

# ECS614U/ECS749P: Sound Recording and Production

Michael Terrell

`michael.terrell@eecs.qmul.ac.uk`

`http://qmplus.qmul.ac.uk/course/view.php?id=3243`

Centre for Digital Music  
School of Electronic Engineering and Computer Science  
Queen Mary University of London

Semester 1, 2013–14

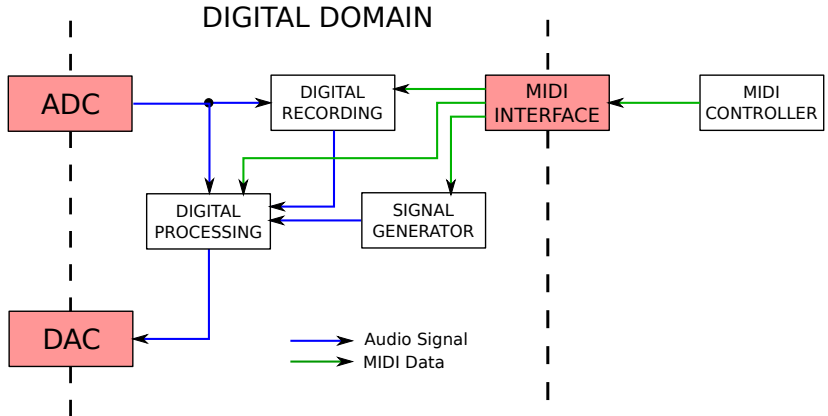
# MIDI

# Introduction

## MIDI: **M**usical **I**nstrument **D**igital **I**nterface.

- A means of controlling audio functionality of a computer.
- Consists of performance event data - **not audio**.
- Serial data passed on a single cable.
- The MIDI standard allows interface between manufacturers.

# The Audio Chain



# MIDI controls

- What can we do with a MIDI keyboard controller?
  - **KEYS:** Output note events to play synthesisers and samplers.
  - **BUTTONS:** Activate and deactivate audio effects, switch between patches.
  - **NOBS, SLIDERS:** Change the parameters of audio effects.

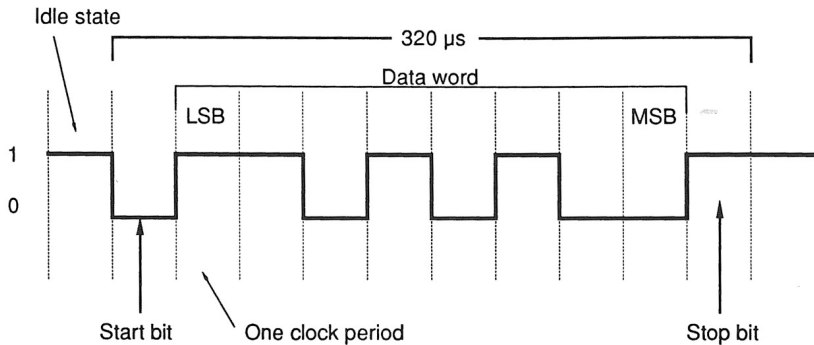
# MIDI Protocol

- Regulating body is MIDI Manufacturers Association (introduced in 1983).
- Not all messages are implemented on all equipment, but those that are **must conform**.
  - Electronic instruments can communicate and synchronise.
  - Computer/instrument interaction is standardised.
  - MIDI sequencing replaces standard music notation.
  - Instruments can be replaced with synths/samplers.

# MIDI event data

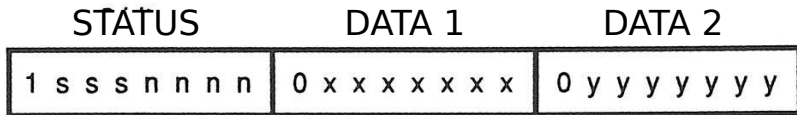
- MIDI uses serial data at 31.25 kbaud (31,250 pulses per second).
- Shift register converts parallel stored data to serial data.
- Asynchronous communication, with start and stop bits to avoid drifting.
- MIDI word is 10 bits  $\rightarrow$  320  $\mu$ s per word.

# A MIDI Word





# MIDI Message



- A MIDI message is composed from three MIDI words:
  - STATUS - type of message begin sent.
  - DATA 1 - data describing properties of the message.
  - DATA 2 - data describing properties of the message.

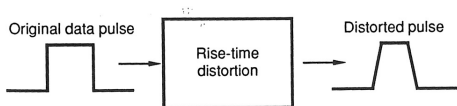
# MIDI data cables

- 5-pin DIN connectors
- Shielded twisted pair, screen to pin 2 at both ends.
- Maximum cable length is 15 m.
- Alternatively use a USB cable.



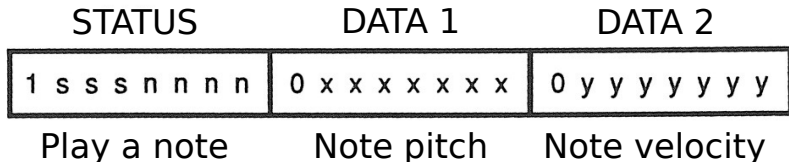
# MIDI data distortion and delay

- Opto-isolator rise-time  $\leq 2 \mu\text{s}$ .



- Long cables act as low pass filters.
- Delays
  - Thru delays: message sent through other device.
  - Serial delays: only one byte/message can be sent at a time.
  - Buffer delay: system allocates serial messages.
  - Processing delay: system response to instruction.

# MIDI Note Message



- When a note is played a note-on channel message is sent (identified by status).
- The message data contains the note pitch and velocity.
- A second off-message is sent when the note is released.

# Generating Audio Signals with MIDI

- Audio signals can be generated from MIDI note messages using synthesisers or samplers.
- Synthesisers use algorithms to generate the audio signal.
- Samplers play a prerecorded segment of audio signal, referred to as a sample.

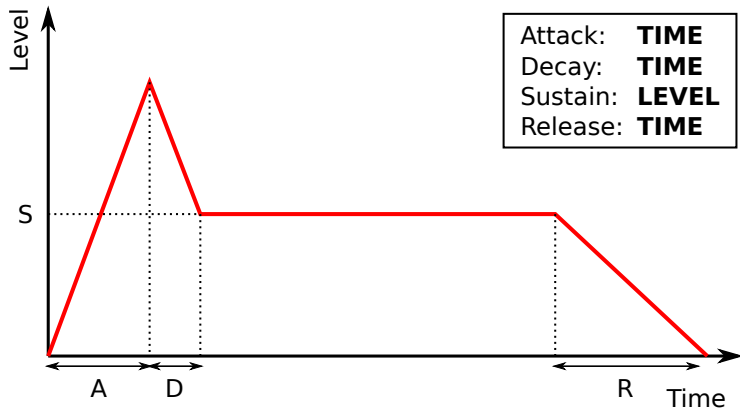
# Synthesis Methods

- The simplest component of synthesis is an oscillator, which produces a wave-form of a given type (e.g. sine, square), at a given frequency.
- How can we use these components to make "real" sounding audio signals?

# Additive Synthesis

- Sum many generated waveforms at different frequencies.
- Each component represents a different harmonic of the modelled sound.
- The amplitude envelope of each component can be controlled to represent the modelled sound.
- It's very hard and complicated to make real sounding additive synthesisers.

# ADSR envelope





# ADSR envelope

- The way that the amplitude of a synthesised audio signal changes with time is defined by the amplitude envelope.
  - **Attack time:** the time it takes for the note to reach maximum amplitude when the note is triggered.
  - **Decay time:** the time it takes for the note to decay to a steady level once the peak has been reached.
  - **Sustain level:** the steady state amplitude of note.
  - **Release time:** the time it takes for the note to decay to silence from the sustain level once the note is released.

# Synthesis Considerations

- Formants: resonances that do not change with fundamental frequency.
- Dynamic spectrum:
  - Each partial can have a different amplitude envelope.
  - Real instruments produce a different sound when played with different intensity.
- Vibrato: small frequency variations that can be independent for different partials.
- ADSR is an approximation to the real envelopes.

# Synthesis Methods

There are a number of other synthesis techniques.

- **Additive**: summing waves, controlling amplitude envelope of each partial separately. Can get complex quickly for rich timbres.
- **Subtractive**: start with a rich sound, can be noise or pitched, and apply filters. Easier to use than additive but cannot control individual partials.
- **Waveshaping**: apply non-linear transfer function to distort simple input waveform. Computationally efficient, good control over spectral dynamics but fine control is difficult.

# Synthesis Methods

- **Frequency modulation (FM):** frequency of an oscillator (carrier) is controlled by the output of another oscillator (modulator). Easy and efficient to produce complex timbres but can be challenging to design and control.
- **Granular synthesis:** many short (5–50 ms) grains of audio layered on top of one another and manipulated in time and frequency. Good for producing new textures but hopeless for synthesising acoustic instruments.
- **Physical modelling:** build a mathematical model that simulates how an instrument produces sound.

# Sampling

# Sampling

- Small excerpts of real sounds, e.g. notes, are recorded and played back according to MIDI control.
- How do we incorporate all notes, all levels and all durations?

# Sampling Methods

- Record fewer notes and pitch shift to those in between.
- Record few volume levels and cross-fade between.
- Loop the sustain portion for different durations.
- Functionality of samplers and synthesisers overlap, e.g. ADSR and synthesiser filtering techniques.

# Synthesis vs Sampling

Which is better, synthesis or sampling?



# Sequencers

- A device that plays back musical notation.
- Temporal resolution is defined pulses per quarter note (typically 100–1000 ppqn), so tempo affects absolute resolution.
- MIDI data is easy to edit and can be quantised.
- In Logic we use the Piano Roll.