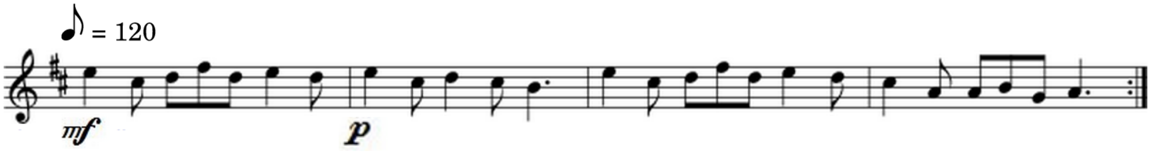
15-323/15-623 Spring 2019
Practice Midterm Exam

1. **Music Theory**



This is a fraction of the piece of music “Donald, Willie and His Dog”. Please answer the following questions based on this fraction of the score.

1.1. What is the key signature?

1.2. What is the time signature?

1.3. How many measures are notated in the score?

1.4. How many measures are played in a full performance of this score (including repeats)?

1.5. How long does it take to perform a measure by strictly following the score’s tempo?

1.6. Translate the first two measures of the score[1] into a Serpent note list representation: Use an array of notes where each note is represented by an array of the form [*time, duration, pitch, velocity*], where

- *time* and *duration* are in seconds (floating point),
- *pitch* is a MIDI key number (integer), and
- *velocity* is a MIDI velocity number (integer).

[1] Note that there is useful information on the last pages of this exam.

2. MIDI (Please consult tables on the last pages of this exam)

2.1. Write MIDI messages (in hexadecimal or binary) for the following actions:

2.1.1. Select an oboe sound on channel 3 (numbered from zero; the first channel would be channel 0). Assume General MIDI.

2.1.2. Start an F below middle-C with maximum velocity.

2.1.3. Change the modulation wheel to 50_{10} using a control change message.

2.1.4. Turn the note off using a note-on (key-down) message.

2.2. How does a synthesizer "know" what time to paly a note when it receives a note-on message?

2.3. How many channels does MIDI support?

2.4. For the score in question 1, assume that the 1st measure is played by a trumpet and the 2nd measure is played by a Bassoon. Write down the MIDI messages for the first two notes of the first two measures (four notes in total) with time stamps. (If consecutive timestamps are equal, we will assume the messages are sent as quickly as possible in the given order.)
A possible (wrong) answer could look like the following (use of hex or decimal or mixed is your choice):

- t=0 : **0x90 - 0x40 - 0x40**
- t=1 : **0x80 - 0x43 - 0x00**

2.5. Name two kinds of information that can be represented in MIDI but not in Common Practice Music Notation.

2.6. Name two kinds of information that can be represented using Common Practice Music Notation but not in MIDI.

3. **Algorithmic Composition**

3.1. Using the pitch sequence of the score for question 1, estimate the transition probabilities from pitch D using a first-order Markov model. You should write just the pitch and probability for each non-zero probability transition from D.

3.2. Here is a trie with counts for pitch sequences represented

```
A(12) A(5) B(5) C(5) A(5)
      B(8) A(5) A(5) B(5)
           C(3) A(3) B(3)
      C(2) A(2) C(2) B(2)
B(11) A(5) A(3) B(3) C(3)
      B(2) C(2) A(2) C(2)
      C(4) A(3) C(3) B(3)
           B(1) B(1) B(1)
C(7)  A(6) C(3) B(3) A(2)
                     B(1)
           B(3) A(3) A(3)
      B(1) B(1) B(1) A(1)
```

Given a sequence A B C A B, and using a 1st order Markov model to generate a continuation to this sequence,

3.2.1. What does the next state (pitch) depend upon?

3.2.2. What are the estimated probabilities of each next state?

3.2.3. Now, assume a 2nd order Markov model. What does the next state (pitch) depend upon?

3.2.4. What are the estimated probabilities of each next state using a 2nd order model?

3.2.5. Now, assume a 3rd order Markov model. What does the next state (pitch) depend upon?

3.2.6. What are the estimated probabilities of each next state using a 3rd order model?

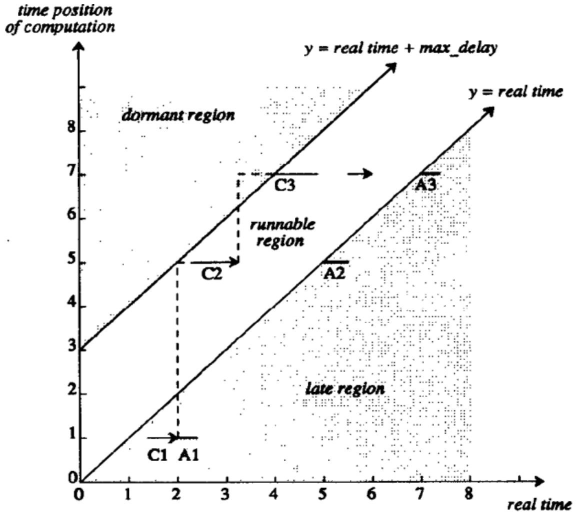
3.3. Here is a random sequence of pitch classes:

```
7 8 5 6 1 2 0 3 9 11 10 4
```

Modify these pitch class numbers by subtracting one (mod 12) as necessary so that all pitch classes will be members of the G-Major scale.

4. **Scheduling**

In the Timing in FORMULA graph (Figure 6 of Anderson and Kuivila and included below), we see three scheduled and executed events. Show your understanding of this important graph by answering the following questions:



4.1. Which event is executed on time? Why?

4.2. If the time position of computation (the ideal time) of the third event was 6 rather than 7, what would the graph look like? You can describe time points in Cartesian coordinates, e.g. (4, 6) would be real time = 4, time position of computation = 6.

4.3. Write a Serpent function named `start()` to call `play_note()` every 0.5 seconds until `stop()` is called. Assume that `rtsched` is defined and that `rtsched.poll()` is called periodically.

5. **Open Sound Control**

5.1. Assume that you are using Open Sound Control to control a four-voice synthesizer. The voices have a pitch bend parameter addressed as `/voice/`*`n`*`/pitchbend`, where *`n`* is `1`, `2`, `3`, or `4`. Write an Open Sound Control address string you could use if you wanted to set *all* pitch bend parameters to 20.

5.2. What mechanism does Open Sound Control provide for setting parameters simultaneously?

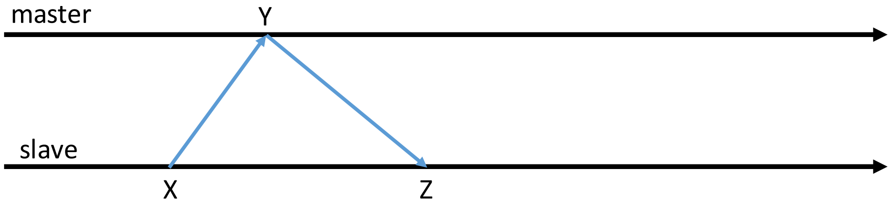
6. **Standard MIDI Files**

6.1. The <division> field of a SMF header has two formats, one for metrical time, and one for time-code-based time. What does this mean?

6.2. How are times encoded in SMF?

6.3. Write a MIDI Track Chunk to play the first measure of the score from problem 1. You may assume the chunk type, length, and footer are already written, that both the score and synthesizer are set with a tempo of 120 BPM, and that there are 16 ticks per quarter-note. If you do not know the actual bit-level representation (worth 10% of this problem), give your answer schematically with as much detail as you know.

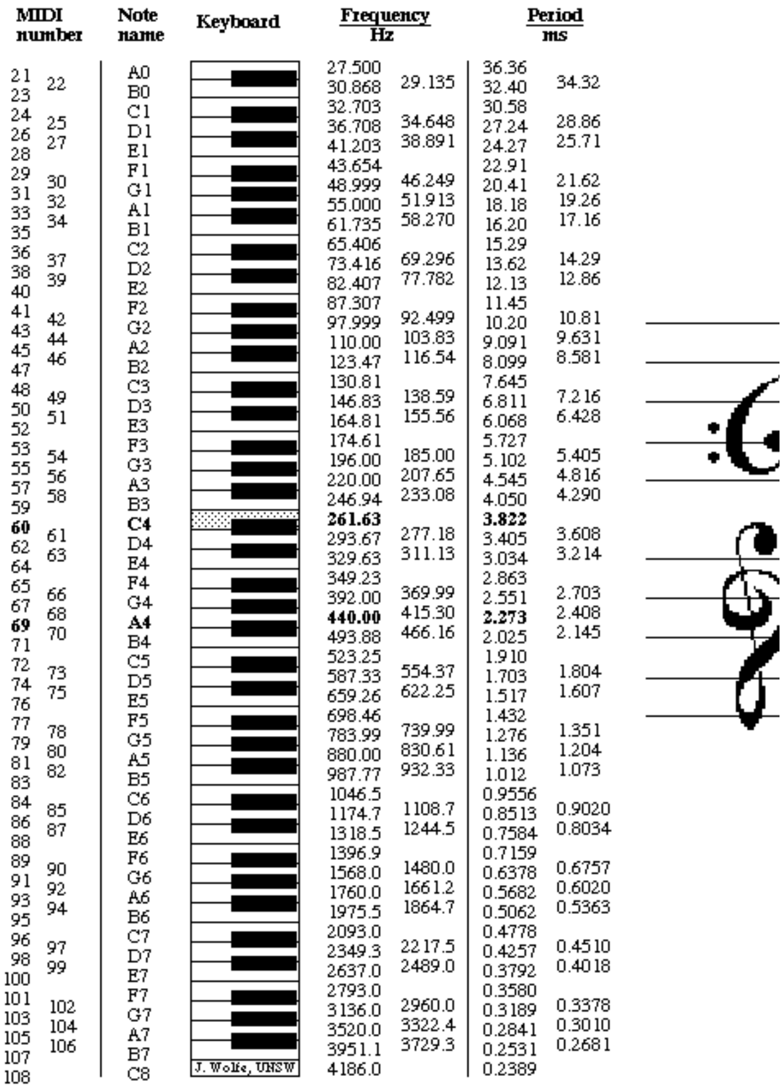
7. Clock Synchronization



7.1 Given the above diagram, what should the slave conclude the time at the master is at time z?

7.3 To improve accuracy, the slave sends 10 messages to read the Master clock knowing that some round-trip messages will be delayed. How should the slave combine the results of the 10 readings to get the best estimate of the Master's clock time? (You can assume that the 10 round trip messages all happened recently and clock drift is negligible.)

Useful Constants



MIDI number		Note name	Frequency Hz		Period ms	
21		A0	27.500		36.36	
	22			29.135		34.32
23		B0	30.868		32.40	
24		C1	32.703		30.58	
	25			34.648		28.86
26		D1	36.708		27.24	
	27			38.891		25.71
28		E1	41.203		24.27	
29		F1	43.654		22.91	
	30			46.249		21.62
31		G1	48.999		20.41	
	32			51.913		19.26
33		A1	55.000		18.18	
	34			58.270		17.16
35		B1	61.735		16.20	
36		C2	65.406		15.29	
	37			69.296		14.29
38		D2	73.416		13.62	
	39			77.782		12.86
40		E2	82.407		12.13	
41		F2	87.307		11.45	
	42			92.499		10.81
43		G2	97.999		10.20	
	44			103.83		9.631
45		A2	110.00		9.091	
	46			116.54		8.581
47		B2	123.47		8.099	
48		C3	130.81		7.645	
	49			138.59		7.216
50		D3	146.83		6.811	
	51			155.56		6.428
52		E3	164.81		6.068	
53		F3	174.61		5.727	
	54			185.00		5.405
55		G3	196.00		5.102	
	56			207.65		4.816
57		A3	220.00		4.545	
	58			233.08		4.290
59		B3	246.94		4.050	
60		**C4**	**261.63**		**3.822**	
	61			277.18		3.608
62		D4	293.67		3.405	
	63			311.13		3.214
64		E4	329.63		3.034	
65		F4	349.23		2.863	
	66			369.99		2.703
67		G4	392.00		2.551	
	68			415.30		2.408
69		**A4**	**440.00**		**2.273**	
	70			466.16		2.145
71		B4	493.88		2.025	
72		C5	523.25		1.910	
	73			554.37		1.804
74		D5	587.33		1.703	
	75			622.25		1.607
76		E5	659.26		1.517	
77		F5	698.46		1.432	
	78			739.99		1.351
79		G5	783.99		1.276	
	80			830.61		1.204
81		A5	880.00		1.136	
	82			932.33		1.073
83		B5	987.77		1.012	
84		C6	1046.5		0.9556	
	85			1108.7		0.9020
86		D6	1174.7		0.8513	
	87			1244.5		0.8034
88		E6	1318.5		0.7584	
89		F6	1396.9		0.7159	
	90			1480.0		0.6757
91		G6	1568.0		0.6378	
	92			1661.2		0.6020
93		A6	1760.0		0.5682	
	94			1864.7		0.5363
95		B6	1975.5		0.5062	
96		C7	2093.0		0.4778	
	97			2217.5		0.4510
98		D7	2349.3		0.4257	
	99			2489.0		0.4018
100		E7	2637.0		0.3792	
101		F7	2793.0		0.3580	
	102			2960.0		0.3378
103		G7	3136.0		0.3189	
	104			3322.4		0.3010
105		A7	3520.0		0.2841	
	106			3729.3		0.2681
107		B7	3951.1		0.2531	
108		C8	4186.0		0.2389	

Midi Program Numbers

Ensemble

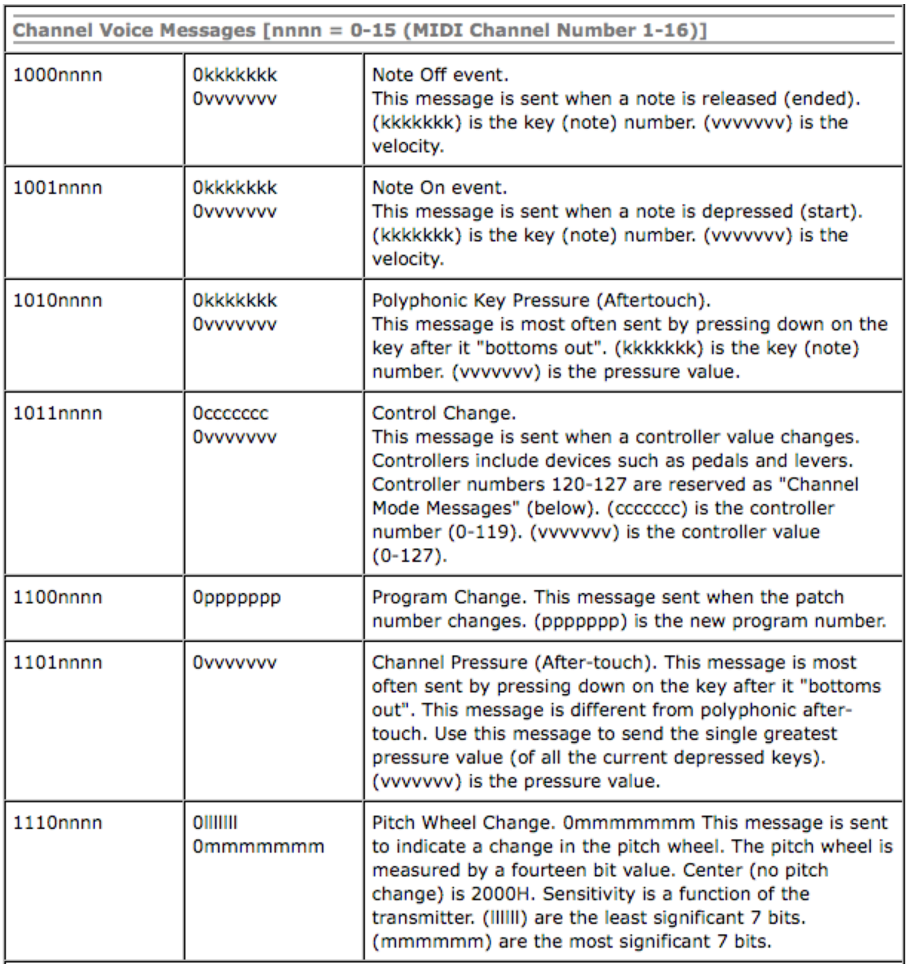
- 49 String Ensemble 1
- 50 String Ensemble 2
- 51 Synth Strings 1
- 52 Synth Strings 2
- 53 Choir Aahs
- 54 Voice Oohs
- 55 Synth Choir
- 56 Orchestra Hit

Brass

- 57 Trumpet
- 58 Trombone
- 59 Tuba
- 60 Muted Trumpet
- 61 French Horn
- 62 Brass Section
- 63 Synth Brass 1
- 64 Synth Brass 2

Reed

- 65 Soprano Sax
- 66 Alto Sax
- 67 Tenor Sax
- 68 Baritone Sax
- 69 Oboe
- 70 English Horn
- 71 Bassoon
- 72 Clarinet



Channel Voice Messages [nnnn = 0-15 (MIDI Channel Number 1-16)]		
1000nnnn	0kkkkkkk 0vvvvvvv	Note Off event. This message is sent when a note is released (ended). (kkkkkkk) is the key (note) number. (vvvvvvv) is the velocity.
1001nnnn	0kkkkkkk 0vvvvvvv	Note On event. This message is sent when a note is depressed (start). (kkkkkkk) is the key (note) number. (vvvvvvv) is the velocity.
1010nnnn	0kkkkkkk 0vvvvvvv	Polyphonic Key Pressure (Aftertouch). This message is most often sent by pressing down on the key after it "bottoms out". (kkkkkkk) is the key (note) number. (vvvvvvv) is the pressure value.
1011nnnn	0ccccccc 0vvvvvvv	Control Change. This message is sent when a controller value changes. Controllers include devices such as pedals and levers. Controller numbers 120-127 are reserved as "Channel Mode Messages" (below). (ccccccc) is the controller number (0-119). (vvvvvvv) is the controller value (0-127).
1100nnnn	0ppppppp	Program Change. This message sent when the patch number changes. (ppppppp) is the new program number.
1101nnnn	0vvvvvvv	Channel Pressure (After-touch). This message is most often sent by pressing down on the key after it "bottoms out". This message is different from polyphonic after-touch. Use this message to send the single greatest pressure value (of all the current depressed keys). (vvvvvvv) is the pressure value.
1110nnnn	0lllllll 0mmmmmmm	Pitch Wheel Change. 0mmmmmmm This message is sent to indicate a change in the pitch wheel. The pitch wheel is measured by a fourteen bit value. Center (no pitch change) is 2000H. Sensitivity is a function of the transmitter. (llllll) are the least significant 7 bits. (mmmmmm) are the most significant 7 bits.

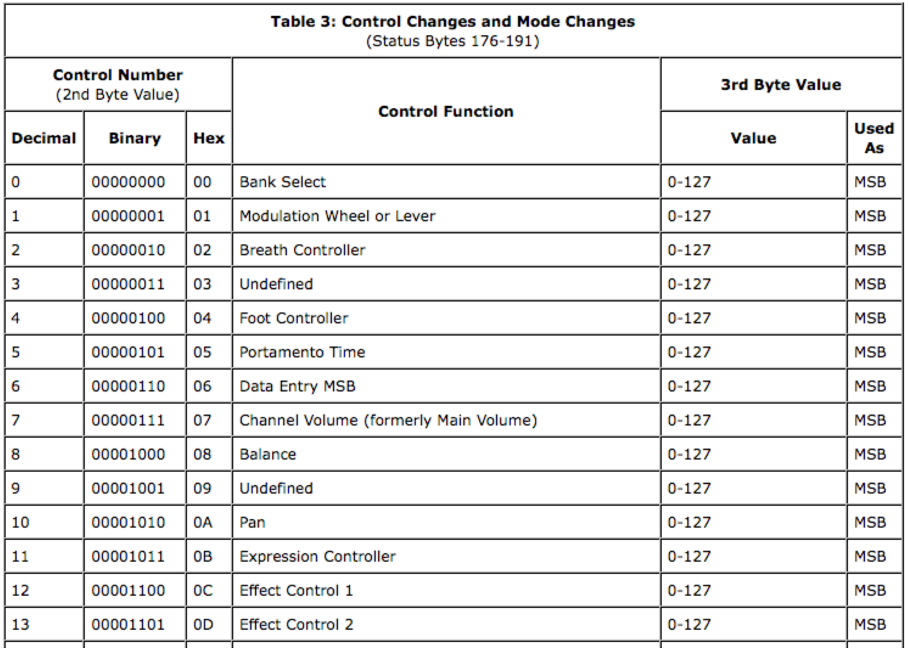


Table 3: Control Changes and Mode Changes
(Status Bytes 176-191)

Control Number (2nd Byte Value)			**Control Function**	**3rd Byte Value**	
Decimal	**Binary**	**Hex**		**Value**	**Used As**
0	00000000	00	Bank Select	0-127	MSB
1	00000001	01	Modulation Wheel or Lever	0-127	MSB
2	00000010	02	Breath Controller	0-127	MSB
3	00000011	03	Undefined	0-127	MSB
4	00000100	04	Foot Controller	0-127	MSB
5	00000101	05	Portamento Time	0-127	MSB
6	00000110	06	Data Entry MSB	0-127	MSB
7	00000111	07	Channel Volume (formerly Main Volume)	0-127	MSB
8	00001000	08	Balance	0-127	MSB
9	00001001	09	Undefined	0-127	MSB
10	00001010	0A	Pan	0-127	MSB
11	00001011	0B	Expression Controller	0-127	MSB
12	00001100	0C	Effect Control 1	0-127	MSB
13	00001101	0D	Effect Control 2	0-127	MSB