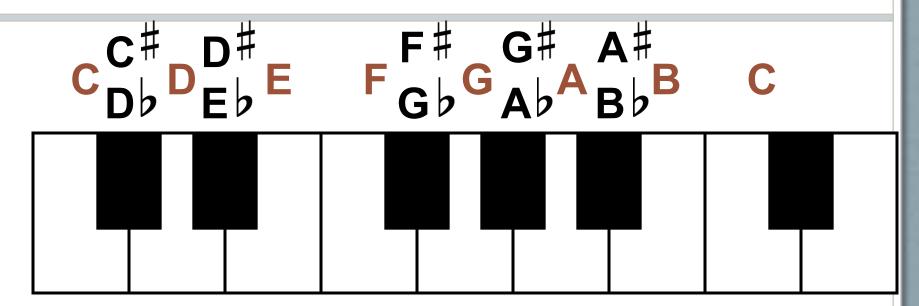
# Music and Engineering: Review of the Western Music system for Engineers

Tim Hoerning
Fall 2017
(last modified 9/12/17)

### Outline

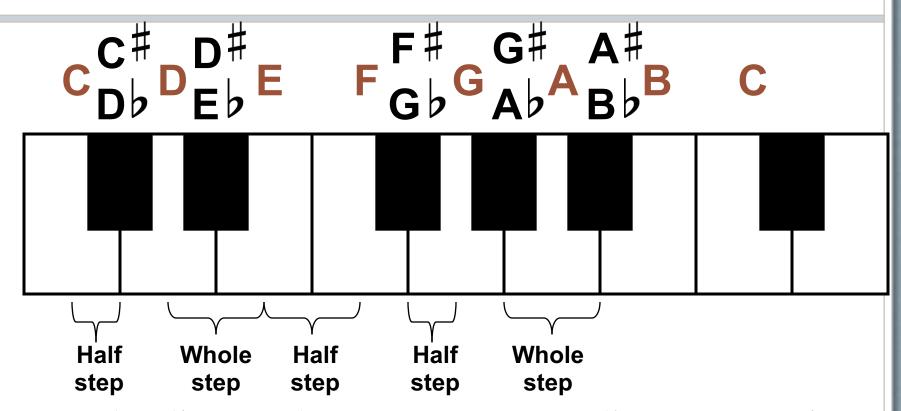
- Twelve Tones of Equal Temperament
- Clefs
- The Staff
- Pitch & Rhythm
- Notes & Rests
- Measure & Rhythm
- Intervals
- Scales
  - Major
  - Minor
- Chords
  - Major
  - Minor
  - 7th

### Twelve Tones of Equal Temperament



- 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 (b) sign next to the note letter
  - Each enharmonic has two names. The key signature determines which name is used.

### Twelve Tones of Equal Temperament



- 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



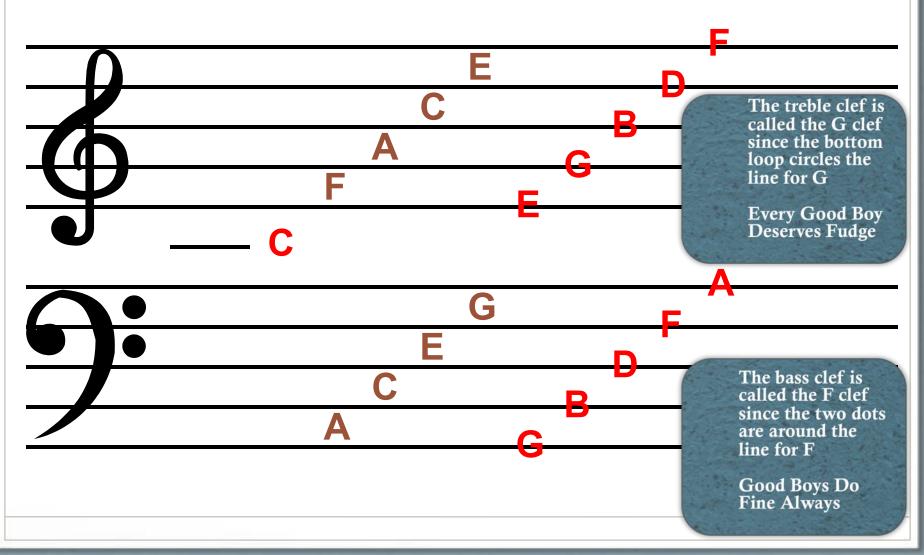
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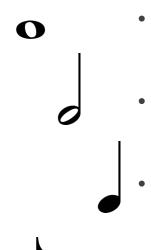
- Western music uses a notation of special characters called notes written on a set of lines called the staff.
- There are multiple mappings of note names to lines.
  - **Treble Clef** (shown above in stylized form at upper left) is used for high frequency instruments. Middle C (~261 Hz) is located below 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 staffs (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
  - Middle C is one ledger line below the treble staff and one ledger line above the bass staff

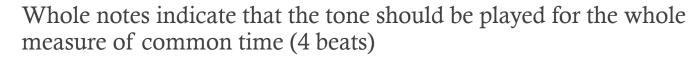
### Staff

• The full staff above shows the locations of notes around the note known as middle C

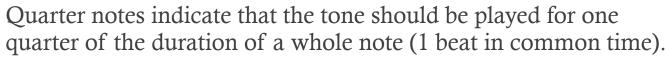


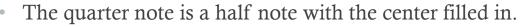
#### Notes

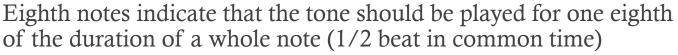




- The whole note is drawn as an oval.
- Half notes indicate that the tone should be played for half of the duration of a whole note (2 beats in common time).
- The half note is basically a whole note with a vertical line.







- 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 eight notes, the flags are bridged together

Similarly there are 16<sup>th</sup> and 32<sup>nd</sup> notes that scale their durations as expected

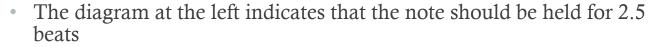


- For each division by 2 in duration, an extra flag is added.
- The same rules for bridging flags apply
- Flags between 8ths, 16th and 32nd notes can be bridged as well.

# Notes (cont.)



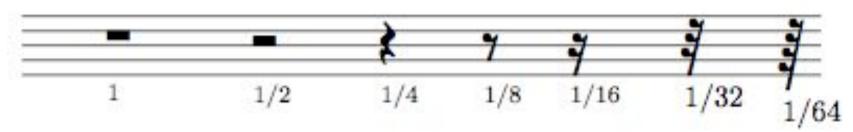
- These notes work well, but what if you need something <sup>3</sup>/<sub>4</sub> of a whole note?
- The dotted note extends the duration of the note by 50%.
  - A dotted half note is 3 beats
  - A dotted quarter note is 1.5 beats
- Besides dots, it is also possible to "tie" notes together.





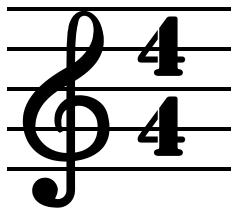
- This gives multiple ways of presenting the same note duration
  - A dotted half note is the same duration as a half note tied to a quarter note
  - A dotted quarter note is the same duration as a quarter note tied to an eighth note
- Ties are only for notes of the same pitch. If the notes under the 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 "tonguing" the note
    - On a string instrument, a slur can be executed by a hammer-on, a pull-off or a slide. 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 which note "gets 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, <sup>3</sup>/<sub>4</sub> and 6/8
  - 6/8 is actually a Compound Time Signature. In component 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)

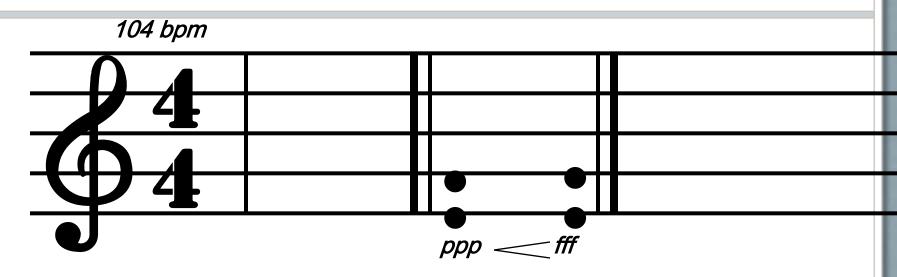
# Sheet Music Examples

- Limelight
- Ring of Fire

# Some Time Signature Examples

Meter	Description	Туре	Examples
4/4	Any rock song	Simple	
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
12/8		Compound	Hallelujah – Leonard Cohen
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



- 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 tempo change) in Beats Per Minute
- Dynamic markings are given below the scale and range from pianissimo (quietest) to fortissimo (loudest)
- Sometimes 8va is written above or below the staff
  - Written above the staff indicates to play the pitches one octave higher than written.
  - Written below the staff indicates to play the pitches one octave lower than written.
  - 15 ma is used in a similar fashion to indicate a difference of two octaves

### 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 ( ) means drop the pitch from the letter value by one half step
  - Sharp ( # ) indicates the raise the pitch by one half step
  - 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 2<sup>nd</sup> 3<sup>rd</sup> 6<sup>th</sup> and 7<sup>th</sup> are called major intervals

The 1<sup>st</sup> 4<sup>th</sup> 5<sup>th</sup> and octave are called perfect

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

#### Intervals

If flattened by one half step

The 2<sup>nd</sup> 3<sup>rd</sup> 6<sup>th</sup> and 7<sup>th</sup> are called minor
The 4<sup>th</sup> and 5<sup>th</sup> are called diminished

If raised by one half step

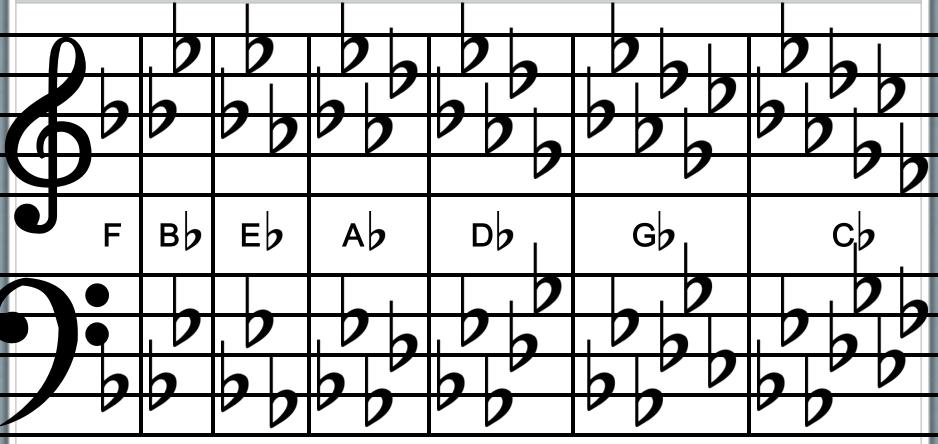
The 4<sup>th</sup> and 5<sup>th</sup> are called augmented

Number of half steps	Name	Note in C major
0	Union	С
1	Minor 2nd	D♭
3	Minor 3rd	Εþ
4	Diminished 4th	Fb
6	Diminished 5 <sup>th</sup> (Tri- tone)	G♭
8	Minor 6 <sup>th</sup>	ΑЬ
10	Minor 7th	ВЬ
12	Octave	С

# Key signatures

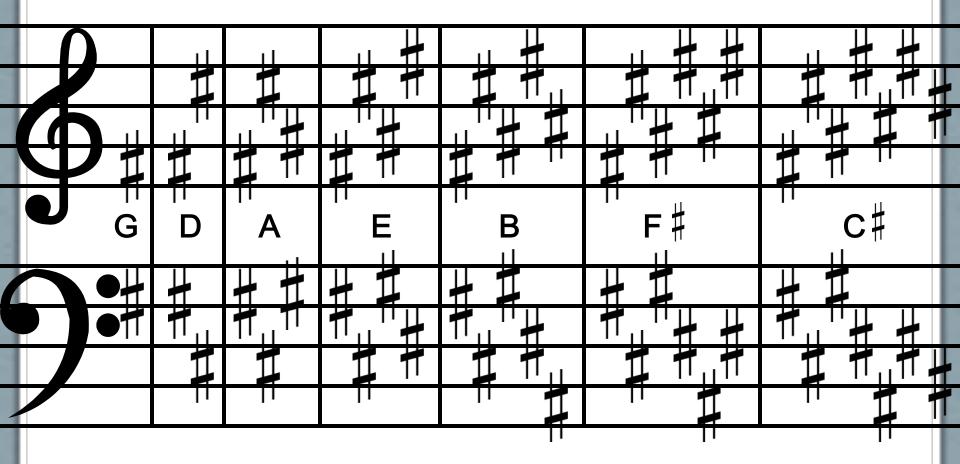
- Sometimes a note is supposed to always be played as sharp or flat
- These modifications are shown in the key signatures. These are shown as flats or sharps at the beginning of the piece or key change.
- There are only 15 given key signatures
  - No key signature combines sharps and flats
  - There 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

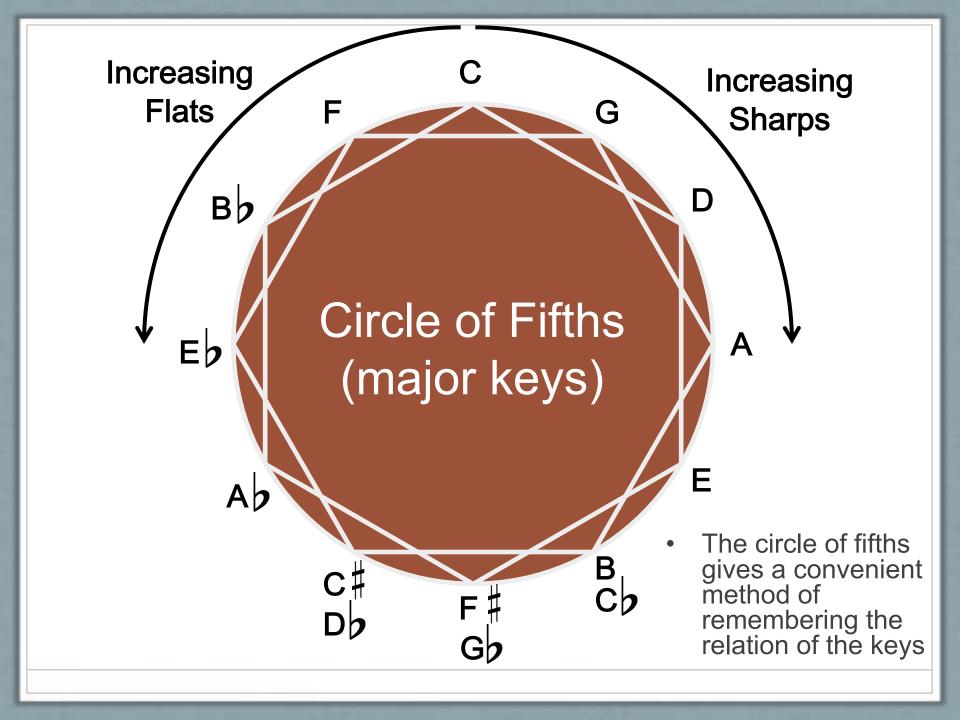


- The first flat major key is called F
- All subsequent major keys are named after the next to last flat added

# Sharp key signatures

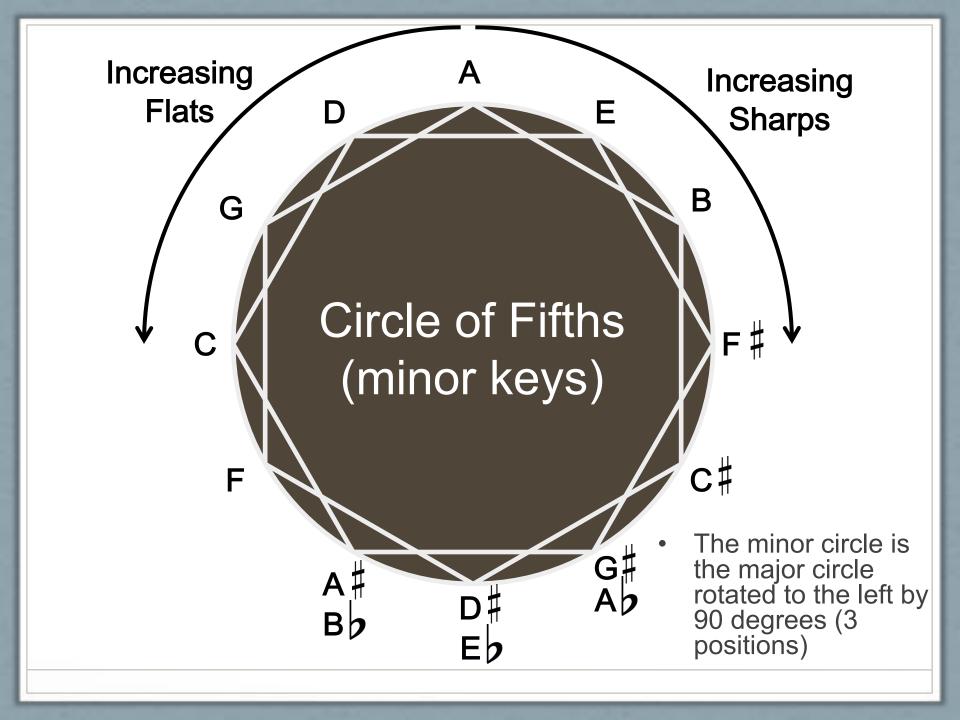


• Sharp major keys are named after the note just above the last sharp in the key signature



### **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 6<sup>th</sup> note in the major scale



### 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
    - 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# G
- The major scale is simply two tetra chords separated by a whole step. (interval pattern: whole whole half whole whole half)
  - In the major key of F, this translates to F G A B > 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 # G
  - In the major key of D, this translates to D E F # G A B C # 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 6<sup>th</sup> position). (interval pattern: whole half whole 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 EF# GABCDE
  - In the minor key of Bm, this translates to B C# D E F# G A B
- In addition to the Natural Minor Scale, there are two other minor scales
  - Harmonic Minor (natural minor with a raised 7<sup>th</sup>)
    - In the minor key of Dm, this translates to DEFGAB 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 EF#GABCD#E
    - In the minor key of Bm, this translates to B C# D E F# G# A
  - Melodic Minor (natural minor with a raised 6<sup>th</sup> & 7<sup>th</sup> when ascending and natural 6<sup>th</sup> and 7<sup>th</sup> 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 1<sup>st</sup> note (same as major scale)
    - CDEFGABC
    - No sharps or flats relative to the major scale with the same tonic
  - Dorian starting on 2<sup>nd</sup> note
    - DEFGABCD
    - Flat third and flat sixth relative to the major scale with the same tonic
  - Phrygian starting on 3<sup>rd</sup> note
    - EFGABCD
    - Flat second, flat third and flat sixth and flat seventh relative to the major scale with the same tonic
  - Lydian starting on 4<sup>th</sup> note
    - FGABCDEF
    - Augmented fifth relative to the major scale with the same tonic
  - Mixolydian start on 5<sup>th</sup> note
    - GABCDEFG
    - Flat 7th relative to the major scale with the same tonic
  - Aeolian start of 6<sup>th</sup> note (same as natural minor scale)
    - ABCDEFGA
    - Flat third, flat sixth and flat seventh relative to the major scale with the same tonic
  - Locrian start of 7<sup>th</sup> note
    - BCDEFGAB
    - 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 5<sup>th</sup> 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 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> 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 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> 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 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 2<sup>nd</sup> or the 4<sup>th</sup>)
- The suspended second chord is formed from the 1<sup>st</sup>, 2<sup>nd</sup> and 5<sup>th</sup> 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 1<sup>st</sup>, 4<sup>th</sup> and 5<sup>th</sup> notes of the minor scale
  - In the major key of F, this translates to F B<sub>b</sub> 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 7<sup>th</sup> chords. Named because they include the major or minor triad plus a 7<sup>th</sup> from the scale

- The Dominant 7<sup>th</sup> chord is formed from the 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> and flattened 7th notes of the major scale (quite common in Barbershop acapella)
  - In the major key of F, this translates to F A C E
  - In the major key of C this translates to C E G B b
  - In the major key of G, this translates to G B D F
  - In the major key of D, this translates to D F# A C
- The minor 7th is formed from the 1st, 3rd, 5th and 7th notes of the minor scale
  - In the major key of F, this translates to F A, C E
  - In the major key of C this translates to C E G Bb
  - In the major key of G, this translates to G B D F
  - In the major key of D, this translates to D F A C
- The major 7<sup>th</sup> chord is formed from the 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> and 7<sup>th</sup> notes of the major scale (it is less common than the Dominant 7<sup>th</sup> chord)

#### 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 3<sup>rd</sup>, dim 5<sup>th</sup>)
    - Augmented triads (1 3 aug 5<sup>th</sup>)
  - Adding 9ths and 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 7<sup>th</sup> 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, B dim7

# Harmony and Melody

- Lots of books about Harmony, almost none about Melody
- Tension and Release

# Chord Progressions

- 12 bar
- Turnaround
- Four magic chors
- Others

# Song Structure

- Verse / chorus / bridge
- AABA
- Self referential (Hallelujah)
- Lyrics / melody (Pinball Wizard / Folsom Prison)

#### Modulations

- A Modulation is a change of key
- It is typically executed to correspond with the lyrical theme of the music.
- Chords follow the same pattern.
  - Assume the pattern is I, IV V in C (C, F, G)
  - Modulating up to D, the new progression is D, G, A.
- Very popular in certain genres (acapella, barbershop)
- <a href="http://www.switchedonpop.com/44-how-beyonce-to-the-beatles-modulate-your-emotions/">http://www.switchedonpop.com/44-how-beyonce-to-the-beatles-modulate-your-emotions/</a>

Song	Artist	Modulation
Love Story	Taylor Swift	Up a whole step at the climax of the story
Already Gone	Eagles	Modulates up by a 4 <sup>th</sup> (that's a lot)
On Broadway	George Benson	Modulates up a ½ step every verse
Walk the Line	Johnny Cash	Each verse is a different Key (E, A, D, A, E (octave lower)

### 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
- <a href="https://www.ted.com/talks/bobby\_mcferrin\_hacks\_your\_brain\_with\_music">https://www.ted.com/talks/bobby\_mcferrin\_hacks\_your\_brain\_with\_music</a>
  - Best possible demonstration of the intrinsic nature of music
    - Who's on that panel?!?
- http://www.cuttime.com/symbol.htm
- <a href="http://en.wikipedia.org/wiki/List of works in unusual time signatures">http://en.wikipedia.org/wiki/List of works in unusual time signatures</a>
- http://www.worldsciencefestival.com/video/notes-neurons-full
- https://books.google.com/books?id=LeriAwAAQBAJ&pg=PA91&lpg=PA91&dq=%22on+broadway%22+george+benson+modulation&source=bl&ots=DjnFAClKOa&sig=NBu1GUh1L0o9lhRz2AY12wHujuk&h1=en&sa=X&ved=0ahUKEwjPqdS97Z\_WAhVK1lQKHU3BBZMQ6AEINzAD#v=onepage&q=%22on%20broadway%22%20george%20benson%20modulation&f=false
  - Discussion of Progressions and modulation
- https://books.google.com/books?id=Ou9oAgAAQBAJ&pg=PA7-IA44&lpg=PA7-IA44&dq=%22on+broadway%22+george+benson+modulation&source=bl&ots=YGfKAhYThj&sig=tfm31OfjTDVMJIzxYK91Yrlckd8&hl=en&sa=X&ved=0ahUKEwjPqdS97Z\_WAhVKllQKHU3BBZMQ6AEIOjAE#v=onepage&q=%22on%20broadway%22%20george%20benson%20modulation&f=false
  - Nice overview of using technology to enhance the art