ROSALIND UNRAVELS

THE BUNDLE OF LIFE

AD HONOREM

ROSALIND FRANKLIN

JORDAN ALEXANDER KEY

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ROSALIND UNRAVELS THE BUNDLE OF LIFE

FOR
ANNE LAVER

Duration: c. 9”

Summer, 2021

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Rosalind Franklin:

Rosalind Franklin (1920 – 1958) was a British chemist and X-ray crystallographer, whose pioneering work was pivotal to our present understanding of the molecular structure of DNA, as well as RNA, viruses, coal, and graphite. Rosalind is best known now for her work on the X-ray diffraction imaging of DNA crystals during her time at Kind's College in London. Her X-ray diffraction pattern, Photo-51, was the image that ultimately led to the deduction that DNA has a double helix structure.

Rosalind's significant contributions to the discovery of the structure of DNA were largely unrecognized during her life, her work and data having been taken, used, and uncredited by the commonly recognized scientists James Watson (b. 1928) and Francis Crick (1916 – 2004), who were jointly awarded the Nobel Prize for Medicine in 1962, along with Maurice Wilkins, "for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material."

Rosalind's contributions in deciphering the structure of DNA also went unrecognized by the Nobel Prize committee. Franklin was dead by the 1962 Nobel Prize award. The current rules prohibiting posthumous nominations or splitting the Prizes more than three ways were not extant until 1974, thus allowing the Prize committees to nominate Rosalind anytime between 1962 and 1974. However, the seminal papers of Watson and Crick did not properly cite Rosalind's work and so few people knew of her contributions until much later.

Beginning in 1975, Rosalind Franklin's contributions have been publicized and vindicated. Watson and Crick, despite their highly questionable research and citation practices and perhaps conscious exploitations of a disempowered female colleague, still hold the recognition of the Nobel Prize and title "discovers of DNA."

Rosalind Franklin died in 1958 at the age of 37 from ovarian cancer contracted from working intimately with radioactive materials during her work in X-ray crystallography. Both Watson and Crick have lived long and productive lives, Francis Crick lived to 88 and James Watson is still alive at the age of 93. Likely, their longevity owes to not having had to work with highly radioactive X-ray technology during the mid 20th-century to make their "discovery."

The inscription on her tombstone reads:

IN MEMORY OF
ROSALIND ELSIE FRANKLIN
DEARLY LOVED ELDER DAUGHTER OF
ELLIS AND MURIEL FRANKLIN
25TH JULY 1920 – 16TH APRIL 1958
SCIENTIST
HER RESEARCH AND DISCOVERIES ON
VIRUSES REMAIN OF LASTING BENEFIT
TO MANKIND
ת נ צ ב ה

The final characters on the tombstone are the Hebrew initials for “her soul shall be bound in the bundle of life.”

Story of the Music:

This work, *Rosalind Unravels the Bundle of Life*, was written for organist Anne Laver and was originally intended for performance on the Italian Baroque Organ at the Memorial Art Gallery at the Eastman School of Music (further information about the organ given below), though this piece can be played on any organ. The form of the work is intimately tied to both the program of Rosalind's contributions to the discovery of DNA's helical structure and to the tuning of the pipe organ itself. The title of the work is referential to the epitaph on Rosalind Franklin's tombstone.

The form of the work generally is taken from the rather obscure 15th and 16th century form of a "modal spiral," wherein through a progressive application of *musica ficta* one modulates either one semitone up or down by the conclusion of the piece. This odd modal modulation is necessitated by an initial, carefully placed contrapuntal moment, wherein if one chooses to apply some seemingly logical or necessary *ficta* to one note often to avoid a tritone harmony) another ficta is required on some nearby subsequent note, which itself will necessitate another *ficta* on some subsequent note. This domino effect of *ficta* continues until the end of the work, by which time all flats are either flattened or sharpened. Pieces of this style tend to follow progression of flats and modulate from some modal center of C or G to some center on C-flat (B) or G-flat (F-sharp). The pieces are rarely (perhaps only one know example) notated with the *ficta* given; these conceits are often obscured and only suggested by the text (title or lyrics), shape of the music given (as in the circular work *Salve Radix*), and/or by some canonic key. This conceit gives the work a modal "spiral" progression, spiraling around the circle of 4ths, and hence the name "modal spiral."

We, however, are not dealing with spirals in this work, but helices. Thus, this work has two contrasting spirals, one moving forward through the piece and one moving backwards. Though we will not hear the piece played backwards, the modal scaffolding of the work presents two intertwining modal layers. At times, one layer will be more present than the other, but occasionally both appear together in equal proportion, creating moments of high pitch density and dissonance. Consequently, the harmonic scheme of the work follows two intertwined and chirally opposed modal spirals, namely a "modal helix."

In addition to these two contrasting modal spirals, this work also presents two intertwined and contrasting rhythmic layers, which emerge both through cross-related, indivisible accent patterns and through the alternation between two tempos, which are related through a dectadic rhythmic hierarchy.

This helical, modulatory form was selected due to the tuning of the pipe organ, which is not in equal temperament. Thus, "key signatures" distal from C-major will sound very "out of tune." Consequently, the work slowly progresses us from something that will sound highly "in tune" to something that sounds highly "out of tune:" G-major/mixolydian to F-sharp (G-flat) major/mixolydian. In my mind, this progression from a harmonic space familiar to us ("in tune") to a space that is perhaps wholly alien sounding ("out of tune"), stands as a musical counterpart to X-ray crystallography.

In X-ray crystallography, one takes images that are simple geometric projections of more complex structures; these simple images, taken from various angles and giving various projections, must then be collectively interpreted to understand the 3-dimensional structure of an object that is not directly or easily observable. For example, the famous Photo-51 is not a helical image but an X-shape. It takes much experience as an X-ray crystallographer and understanding of the chemical structure of crystals to know that such a shape is indicative of a helix.

Thus, when we see or when Rosalind saw Photo-51, we are only seeing a projection, something that only points to the complete reality of something but does not and cannot give us a complete representation of it. To get a better understanding of the real object itself, we must take many projections (or have foreknowledge of many projections) and consider them collectively.

Similarly, a tuning system is like a complex crystalline structure, and a key (or mode) is only a particular projection of that pitch space, which itself is only one possible pitch space (or crystalline structure) possible in the universe of pitch. Thus, we can take a projection of our pitch space, let's say G-major; given the pitch space we are imaging, G-major is clear and seemingly understandable, but taken from another vantage point, let's say F-sharp major, the image is very different and seemingly unrelated, though both are projections of the same pitch object. To understand all this pitch space, we need to take and compare each projection, each key/mode progressively, juxtapositionally, and collectively. Ultimately, our

pitch space resides behind these projections, and the universe of all possible pitch spaces is behind this singular crystalline pitch structure, which itself is merely a one configuration or metaphorical projection of all possible pitch spaces.

Photo-51 is only one projection of a vastly dense and complex 3-dimensional structure. Similarly, when we listen to the harmonic transformation of this organ from “in tune” to “out of tune,” we are observing singular projections, sometimes in succession and sometimes in juxtaposition, of a vastly more complex structure, which itself is not as easily observable. As Rosalind unraveled the mystery of life through the lens of X-ray projections of a crystal, we similarly unravel the life of an instrument through the various projections of its inner, metaphorical DNA that determines all its pitch capabilities: melody, harmony, counterpoint, mode, ambitus, and timbre. We cannot necessarily see the mechanisms (physical or mathematical) that give it such a “crystalline” structure, but we can indirectly observe the crystal through the projections of various tonalities and modalities.

The Instrument:

The pipe organ is owned by the Eastman School of Music and is placed in the Fountain court of the University of Rochester's Memorial Art Gallery.

Size: 22' tall, 9' wide, 600 pipes
Builder: unknown, c. 1770

At the time of this composition, it is the only full-sized Italian baroque organ in North America. The keyboard has been kept in the condition in which it was found, therefore one can see the feel the grooves of centuries of fingers playing on it. It is representative of a typical Italian organ.

Characteristics:

- One manual
- Small pedalboard with short octave (see below)
- A single (spring or slider) windchest
- Limited number of stops
- Soft vocal sound of Principal 8' (the aesthetic was close to the vocal repertory)

Specifications, 14 stops:

Manual: C2 to C6

- Principale bassi 8'
- Principale soprano 8'
- Ottava 4'
- Decimaquinta 2' (reconstructed pipes)
- Decimanona 1 1/3'
- Vigesima Seconda 1'
- Vigesima Sesta e Nona 1/2' and 1/3'
- Flauto in ottava 4'
- Flauto in duodecima 2 2/3'
- Flauto in XVII 1 3/5' (from F2)
- Voce Umana (from D2)
- Tromboncini bassi
- Tromboncini soprani

Pedal: C2 to G3 (lowest 6th has no accidentals, accidentals begin at A#2)

- Contrabassi 16’
- Tamburo (C#3, D#3, F#3, G#3)

Tiratutti (Ripieno)
Uccelliera

More information can be found here:
https://www.esm.rochester.edu/organ/instruments/italian-baroque/

Notes on Registration and Notation:

REGISTRATION

Though this piece is written for a very particular instrument, given I wish the work would be potentially performed on any organ, there are no particular registrations suggested. However, I will give some general suggestions, which may or may not be taken into consideration. Ultimately, I trust the taste and orchestration capabilities of the organist.

Suggestions:

1. General comments applicable to any organ:
    a. All staccato marks need to be taken into consideration with the instrument and space. The staccato should not sound too short as to sound foreshortened or awkwardly terse. There should simply be a sense of *detaché* playing on repeated notes or where there are staccato markings. Where there are slurs, one should play less *detaché and more legato.* Naturally, the shortness of the staccatos and the degree of attachment in the slurs will vary depending on the reverberance of the space.
    b. Where there are tenuto markings, the note should be ever so slightly stretched. It should not feel artificial, but like a slight and natural *rubato*.
2. If on simple organs:
    a. The work is not intimate, but joyous. Thus, if changes in registration are not available, I suggest a bright and somewhat loud character throughout.
3. If on more complex organs:
    a. The work is not intimate, but joyous and bombastic. However, the piece has moments where there can be a dynamic pull-back for dramatic effect. If the organist sees fit, there are many possibilities for registration change (and use of swell/crescendo pedal) to allow for dramatic shifts and effects. I fully encourage the organist to explore these possibilities if the instrument allows.

b. The piece was designed for a one-manual instrument, but the piece should be played on multiple manuals with various sounds if the organist and instrument can facilitate this. I can and did imagine various instrumental choirs between the left and right hands (sometimes one with a solo reed and one on something like accompanimental flutes and/or principles). Thus, look for opportunities for soloistic, echo, and general orchestration changes. In my own organ playing, I try to be as colorful as my skills allow. I would be thrilled to hear this work with many, vibrant, colorful, and dramatic changes in timbre as we also shift dynamically through tonal spaces.
    i. Note: even specialized stops like the Zymbelsten are not sacrilegious. Be creative but use good taste always!

NOTATION

This piece was originally conceived using Jordan Key's system of pan-rational rhythmic notation. The application of tempo changes is a compromise to make the reading of the music perhaps easier for those uncomfortable with the rhythmic notation. Versions of both notations are provided in this score.

First given is the version with tempo changes. These tempo changes are proportional to 4:5. In essence, the notes that are under Tempo II (♪ = 128 bpm) are 8^{th} and 16^{th} notes, while the notes under Tempo I (♪ = 320 bpm) are 8^{th}-note quintuplets by comparison to the 8^{th} notes in Tempi II. Perhaps more simply put, the "8^{th}-notes" under Tempo I are actually 20^{th}-notes and the "8^{th}-notes" under Tempi II are true 8^{th}-notes with all notes sharing a common whole note at 16 bpm.

Thus, the second given score does not have tempo changes, but rather time signature changes between dyadic and dectadic rhythmic hierarchies (see explanation of pan-rational rhythmic notation below), which allows for the fluid interchange and intermingling of note values that are powers of 2 (half, quarter, 8^{th}, 16^{th}, etc) as well as powers of 5 and multiples of 2 and 5 (5^{th}, 10^{th}, 20^{th}, 25^{th}, 40^{th}, etc.). If one wishes to read from the pan-rational rhythmic score, I suggest reading the explanation of the system given below. Otherwise, simply follow the tempo changes precisely.

Explanation of Pan-Rational Rhythmic Notation:

This work uses what I call "pan-rational time signatures" (known elsewhere and erroneously as "irrational time signatures"). I do not call them "irrational" since they are in no way "irrational" (either psychologically or mathematically). They are "rational" proportions, but do not use powers of 2 for the bottom number (not written over 2, 4, 8, 16, 32, 64, etc.). Such a system of time signature grew out of questions like "why isn't there a 'fifth' or 'third' note?" Well, many music teachers will simply say, "because there isn't one," but of course there is.

What we call a triplet is actually just some multiple or divisions of a "third note," and similarly the quintuplet some "fifth note." Systems of subdividing fundamental note values (like the breve or whole-note) into groups other than "dyadic-rationals" (note subdivisions in the form $\frac{1}{2^n}$) into "pan-rationals" (third, fifth, seventh as compared to half, fourth, eighth, sixteenth, etc.) have existed at prior points in music history (particularly the late Middle Ages and Renaissance), using uncommon and arcane systems of mensuration. Such systems have long fallen out of favor; however, if reincorporated into our system of musical language, they can allow for the fluid notations of some rather complex rhythmic ideas without the use of excessive tempo changes or tuplet (and embedded tuplet) markings.

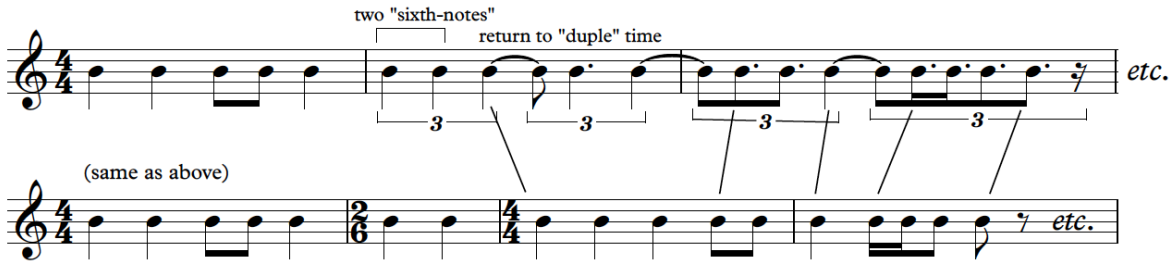
This work employs my system of pan-rational rhythmic notation to execute a rhythmic hierarchy with not only dyadic note subdivisions, but also notes that are pentadic and dectadic (note subdivisions in the form of $\frac{1}{5^n}$ and $\frac{1}{2^n 5^{m'}}$, e.g. 5th-notes and their subdivisions and combinations with dyadic values, like 10th notes). Thus, this piece employs a whole-note value that is simultaneously dyadically (2), pentadically (5), and dectadically (2*5) divisible.

The system of pan-rational rhythmic notation ("pan-rationalism") is the culmination of my dissertation, which surveyed past and present systems of exceptional rhythmic notation in an effort to understand how systems of "non-dyadic" rhythmic notation came into being and why/how they disappeared from use in order that I could fashion a better, more comprehensive system that would allow for the notation of any subdivision or combination of note values apart from tuplets and the requirements of their aggregation. By this, I mean that pan-rational notation no longer requires exceptional rhythmic values be confined to tuplets, which themselves require their own completion and grouping. This grouping disallows easy intermingling of dyadic and non-dyadic rhythmic values and the presentation of non-dyadic rhythmic values without their compete set of related subdivisions (i.e. pan-rationalism permits the presentation of fractional parts of a tuplet).

For example, imagine if I wanted to write a quarter note triplet in a 4/4 time signature, but I only wanted two-thirds of that triplet (namely, two quarter notes of the three within the quarter-note triplet), and then I wanted to return directly to duple time with no hint of the prior triplet. What would I do? Well, I would have to write the two notes of the triplet, but then, in returning to the simple duple time from the 4/4, I would have to endlessly tie over values from within triplets.

However, if I just recognize that I can create “sixth notes,” then I can specify that I want two “sixth-notes” without the use of triplet and many ties subsequently. This can be done using a “pan-rational” time signature, namely 2/6. See Figure 1.

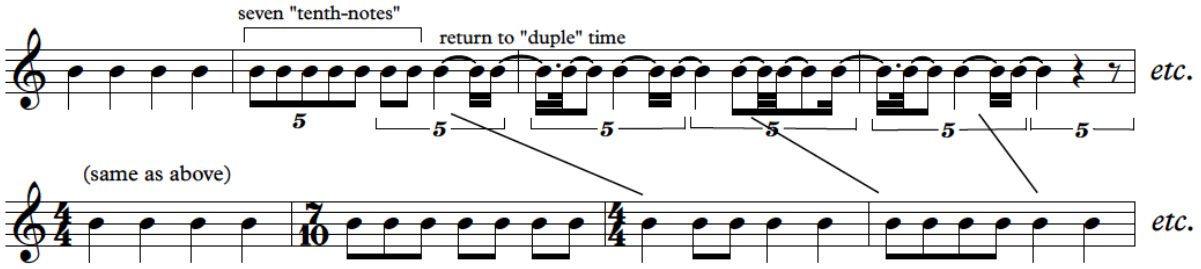
Figure 1:



Why “2/6” and “sixth-notes” rather than “third-notes”? Well, if we consider the “whole-note” as the fundamental value of rhythm (perhaps appropriately since it is “whole”), then to get the quarter-note triplets, we must recognize that the whole-note must be divided equally into six parts. Then, to get only two of these six equal divisions of the whole note, we simply specify “2,” just as one might specify “3” in 4 equal divisions of the whole to get 3/4 rather than 4/4.

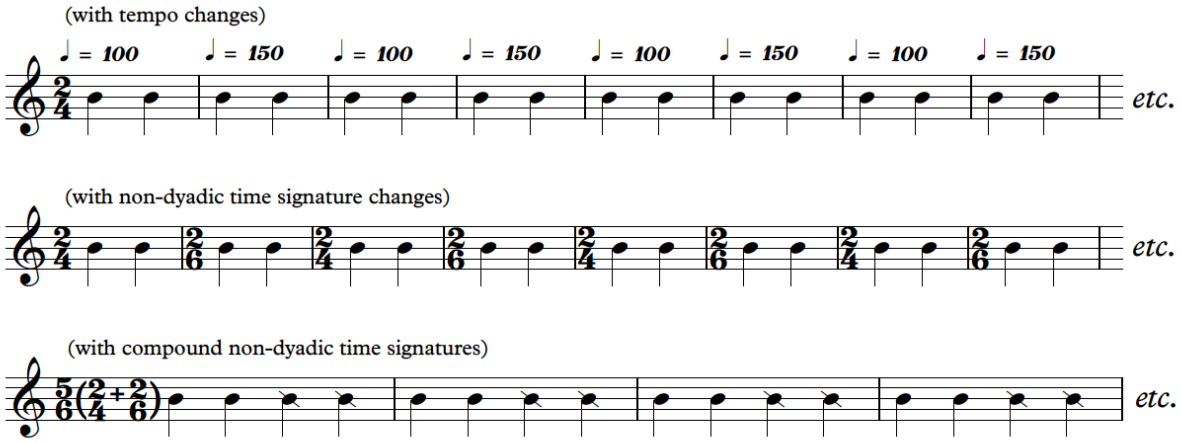
Similarly, if we want seven units of five equal divisions of the whole note (1 and 2/5’s of an eighth-note quintuplet), we will recognize that we must divide the whole into 10 equal parts and play seven of those parts, thus requiring a 7/10 time signature and “tenth-notes.” See Figure 2.

Figure 2:



Such a system allows for the rapid alternation between different tempos without the use of tempo markings on each measure. Furthermore, it utilizes and recognizes those rhythmic fluctuations that are proportional to each other. The notational possibilities of non-dyadic time signatures as compared to tempo changes are demonstrated, in a rudimentary form, in Figure 3.

Figure 3:



Naturally, there are limits to the performability of such diverse rhythmic structures; consequently, the number of available non-dyadic rhythmic values is limited to a relatively small subset of low primes (2, 3, 5, 7, 11, 13, and maybe 17 and 19). Beyond such unique subdivisions, performability becomes exceedingly difficult and the difference between closely values rhythmic subdivisions becomes difficult to accurately perform and perceive. Thus, as the potential of performer of this piece, do not initially worry that the rhythmic subdivision contained herein might be unperformable; they are well within the capabilities of human performance and perception!

However, the challenge of this work (beyond the typically technical issues) is that this piece presents rhythmic structures that are unique to music at present (i.e. concatenations of various combinations of dyadic and tridectadic note values without their respective aggregates). However, I imagine the prospect of a wholly unique rhythmic world yet to be explored might be well-worth the new cognitive challenge.

To notate this music, I have made two general additions to our present system of rhythmic notation: first, the interpretation of time signature; second, the meaning of note shapes.

In regards to time signature, you will find the time signatures in this work are in the form of $\frac{k}{2^n 5^m}$, where the lower number designates the unique subdivisions available within the rhythmic hierarchy according to the available unique prime factors of the number given (note n or m may be 0) and k represents the number of those equal subdivisions of the whole note appearing in each measure (e.g. 10/10 means that the whole note may be divided into either 10 equal parts or any combination or subdivision of the prime factors of 10). The charts below give the notation of these values along with all theoretical further subdivisions. Those notes highlighted in green are those used in this piece.

To differentiate (5^{th}-notes (generally called q-notes) from 2^{nd}-notes (p-notes) depending on the pan-rational hierarchy in use in any moment, a slash (backward and forwards respectively) have been placed over the note heads. The tempo value of these notes, if one desires it can be calculated by taking the tempo of the whole note (16 bpm in this piece) and multiplying it by the value of the note (e.g., the tempo for the 10^{th}-note is 16*10 = 160 bpm or as close as one can reasonably get).

For further clarification of this system of rhythmic notation, see this summary video: https://www.youtube.com/watch?v=fN4fU4laue4

If the performer has any questions or needs any clarification on this system of pan-rational rhythmic notation, please do not hesitate the contact the composer (contact information is given below) or refer to his thesis, wherein this system is comprehensively given.

Composer Contact:

Jordan Alexander Key
Phone: (5450) 588-2409
Email: jordanalexanderkey@gmail.com
Website: http://www.jordanalexanderkey.com

Dissertation Title: "Pan-Rational & Irrational Rhythm, The History, Development, and Modern Implementation of Nondyadic Rational Rhythms in Western Music" (University of Florida, 2021)

Decaplex Two-Dimensional Rhythmic Hierarchy:

Hierarchy for $\frac{k}{10}$, where k is an integer partition of the whole-note, p and q are the prime factors of 10 ($p = 2$ and $q = 5$), and n is any positive integer. Areas highlighted in green are those values used in this piece.

q-hierarchy \ p-hierarchy						
			p^{-2} note	$p^{-2}q$ note	$p^{-2}q^2$ note	$p^{-2}q^3$ note	$p^{-2}q^4$ note
		$p^{-1}q^{-1}$ note FTU^2	p^{-1} note	2/5th note	$p^{-1}q^2$ note	$p^{-1}q^3$ note	$p^{-1}q^4$ note
	q^{-2} note	q^{-1} note	$\frac{k}{10}$ FTU (p^0q^0 note)	5th note	q^2 note	q^3 note	q^4 note
	pq^{-2} note	pq^{-1} note	half note	10th note	pq^2 note	pq^3 note	pq^4 note
	p^2q^{-2} note	p^2q^{-1} note	quarter note	20th note	p^2q^2 note	p^2q^3 note	p^2q^4 note
	p^3q^{-2} note	p^3q^{-1} note	8th note	p^3q note	p^3q^2 note	p^3q^3 note	p^3q^4 note
	p^4q^{-2} note	p^4q^{-1} note	16th note	p^4q note	p^4q^2 note	p^4q^3 note	p^4q^4 note

Congruent Rest Values to the Above Notes in the RED REGION:

$\frac{k}{pq(n)}$	q	q^2	q^3	q^4
p	pq	pq^2	pq^3	pq^4
p^2	p^2q	p^2q^2	p^2q^3	p^2q^4
p^3	p^3q	p^3q^2	p^3q^3	p^3q^4
p^4	p^4q	p^4q^2	p^4q^3	p^4q^4

NOTE: Any complete measure of rest is marked by a whole rest, regardless of the length of that measure. Thus, we do not require a 2/5ths rest.

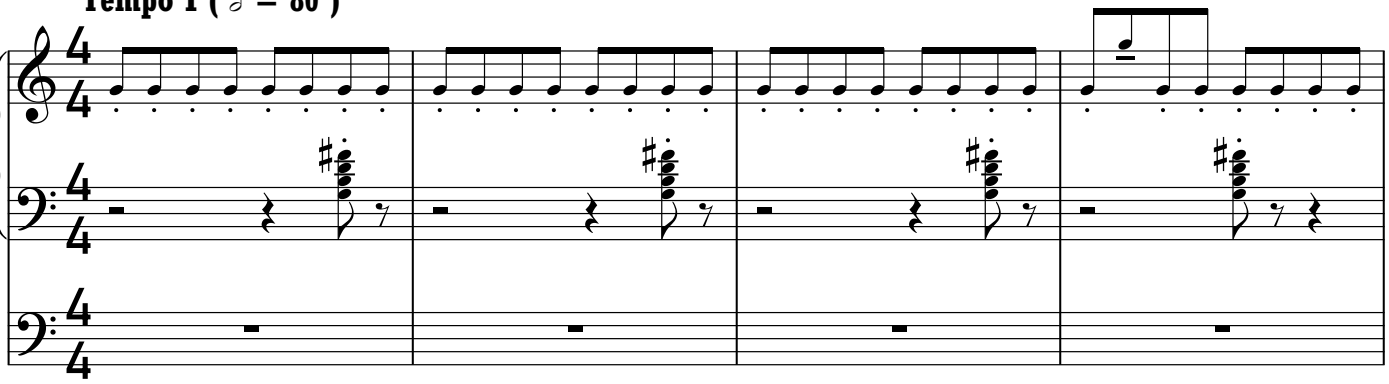
Tempo I, Exuberantly Mechanical (♩ = 80)
Tempo II, Slightly Slower, 5:4 (♪ = 128)

Rosalind Unravels the Bundle of Life

- Fantasia upon a Modal Helix ad honorem Rosalind Franklin -

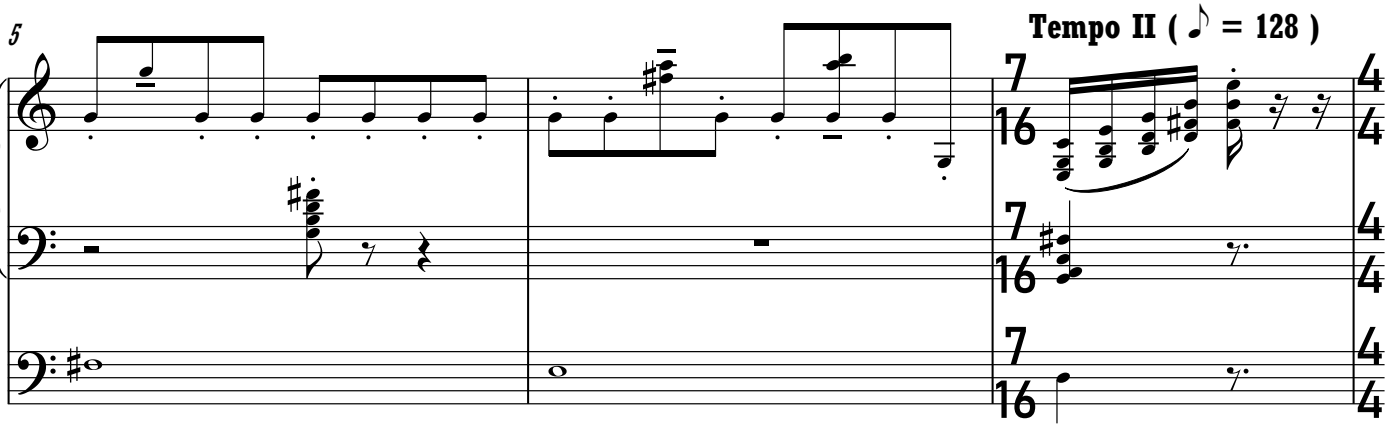
Jordan Alexander Key
Summer 2021

Tempo I (♩ = 80)

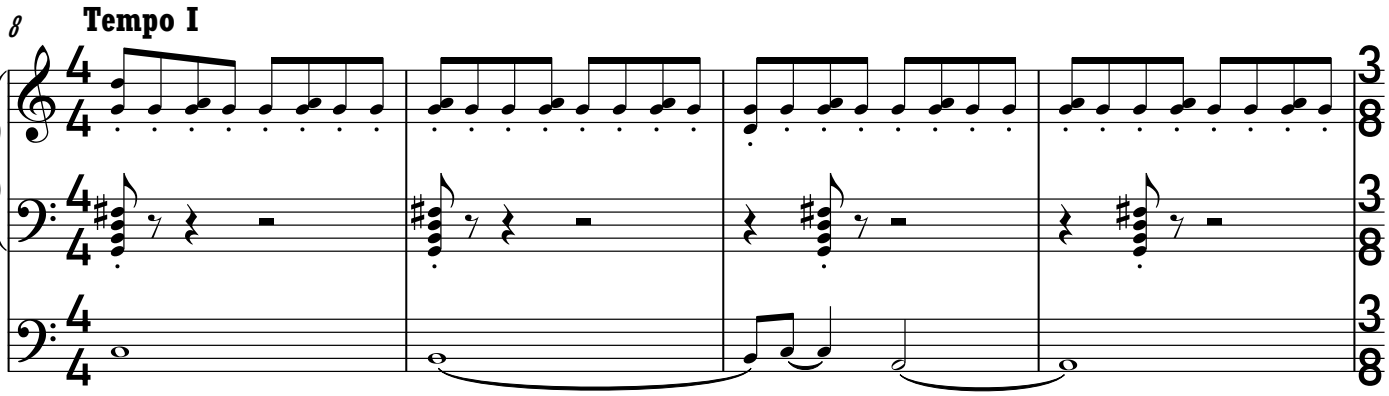


5

Tempo II (♪ = 128)



8 **Tempo I**



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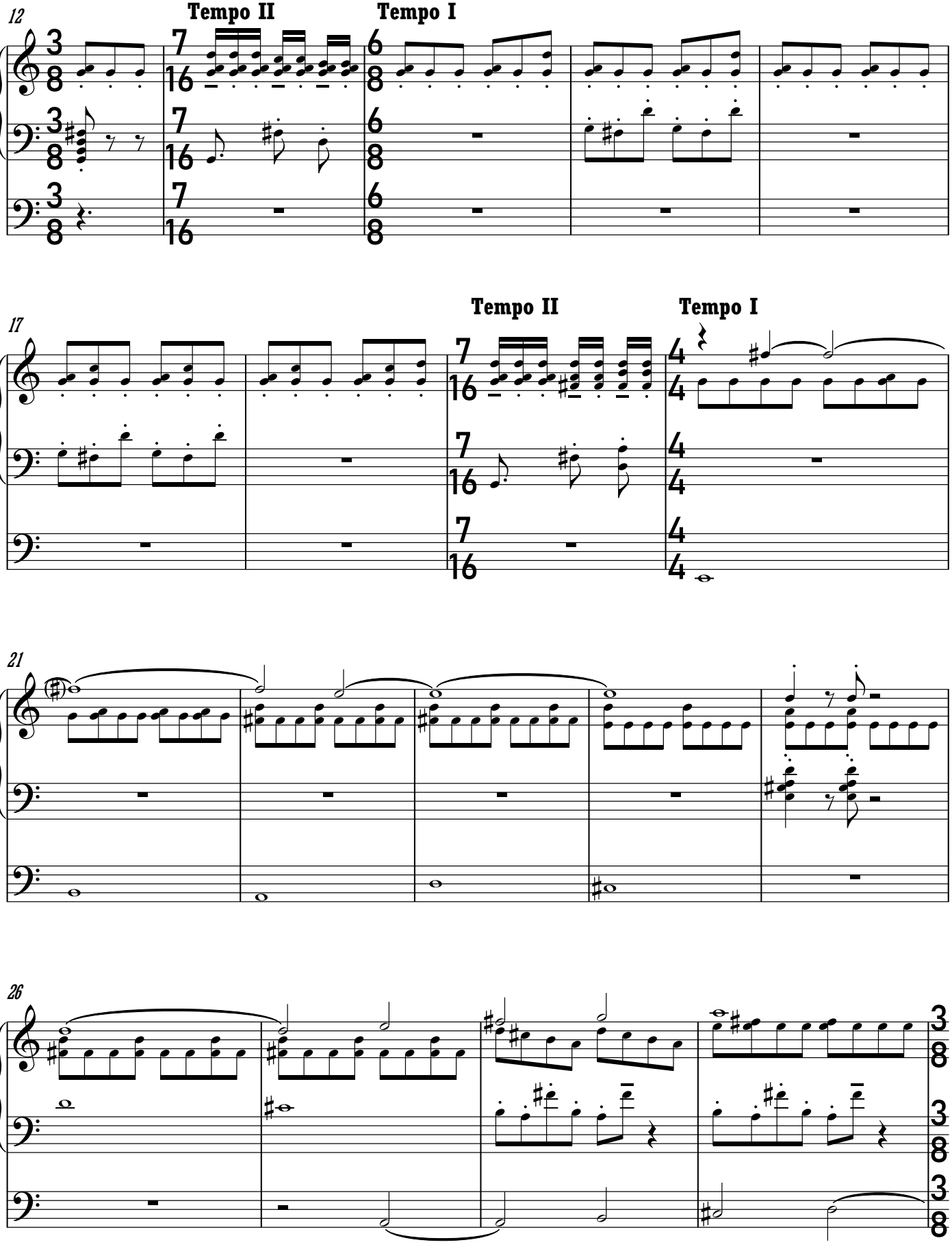
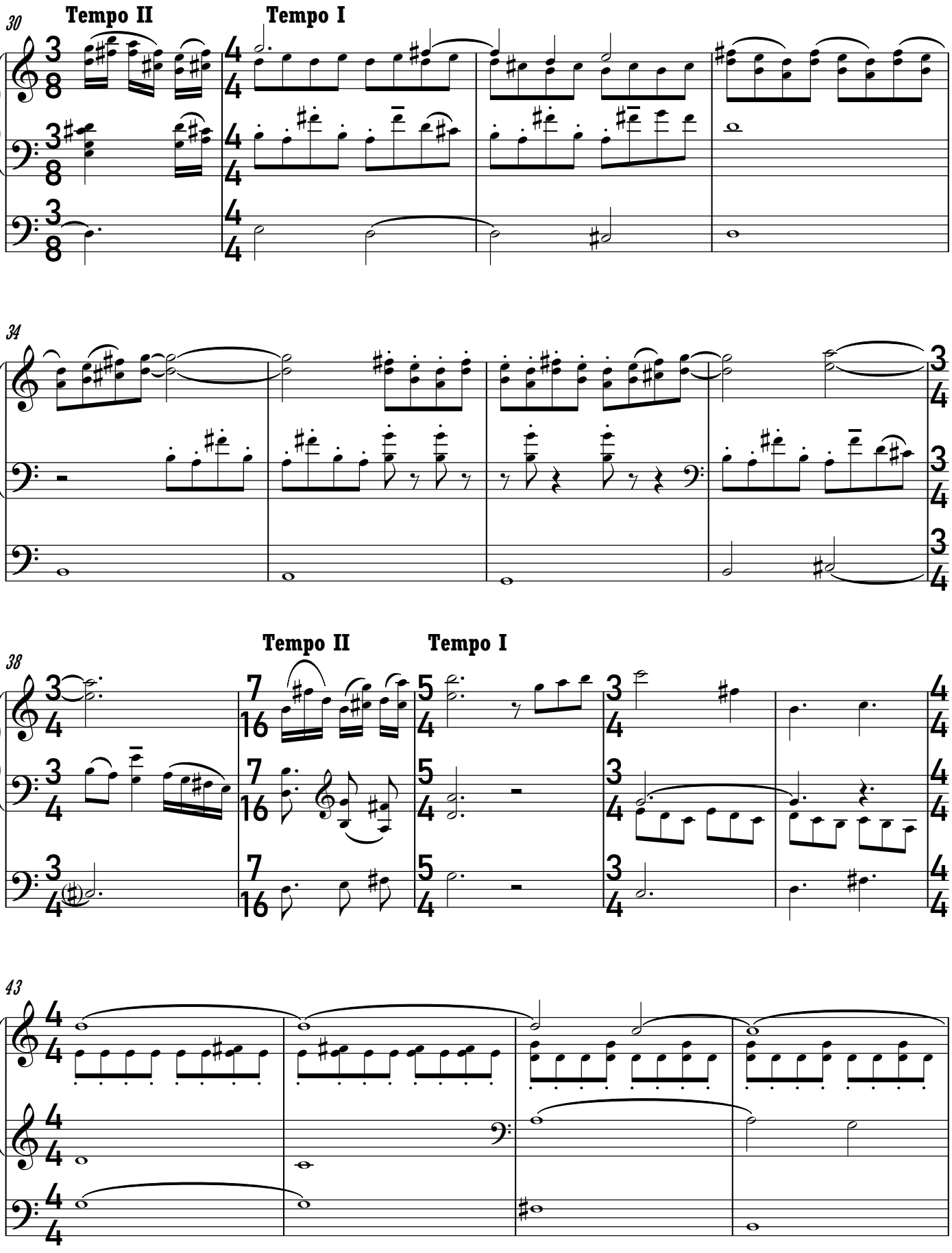
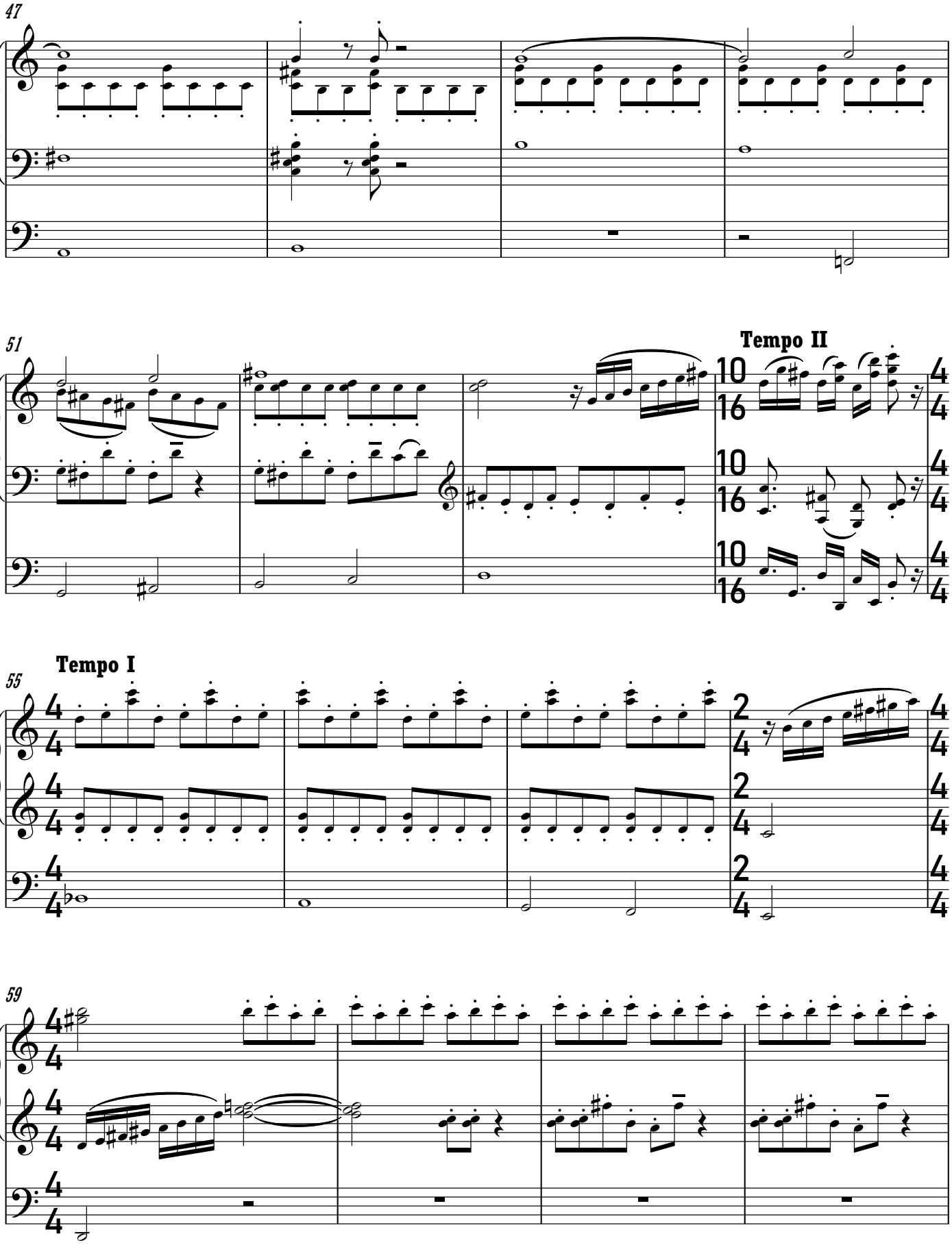
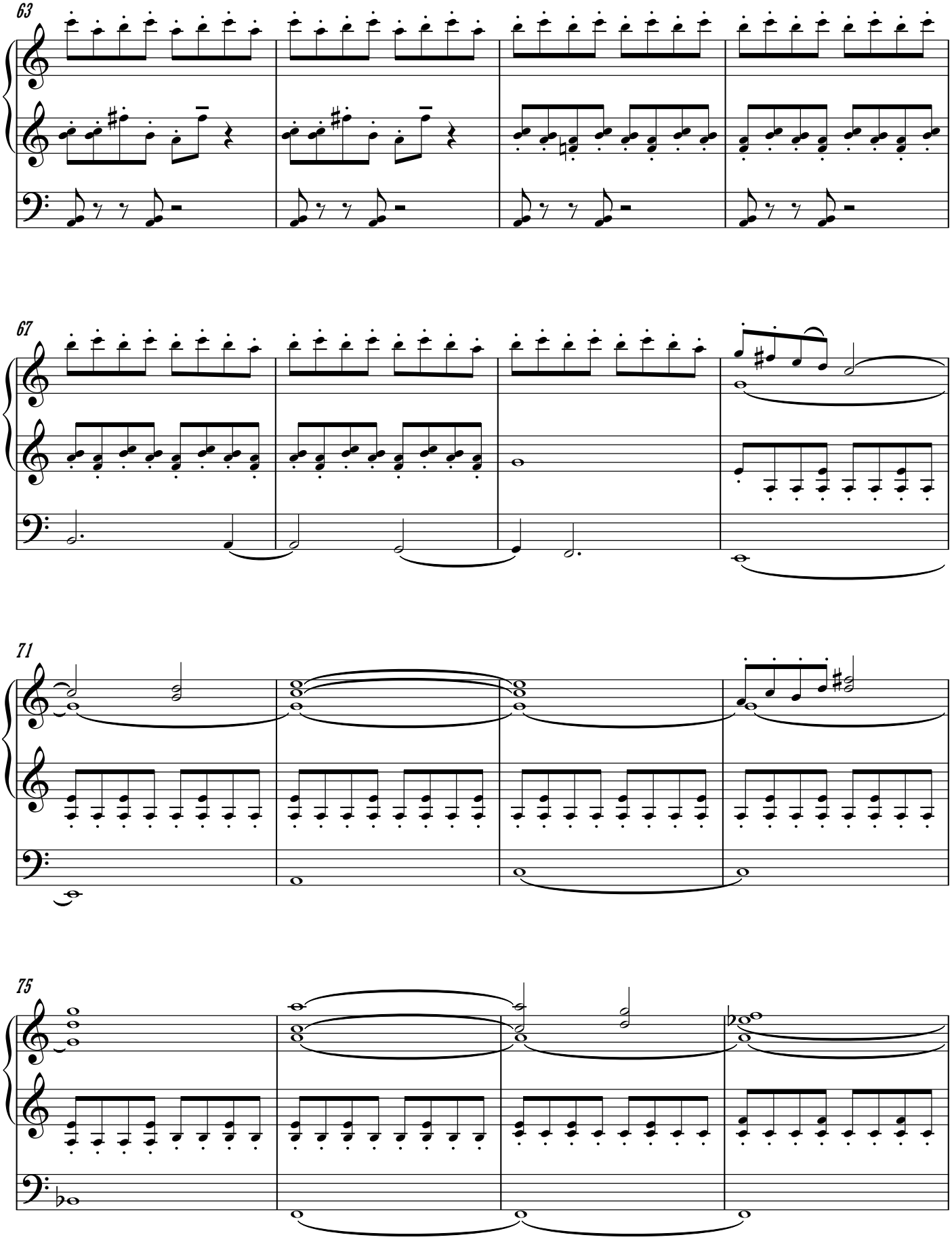
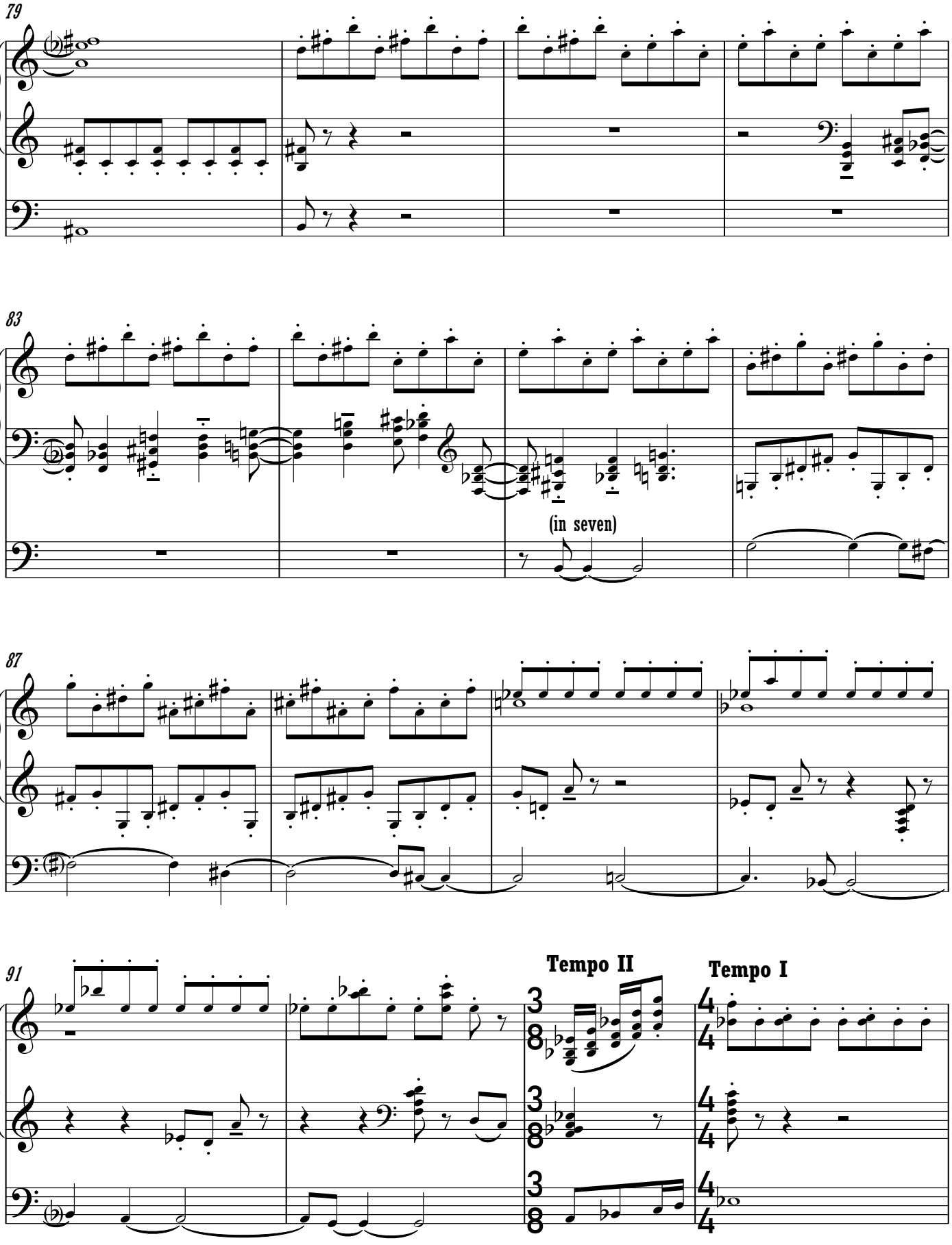
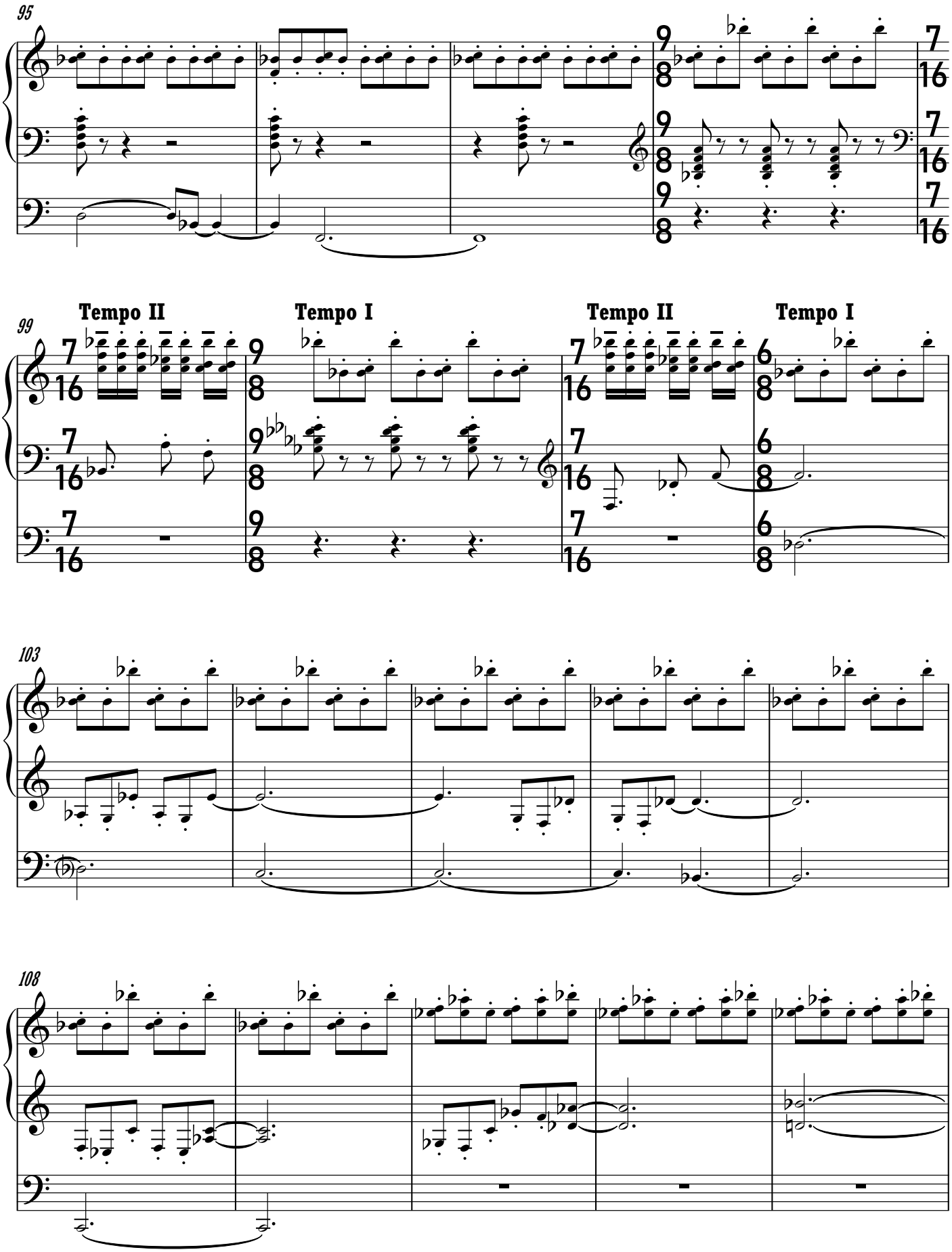

12
Tempo II
Tempo I
17
Tempo II
Tempo I
21
26

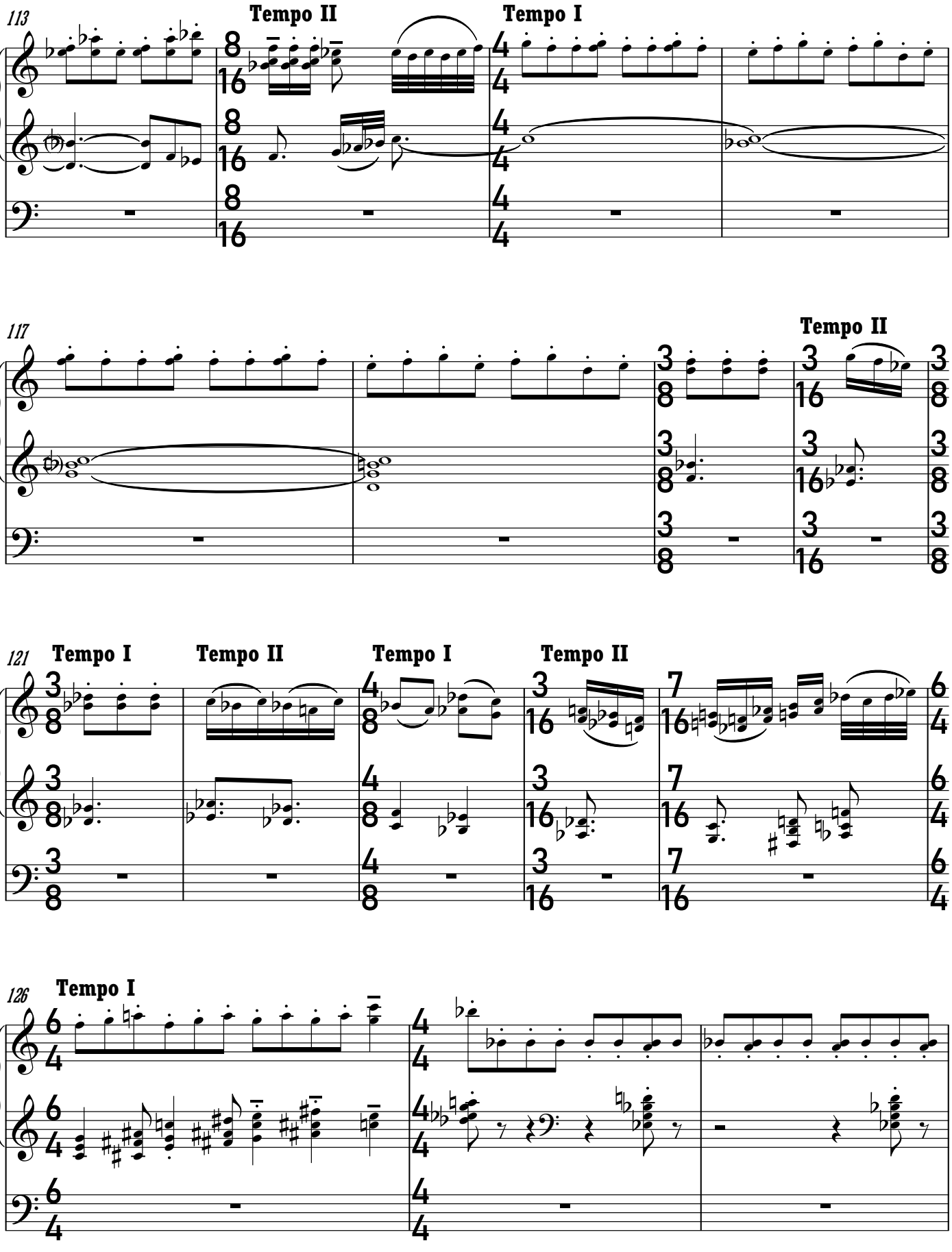

30
Tempo II
Tempo I
34
38
Tempo II
Tempo I
43

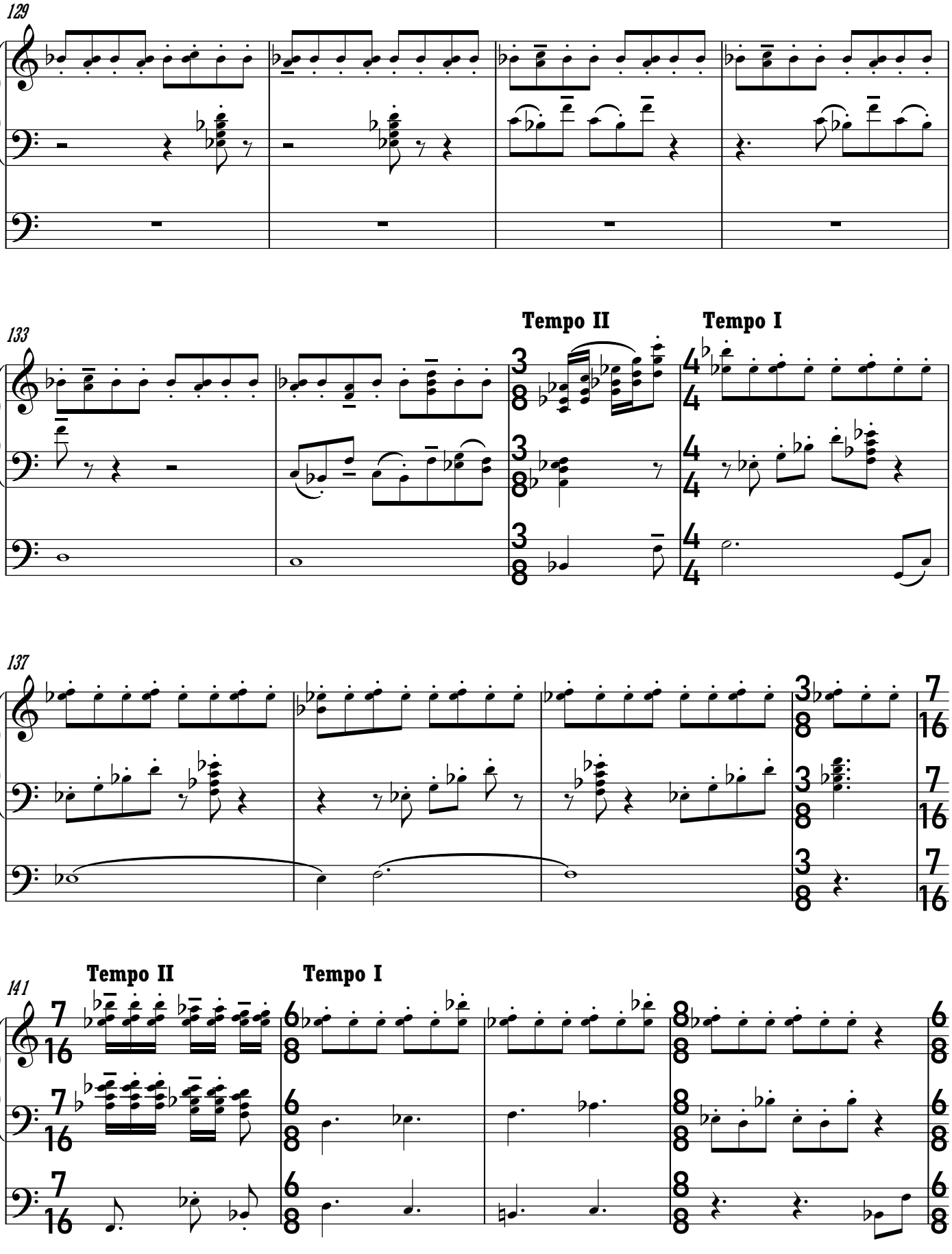

47
51
Tempo II
Tempo I
55
59


63
67
71
75

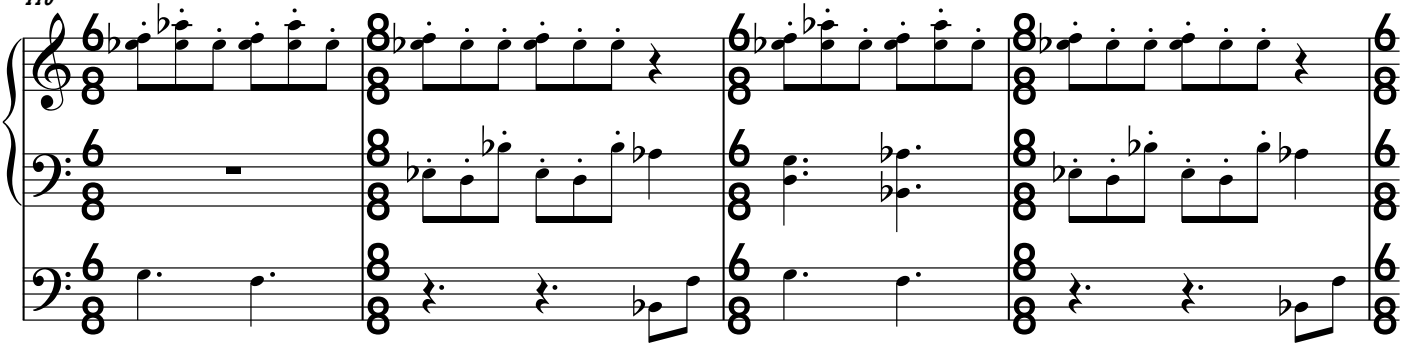

79
83
(in seven)
87
91
Tempo II
Tempo I


95
99
Tempo II
Tempo I
Tempo II
Tempo I
103
108


113
Tempo II
Tempo I
117
Tempo II
121
Tempo I
Tempo II
Tempo I
Tempo II
126
Tempo I


129
133
Tempo II
Tempo I
137
141
Tempo II
Tempo I

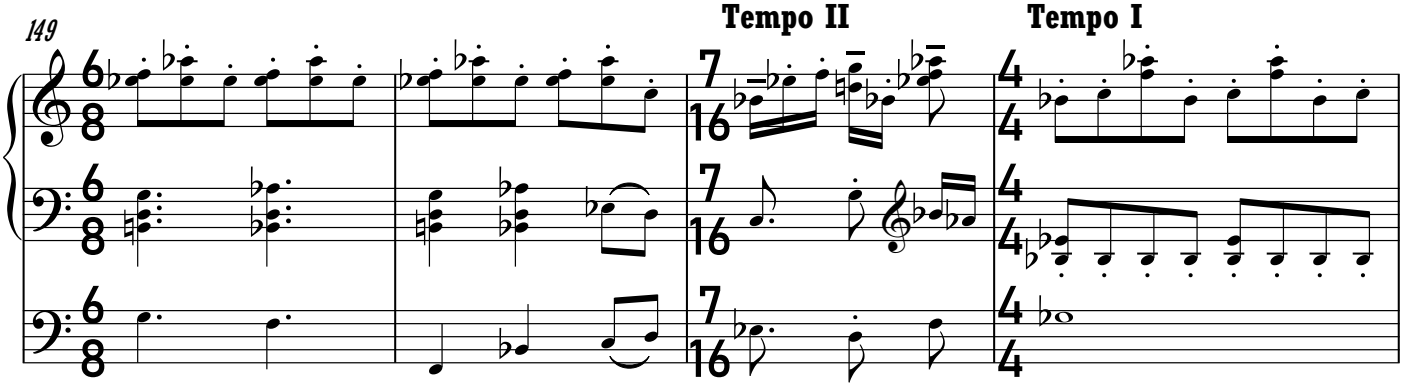
145



149

Tempo II

Tempo I



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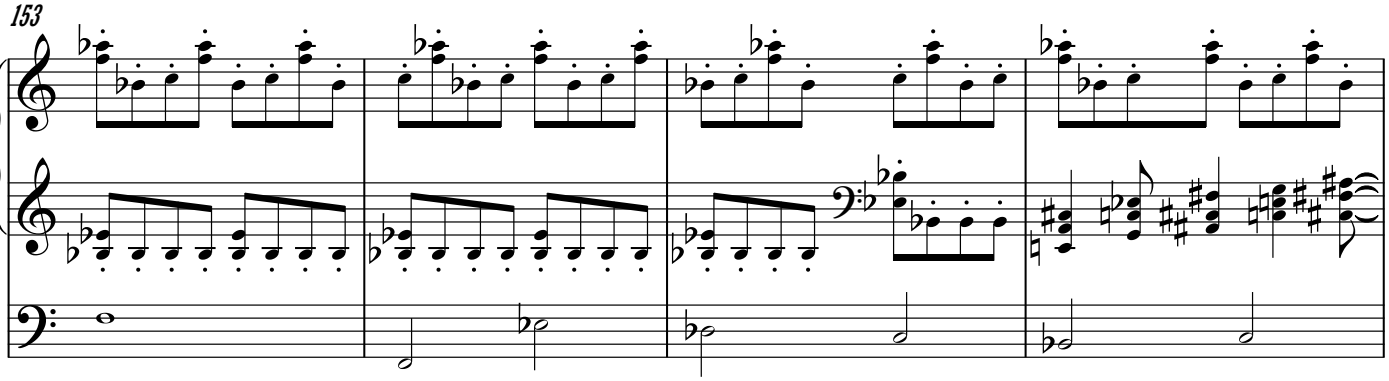

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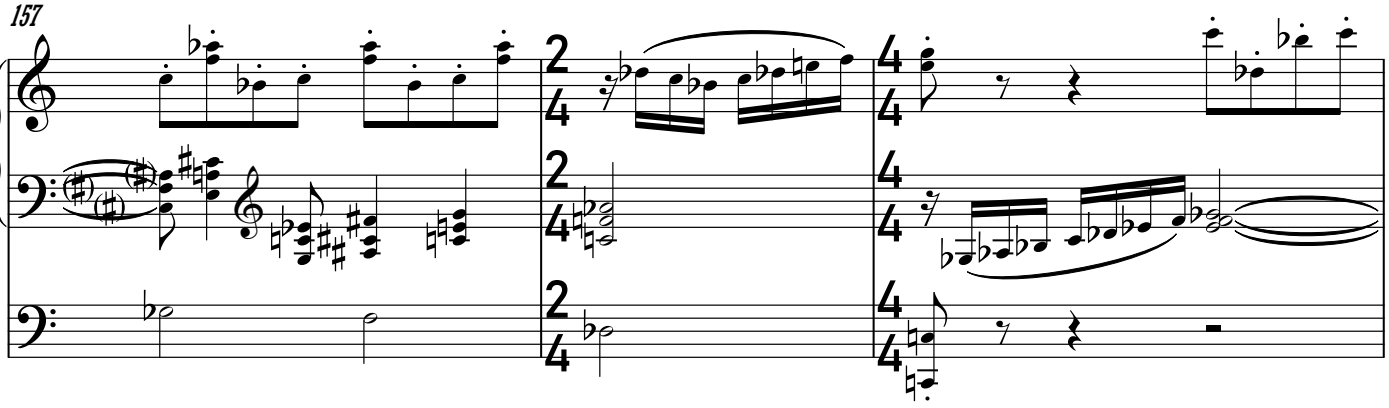

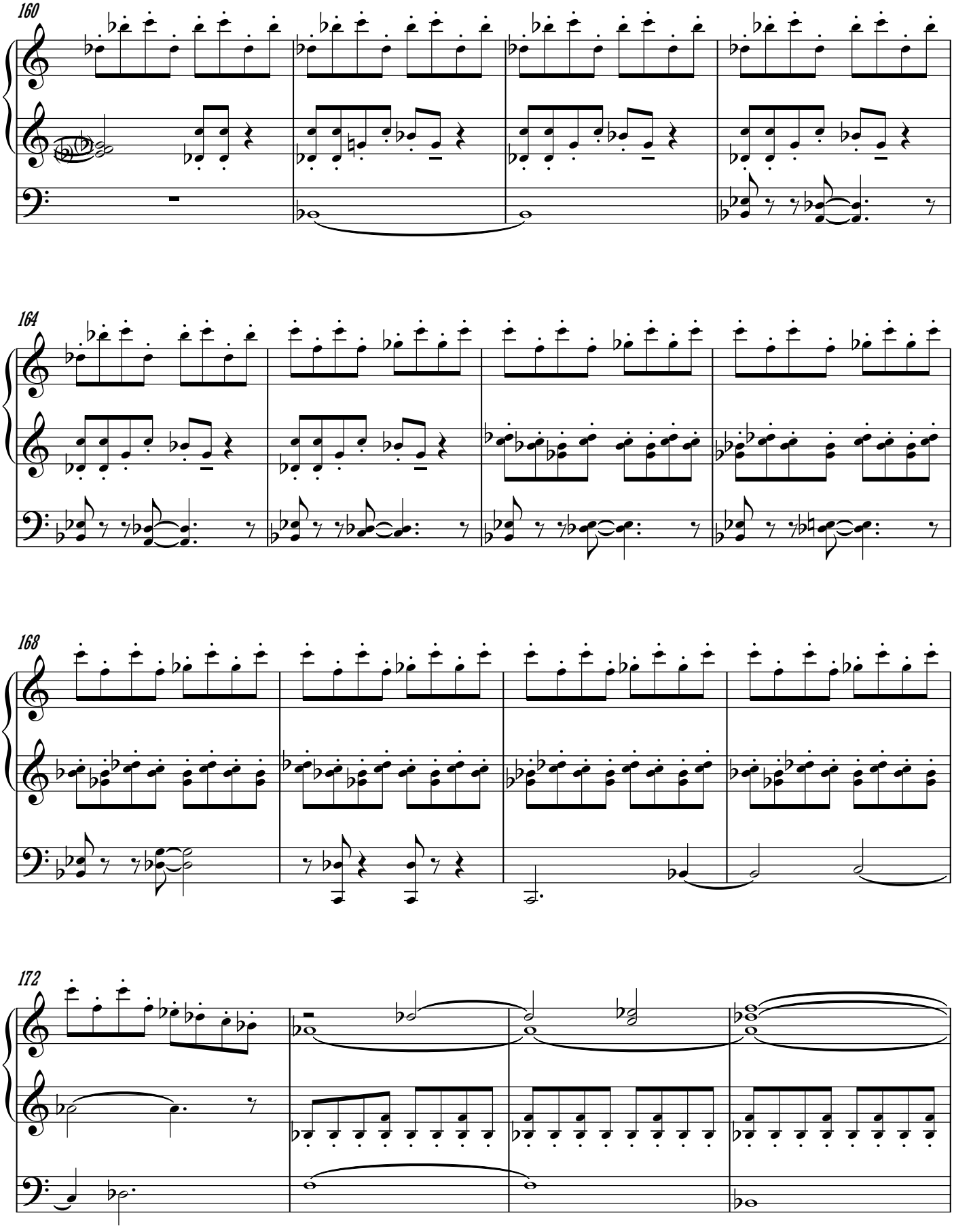
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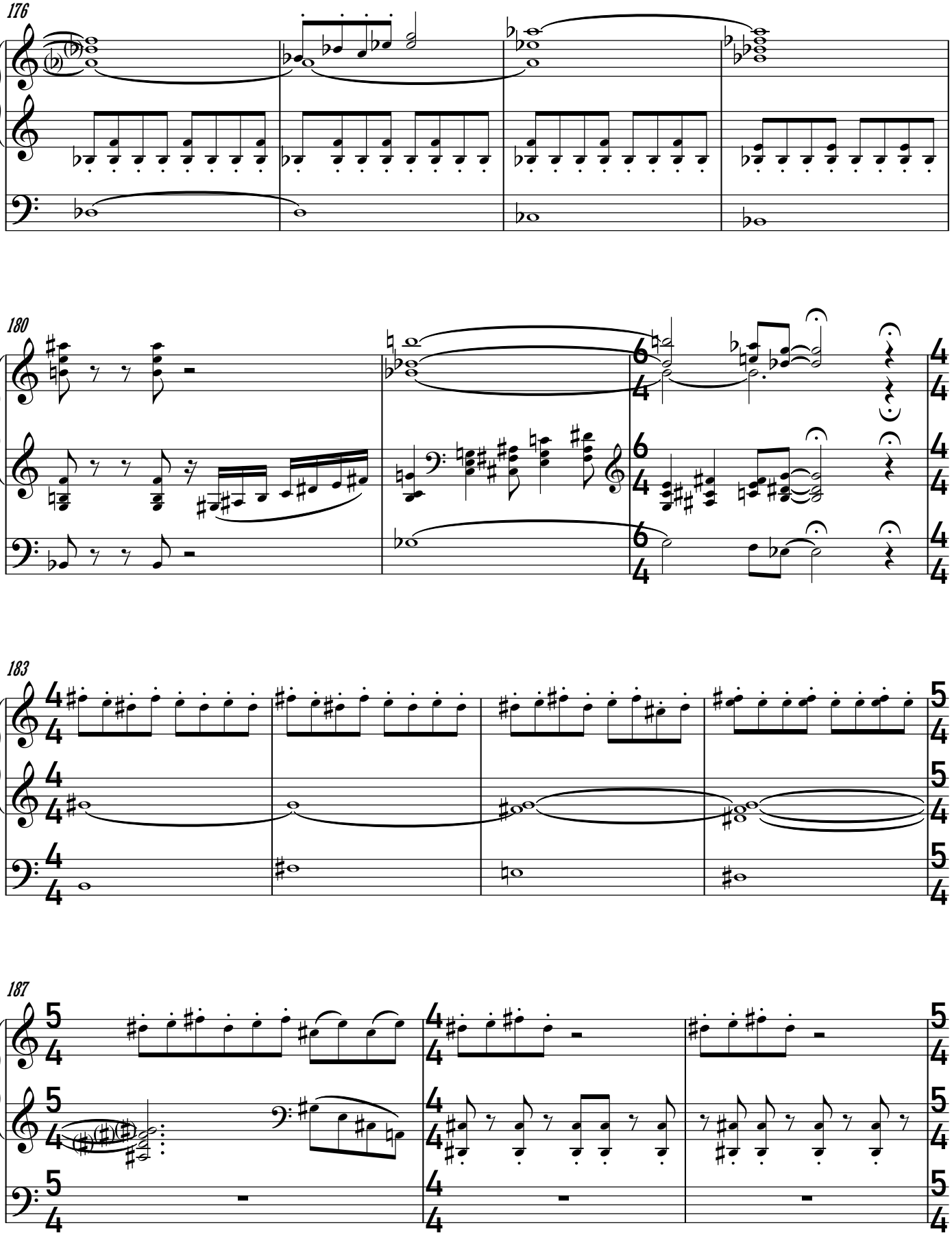
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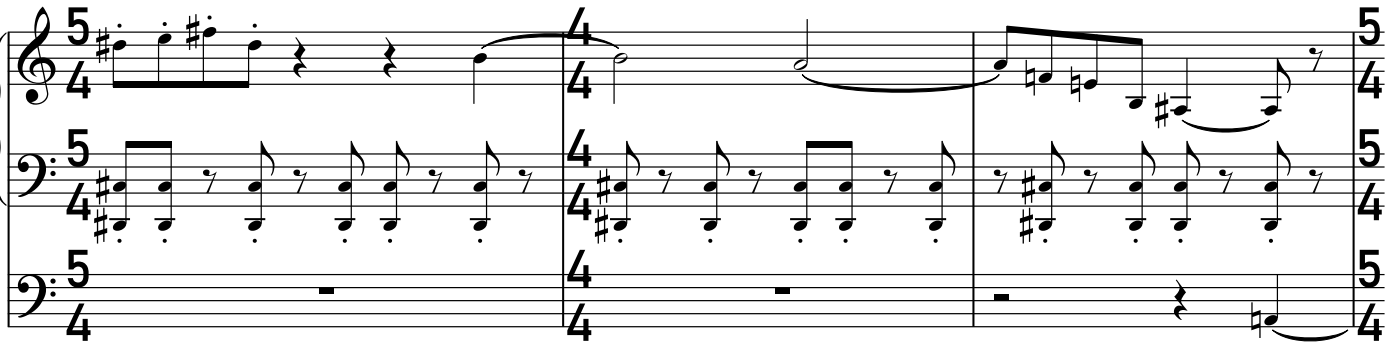

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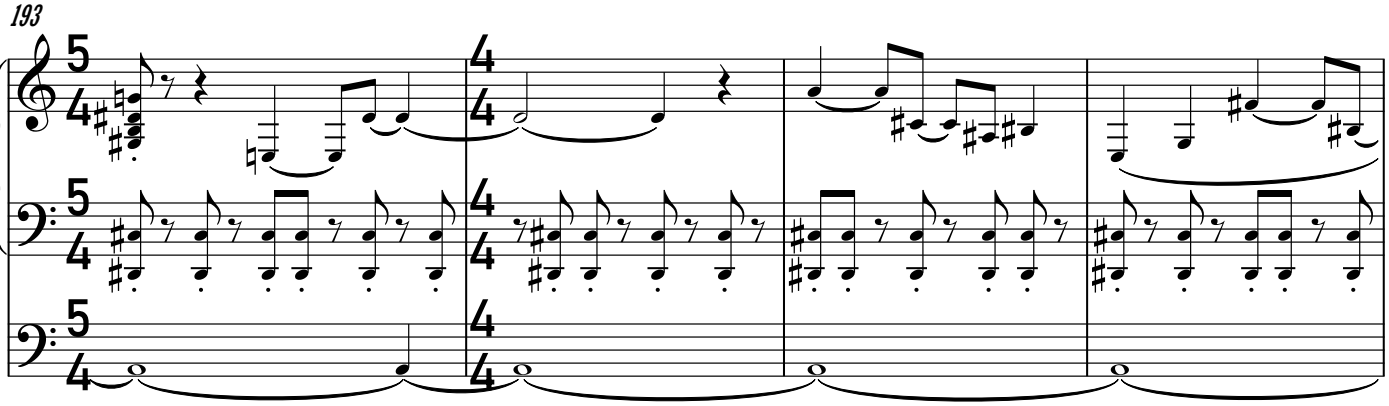

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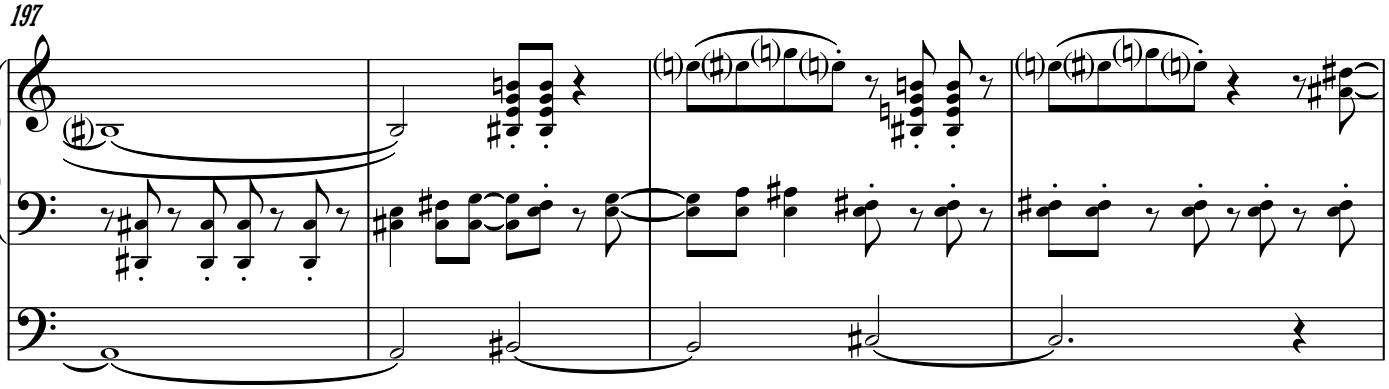

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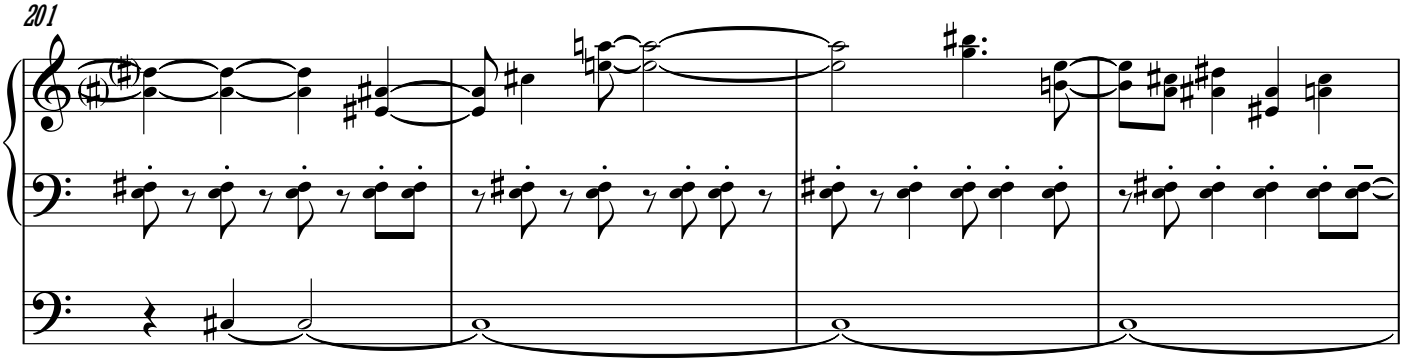

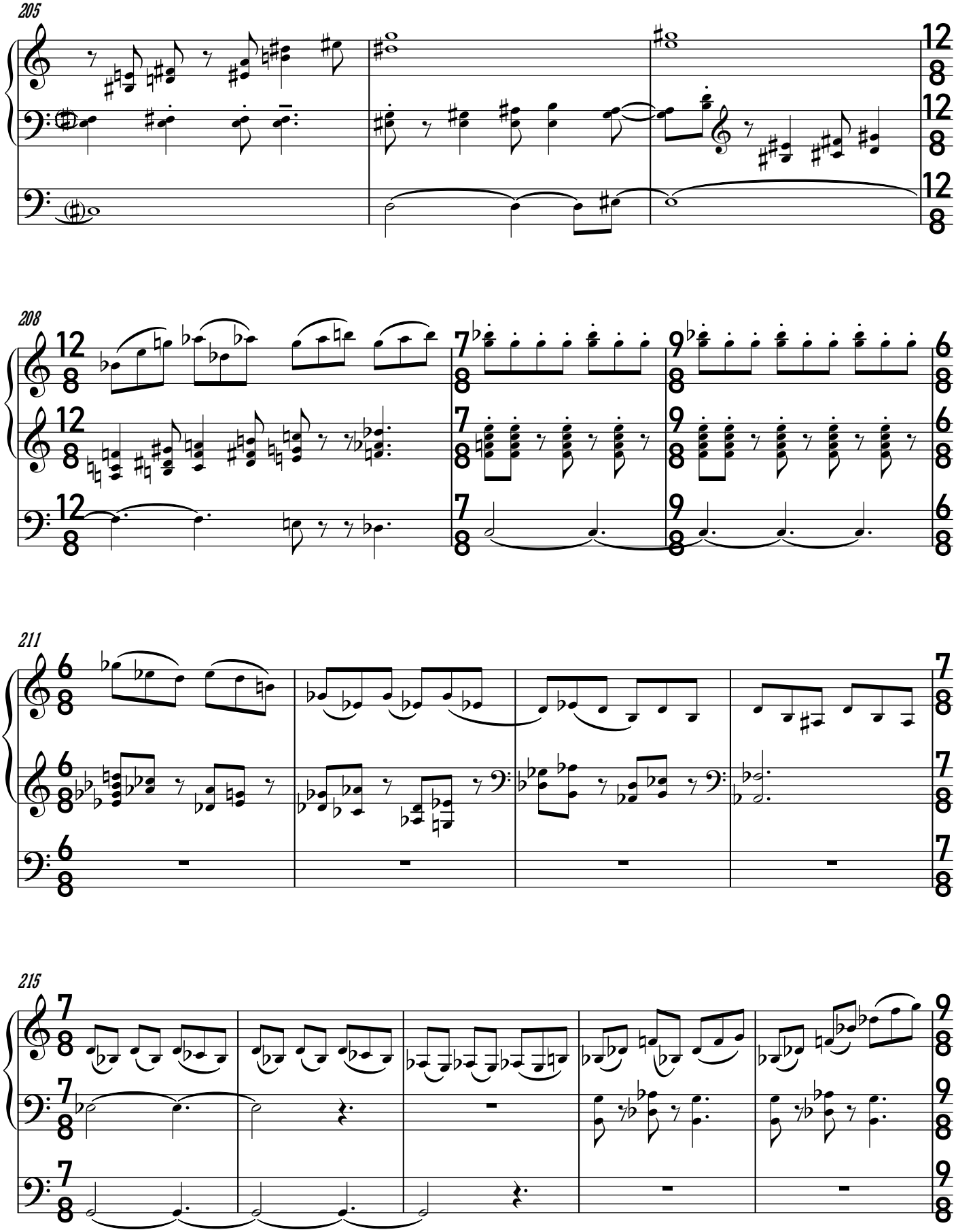
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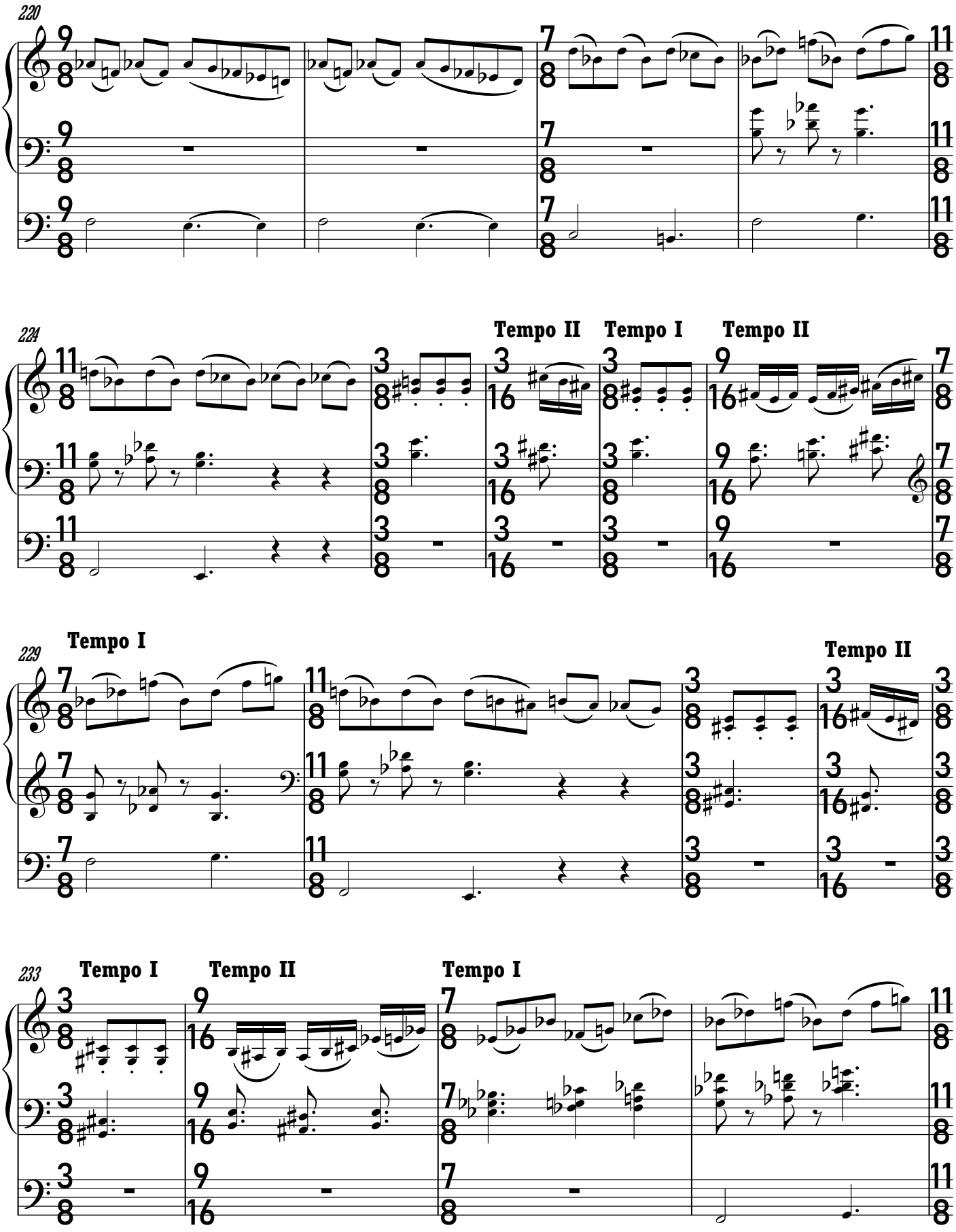
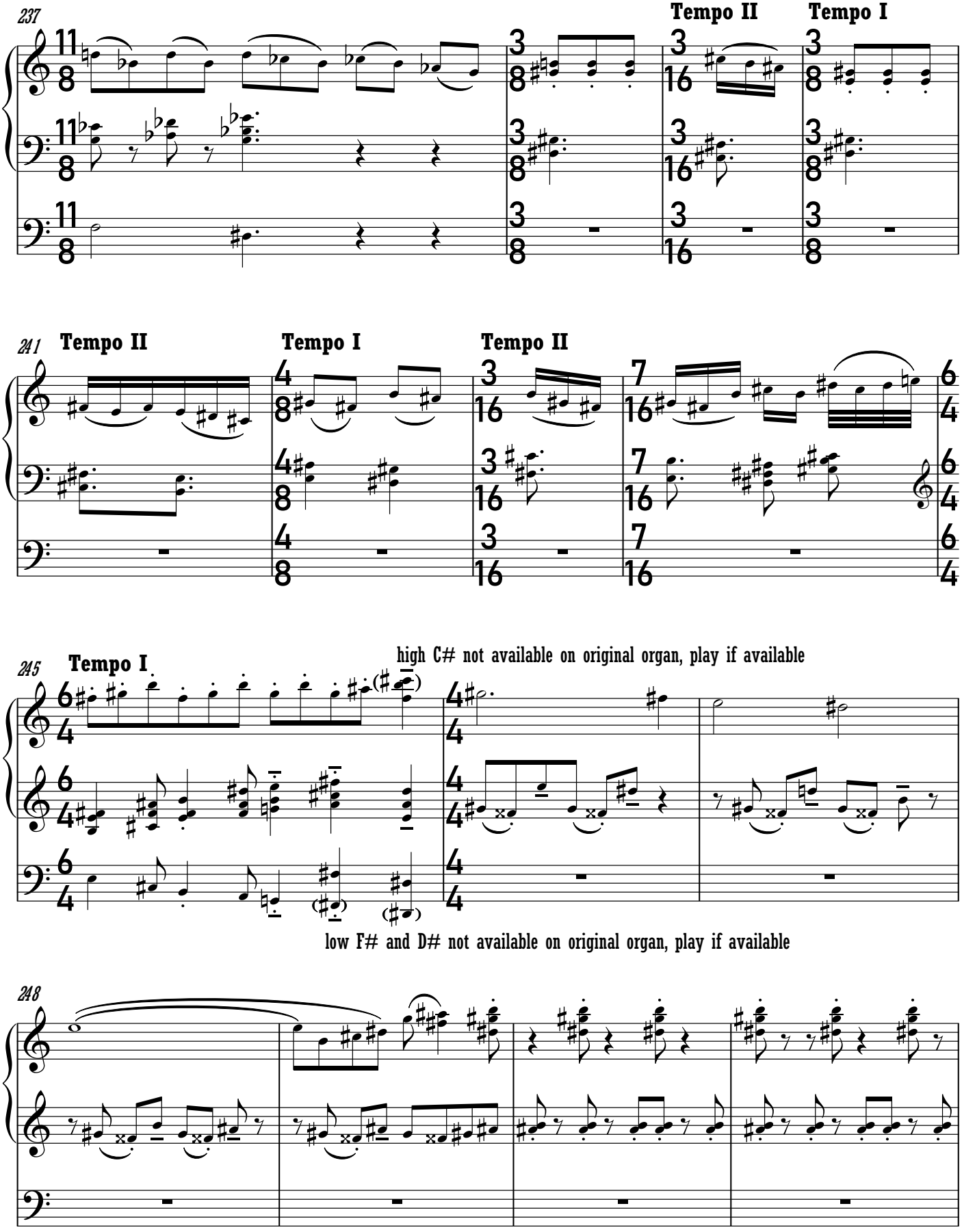
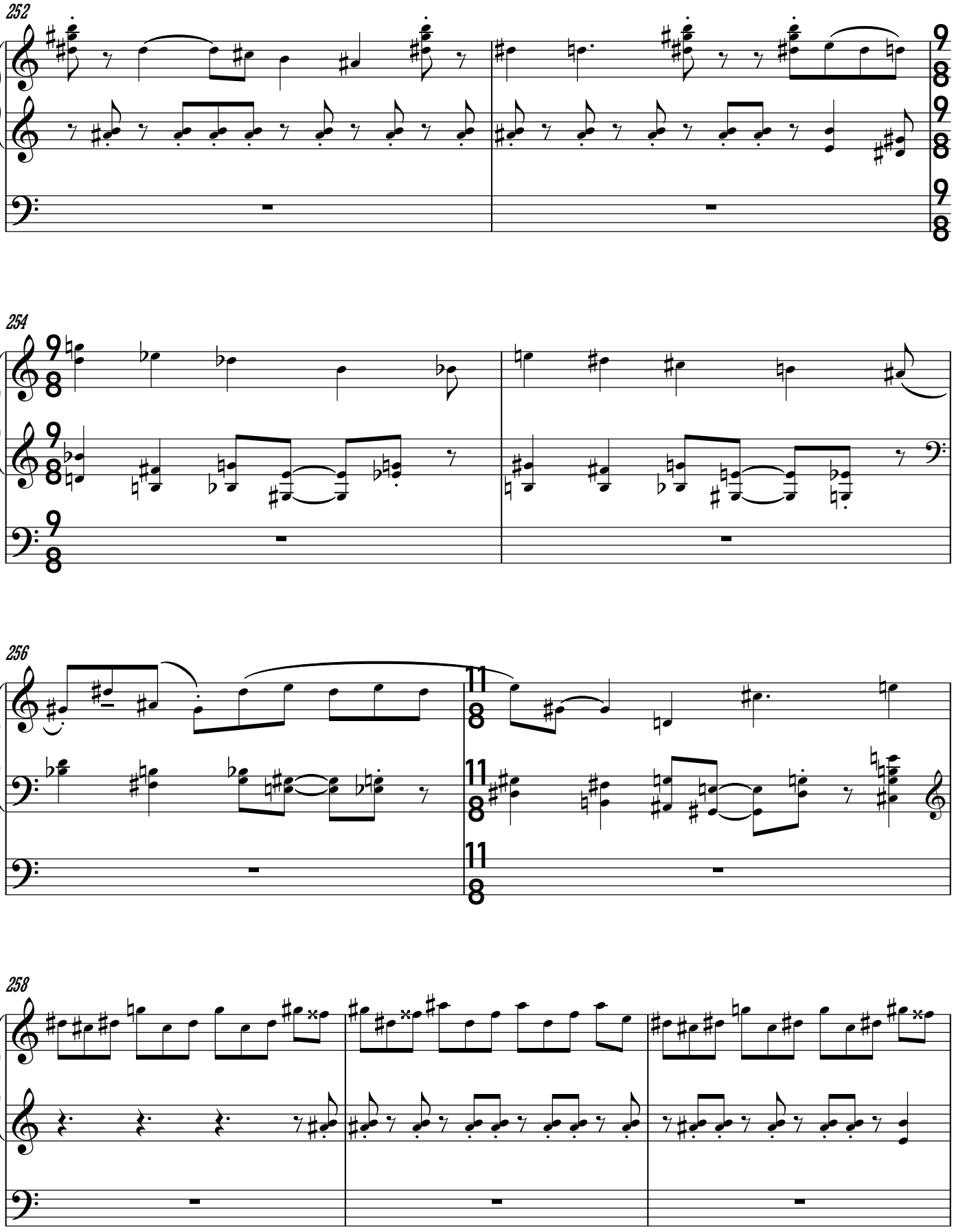

220
224
Tempo II
Tempo I
Tempo II
229
Tempo I
Tempo II
233
Tempo I
Tempo II
Tempo I


237
Tempo II
Tempo I
241
Tempo II
Tempo I
Tempo II
245
Tempo I
high C# not available on original organ, play if available
low F# and D# not available on original organ, play if available
248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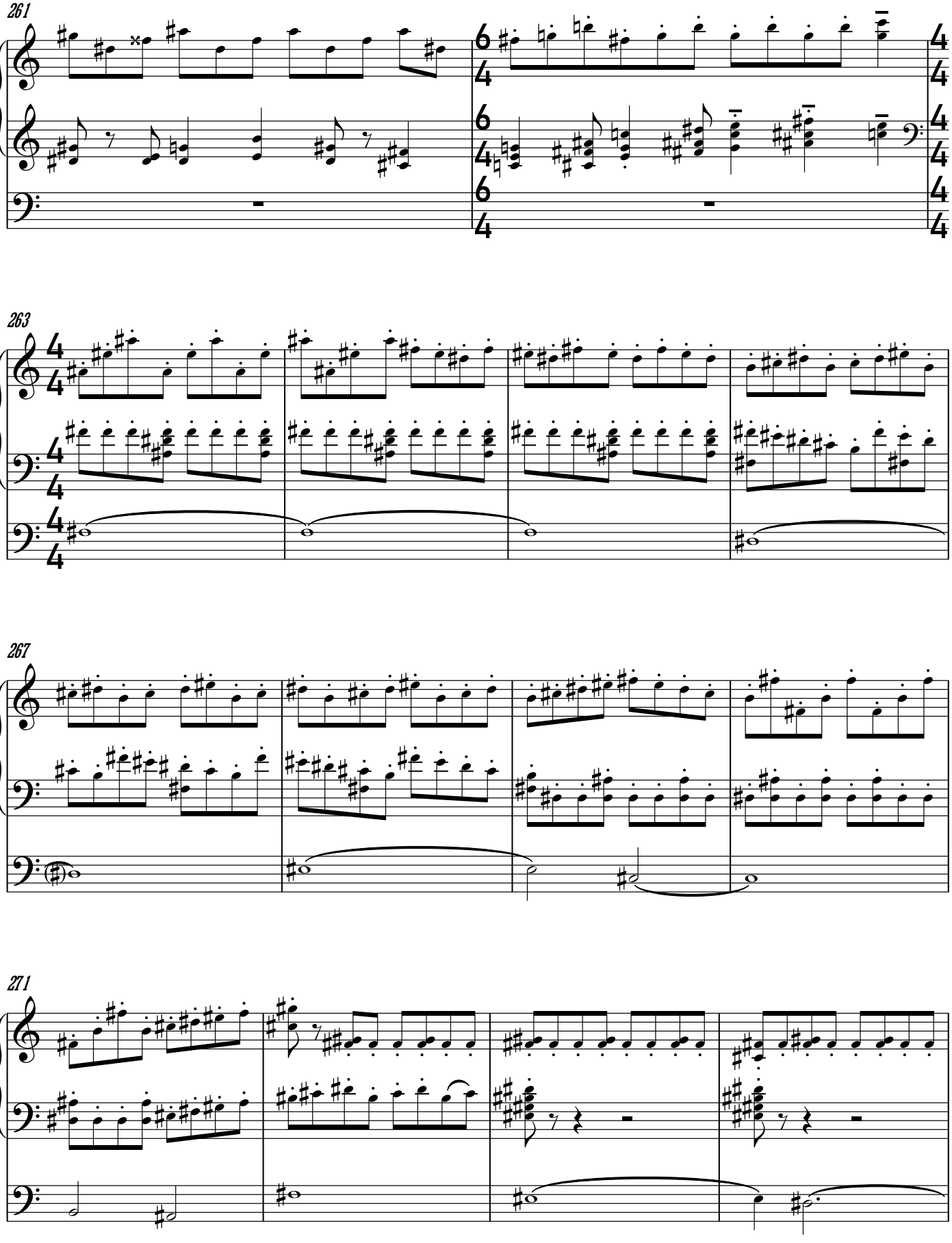
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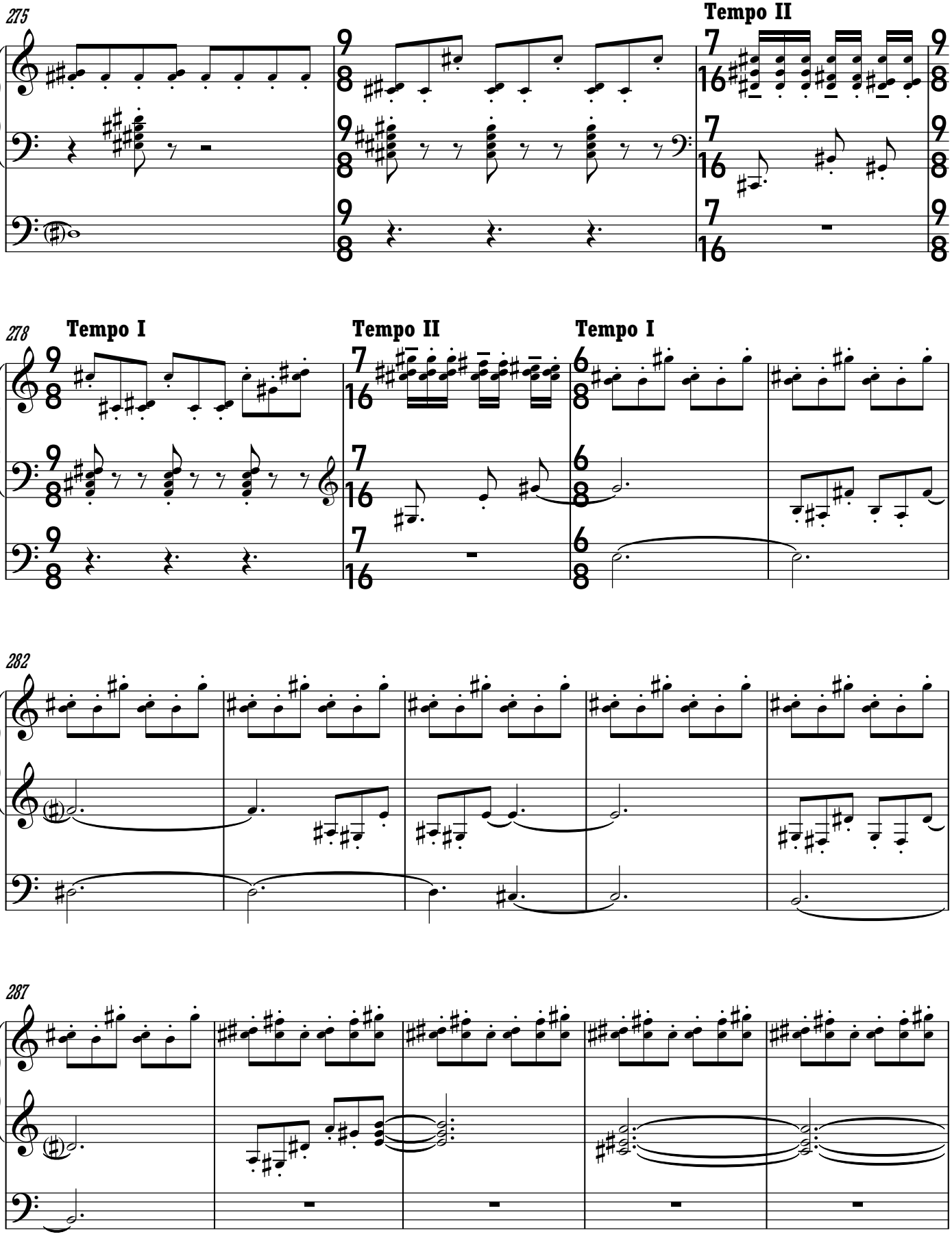
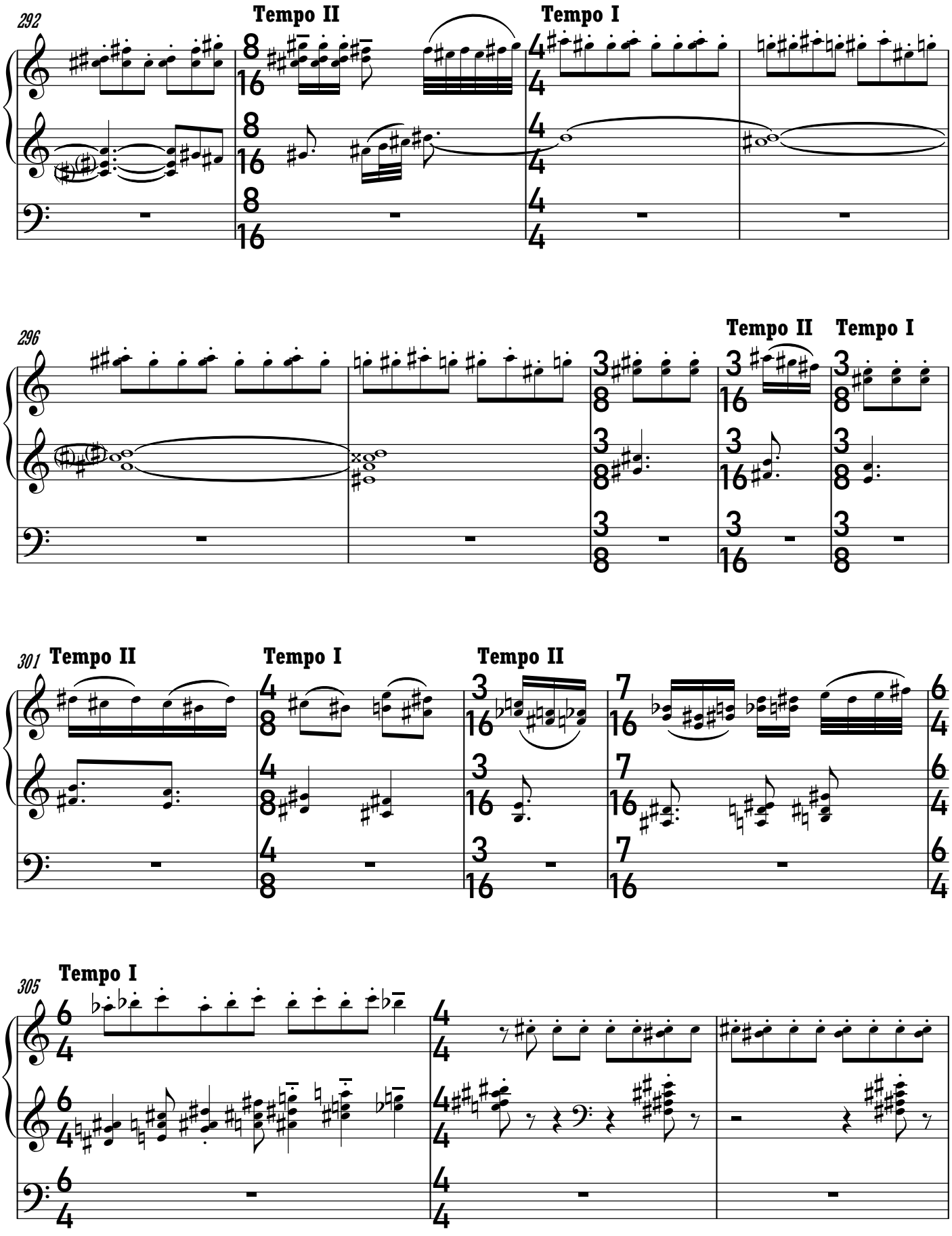

275
Tempo II
278
Tempo I
Tempo II
Tempo I
282
287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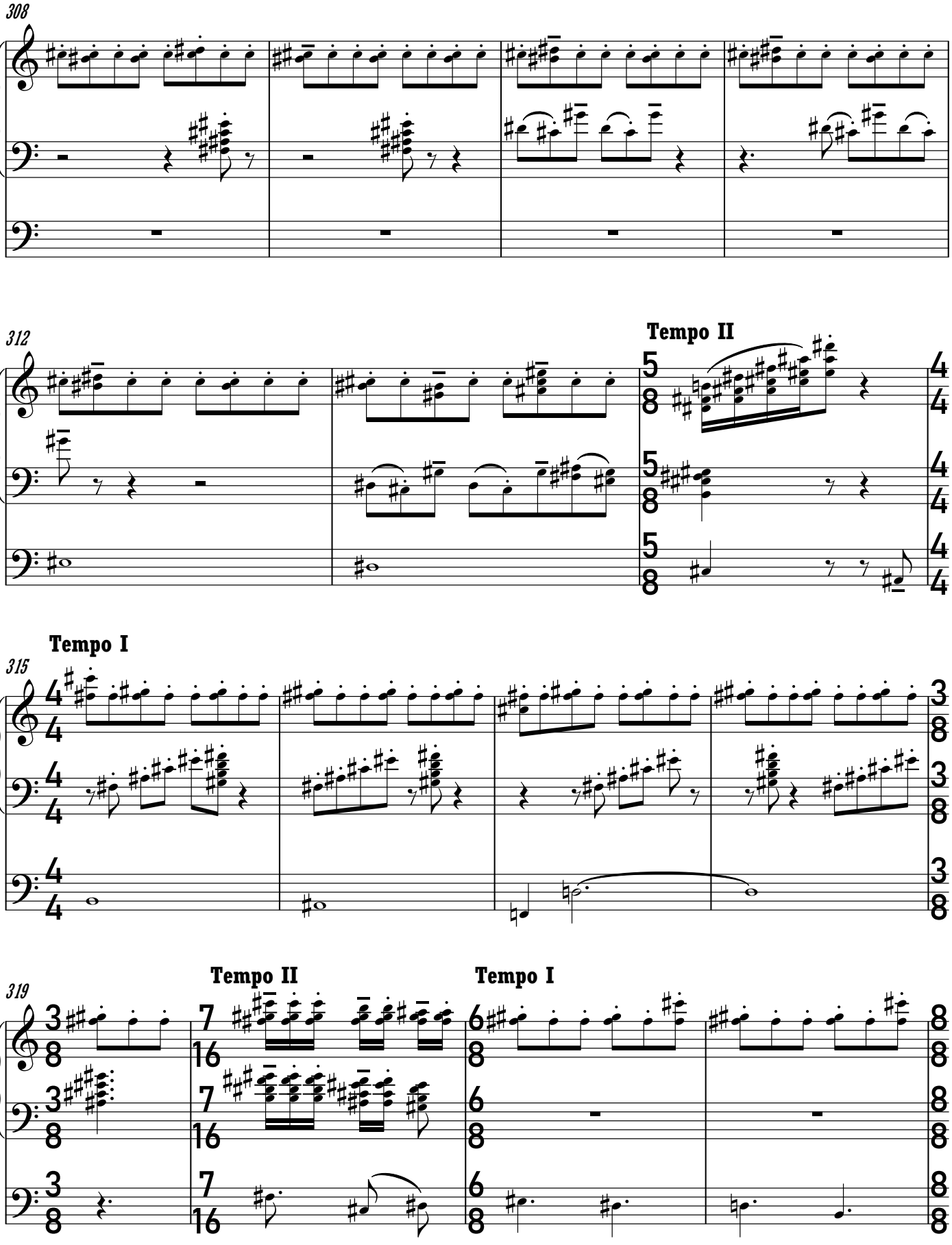
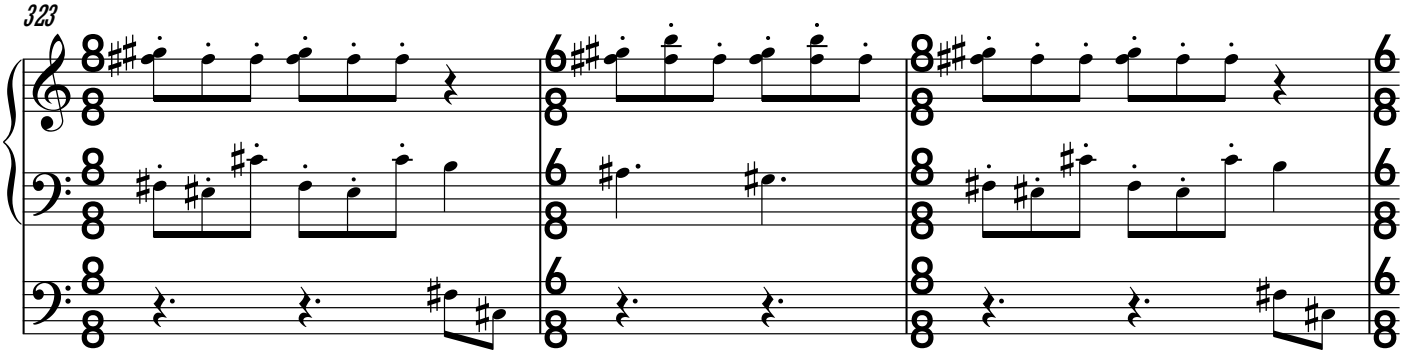
Tempo II
Tempo I
296
Tempo II
Tempo I
301
Tempo II
Tempo I
Tempo II
305
Tempo I


308
312
Tempo II
Tempo I
315
Tempo II
Tempo I
319

323



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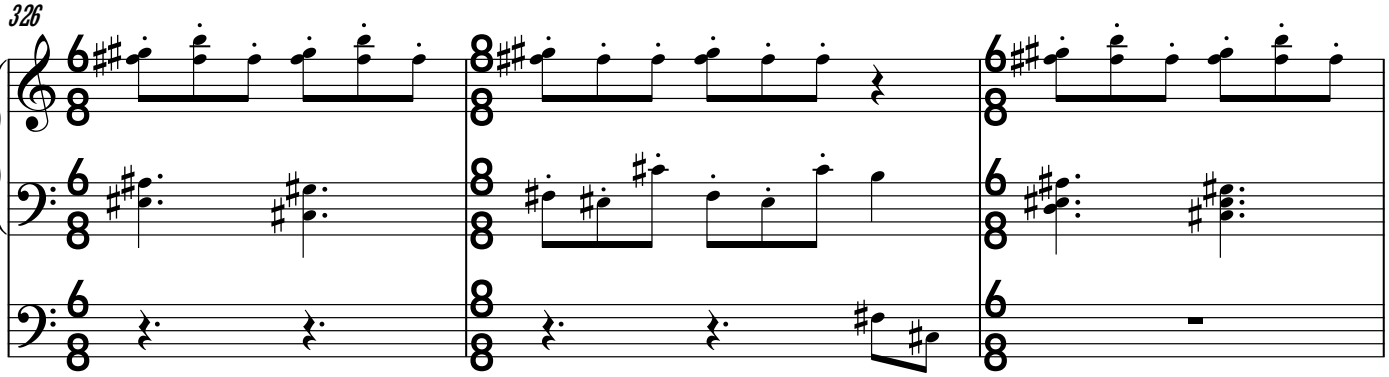
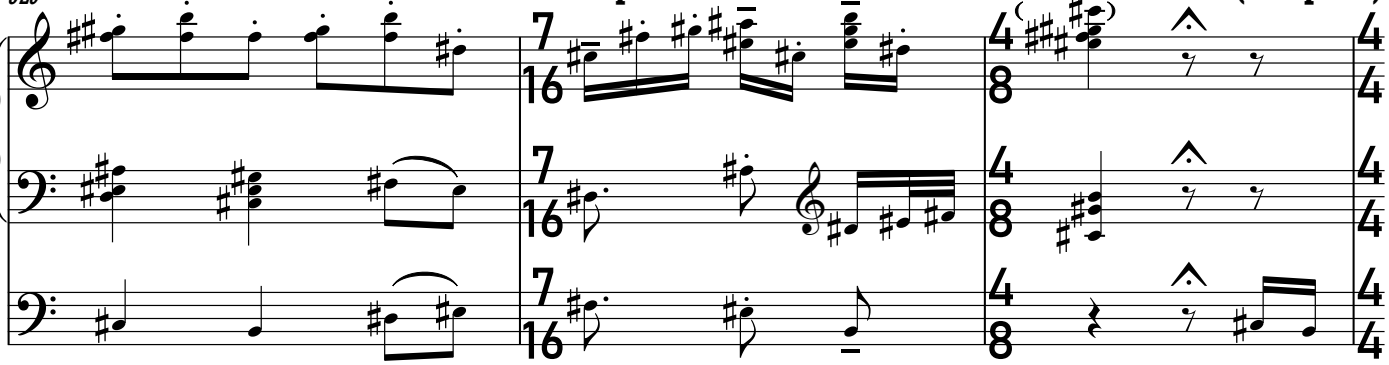


molto rit.

Tempo II

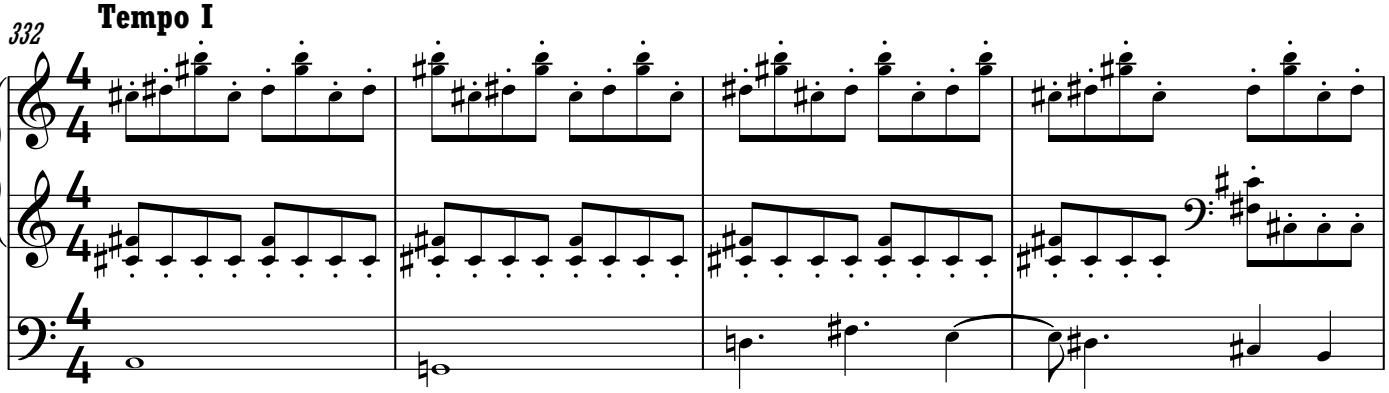
(Tempo II)

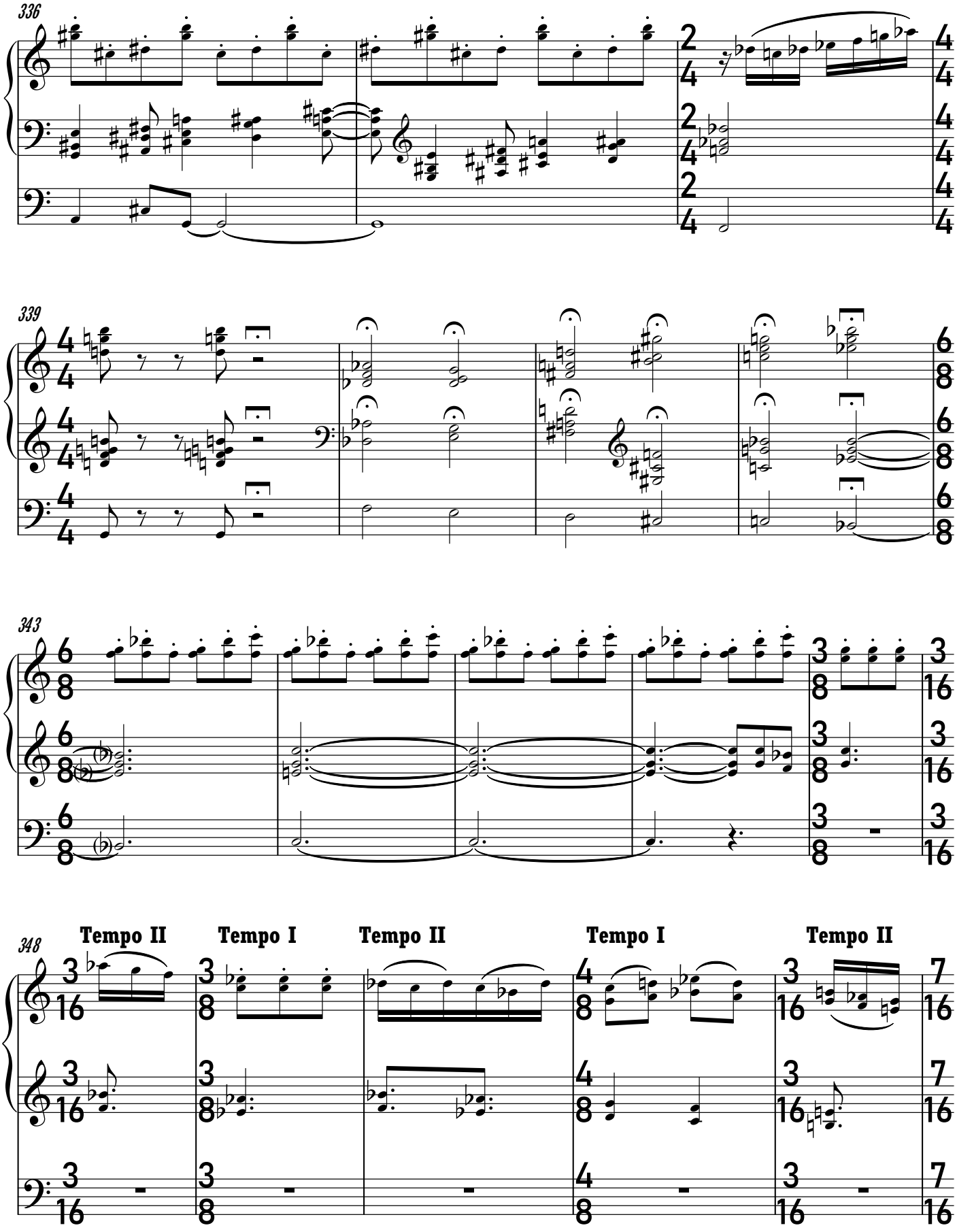
329

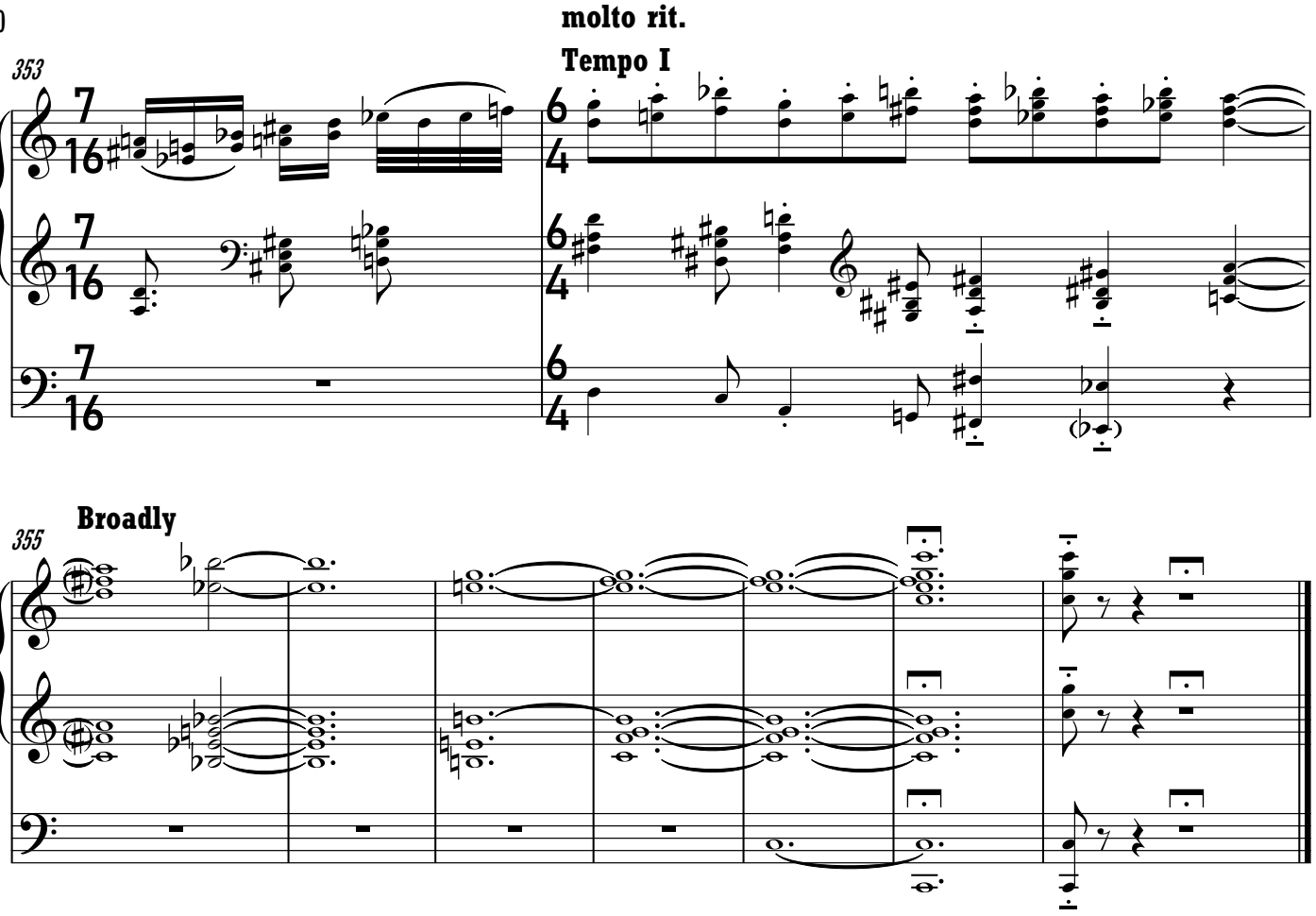


Tempo I

332




336
339
343
348
Tempo II
Tempo I
Tempo II
Tempo I
Tempo II


molto rit.
Tempo I
353
Broadly
355

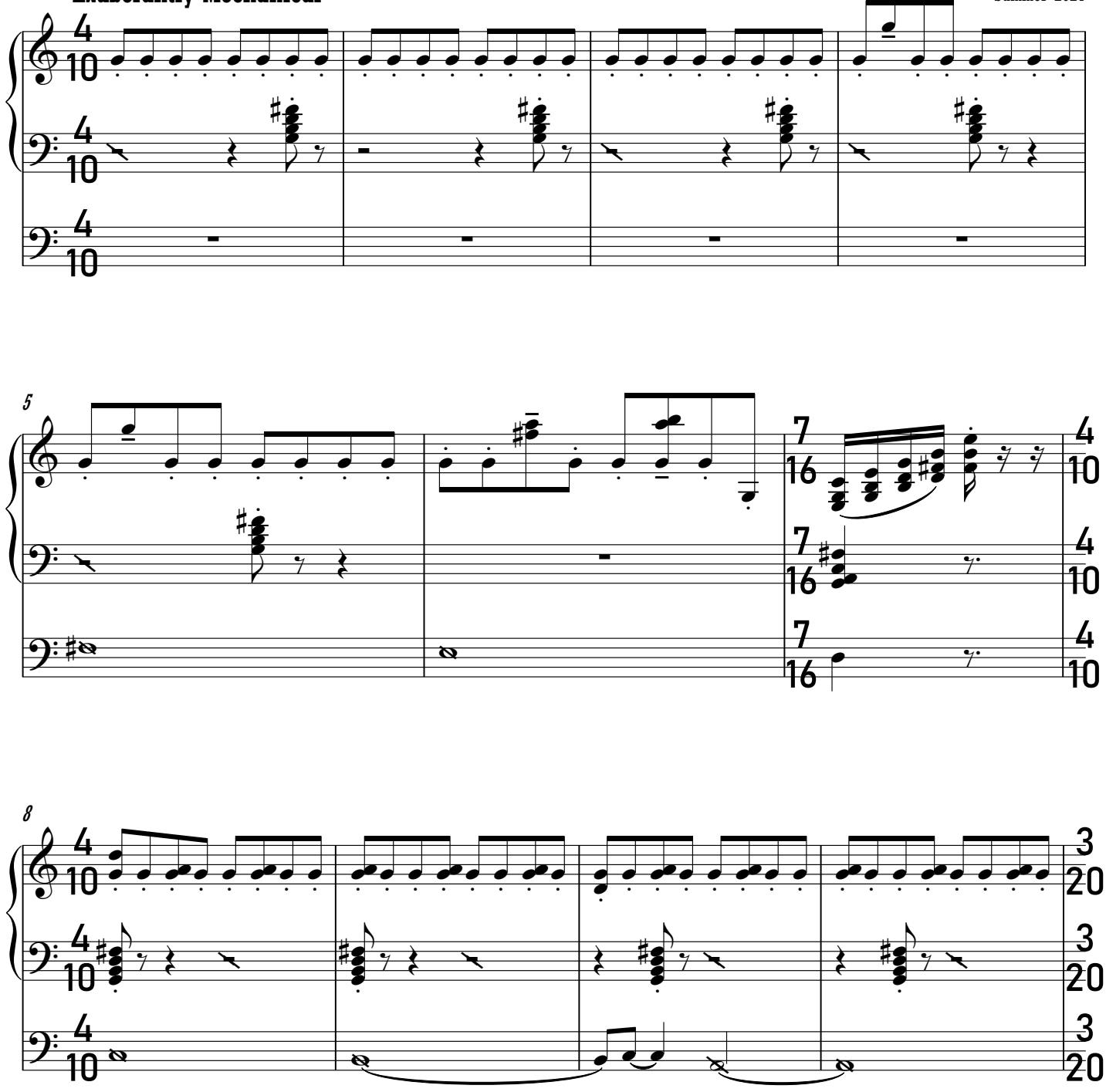
PAN-RATIONAL SCORE
Decaplex:
q-notes = 80 bpm
p-notes = 32 bpm
pq-notes = 160 bpm

Rosalind Unravels the Bundle of Life

- Fantasia upon a Modal Helix ad honorem Rosalind Franklin -

Jordan Alexander Key
Summer 2021

Exuberantly Mechanical



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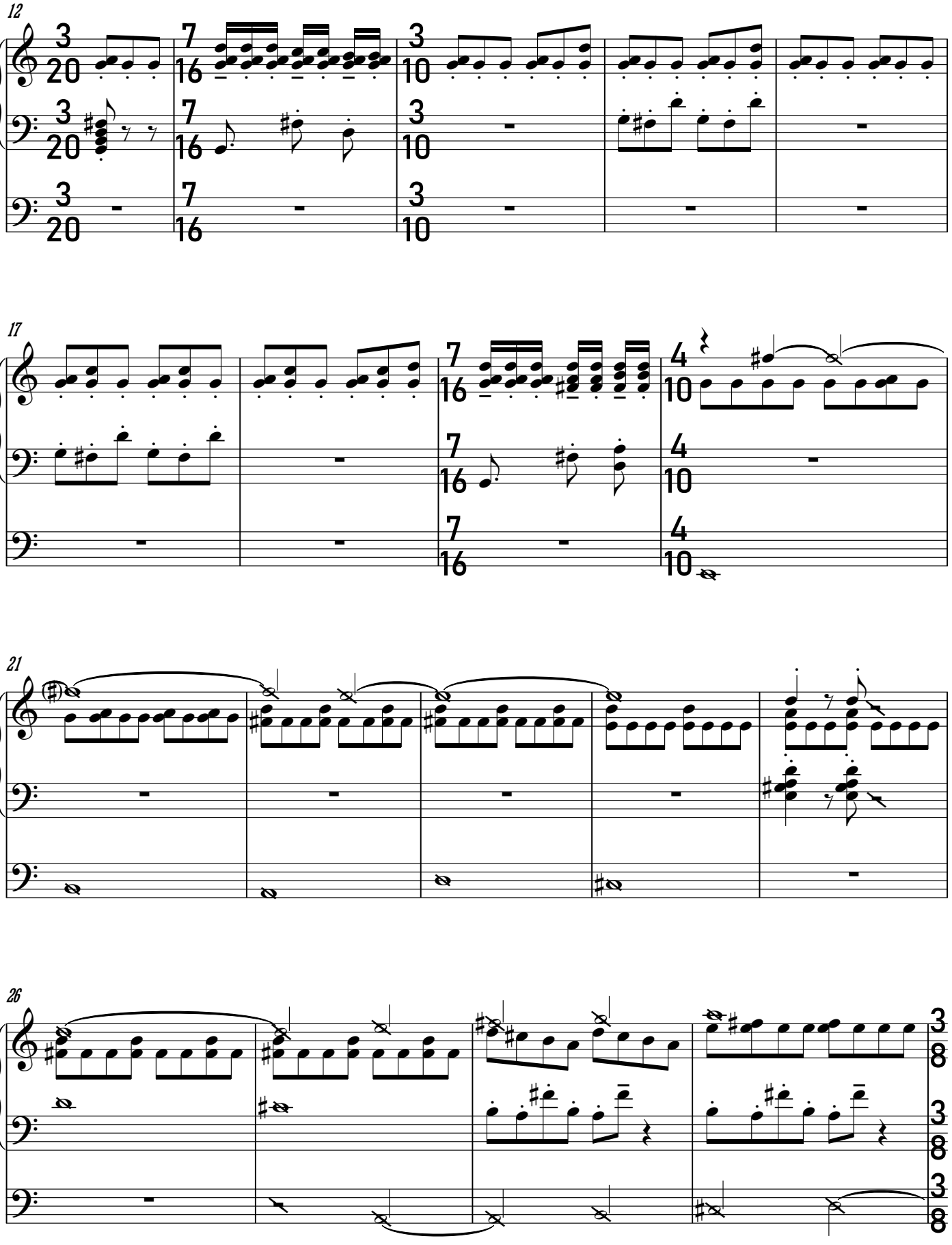
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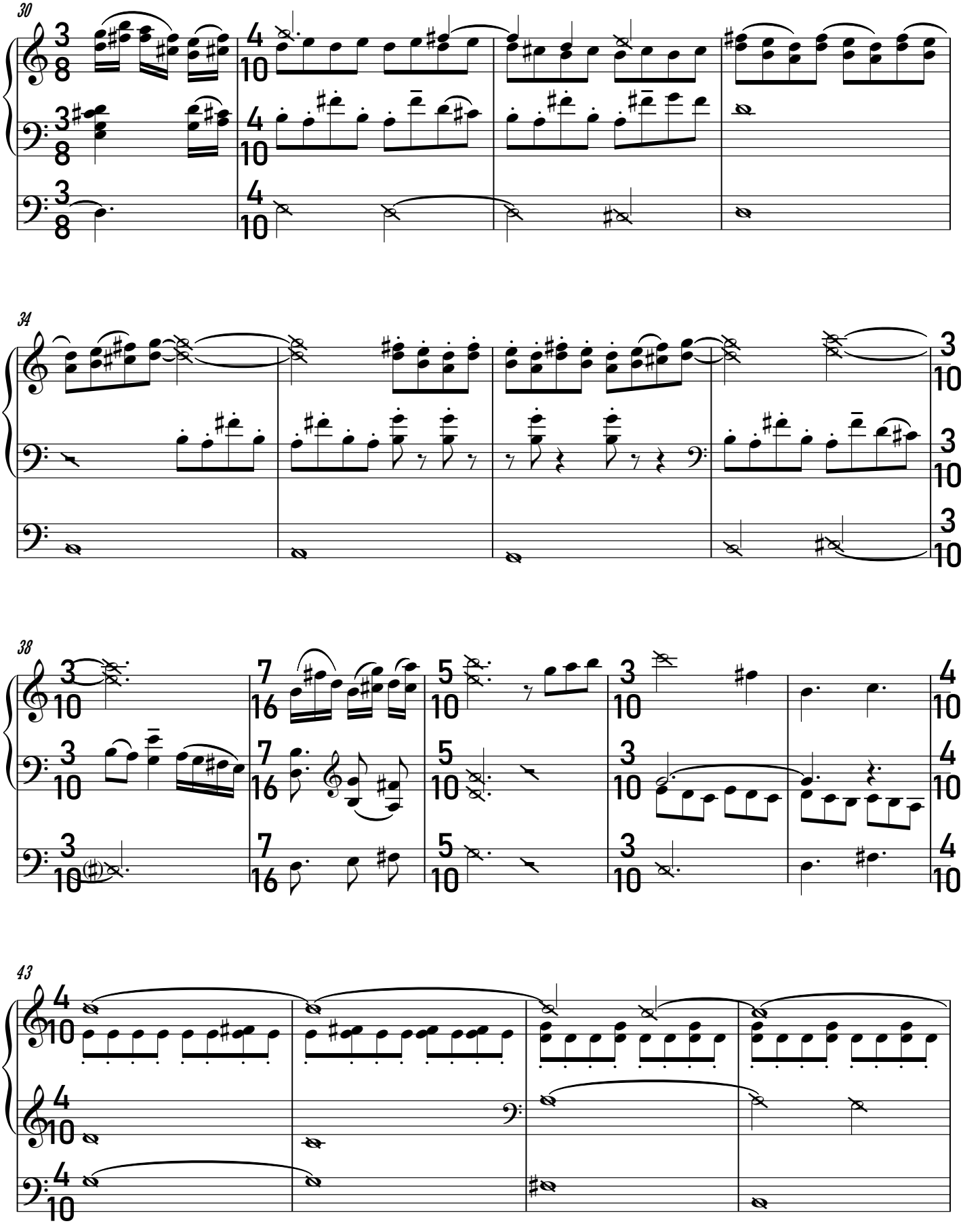
17
21
26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38
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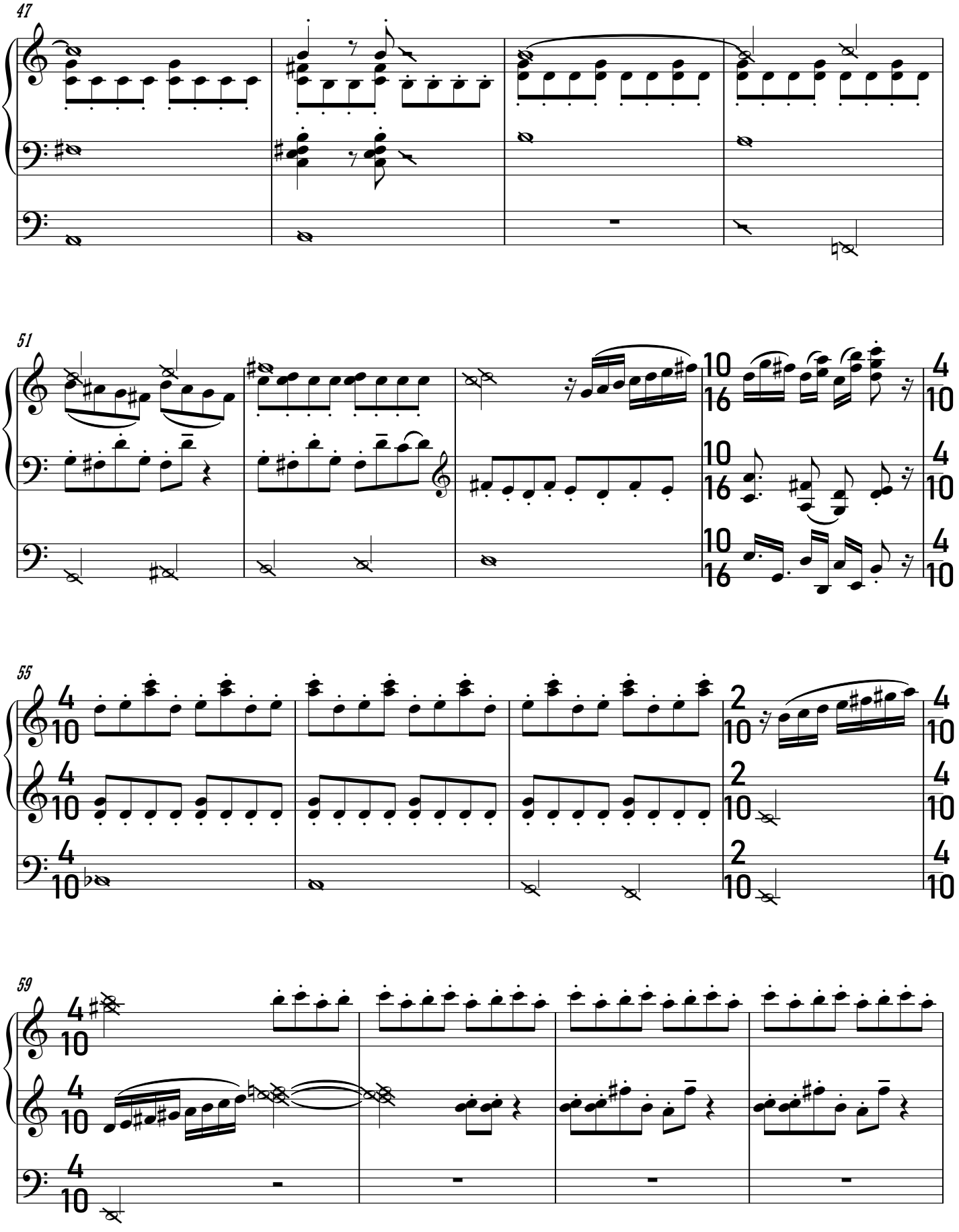
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51
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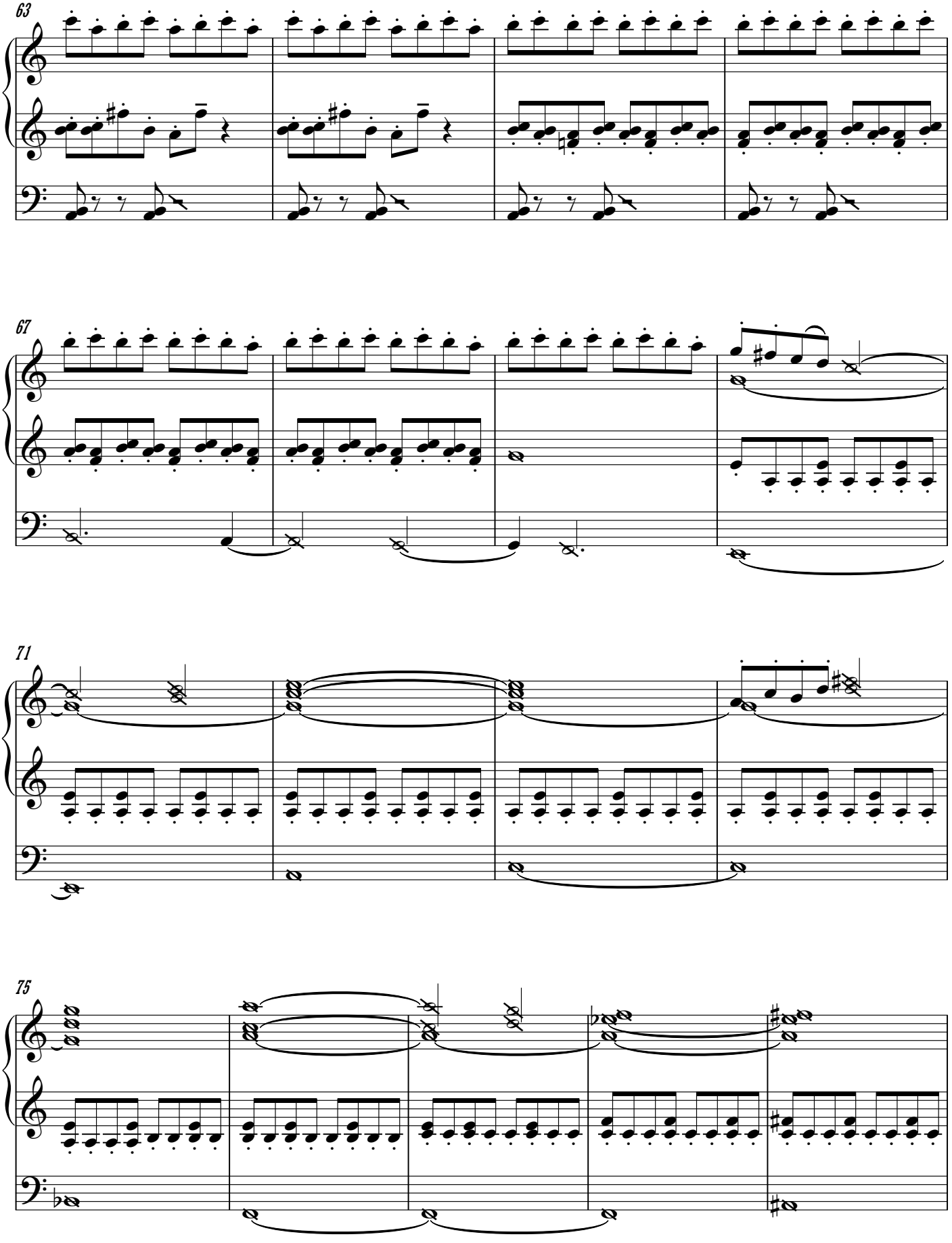
59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67
71
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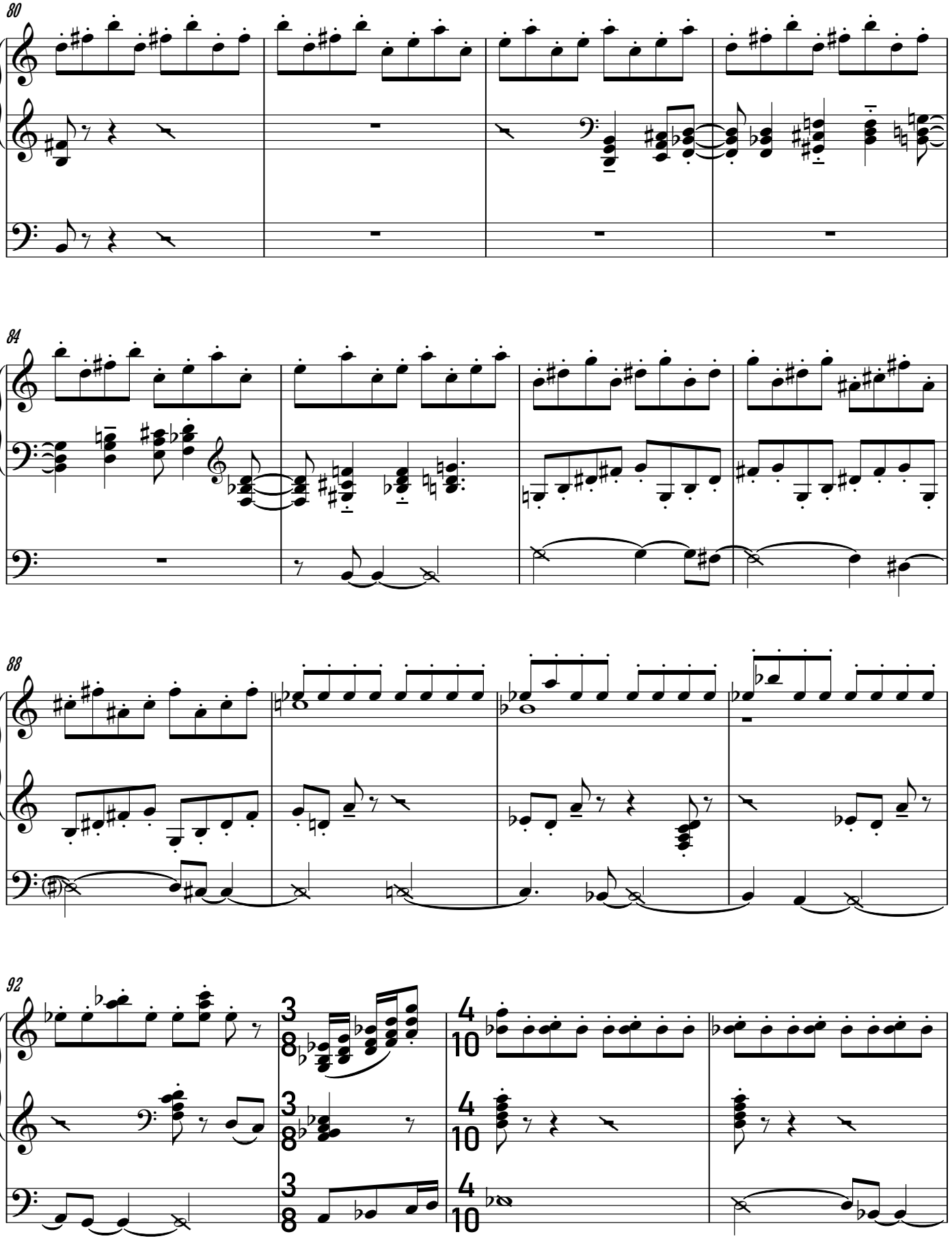
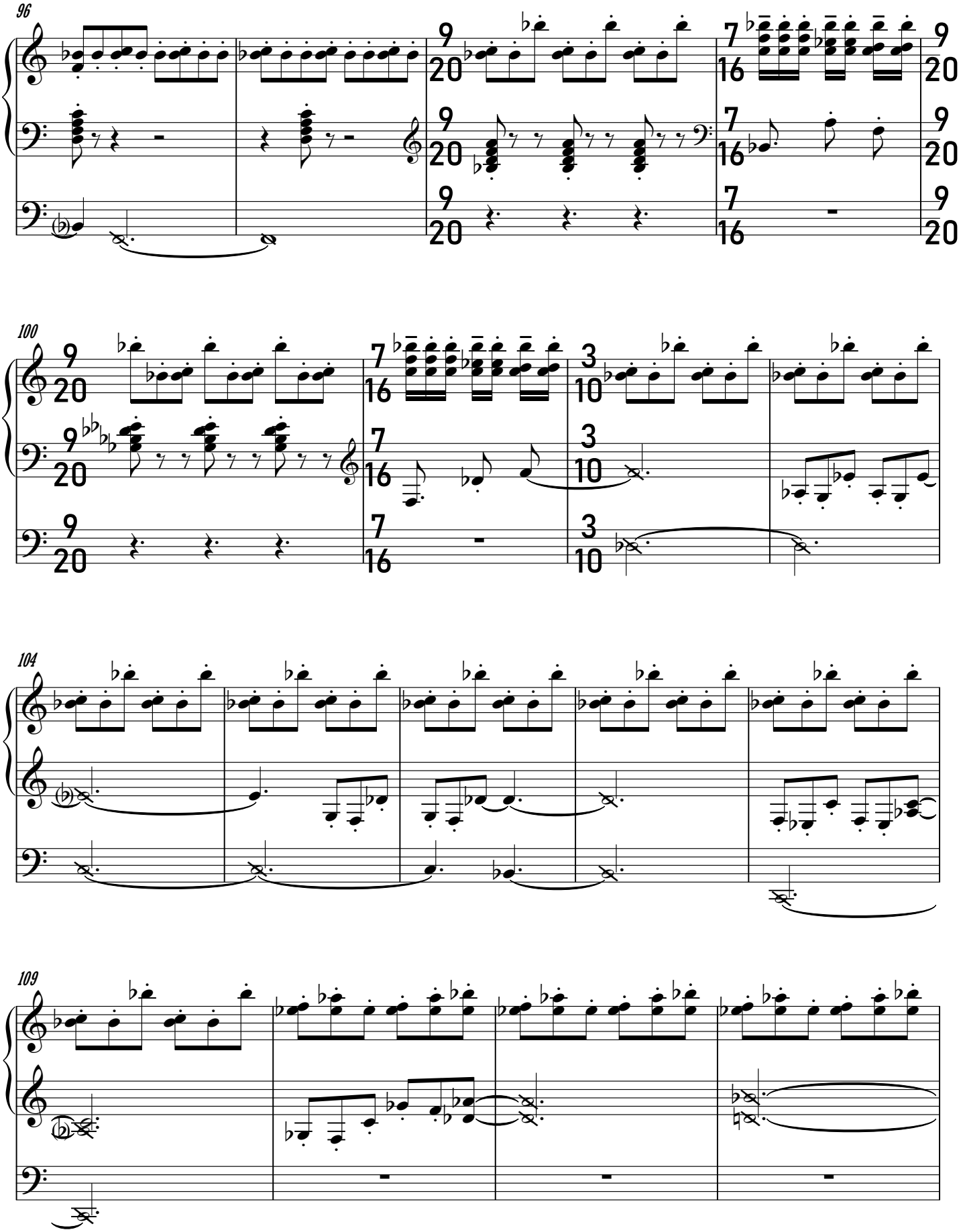

80
84
88
92
3
8
4
10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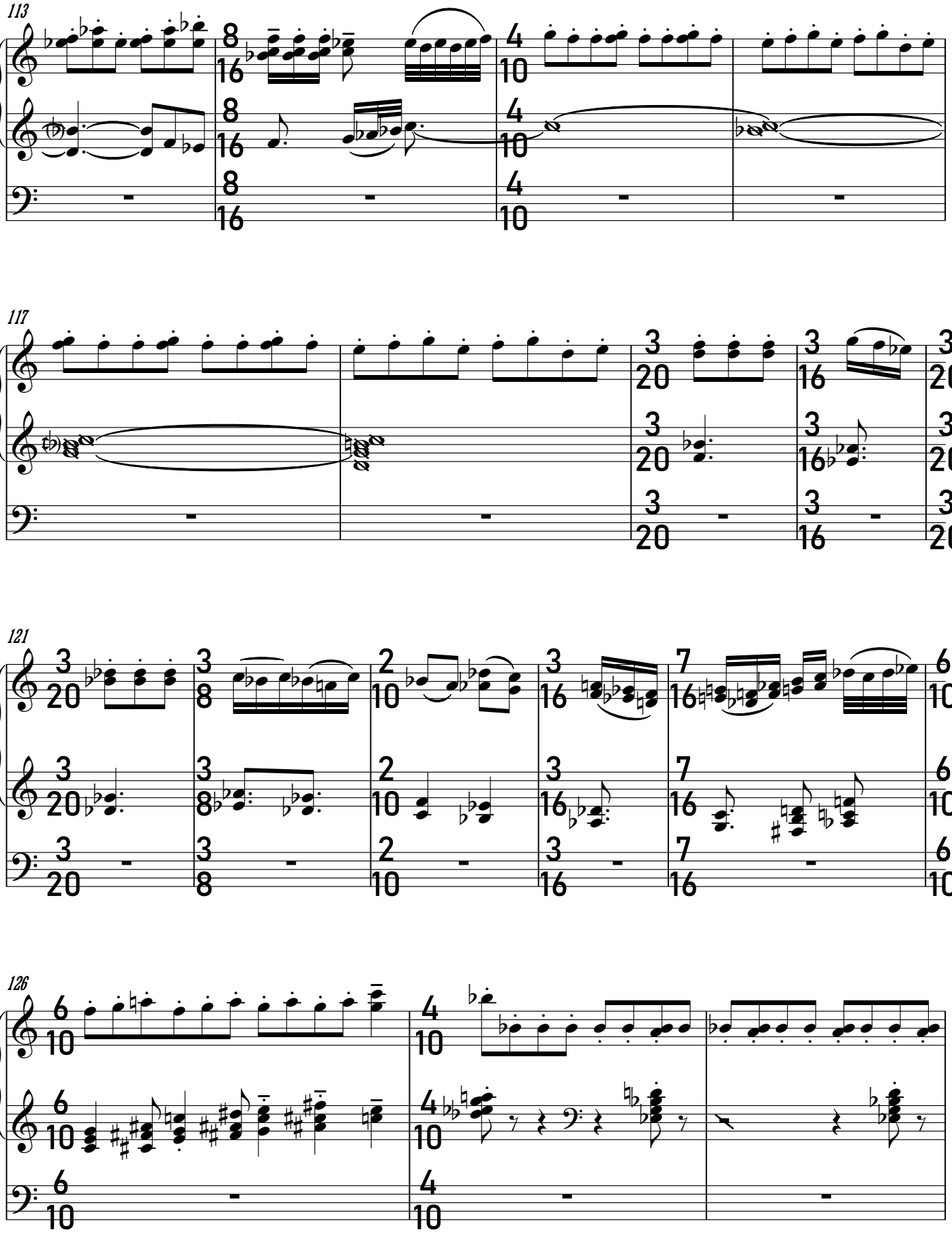
100
104
109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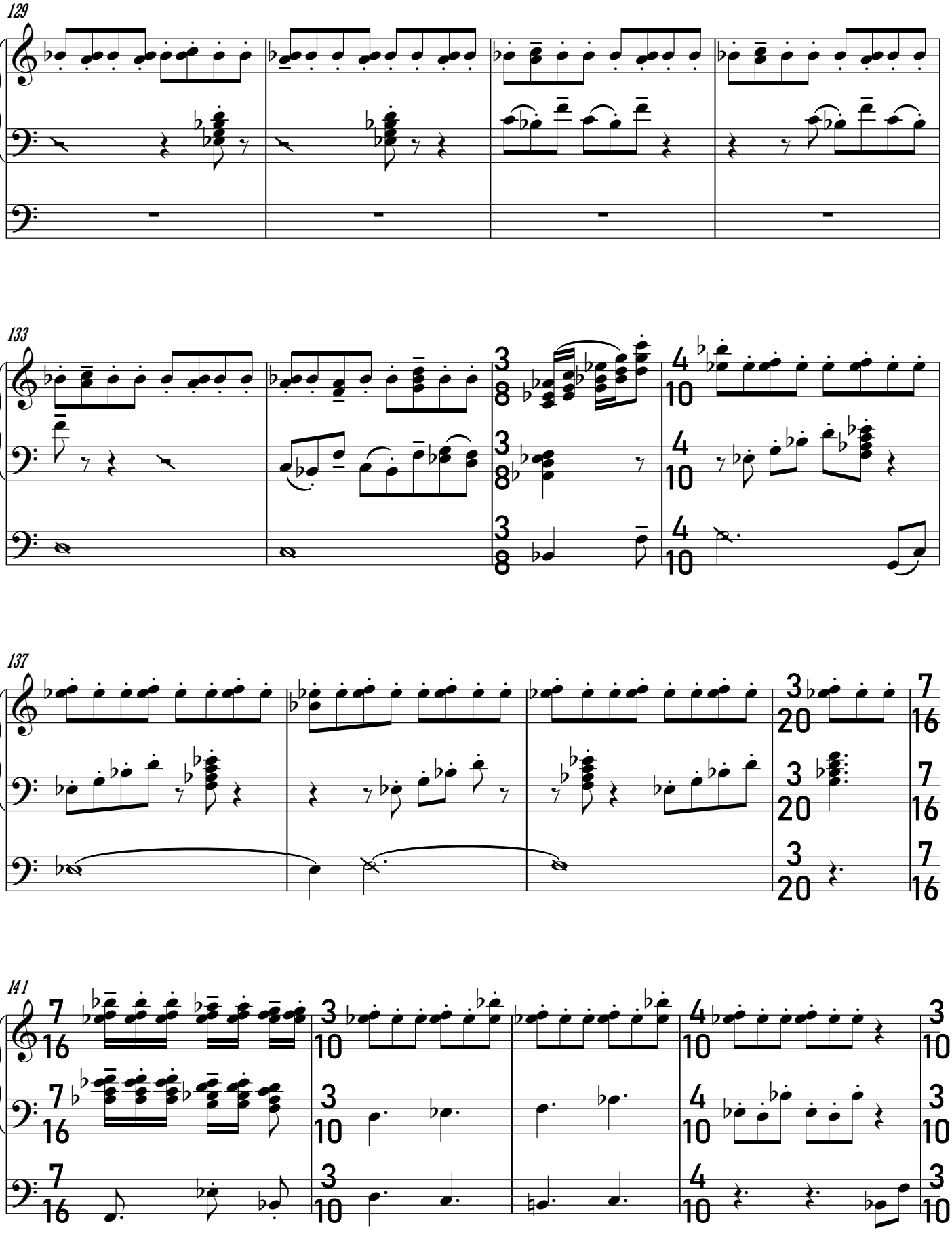
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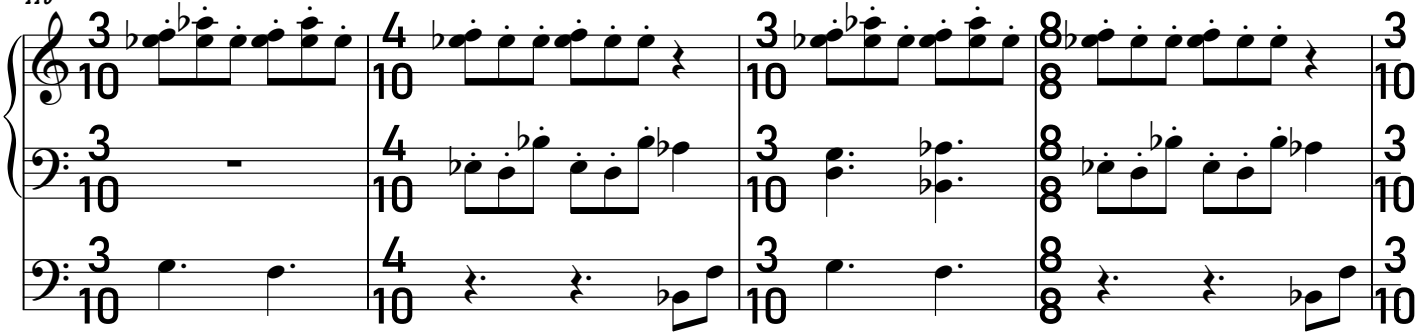
141

145



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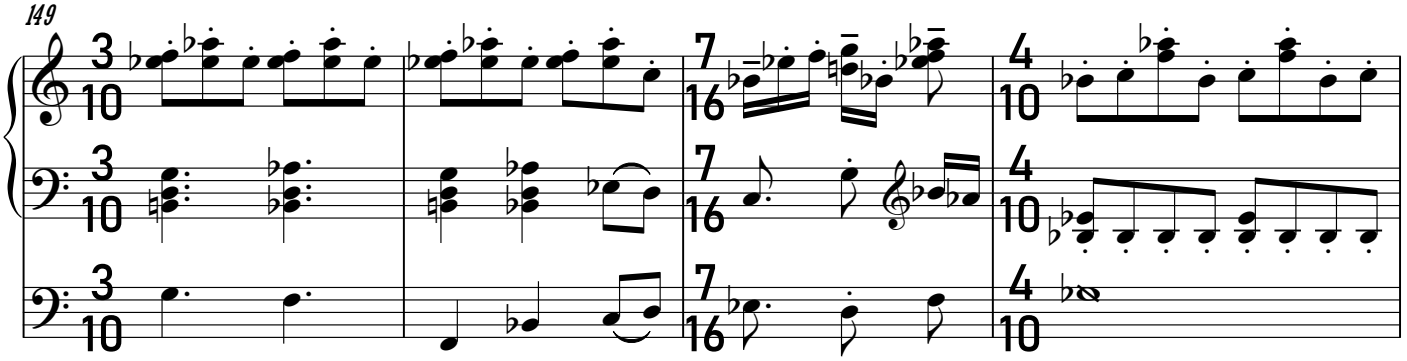

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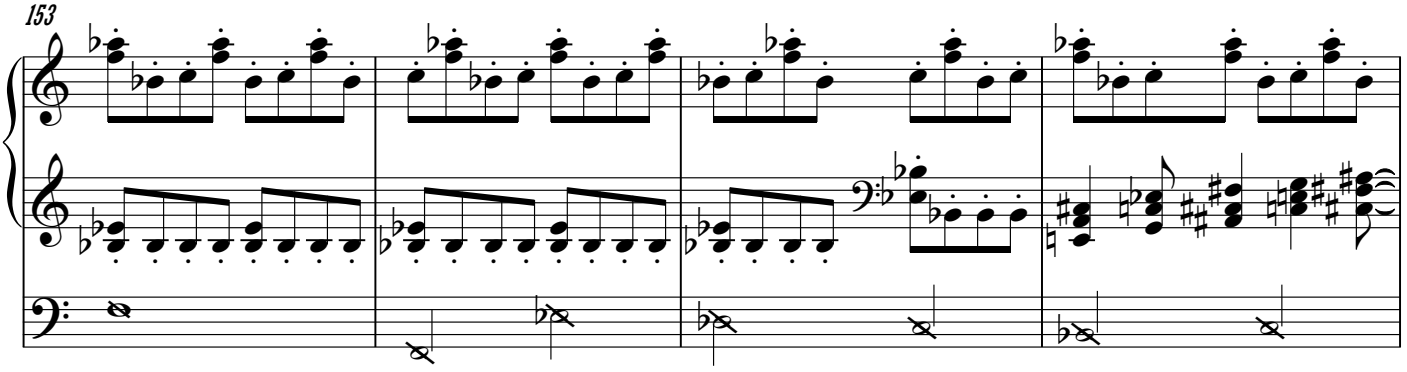

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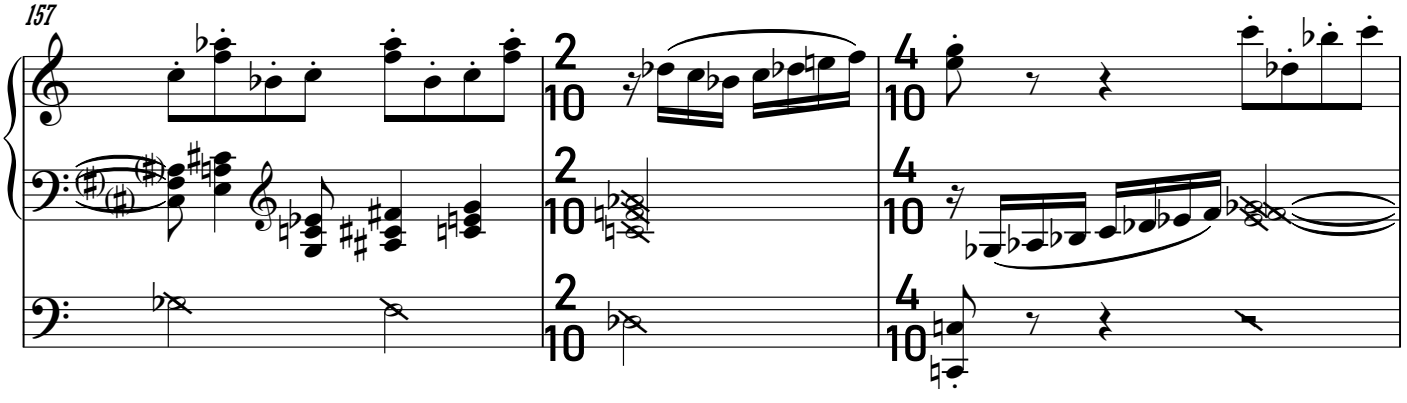

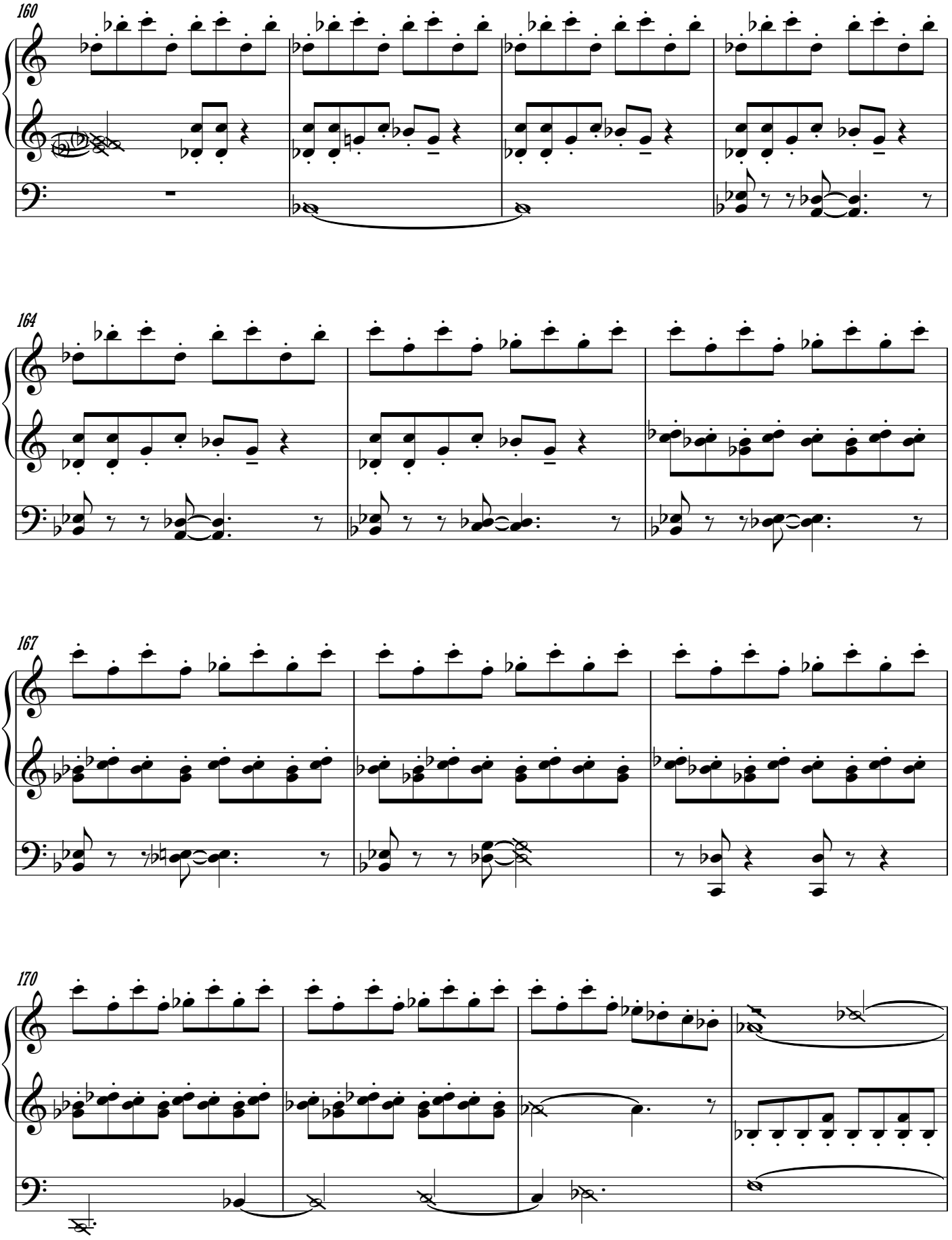
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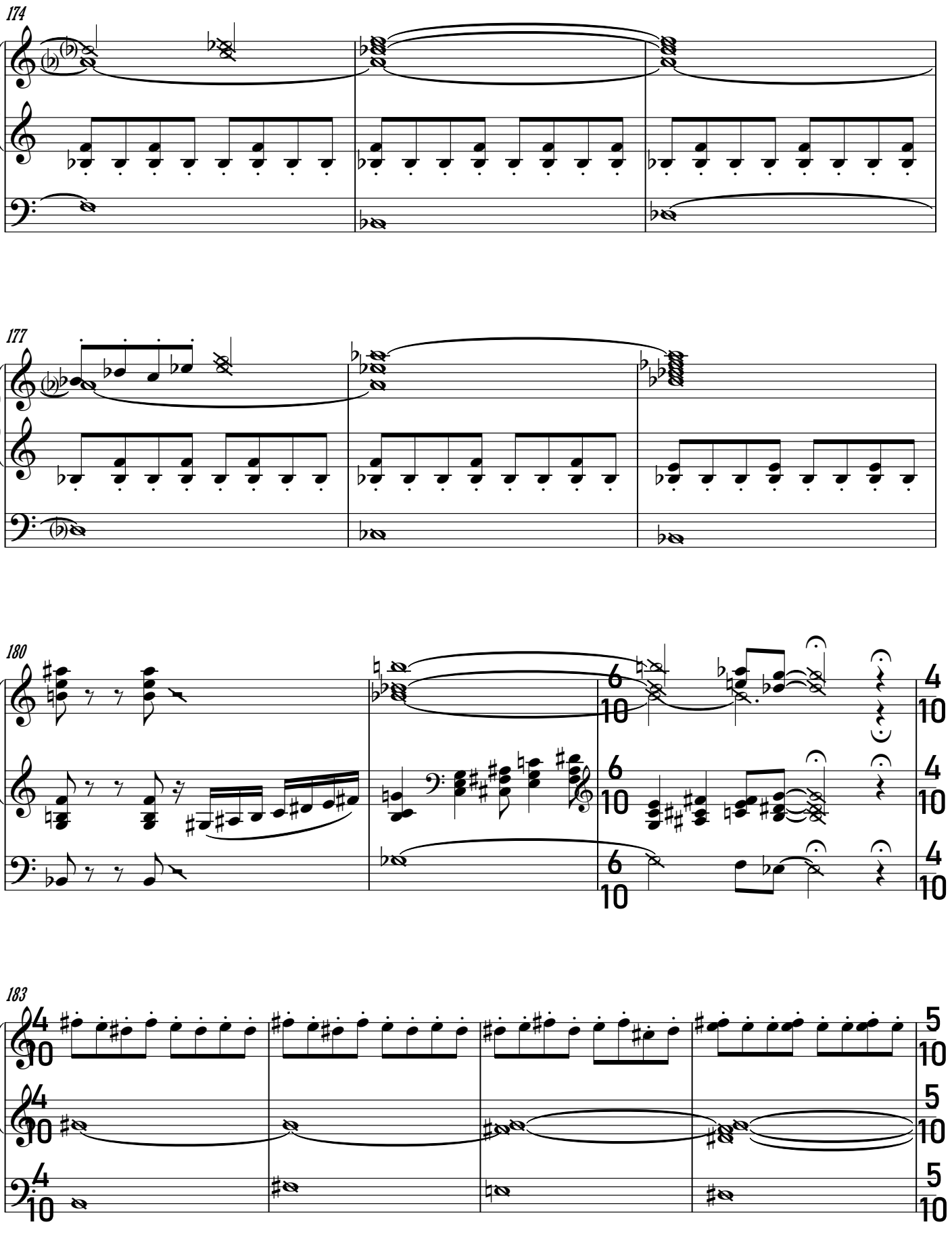
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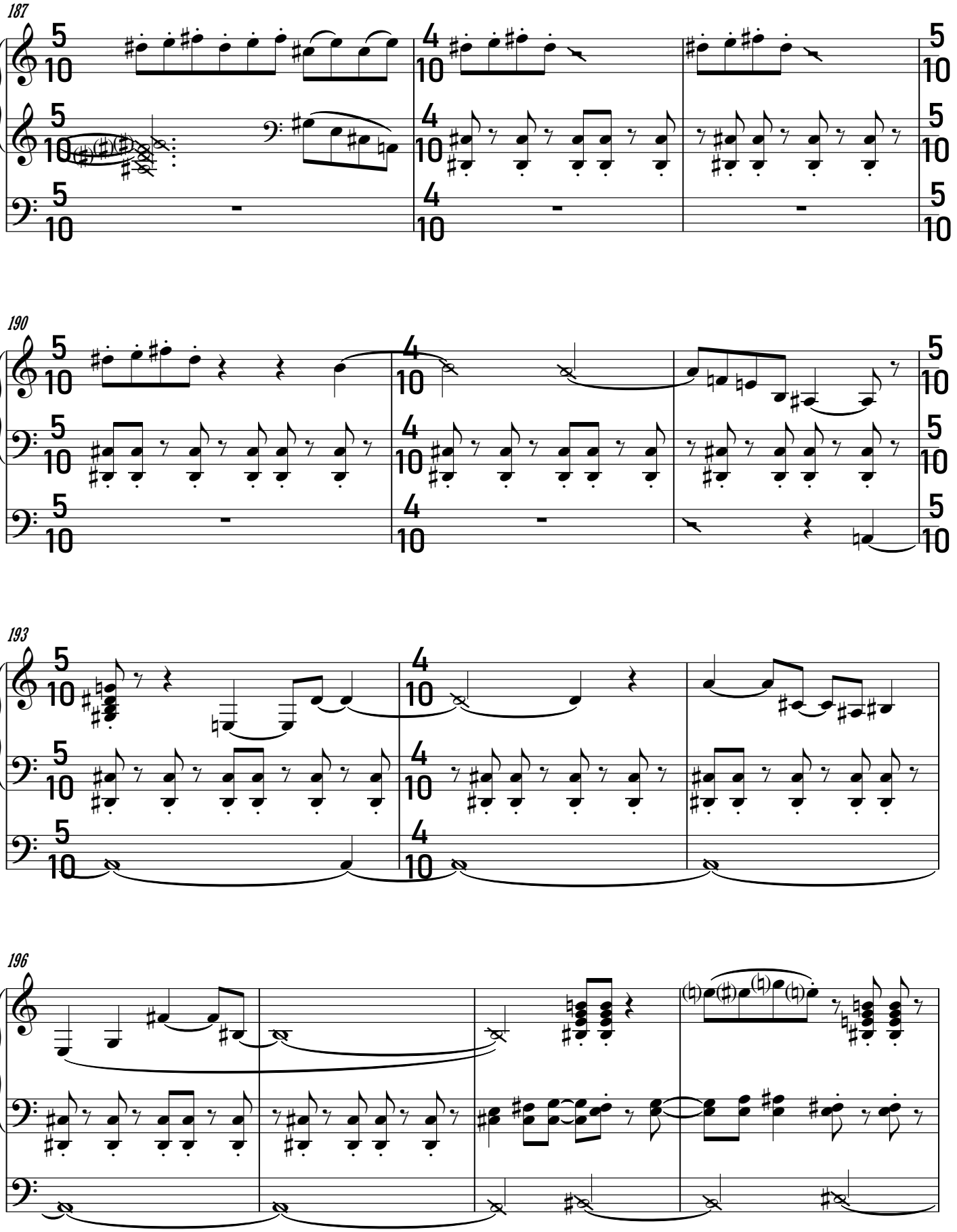
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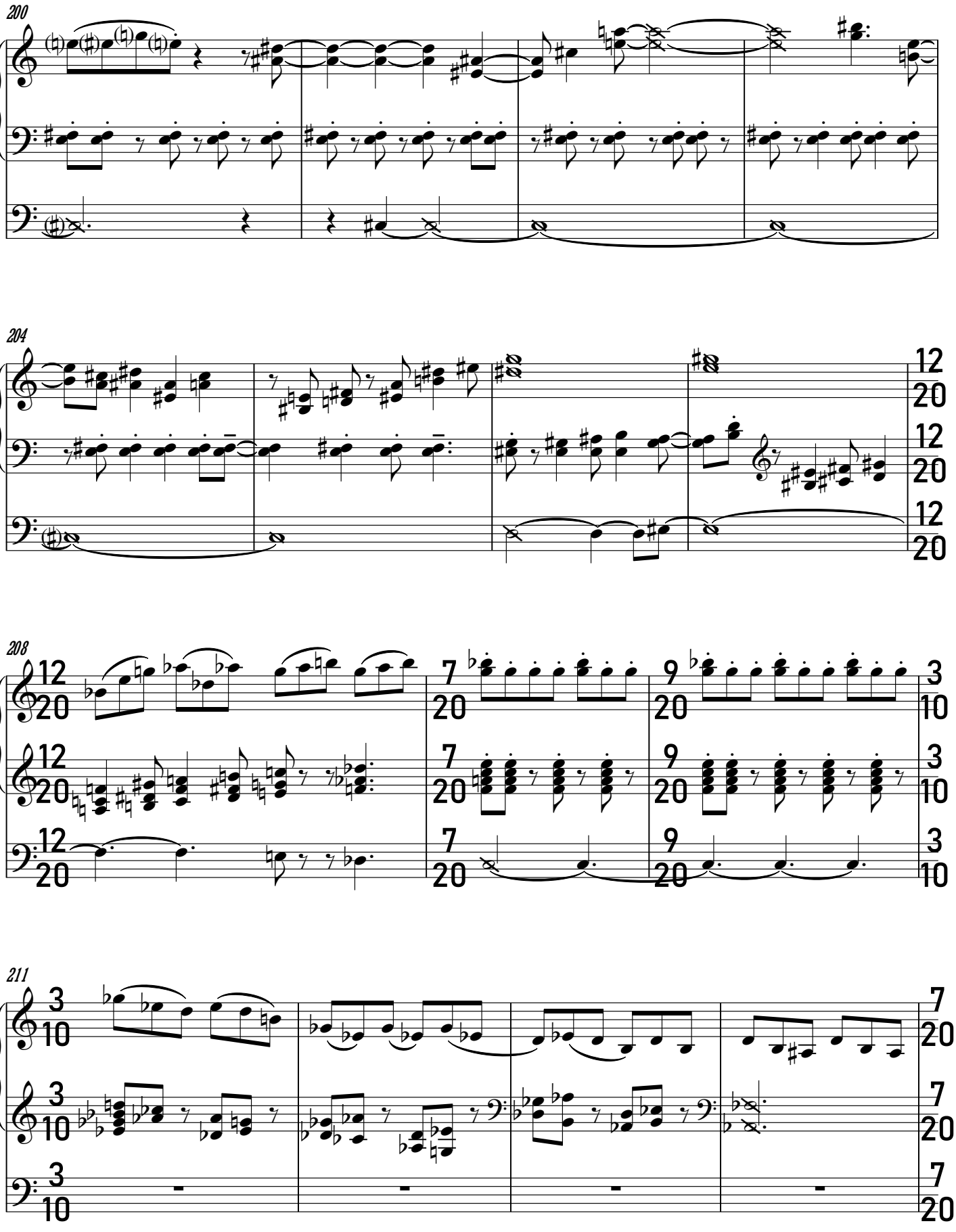
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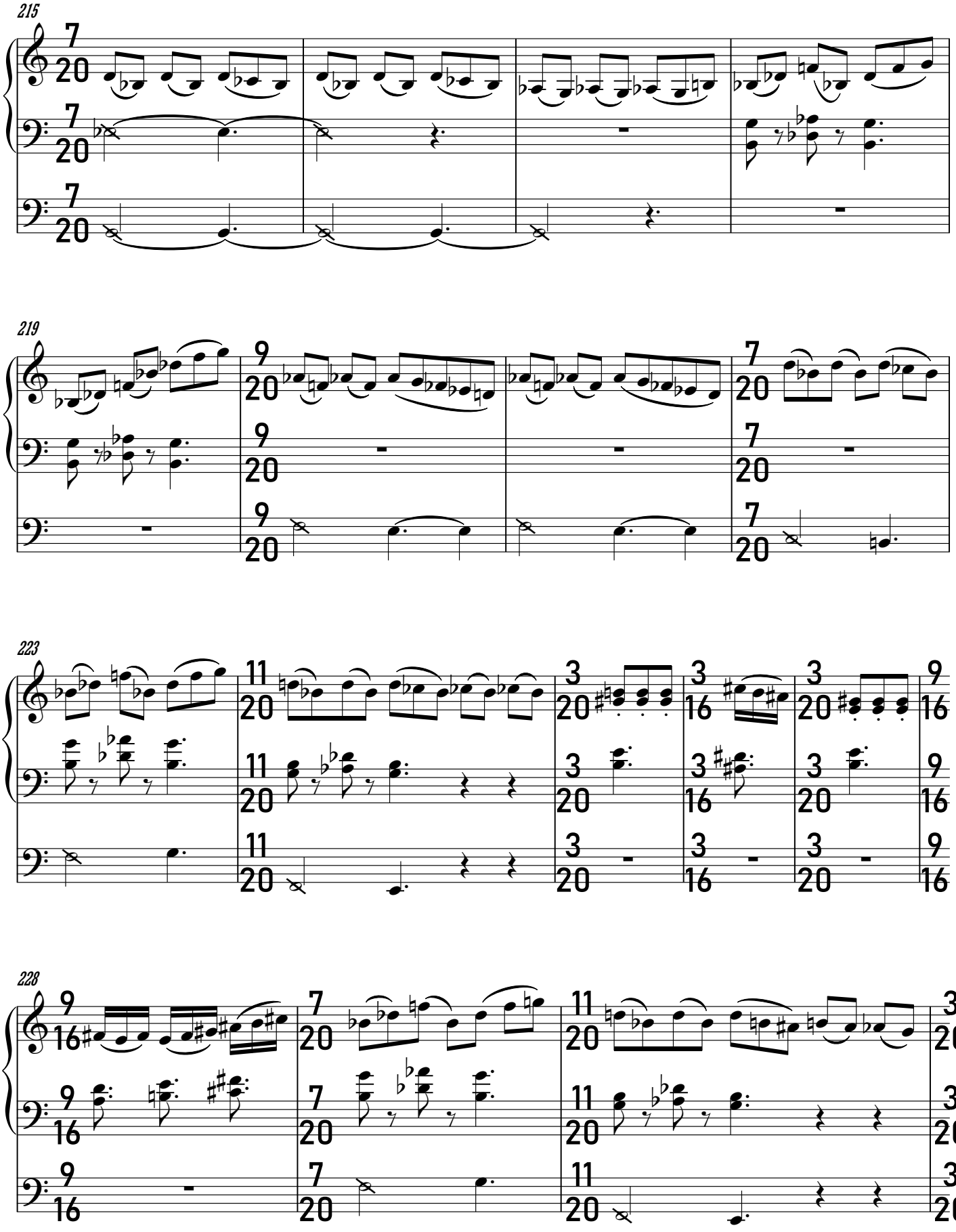
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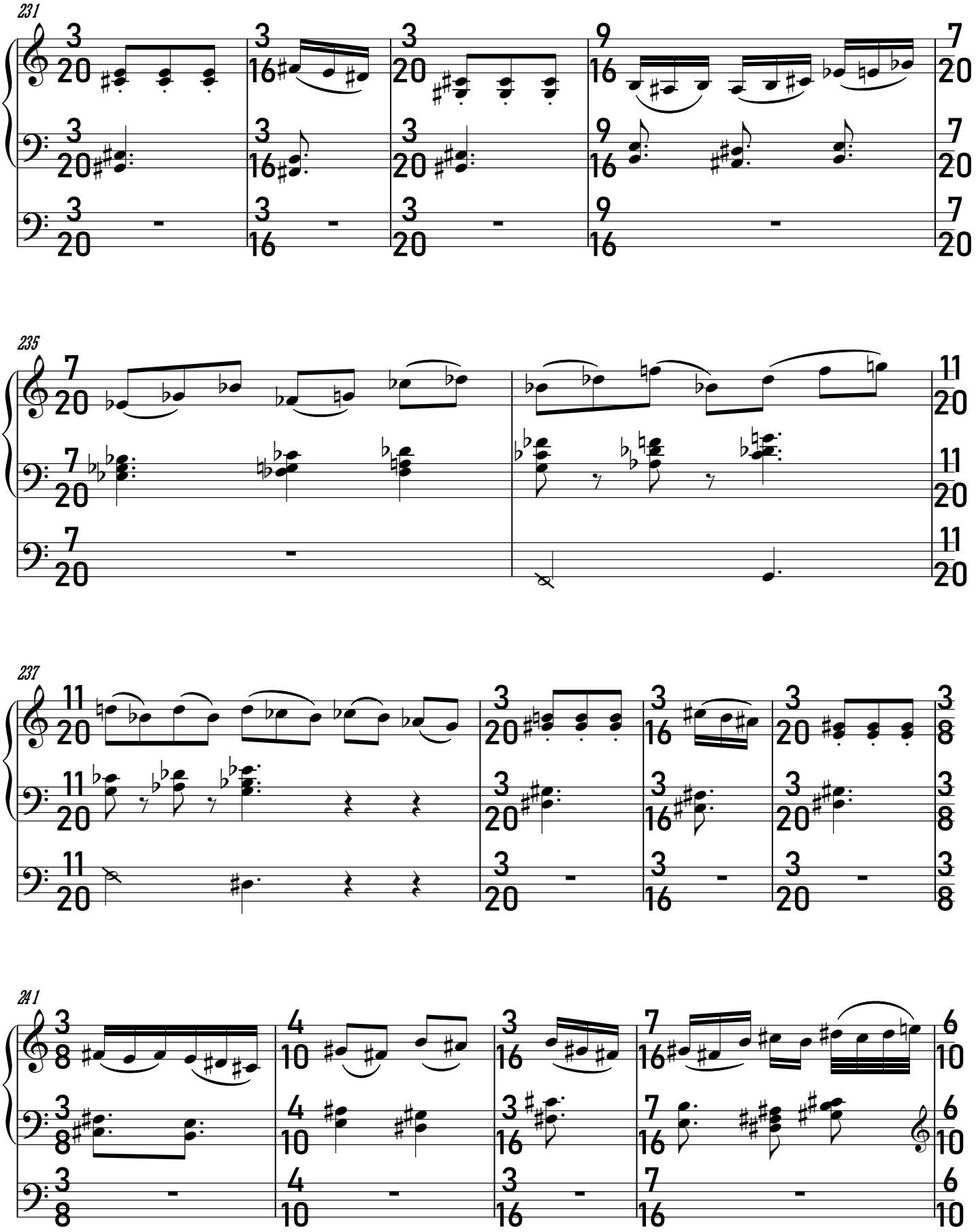
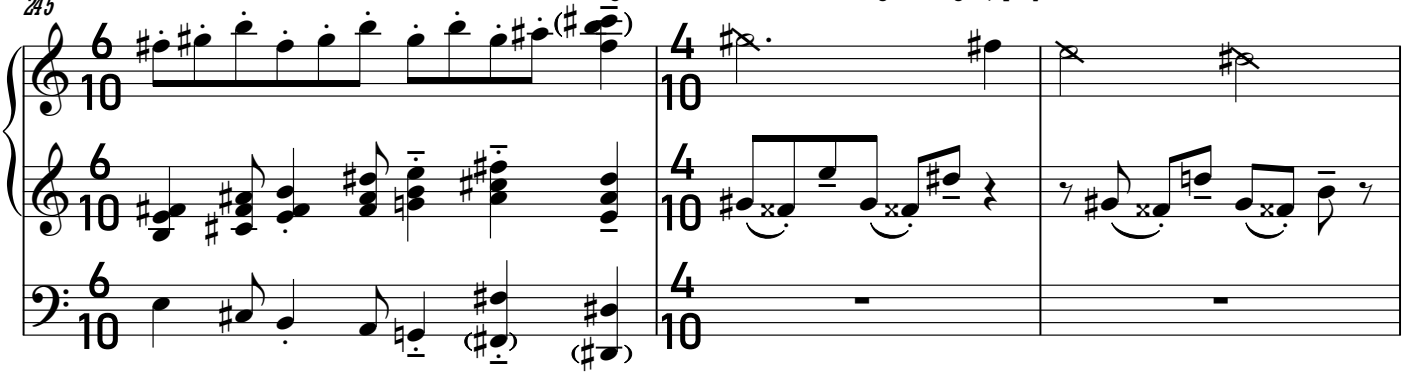

231
235
237
241

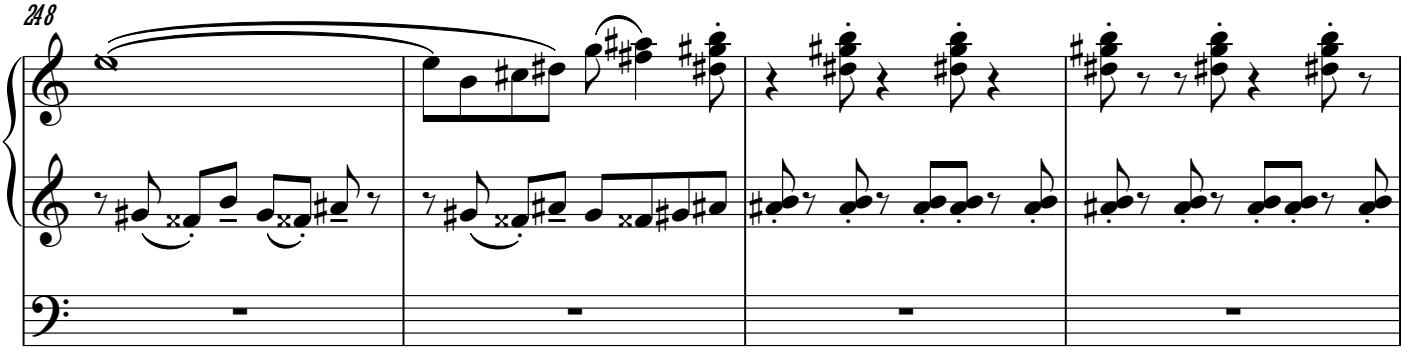
high C# not available on original organ, play if available

245



low F# and D# not available on original organ, play if available

248



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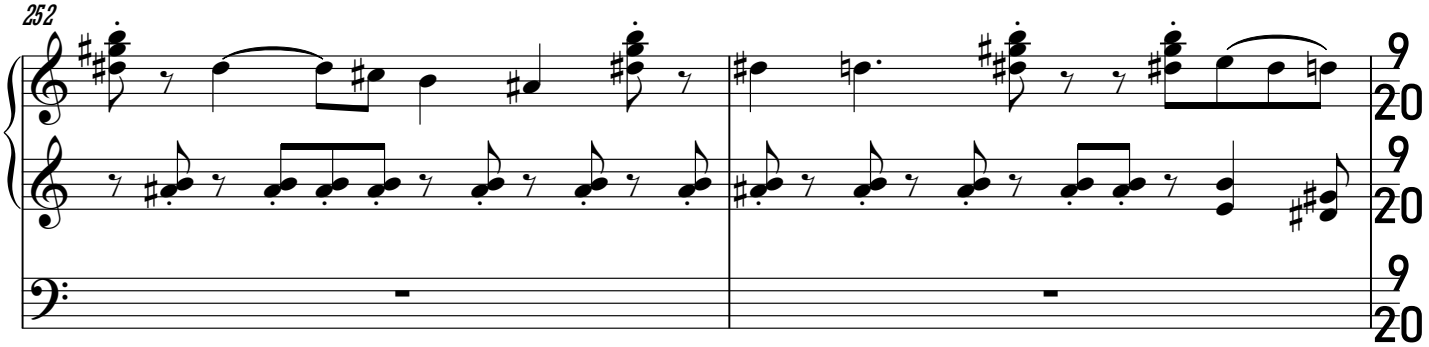

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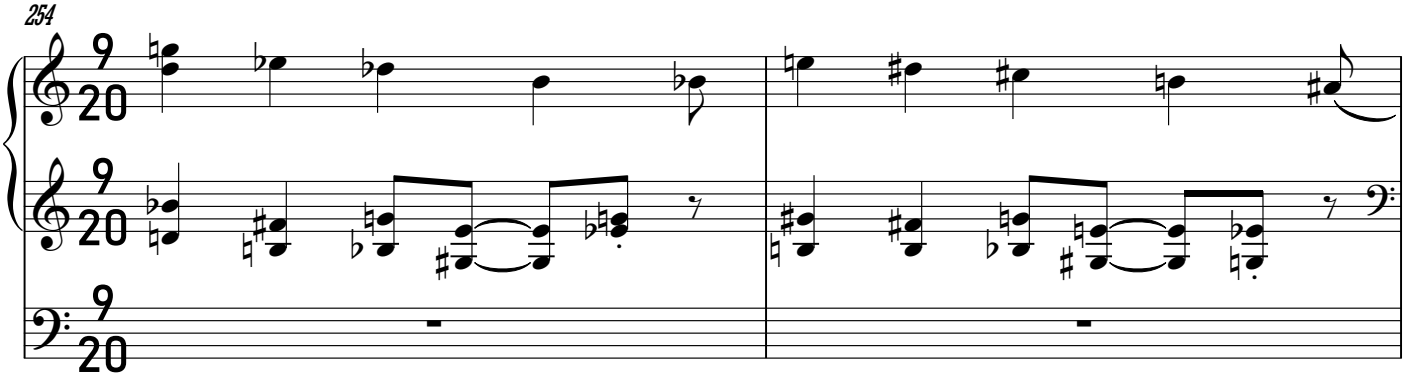

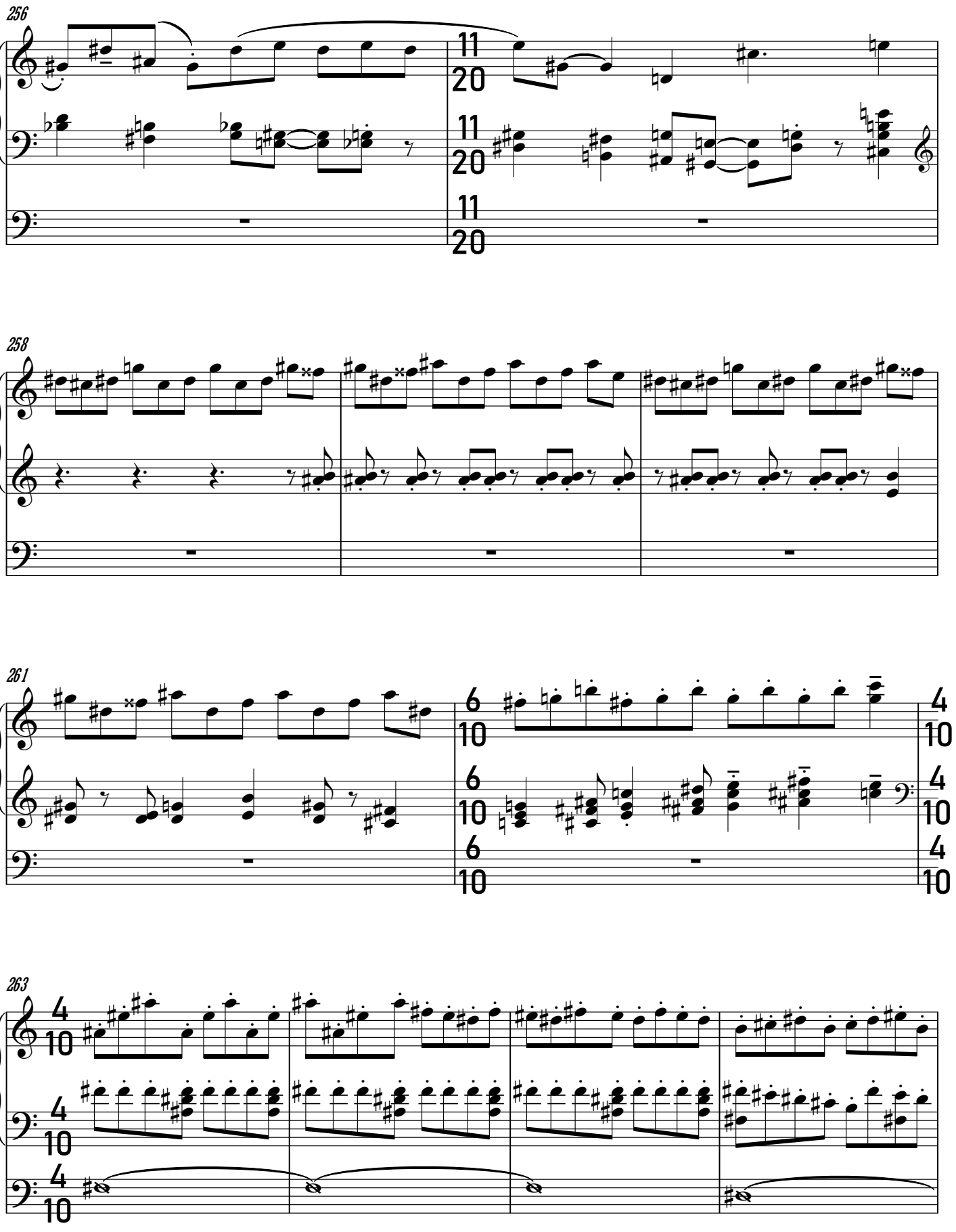
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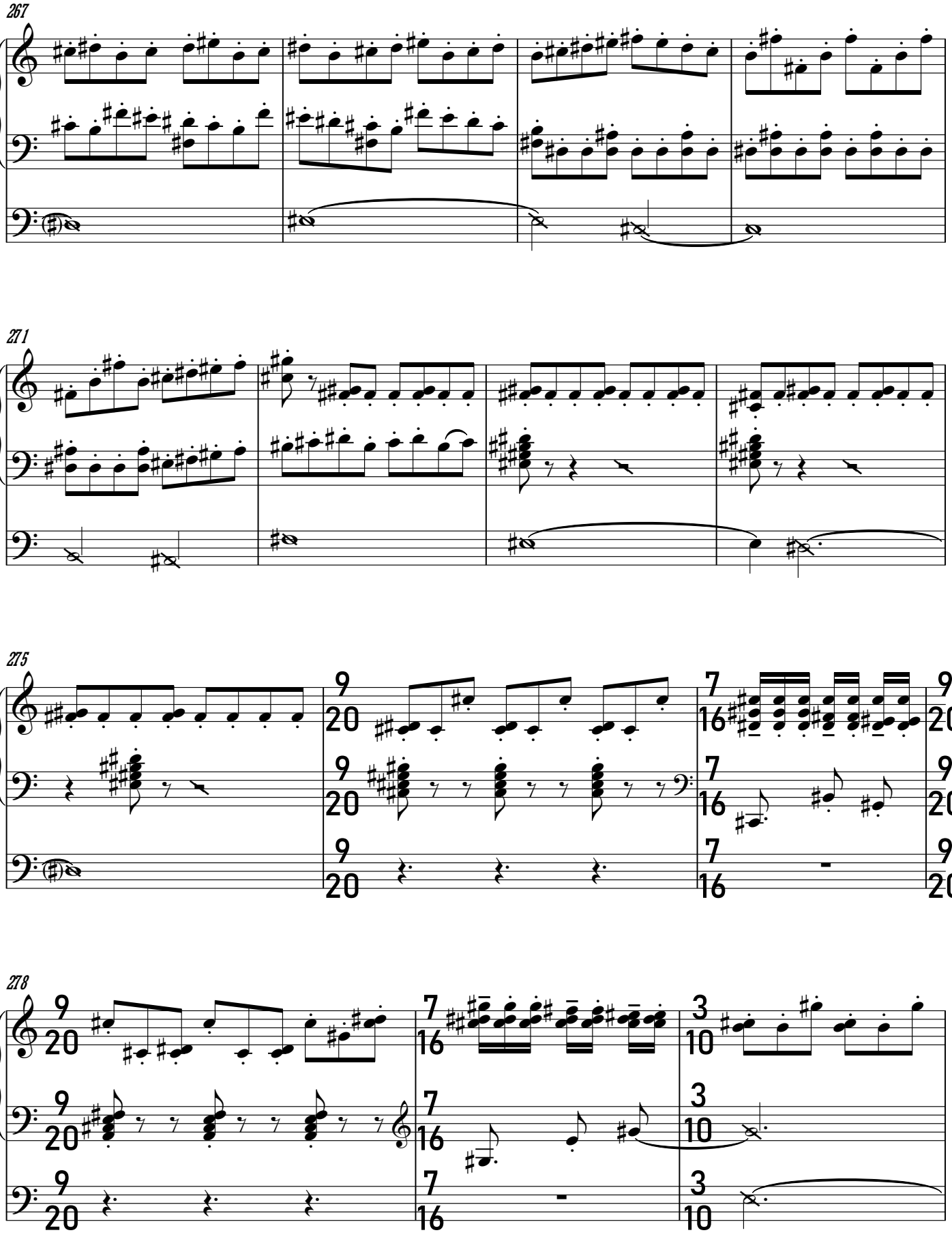
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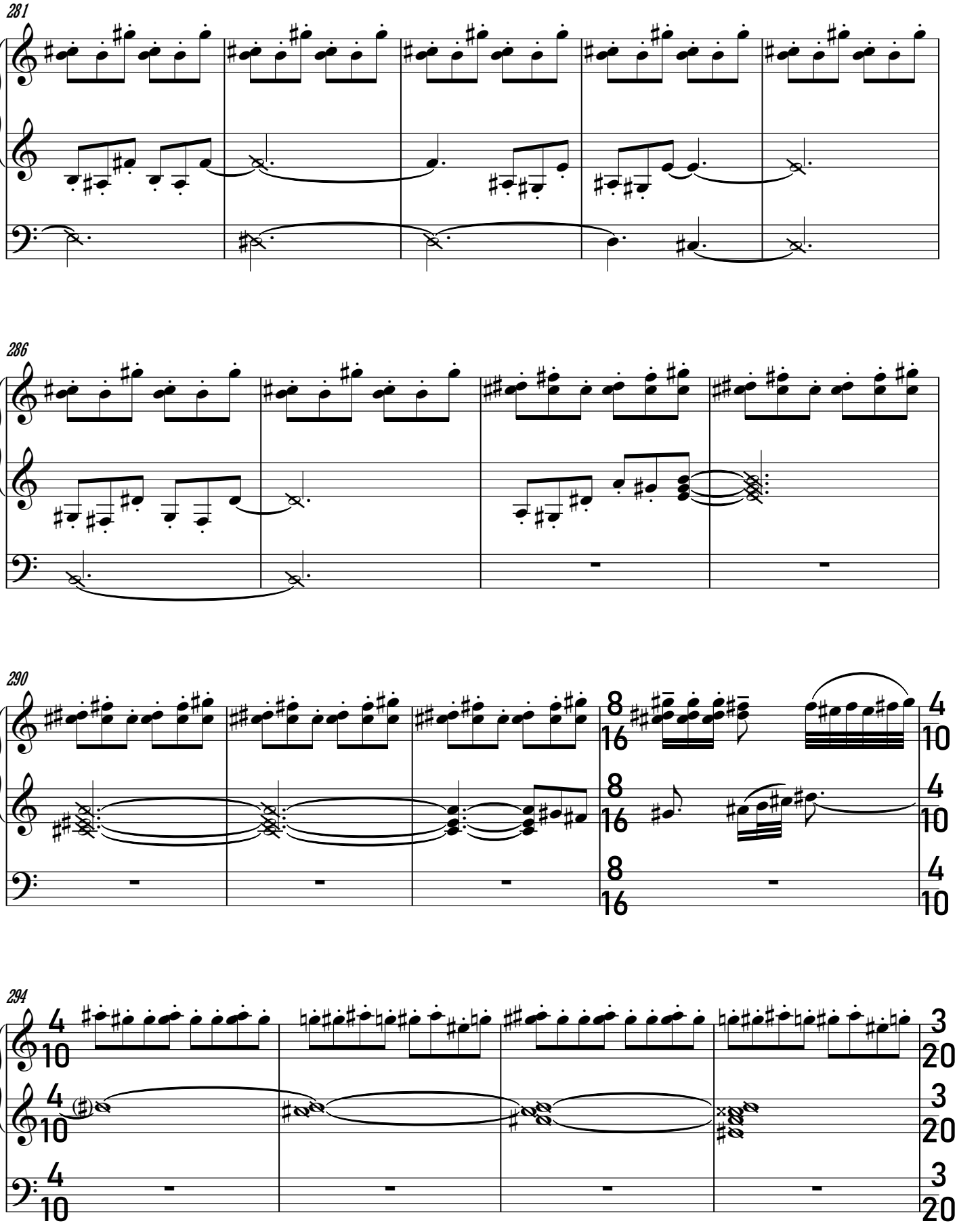
271
275
9/20
7/16
278
3/10


281
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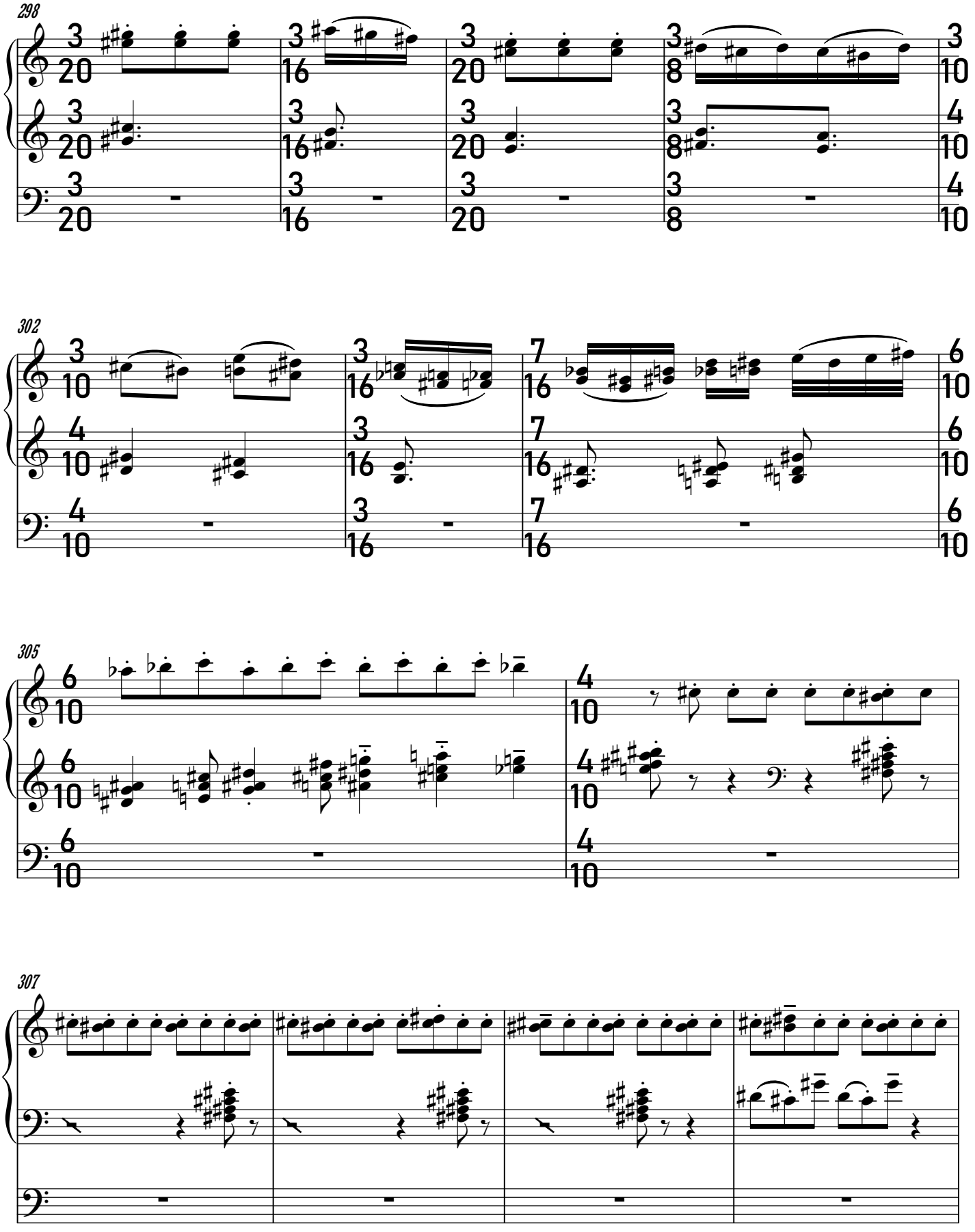
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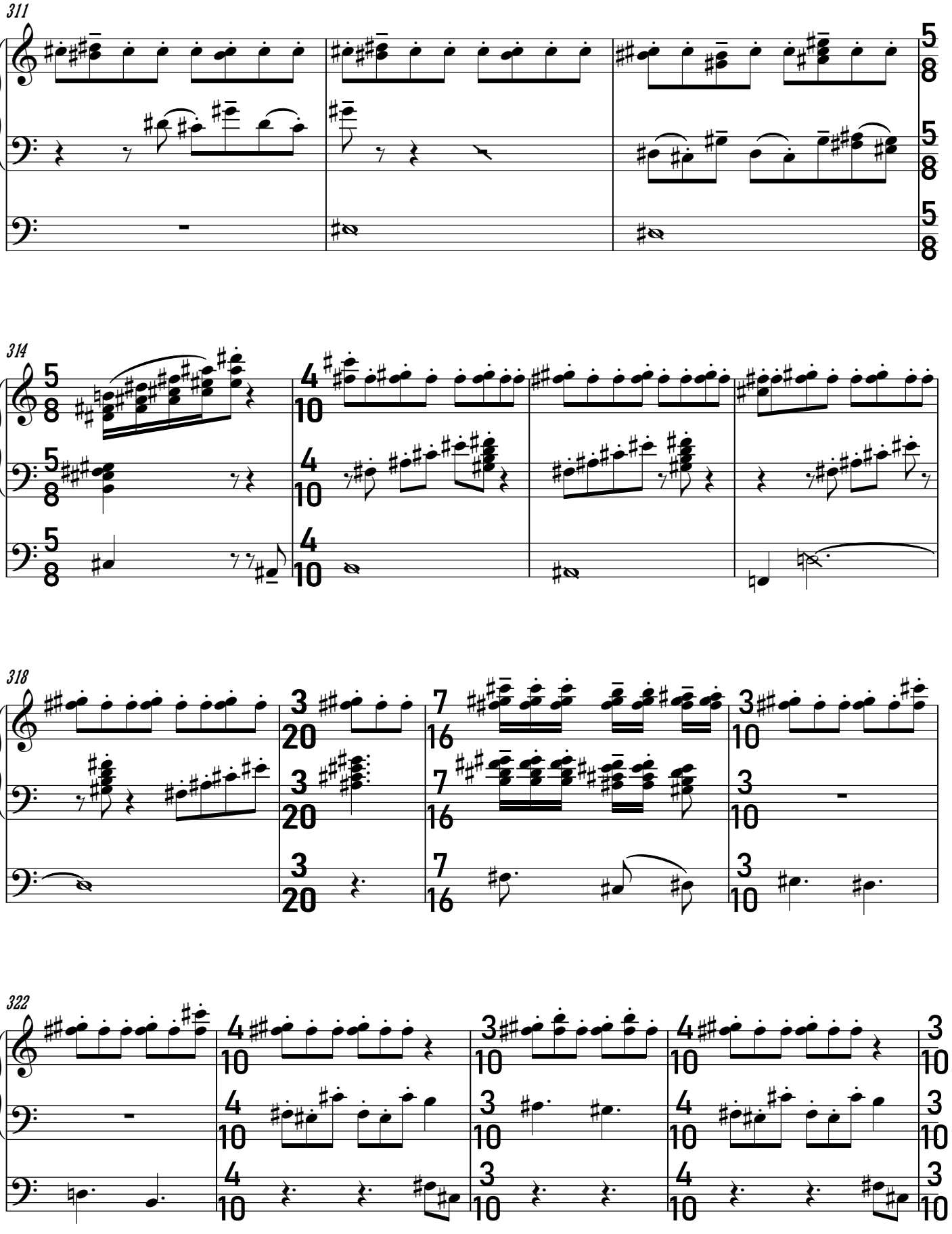
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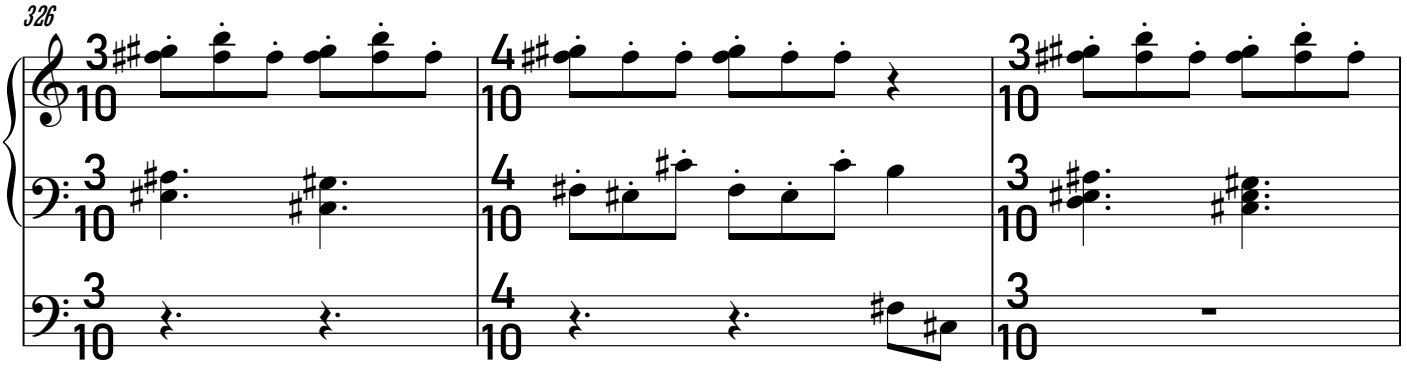

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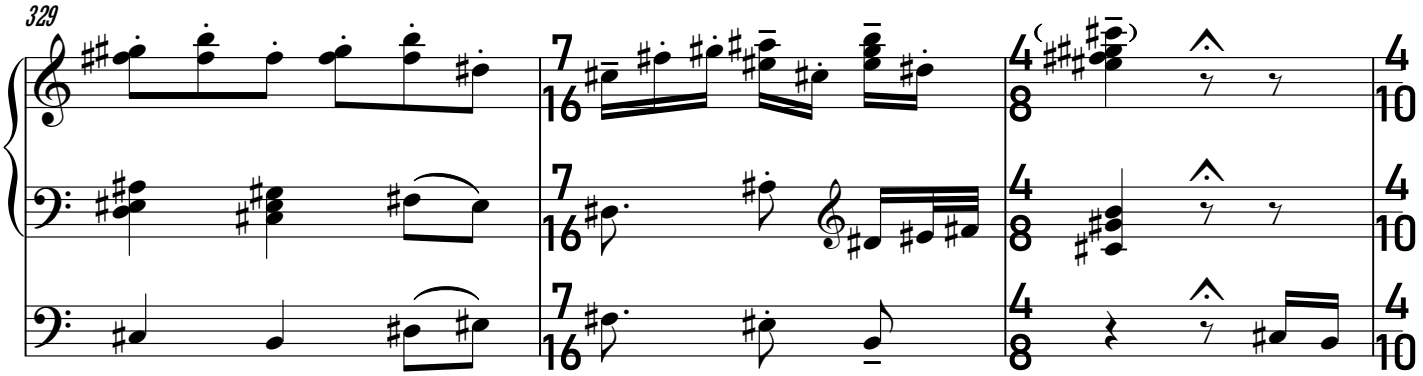

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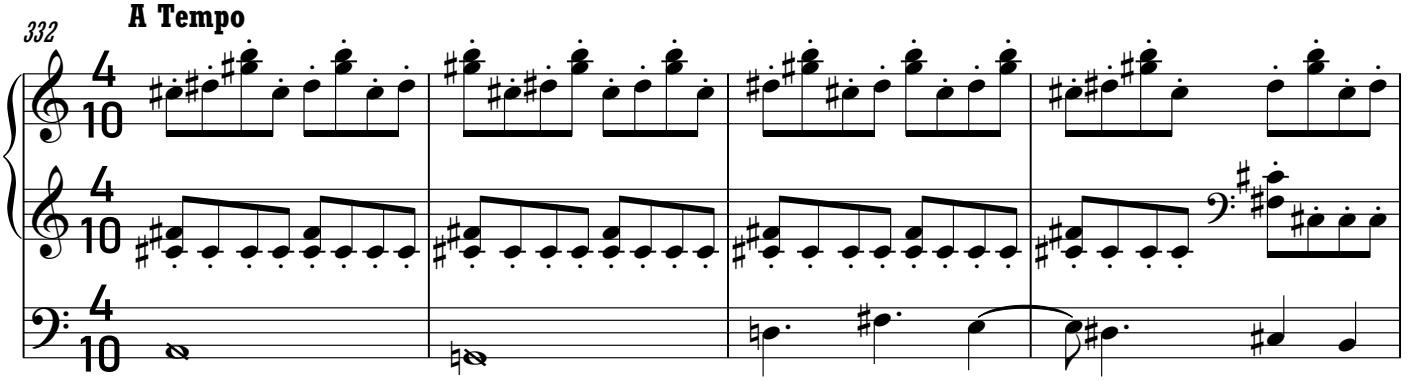

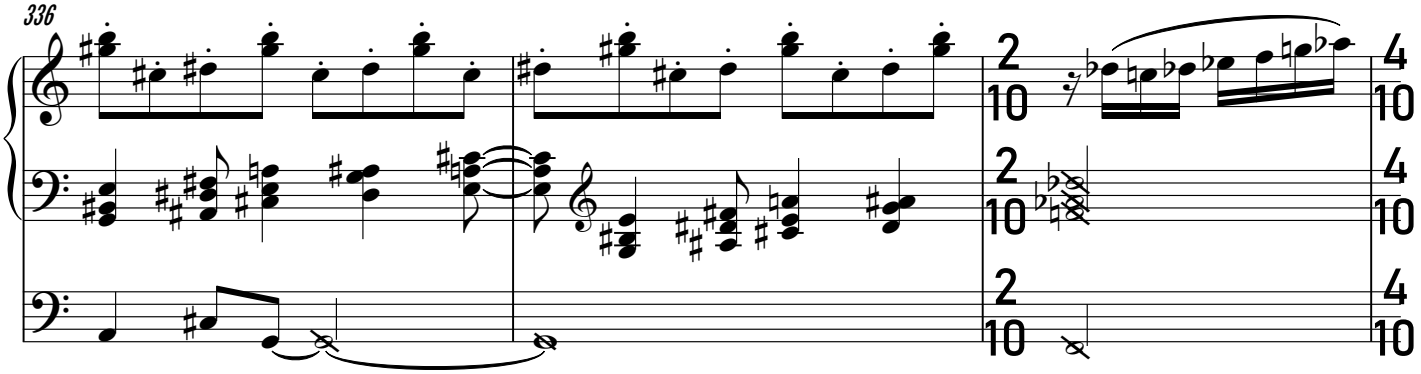

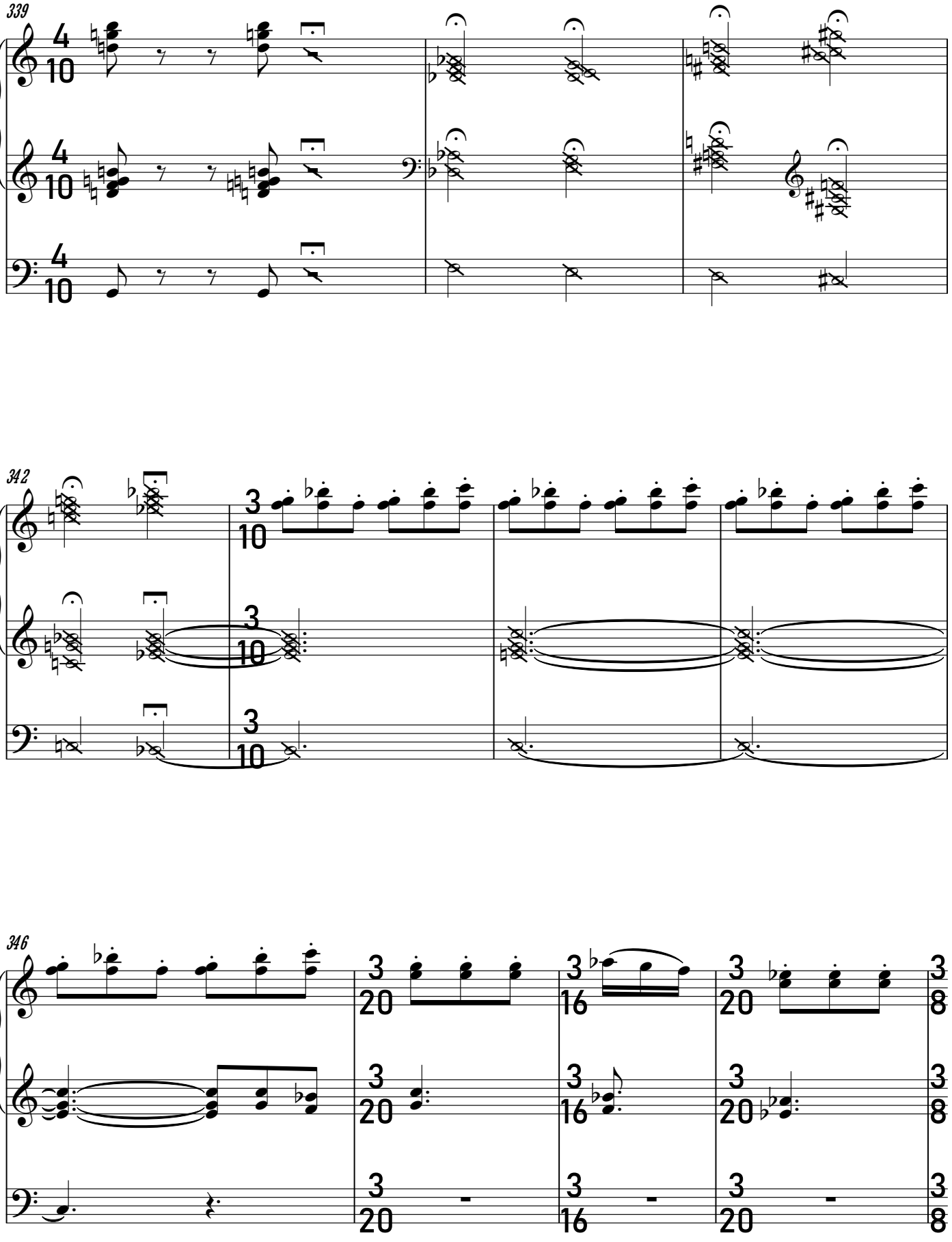
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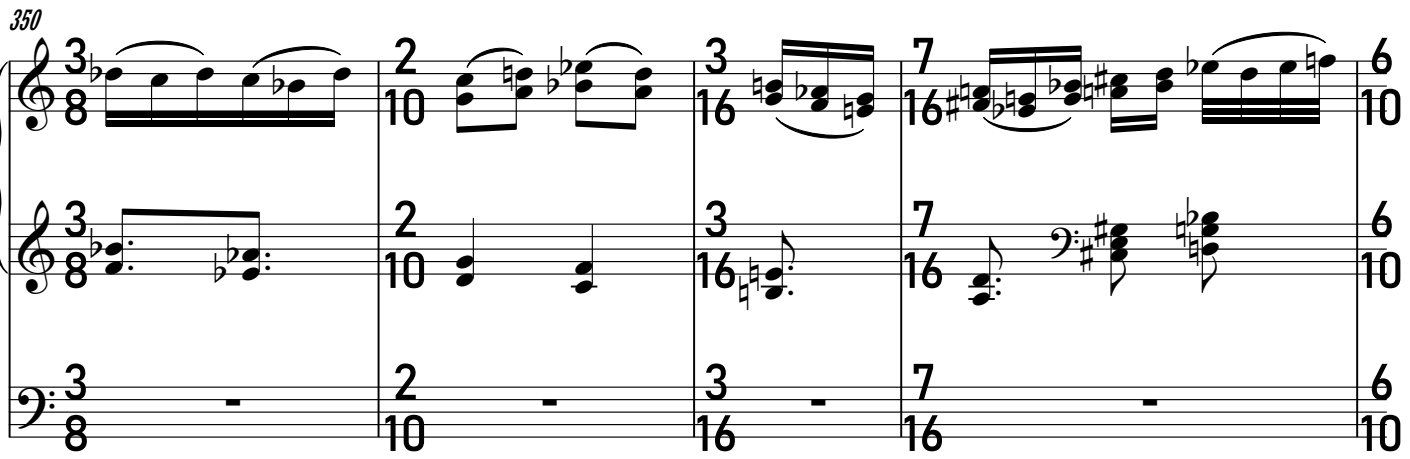
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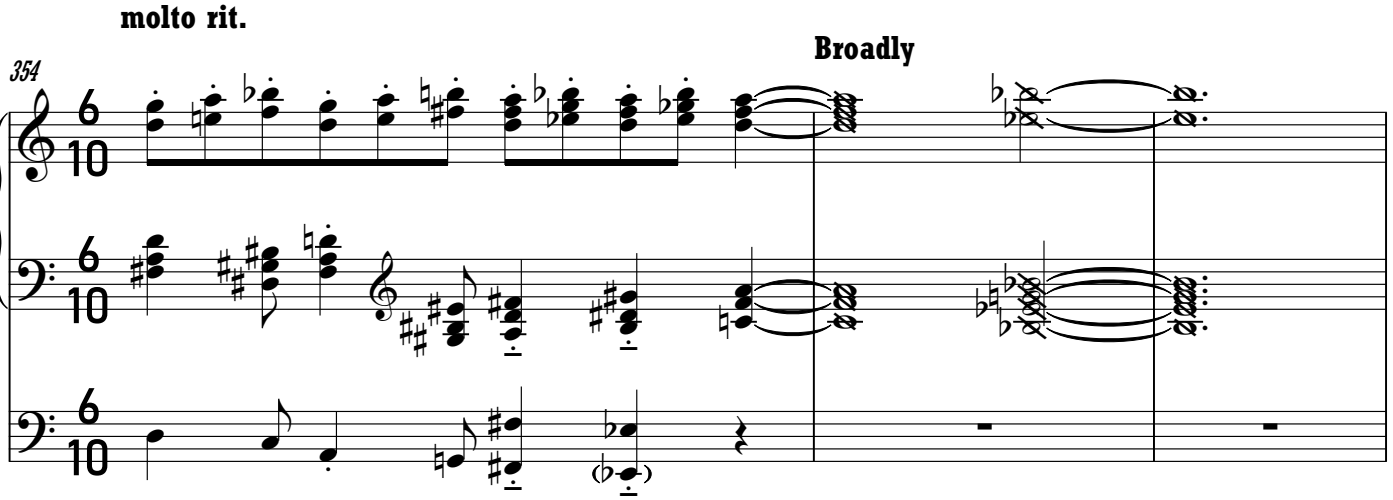
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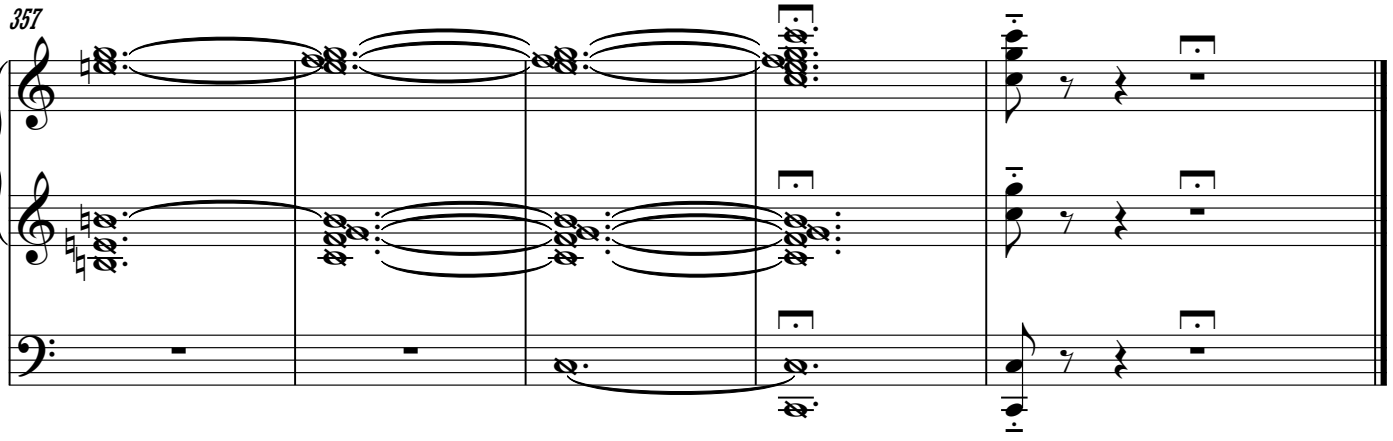
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