and fully equivalent under Unicode normalisation.

Let's compare this to a Znamenny example from page 28 of the original proposal:

Figure 2

The proposed Unicode representation of this note is:

- U+1CF51 ZNAMENNY NEUME KRYUK TIKHY

- U+1CF31 ZNAMENNY COMBINING TONAL RANGE MARK SVETLO

- U+1CF07 ᳇◌ ⟨π⟩ ZNAMENNY COMBINING MARK POVYSHE ON LEFT

- U+1CF27 ◌ ⟨ʌº⟩ ZNAMENNY COMBINING MARK LOMKA

All of these characters have a CCC value of 0 and so cannot be reordered in any way, even though once again none of the combining marks typographically interact. In other words, the above sequence is the *only* valid representation of that particular symbol. Arranging the combining marks in a different order, for example *svetlo + lomka + povyshe*, would theoretically produce exactly the same glyph and the resulting neume would have exactly the same meaning, but that sequence must never be used because none of these permutations are canonically equivalent.

Fonts and rendering engines would need to deliberately break the glyphs for these incorrect sequences (by inserting dotted circles or through similar measures) to let the user know that the text they have typed is malformed and does not mean anything as far as the Unicode Standard is concerned, which they had no way of predicting. In contrast to the encoding model used for Western musical notation, the user would therefore need to remember the exact prescribed order of combining marks every time they want to typeset Znamenny notation, which strikes me as a vastly inferior solution.

On page 15, the proposal states that neumes are "commonly" written in a certain order: Base neume, then tonal range markers, then other black modification marks, then cinnabar pitch marks, and finally other red modification marks. This is visualised with the following diagram:
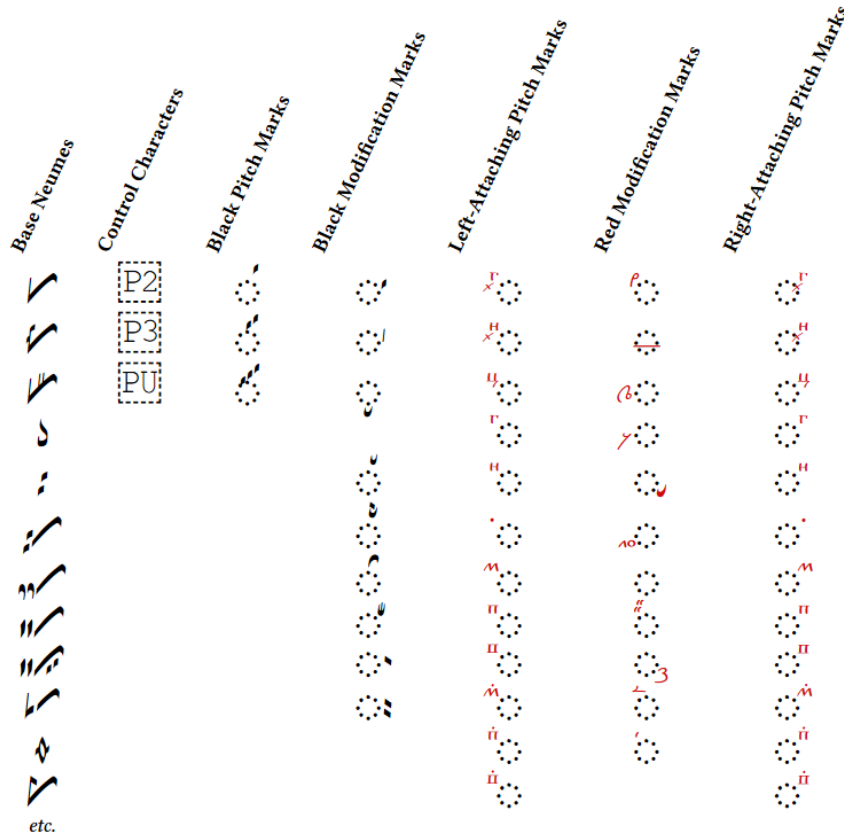

Figure 3

This proposed ordering is quite complex and groups marks in wildly different positions together. While the idea of ordering marks within a grapheme cluster primarily by function rather than by position is not per se bad, it is fundamentally at odds with how Unicode deals with combining characters in most other contexts through the use of canonical reordering.

Glyphic appearance is the important factor – the goal is after all to prevent visual confusables. This is why most CCC values correspond directly to where the mark is placed in relation to the base character; only the order of marks that interact typographically with each other can affect the appearance of the whole grapheme.

In my view, the order in which an actual scribe would write neumes with pen and paper is only of secondary relevance to the notation system's digital representation, as this is also never a concern elsewhere. A character like U+1E68 Ṩ Latin Capital Letter S with Dot Below and Dot Above may have its upper dot written before the lower one or the other way around varying from person to person and from situation to situation, but Unicode does not prescribe either order as the correct one and normalisation will treat both variants as fully equivalent to the precomposed letter. And again, the canonical representation of the Western musical note shown above has the tremolo mark encoded *before* the stem on which it rests, which no actual person would ever think to do on paper.

If Znamenny marks had non-zero CCC values, individual users could still input them in the order put forth by the proposal (or in any other order they see fit), but it would not be a requirement to memorise and enforce this exact sequence to produce a well-formed neume. The order of marks would then only matter when multiple signs in the same typographic position are applied to a base neume. In this case, the interacting marks would simply be stacked outwards from the base character or – for pitch marks – stacked diagonally from left to right as suggested by the authors on page 16.

3. Proposed Values

Looking through the large list of examples starting on page 28, I have found several sequences whose proposed order of codepoints I cannot explain based on the other information in the document, such as #82 and #85:
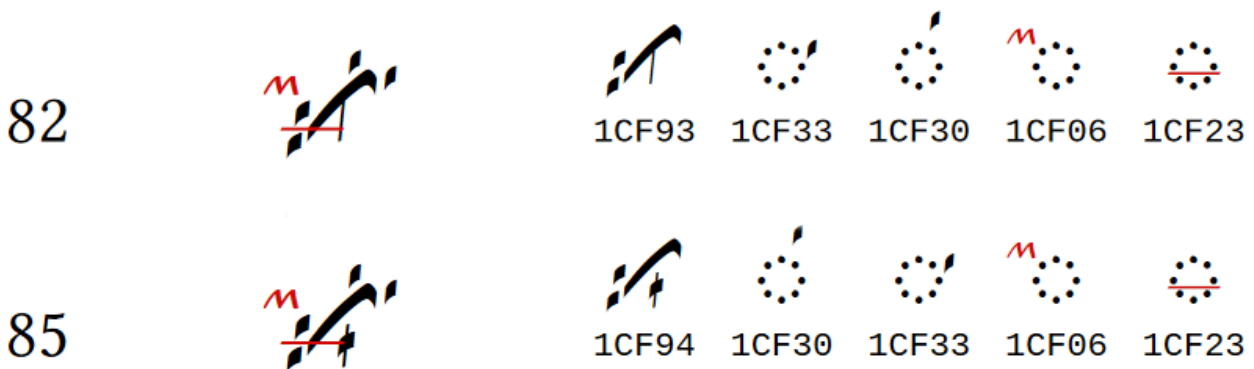

Figure 4

Here, both neumes use the same four combining marks, with only the order of U+1CF30 and U+1CF33 changing between them. However, there is no visual difference in the resulting glyph as

far as the combining marks are concerned, so the changed order seems to have been completely meaningless.

Because these two marks never interact with each other, their relative order should not matter, but that requires them to have distinct CCC values.

Examining all the example sequences, I have come to the conclusion that it is indeed possible to assign each combining character a non-zero CCC. In fact, most of them can be directly derived from the stand-alone sample glyphs provided in the proposal by simply observing where the mark is drawn in relation to the dotted circle placeholder.

- Black pitch marks are all *Above*.
- Black modification marks occupy a variety of classes depending on their position.
- Left-attaching pitch marks are all *Above_Left*.
- Red modification marks likewise occupy a variety of classes.
- Right-attaching pitch marks are all *Right*.

This approach will occasionally result in sequences where marks are *rendered* in places that are non-obvious from the alias assigned to their respective CCC. Notable examples are U+1CF24 ZNAMENNY COMBINING MARK BORZAYA and U+1CF25 ZNAMENNY COMBINING MARK UDARKA, which have a proposed CCC of *Below*, but are sometimes drawn to the left of the base neume. Another edge case is U+1CF29 ZNAMENNY COMBINING MARK KACHKA, which can appear both above and to the left of its base.

However, CCC aliases are merely abstractions and need not correspond directly to actual positions. There are other cases where the placements of combining marks is non-obvious, such as the aforementioned tremolo mark which appears above and to the right of the note head to match the stem despite being classified as an *Overlay*. Some Latin letters will also occasionally produce such apparent irregularities.

What is important is that my proposed ordering possesses the following properties:

- There is never a case where two characters with distinct CCCs interact typographically, meaning that their relative order to one another never has an effect on the appearance of the whole neume.
- There is never a case where two characters with identical CCCs can be input in a different order to one another without inducing some change in the final glyph. Of course, such rearrangements may not always have any defined meaning or ever occur in real writing.
- When two characters with identical CCCs appear on the same base neume, their relative placement is always predictable. If they are red pitch marks, they are stacked diagonally from left to right. Otherwise – with some exceptions that are particular to certain marks – they stack growing outwards from the base.

Whenever a black mark and a red mark occur in the same typographic position, the red mark is written after the black mark (i.e. further away from the base), both in the character stream and on actual paper.

The following values are proposed. Cinnabar marks are listed in red for convenience.

Overlay (1)

- U+1CF23   ⬚   ZNAMENNY COMBINING MARK TIKHAYA

Attached_Right (210)

Note that U+1CF40 *Kryzh* does not fully attach to all base neumes; one such exception is U+1CF56 *Stopitsa*. Several instances of *Kryzh* on the same neume also don't attach to each other, but likewise leave a small gap between individual glyphs.

It would be possible to merge these two characters into the *Right* class with other black modifying marks. This wouldn't affect encoded character order in practice, but it would allow the representation of additional sequences that are meaningless and never appear in actual use.

- U+1CF3E   ⬚   ZNAMENNY COMBINING ATTACHING VERTICAL OMET

- U+1CF40   ⬚   ZNAMENNY COMBINING MARK KRYZH

Below_Left (218)

While U+1CF27 *Lomka* is drawn above and to the right of the dotted circle in the code chart, in all the examples provided it occurs below and to the left. Aleksandr Andreev explained to me that its placement varies from source to source and that the original proposal followed a particular tradition where *Lomka* is always drawn below-left. When it appears on the right side instead, there are no other marks with which it can meaningfully interact there.

U+1CF41 *Lower Tonal Range Indicator* may be drawn centred below the base. Under very rare circumstances, it can occur on the same neume as U+1CF36 *Podchashie* (CCC=Below). However, these two characters never interact typographically.

- U+1CF27   ⬚   ZNAMENNY COMBINING MARK LOMKA

- U+1CF28   ⬚   ZNAMENNY COMBINING MARK KUPNAYA

- U+1CF41   ⬚   ZNAMENNY COMBINING LOWER TONAL RANGE INDICATOR

Below (220)

By default, U+1CF24 *Borzaya* and U+1CF25 *Udarka* are drawn below the base neume. However, if the base neume is shaped in such a way as to prevent placement below, or if U+1CF36 *Podchashie* is also present, *Borzaya* and *Udarka* get pushed to the left side of the neume instead.

Podchashie is a black mark and thus always written before the red marks *Borzaya* and *Udarka*, which would need to be reflected in the character stream. While the reverse order is not canonically equivalent, it never occurs in practice and has no defined glyphic appearance.

Borzaya and *Udarka* shifting position is unproblematic as there are no marks on the left side of the neume with which they exhibit interactions.

- U+1CF24 ZNAMENNY COMBINING MARK BORZAYA

- U+1CF25 ZNAMENNY COMBINING MARK UDARKA

- U+1CF36 ZNAMENNY COMBINING MARK PODCHASHIE

- U+1CF37 ZNAMENNY COMBINING MARK PODCHASHIE WITH VERTICAL STROKE

Below_Right (222)

While U+1CF2A *Zevok* is drawn above and to the right of the dotted circle in the code chart, in actual use it always appears below and to the right of the base neume. Andreev has confirmed to me that below-right is the standard usage and that the code chart glyph will probably be adjusted.

- U+1CF2A ZNAMENNY COMBINING MARK ZEVOK

Right (226)

This class includes all right-attaching pitch marks (U+1CF0C–U+1CF17), as well as one red modifying mark (U+1CF26). The remaining characters are black modifying marks.

U+1CF3C *Tochka*, U+1CF3D *Dvoetochie*, and U+1CF3F *Curved Omet* behave more or less identically to the black modifying marks in the *Attached_Right* class, but do not graphically attach to their base in the literal sense, so that CCC value seemed inappropriate.

In the presence of U+1CF3B *Sorochya Nozhka*, the right-attaching pitch marks are sometimes drawn above the base neume. In these cases, they are differentiated from the left-attaching pitch marks by being drawn further to the right. This doesn't always happen, but *Sorochya Nozhka* being a black mark, it is always encoded before the red pitch marks either way. The position of *Sorochya Nozhka* itself varies from neume to neume, but it does not interact with any other characters.

U+1CF26 *Podvertka* exhibits variable placement, appearing to the right, below-right or directly below the base. *Right* was chosen as its CCC because it only interacts with other characters of that particular class.

- U+1CF0C ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZHEM ON RIGHT

- U+1CF0D ZNAMENNY COMBINING MARK NIZKO S KRYZHEM ON RIGHT

- U+1CF0E ZNAMENNY COMBINING MARK TSATA ON RIGHT

- U+1CF0F ZNAMENNY COMBINING MARK GORAZDO NIZKO ON RIGHT

- U+1CF10 ZNAMENNY COMBINING MARK NIZKO ON RIGHT

- U+1CF11 ZNAMENNY COMBINING MARK SREDNE ON RIGHT

- U+1CF12 ZNAMENNY COMBINING MARK MALO POVYSHE ON RIGHT

- U+1CF13 ◌ᵖ ZNAMENNY COMBINING MARK POVYSHE ON RIGHT
- U+1CF14 ◌ᵖ ZNAMENNY COMBINING MARK VYSOKO ON RIGHT
- U+1CF15 ◌ᴍ̇ ZNAMENNY COMBINING MARK MALO POVYSHE S KHOKHLOM ON RIGHT
- U+1CF16 ◌ᴨ̈ ZNAMENNY COMBINING MARK POVYSHE S KHOKHLOM ON RIGHT
- U+1CF17 ◌ᴨ̈ ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON RIGHT
- U+1CF26 ◌ᵤ ZNAMENNY COMBINING MARK PODVERTKA
- U+1CF3B ◌ᵤ ZNAMENNY COMBINING MARK SOROCHYA NOZHKA
- U+1CF3C ◌ᴖ ZNAMENNY COMBINING MARK TOCHKA
- U+1CF3D ◌ᴦ ZNAMENNY COMBINING MARK DVOETOCHIE
- U+1CF3F ◌ᴵ ZNAMENNY COMBINING MARK CURVED OMET

Above_Left (228)

- U+1CF00 ᴦ×◌ ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZHEM ON LEFT
- U+1CF01 ᴨ×◌ ZNAMENNY COMBINING MARK NIZKO S KRYZHEM ON LEFT
- U+1CF02 ᴜ◌ ZNAMENNY COMBINING MARK TSATA ON LEFT
- U+1CF03 ᴦ◌ ZNAMENNY COMBINING MARK GORAZDO NIZKO ON LEFT
- U+1CF04 ᴨ◌ ZNAMENNY COMBINING MARK NIZKO ON LEFT
- U+1CF05 ᐧ◌ ZNAMENNY COMBINING MARK SREDNE ON LEFT
- U+1CF06 ᴹ◌ ZNAMENNY COMBINING MARK MALO POVYSHE ON LEFT
- U+1CF07 ᴨ◌ ZNAMENNY COMBINING MARK POVYSHE ON LEFT
- U+1CF08 ᴨ◌ ZNAMENNY COMBINING MARK VYSOKO ON LEFT
- U+1CF09 ᴹ̇◌ ZNAMENNY COMBINING MARK MALO POVYSHE S KHOKHLOM ON LEFT
- U+1CF0A ᴨ̈◌ ZNAMENNY COMBINING MARK POVYSHE S KHOKHLOM ON LEFT

- U+1CF0B ⬤ ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON LEFT
- U+1CF18 ⬤ ZNAMENNY COMBINING MARK TSATA S KRYZHEM
- U+1CF19 ⬤ ZNAMENNY COMBINING MARK MALO POVYSHE S KRYZHEM
- U+1CF1A ⬤ ZNAMENNY COMBINING MARK STRANNO MALO POVYSHE
- U+1CF1B ⬤ ZNAMENNY COMBINING MARK POVYSHE S KRYZHEM
- U+1CF1C ⬤ ZNAMENNY COMBINING MARK POVYSHE STRANNO
- U+1CF1D ⬤ ZNAMENNY COMBINING MARK VYSOKO S KRYZHEM
- U+1CF1E ⬤ ZNAMENNY COMBINING MARK MALO POVYSHE STRANNO
- U+1CF1F ⬤ ZNAMENNY COMBINING MARK GORAZDO VYSOKO
- U+1CF20 ⬤ ZNAMENNY COMBINING MARK ZELO
- U+1CF21 ⬤ ZNAMENNY COMBINING MARK ON
- U+1CF22 ⬤ ZNAMENNY COMBINING MARK RAVNO
- U+1CF2D ⬤ ZNAMENNY COMBINING MARK KRYZH
- U+1CF34 ⬤ ZNAMENNY COMBINING MARK DEMESTVENNY ZADERZHKA

Above (230)

U+1CF29 *Kachka* sometimes exhibits variable placement, similar to U+1CF27 *Lomka*. In some examples it is drawn to the left of the neume, but there exist no other marks with which it ever interacts while in that position.

- U+1CF29 ⬤ ZNAMENNY COMBINING MARK KACHKA
- U+1CF2B ⬤ ZNAMENNY COMBINING MARK SKOBA
- U+1CF2C ⬤ ZNAMENNY COMBINING MARK RAZSEKA
- U+1CF30 ⬤ ZNAMENNY COMBINING TONAL RANGE MARK MRACHNO
- U+1CF31 ⬤ ZNAMENNY COMBINING TONAL RANGE MARK SVETLO
- U+1CF32 ⬤ ZNAMENNY COMBINING TONAL RANGE MARK TRESVETLO
- U+1CF38 ⬤ ZNAMENNY COMBINING MARK CHASHKA

- U+1CF39 ⃝ ZNAMENNY COMBINING MARK CHASHKA POLNAYA

- U+1CF3A ⃝ ZNAMENNY COMBINING MARK OBLACHKO

Above_Right (232)

- U+1CF33 ⃝ ZNAMENNY COMBINING MARK ZADERZHKA

- U+1CF35 ⃝ ZNAMENNY COMBINING MARK OTSECHKA

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1CF00;ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZHEM ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF01;ZNAMENNY COMBINING MARK NIZKO S KRYZHEM ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF02;ZNAMENNY COMBINING MARK TSATA ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF03;ZNAMENNY COMBINING MARK GORAZDO NIZKO ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF04;ZNAMENNY COMBINING MARK NIZKO ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF05;ZNAMENNY COMBINING MARK SREDNE ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF06;ZNAMENNY COMBINING MARK MALO POVYSHE ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF07;ZNAMENNY COMBINING MARK POVYSHE ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF08;ZNAMENNY COMBINING MARK VYSOKO ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF09;ZNAMENNY COMBINING MARK MALO POVYSHE S KHOKHLOM ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF0A;ZNAMENNY COMBINING MARK POVYSHE S KHOKHLOM ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF0B;ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF0C;ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZHEM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF0D;ZNAMENNY COMBINING MARK NIZKO S KRYZHEM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF0E;ZNAMENNY COMBINING MARK TSATA ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF0F;ZNAMENNY COMBINING MARK GORAZDO NIZKO ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF10;ZNAMENNY COMBINING MARK NIZKO ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF11;ZNAMENNY COMBINING MARK SREDNE ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF12;ZNAMENNY COMBINING MARK MALO POVYSHE ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF13;ZNAMENNY COMBINING MARK POVYSHE ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF14;ZNAMENNY COMBINING MARK VYSOKO ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF15;ZNAMENNY COMBINING MARK MALO POVYSHE S KHOKHLOM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF16;ZNAMENNY COMBINING MARK POVYSHE S KHOKHLOM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF17;ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF18;ZNAMENNY COMBINING MARK TSATA S KRYZHEM;Mn;228;NSM;;;;N;;;;;
1CF19;ZNAMENNY COMBINING MARK MALO POVYSHE S KRYZHEM;Mn;228;NSM;;;;N;;;;;
1CF1A;ZNAMENNY COMBINING MARK STRANNO MALO POVYSHE;Mn;228;NSM;;;;N;;;;;
1CF1B;ZNAMENNY COMBINING MARK POVYSHE S KRYZHEM;Mn;228;NSM;;;;N;;;;;
1CF1C;ZNAMENNY COMBINING MARK POVYSHE STRANNO;Mn;228;NSM;;;;N;;;;;
1CF1D;ZNAMENNY COMBINING MARK VYSOKO S KRYZHEM;Mn;228;NSM;;;;N;;;;;
1CF1E;ZNAMENNY COMBINING MARK MALO POVYSHE STRANNO;Mn;228;NSM;;;;N;;;;;
1CF1F;ZNAMENNY COMBINING MARK GORAZDO VYSOKO;Mn;228;NSM;;;;N;;;;;
1CF20;ZNAMENNY COMBINING MARK ZELO;Mn;228;NSM;;;;N;;;;;
1CF21;ZNAMENNY COMBINING MARK ON;Mn;228;NSM;;;;N;;;;;
1CF22;ZNAMENNY COMBINING MARK RAVNO;Mn;228;NSM;;;;N;;;;;
1CF23;ZNAMENNY COMBINING MARK TIKHAYA;Mn;1;NSM;;;;N;;;;;
1CF24;ZNAMENNY COMBINING MARK BORZAYA;Mn;220;NSM;;;;N;;;;;
1CF25;ZNAMENNY COMBINING MARK UDARKA;Mn;220;NSM;;;;N;;;;;
1CF26;ZNAMENNY COMBINING MARK PODVERTKA;Mn;226;NSM;;;;N;;;;;
1CF27;ZNAMENNY COMBINING MARK LOMKA;Mn;218;NSM;;;;N;;;;;
1CF28;ZNAMENNY COMBINING MARK KUPNAYA;Mn;218;NSM;;;;N;;;;;
1CF29;ZNAMENNY COMBINING MARK KACHKA;Mn;230;NSM;;;;N;;;;;
1CF2A;ZNAMENNY COMBINING MARK ZEVOK;Mn;222;NSM;;;;N;;;;;
1CF2B;ZNAMENNY COMBINING MARK SKOBA;Mn;230;NSM;;;;N;;;;;
1CF2C;ZNAMENNY COMBINING MARK RAZSEKA;Mn;230;NSM;;;;N;;;;;
1CF2D;ZNAMENNY COMBINING MARK KRYZH;Mn;228;NSM;;;;N;;;;;
1CF30;ZNAMENNY COMBINING TONAL RANGE MARK MRACHNO;Mn;230;NSM;;;;N;;;;;
1CF31;ZNAMENNY COMBINING TONAL RANGE MARK SVETLO;Mn;230;NSM;;;;N;;;;;
1CF32;ZNAMENNY COMBINING TONAL RANGE MARK TRESVETLO;Mn;230;NSM;;;;N;;;;;
1CF33;ZNAMENNY COMBINING MARK ZADERZHKA;Mn;232;NSM;;;;N;;;;;
1CF34;ZNAMENNY COMBINING MARK DEMESTVENNY ZADERZHKA;Mn;228;NSM;;;;N;;;;;
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1CF35;ZNAMENNY COMBINING MARK OTSECHKA;Mn;232;NSM;;;;N;;;;;
1CF36;ZNAMENNY COMBINING MARK PODCHASHIE;Mn;220;NSM;;;;N;;;;;
1CF37;ZNAMENNY COMBINING MARK PODCHASHIE WITH VERTICAL STROKE;Mn;220;NSM;;;;N;;;;;
1CF38;ZNAMENNY COMBINING MARK CHASHKA;Mn;230;NSM;;;;N;;;;;
1CF39;ZNAMENNY COMBINING MARK CHASHKA POLNAYA;Mn;230;NSM;;;;N;;;;;
1CF3A;ZNAMENNY COMBINING MARK OBLACHKO;Mn;230;NSM;;;;N;;;;;
1CF3B;ZNAMENNY COMBINING MARK SOROCHYA NOZHKA;Mn;226;NSM;;;;N;;;;;
1CF3C;ZNAMENNY COMBINING MARK TOCHKA;Mn;226;NSM;;;;N;;;;;
1CF3D;ZNAMENNY COMBINING MARK DVOETOCHIE;Mn;226;NSM;;;;N;;;;;
1CF3E;ZNAMENNY COMBINING ATTACHING VERTICAL OMET;Mn;210;NSM;;;;N;;;;;
1CF3F;ZNAMENNY COMBINING MARK CURVED OMET;Mn;226;NSM;;;;N;;;;;
1CF40;ZNAMENNY COMBINING MARK KRYZH;Mn;210;NSM;;;;N;;;;;
1CF41;ZNAMENNY COMBINING LOWER TONAL RANGE INDICATOR;Mn;218;NSM;;;;N;;;;;
```

4. Changes

The following changes have been made to this encoding model from the previous iteration:

- The numerical value associated with CCC *Attached_Right* was corrected from 208 to 210 in accordance with section 5.7.4 of UAX #44.

- The CCC of U+1CF3F *Curved Omet* was changed from *Attached_Right* to *Right*. This has no bearing on character order in practice, but better describes the character's glyphic behaviour.

- The CCC of U+1CF2A *Zevok* was changed from *Above_Right* to *Below_Right*. The original value was a mistake, as *Zevok* never interacts with other characters in the *Above_Right* class.

- The CCC of U+1CF24 *Borzaya* and U+1CF25 *Udarka* was changed from *Left* to *Below.* These two characters can appear in either position depending on the shape of the base neume, but also based on whether a U+1CF36 *Podchashie* is present or not. Since this technically means that *Borzaya* and *Udarka* interact typographically with *Podchashie*, they were merged into the same CCC.

- The CCC of U+1CF2D *Kryzh* was changed from *Left* to *Above_Left* because the character has interactions with the left-aligned pitch marks. This value is preferred by Aleksandr Andreev. As a consequence of this change, there will no longer be any Znamenny characters belonging to class *Left*.

- The CCC of U+1CF26 *Podvertka* was changed from *Below_Right* to *Right*. While its placement can be highly variable, it reacts directly to the presence of other marks in the *Right* class. However, there is no case where *Podvertka* can meaningfully change places with another *Right* character, so in actual use it will always be encoded before any other red *Right* marks.

- The CCC of U+1CF3B *Sorochya Nozhka* was changed from *Above_Right* to *Right* because its presence can cause other *Right* characters – namely the right-attached pitch marks – to shift to a different position in some cases.

5. Case Studies

The following are several examples demonstrating some of the more complex interactions between Znamenny combining marks. In every case, the fixed order of marks put forth by the original proposal is canonically equivalent to a well-formed (i.e. meaningful and graphically well-defined) sequence if the proposed CCC values are used.
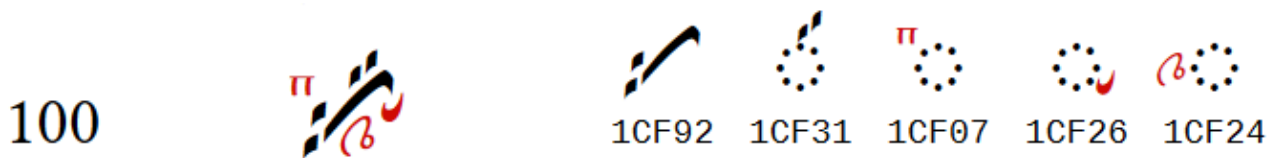
100

1CF92 1CF31 1CF07 1CF26 1CF24

Figure 5

Canonical order:

- U+1CF92 *Strela Prostaya* (0: Not_Reordered)

- U+1CF24 *Borzaya* (220: Below)

- U+1CF26 *Podvertka* (226: Right)

- U+1CF07 *Povyshe on Left* (228: Above_Left)

- U+1CF31 *Tonal Range Mark Svetlo* (230: Above)
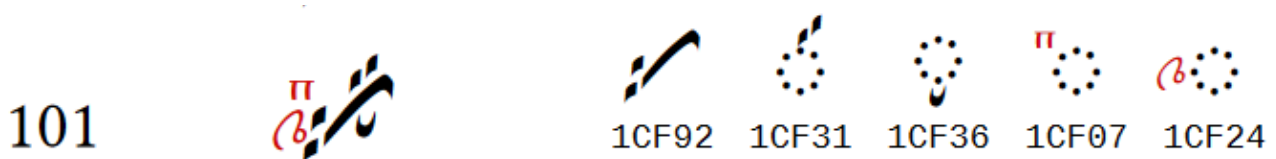
By default, *Borzaya* rests directly below the base neume.

101

1CF92 1CF31 1CF36 1CF07 1CF24

Figure 6

Canonical order:

- U+1CF92 *Strela Prostaya* (0: Not_Reordered)

- U+1CF36 *Podchashie* (220: Below)

- U+1CF24 *Borzaya* (220: Below)

- U+1CF07 *Povyshe on Left* (228: Above_Left)

- U+1CF31 *Tonal Range Mark Svetlo* (230: Above)

Because *Podchashie* is present, *Borzaya* gets pushed to the left side of the neume. *Podchashie* is a black mark and therefore always encoded before the red mark *Borzaya* in the same typographic position. The inverse order never occurs in practice and is undefined.

259   Mechik Klyuchepovodny with Podvertka

Figure 7

Canonical order:

- U+1CFAA *Mechik Klyuchepovodny* (0: Not_Reordered)

- U+1CF26 *Podvertka* (226: Right)

- U+1CF11 *Sredne on Right* (226: Right)

- U+1CF08 *Vysoko on Left* (228: Above_Left)

- U+1CF29 *Kachka* (230: Above)

While it isn't obvious at first given their code chart glyphs, modifying mark *Podvertka* and pitch mark *Sredne on Right* do indeed occupy the same typographic position. The presence of the former causes to latter to be drawn further away from the base neume. The inverse order never occurs in practice and is undefined.
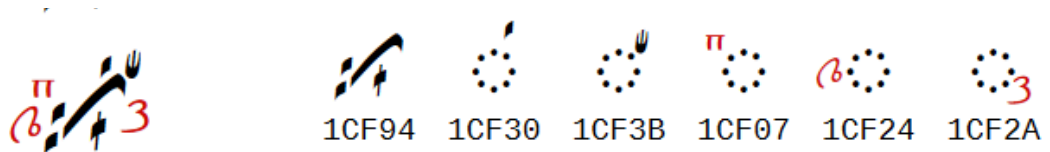
88

Figure 8

Canonical order:

- U+1CF94 *Strela Kryzhevaya* (0: Not_Reordered)

- U+1CF24 *Borzaya* (220: Below)

- U+1CF2A *Zevok* (222: Below_Right)

- U+1CF3B *Sorochya Nozhka* (226: Right)

- U+1CF07 *Povyshe on Left* (228: Above_Left)

- U+1CF30 *Tonal Range Mark Mrachno* (230: Above)

The lower element of the base neume leaves no room for *Borzaya*, which gets pushed to the left side even in the absence of *Podchashie*. On this particular neume, *Sorochya Nozhka* visually appears above-right, but on other neumes it could also be centred above or directly right. *Zevok* is drawn below-right despite its misleading code chart glyph.
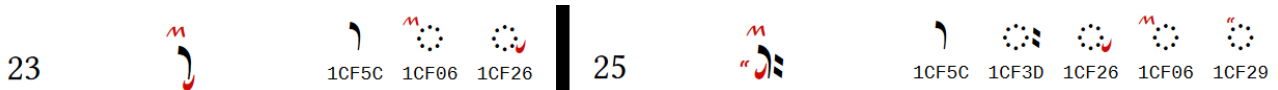
23   1CF5C   1CF06   1CF26 | 25   1CF5C   1CF3D   1CF26   1CF06   1CF29

Figure 9

Canonical order:

- U+1CF5C ⌐ *Palka* (0: Not_Reordered)

- U+1CF26 *Podvertka* (226: Right)

- U+1CF06 *Malo Povyshe on Left* (228: Above_Left)

Canonical order:

- U+1CF5C ⌐ *Palka* (0: Not_Reordered)

- U+1CF3D *Dvoetochie* (226: Right)

- U+1CF26 *Podvertka* (226: Right)

- U+1CF06 *Malo Povyshe on Left* (228: Above_Left)

- U+1CF29 *Kachka* (230: Above)

On this particular neume, *Podvertka* is drawn below by default despite being classified as *Right*. However, when fellow *Right* mark *Dvoetochie* is also present, *Podvertka* interacts with it and shifts to a different position.

Note also the instance of *Kachka* appearing to the left of the base neume in this example. This is not caused by typographic interaction with *Malo Povyshe on Left* (*Kachka* never interacts with left-attached pitch marks), but rather a feature of the particular type of notation that these examples were derived from.
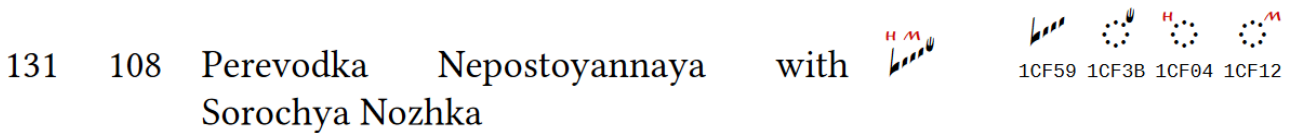

131   108   Perevodka   Nepostoyannaya   with   1CF59 1CF3B 1CF04 1CF12

Figure 10

Canonical order:

- U+1CF59 *Perevodka Nepostoyannaya* (0: Not_Reordered)

- U+1CF3B *Sorochya Nozhka* (226: Right)

- U+1CF12 *Malo Povyshe on Right* (226: Right)

- U+1CF04 *Nizko on Left* (228: Above_Left)

Malo Povyshe on Right shifts to an upper position due to the presence of *Sorochya Nozhka*, which would not have happened with other right-aligned marks such as U+1CF3F *Curved Omet*. Due to this, the left-attached pitch mark *Nizko* and the right-attached pitch mark *Malo Povyshe* now appear closer together. If both were left-attached instead, they would be stacked diagonally upwards.

211	136	Strela Dvoechelnaya with Kryzh and Sorochya Nozhka

1CF9B 1CF40 1CF3B 1CF06 1CF22 1CF07 1CF12

Figure 11

Canonical order:

- U+1CF9B *Strela Dvoechelnaya* (0: Not_Reordered)

- U+1CF40 *Kryzh* (210: Attached_Right)

- U+1CF3B *Sorochya Nozhka* (226: Right)

- U+1CF12 *Malo Povyshe on Right* (226: Right)

- U+1CF06 *Malo Povyshe on Left* (228: Above_Left)

- U+1CF22 *Ravno* (228: Above_Left)

- U+1CF07 *Povyshe on Left* (228: Above_Left)

In this example, *Malo Povyshe on Right* does not get pushed to an upper position by *Sorochya Nozhka*, instead remaining on the right. Without cases such as the previous one, it would not be obvious that these two marks can interact at all.

The three left-aligned pitch marks exhibit their default behaviour of stacking diagonally from left to right.