Learning

Aural Piano Tuning

Norman Brickman, MPT

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Objectives

- Introduce aural piano tuning
- Provide the core principles and explain the process step-by-step in charts
  - Using the basic approach as presented by John W. Travis
    - Contained in his book Let's Tune Up (published 1968) and based on the Grabau-Travis Tuning Theory
    - John was the first co-president of the Piano Technicians Guild in 1957
- Present the several musical intervals that are used
  - And convey an understanding of why and how they are used
- Include accompanying audio throughout to clarify and demonstrate
  - And allow for additional, offline, individual practice
- Convey the enjoyment of tuning by ear
  - Versus visual tuning
  - And provide a good understanding of the piano's sound quality and characteristics
- Bottom Line:
  - Industry standard Equal Temperament (12-TET based on the Octave)
  - All with no counting of beats, only comparisons of beat rates

Nine of these charts have a green audio button available to click on. This will play some optional audio that discusses and demonstrates the chart content in more detail. A slow Internet connection to Google Drive can take several seconds for the audio to start. (If it does not start, try closing your browser and click again. You can also download the audio and play it locally.)

We Need A Few Terms

Interval	Musically known as	Half-Steps In The Interval	Where To Listen For The Beats	Equal Temperament Effect on the Interval
2:1	Octave	12	Upper note + multiple octaves up	Exact / Pure
3:2	Perfect Fifth (5th)	7	One octave above upper note	Slightly narrowed
4:3	Perfect Fourth (4th)	5	Two octaves above the low note	Slightly widened
5:4	Major Third (M3)	4	Two octaves above the upper note	Widened
5:3	Major Sixth (M6)	9	Two octaves above the “4” in 5:4:3	Widened
6:5	Minor Third (m3)	3	Two octaves above the “4” in 6:5:4	Narrowed
7:4	Minor Seventh (m7)	10	Two octaves above the upper note	Widened
8:5	Minor Sixth (m6)	8	Three octaves above the lower note	Narrowed
5:2	Tenth	16 (one octave + M3)	One octave above the high note	Widened
3:1	Twelfth	19 (one octave + 5th)	At the high note	Slightly narrowed
5:1	Seventeenth	28 (two octaves + M3)	At the high note	Widened

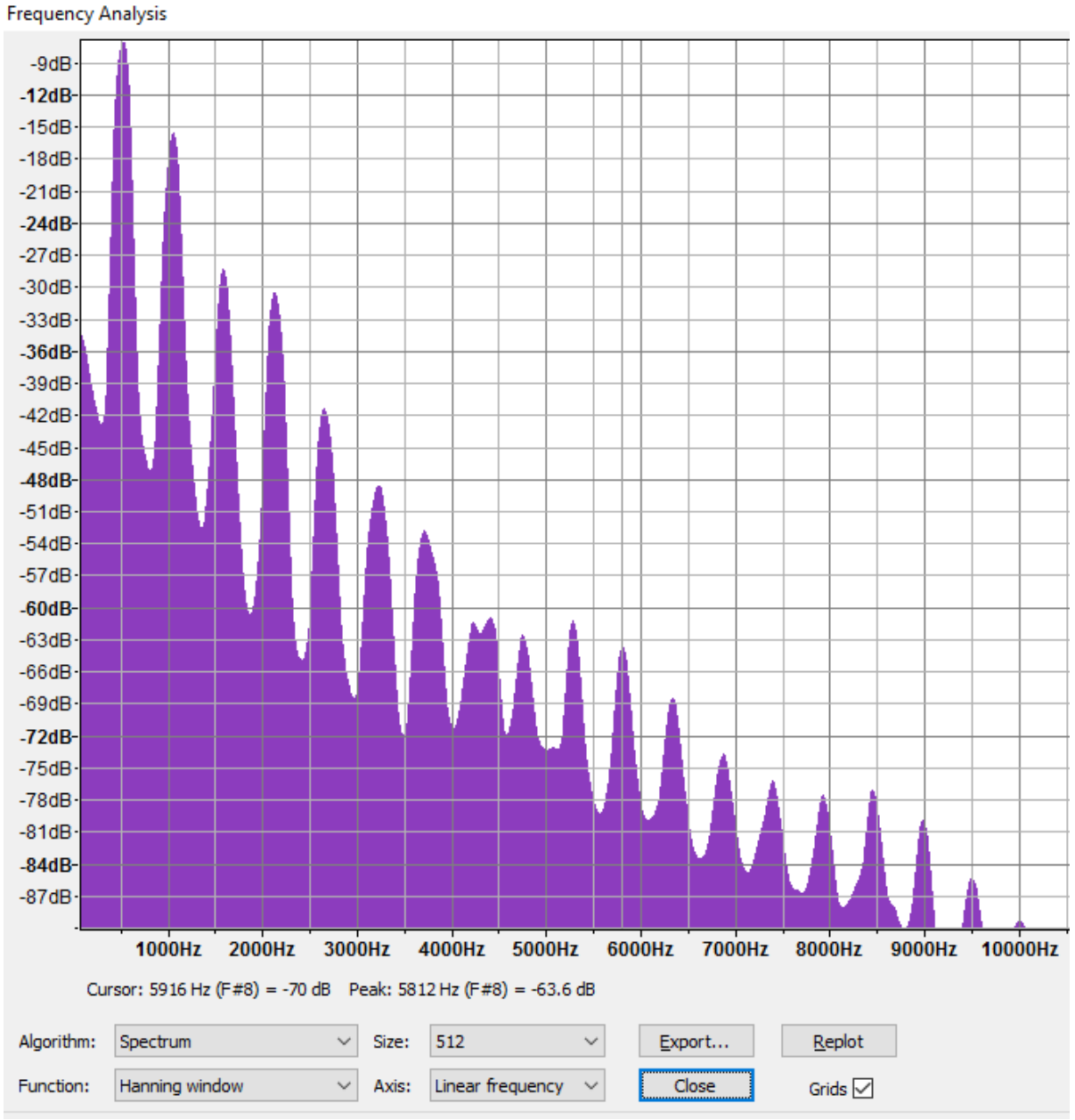
(1) A Vibrating String

- Produces partials (harmonics)
  - 2x (octave), 3x (tenth),
  - 4x (double-octave), 5x (seventeenth), 6x, etc.
- Easy to demonstrate
  - While holding down the C4 key (damper raised), play C3 and release
    - Hear the 2x partial of C3 still sounding
  - While holding down the C#4 key, play C3 and release
    - Hear silence
  - While holding down the G4 key, play C3 and release
    - Hear the 3x partial of C3 still sounding
  - While holding down the E4# key, play C3 and release
    - Hear silence.
  - While holding down the C5 key, play C3 and release
    - Hear the 4x partial of C3 still sounding
  - And continuing -- 5x, 6x, etc.

Play the Audio

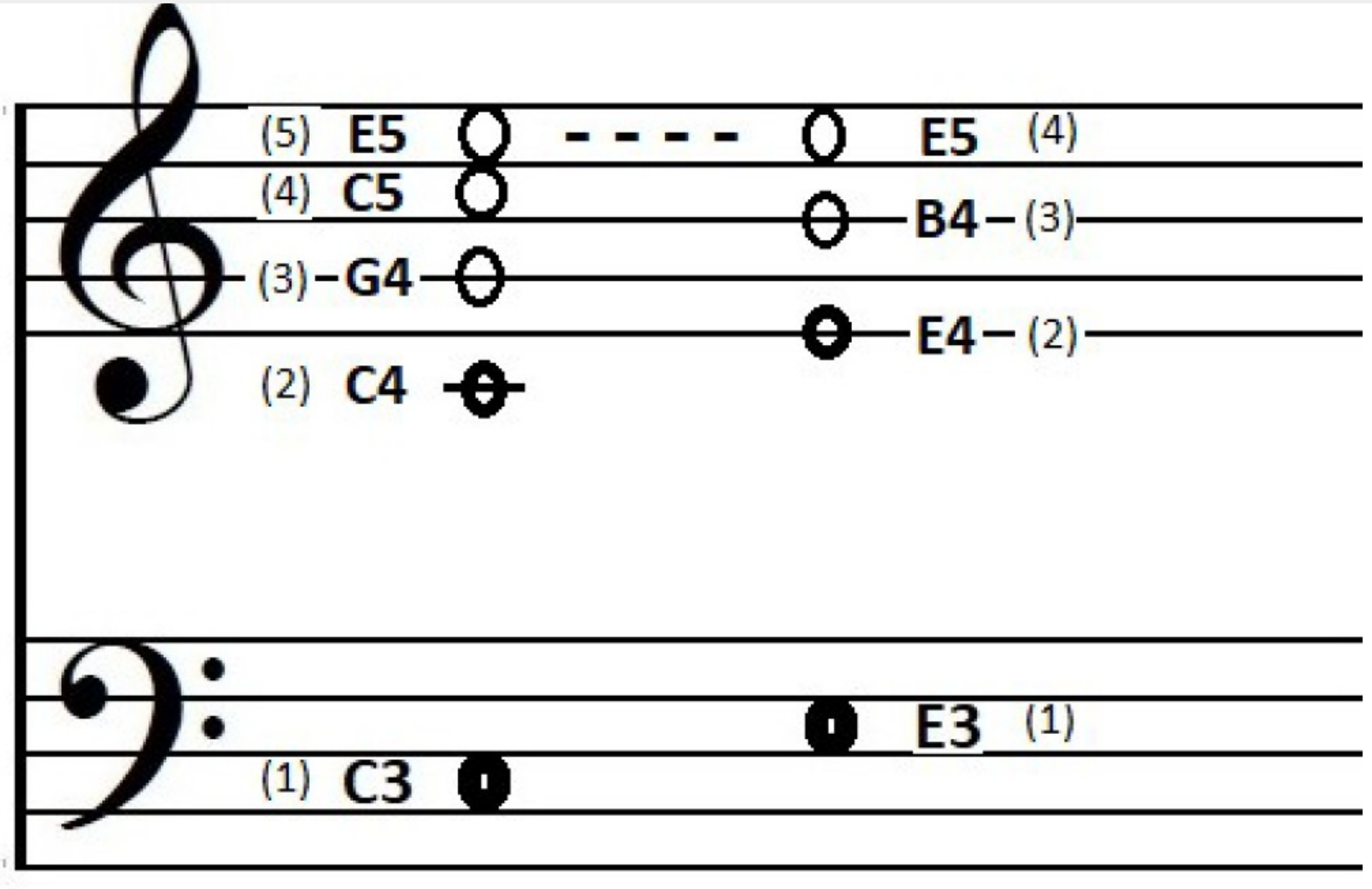
A Vibrating String

(C5 on a piano)



https://math.stackexchange.com/questions/1972767/how-does-the-harmonic-series-relate-to-the-frequency-spectrum-of-a-sound

(2) - Intervals and Beats

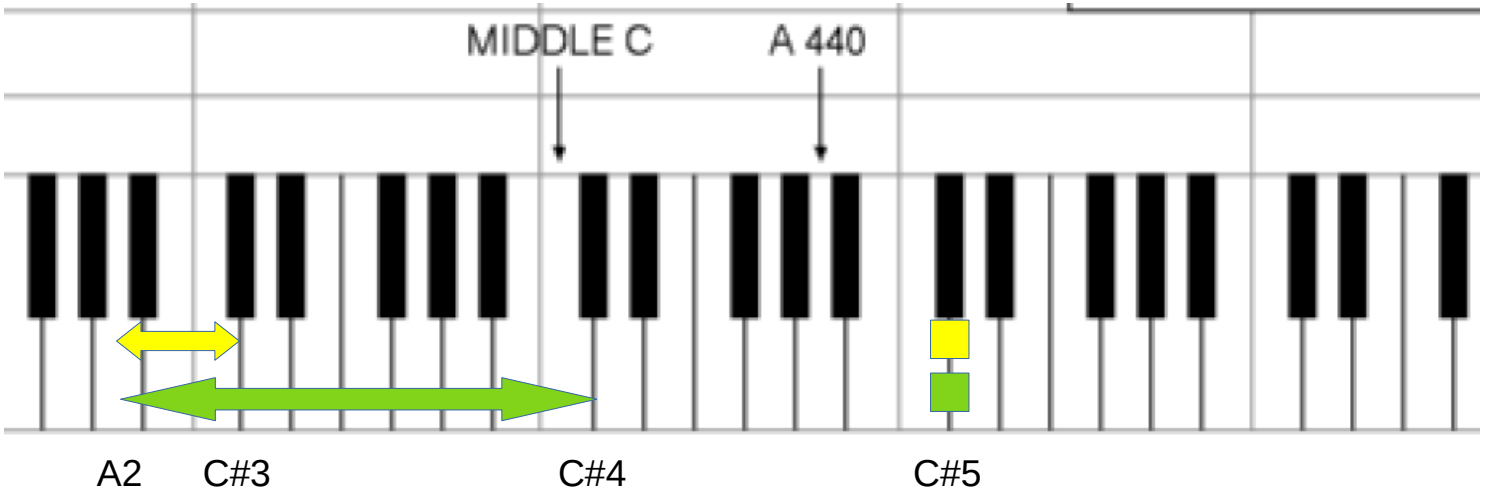


Harmonics and near-Coincident Partials of the C3-E3 major third

Intervals and Beats

1 of 2 (and Demo)

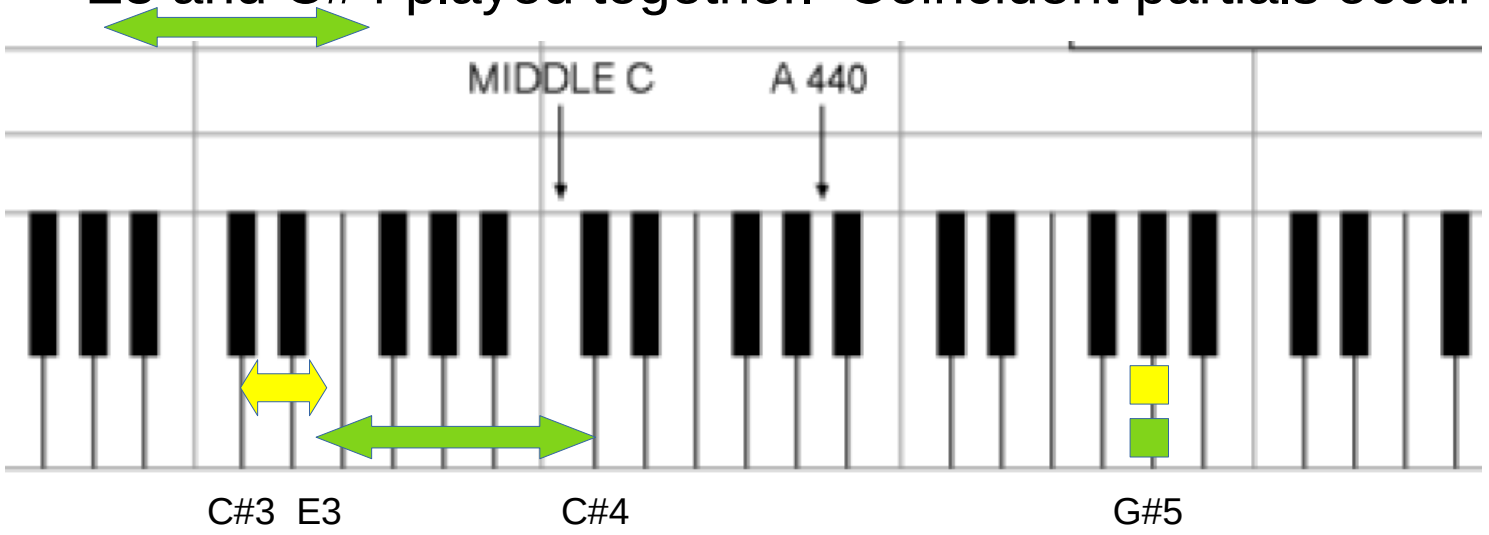
- Play two notes simultaneously
  - Hear beats at their near-common upper note (or below)
  - Referred to as **Coincident Partials**
- 5:4 (major third) example
  - A2 and C#3 played together. Coincident partials occur at C#5
- 5:2 (tenth) example
  - A2 and C#4 played together. Coincident partials occur at C#5



Intervals and Beats

2 of 2 (and Demo)

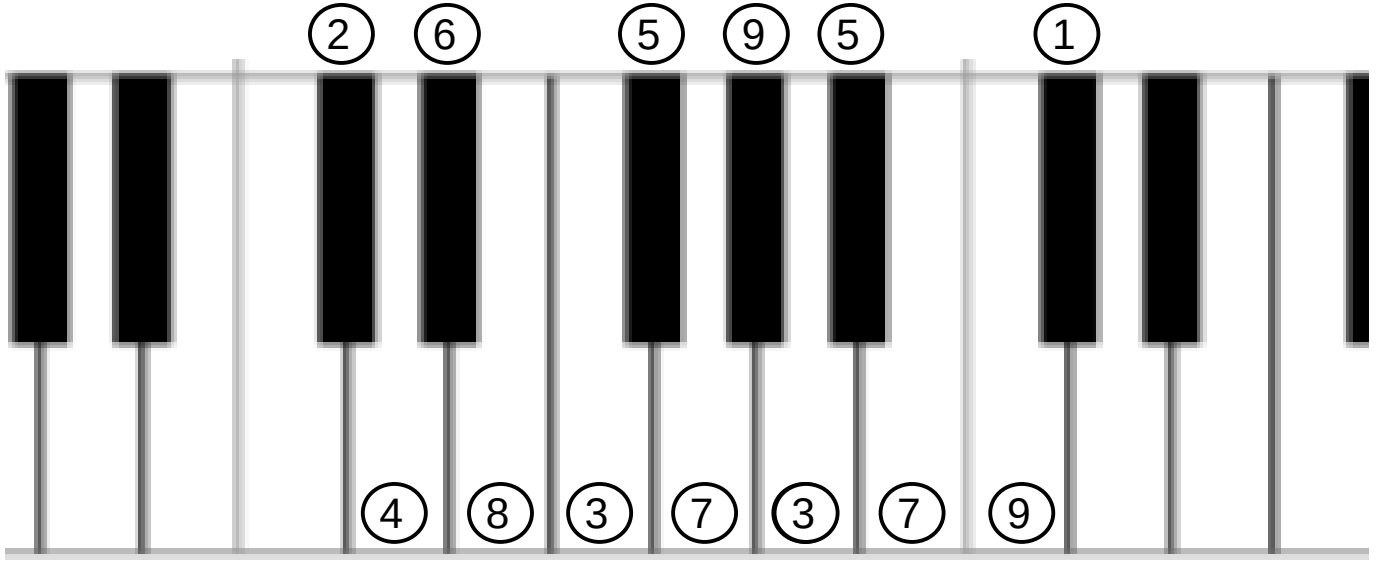
- Play two notes simultaneously
  - Hear beats at their near-common upper note
  - Referred to as Coincident Partials
- 6:5 (minor third) example
  - C#3 and E3 played together. Coincident partials occur at G#5
- 5:3 (major sixth) example
  - E3 and C#4 played together. Coincident partials occur at G#5



Play the audio

(3) - Setting the Temperament Octave
(in 9 steps)

- C#3 to C#4
- Outlined in the following 12 charts
  - With accompanying audio exercises
- The complete, straight-forward tuning process for the temperament octave is:
  - (a) Set C#4 and C#3
  - (b) Tune two major thirds up from C#3
  - (c) Tune down a fifth from A3
  - (d) Repeat (b) and (c) three times
- Available tests for the notes increase as the octave is filled in
- I use a mute strip for this octave, and only tune one string per note at this time
  - And I tune uprights left-handed, and grands right-handed (except for the highest octave)

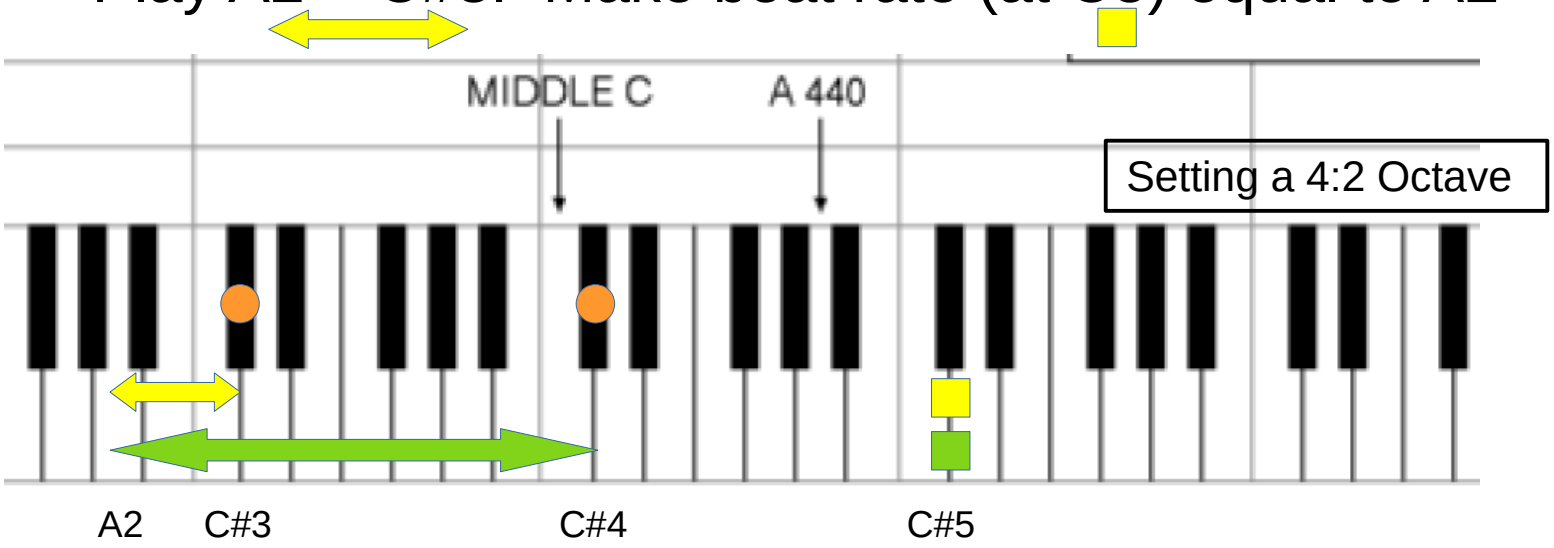


Temperament Octave

Chart 1 of 2 (Steps 1 and 2 to **Set** C#3 & C#4)

- Set C#4 (using a 5:2 interval)
  - Play A2 + C#4 tuning fork. Hear beat rate (at C#5)
  - Play A2 + C#4 key. Hear beat rate (at C#5)
  - Adjust C#4 tuning pin. Make these two beat rates equal

    (The tuning fork is touched against the piano to make it more audible)
- Set C#3 (using a 5:4 interval)
  - Play A2 + C#3. Make beat rate (at C5) equal to A2 + C#4.

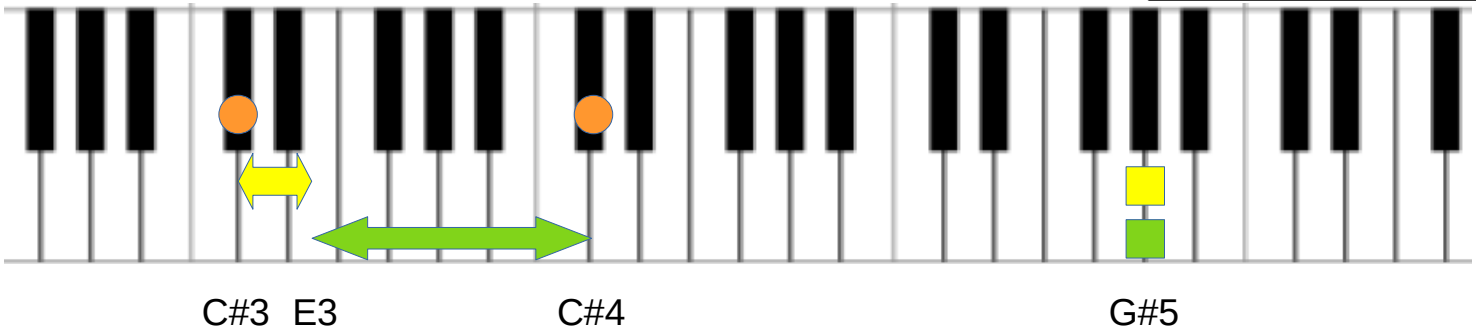


Temperament Octave

Chart 2 of 2 (Steps 1 and 2 to **Set** C3 & C4)

- Preceding chart set a 4:2 octave
  - Used 5:2 for C#4 and 5:4 for C#3
- The tuner's alternative is to set a 6:3 octave
  - After tuning the 4:2 octave, test as a 6:3 octave also
    - C#3 to E3 (6:5) and E3 to C#4 (5:3). Are they also equal beating?
  - Alternative is to tune a 6:3 octave for C#3 to C#4
    - 6:5 and 5:3 equal-beating. See the keyboard figure below, and the earlier "Intervals and Beats" chart
- Decision: Use 4:2 or 6:3?
  - Function of piano scale
    - Inharmonicity of actual vibrating strings
  - Usually the 4:2 octave and the 6:3 octave are equal or very-near-equal
    - If not, choice is usually dictated by obvious tonal dominance of one versus the other
  - I usually wind up setting a 4:2 temperament octave

Setting a 6:3 Octave



Play the audio

Temperament Octave

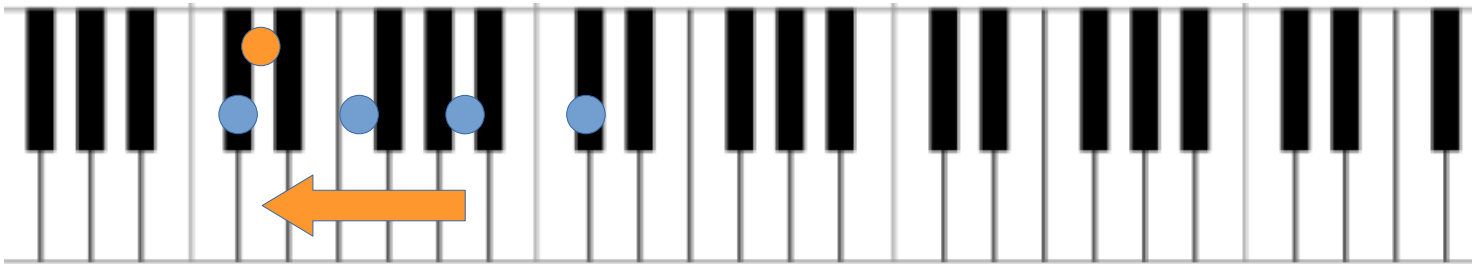
(Step 3 to **Set** F3 and A3)

- Tune F3 and A3
  - Up two major thirds starting at C#3
- Listen to beats of three major thirds
  - C#3-F3; F3-A3; A3-C#4
- Adjust F3 and A3 for a uniform progression of beat rates
  - Each octave up will result in doubling the beat rate for an interval
  - If you have an A4 tuning fork (or an app) you can check A3 now also

Temperament Octave

(Step 4 to **Set** D3)

- Tune D3
  - Down a fifth
  - Tune D3 as a fifth (3:2) down from A3
- Test: the fifth is slightly narrowed
  - Almost 0.5 beats per second (bps) here
- Test: D3-F (m3) and F-A3 (M3)
  - m3 will have the slightly faster beat rate
    - Approx. 7.5 bps (m3) and 6.5 bps (M3) in this octave

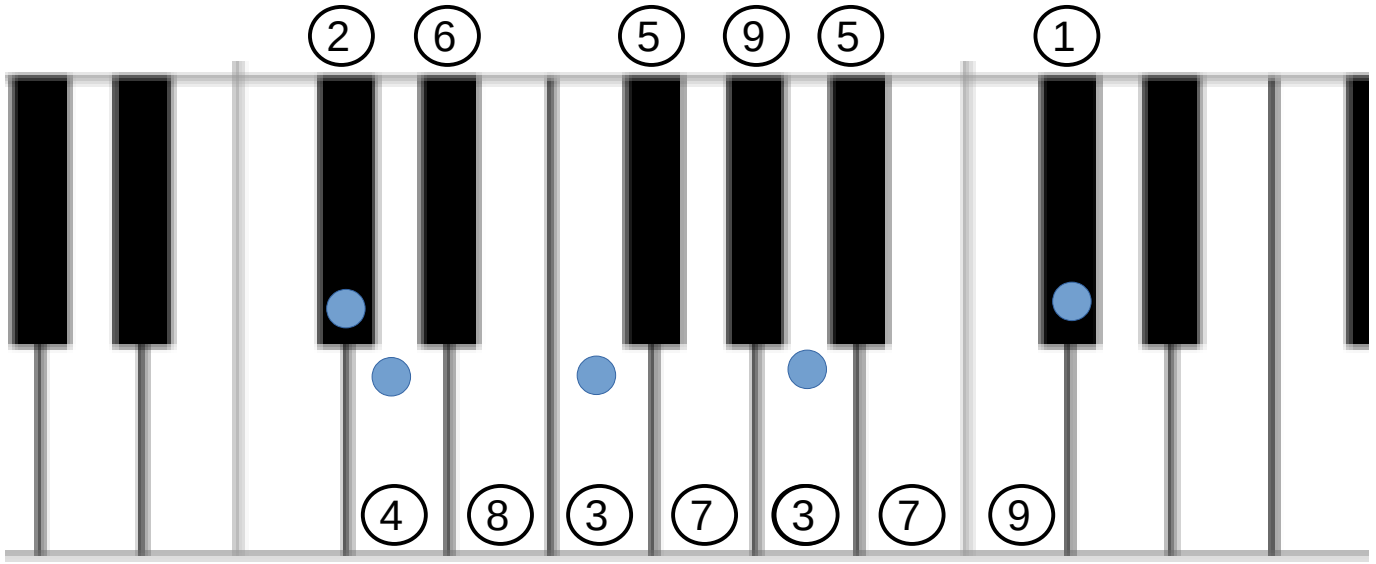


D3

Play the audio

Setting the Temperament Octave

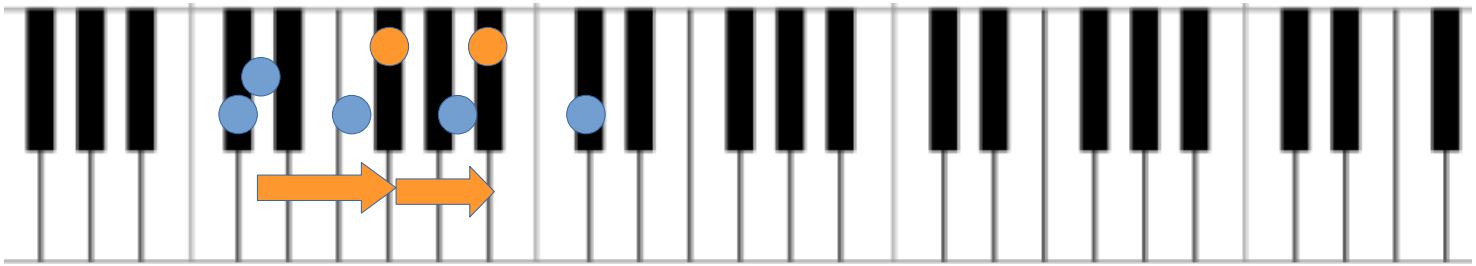
- So far you have completed steps 1 through 4
- Steps 5 through 9 are a repetition of 1 through 4
  - Learning through repetition is good!
  - But you do have the option to skip the next 5 charts



Temperament Octave

(Step 5 to **Set** F#3 and A#3)

- Tune F#3 and A#3
  - Up two major thirds starting at D3
- Listen to beats of five major thirds
  - C#3-F3; D3-F#3; F3-A3; F#3-A#3; A3-C#4
- Adjust F#3 and A#3 for an increasing progression of beat rates
  - With other tests now becoming available
    - Fourths, fifths, minor sixths, and major sixths

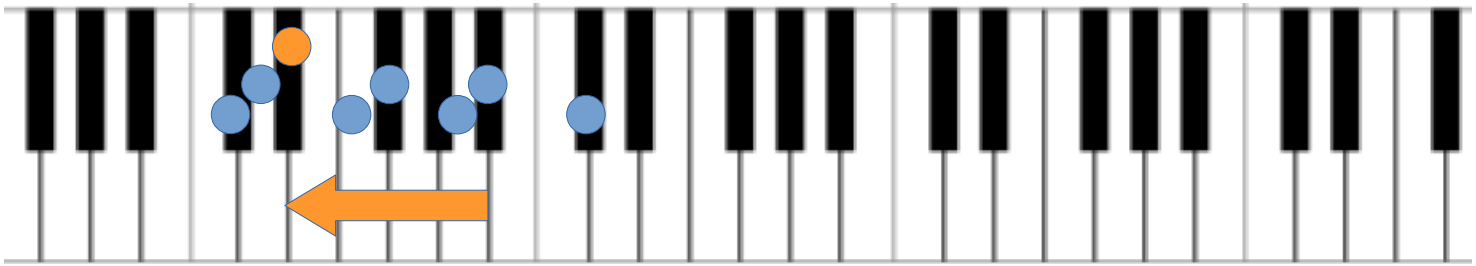


Play the audio

Temperament Octave

(Step 6 to **Set** D#3)

- Tune D#3
  - Down a fifth
  - Tune D#3 as a fifth (3:2) down from A#3
- Test: the fifth is slightly narrowed
  - Approx 0.5 bps here
- Test: D#3-F#3 (m3) and F#3-A#3 (M3)
  - m3 will have the slightly faster beat rate
- Continued use of the interval tests already mentioned
  - Some for comparison, some for progression
- Readjust any of the notes set in steps 3 – 5 if required

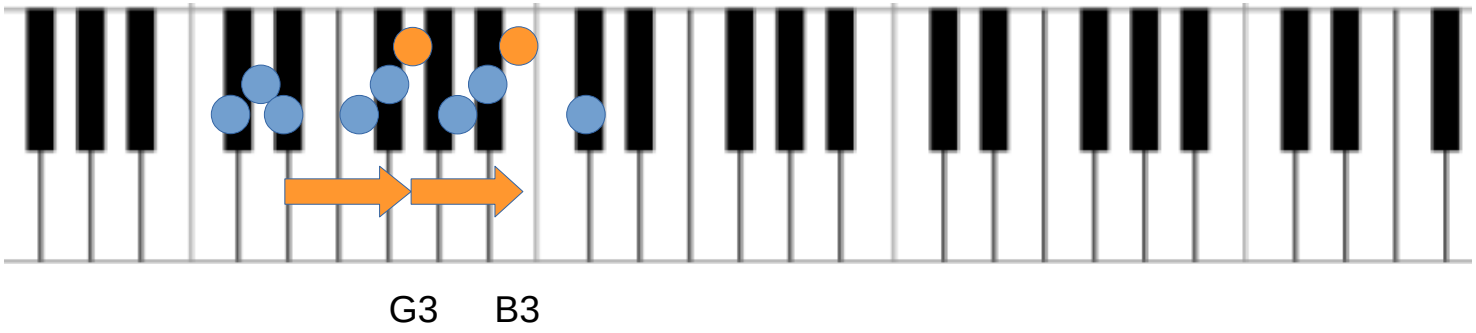


D#3

Temperament Octave

(Step 7 to **Set** G3 and B3)

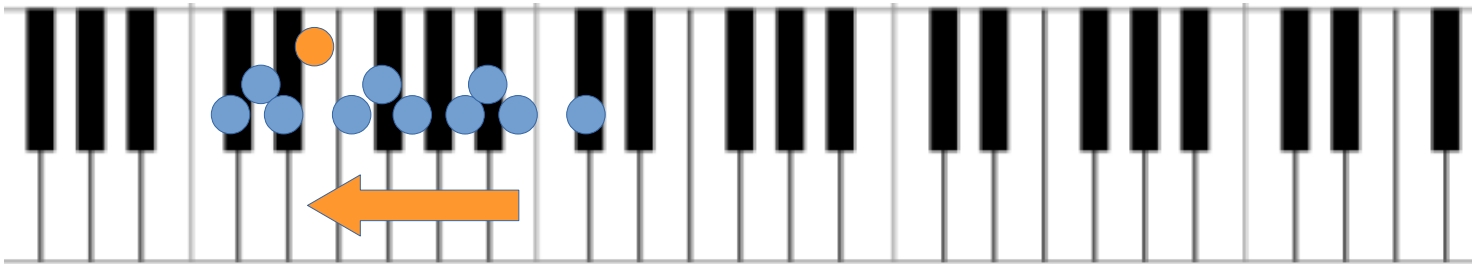
- Tune G3 and B3
  - Up two major thirds starting at D3
- Listen to beats of seven major thirds
  - C#3-F3; D3-F#3; D#3-G3; F3-A3; F#3-A#3; G3-B3; A3-C#4
- Adjust G3 and B3 for an increasing progression of M3 beat rates
  - Continue using the other intervals tests
    - fourth, fifth, m3, M6
- Readjust any of the notes set in steps 3 – 6 if required



Temperament Octave

(Step 8 to **Set** E3)

- Tune E3
  - Down a fifth
  - Tune E3 as a fifth (3:2) down from B3
- Test: the fifth is slightly narrowed
  - Approx 0.5 bps here
- Test: E3-G3 (m3) and G3-B3 (M3)
  - m3 will have the slightly faster beat rate
- Other interval tests used as normal
  - Some for comparison, some for progression
- Readjust any of the notes set in steps 3 – 7 if required

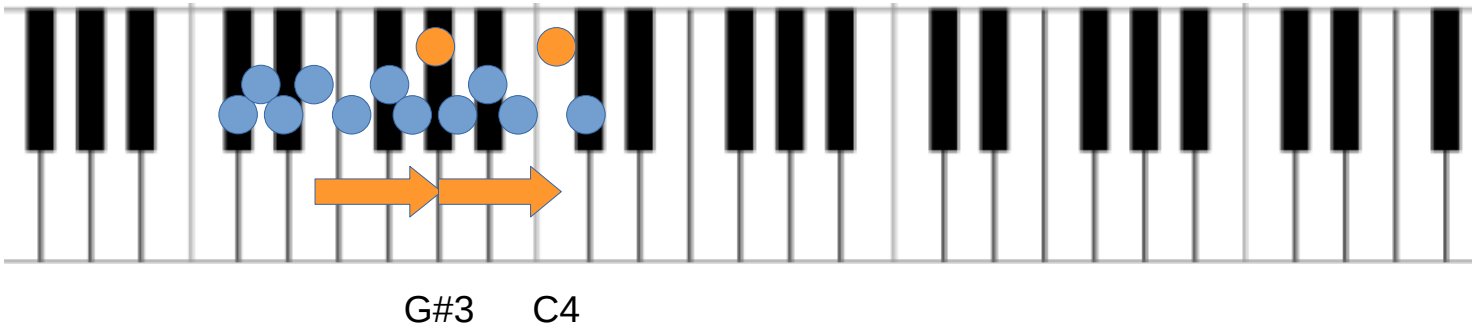


E3

Temperament Octave

(Step 9 to **Set** G#3 and C4)

- Tune G#3 and C4
  - Up two major thirds starting at E3
- Listen to beats of all nine major thirds
  - C#3-F3; D3-F#3; D#3-G3; E3-G#3; etc.
- Adjust G#3 and C4 for an increasing progression of M3 beat rates
  - Be prepared to use all interval tests as needed to validate G#3 and C4
    - Both for comparison and for progression
      - fourth, fifth, m3, M3, M6, others
- Readjust any of the notes set in steps 3 – 8 if required



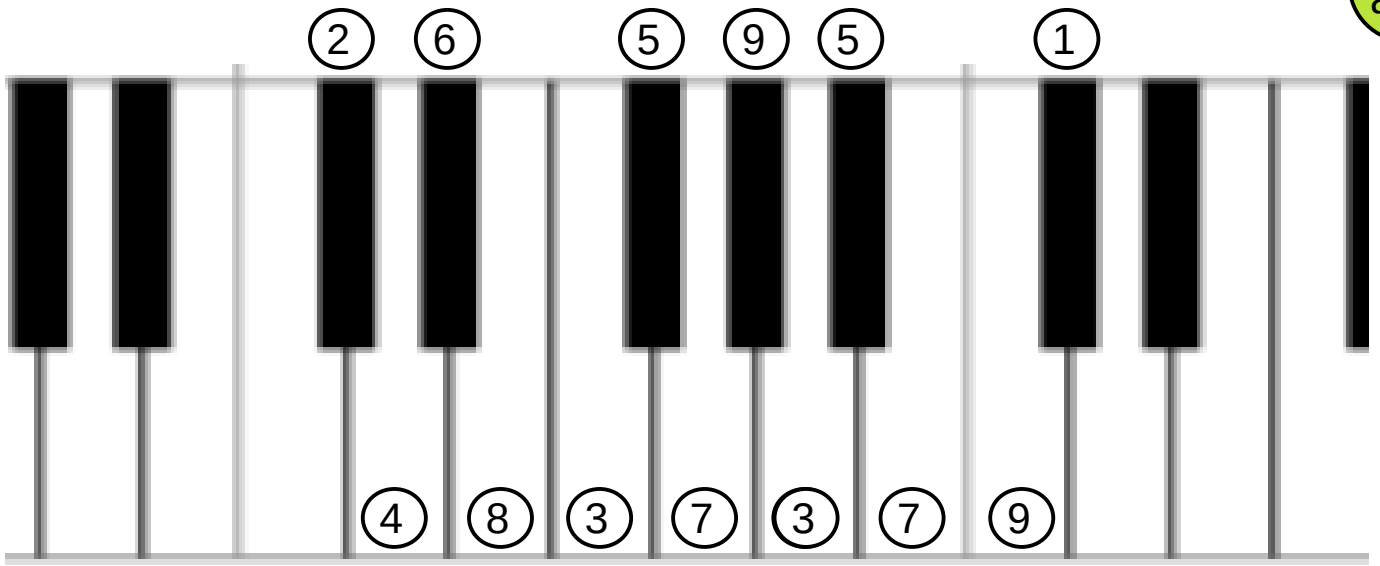
Temperament Octave

(Summary of Steps 5 through 9)

- 5. Tune two major thirds up from D3
  - F#3 and A#3. Test for increasing beat rates
    - C#3-F3, D3-F#3, F3-A3, F#3-A#3, A3-C#4
- 6. Tune D#3 a fifth down from A#3.
  - Test for D#3-F#3 (m3) slightly faster than F#3-A#3 (M3)
- 7. Tune two major thirds up from D#3
  - G3 and B3
- 8. Tune E3 a fifth down from B3
- 9. Tune two major thirds up from E3
  - G#3 and C4
- Test complete temperament octave for M3 increasing beat rates
  - Also test with the several other intervals that were in use during these steps

The Temperament Octave is Complete

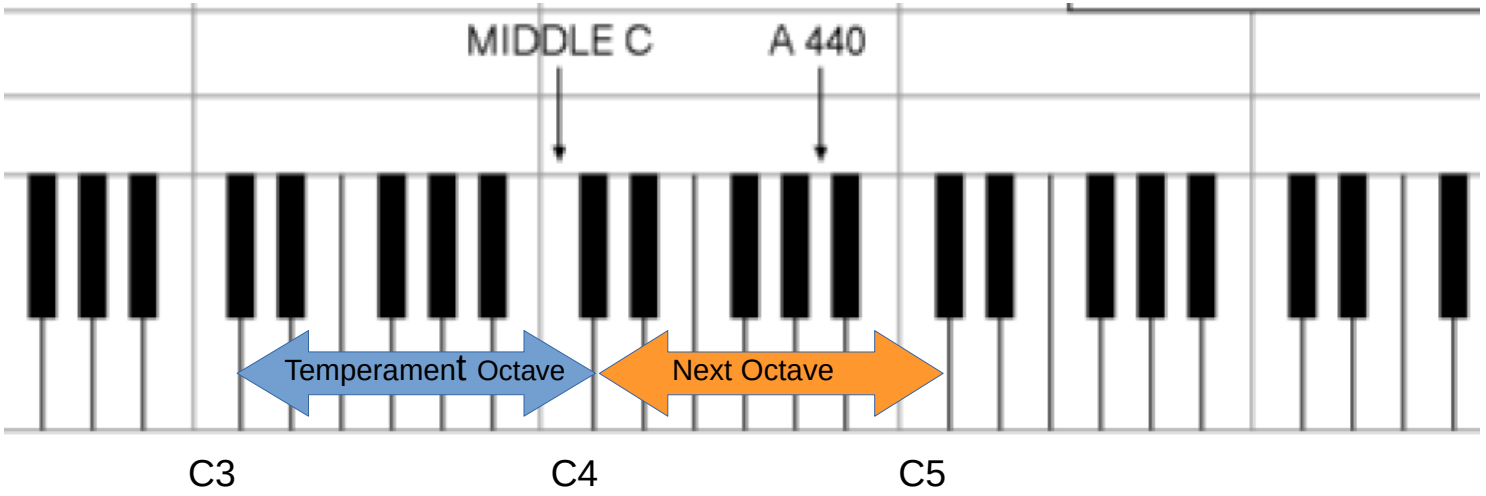
- Test using a uniform progression of major thirds
- Test using other commonly-used intervals
  - That were also used during setting of the octave
  - Relative beat rates / comparisons, as well as progressions
  - Intervals such as:
    - Fourth, fifth, m3, M3, M6
- Readjust any of the notes as required



Play the audio

(4) - Proceed Up One Octave

- Extend the initial tuning to be C#3 through C#5
- Additional checks are now available
  - Based on the temperament octave that has been tuned
- Initially set each note based on an octave test
  - Then test (for increased accuracy) based on:
    - 4:2 and 6:3 octave tests
      - 5:4 + 5:2; 6:5 + 5:3
    - Progression of various intervals' beat rates
      - M3, tenth, m3, M6, fourth, fifth, etc.
- Tuning unisons beyond the temperament octave:
  - For uprights I use an extended mute strip
  - For grands, I tune via what I consider traditional "Triple String Unisons" in the upper octaves
    - Using a rubber wedge, tune left string, then left + middle strings, then right + middle strings

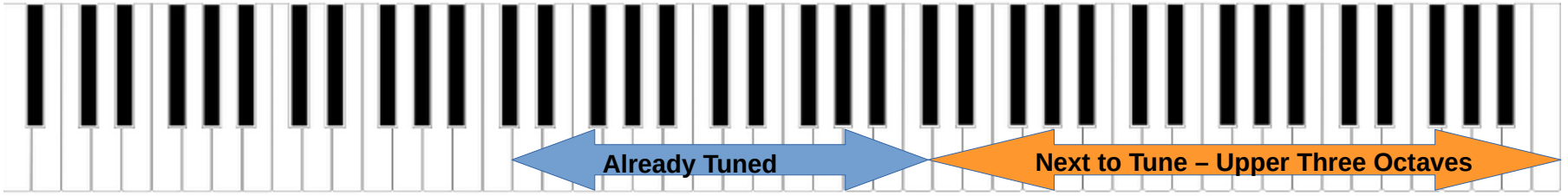


Play the audio

(5) Tune the Upper Three Octaves

- Extend the initial tuning to be C#3 through C8
- Common intervals in use expanded to now include:
  - Setting and testing: octave (2:1), double-octave (4:1), tenths (5:2), seventeenths (5:1)
  - Checking and progressions: twelfths (3:1), and nineteenths (6:1)
  - Some intervals in use in lower octaves eventually become too rapidly beating
  -

Play the audio

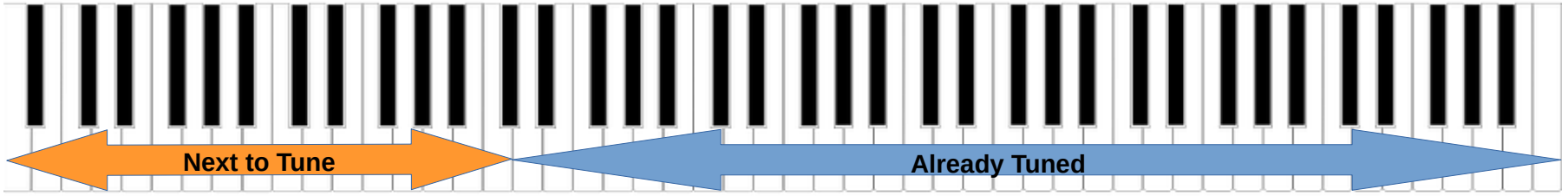


(6) Tune the Lower Octaves

- Extend the tuning to the remainder

  of the scale
- Commonly used: double octave (4:1) tenths (5:2), seventeenths (5:1), and m3-M6 test
- A couple additional intervals supplement the others in testing progressions, such as:
  - The 7:4 (minor seventh) in the very lowest areas
  - The 8:5 (minor sixth)

Play the audio



Summary

- Introduced traditional aural piano tuning
- Provided the core musical principles
- Accounted for different piano scales
  - 4:2 and/or 6:3 octave considerations
- Introduced the necessary musical intervals that are used
  - And where to listen for the beating of their coincident partials
- Incorporated the inherent inharmonicity, or stretch, of the piano’s scale
- Explained the use of beat rates
  - In testing for equality of rates
    - And the uniform progression of rates
  - With no counting of beats, and no estimating of beat rates
- Initialized with one tuning fork or a cellphone app

Notes

- Inharmonicity
  - See wikipedia.com article on “Piano Acoustics”
    - And the Railsback curve shown there – and here on a subsequent chart.
- Accuracy
  - Function of the test interval in use
    - And where on the keyboard, and which of the two notes is being tested
      - Example: the 5:1 interval (seventeenth). For a frequency change in the lower note, the delta is multiplied by 5 at the coincident partial frequency, while the same change in the upper note is not “amplified” / multiplied at all.
- Additional materials available
  - See three recent articles on aural piano tuning at https://potomacpiano.com/tuning-articles
    - “The Aural Tuning Of Pianos”
      - Master Piano Technicians Journal, Spring 2020
    - “Piano Tuning Considerations”
    - “The Beats Go On”
  - Bill Bremmer, RPT, “Tuning A Chain Of Initial Contiguous Major Thirds In Equal Temperament“, Piano Technicians Journal, March 2021
- Why the temperament octave is set C#3 to C#4
  - Explained in John Travis’s book
    - Usual errors are less likely to be noticed
  - Typical to start with a C# 277.2 tuning fork and check with an A 440 fork
    - Or use an app to create both in place of using a fork.

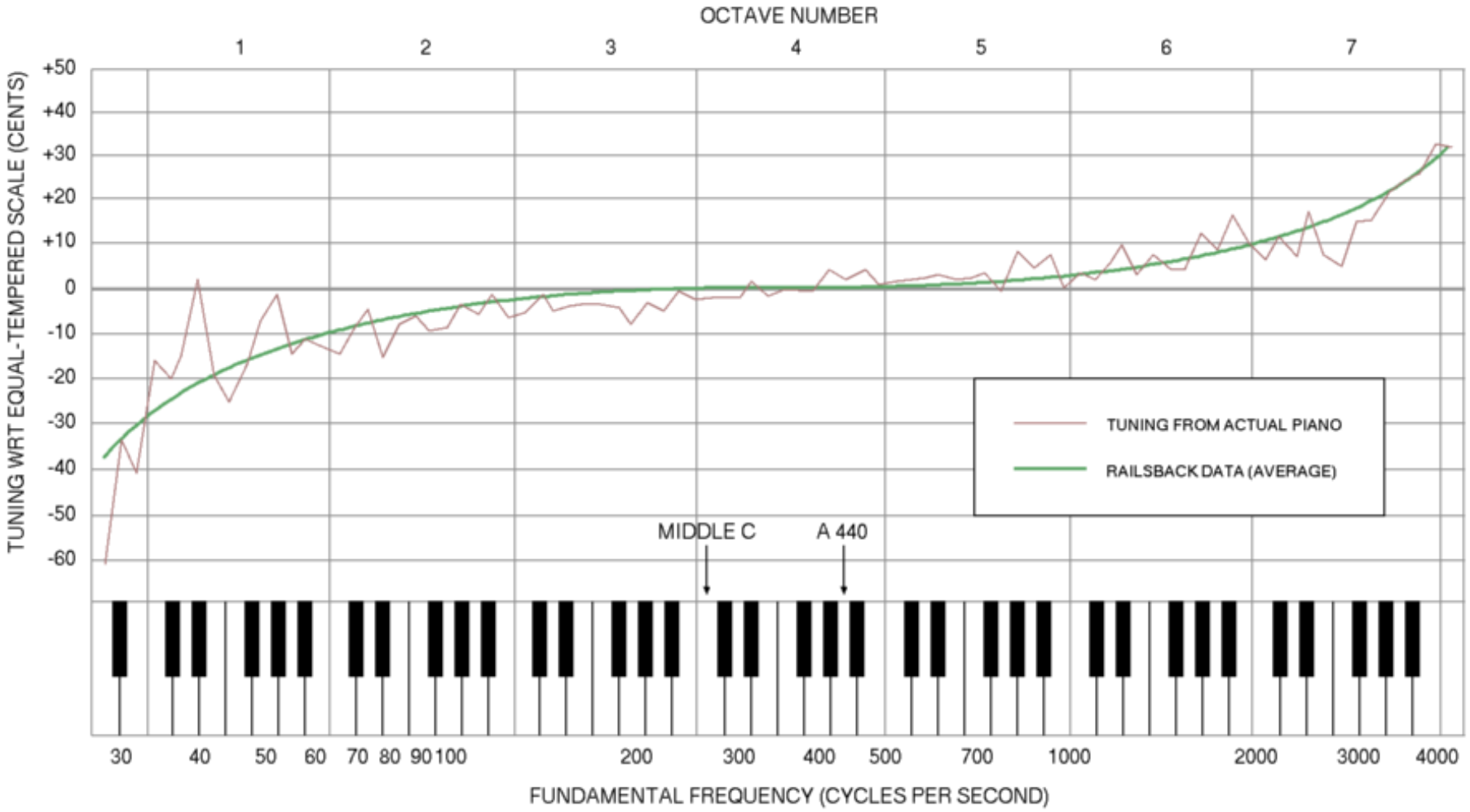
Equal Temperament Beating

Equal temperament beatings (all figures in Hz)

261.626	277.183	293.665	311.127	329.628	349.228	369.994	391.995	415.305	440.000	466.164	493.883	523.251
0.00000			14.1185	20.7648	1.18243		1.77165	16.4810	23.7444			C
		13.3261	19.5994	1.11607		1.67221	15.5560	22.4117			B	
	12.5781	18.4993	1.05343		1.57836	14.6829	21.1538			A♯		
11.8722	17.4610	.994304		1.48977	13.8588	19.9665			A			
16.4810	.938498		1.40616	13.0810	18.8459			G♯				
.885824		1.32724	12.3468	17.7882			G				Fundamental	
	1.25274	11.6539	16.7898			F♯					Octave	
1.18243	10.9998	15.8475			F						Major sixth	
10.3824	14.9580			E							Minor sixth	
14.1185			D♯								Perfect fifth	
		D									Perfect fourth	
	C♯										Major third	
C											Minor third	

https://en.wikipedia.org/wiki/Piano_tuning

Railsback Curve on Inharmonicity



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Norman Brickman, MPT
Potomac, Maryland

https://potomacpiano.com
potomacpiano@verizon.net