

Music and Engineering: Review of the Western Music system for Engineers

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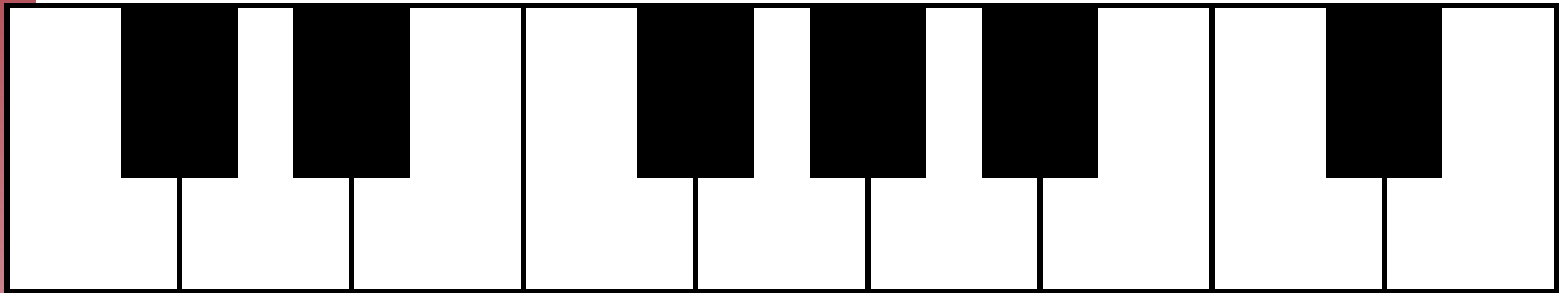


Outline

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- The Staff
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- Notes & Rests
- Measure & Rhythm
- Intervals
- Scales
 - Major
 - Minor
- Chords
 - Major
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Twelve Tones of Equal Temperament

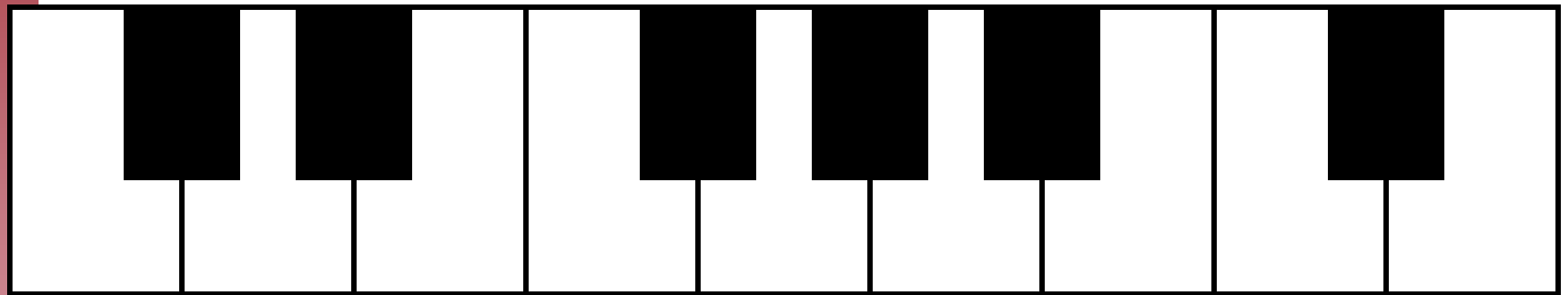
C **C#** **D** **D#** **E** **F** **F#** **G** **G#** **A** **A#** **B** **C**
D \flat **E \flat** **F \flat** **G \flat** **A \flat** **B \flat**



- In the modern western Equal Tempered system of musical notation there are 7 letters that are used to represent the notes
- In between some of the letters are enharmonics.
 - These are indicated with a sharp (#) or flat (\flat) sign next to the note letter
 - Each enharmonic has two names. The key signature determines which name is used.

Twelve Tones of Equal Temperament

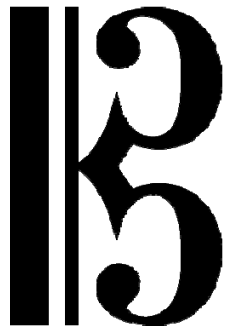
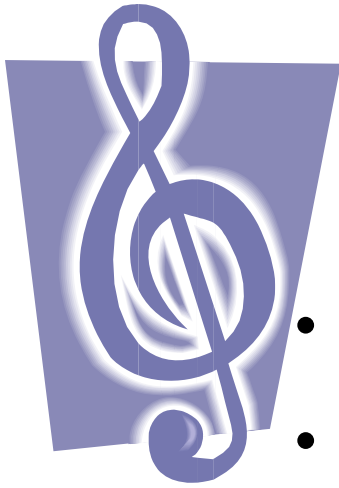
C **C#** **D** **D#** **E** **F** **F#** **G** **G#** **A** **A#** **B** **C**
D \flat **E \flat** **F \flat** **G \flat** **A \flat** **B \flat**



Half step Whole step Half step Half step Whole step

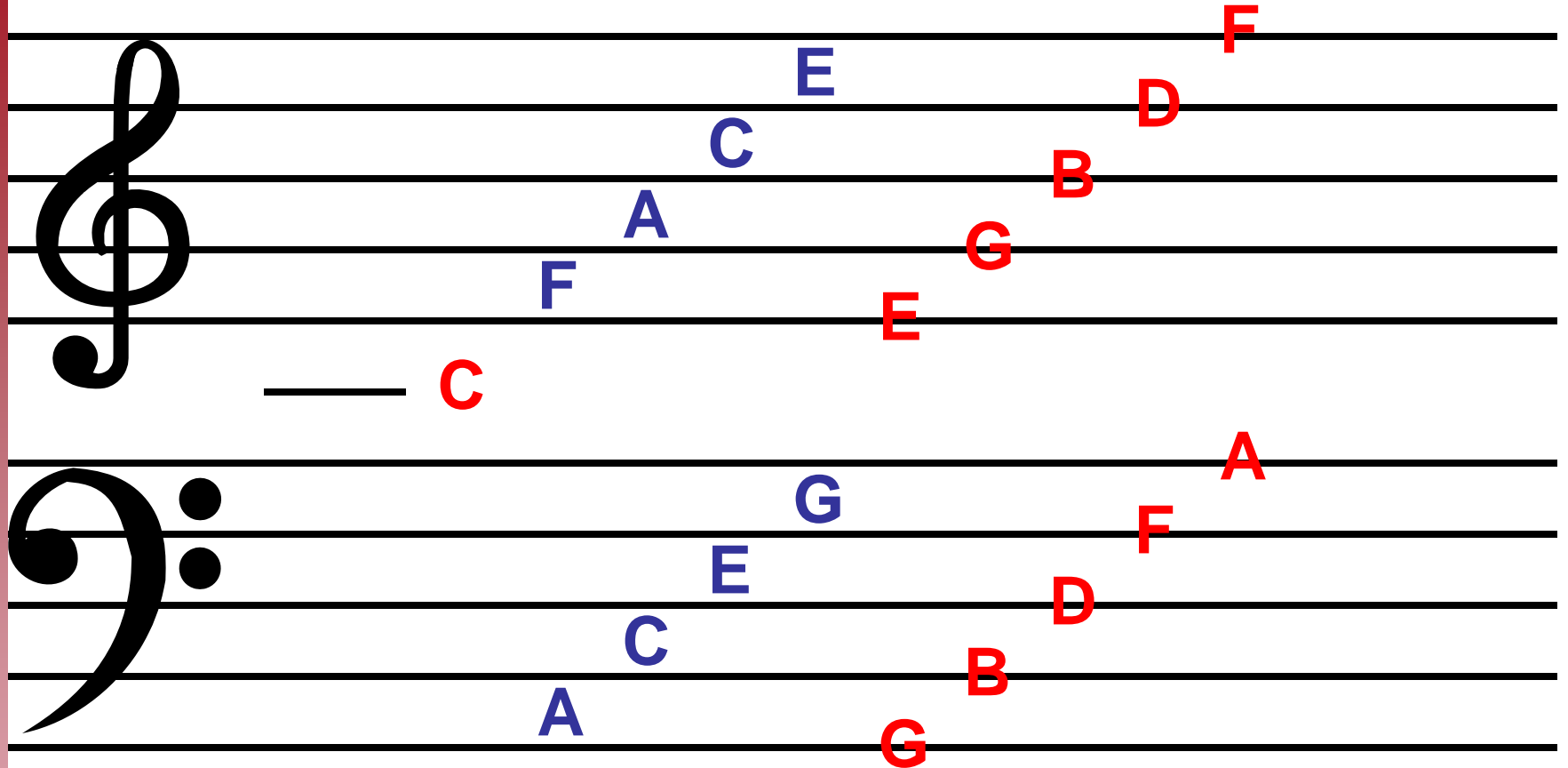
- The distance between any two adjacent notes is a half step. Two half steps make a whole step
- The same notes names are reused for each octave in the musical scale

Clefs



- Western music uses a notation of special characters called notes written on a set of lines called the staff.
- There are multiple mappings of note names to lines.
 - Treble Clef (shown above in stylized form at upper left) is used for high frequency instruments. Middle C (~261 Hz) is located below the lines of the treble clef staff
 - Bass clef (shown below in stylized form at left) is used for low frequency instruments. Middle C is located above the lines of the bass clef staff
 - There is another clef, called C clef which will locate Middle C on any one of the 5 lines of the staff. This is less common and typically only used for certain instruments that would otherwise live between the staves (such as trombones and certain vocal parts)
- For notes above or below any given staff, ledger lines are used to indicate their height relative to the staff

Staff



- The full staff above shows the locations of notes around the note known as middle C
- The clefs have other mnemonic names
 - The treble clef is called the G clef since the bottom loop circles the line for G
 - The bass clef is called the F clef since the two dots are around the line for F
- There are other mnemonics for remembering the line notes
 - Every Good Boy Deserves Fudge
 - Good Boys Do Fine Always

Notes



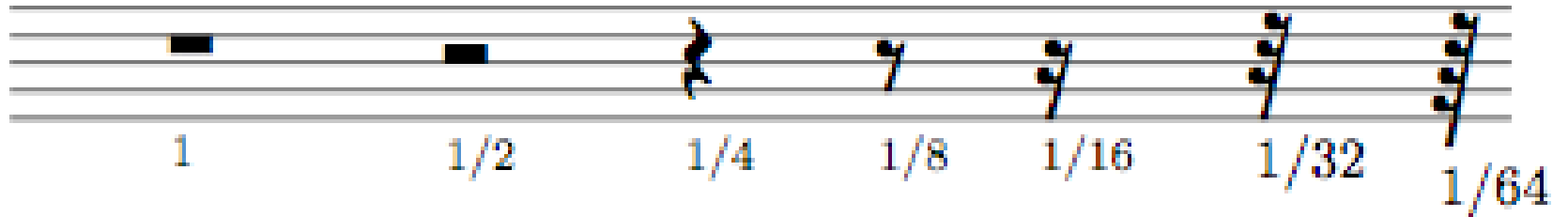
- Whole notes indicate that the tone should be played for the whole measure of common time (4 beats)
 - The whole note is drawn as an oval.
- Half notes indicate that the tone should be played for half of the duration of a whole note (2 beats in common time).
 - The half note is basically a whole note with a vertical line.
- Quarter notes indicate that the tone should be played for one quarter of the duration of a whole note (1 beat in common time).
 - The quarter note is a half note with the center filled in.
- Eighth notes indicate that the tone should be played for one eighth of the duration of a whole note (1/2 beat in common time)
 - The eighth note is like a quarter note with a flag on top.
 - When an eighth note is by itself, the flag is wavy. When there are multiple eighth notes, the flags are bridged together
- Similarly there are 16th and 32nd notes that scale their durations as expected
 - For each division by 2 in duration, an extra flag is added.
 - The same rules for bridging flags apply
 - Flags between 8ths, 16th and 32nd notes can be bridged as well.

Notes (cont)

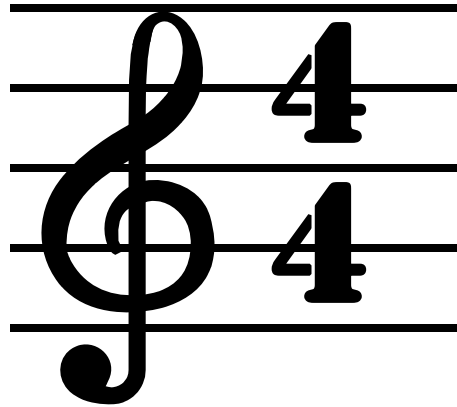


- These notes work well, but what if you need something $\frac{3}{4}$ of a whole note?
- The dotted note extends the duration of the note by 50%.
 - A dotted half note is 3 beats
 - A dotted quarter note is 1.5 beats
- Besides dots, it is also possible to “tie” notes together.
 - The diagram at the left indicates that the note should be held for 2.5 beats
 - This gives multiple ways of presenting the same note duration
 - A dotted half note is the same duration as a half note tied to a quarter note
 - A dotted quarter note is the same duration as a quarter note tied to an eighth note
- Ties are only for notes of the same pitch. If the notes under the curved line are different pitches, it is called a slur.
 - How a slur is implemented physically depends on the instrument.
 - With a wind or brass instrument, a slur can be played when a musician changes the keys being played without “tongueing” the note
 - On a string instrument, a slur can be executed by a hammer-on or pull-off. Basically moving the “fretting” hand while not plucking or bowing with the other hand.

Rests



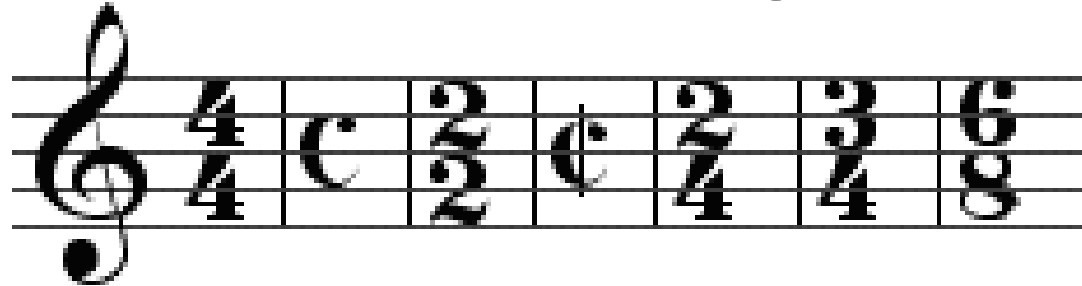
- Rests are used to indicate that the musician shouldn't play anything.
- A Whole Rest looks like a small filled in box hanging below a line in the middle of the staff. It has the same duration as a whole note.
- A Half Rest looks like a small filled in box resting on a line in the middle of the staff. It has the same duration as a half note.
- A Quarter Rest looks kind of like a seagull flying sideways. It has the same duration as a quarter note.
- An Eighth Rest looks like a slash with a ball on top. It has the same duration as an eighth note.
- The division can be further divided by 2 by adding extra balls to the rest.
- All the same rules of dotting and tying that apply to notes also apply to rests.



Time Signature or Meter

- Besides pitch and duration of individual notes, there is also rhythmic organization in the music
- In music, most songs are broken down into measures.
- The rhythm of the piece is indicated by the “time signature”
- The time signature is generally represented by two numbers, one above another, right after the clef at the beginning of a musical piece
 - The lower number tells you how many notes “get one beat”
 - The upper number tells you how many notes are in a measure.

Common Time Signatures



- Of all the time signatures, 4/4 is probably the most common in the modern era. Most rock songs are in 4/4
- It is so common, it has been called “common time” and a symbol is often used to represent it.
- A common variation of 4/4 is 2/2 or “cut time” This also has a special symbol that looks like the common time symbol with a line through it.
- Other common times include 2/4, $\frac{3}{4}$ and 6/8
 - 6/8 is actually a Compound Time Signature. In compound Time Signatures, each beat is divided into three equal parts.
 - The previous time signatures are considered Simple Time Signatures, where the beat is divided into two parts
- Other time signatures (called complex time signatures) are sometimes used in more “progressive” music (7/8, 5/8, etc)

Some Time Signature Examples

Meter	Description	Type	Examples
4/4	Any rock song	Simple	
$\frac{3}{4}$	Waltzes	Simple	
2/4	Polkas or Marches	Simple	
6/8	Certain types of jigs	Compound	Manic Depression - Hendrix
9/8	Slip Jigs	Compound	Flight of the Valkries - Wagner
5/4	Progressive	Complex	"Take Five" – Dave Brubeck
7/4	Progressive	Complex	"Money" (except break)– Pink Floyd Limelight - Rush
7/8	Progressive	Complex	Them Bones (verse) – Alice in Chains

Other Notation

104 bpm

The image shows a grand staff with two treble clefs and a 4/4 time signature. The staff is divided into measures by vertical lines. A repeat sign (two vertical lines with dots) is placed around a central measure. Below the staff, the dynamic marking *ppp* is followed by a wedge-shaped symbol pointing to the right, and then *fff*.

- Measures are divided by a simple vertical line.
- Measures that are to be played multiple times are surrounded by repeat signs
- The tempo is given at the beginning of the song (or at each temp change) in Beats Per Minute
- Dynamic markings are given below the scale and range from pianissimo (quietest) to fortissimo (loudest)

Accidentals

- Notes can be specified as their natural values, or as modified with accidental notation
- There are three common accidental markings and 2 double markings
 - Flat – (\flat) means drop the pitch from the letter value by one half step
 - Sharp – (\sharp) indicates the raise the pitch by one half step
 - Natural – (\natural) cancels a previous sharp or flat sign.
 - There are also double flat and double sharp which indicate alteration of the tone by a whole step
- Any accidental only lasts for the duration of the measure. If a sharp is to be applied to only one note out of a series, a natural must be used to cancel it.

Intervals

- The distance between notes is referred to as an interval
- The intervals are typically taken from the note order in the major scale.
 - The 2nd 3rd 6th and 7th are called major intervals
 - The 1st 4th 5th and octave are called perfect

Number of half steps	Name	Note in C major
0	Unison	C
2	Major 2nd	D
4	Major 3rd	E
5	Perfect 4th	F
7	Perfect 5th	G
9	Major 6th	A
11	Major 7th	B
12	Octave	C

Intervals

- If flattened by one half step
 - The 2nd 3rd 6th and 7th are called minor
 - The 4th and 5th are called diminished
- If raised by one half step
 - The 4th and 5th are called augmented

Number of half steps	Name	Note in C major
0	Unison	C
1	Minor 2nd	D \flat
3	Minor 3rd	E \flat
4	Diminished 4th	F \flat
6	Diminished 5 th (Tri-tone)	G \flat
8	Minor 6 th	A \flat
10	Minor 7 th	B \flat
12	Octave	C

Key signatures

- Sometimes a note is supposed to always be played as sharp or flat
- These modifications are shown in the key signatures. These are shown as flats or sharps at the beginning of the piece or key change.
- There are only 15 given key signatures
 - No key signature combines sharps and flats
 - There is a fixed order in which sharps or flats can be added.
- Accidentals (such as the natural) can be used to temporarily over ride the key signature within a measure.
- The key of no sharps or flats is the key of C

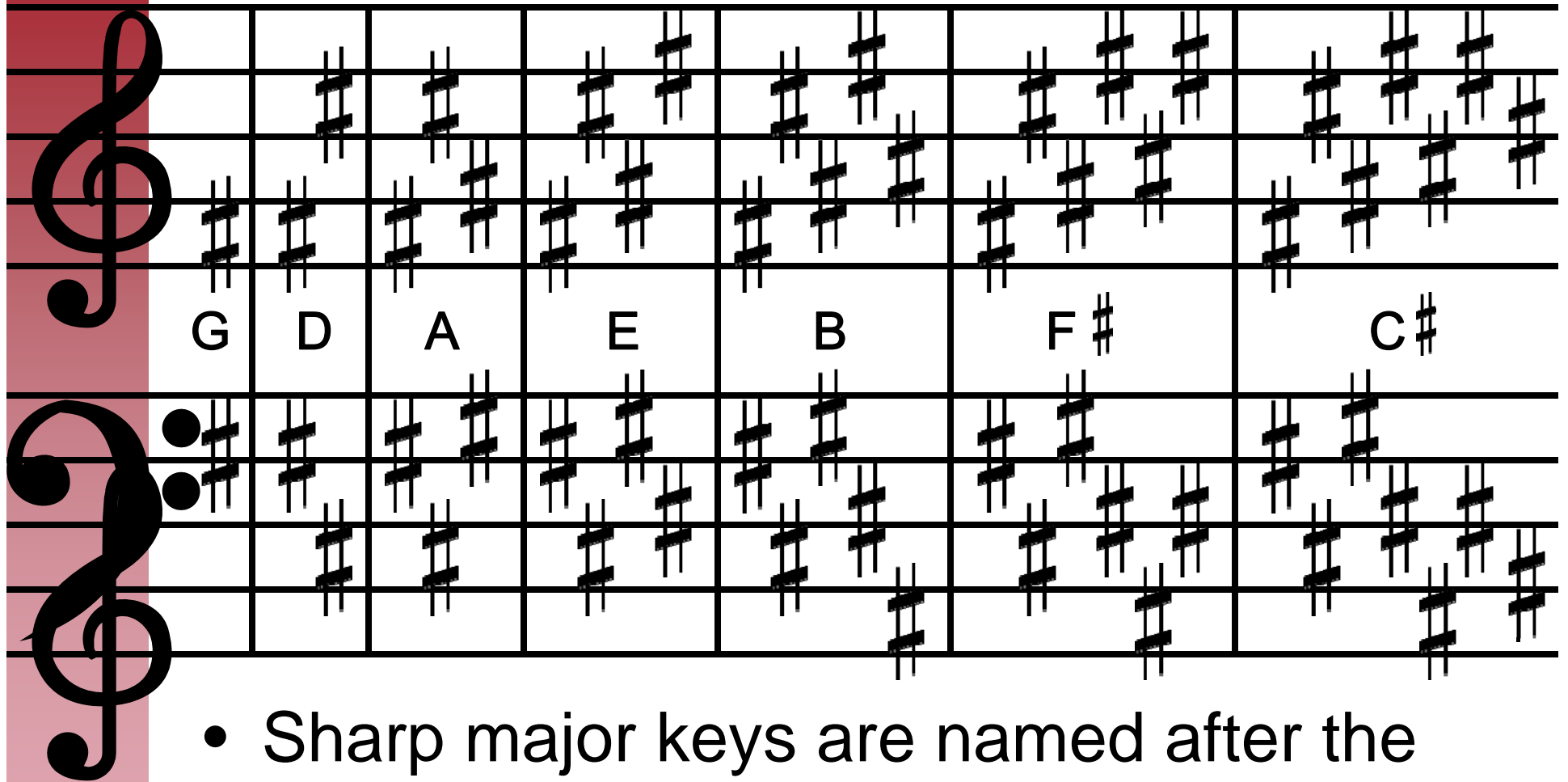
Flat key signatures

The image displays two musical staves, one for the treble clef and one for the bass clef, illustrating the sequence of flat key signatures. Each staff contains seven measures, each with a single note. The notes are: F (first measure), Bb (second), Eb (third), Ab (fourth), Db (fifth), Gb (sixth), and Cb (seventh). The notes are arranged in a chromatic scale, moving up by half steps. The bass clef staff shows the same sequence of notes, but the notes are positioned lower on the staff, reflecting the lower pitch range of the bass clef.

F	B \flat	E \flat	A \flat	D \flat	G \flat	C \flat
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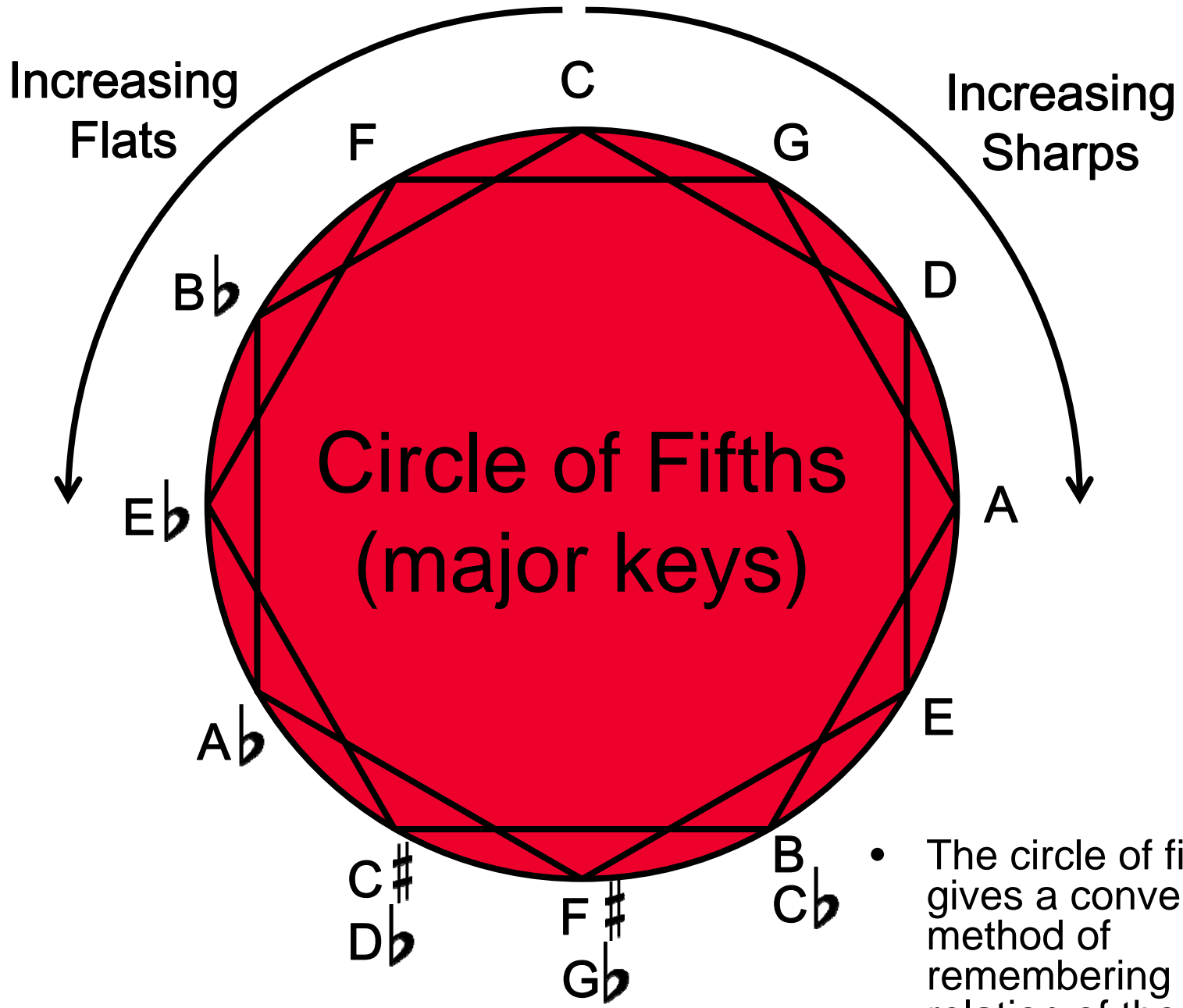
- The first flat major key is called F
- All subsequent major keys are named after the next to last flat added

Sharp key signatures



The image displays two musical staves, one in treble clef and one in bass clef, illustrating sharp key signatures. The treble clef staff shows the key signatures for G major (one sharp), D major (two sharps), A major (three sharps), E major (four sharps), B major (five sharps), F# major (six sharps), and C# major (seven sharps). The bass clef staff shows the key signatures for G minor (two sharps), D minor (three sharps), A minor (four sharps), E minor (five sharps), B minor (six sharps), F# minor (seven sharps), and C# minor (seven sharps). The notes are represented by sharp symbols (#) on the staff lines. The key names are labeled below the treble clef staff: G, D, A, E, B, F#, and C#.

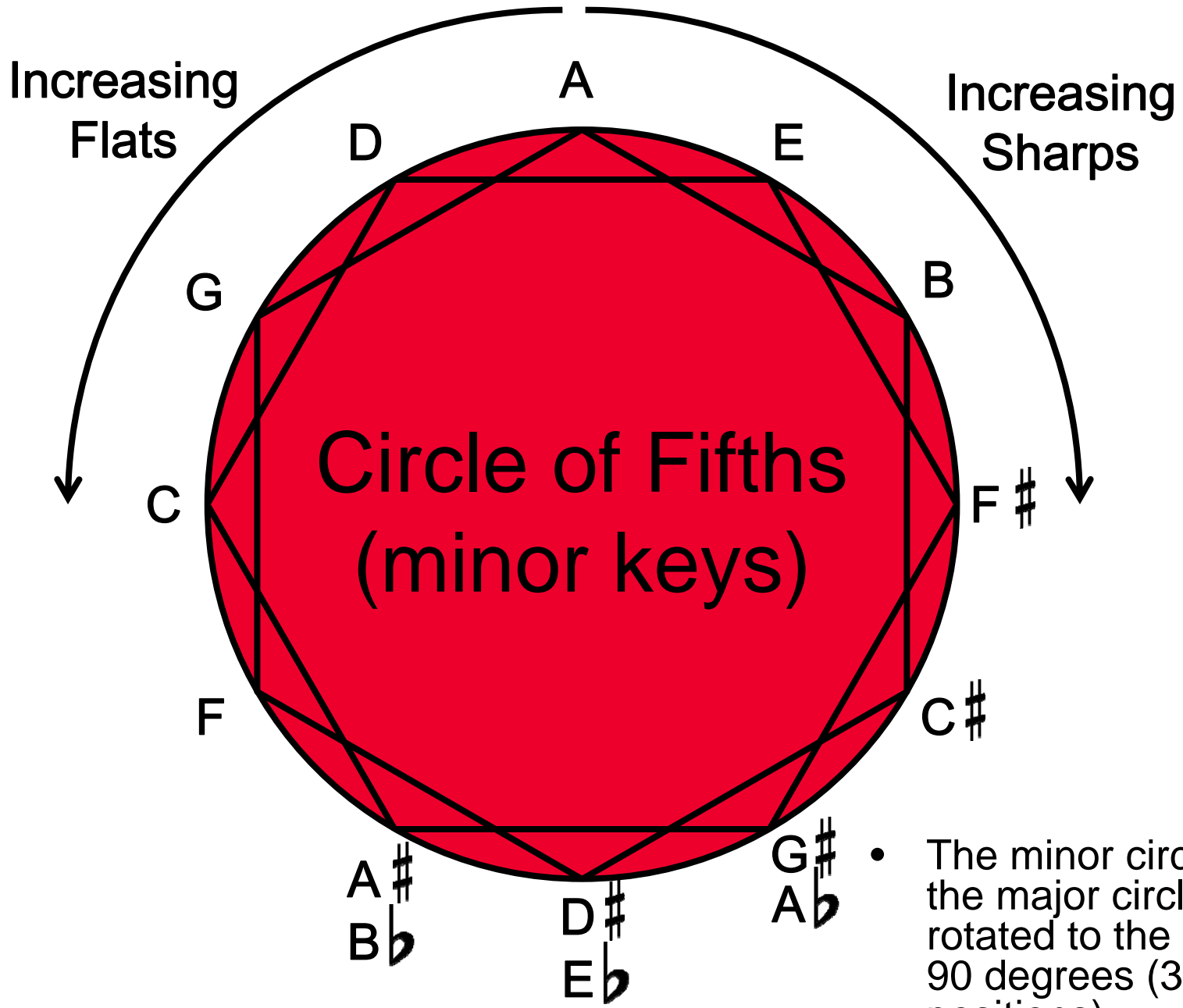
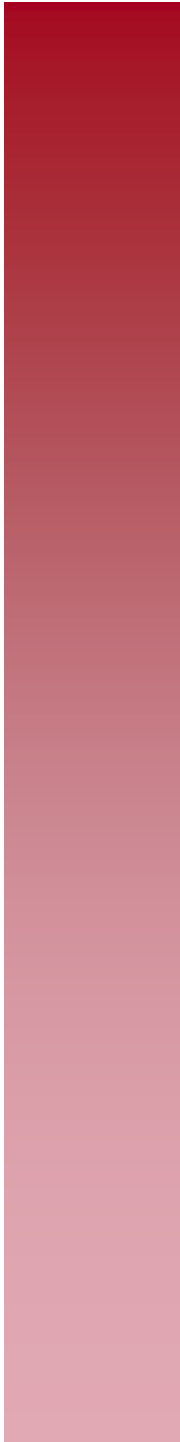
- Sharp major keys are named after the note just above the last sharp in the key signature



- The circle of fifths gives a convenient method of remembering the relation of the keys

Relative Minors

- Thus far we've considered keys based on their Major scale names
- Each major scale also has a Relative Minor key
 - These have the same number of sharps or flats as their relative major, but are named after the 6th note in the major scale



- The minor circle is the major circle rotated to the left by 90 degrees (3 positions)

Scales

- Scales are series of musical notes strung together.
- Some Scales don't belong to a key
 - There is Chromatic scale is the simply all of the 12 notes in a row.
 - There are two whole tone scales which have a whole tone between intervals
 - One beginning on C and another C #

Diatonic Scales

- Most scales belong to notes within a key
- The tetra chord is actually a simple 4 note scale.
 - It is specified completely by the intervals whole step, whole step, half step.
 - In the major key of F, this translates to F G A B \flat
 - In the major key of C this translates to C D E F
 - In the major key of G, this translates to G A B C
 - In the major key of D, this translates to D E F \sharp G
- The major scale is simply two tetra chords separated by a whole step. (interval pattern: whole whole half whole whole whole half)
 - In the major key of F, this translates to F G A B \flat C D E F
 - In the major key of C this translates to C D E F G A B C
 - In the major key of G, this translates to G A B C D E F \sharp G
 - In the major key of D, this translates to D E F \sharp G A B C \sharp D
- Notice that the major scale is the first tetra chord of the key and the first tetra chord of next key to the right on the circle of fifths

Diatonic Scales (cont)

- The natural minor scale is the same pattern as the major scale, but rotated to start on the relative minor (the 6th position). (interval pattern: whole half whole whole whole half whole)
 - In the minor key of Dm, this translates to D E F G A B C D
 - In the minor key of Am this translates to A B C D E F G A
 - In the minor key of Em, this translates to E F \sharp G A B C D E
 - In the minor key of Bm, this translates to B C \sharp D E F \sharp G A
- In addition to the Natural Minor Scale, there are two other minor scales
 - Harmonic Minor (natural minor with a raised 7th)
 - In the minor key of Dm, this translates to D E F G A B \flat C \sharp D
 - In the minor key of Am this translates to A B C D E F G \sharp A
 - In the minor key of Em, this translates to E F \sharp G A B C D \sharp E
 - In the minor key of Bm, this translates to B C \sharp D E F \sharp G \sharp A
 - Melodic Minor (natural minor with a raised 6th & 7th when ascending and natural 6th and 7th when descending)

Modes

- In addition to the Major and Minor scales there are other scales that have other flavors
- These are called the Modes and are based around the intervals of the major scale, but starting on different root notes
 - Ionian – starting on 1st note (same as major scale)
 - C D E F G A B C
 - No sharps or flats relative to the major scale with the same tonic
 - Dorian – starting on 2nd note
 - D E F G A B C D
 - Flat third and flat sixth relative to the major scale with the same tonic
 - Phrygian – starting on 3rd note
 - E F G A B C D
 - Flat second, flat third and flat sixth and flat seventh relative to the major scale with the same tonic
 - Lydian – starting on 4th note
 - F G A B C D E F
 - Augmented fifth relative to the major scale with the same tonic
 - Mixolydian – start on 5th note
 - G A B C D E F G
 - Flat 7th relative to the major scale with the same tonic
 - Aeolian – start of 6th note (same as natural minor scale)
 - A B C D E F G A
 - Flat second, flat third and and flat seventh relative to the major scale with the same tonic
 - Locrian – start of 7th note
 - B C D E F G A B
 - Flat second, flat third, diminished fifth, flat sixth and flat seventh relative to the major scale with the same tonic

Chords

- Scales are a group of notes played in sequence, a Chord is a group of notes played simultaneously. (a chord can also be played in sequence, which is called an arpeggio)
- The simplest chord has two notes: the Diad.
 - The Root and 5th played together is called the Power Chord and is the most common 2 note chord.
 - Many musicians are famous for their use of the power chord (Link Wray, Black Sabbath, SLAYER!)
 - It is a good chord for very distorted guitar because there are fewer notes to interact in the non linear distortion product generator.
 - Other diads are often played by string players such as the fourth (inverted fifth), major and minor 3rds.

Triads

- After Diads, the next set of more complex chords is Triads (or three note chords)
- The most common combination of notes is the Major Triad. This is formed from the 1st, 3rd and 5th notes of the major scale
 - In the major key of F, this translates to F A C
 - In the major key of C this translates to C E G
 - In the major key of G, this translates to G B D
 - In the major key of D, this translates to D F[♯] A
- The next most common chord is the Minor chord. This is formed from the 1st, 3rd and 5th notes of the minor scale
 - In the major key of F, this translates to F A[♭] C
 - In the major key of C this translates to C E[♭] G
 - In the major key of G, this translates to G B[♭] D
 - In the major key of D, this translates to D F A

Suspended Chords

- Another type of chords are called suspended. In these chords, the third is suspended and replaced by it's neighbor (the 2nd or the 4th)
- The suspended second chord is formed from the 1st, 2nd and 5th notes of the major scale
 - In the major key of F, this translates to F G C
 - In the major key of C this translates to C D G
 - In the major key of G, this translates to G B D
 - In the major key of D, this translates to D E A
- The suspended fourth chord is formed from the 1st, 4th and 5th notes of the minor scale
 - In the major key of F, this translates to F B^b C
 - In the major key of C this translates to C F G
 - In the major key of G, this translates to G C D
 - In the major key of D, this translates to D G A

7th Chords

- After Triads, the next group of chords includes four notes.
- The most commonly used chords are the 7th chords. Named because they include the major or minor triad plus a 7th from the scale
- The Dominant 7th chord is formed from the 1st, 3rd and 5th and flattened 7th notes of the major scale
 - In the major key of F, this translates to F A C E \flat
 - In the major key of C this translates to C E G B \flat
 - In the major key of G, this translates to G B D F
 - In the major key of D, this translates to D F \sharp A C
- The minor 7th is formed from the 1st, 3rd and 5th notes of the minor scale
 - In the major key of F, this translates to F A \flat C E \flat
 - In the major key of C this translates to C E \flat G B \flat
 - In the major key of G, this translates to G B \flat D F
 - In the major key of D, this translates to D F A C

Other Chords

- The previous few slides showed just some of the basic chords.
- There are many other chords that can be created by
 - Altering the degree of a note in the triad
 - Diminished triads (1 flat 3rd , dim 5th)
 - Augmented triads (1 3 aug 5th)
 - Adding 9ths or 11ths (or various other intervals)
 - Adding a defined bass note.
 - A countably infinite number of other combinations.
- A chord inversion is when the tonic is not the lowest note in the chord.

Chords and Keys

- It is possible to create chords only from the key signature
- These are called diatonic chords
- To figure out what type of chord starts on a given note, start with the interval as a root, then find the other parts of the chord and compare them to the major key that would start with that note
 - For instance, in the key of C, the triad beginning with D would be D F A. Comparing that to D major shows that it is a minor triad (the third is flat)
- The chart at right shows the chords from a major key.
 - Also included are diminished chords on the 7th of the major scale.
 - Diminished chords are like minor chords with a diminished 5th

Interval	Triad	Seventh	In the key of C
1	maj	maj 7th	C, Cmaj7
2	min	min 7th	Dm, Dm7
3	min	Min 7th	Em, Em7
4	maj	Maj 7th	F, Fmaj7
5	maj	dom 7th	G, G7
6	min	min 7th	A, Am7
7	min	dim 7th	Bdim, Bdim7

Annotated References

- Master Theory – Charles S. Peters, Paul Yoder
 - The original series of music theory books I learned from
- <http://www.edly.com/>
 - Good books on Theory and Piano playing
- http://en.wikipedia.org/wiki/Time_signature
 - Most of the Wikipedia articles on music are pretty good for a reference
- <http://www.cuttime.com/symbol.htm>
- http://en.wikipedia.org/wiki/List_of_works_in_unusual_time_signatures