ECS614U/ECS749P: Sound Recording and Production

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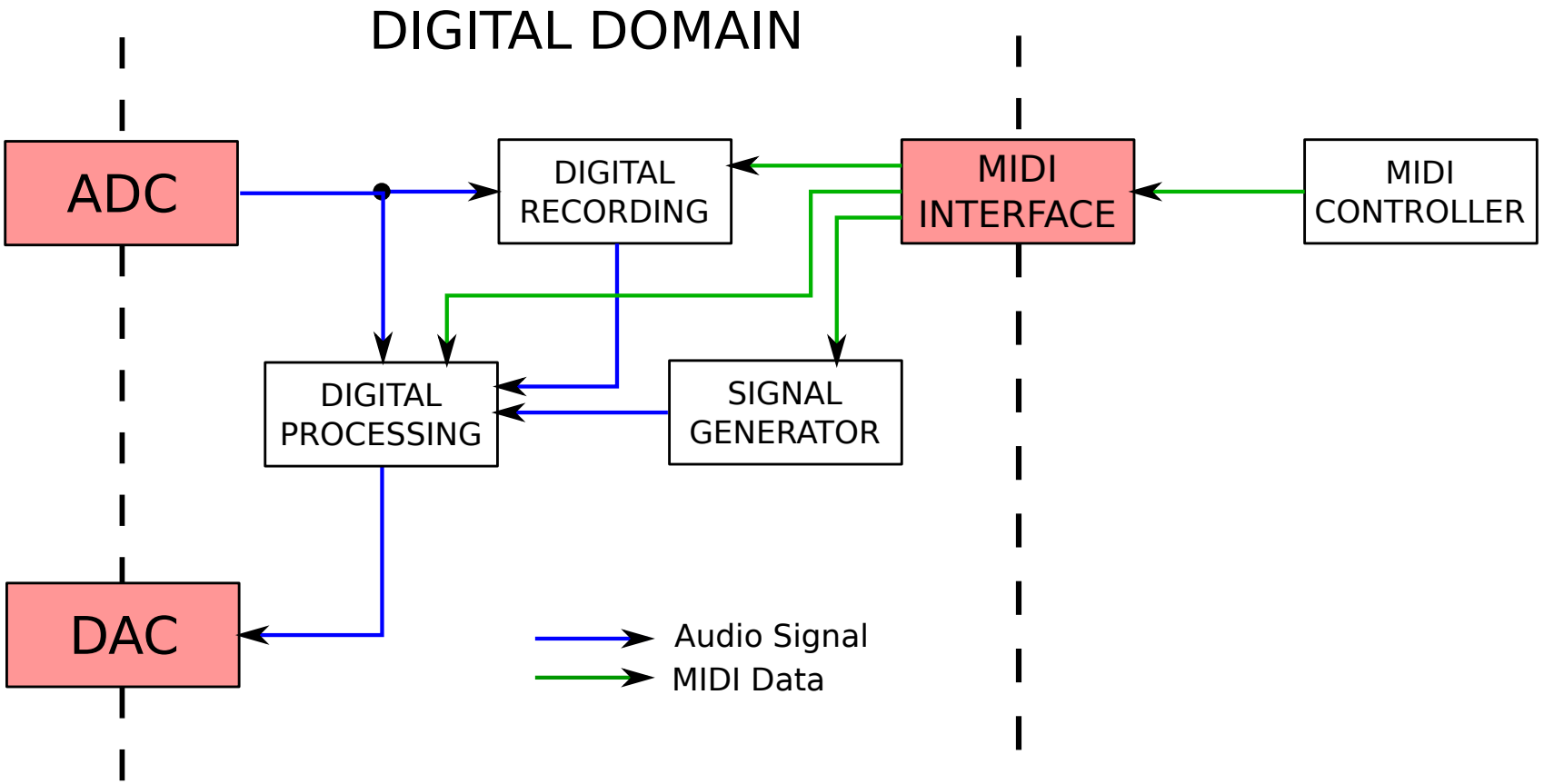
MIDI

Introduction

MIDI: **Musical Instrument Digital Interface.**

- 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.

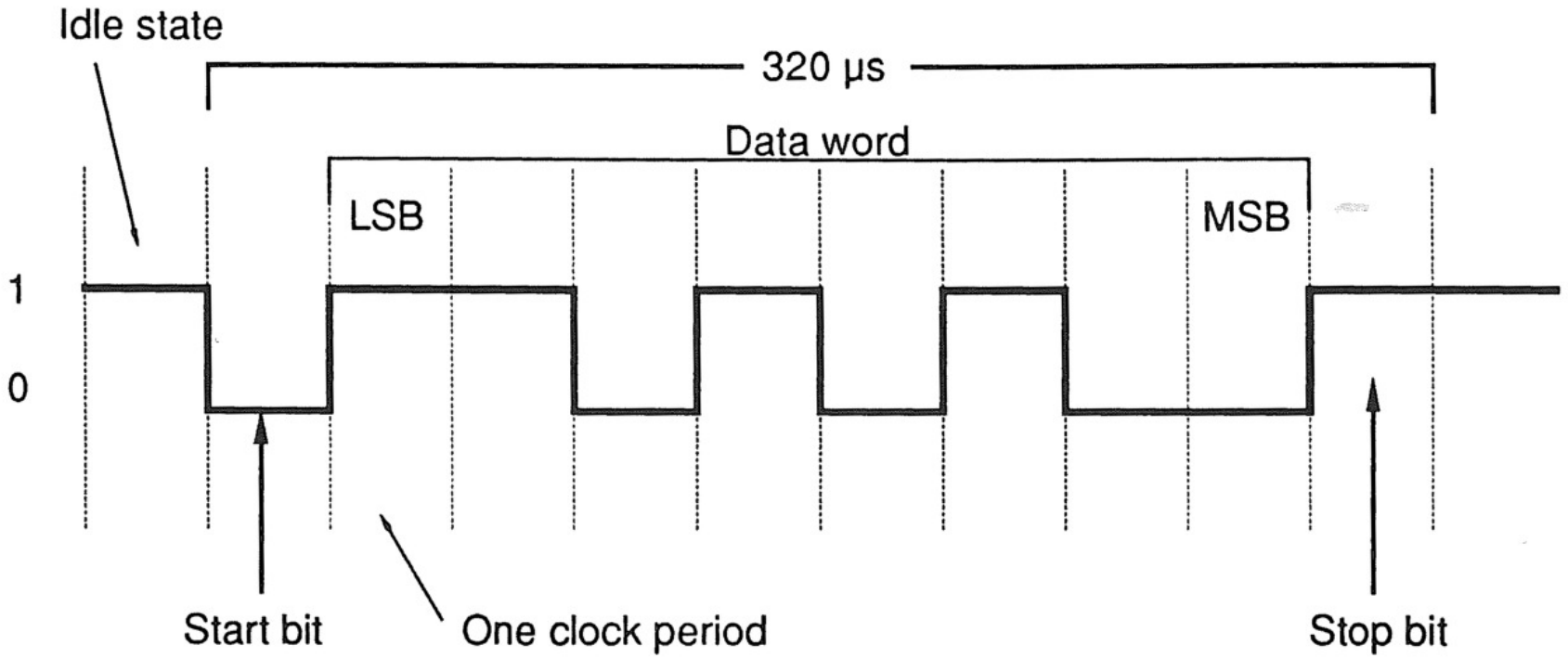
MIDI Protocol

- 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 μs per word.

A MIDI Word


Idle state
320 µs
Data word
LSB
MSB
1
0
Start bit
One clock period
Stop bit

MIDI Message

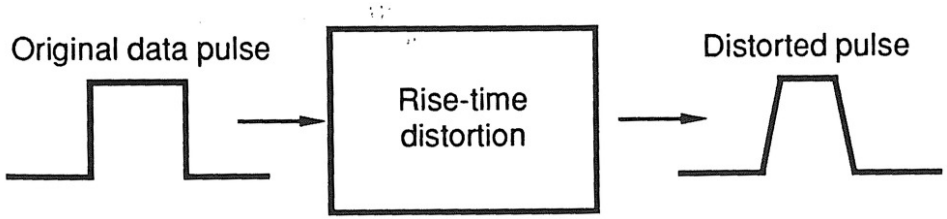
- A MIDI message is composed from three MIDI words:
  - STATUS - type of message begin sent.
  - DATA 1 - data describing properties of the message.
  - DATA 2 - data describing properties of the message.

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.

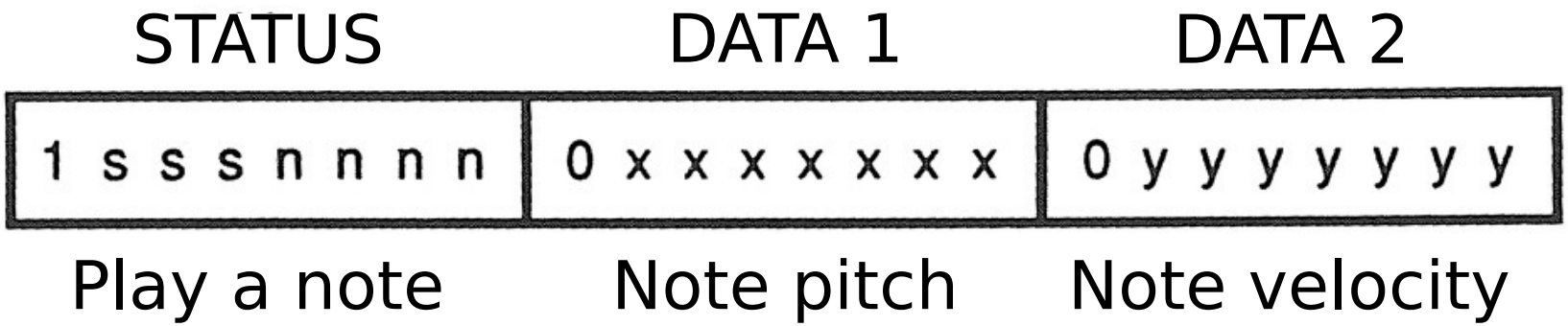
MIDI data distortion and delay

- Opto-isolator rise-time $\leq 2\,\mu$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.

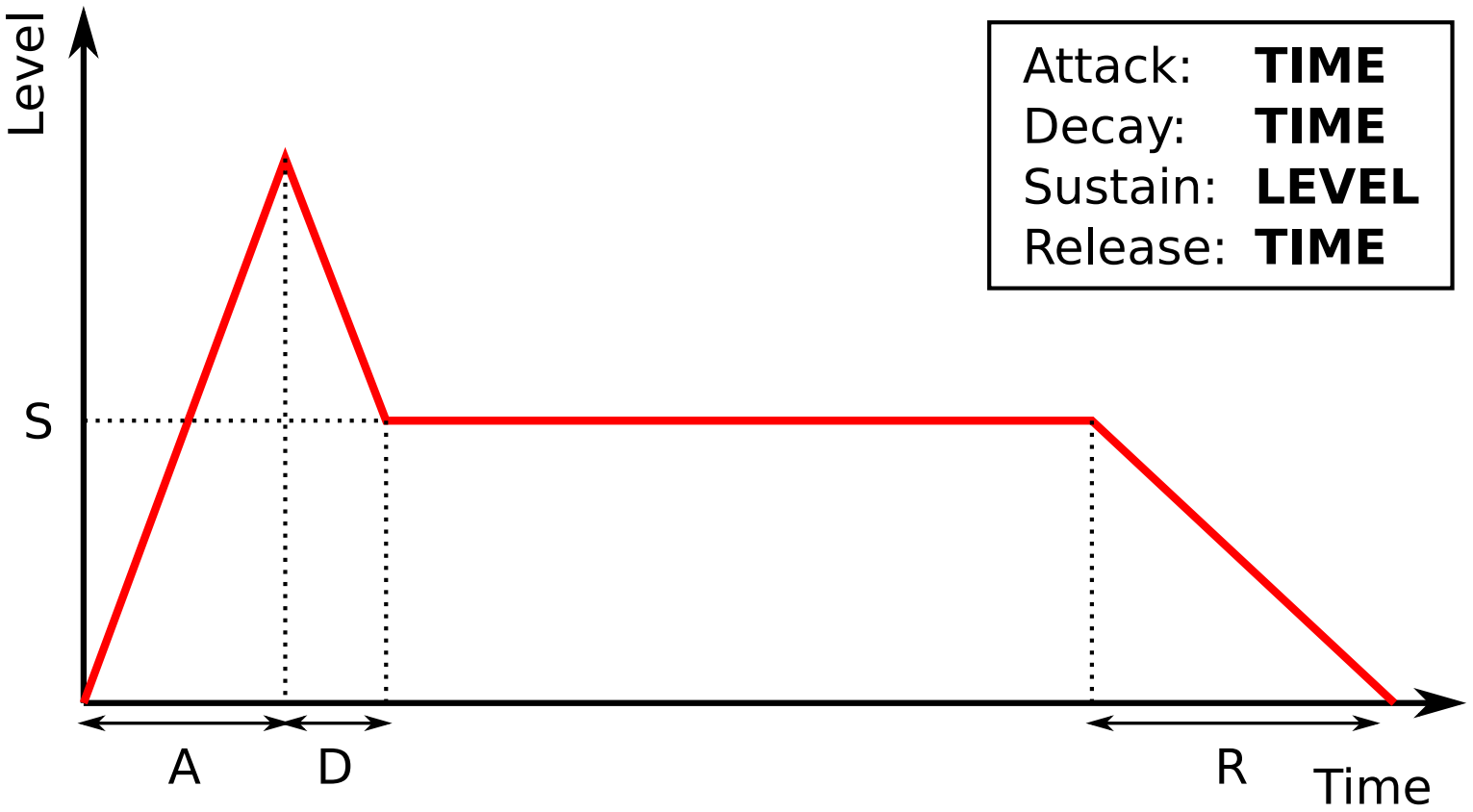
Synthesis Methods

- 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.
  - **A**ttack time: the time it takes for the note to reach maximum amplitude when the note is triggered.
  - **D**ecay time: the time it takes for the note to decay to a steady level once the peak has been reached.
  - **S**ustain level: the steady state amplitude of note.
  - **R**elease time: the time it takes for the note to decay to silence from the sustain level once the note is released.

Synthesis Methods

- **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.

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:
  - Subtractive synthesis.
  - Granular synthesis.
  - Frequency modulation (FM) synthesis.
  - Waveshaping.
  - Instrument modelling.

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.

Sequencers

- An 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.