
MIDI

# Overview

- MIDI – Musical Instrument Digital Interface
- Protocol for communication between musical devices
  - Specifies musical notes
  - Uses equal temperament
- MIDI sources
  - Keyboard
  - Guitar with MIDI pickup
  - Computer software

# MIDI Model

- Maximum of 16 instruments
  - Each instrument is called a **channel**
  - The instrument voice type is called a **patch**
- Each channel may play several different notes at the same time
  - Notes are pitch indices in the range 0 to 127
    - A440 Hz is index 69
  - Volume of a note is also called its **velocity**
    - Has value in the range 0 to 127

# Frequency and Pitch (1)

- Frequency
  - An absolute measure of tonality
  - Measured in Hertz (Hz), the number of cycles per second
  - Multiplying by 2 increases a tone by one octave
  - Multiplying by ½ decreases a tone by one octave
  - Example

    Root frequency: $f = 200$ Hz

    One octave up: $2f = 2(200) = 400$ Hz

    One octave down: $\frac{1}{2}f = \frac{1}{2}(200) = 100$ Hz

# Frequency and Pitch (2)

- Pitch
  - A relative measure of frequency
  - Measured in **cents**
  - A shift of one octave is 1200 cents
    - 12 semi-tones (half-steps) in one octave
    - One semi-tone is 100 cents
  - Changing the pitch by $p$ cents corresponds to multiplying the frequency by the factor

$$m = 2^{p/1200}$$

# Examples

- Suppose the root frequency is *300 Hz*. What is the frequency if we shift up by 2 semi-tones?

  Pitch shift: *200 cents*

  Frequency multiplier: $m = 2^{200/1200} \approx 1.122$

  Shifted frequency: *(m)(300) ≈ 337 Hz*

- What is the pitch shift (in cents) from *312 Hz* to *275 Hz*?

  Frequency mulitplier: *275/312 = 0.881*

  Pitch shift:

$$0.881 = 2^{p/1200} \Rightarrow p = 1200 \frac{\log(0.881)}{\log 2} \approx -219\, cents$$

# MIDI Pitch Indices

- In the range 0 … 127
- Index 69 corresponds to 440 Hz (A440 standard)
- Adjacent indices differ by 1 semi-tone (100 cents)
- Example: find the frequency for index 83

  83 - 69 = 14 semitones (1400 cents) from 440 Hz

  So, frequency is

$$\left(2^{1400/1200}\right)\left(440\right)\approx 988\,Hz$$

# MIDI Messages (1)

- “Short” messages are used to
  - Play a note
  - Stop a note
  - Change note volume
  - Pitch shift a note
  - Change patch (instrument)
  - Stereo pan
- Reference:

http://www.midi.org/techspecs/midimessages.php

# MIDI Messages (2)

- 4 byte structure
- First byte is divided into two 4 bit nibbles
  - High order nibble = message number
  - Low order nibble = channel number
- Common message numbers:
  - 9h – note on
  - Ch – patch change
  - Eh – pitch shift
  - Bh – control change (used for panning)

# MIDI Messages (3)

- The meaning of the remaining 3 bytes depends on the message number
- For note on message (9h)
  - Second byte gives the pitch index
  - Third byte gives the note velocity
  - Remaining byte not used
- For patch change (Ch)
  - Second byte is the patch number
  - Other two bytes not used

# MIDI Patches

- Patch numbers are in the range 0 to 127
- The actual voices used depend on the MIDI implementation platform
- Most computer implementations default to General MIDI (GM) voices
  - Reference

    http://www.midi.org/techspecs/gm1sound.php
  - Channel 10 is reserved for percussion

# Using MIDI Messages

- Notes are turned on and off with message 9h
  - Turn on with a nonzero velocity (volume)
  - Turn off with a zero velocity (volume)
- Officially, message 8h turns off a note
  - Not implemented on some platforms
- A high-resolution timer should be used to turn notes on and off

# Pros and Cons of MIDI

- Compact musical representation
  - MIDI data files are *much* smaller than WAVE or MP3 files
- De facto standard interface for electronic musical instruments
- Sound quality depends highly on instrument sounds used to represent MIDI patches
- No standard sounds for patches