ABC Player Final Design

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To see our ABC Player in action, try running Main.java in the player package. You can change the String contents of Main.play() in the main file to try playing any piece listed in the sample_abc directory (e.g. Main.play("sample_abc/**nyannn.abc**");)

Contents

Our document contains the follow information. Bolded typeface indicates updated sections.

Summary of Design Changes

The major change in our design was that we 'split' the Parser's functionality into three levels. The top level parser, parseHeader, processes the header and deals with in-body Voice changes in the given piece data. When it sees a Token corresponding to the music of the ABC line, it calls the mid level parser, parseMeasureStructure. parseMeasureStructure parses the contents of the ABC line into measures, creating new Measures when it sees barlines, and links Measures appropriately according to repeats and alternate endings. When it encounters 'playable' elements such as notes (accidentals and basenotes) and rests, it calls the lowest level parser, parseMeasureContents. parseMeasureContents parses the objects in a single Measure, and stops when it sees the end of the Measure.

To help us parse playable elements, we have the parseNoteElement general parser for notes and rests. It parses notes and rests with their appropriate duration, and accidentals for notes, using helper methods, such as parseAccidentals and parseOctaves. It also treats rests as notes with a null pitch. We add the 'notes' parsed from parseNoteElement to our current Measure in parseMeasureContents.

Another large change occurred in our design of Voice. Our overall musical data structure consisted of a Piece which had mutliple Voice objects, each of which was immutable. We decided to allow Voice objects to be mutable to make parsing more manageable. This way, it would be easy to simply initialize the Voice objects when defined in the abc file header and later add measures when parsing the abc file.

In our final design, several helper classes became integral to the project's functionality. One of which, Fraction, allowed us to easily calculate the proper duration of a note, store the meter of a piece, or measure the total running length of a measure. It also allowed us to easily make calculations for SequencePlayer's numberOfTicksPerQuarterNote, by finding the shortest note durations and calculating the maximum possible divisions per quarter note.

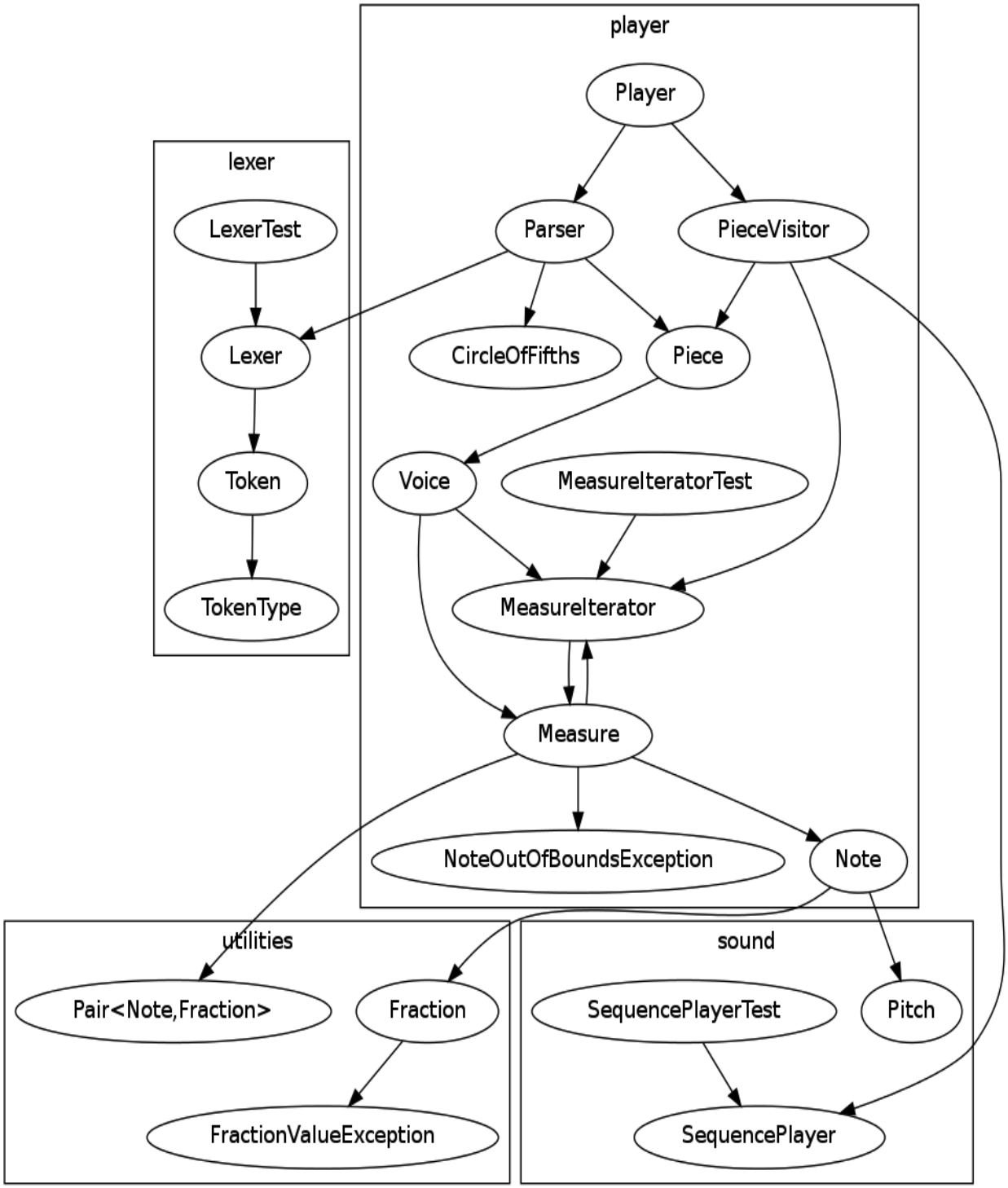
Another important class was the CircleOfFifths, which allowed us to apply key signature changes to notes throughout an entire piece.

While we were working on our ABC player, we found various edge case situations and had to make design decisions about how to deal with them. The following are some decisions that we had to make:

-If a voice is declared in the header and the body of the music attempts to list a line of music that is not attributed to any named voice, we will throw an exception. This is because we believe that the author has made a mistake with their file and forgot to name the voice.
-If a measure is too short, we will not throw an exception, because it may be the initial pickup measure into a piece, which is intentionally front padded with rests. We do, however, throw exceptions for measures that are too long.

1. Dependency Diagram

The following dependency diagram describes all of the classes that will be included in the ABC music player. The boxes represent classes, which form common functionalities.



2. Design Flow

Lexing

TokenType objects describe the type of tokens that can be made (i.e. note or accidental tokens) while Token objects represent the different kinds of tokens that are lexed from the .abc file contents.

A Lexer object is created with a list of TokenTypes representing the kinds of tokens that it can lex. It accepts the .abc text input and returns a list of valid tokens or throws an exception if invalid tokens are found.

Parsing

The Parser object uses the Lexer object to get the tokenized version of the music file and creates a Piece object, which is our representation of the .abc input.

The Parser will use recursive descent parsing. It will look ahead in the list of tokens and determine from the token types which production to use. For example, when encountering a field header token “T:”, the parser will recognize that this and the text tokens before a line break and know that this represents a field-title as described in the grammar. In terms of parsing the musical body, the parser will look for an element token (i.e. a note-element, tuple-element, etc.) and parse the following tokens before the line break as a abc-line.

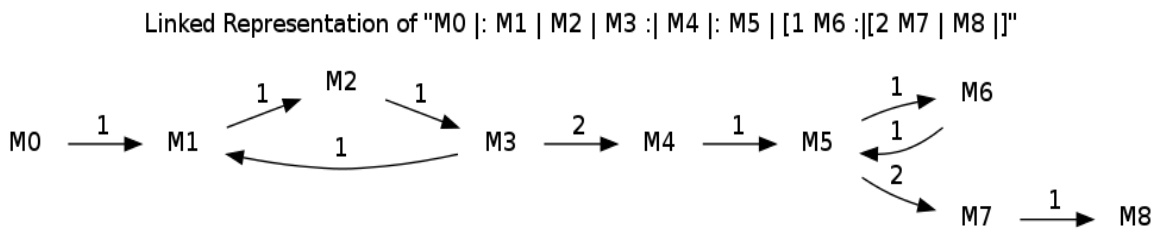
The Parser will track and throw errors when encountering invalid measure durations (too long or too short), incorrect repeat braces, musically incorrect accidental stacking, invalid tuplets (length-wise), and invalid beat times (negatives, decimals, and the Fraction class should ensure there are no divide by 0s). It will catch these errors through the nature of recursive descent parsing; for example, opening and closing repeat braces are expected to match correctly in number, and the parser will throw an exception if there are no more tokens to parse when there is an unclosed repeat brace, or if there is an matching closing brace. Invalid lengths of measures will be caught by keeping a running total of the measure length that is being created and throwing an exception when extra beats are added.

Creating a Piece

The Piece is our musical representation data type, which is created as the parser parses the .abc input tokens. It contains fields, which describe the piece data as described in the .abc file headers, such as tempo, default length of a note, and meter. The Piece object contains references to the different voices in the piece.

A voice object represents the musical lines that belong to one voice in the abc file. It contains a reference to a “linked list” of Measure objects that belong to that voice by keeping a pointer to the first measure of the voice.

Each Measure is a container of Note instances, each Note being associated with a start time, represented by a Fraction, relative the beginning of the measure. Measures are structured like nodes in a linked list, with pointers to subsequent measures. They can have multiple pointers if the measure is the end of a repeat or part of a multiple ending sequence (see below)



Therefore, the same Measure object can represent both of its instantiations in a repeat.

Transformation into a Playable Sequence

Given a Piece object, we have a Visitor traverse through the Voices (e.g. the linked lists of Measures), and in accordance to the rules of transcription, transcribe MIDI-format playable music for the sequence player.

The Visitor will traverse each Voice in a given piece, and traverse the linked list of Measures in each voice. In transcribing the notes in a measure, Visitor will track global time in order to correctly time each note in the piece especially given that there may be multiple voicings and that Note objects in a measure only have descriptors of their relative times in each given measure.

MeasureIterator is an Iterator which helps the Visitor accurately navigate through the 'linked list of Measures'.

In the case of multiple endings, if the Visitor has seen a specific measure before (measured by reference NOT value, as two different measures may contain the same musical content), it will follow the second pointer to the next measure rather than the first pointer.

3. List of Classes and Data types

The following list shows all the classes that will be implemented for the ABC music player. They are grouped by functionality as shown by the boxes in the above dependency diagram. For the data type classes that describe the music

Lexer Classes

```
public class Lexer {
        private final List<TokenType> types;
        public Lexer(List<TokenType> types)
        //Lexes the passed string into Tokens, returns a list of tokens
        public List<Token> lex(String input) throws RuntimeException
}

public class Token {
        public final TokenType type;
        public final String contents;
        public Token(String contents, TokenType type)
        public String toString()
```

```
}

public class TokenType {
        public final String name;
        public final Pattern pattern;
        public TokenType(String name, Pattern pattern)
}

public class LexerTest {
        //Test file
}
```

Player Classes

Main

```
private static String readFile(String pathname) throws IOException
//Opens a file and returns its contents.
private static void play(String file) throws Exception
//Plays the input file using Java MIDI API and displays header information to the standard output stream.
private static void play(String file) throws Exception
//Main method for playing abc files.
```

Player

```
private Piece piece
public Player(String abcContents) throws RuntimeException, NoteOutOfBoundsException
public void play() throws Exception
//Play this.piece.
```

Parser

```
public class Parser {
public static TokenType[] typeArray = {//Various TokenTypes}

public static List<TokenType> types = new ArrayList<TokenType>(
                Arrays.asList(typeArray))
//List of TokenTypes
public static HashMap<Pitch, Pitch> accidentalChanges
//HashMap keeps track of accidentals in a certain Measure
public static Piece parse(String abcContents) throws NoteOutOfBoundsException
//Overall parser; calls Lexer for Tokens which it passes to top-level parseTokens subparser
public static Piece parseTokens( List<Token> tokens ) throws NoteOutOfBoundsException
//Top-level subparser; parses the piece's header and in-body voices; calls parseMeasureStructure
public static void parseMeasureStructure(Piece piece, Measure currentMeasure,
                ListIterator<Token> iter, Stack<Measure> openRepeatStack, Measure lastPreOne )
//Mid-level subparser; parses the ABC lines of a piece; calls parseMeasureContents for musical playables, and
jumps back to the parseTokens when it sees a Voice declaration
public static void parseMeasureContents(Piece piece, Measure measure, ListIterator<Token> iter,
HashMap<String, Pitch> scale) throws NoteOutOfBoundsException
```

```
//Bottom-level subparser; parses the musical playable objects in a measure; calls parseNoteElement to parse
individual musical playables, and jumps back to the parseTokens when it sees a Voice declaration
public static Note parseNoteElement(Piece piece,
                    ListIterator<Token> iter, HashMap<String, Pitch> scale, Fraction modifier)
//Helper subparser; parses a musical playable such as a note or a rest.  Treats rests as notes with pitch = null.
public static Pair<Pitch,Pitch> parseAccidental(Token next, ListIterator<Token> iter,HashMap<String, Pitch> scale)
//Determines correct pitch of a note with accidentals and key signature all factored in.
public static Pitch parseBasenote(Token next, int accidental, HashMap<String, Pitch> scale)
//Helper subparser; parses a base note
public static Pitch parseOctave(Token next, Pitch p)
//Helper subparser; parses octave notation
public static Fraction parseNoteLength(Token next)
//Helper subparser; parses note lengths
public static Token eatSpaces(ListIterator<Token> iter)
//Pass over SPACE Token
public static boolean eatNewLine(ListIterator<Token> iter)
//Pass over NEWLINE Token
public static Fraction parseFraction(String frac)
//Parses a FRACTION token and returns a Fraction representation
public static Fraction parseFractionNotStrict(String frac)
//Parses a FRACTION_NOT_STRICT token and returns a Fraction representation
public static String parseHeaderKey(ListIterator<Token> iter)
//Get additional key signature information



}
public class ParserTest {
        //Test file
}

// Custom exception for handling notes which when added would make a measure too long.
public class NoteOutOfBoundsException extends RuntimeException {
        public NoteOutOfBoundsException(String message)
}
```

Musical Data Type

MUTABLE

```
public class Piece {

        private String title;
        //The title of the piece.
        private String composer;
        //The composer of the piece.
        private int trackNumber;
        //Track Number of the piece.
        private Fraction defaultNoteLength;
        //Default length or duration of a note.
        private Fraction meter;
        //It determines the sum of the durations of all notes within a complete measure
```

```
        private int tempo;
        // The number of default-length notes per minute.
        private String key;
        //Determines the key signature for the piece.
        private List<Voice> voices;
        //The List of all the starting measures for each voice.
        private Fraction smallestDivision;
        //The (largest, ideally) smallest division needed such that the length of each note (and rest) is an integer
multiple.
        public Fraction getMeter()
        // get the meter for the piece

        public void setMeter(Fraction meter)
        // set the meter for the piece
        public int getTempo()
        // get the tempo for the piece
        public void setTempo(int tempo)
        // set the tempo for the piece
        public Fraction getSmallestDivision()
        // get the smallest note division for the piece
        public void getKey()
        // get the key signature of this piece
        public void setKey(String key)
        // set the key signature of this piece
        public String getTitle()
        // get the title for the piece
        public void setTitle(String title)
        // set the title for the piece
        public String getComposer()
        // get the composer for the piece
        public void setComposer(String composer)
        // set the composer for the piece
        public int getTrackNumber()
        // get the track number for the piece
        public void setTrackNumber(int trackNumber)
        // set the track number for the piece
        public Fraction getDefaultNoteLength()
        // get the default note length for the piece
        public void setDefaultNoteLength(Fraction defaultNoteLength)
        // set the default note length for the piece
        public List<Voice> getVoices()
        // get the list of voices in the piece
        public void setVoices(List<Voice> voices)
        // set the list of voices in the piece
        public void addVoice(Voice voice)
        // add a voice to this piece
        public Voice getVoice(String name)
        // return a voice with this name if in the piece; return null if not found

}
```

MUTABLE

```
public class Voice implements Iterable<Measure> {
        public final String name;
        private Measure firstMeasure;
        public Voice(String name, Measure firstMeasure)
        //Set the first measure in this voice.
        public void setStart(Measure firstMeasure)
        //Returns the first measure in this voice.
        public Measure getStart()
        //Returns an iterator to traverse all the measures in this voice, starting with the first.
        public Iterator<Measure> iterator()
        //Returns the last measure in this voice so far.
        public Measure tail()
        //Gets the smallest division note in this voice.
        public Fraction getSmallestDivision()


}
```

MUTABLE (contains methods to changing the measure's pointers to other measures and adding or modifying what notes are in the method)

```
public class Measure implements Iterable<Measure> {

        private final Fraction duration;
        //Duration of the measure.
        public Fraction getDuration()
        //Get the duration of the measure.
        private List<Pair<Note, Fraction>> notes;
        //A list of notes, each associated with their start times
        private Measure next;
        //The typical next measure in the larger piece.
        private Measure alternateNext = null;
        // An alternate next measure, e.g. the escape from a repeat.

        public Measure(Measure next, Measure alternateNext,List<Pair<Note, Fraction>>notes) throws
NoteOutOfBoundsException
        //Full constructor for Measure
        public Measure(Measure next, Measure alternateNext)
        //Constructor with a list of empty notes
        public Measure(Measure next)
        //Constructs measure only based off the next Measure
        public Measure()
        //Default constructor
        public Iterator<Measure> iterator()
        //Returns an iterator which will start with this measure, and continue until the end of the piece is reached.
        public Measure getNext()
        //Getter for this.next
        public void setNext(Measure next)
        //Setter for this.next
```

```
        public Measure getAlternateNext()
        //Getter for this.alternateNext
        public void setAlternateNext(Measure alternateNext)
        //Setter for this.alternateNext
        public List<Pair<Note, Fraction>> getNotes()
        //Getter for this.notes
        public void addNote(Note note, Fraction startTime ) throws NoteOutOfBoundsException
        // Safe method to add a note to this measure.  A note with pitch=null is a rest, and is not really 'added'.
        public Fraction getSmallestDivision()
        // Finds the smallest division note in this Measure

}

IMMUTABLE
public class Note {
        public final Fraction duration;
        public final Pitch pitch;
        public Note(Fraction duration, Pitch pitch)
        public Fraction getDuration()

}

IMMUTABLE
public class CircleOfFifths {
        //return a HashMap of the scale for the given key with the approrpriate key signature
        public static HashMap<String, Pitch> getKeySignature(String key)
}
```

Visitor

```
public class PieceVisitor {
        // Processes a Piece to play
        public static SequencePlayer process(Piece piece)
                        throws MidiUnavailableException, InvalidMidiDataException

        // Convert time (in fractional length) to ticks
        private static int fractionToTicks(Fraction time, Fraction divisionLength)

}

public class MeasureIterator implements Iterator<Measure> {
        //The measure we are currently initialized with.
        // get the key for the piece
        public String getKey()
        // set the key for the piece
        public void setKey(String key)
        // get the title for the piece
        public String getTitle()
        // set the title for the piece
        public void setTitle(String title)
        // get the composer name for the piece
```

```
        public String getComposer()
        // set the composer name for the piece
        public void setComposer(String composer)
        // get the track number for the piece
        public int getTrackNumber()
        // set the track number for the piece
        public void setTrackNumber(int trackNumber)
        // get the default note length for the piece
        public Fraction getDefaultNoteLength()
        // set the default note length for the piece
        public void setDefaultNoteLength(Fraction defaultNoteLength)
        // get the voices of this Piece
        public List<Voice> getVoices()
        // set the voices of this Piece
        public void setVoices(List<Voice> voices)

}
```

Utilities

```
//Represenation of a fraction, useful for calculating the duration of a note and ensuring //that measures contain the correct length of notes
public class Fraction {
        public final int numerator;
        public final int denominator;
        public Fraction(int value)
        public Fraction(int numerator, int denominator)

        // Finds gcd of two integers
        public static int gcd(int first, int second)
        // Finds gcd of two Fractions; used to calculate smallestDivision in Piece
        public static Fraction gcd(Fraction first, Fraction second)
        // Finds lcm of two integers
        public static int lcm(int first, int second)
        // Returns true if this Fraction is nonnegative
        public boolean isPositive()
        // Finds sum of this plus a Fraction
        public Fraction plus(Fraction other)
        // Finds sum of this plus an int
        public Fraction plus(int other)
        // Finds difference of this and a Fraction
        public Fraction minus(Fraction other)
        // Finds difference of this and an int
        public Fraction minus(int other)
        // Finds product of this and a Fraction
        public Fraction times(Fraction other)
        // Finds product of this and an int
        public Fraction times(int other)
        // Finds quotient of this and a Fraction
        public Fraction quotient(Fraction other)
```

```
        // Finds quotient of this and an int
        public Fraction quotient(int other)
        // Finds the inverse of this
        public Fraction inverse() throws FractionValueException
        // Finds float approximation of this
        public float approximation()
        // Finds hash of this
        public int hashCode()
        // Equals method for Fraction class
        public boolean equals(Object other)
        // Express this Fraction as a String
        public String toString()
}

// Custom exception for handling errors dealing with fractions
public class FractionValueException extends IllegalArgumentException {
        public FractionValueException(String message)
}

//Class representing a Pair of generic types
public class Pair<First, Second> {
        public First first;
        public Second second;
        public Pair(First first, Second second)
        // Finds hash of this
        public int hashCode()
        // Equals method for Pair objects.
        public boolean equals(Object other)
}
```

4. Testing

The modularity of our design allows that each major class can be tested. We would like to test the following classes for specific details as follows:

1. Lexer can separate every kind of token, throws exception of invalid tokens, and correctly handles null input.

2. Parser throws exceptions for all errors; correctly parses Measures with both basic notes and more complex tokens (chords, tuples); correctly creates nested repeat structures and multiple endings.

3. Visitor ensures global timekeeping is working and correctly translates to MIDI notes; correctly calculates a ’base’ tick/quarter note from the different beat divisions; correctly traverses through repeats and alternate endings; and ensures that errors thrown in Lexer/Parser also stop its actions.

In addition to testing individual modules, we must test the entire system as a whole using integration tests, to make sure that the components interface correctly with each other.

Testing Strategies

The following is a description of the strategies used to test several of our major test classes. We also have several other test suites, included in their respective file's packages.

FractionTest

* -Comprehensive tests that check each method and constructor
* -Test using the blackbox strategy, not knowing the implementation
* -Check that exceptions are thrown when expected
* Individual component strategies are explained

CircleOfFifthsTests

* Test using the whitebox testing method, knowing the implementation of the class
* -Test each kind of keynote in every category
* (e.g. Major sharps, minor sharps, Major flats, minor flats)
* -Test the keys with all seven accidentals
* -Test keys that have no accidentals
* -Test capitalization and differentiation between major and minor parameters

LexerTest

* -Comprehensive tests that check each general type of Token that Lexer could encounter
* -Check that newlines and spaces are correctly differentiated
* -Check that single and double barlines are correctly recognized
* -Check that exceptions are thrown when expected (null input, non-token input)
* Individual component strategies are explained

ParserTest

*Tests integration between Lexer and Parser; for details on the files used, see Integration Test section below
* Incrementally test different pieces of the parser from bottom up ensuring that helper functions are functional before testing the larger functions.
* Test that major parsing problems throw exceptions, such as missing header fields, or basenotes
* Test suite includes the following (tests may be listed in an arbitrary order):
* -Fraction parsing tests
* -Note parsing tests (accidental changes, octaves, duration)
* -Note element parsing tests (chords, duplets, tuplets, quadruplets, rests)
* -Measure parsing tests (length of measure, accidental changes)
* -Header checks
* -Repeat measure structure

Integration Tests

*Played abc test files from Main.java to ensure that Lexer, Parser, and PieceVisitor work in conjunction.
*Other than the sample test files that were given by the staff (which covered basic notes and measure structures, along with pickups, repeats and multiple endings), we added the following abc files:
alleluia.abc: a basic test, with repeats (open and close); close repeat will go to beginning of the piece or the last double barline if there was no open repeat
finalfantasy.abc: a test with many, many measures and note elements to parse; this ensures the robustness of our Parser.

minuet.abc: a test including interleaving of voices.
nyannn.abc: a test which tests nesting of repeats.