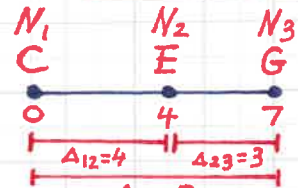
• Chord Consonance and Dissonance

1/26/2025

While it is difficult — or even impossible — to define an "objective quantitative measure for qualitative terms like consonance and dissonance", it is still important to establish at least a "musically acceptable ranking" of 2-note chords, triads and possibly 4-note chords to order chords from "most beautiful" to "most ugly."

One can employ a "minimalistic" form of 2-note chord ranking by considering semi-tone distance from a base/root note and assign "consonance values" between **0** (least consonant, "most ugly") to **12** (most consonant, "most beautiful"):



0	1	2	3	4	5	6	7	8	9	10	11	12
C	C_D	D	D_E	E	F	F_G	G	G_A	A	A_B	B	C
12	1	4	6	7	9	0	10	5	8	2	3	11

Semi-tone indices of octave (top); semi-tones from C to C (middle); "consonance values" for 13 2-note chords on C.

Δ23													
12	34												
11	18	15											
10	16	6	17										
9	28	11	15	25									
8	22	14	11	14	23								
7	32	16	22	18	20	30							
6	12	11	9	14	9	12	11						
5	30	10	23	20	24	20	12	30					
4	26	17	11	23	19	24	9	20	23				
3	24	14	19	12	23	20	14	18	14	25			
2	20	11	15	19	11	23	9	22	11	15	17		
1	14	6	11	14	17	10	11	16	14	11	6	15	
0	36	14	20	24	26	30	12	32	22	28	16	18	34
CO: Triad consonance	0	1	2	3	4	5	6	7	8	9	10	11	12

Δ12

Symmetry of triad consonance CO: CO (Δ12, Δ23) ≡ CO (Δ23, Δ12)

… path from 6 to 30 …

• THE GOAL IS THE ESTABLISHMENT OF A VIABLE, SIMPLE AND "MUSICALLY ACCEPTABLE RELATIVE RANKING OF CHORDS" — NOT OF AN "ABSOLUTE, CHORD-SPECIFIC NUMERICAL VALUE OF CONSONANCE."

(1) The above table provides a "generally accepted ranking."

(2) The left table provides the sum of the three "consonance values" of the three 2-note "sub-chords" of triads $N_1N_2N_3$: N_1N_2, N_2N_3 and N_1N_3.

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• Chord Consonance and Dissonance

It is interesting to list the highest-ranking triads (with root note C) resulting from the simple ranking method described on the previous page:

	CO	Δ_{12}	Δ_{23}	triad	
1	30	5	7	CFC	Subdominant
		7	5	CGC	Dominant
2	25	3	9	C^{D}EC	m3rd on C
		9	3	CAC	m3rd on A
3	24	4	5	CEA	A min. 1st inv.
		5	4	CFA	F maj. 2nd inv.
4	23	2	5	CDG	C sus2
		5	2	CFG	C sus4
		3	4	C^{D}EG	C min. root pos.
		4	3	CEG	C maj. root pos.
		4	8	CEC	M3rd on C
		8	4	C^{G}AC	M3rd on G$_A$
⋮					

Ranking does NOT consider chords for which $\Delta_{12}=0$ or $\Delta_{23}=0$ (chords with "double" or "triple" notes).

• Note. The left table lists the triads with "consonance values" 30, 25, 24 and 23 — using ranks 1, 2, 3 and 4, respectively. This rank order might not be in agreement with other existing and accepted rank orders. In order to produce other "meaningful" rank orders, one can consider the use of weights applied to the 13 2-note chord "consonance values" or, alternatively, the definition of 13 2-note chord "consonance values" where the value sequence is not the uniform, equidistant sequence 0, 1, 2, ..., 12.

• Additional Notes. Chord inversions, 4-note chords, progressions.

(1) Triad/Chord inversions have different "consonance values" — and it should be this way. Depending on one harmonical and musical view of root position and inversions, one must derise one's definition and computation of "consonance values" accordingly.

(2) One can generalize the described method for triads $N_1 N_2 N_3$, "$N_1 \leq N_2 \leq N_3$," to 4-note chords $N_1 N_2 N_3 N_4$, "$N_1 \leq N_2 \leq N_3 \leq N_4$," where one uses interval lengths $\Delta_{12}, \Delta_{23}, \Delta_{34}, \Delta_{13}, \Delta_{24}, \Delta_{14}$.

• Chord Consonance and Dissonance 1/27/2025

(3) Often, one prefers a "gradual and smooth progression" when moving from a (possibly "very dissonant") chord to another (possibly "very consonant") chord — e.g., when moving from a "tension chord" to a "resolution chord." One can use the table / function $CO(\Delta_{12}, \Delta_{23})$ to determine a smooth path / progression from a start triad to a termination triad, by making only minimal changes to "consonance values" when moving from triad to triad. We consider two examples.

	Δ_{12}	Δ_{23}	CO	triad
start	1	1	6	$C\,{}^{C}_{D}\,D$
	1	2	11	$C\,{}^{C}_{D}\,{}^{D}_{E}$
	1	3	14	$C\,{}^{C}_{D}\,E$
	1	4	17	$C\,{}^{C}_{D}\,F$
	2	3	19	$C\,D\,F$
	3	2	19	$C\,{}^{D}_{E}\,F$
	4	3	23	$C\,E\,G$
	5	4	24	$C\,F\,A$
end	7	5	30	$C\,G\,C$

	Δ_{12}	Δ_{23}	CO	triad
start	1	1	6	$C\,{}^{C}_{D}\,D$
	2	2	15	$C\,D\,E$
	4	3	23	$C\,E\,G$
	5	4	24	$C\,F\,A$
end	7	5	30	$C\,G\,C$

The left tables define two paths from the START triad $C\,{}^{C}_{D}\,D$ to the END triad $C\,G\,C$. The START triad is highly dissonant while the END triad is highly consonant. The first progression involves nine triads; the second progression uses only five triads by making "larger jumps" when moving from triad to triad. Both progressions define "non-decreasing paths," i.e., "consonance values" never decrease when moving from a triad to the next. Such a "monotonicity rule" seem reasonable to enforce. Two relevant questions arise:

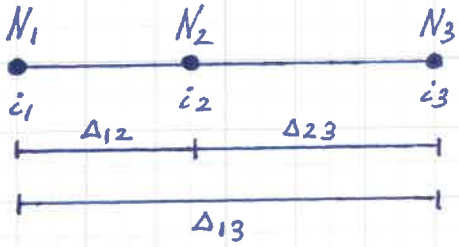
→ Should a "good progression" consist of many or few triads?

→ Are such purely "consonance value"-based progressions musically "nice and acceptable"?

• Chord Consonance and Dissonance

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• **Note.** One can view the described method for calculating "consonance values" as a method for defining consonance (and also dissonance) via multivariate functions. In the case of triads, one uses a bivariate function; in the case of 4-note chords, one uses a trivariate function.

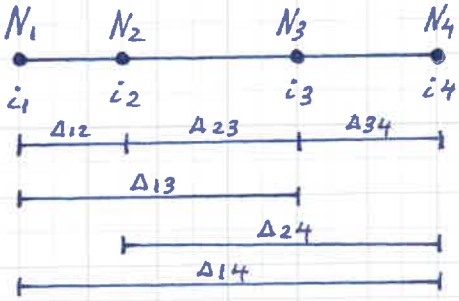


Triad and its parameters.

Triads. A triad is understood as $N_1 N_2 N_3$ with associated (semitone) indices i_1, i_2 and i_3 — where, for example, piano keys could be indexed from 1 to 88.

It is assumed that $i_1 \leq i_2$ and $i_2 \leq i_3$. Thus, the relevant 2-note (diad) chord "interval lengths" are $\Delta_{12} = i_2 - i_1$, $\Delta_{23} = i_3 - i_2$ and $\Delta_{13} = i_3 - i_1 = \Delta_{12} + \Delta_{23}$. The described function for computing "consonance values" is a bivariate function:

$$CO(N_1 N_2 N_3) = CO(i_1, i_2, i_3) = CO(\Delta_{12}, \Delta_{23}, \Delta_{13}) =$$
$$= CO(\Delta_{12}) + CO(\Delta_{23}) + CO(\Delta_{12} + \Delta_{23}) = CO(\Delta_{12}, \Delta_{23}).$$



4-note chord and parameters.

4-note chords. The generalization of the function defined for triads yields a trivariate function for chords $N_1 N_2 N_3 N_4$, where $i_1 \leq i_2$, $i_2 \leq i_3$ and $i_3 \leq i_4$ and $\Delta_{12} = i_2 - i_1$, $\Delta_{23} = i_3 - i_2$, $\Delta_{34} = i_4 - i_3$, $\Delta_{13} = i_3 - i_1 = \Delta_{12} + \Delta_{23}$, $\Delta_{24} = i_4 - i_2 = \Delta_{23} + \Delta_{34}$ and $\Delta_{14} = i_4 - i_1 = \Delta_{12} + \Delta_{23} + \Delta_{34}$. Thus, the function becomes:

$$CO(N_1 N_2 N_3 N_4) = CO(i_1, i_2, i_3, i_4) = CO(\Delta_{12}, \Delta_{23}, \Delta_{34}, \Delta_{13}, \Delta_{24}, \Delta_{14}) =$$
$$= CO(\Delta_{12}) + CO(\Delta_{23}) + CO(\Delta_{34}) + CO(\Delta_{12} + \Delta_{23}) +$$
$$+ CO(\Delta_{23} + \Delta_{34}) + CO(\Delta_{12} + \Delta_{23} + \Delta_{34}) = CO(\Delta_{12}, \Delta_{23}, \Delta_{34}).$$

⇒ As a consequence, one can **plot/visualize** "consonance values" for a 2D or 3D domain (plane or space).

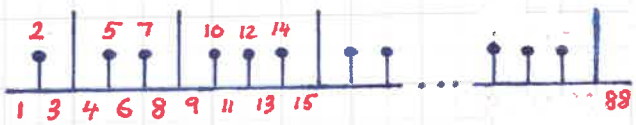
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• Chord Consonance and Dissonance

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• In order to make effective and musically meaningful use of the proposed method for computing "consonance values," one must address and solve a crucial problem:

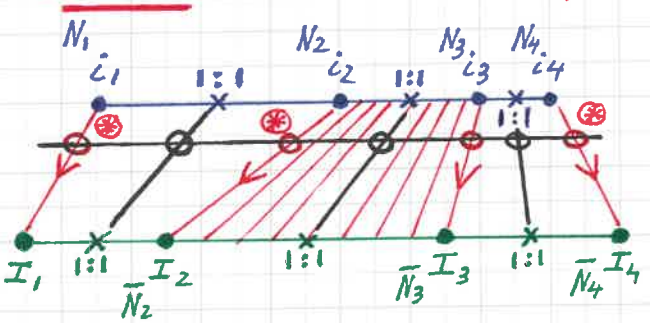
➔ **How** can one establish chord progressions that **BOTH** satisfy and use traditional ways of smooth, gradual harmonic progression principles of movement **AND** consider and incorporate "consonance values" of chords to define "best-possible progressions"?



The left figure is merely provided for context: A "good method" for computing "consonance values" for an 88-key keyboard must consider and use the actual "physical key indices" 1...88 since **(i)** the same chords when played in different octaves of the keyboard should/must have different "consonance values" and **(ii)** a 2-note chord $N_1\,N_2$ should/must have different "consonance values" depending on the octaves where the note N_1 and the note N_2 are played. (Example: N_1 = C, N_2 = D, i_1 = 4, i_2 = 6 should/must have a different "consonance value" than N_1 = C, N_2 = D, i_1 = 4, i_2 = 18.)

• **Note.** One can also define and – if helpful – utilize a PIECEWISE LINEAR MAPPING of the indices of semi-tones.

Piecewise Linear mapping I of a 4-note chord



⊛ "Smooth" movement of note N_1,... to note $\bar{N}_1$,...

The left figure illustrates the map

$$I = \frac{i_{k+1} - i}{i_{k+1} - i_k} I_k + \frac{i - i_k}{i_{k+1} - i_k} I_{k+1}\,, \quad i_{k+1} \neq i_k,\ k = 1 \ldots 3.$$

N_k is mapped to $\bar{N}_k$, and semi-tone index i ($i_k < i < i_{k+1}$) is mapped to semi-tone index I (after rounding) defines a note between $\bar{N}_k$ and $\bar{N}_{k+1}$

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• Chord Progressions and Circles

1/30/2025

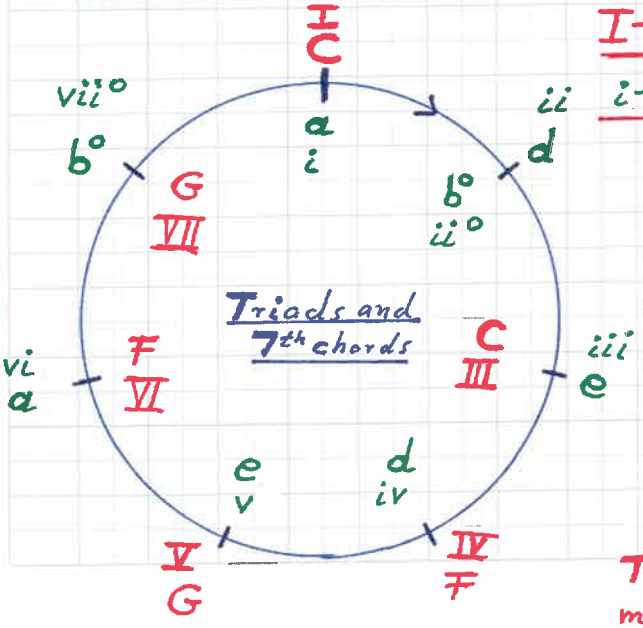
It is extremely important to realize that chord progressions can be established by employing various kinds of CIRCLES, defined by different ways to view periodic / cyclic characteristics. Here, we focus on **triads** and **7th chords**. One must keep in mind that an established circular order (forward and backward) applies to chords in their root positions and to all their inversions. Further, a circular order defines the progressions of both major and (three) minor keys/scales. Key-/scale-inherent chords only use the notes of the respective underlying key/scale; circle-of-fifths-defined chords, on the other hand, use all 12 notes of the chromatic scale. In the following, we summarize these three circles: (1) the "circle of 2nds" using key-/scale-inherent chords only; (2) the "harmonic circle of 5ths" using key-/scale-inherent chords only; and (3) the "standard circle of 5ths" using chords with notes from the entire 12-note chromatic scale.

Ex.:

C	E	G
D	F	A
E	G	B
F	A	C
G	B	D
A	C	E
B	D	F
C	E	G

(1) Circle of 2nds.

This circle defines the progressions I-ii-iii-IV-V-vi-vii°-I and i-ii°-III-iv-v-VI-VII-i. The keys of C maj. and A min. are shown as example keys. For these two keys, the chords are:



$I = C = \{$ CEG-EGC-GCE
CEGB-EGBC-GBCE-BCEG ; ...

$i = a = \{$ ACE-CEA-EAC
ACEG-CEGA-EGAC-GACE ; ...

Thus, the circle representation implies maj. and minor key cycles and all inversions of chords

• Chord Progressions and Circles 1/30/2025

Again, the seven triads / 7th chords defined by the "circle of 2nd's" uses only the 7 notes of a given key / scale (allowing to raise notes by a semi-tone to also capture harmonic and melodic minor scales). We provide the chords for steps vii° and VII as well:

b° = { BDF - DFB - FBD / BDFA - DFAB - FABD - ABDF } ; = vii°

G = { GBD - BDG - DGB / GBDF - BDFG - DFGB - FGBD } . = VII

Ex.:

C E G
G B D
D F A
A C E
E G B
B D F
F A C
C E G

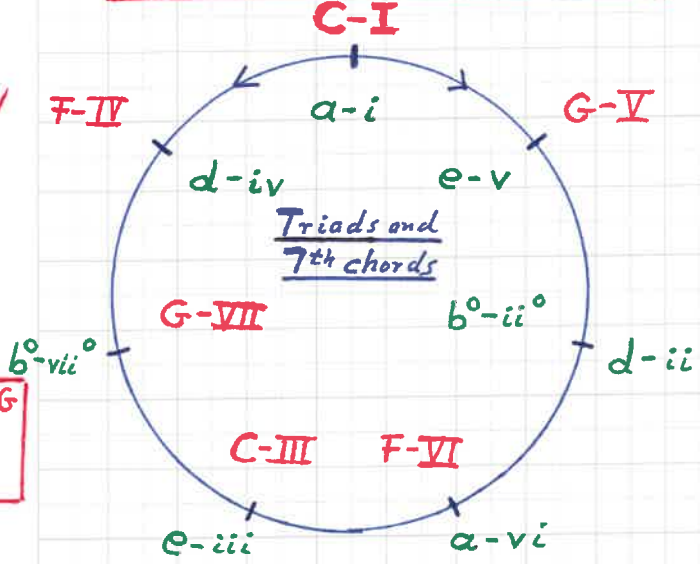
C E G
F A C
B D F

Ex.:

C
G
D
A
E
B
F#
C#
G#
D#
A#
E#
B#=C

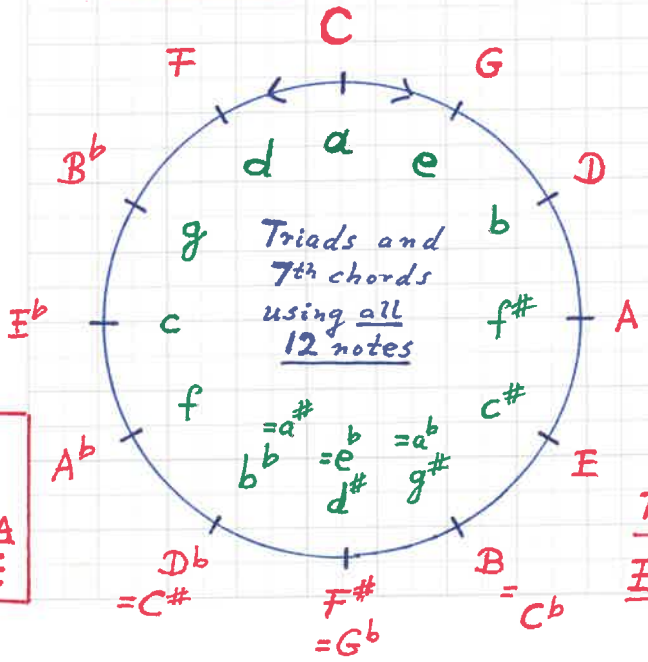
C E G
G B D
D F# A
⋮

(2) Harmonic circle of 5th's.



This circle defines the (forward) progressions I-V-ii-vi-iii-vii°-IV-I and i-v-ii°-VI-III-VII-iv-i. Again, these progressions are shown for the keys / scales of Cmaj. and Amin. The triads and 7th chords (and their inversions) associated with C, F, G, d, e, a and b° only use the seven notes of the Cmaj. and Amin. scales. Thus, the difference between circle (1) and circle (2) is movement by 2nd's vs. 5th's.

(3) Standard circle of 5th's.



In contrast to circles (1) and (2), this circle always moves forward / backward by seven semi-tones — until the "key used as start key" is reached again. Here, C is at the top / center (= start and end key).

Triads / 7th chords use the notes of all 24 keys

Example triads: E ⇒ EG#B - G#BE - BEG# ;
c# ⇒ C#EG# - EG#C# - G#C#E.

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• Chord Progressions and Circles

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The circle of fifths uses fifths to establish an order of the 12 major (12 minor) keys as "neighbor keys" only differ by one semi-tone (and thus one key on the keyboard) only. Thus, when modulating from a key to one of its two neighbors on the circle of fifths, the progression from a key (and its associated key-inherent chords) to a "neighbor key" (and its associated key-inherent chords) is smooth. We consider the "key neighborhood" of F-C-G (d-a-e) as an example.

keys: ^{b}s ⟷ keys: $^{\#}$s

F, d			C, a			G, e		
V	CEG	VII	I	CEG	III	IV	CEG	VI
vi	DFA	i	ii	DFA	iv	V	DF$^{\#}$A	VII
vii^{o}	EG$\underline{B^{b}}$	ii^{o}	iii	EGB	v	vi	EGB	i
I	FAC	III	IV	FAC	VI	vii^{o}	F$^{\#}$AC	ii^{o}
ii	G$\underline{B^{b}}$D	iv	V	GBD	VII	I	GBD	III
iii	ACE	v	vi	ACE	i	ii	ACE	iv
IV	$\underline{B^{b}}$DF	VI	vii^{o}	BDF	ii^{o}	iii	BD$\underline{F^{\#}}$	v

Key-inherent triads

The left table lists the seven key-inherent triads of C, F and G and of the parallel/natural minor keys a, d and e, respectively. The "neighbor key" triads have the semi-tone differences B versus B^{b} and F versus $F^{\#}$. Thus, "neighbor keys" exhibit maximal triad similarity — and key modulations F⟷C and C⟷G imply minimal triad changes. (The same is true, of course, for the parallel/natural minor keys.)

• From C to G with "pivot" GBD:

CEG (=C I)
↓
GBD (=C IV)
↓
DF$^{\#}$A (=G V)
↓
GBD (=G I)

• Underlined triads are "pivot triads" – for smooth modulation.

In the following, we consider simple modulations.

vii^{o} (C): BDE (0) ⟷ BDF$^{\#}$ ⟷ BDG (1) I (G)

DFB (1) ⟷ DF$^{\#}$B ⟷ DGB (2)

FBD (2) ⟷ F$^{\#}$BD ⟷ GBD (0)

(0) = root position
(1), (2) = first, second inversion

C ⟷ G

The example shown here is a modulation C⟷G, where C triad vii^{o} is changed by altering F to F$^{\#}$ (leading tone), moving to G.

• Chord Progressions and Circles

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Other possible modulations are:

vii° E G B^b (0) ↔ E G B ↔ E G C (1) I (C)
(F) G B^b E (1) ↔ G B E ↔ G C E (2)
B^b E G (2) ↔ B E G ↔ C E G (0)

Example shows modulation F↔C, using B^b → B → C.

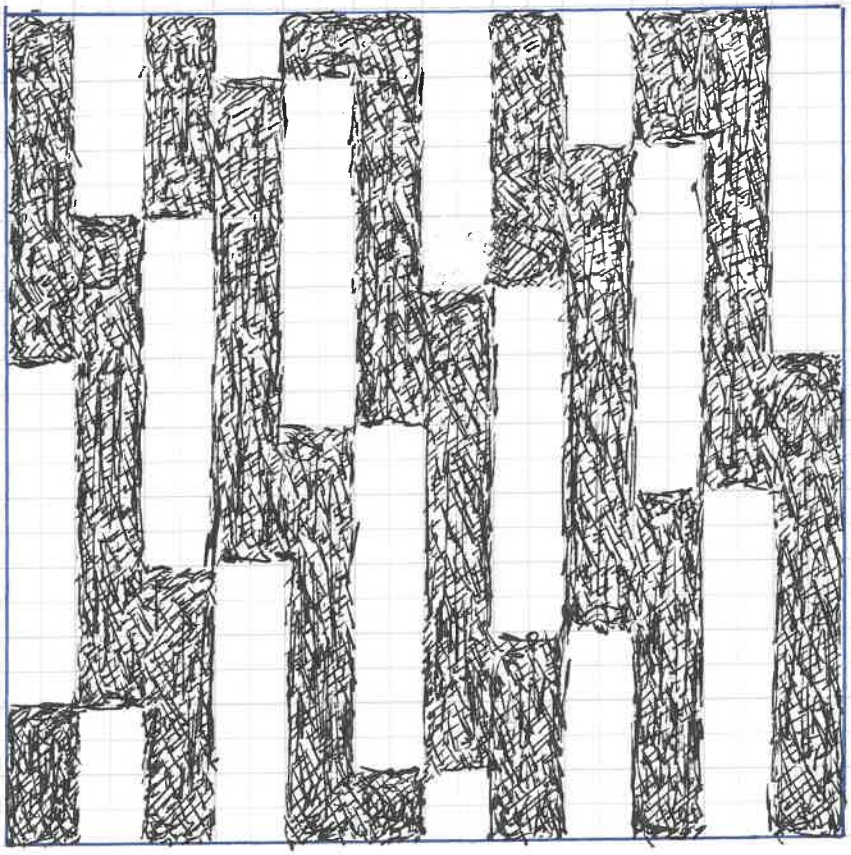
VII G B D (0) ↔ G B $D^\#$ ↔ G B E (1) i (e)
(a) B D G (1) ↔ B $D^\#$ G ↔ B E G (2)
D G B (2) ↔ $D^\#$ G B ↔ E G B (0)

Example shows modulation a↔e, using D → $D^\#$ → E.

VII C E G (0) ↔ C E $G^\#$ ↔ C E A (1) i (a)
(d) E G C (1) ↔ E $G^\#$ C ↔ E A C (2)
G C E (2) ↔ $G^\#$ C E ↔ A C E (0)

Example shows modulation d↔a, using G → $G^\#$ → A.

Of course, the musical, harmonic and "sound" qualities of such "theoretically defined" modulations must be properly evaluated. Further, modulations for minor keys involving minor keys are more complex as one must consider natural, harmonic and melodic minors.



The left illustration shows the pattern obtained when filling in the "squares of physical keyboard keys" played for the 12 (24) keys.

• Chord Progressions and Circles

What are different ways to modulate from C major to G majpr ?

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AI Overview

To modulate from C major to G major, the most common method is to use a "pivot chord," like the A minor chord (which is the vi chord in C major and the ii chord in G major), allowing a smooth transition by sharing common tones between the keys; you can also directly introduce the dominant chord of G major (D major) to clearly establish the new key, or use a sequence of chords that gradually lead to the G major key by incorporating chromatic alterations.

Key approaches to modulating from C major to G major:

Pivot chord method:

- Use the A minor chord (vi in C major, ii in G major) as a pivot chord, progressing from C major chords to A minor, then smoothly transition to G major chords by utilizing the shared tones.

Direct modulation with dominant chord:

- At the end of a phrase in C major, introduce the dominant chord of G major (D major) to clearly signal the key change.

CEG -> GBD -> DF#A -> GBD

Chromatic modulation:

- Use chromatic alterations in chords to gradually move towards the G major key, like adding an F sharp to a C major chord to create a more chromatic sound.

Sequential modulation:

- Transpose a chord progression up a fifth (the interval between C and G) to reach G major.

Important points to consider:

- **Harmonic function:** When choosing pivot chords, consider their harmonic function in both keys to create a logical progression.
- **Smooth transition:** Use smooth voice leading between chords to avoid jarring key changes.
- **Cadence:** Use a strong cadence in the new key (G major) to solidify the modulation.

Generative AI is experimental.

Modulating to Closely Related Keys (Ma Modulation ...

Nov 15, 2021 — number six that could be use three and c number seven is no good it's got

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Modulation Basics - Chord Progressions

In this harmonic outline, the A minor chord is keys: C major and G major and consequently

Chord Progressions in Tonal Music

17. Common Chord / Pivot Chord Modul Pressbooks

These examples only show how to smoothly move from one key to another. * From a majo

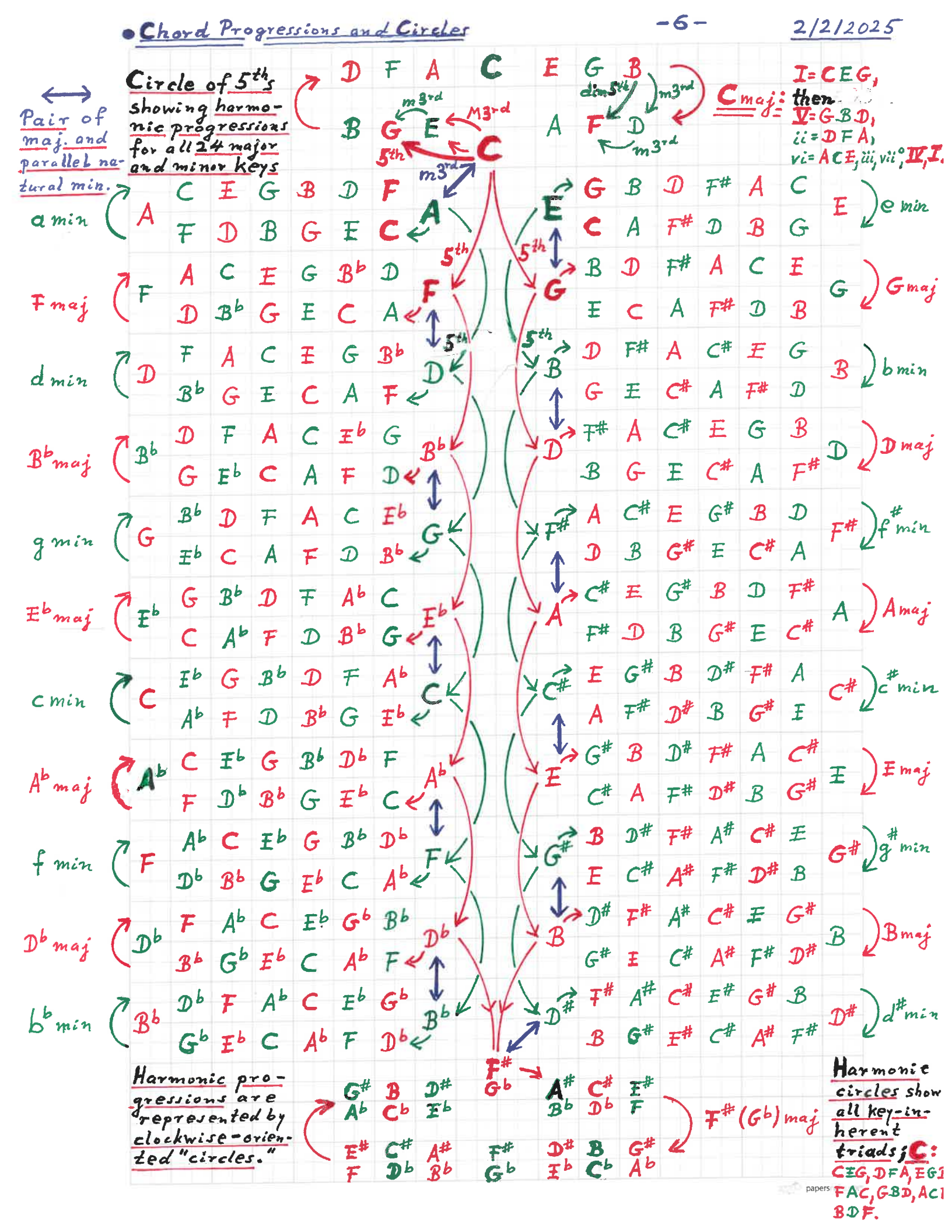
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Chord Progressions and Circles

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• Chord Progressions and Circles

2/3/2025

G major

Key-inherent triads

2nd		5th	
I	G B D	I	G B D
ii	A C E	V	D F# A
iii	B D F#	ii	A C E
IV	C E G	vi	E G B
V	D F# A	iii	B D F#
vi	E G B	vii°	F# A C
vii°	F# A C	IV	C E G
I	G B D	I	G B D

Moving by 2nds

G B D
D F# A
A C E
E G B
B D F#
F# A C
C E G
G B D

G B D F# A C E G B D F# A C E G
I V ii vi iii vii° IV

7th chords defined by circle:

G B D F#
D F# A C
A C E G
E G B D
B D F# A
F# A C E
C E G B

Harmonic circle

G B D F# A C E G B D F# A C E G

e minor

Key-inherent triads

i	E G B	i	E G B
ii°	F# A C	v	B D F#
III	G B D	ii°	F# A C
iv	A C E	VI	C E G
v	B D F#	III	G B D
VI	C E G	VII	D F# A
VII	D F# A	iv	A C E
i	E G B	i	E G B

Moving by 2nds

E G B
B D F#
F# A C
C E G
G B D
D F# A
A C E
E G B

E G B D F# A C E G B D F# A C E
i v ii° VI III VII iv

7th chords defined by circle:

E G B D
B D F# A
F# A C E
C E G B
G B D F#
D F# A C
A C E G

Harmonic circle

E G B D F# A C E G B D F# A C E

Representation of circle of fifths – with "inserted minors":

C♭ G♭ D♭ A♭ E♭ B♭ F C G D A E B F# C#
e♭ b♭ f c g d a e b f# c# g# d# a# e#

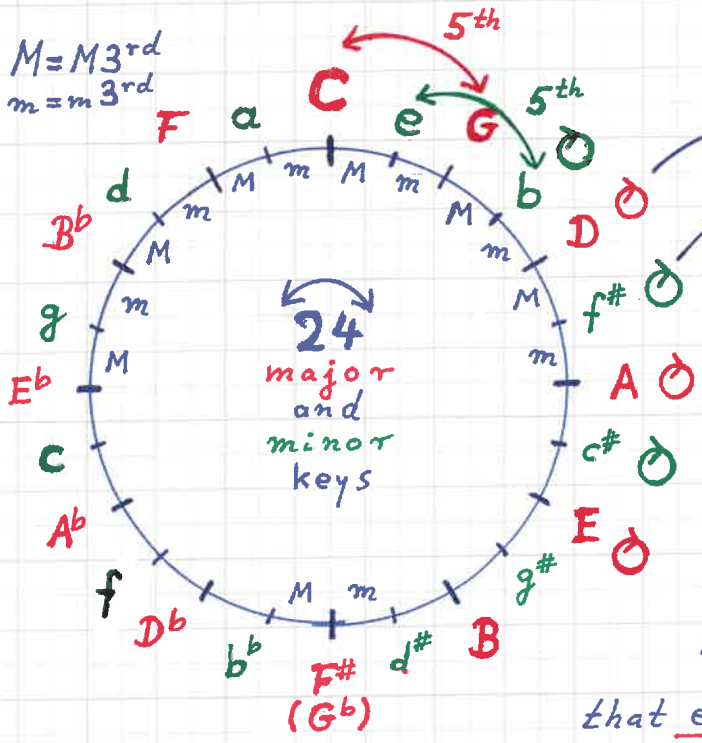
Implied, captured maj. triads: CEG, GBD, DF#A, AC#E, ...

Implied, captured min. triads: ACE, EGB, BDF#, F#AC#, ...

⇒ This representation defines maj. triads by triples • • • (e.g., C e G, G b D) and min. triads by triples • • • (e.g., a C e, e G b).

• Chord Progressions and Circles

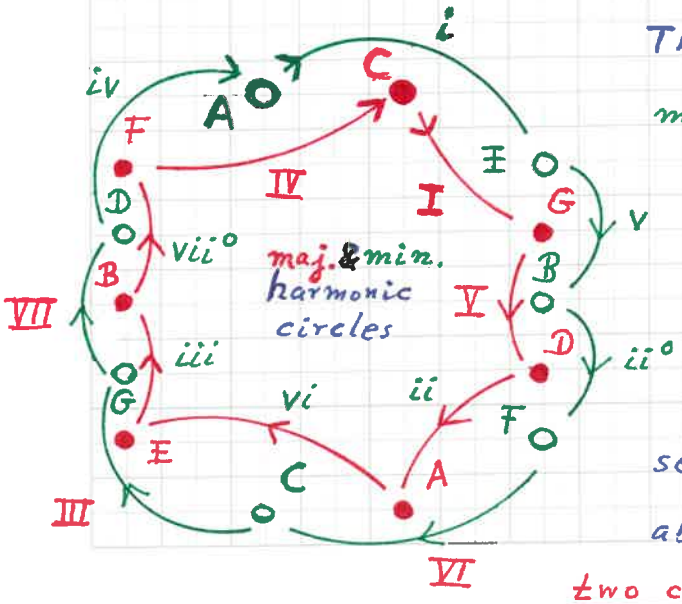
2/3/2025



I-V-ii-vi-iii-vii°-IV-I

i-v-ii°-VI-III-VII-iv-i

The circle of fifths shown here uses a representation that includes all 24 major and minor keys. Further, the left figure indicates that every key has an associated harmonic circle, ↻ or ↺, consisting of the seven key-inherent triads using only the notes of the specific key. This 24-key representation of the circle of fifths — where a major key is placed next to its parallel natural minor key — makes it possible to directly "see" all major and minor triads: CEG, GBD, DF#A, AC#E, EG#B, BD#F#, ...; ACE, EGB, BDF#, F#AC#, C#EG#, G#BD#, ... Also, 7th chords are implied by four consecutive keys/key names.



The left figure shows major and minor harmonic circles, using the specific circles of C major and a minor, to provide context. (These circles are only defined in terms of their Roman numeral sequences next to the figure shown above.) This representation "integrates" two circles and captures M3rds and m3rds.