Music in iOS and Mac OS X

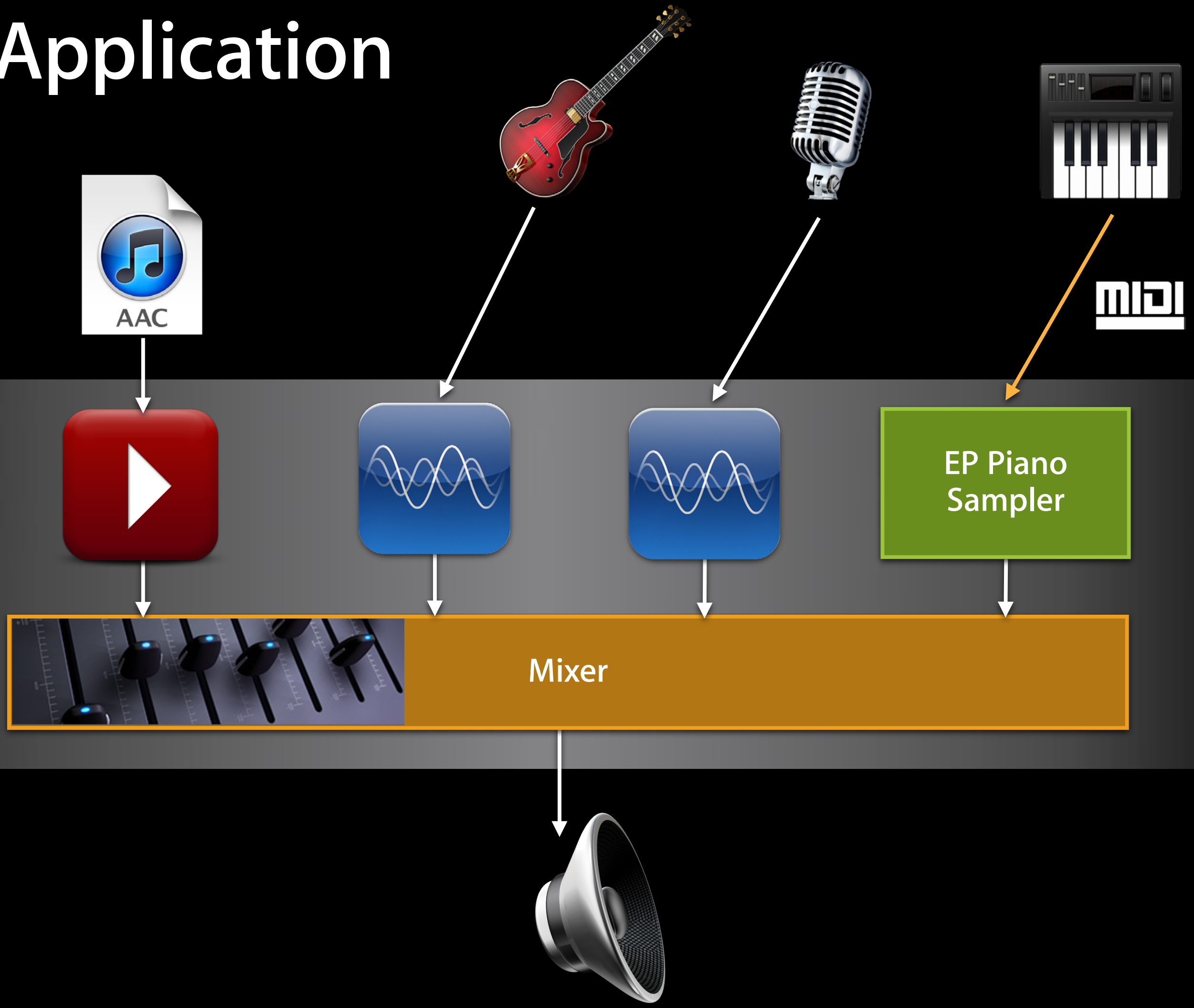
Session 411

Michael Hopkins
Core Audio Engineering

What You Will Learn

- Using Audio Units
- Introduction to the AUSampler
- CoreMIDI on iOS
- Playing of music sequences

Music Application



What Is an Audio Unit?

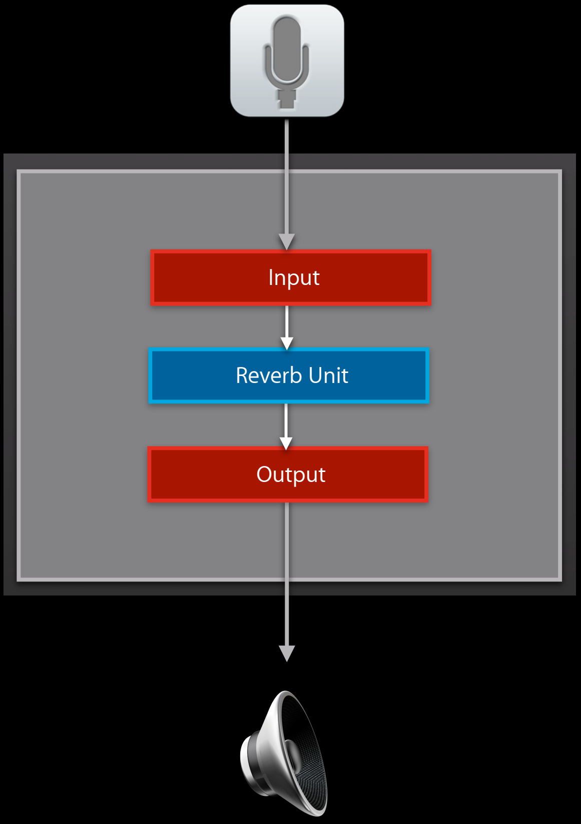
- Plug-in for processing audio
- Supports real-time input, output, or simultaneous I/O
- Organized in an audio processing graph
- Controlled by properties and parameters
- Can have a view (Mac OS X)

Types of Audio Units

- Effects
- Music effects
- Instruments
- Generators
- Panners
- Converters
- Mixers
- Offline effects
- Output units

Using Audio Units

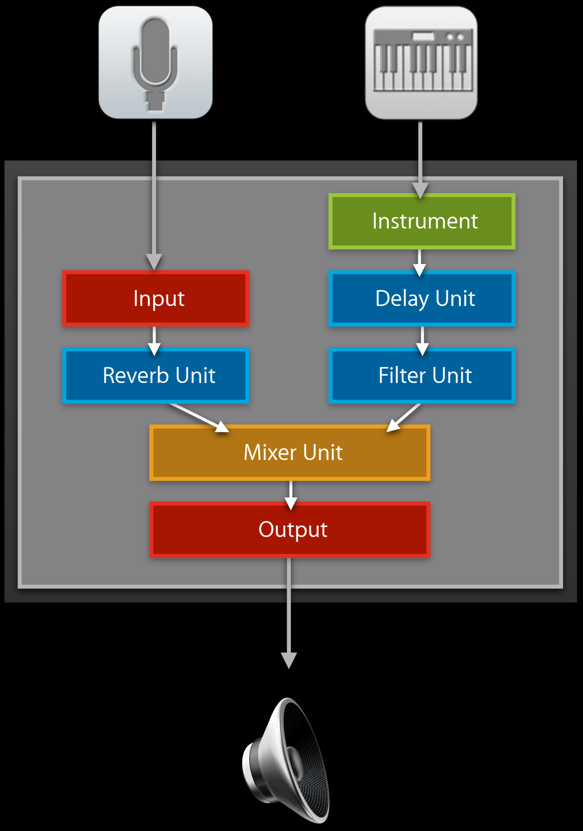
Organizing Audio Units in a graph



- Audio Units can be added to an audio processing network called an AUGraph
  - Each item in the graph is an AUNode
  - Graph defines connections between nodes
  - Signal flow goes from input to output
  - Graph ends with a single output unit

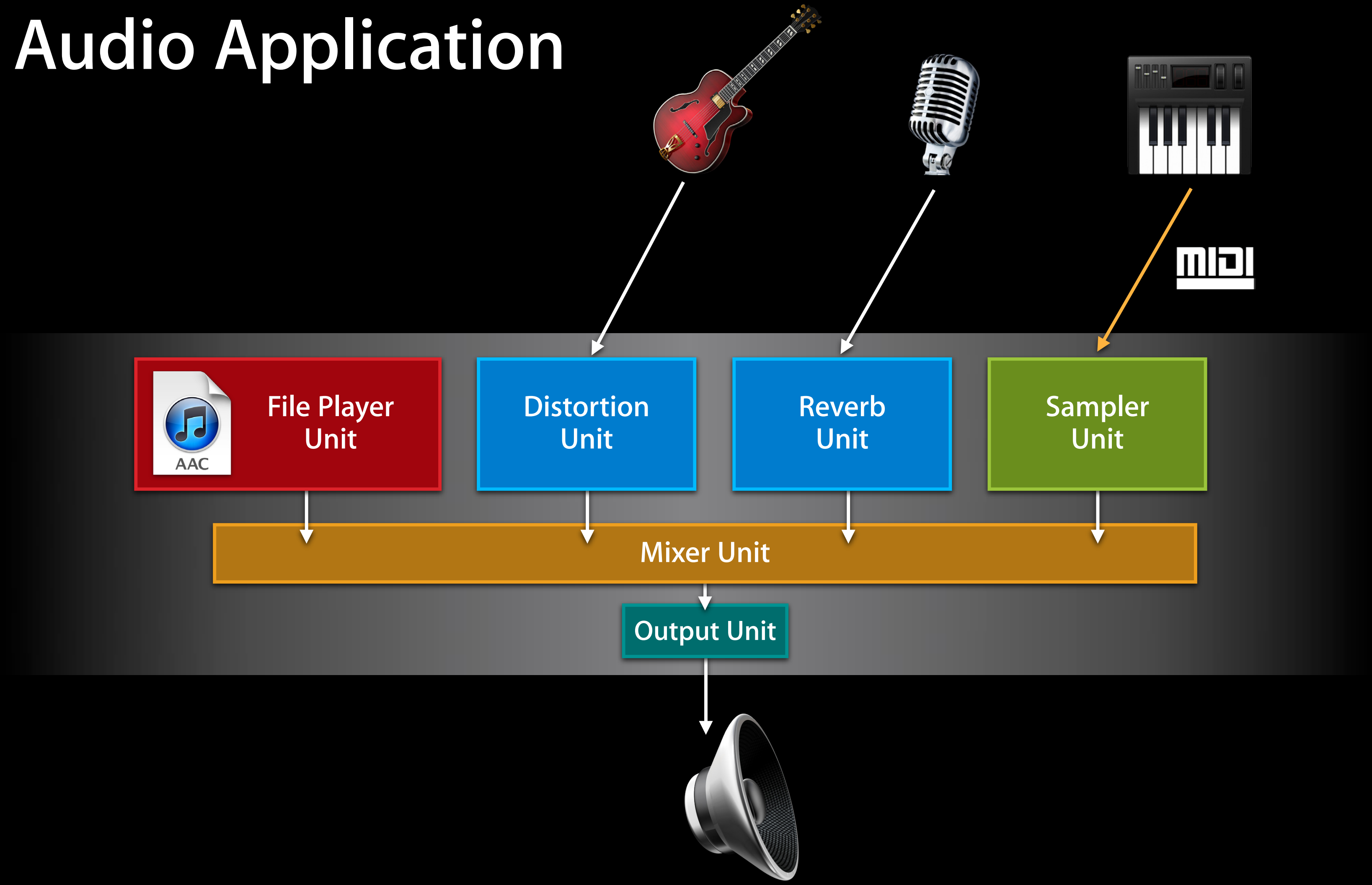
Using Audio Units

AU graphs (cont.)



- Graphs can use a mixer unit to combine separate chains prior to the output

Audio Application



Interacting with Audio Units

Properties

- Key-value pairs
- Configure state that is managed by the host
  - Sample rate
  - Stream format
  - Number of input buses on a mixer
- Set on Audio Unit and take effect at initialization

Interacting with Audio Units

Parameters

- Key-value pairs
- Intended to be used during processing
    - Delay time
    - Feedback amount
    - Stereo panning position
- Generally set through a UI

Demo

Exploring Audio Units in AULab

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New Audio Units in iOS

- Effects
  - Filters
    - Highpass
    - Lowpass
    - Bandpass
    - Highshelf
    - Lowshelf
    - Parametric EQ
  - Peak limiter
  - Dynamics processor
  - Reverb

New Audio Units in iOS

- Effects
  - Varispeed
  - SimpleTime
  - NotQuiteSoSimpleTime
- Generators
  - AudioFilePlayer
  - ScheduledSlicePlayer
- Instruments
  - Sampler

Audio Components

Finding, loading, and instantiating Audio Units

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Core Audio Engineering

Audio Unit Basics

- Audio Unit instances are created from Audio Components
- Uniquely identified by an AudioComponentDescription
    - Each value is a four-character OSType

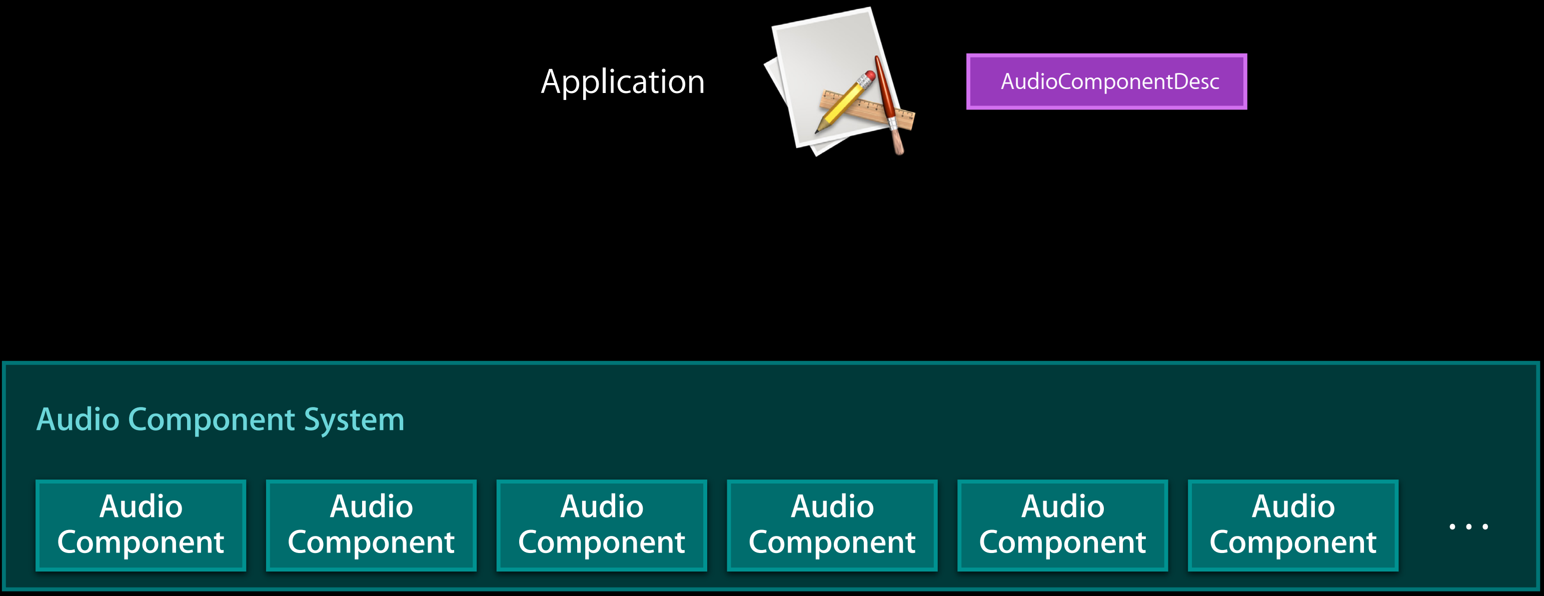
Type	`‘aufx’`
Subtype	`‘dlay’`
Manufacturer	`‘acme’`

- Name
- Version

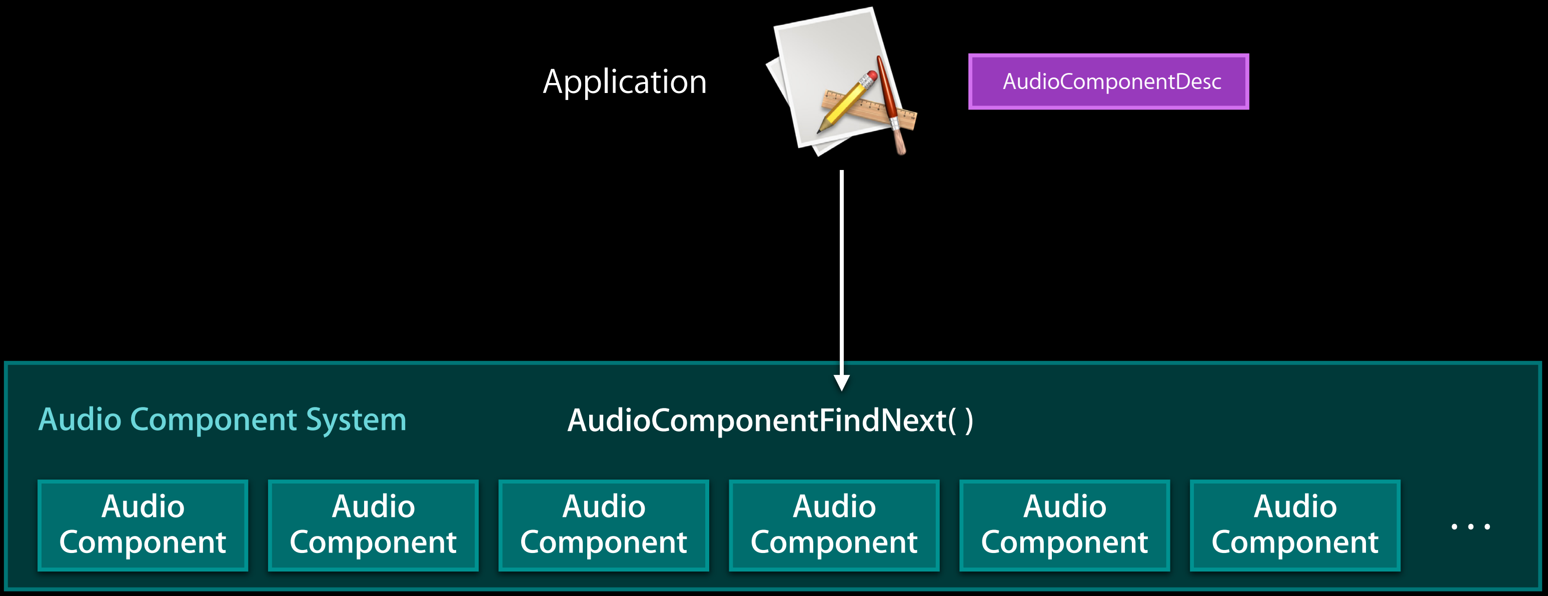
Introducing the AudioComponent API

- Provides facilities for Audio Components
  - Finding
  - Loading
  - State management
- Available in iOS and Mac OS X
- Replaces Component Manager calls on Mac OS X

Finding and Loading an Audio Unit



Finding and Loading an Audio Unit



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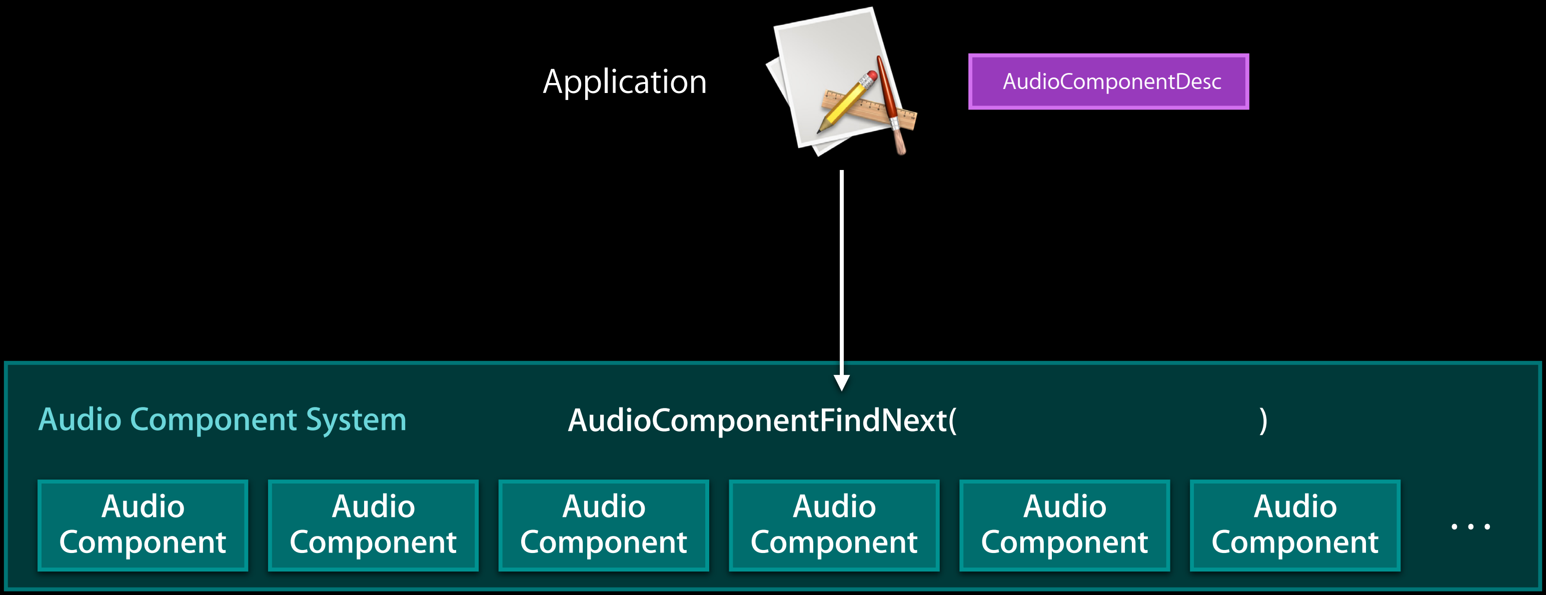

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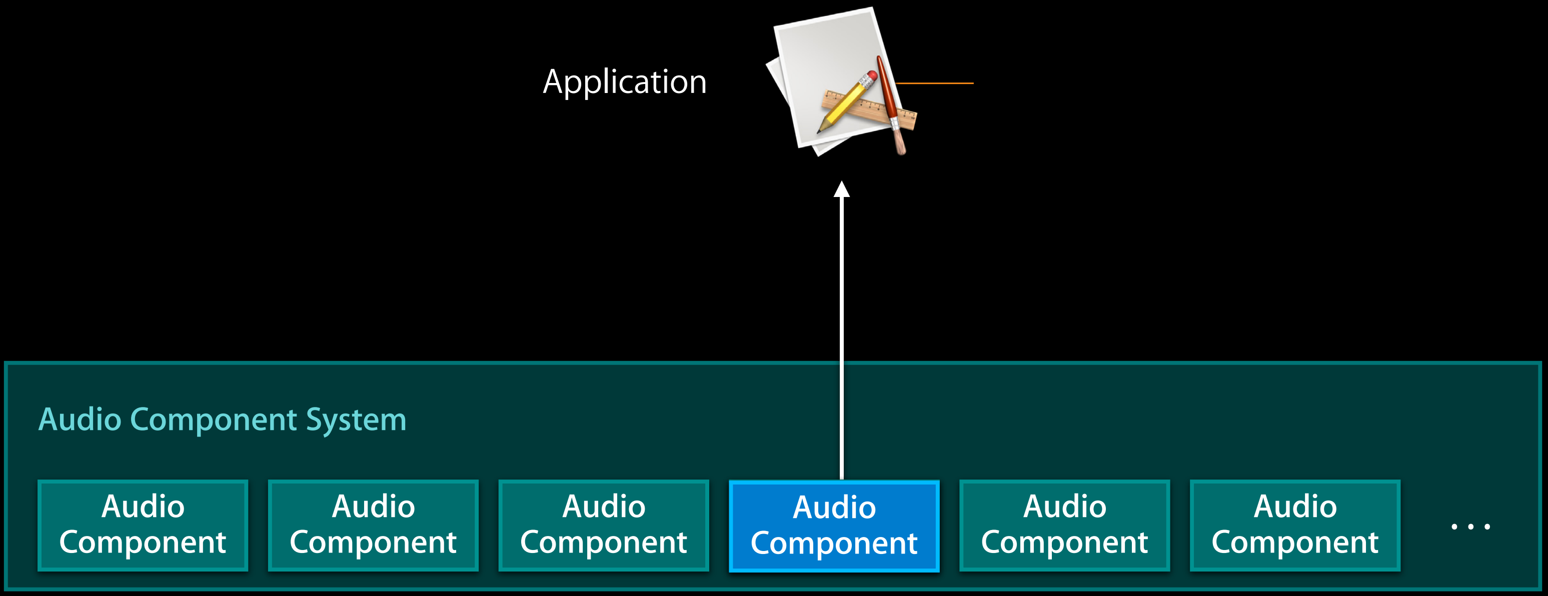

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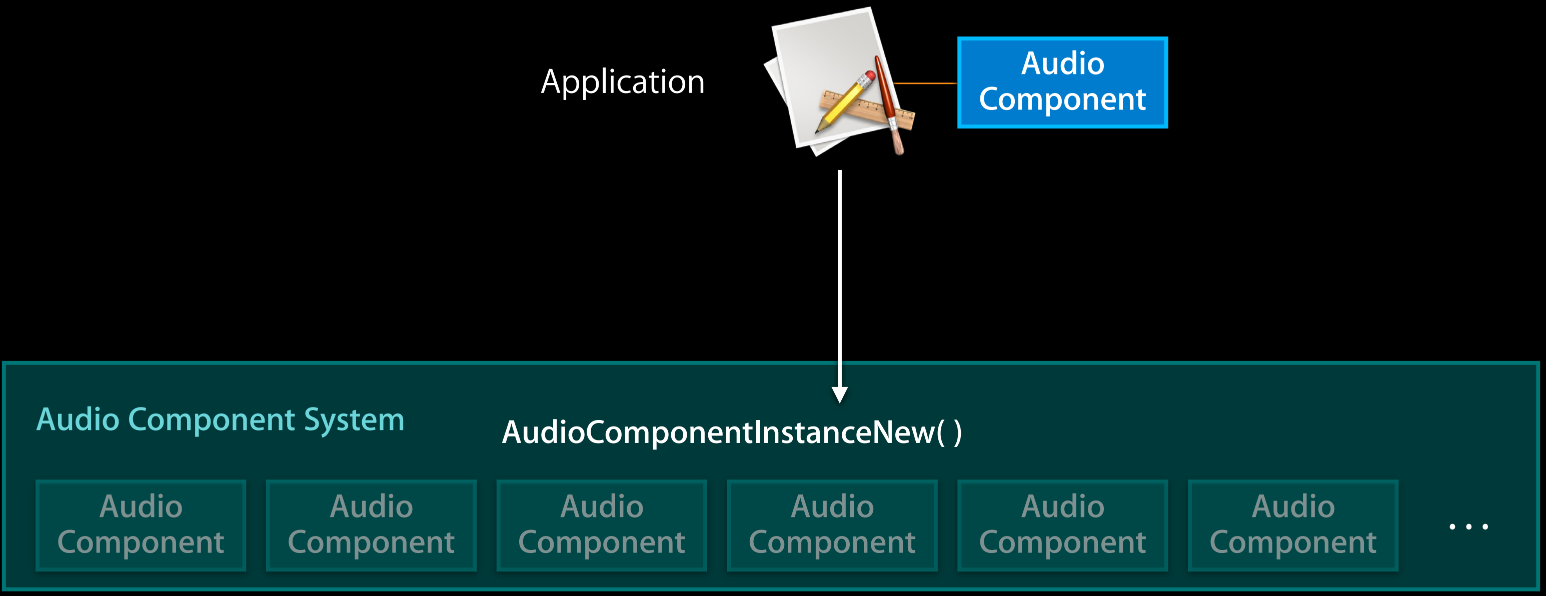

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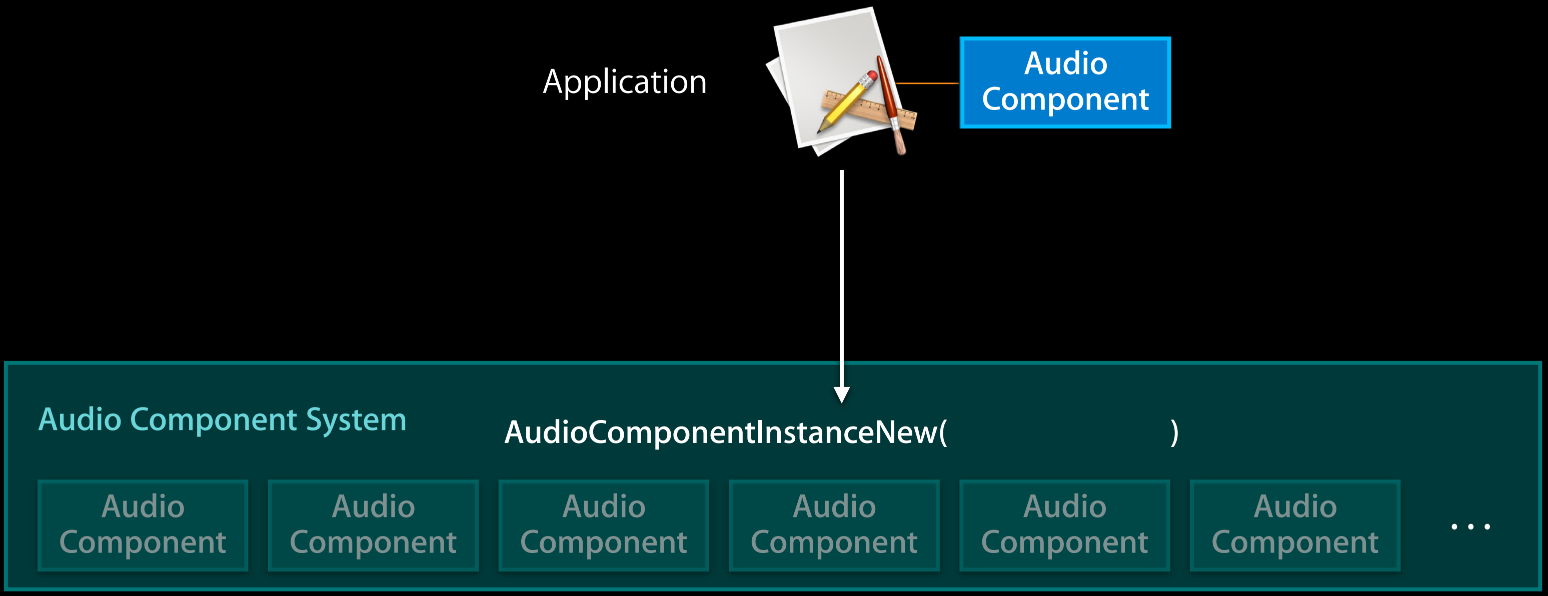
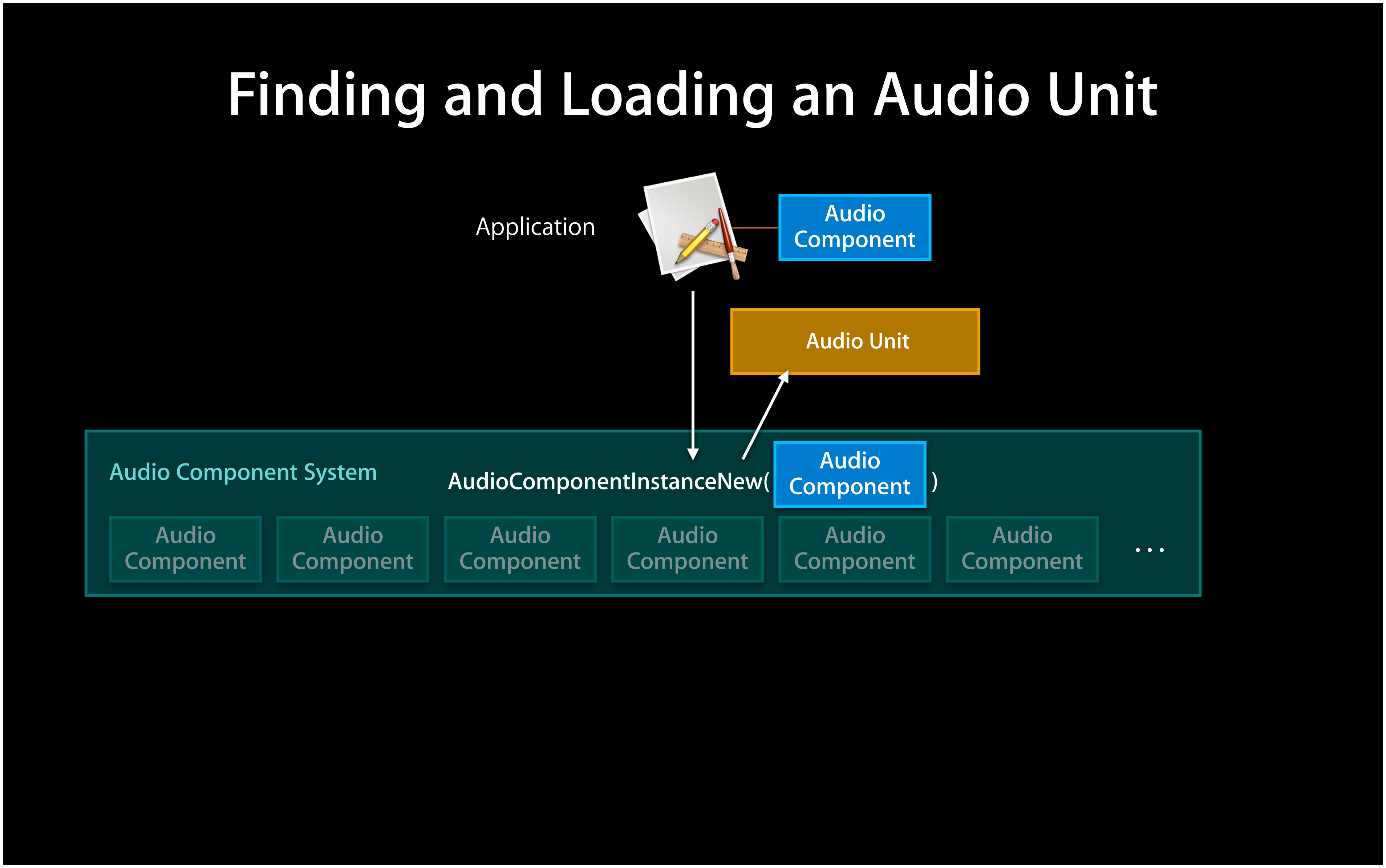




Finding and Loading an Audio Unit

Finding and Creating an Audio Unit

- Use AudioComponentFindNext() to find a specific Audio Component

```
AudioComponent AudioComponentFindNext(AudioComponent *inComp,
                                      const AudioComponentDescription *inDesc)
```

  - First argument can be NULL to start at beginning of component list
  - Pass a specific Audio Component to retrieve next match
  - Wildcard searches allowed

Registering Audio Components

- System scans directories for bundles

```
~/Library/Audio/Plug-Ins/Components
/Library/Audio/Plug-Ins/Components
/System/Library/Components
```

- Bundles have a specific extension
  - .audiocomp (registers with Audio Component System)
  - .component (registers with Component Manager and Audio Component System)

Registering Audio Components

Components can be registered at runtime

```
AudioComponent AudioComponentRegister(AudioComponentDescription *desc,
                                      CFStringRef name,
                                      UInt32 version,
                                      AudioComponentFactoryFunction func)
```

- Component only available in application process

Audio Components

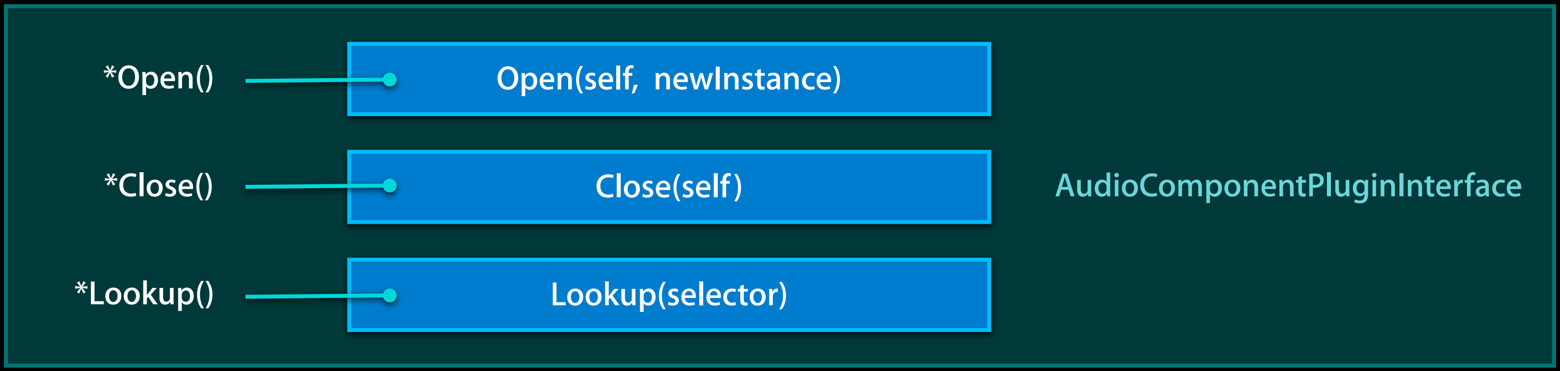
A look under the hood

- All Audio Components have an AudioComponentFactoryFunction
  - Used to create instances of the Component
  - Returns a pointer to an AudioComponentPluginInterface

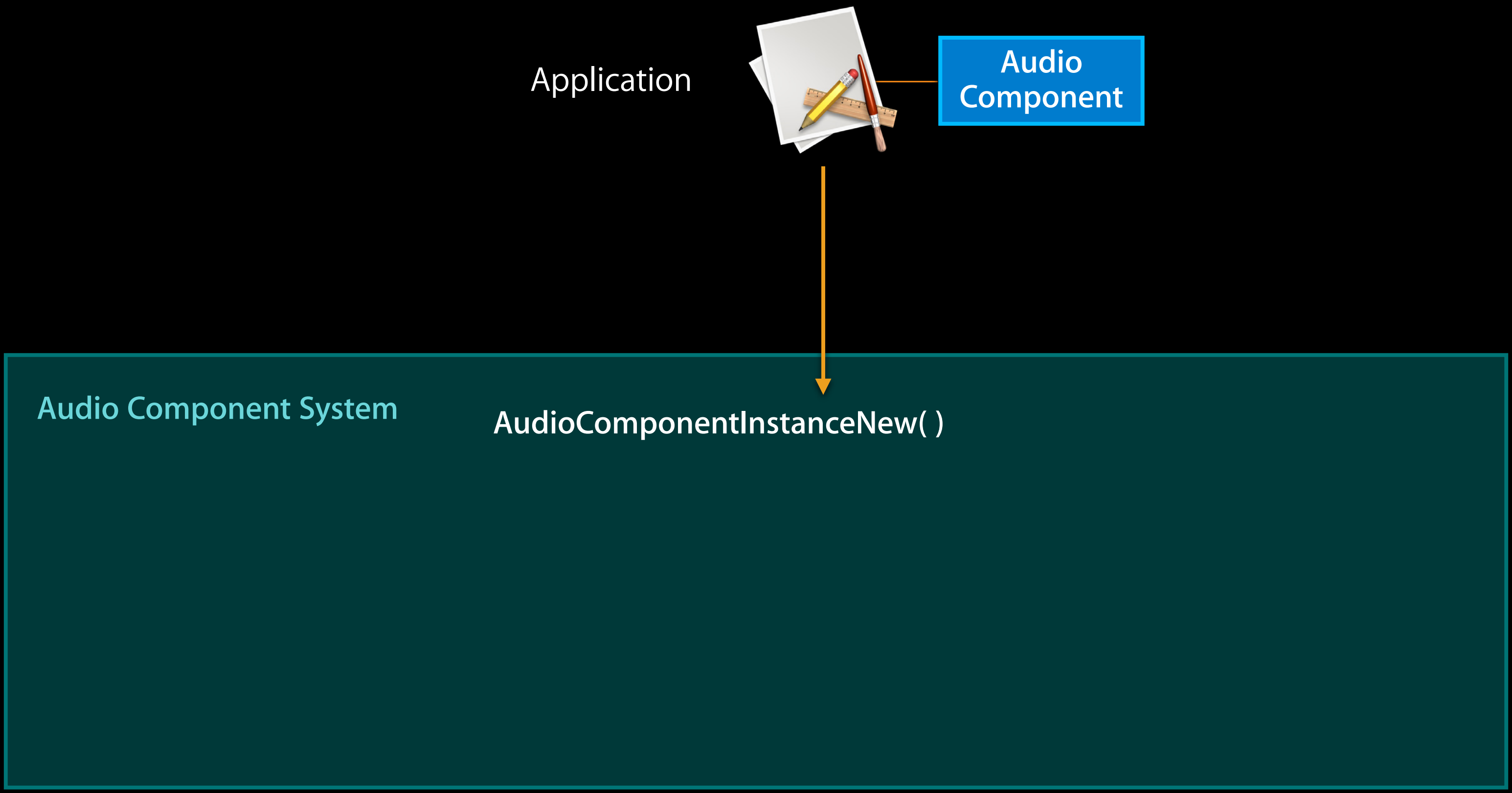
Audio Units

A look under the hood

- All Audio Components have an AudioComponentFactoryFunction
  - Used to create instances of the Component
  - Returns a pointer to an AudioComponentPluginInterface



Creating an Audio Component Instance



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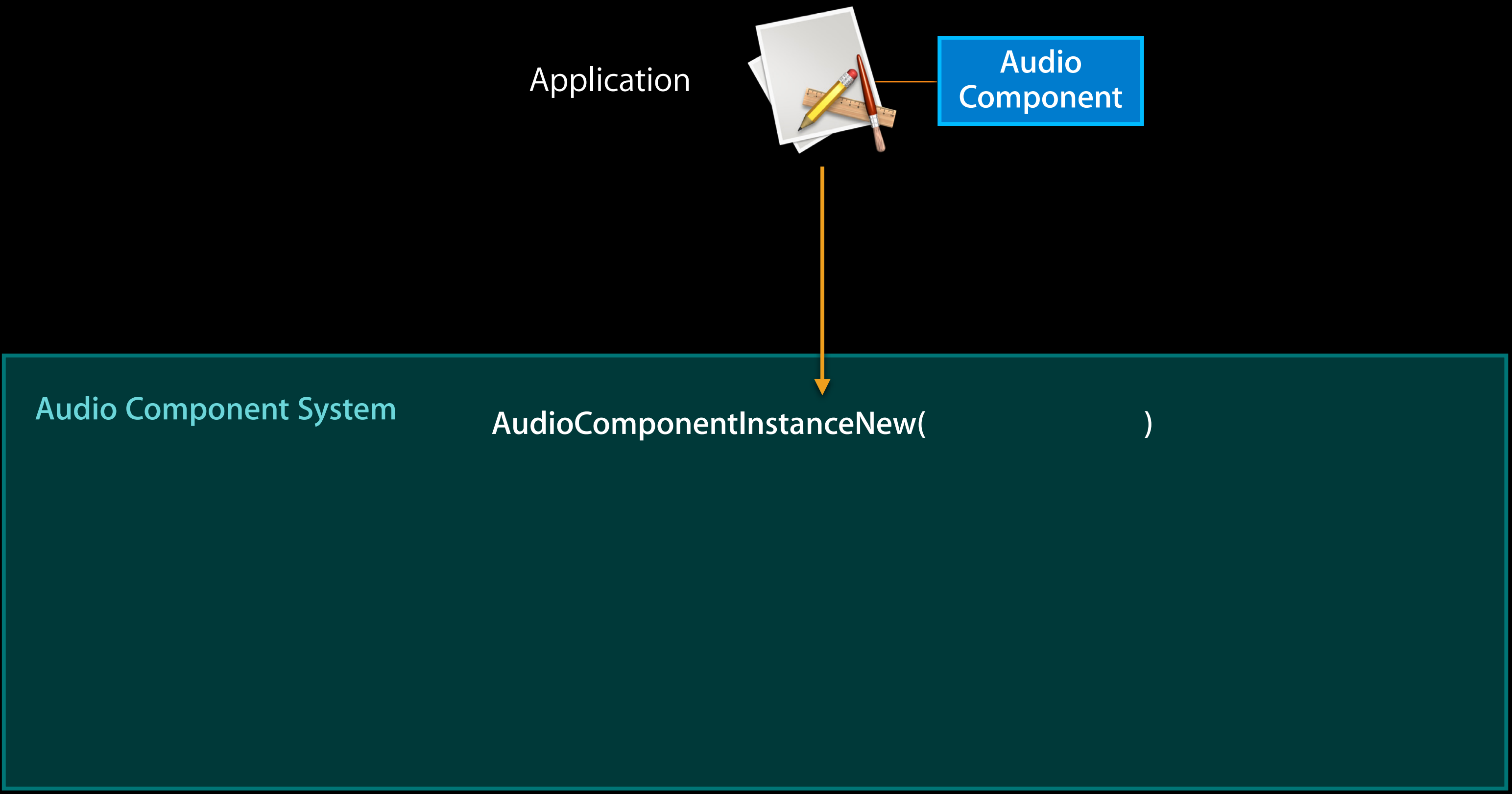
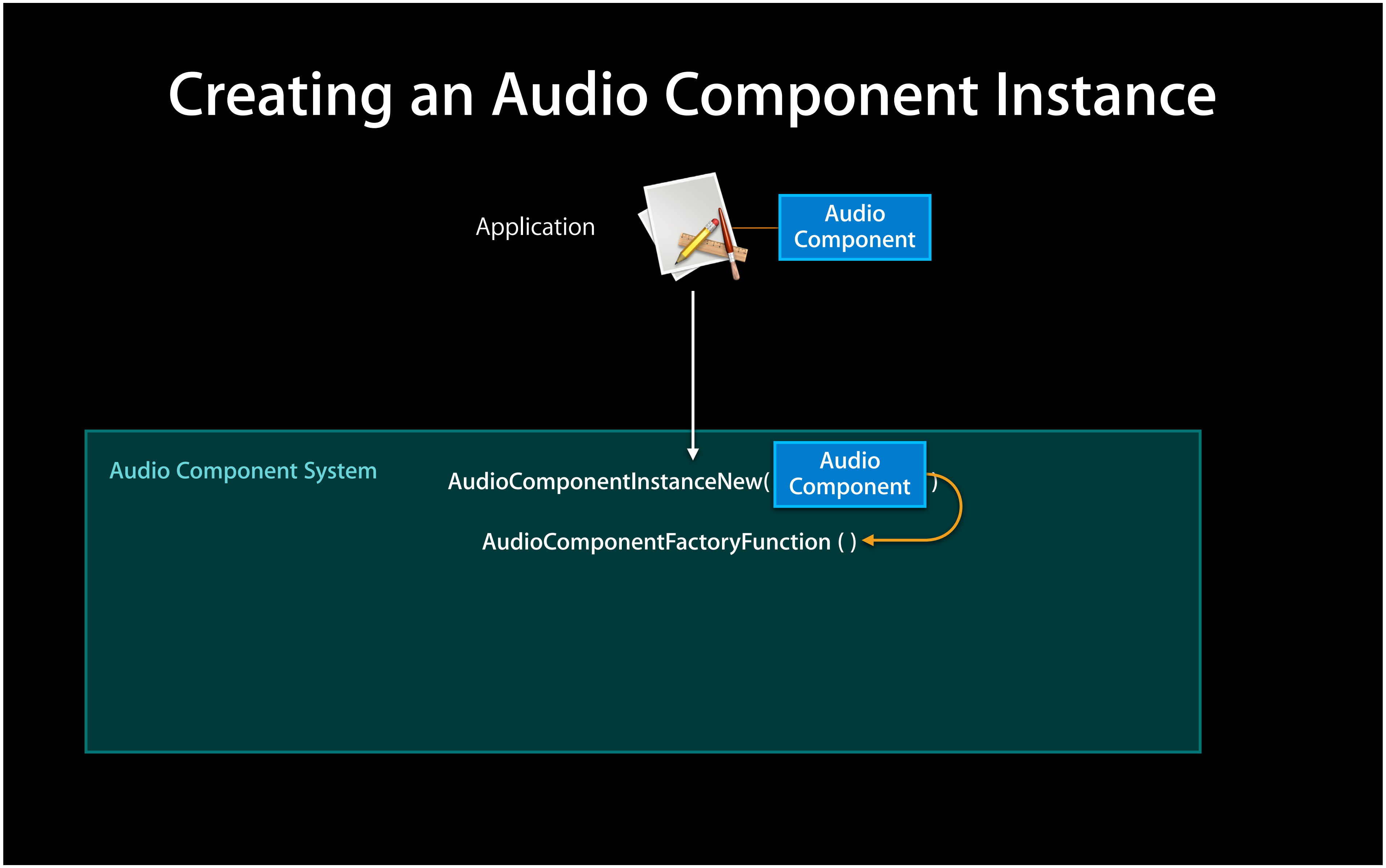
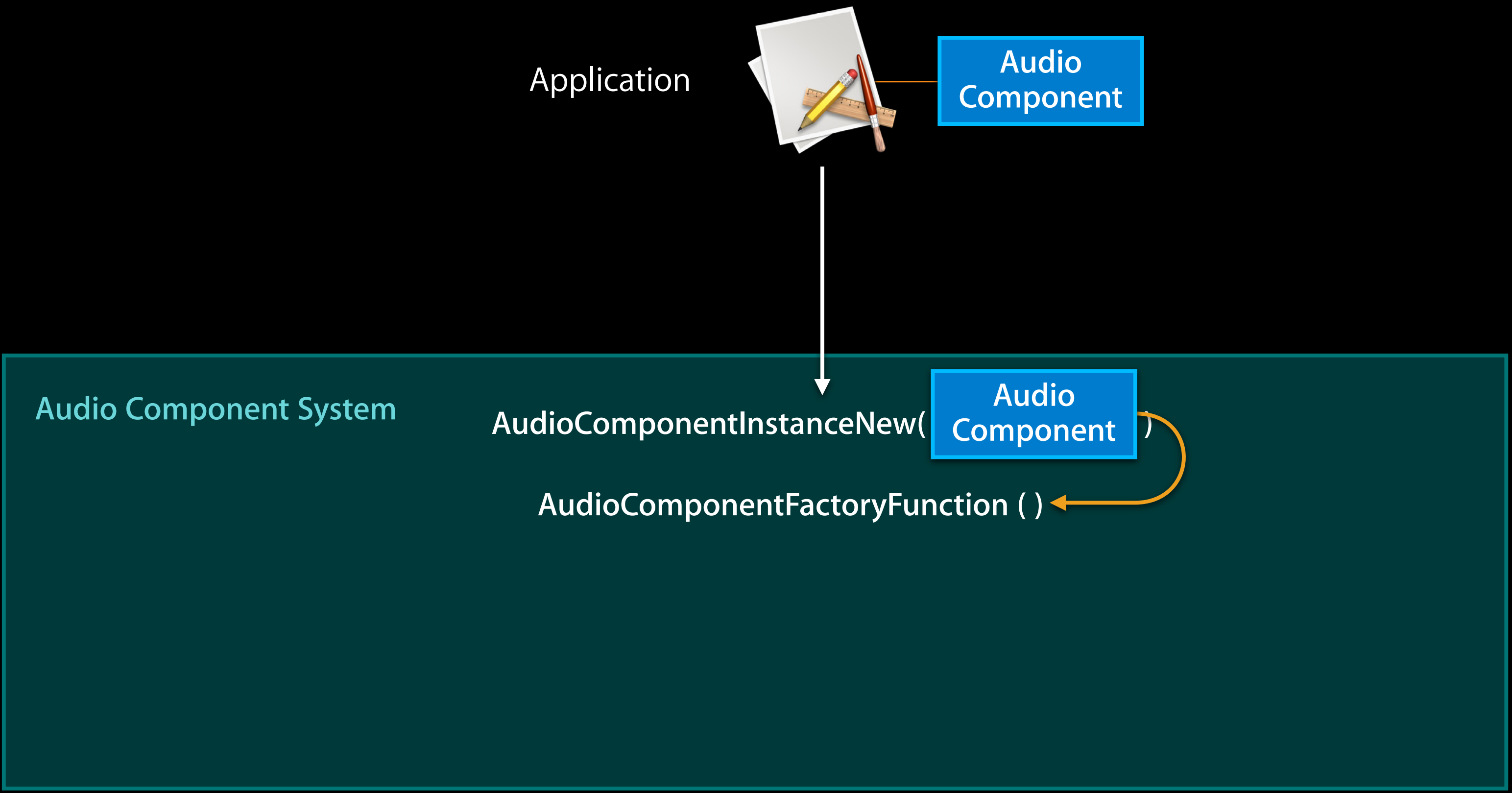


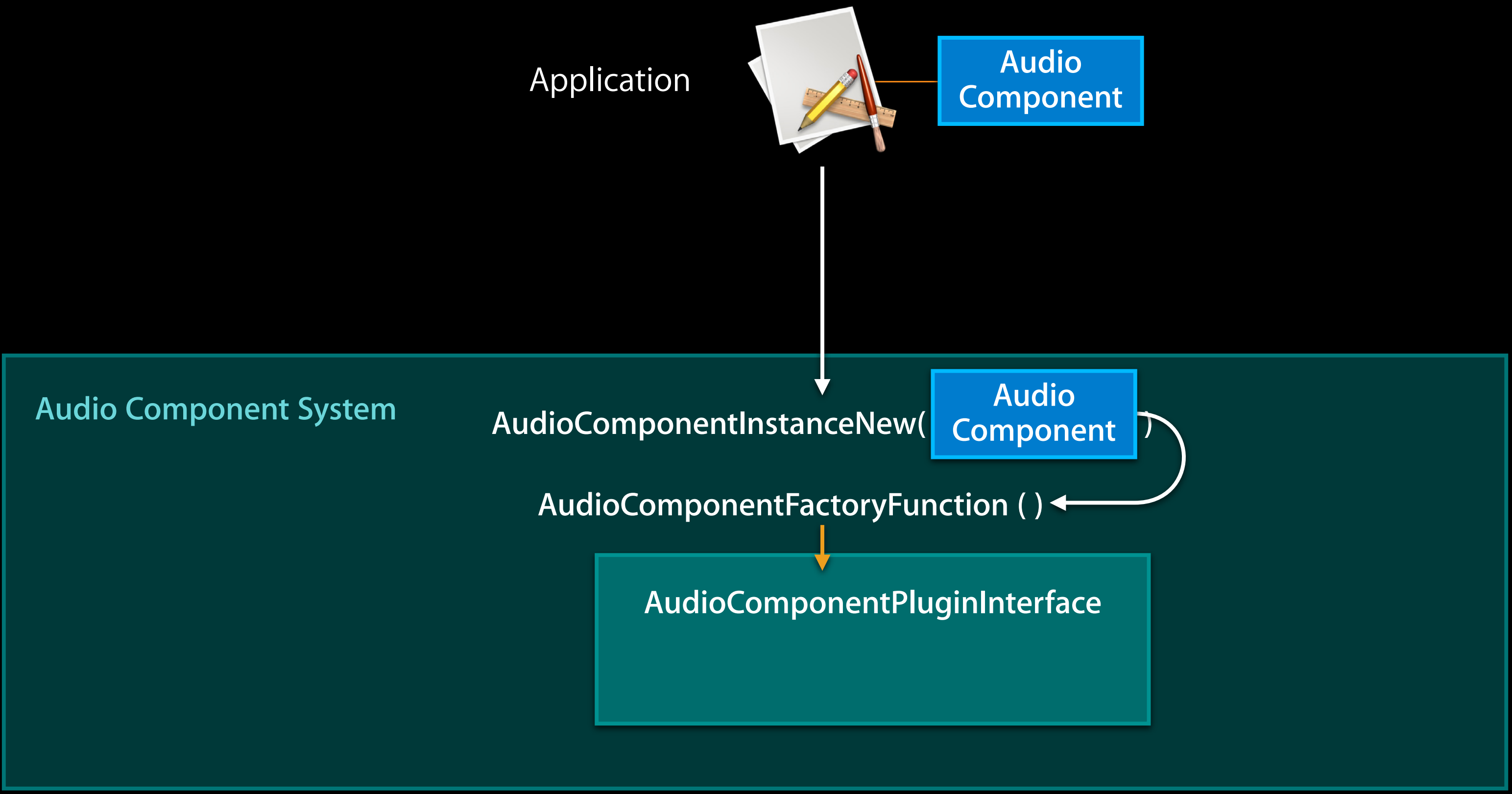
AudioComponentInstanceNew( )



Creating an Audio Component Instance


Application
Audio Component
Audio Component System
AudioComponentInstanceNew(Audio Component)
AudioComponentFactoryFunction ( )

Creating an Audio Component Instance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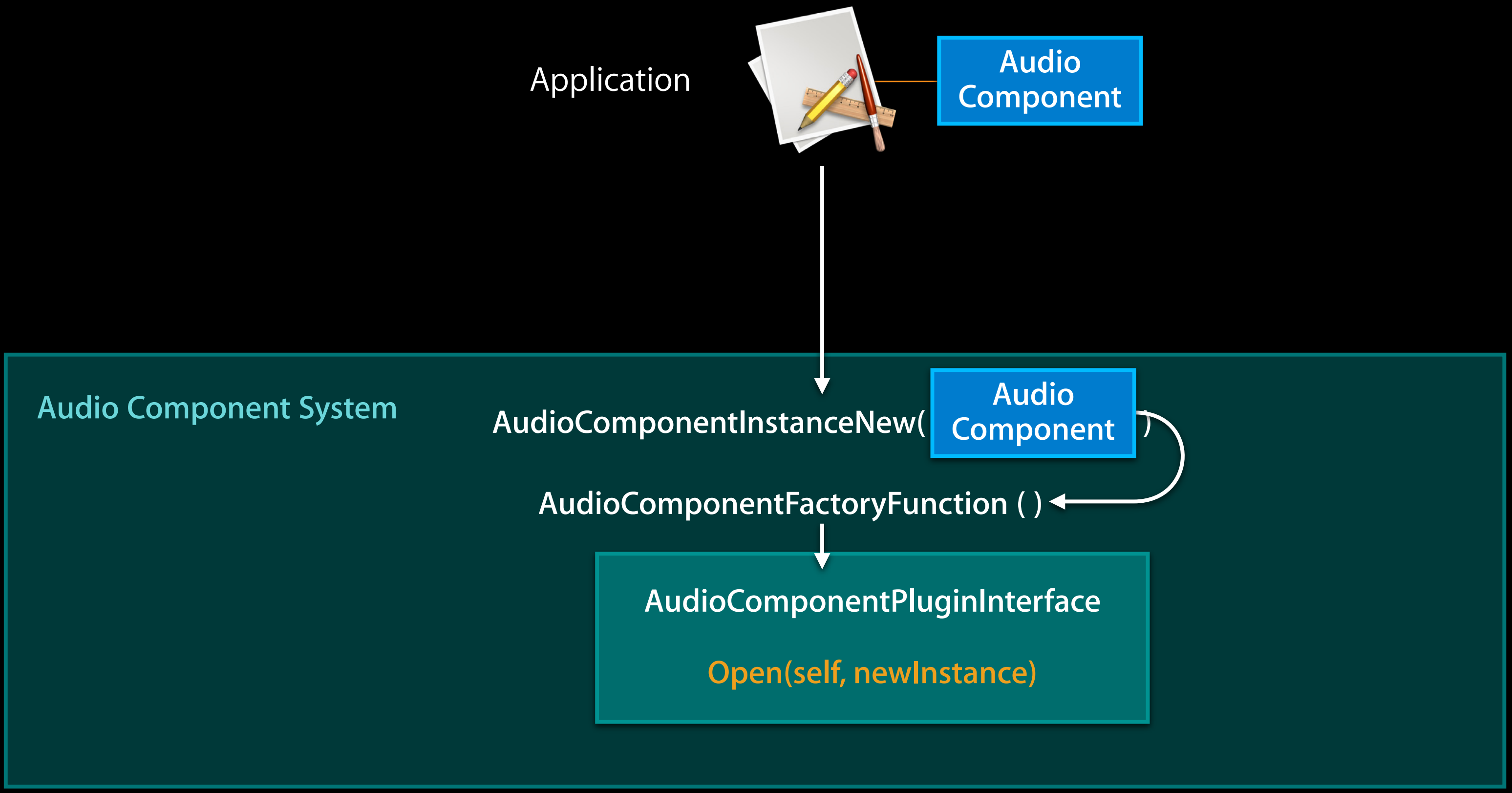
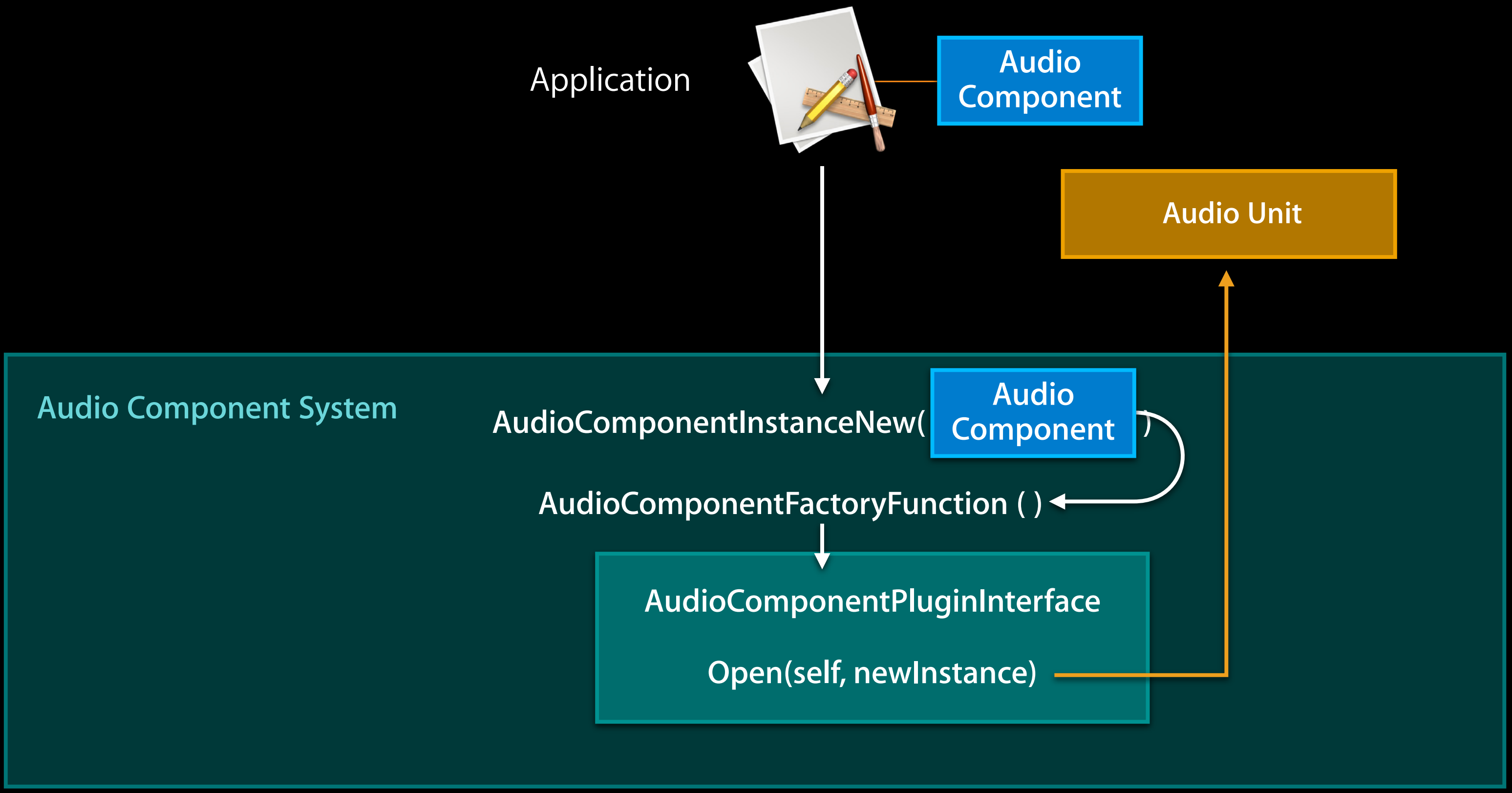
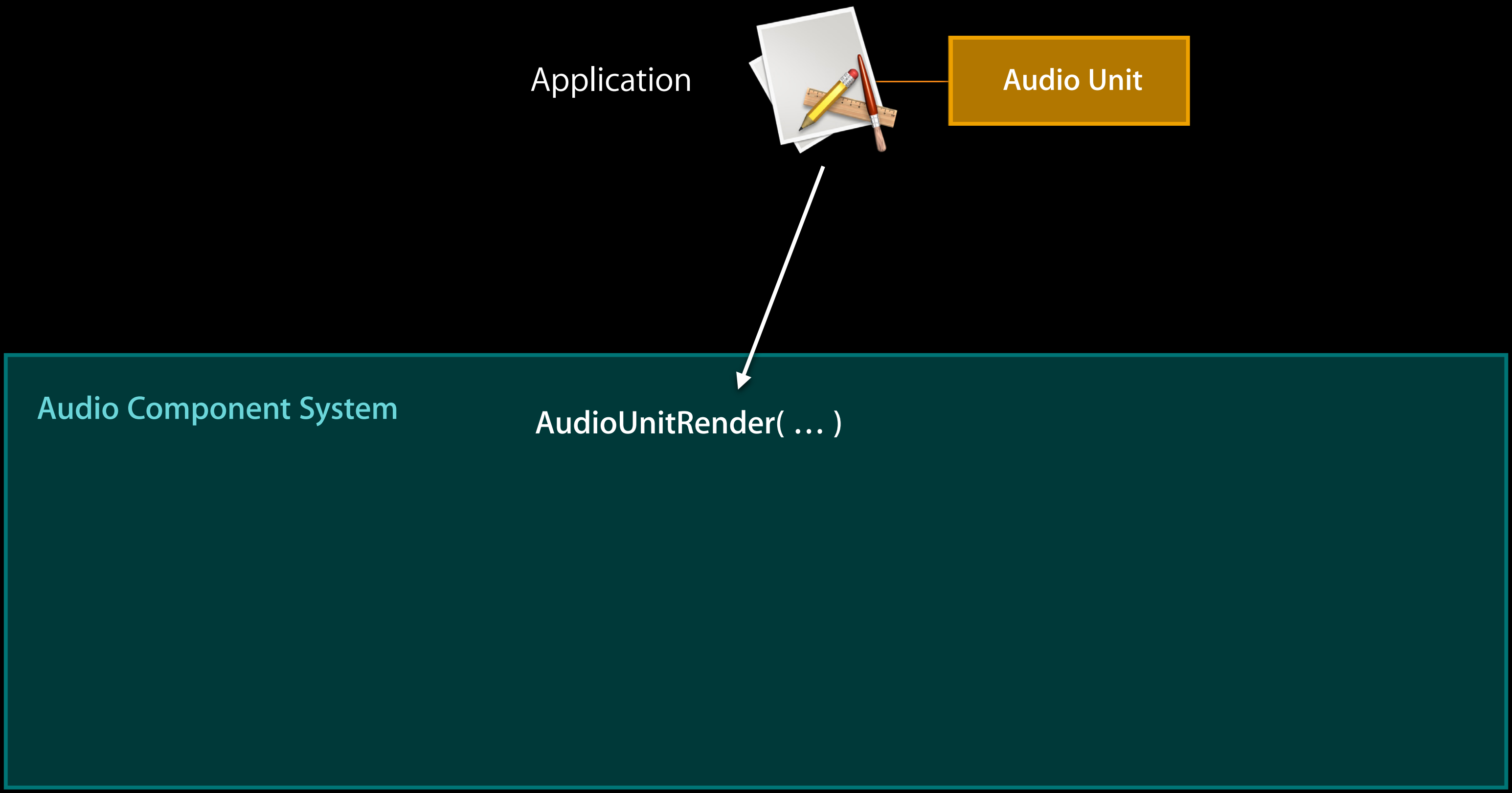


Application
Audio Component
Audio Component System
AudioComponentInstanceNew(Audio Component)
AudioComponentFactoryFunction ( )
AudioComponentPluginInterface
Open(self, newInstance)

Creating an Audio Component Instance


Application
Audio Component
Audio Unit
Audio Component System
AudioComponentInstanceNew(Audio Component)
AudioComponentFactoryFunction ( )
AudioComponentPluginInterface
Open(self, newInstance)

Calling into an Audio Unit



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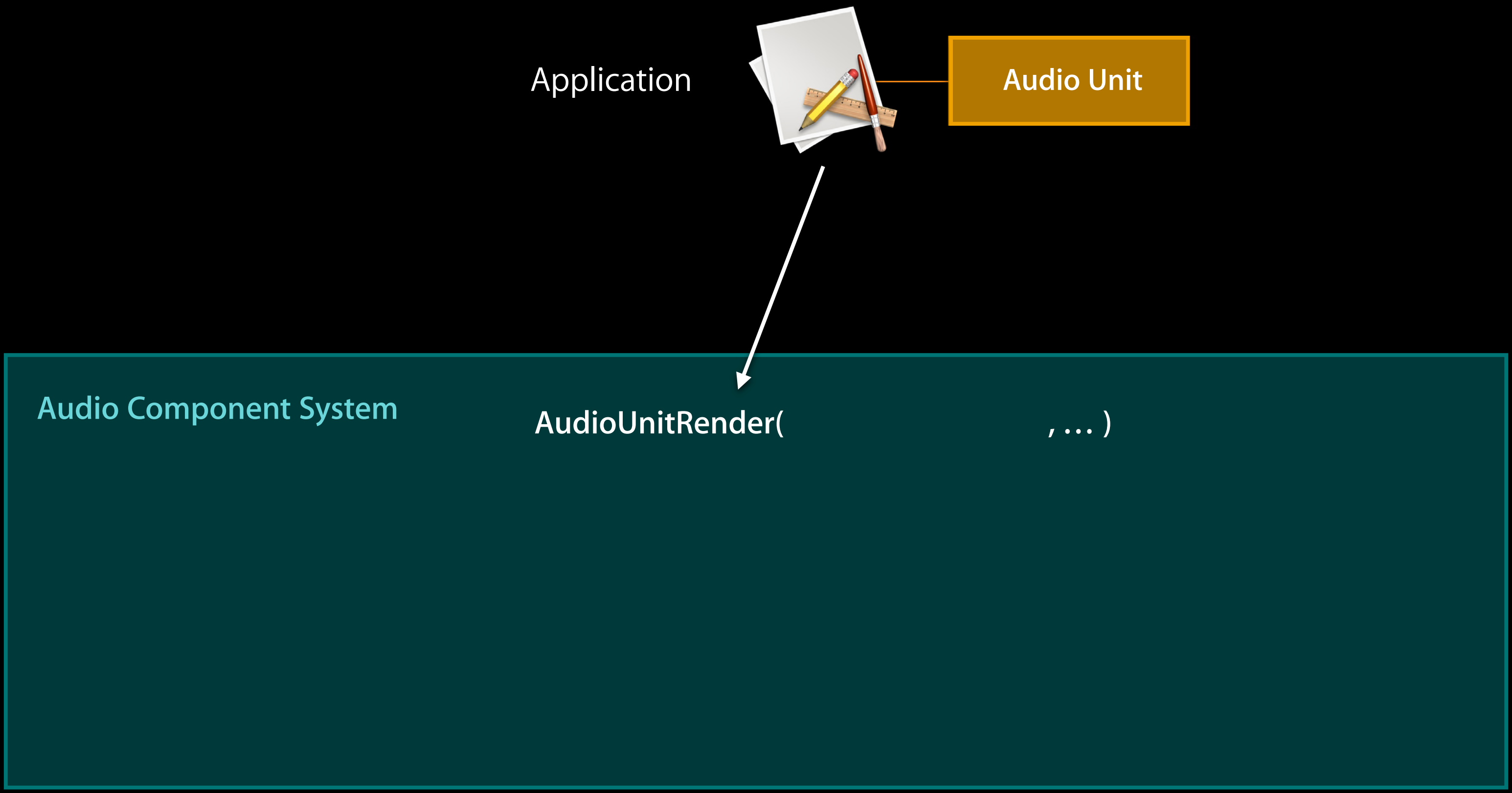
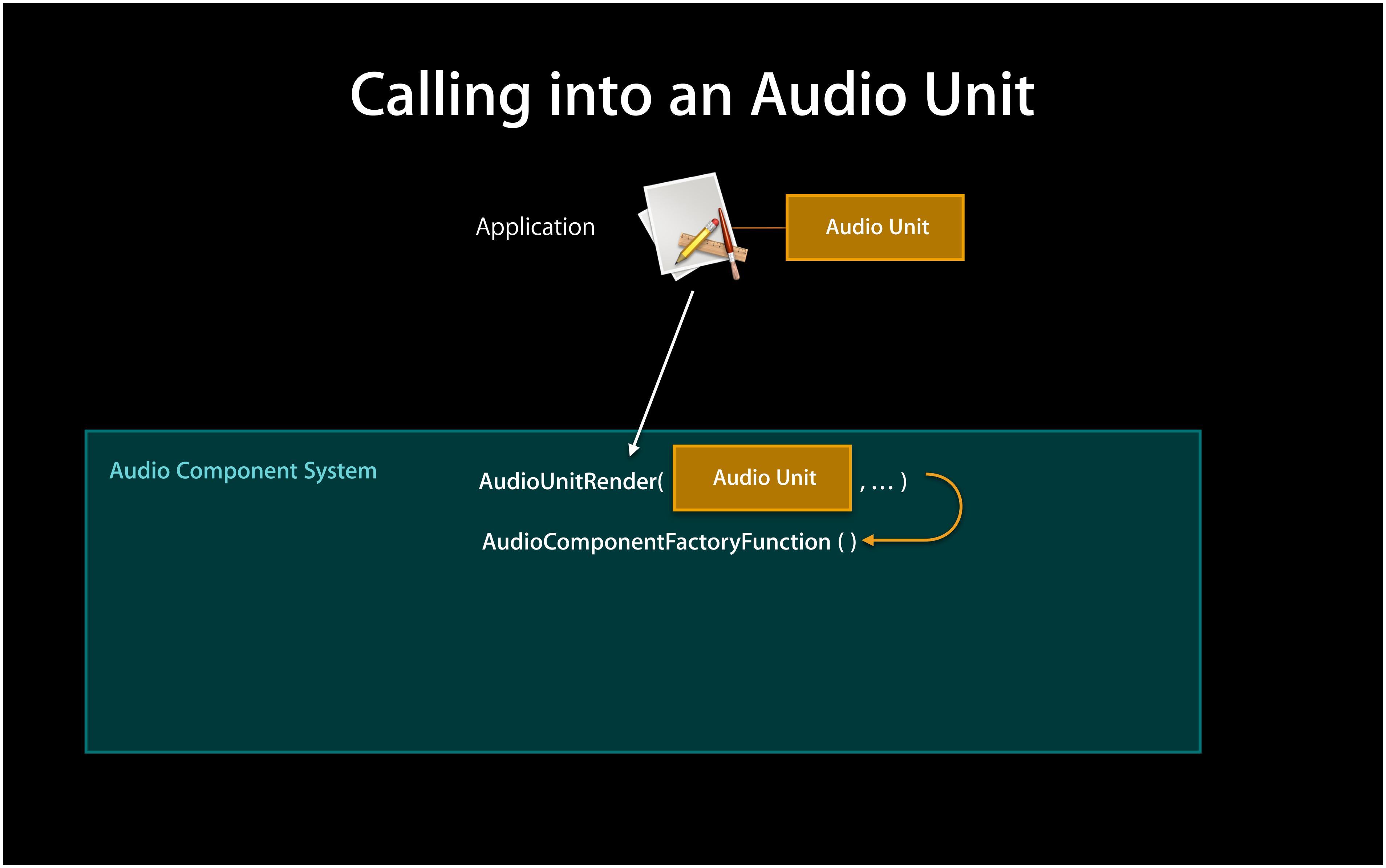
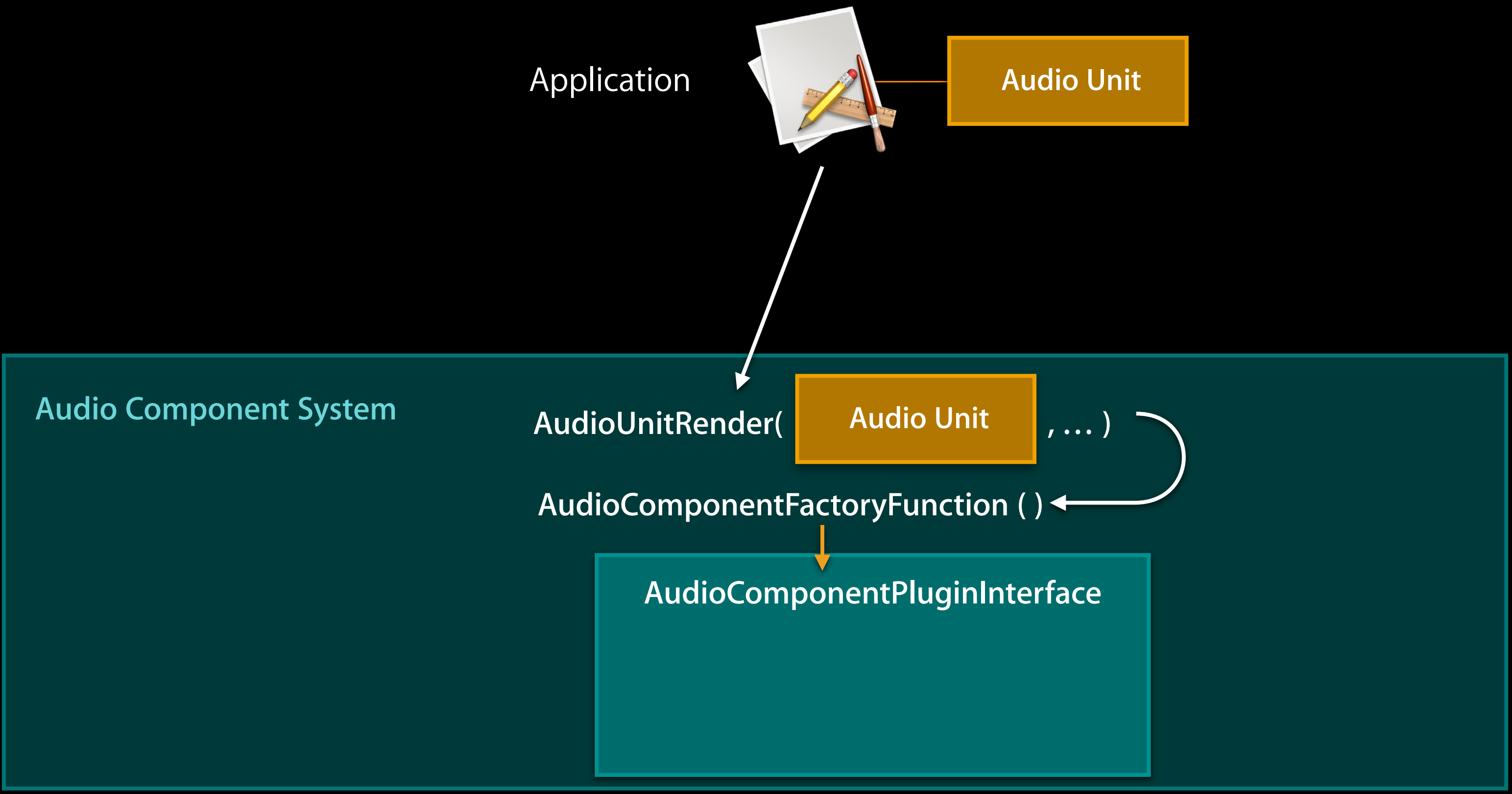




Calling into an Audio Unit

Application
Audio Unit
Audio Component System
AudioUnitRender(Audio Unit , …)
AudioComponentFactoryFunction ( )

Calling into an Audio Unit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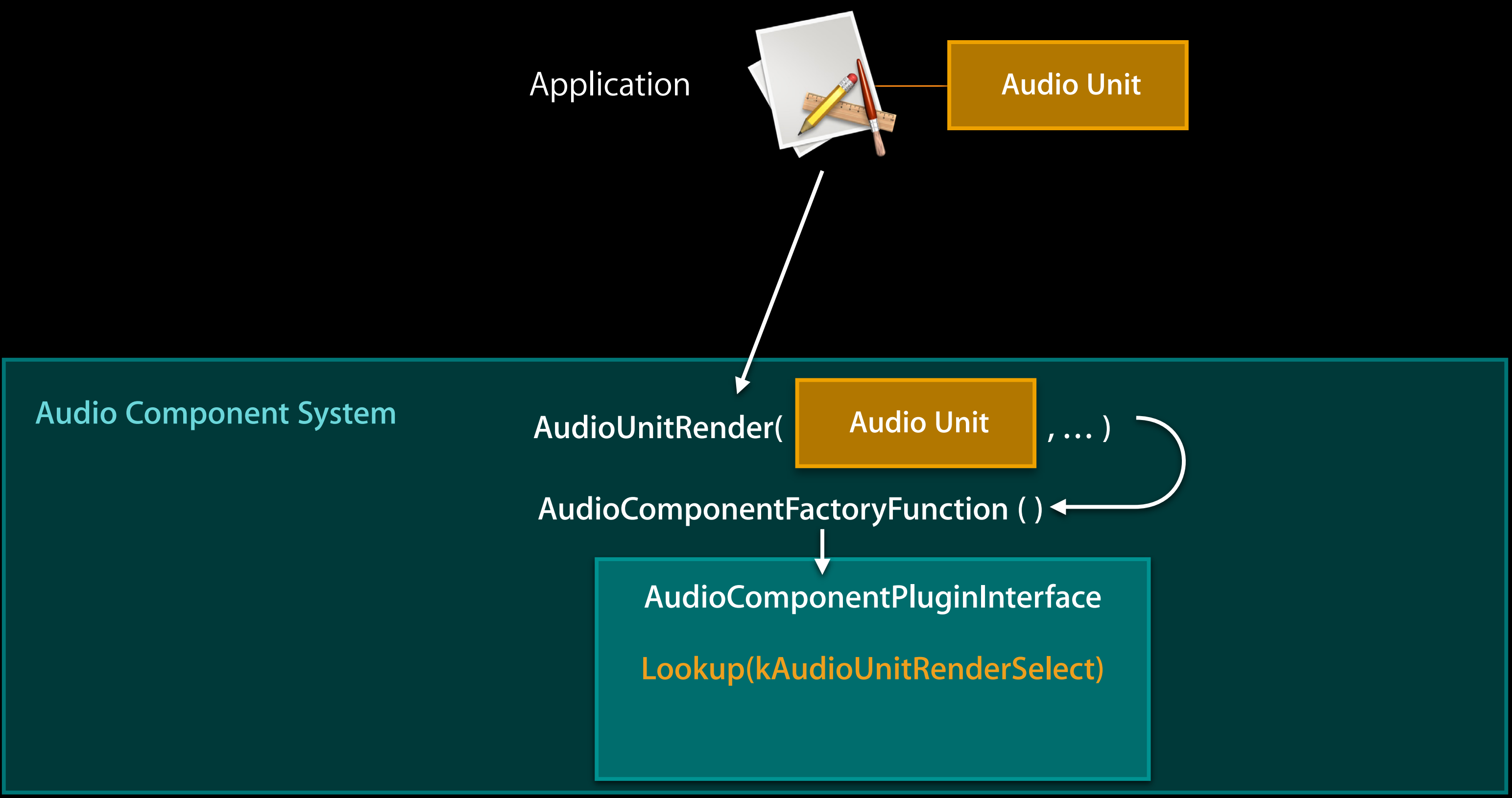
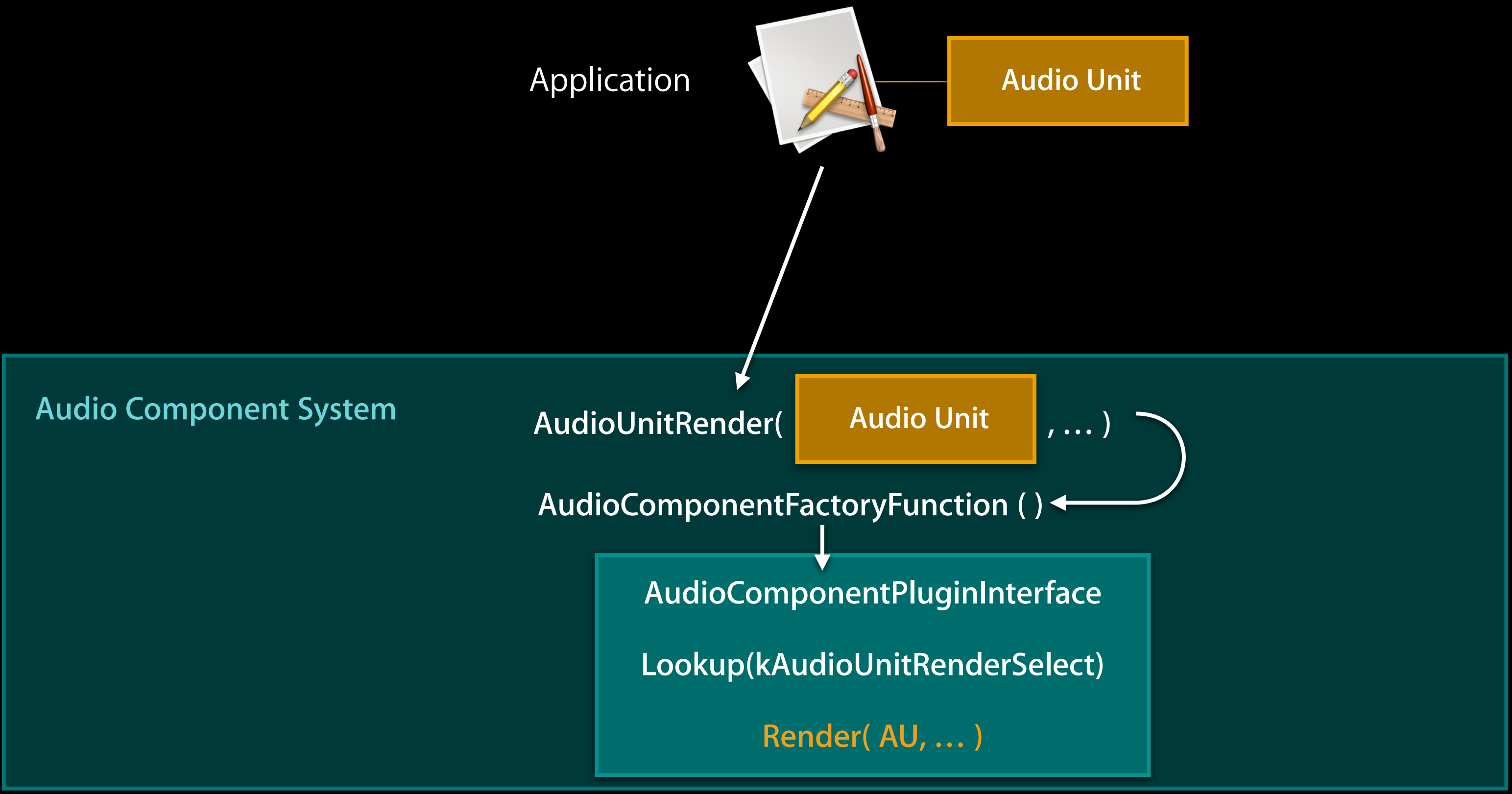
Calling into an Audio Unit


Application
Audio Unit
Audio Component System
AudioUnitRender(Audio Unit , …)
AudioComponentFactoryFunction ( )
AudioComponentPluginInterface
Lookup(kAudioUnitRenderSelect)

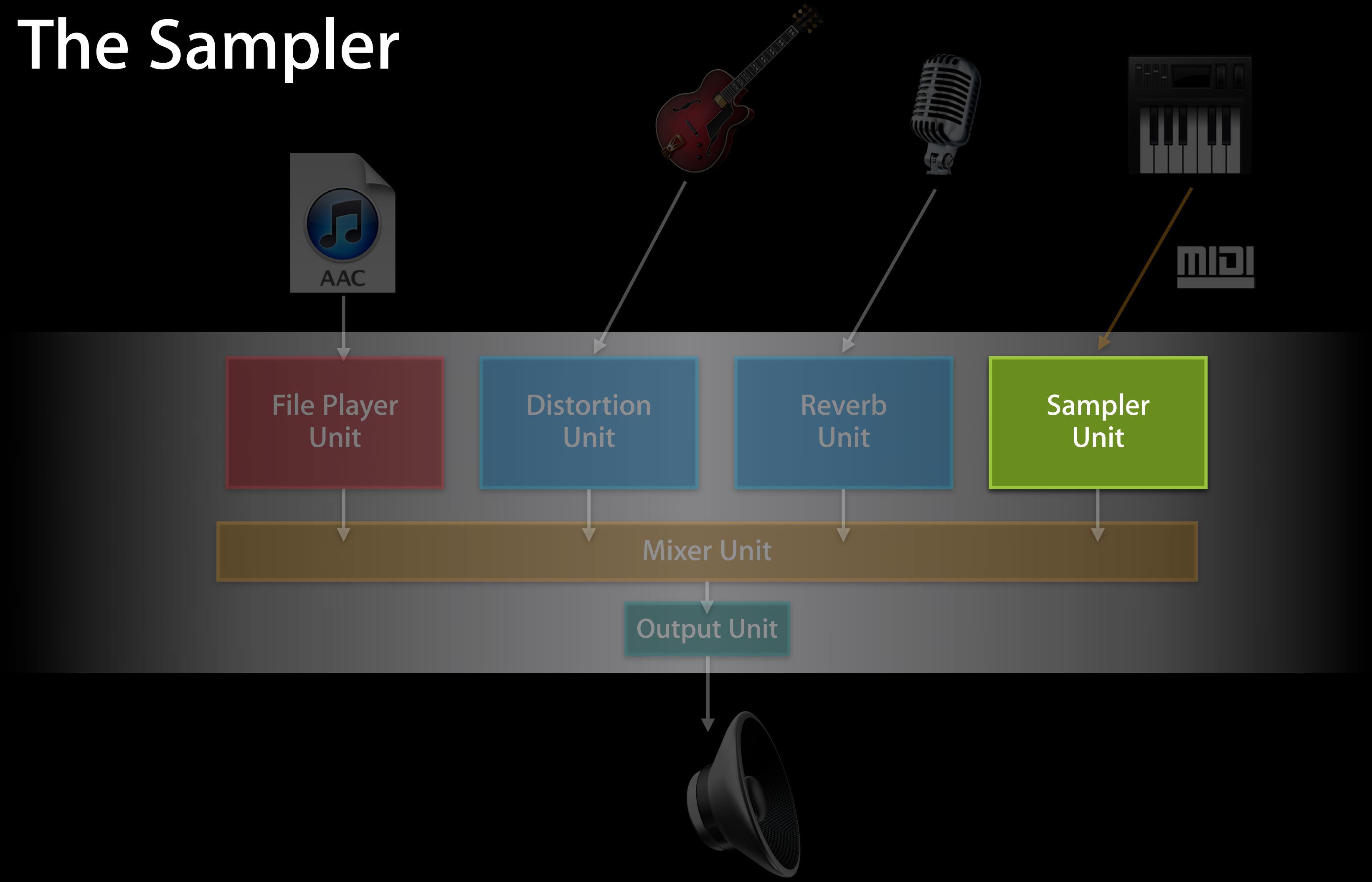
Calling into an Audio Unit


Application
Audio Unit
Audio Component System
AudioUnitRender(Audio Unit , …)
AudioComponentFactoryFunction ( )
AudioComponentPluginInterface
Lookup(kAudioUnitRenderSelect)
Render(AU, …)

The Sampler Audio Unit

Doug Scott
Core Audio Engineering

The Sampler


AAC
MIDI
File Player Unit
Distortion Unit
Reverb Unit
Sampler Unit
Mixer Unit
Output Unit

A New Instrument for iOS and Mac OS X

- What makes this an instrument?
    - Generates audio output
    - Music events trigger notes and change behavior

A New Instrument for iOS and Mac OS X

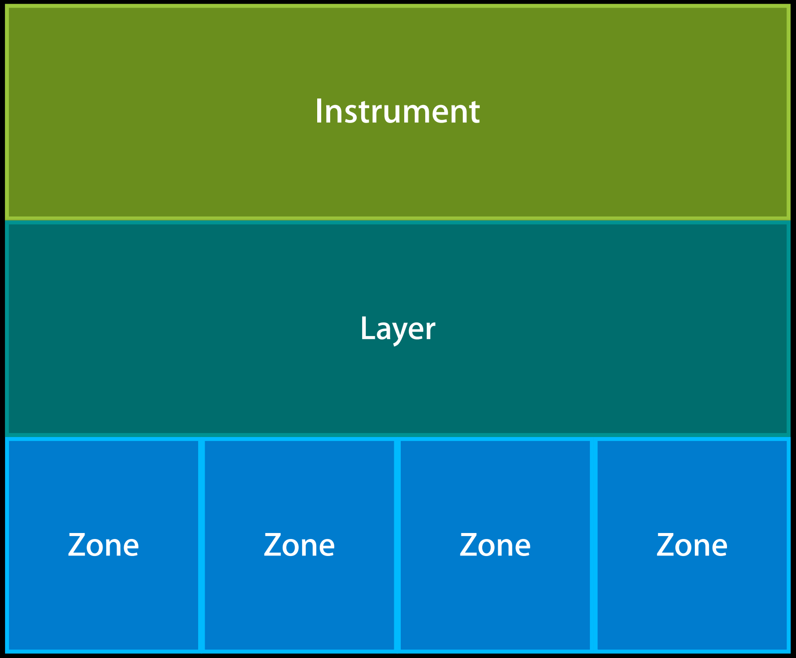
- What makes this an instrument?
  - Generates audio output
  - Music events trigger notes and change behavior
- What makes this a sampler?
  - Audio files organized as a playable instrument
    - Drum kit
    - Acoustic piano
    - Sound effects

Sampler Features

- Accepts samples in multiple formats
- Shares resources
- Streams large audio files
- Lightweight native presets
- Flexible instrument preset design
- Translates DLS and SoundFont2 instrument presets

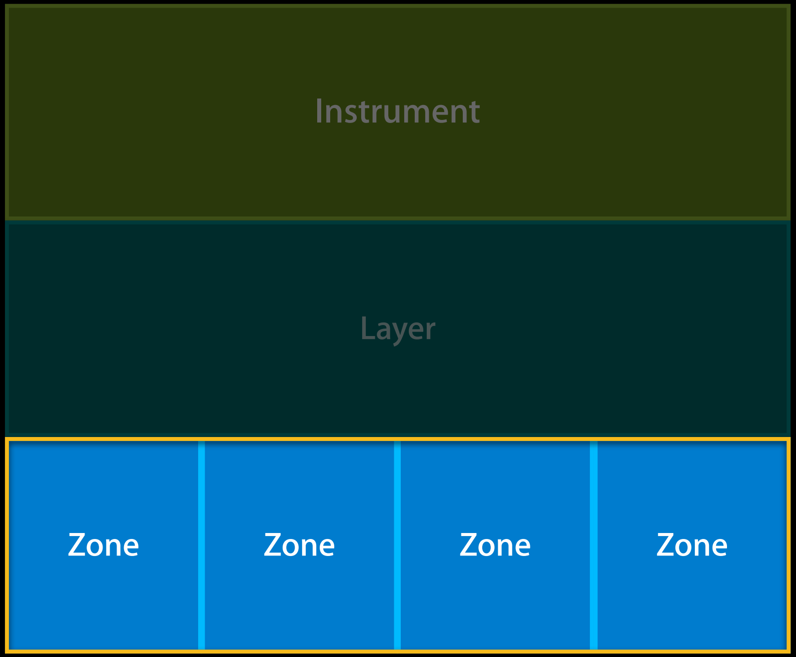
How a Sampler Patch Is Organized

A hierarchy of zones and layers



Zones

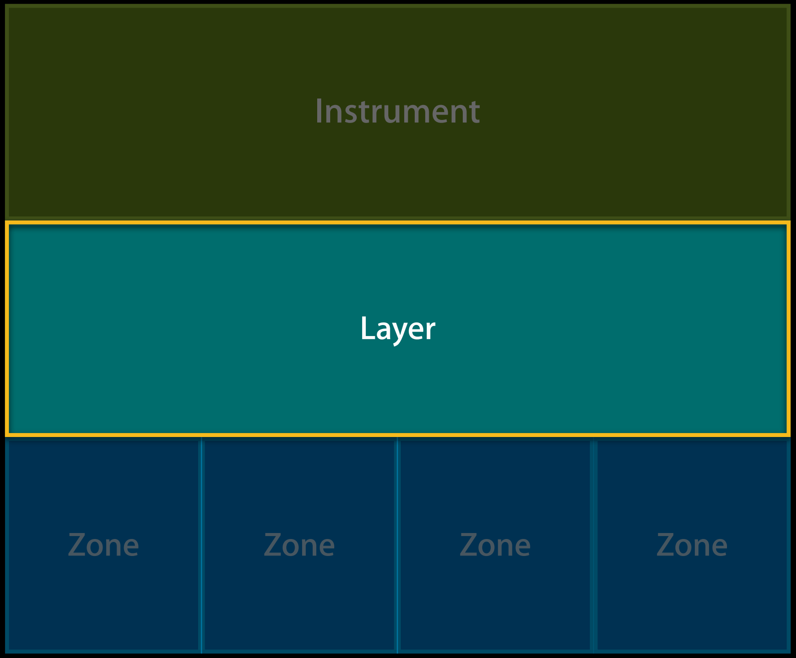
How to map each sample



- Inherit from parent layer
- Root key
- Key number range
- Key velocity range
- Waveform looping
- Gain
- Detune
- etc.

Layers

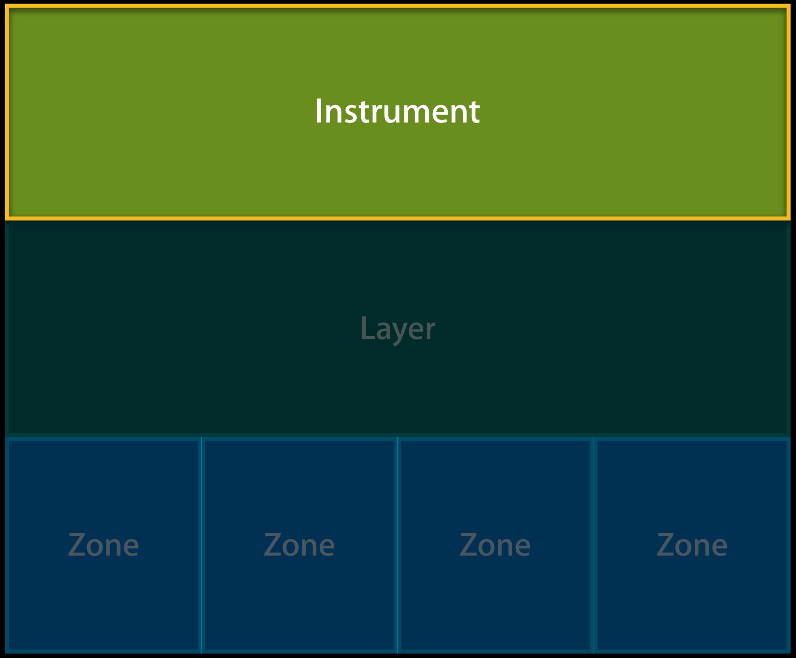
Allow zones to share common settings



- Collection of zones
- Settings for filters, LFOs, envelopes, etc.
- Modulation connections
- Zone selection
- Key offset
- etc.

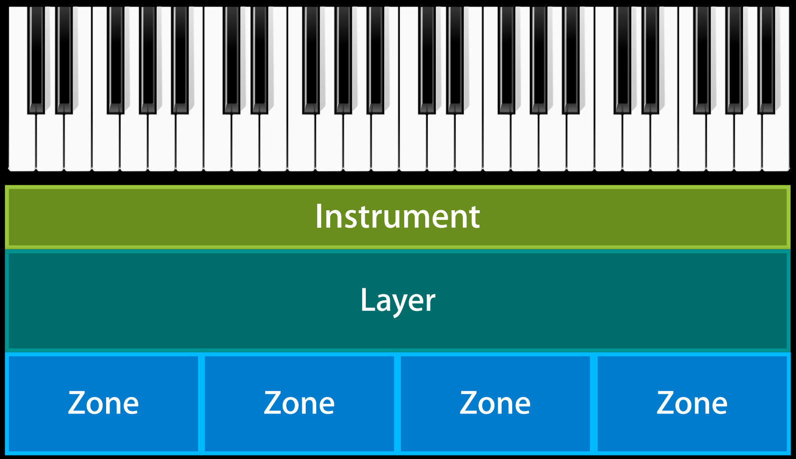
Instrument

A collection of layers



A Simple Patch

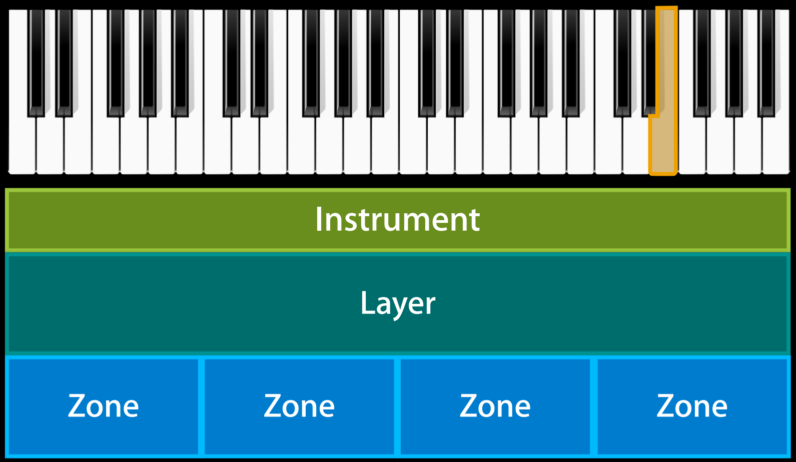
A single layer with multiple zones



- Layer spans entire keyboard
- Divided into four zones

Sampler Behavior

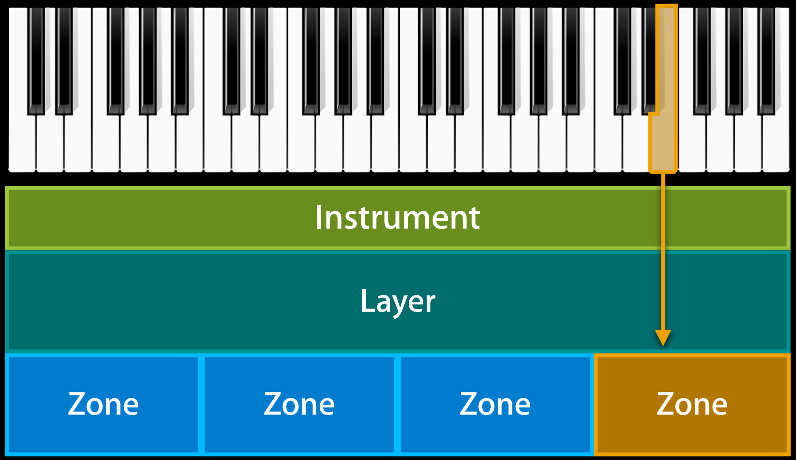
A single layer with multiple zones



- MIDI note on received

Sampler Behavior

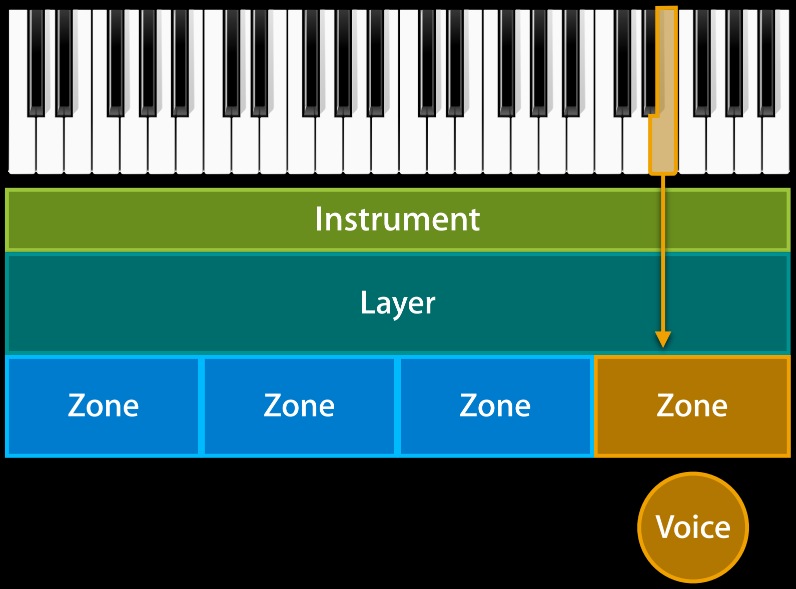
A single layer with multiple zones



- MIDI note on received
- Zone selected

Sampler Behavior

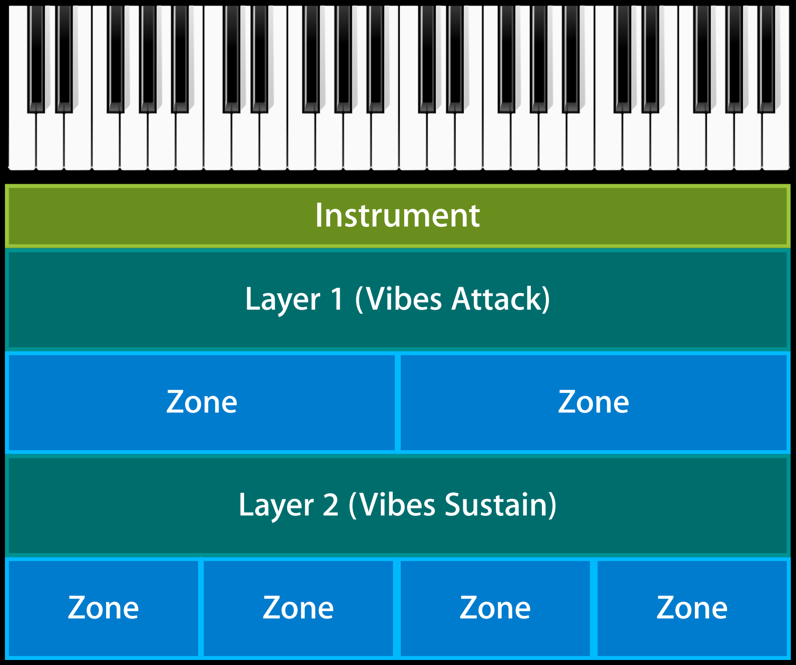
A note-on generates a single voice



- MIDI note on received
- Zone selected
- Voice is activated

A Layered Patch

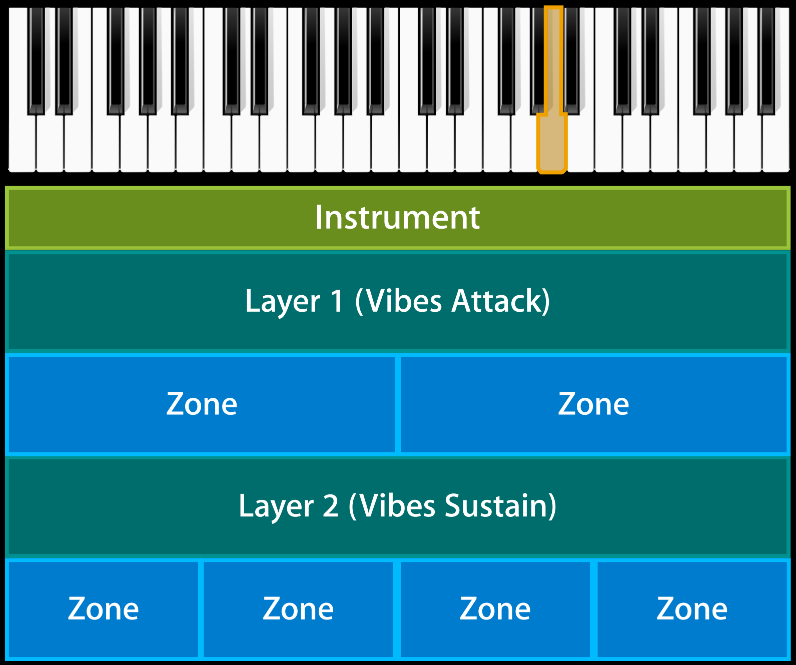
Two layers which overlap to produce a complex instrument



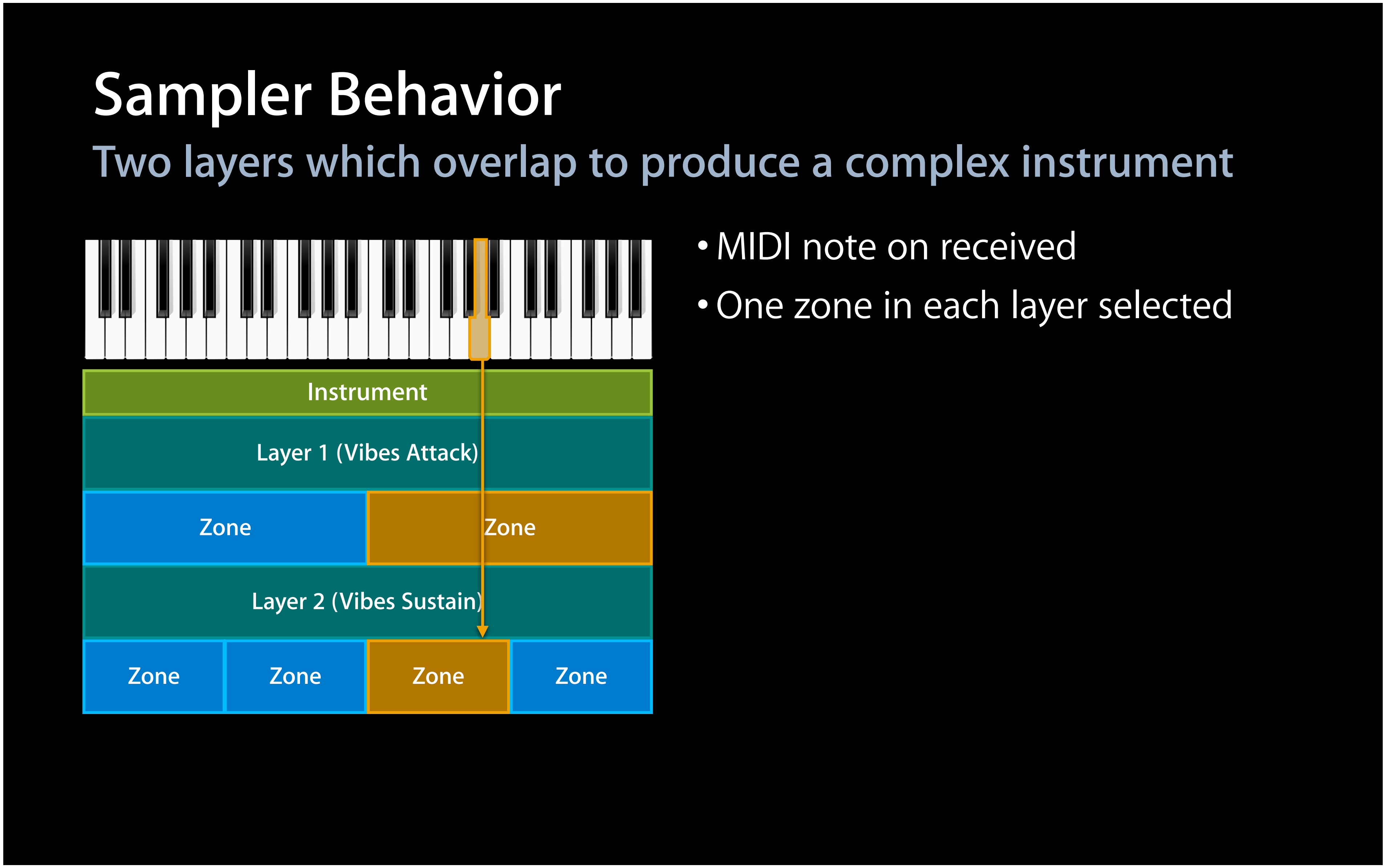
- Both layers span entire keyboard
- First layer divided into two zones
- Second layer divided into four zones

Sampler Behavior

Two layers which overlap to produce a complex instrument



- MIDI note on received



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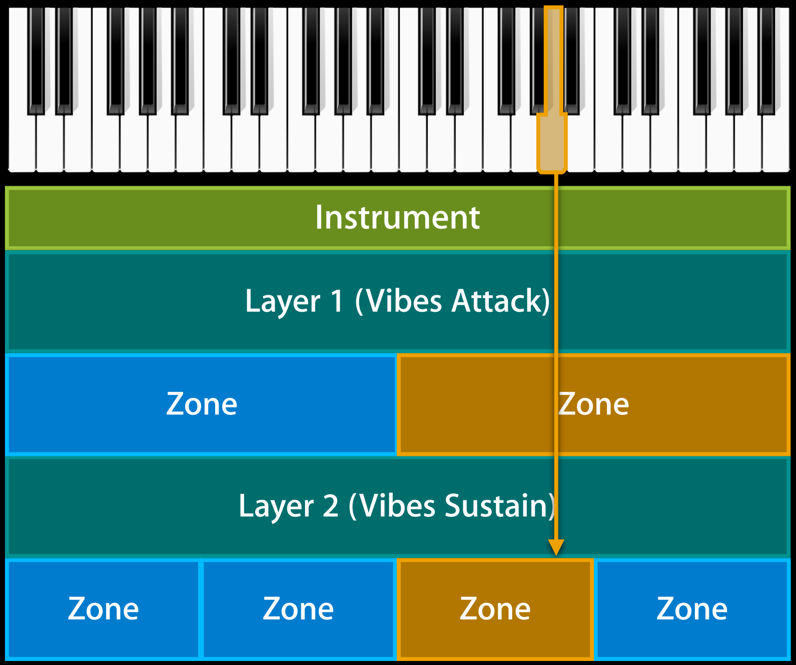
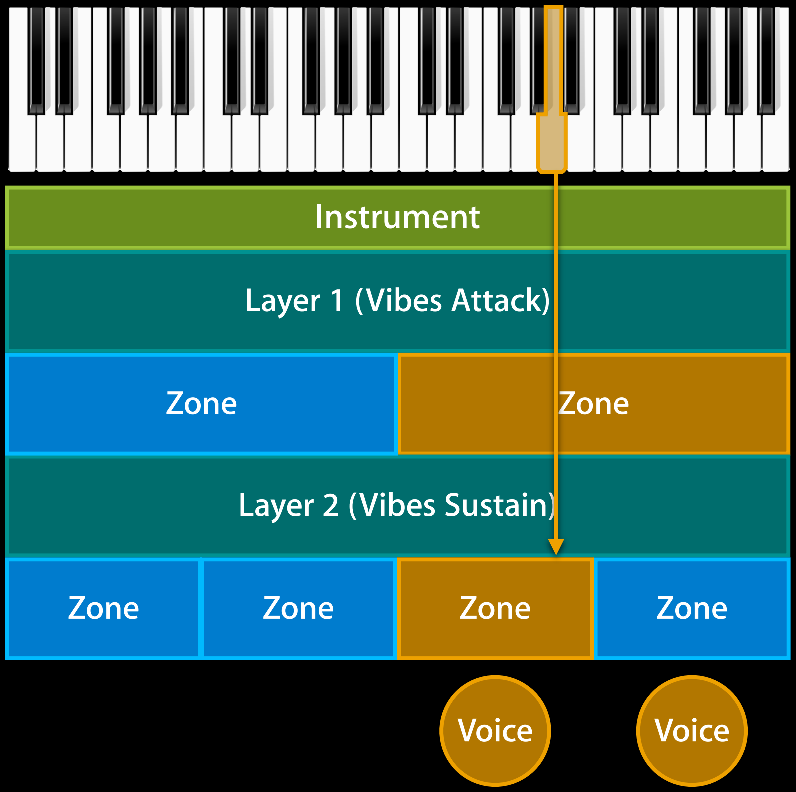


- MIDI note on received
- One zone in each layer selected

Sampler Behavior

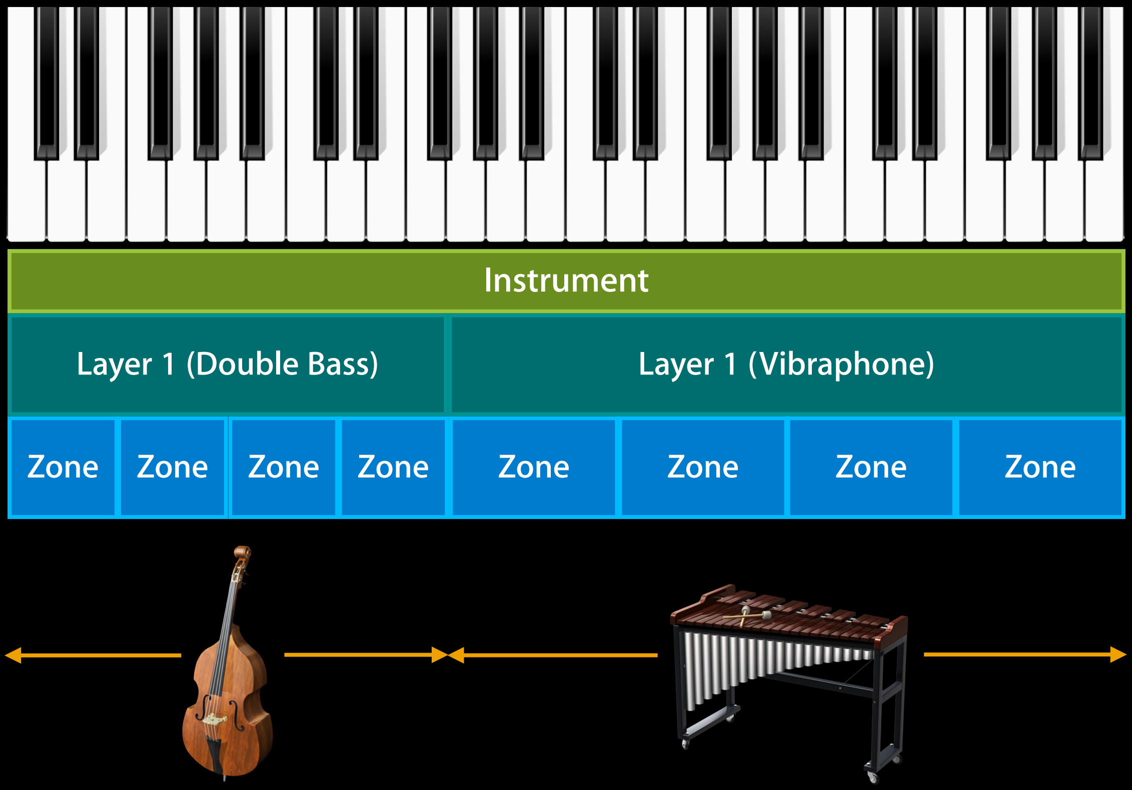
A note on generates two voices



- MIDI note on received
- One zone in each layer selected
- Two voices are activated

Example of a Complex Patch

Keyboard split into two instrumental timbres



Demo

The Sampler’s Custom View and Presets

Doug Scott
Core Audio Engineering

Configuring the Sampler

Loading a patch

- AUPreset file
- Build from set of audio files
- DLS bank or SoundFont 2 files

Loading a Patch Using an AUPreset File

- Audio file assets in app bundle’s resource directory (required on iOS)
- Convert the preset file into a PropertyList
- Load using the ClassInfo property

```
OSStatus result;
result = AudioUnitSetProperty(mySamplerUnit,
                              kAudioUnitProperty_ClassInfo,
                              kAudioUnitScope_Global,
                              0,
                              &presetPropertyList,
                              sizeof(CFPropertyListRef));
```

Creating a Patch from Audio Files

A new custom instrument

- Audio files in app bundle's resource directory (required on iOS)
- Audio file's instrument chunk
  - Sample loop
  - Key range
  - etc.

Loading a Patch from a Sound Bank

Sampler translates DLS and SoundFont2 patches

- Bank file in app bundle's resource directory (required on iOS)
- Select a preset
    - Bank ID
    - Instrument ID
- Load using AudioUnitSetProperty

Demo

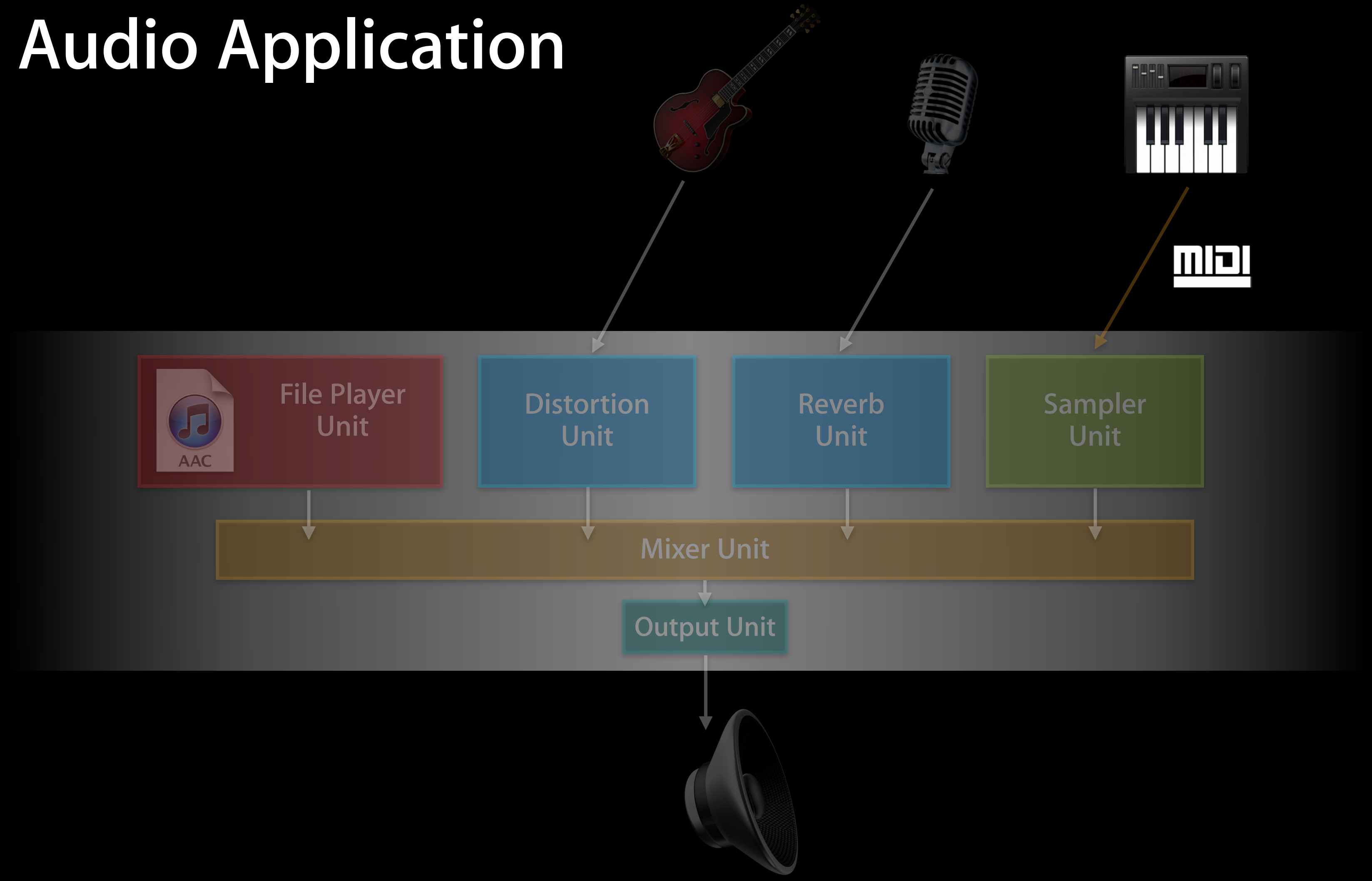
Using a Sampler AUPreset in Your App

Doug Scott
Core Audio Engineering

Introduction to CoreMIDI in iOS

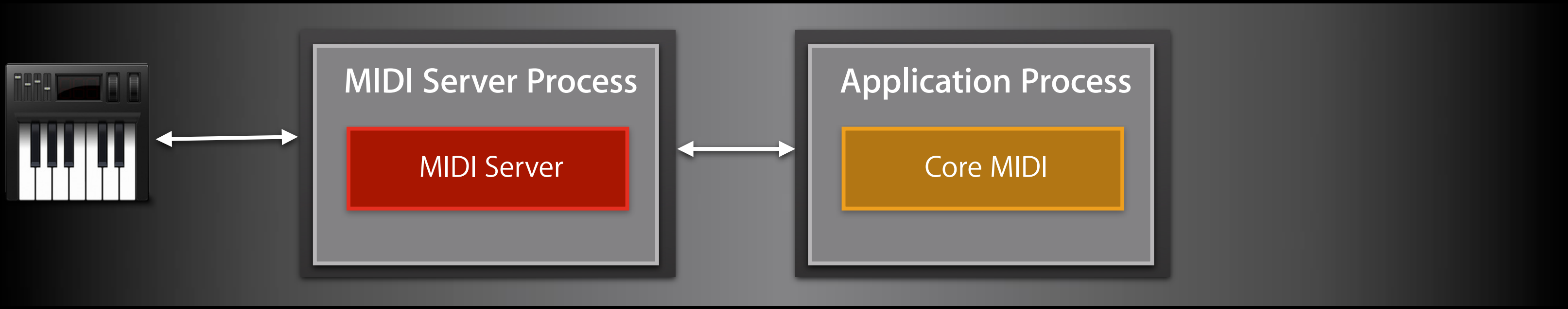
Michael Hopkins
Core Audio Engineering

Audio Application



What Is CoreMIDI?

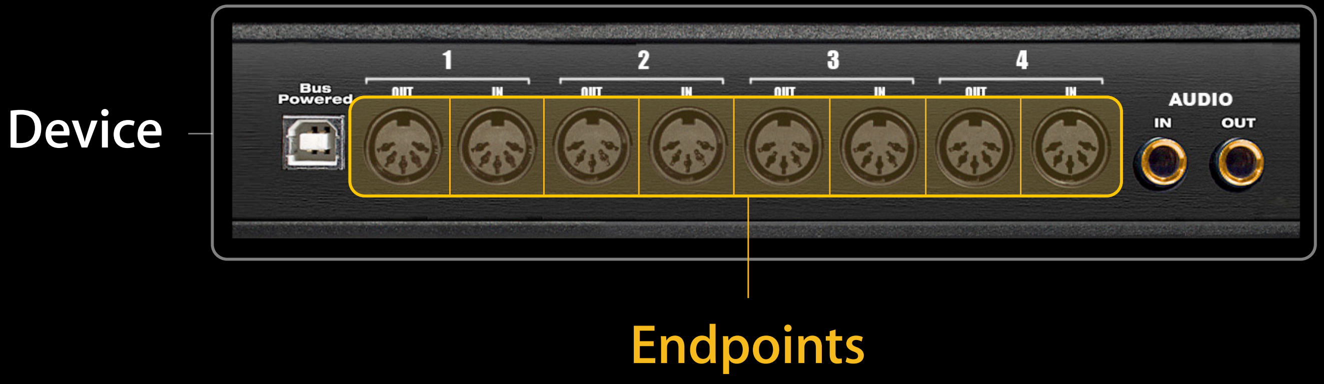
- A set of services that applications can use to communicate with MIDI devices
- Provides abstractions for interacting with a MIDI network



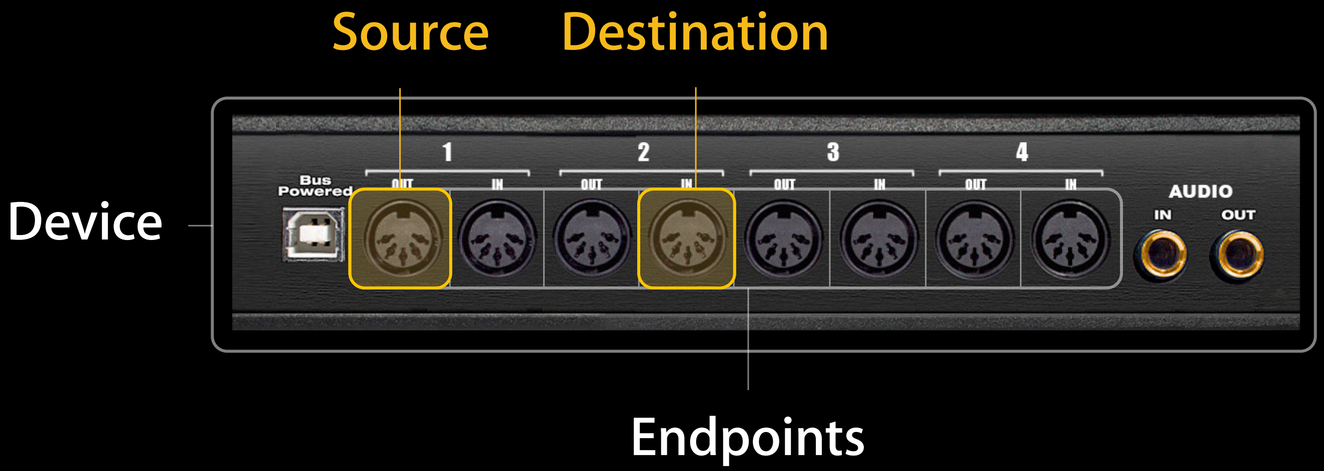
MIDI Devices

Device

MIDI Devices



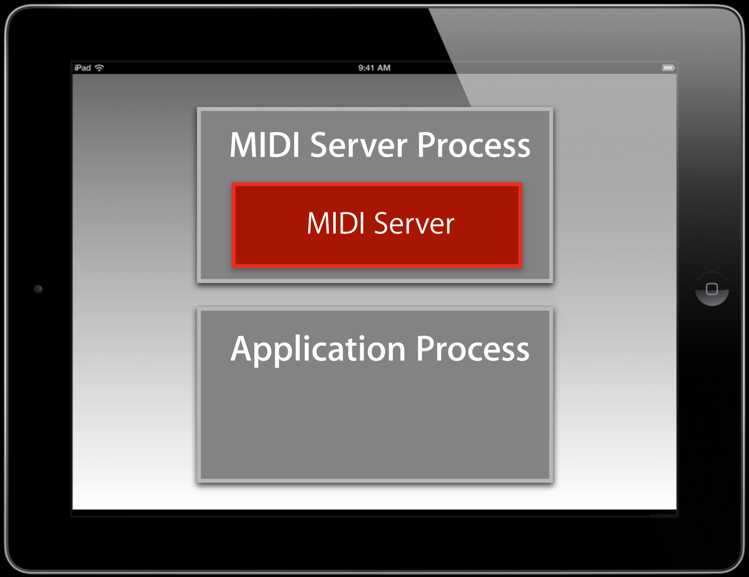
MIDI Devices



Handling Device Notifications

Plugging in a new device

- Application needs to create a client object
- MIDI Server calls application's MIDINotifyProc() when
  - Device changes
  - Property changes
  - Setup changes



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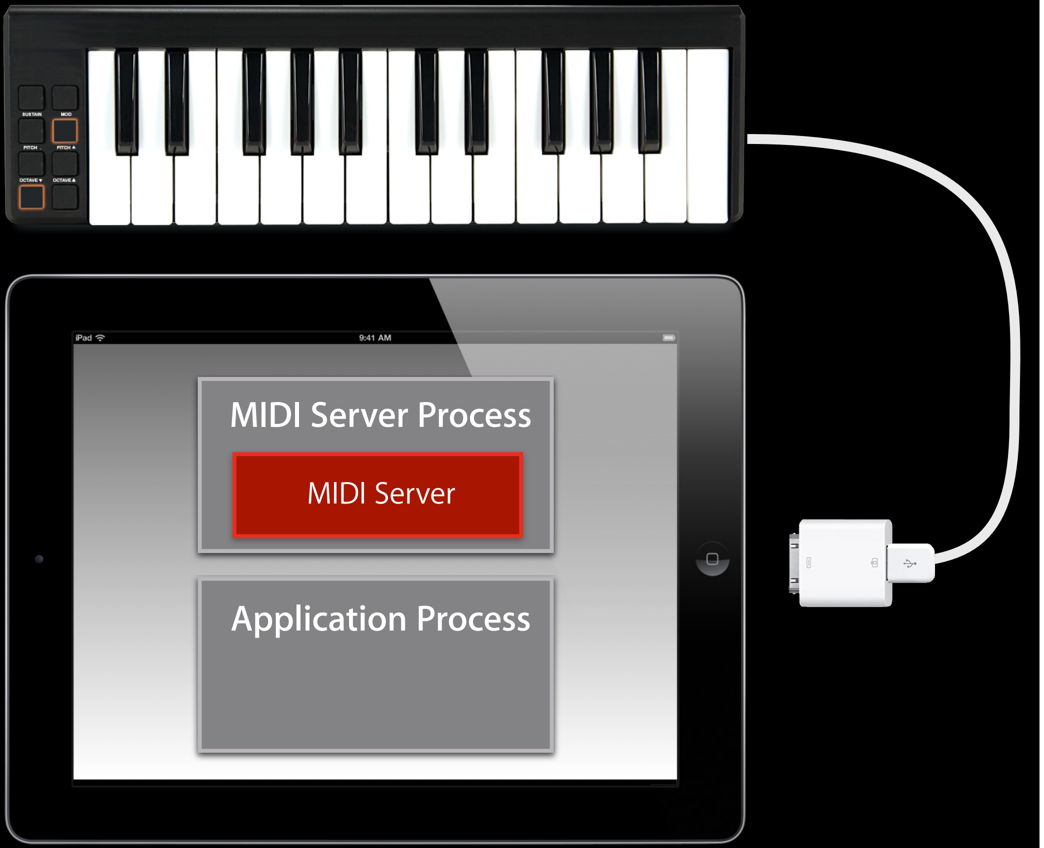

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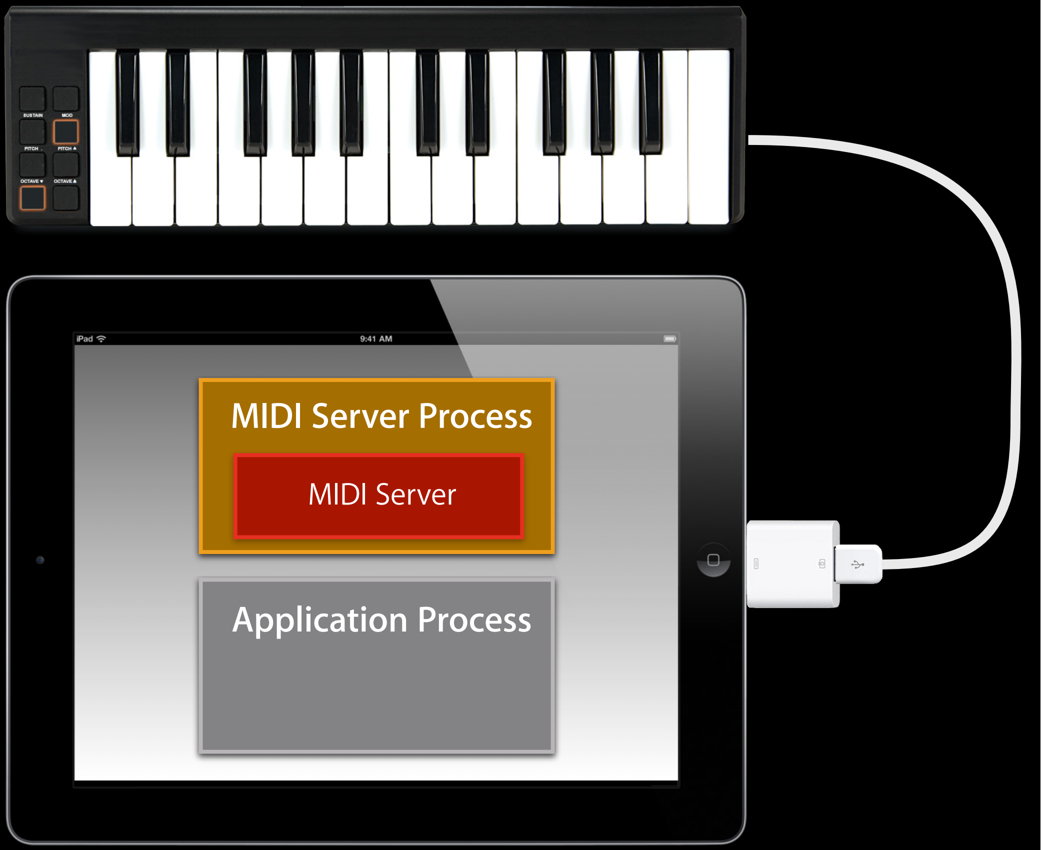

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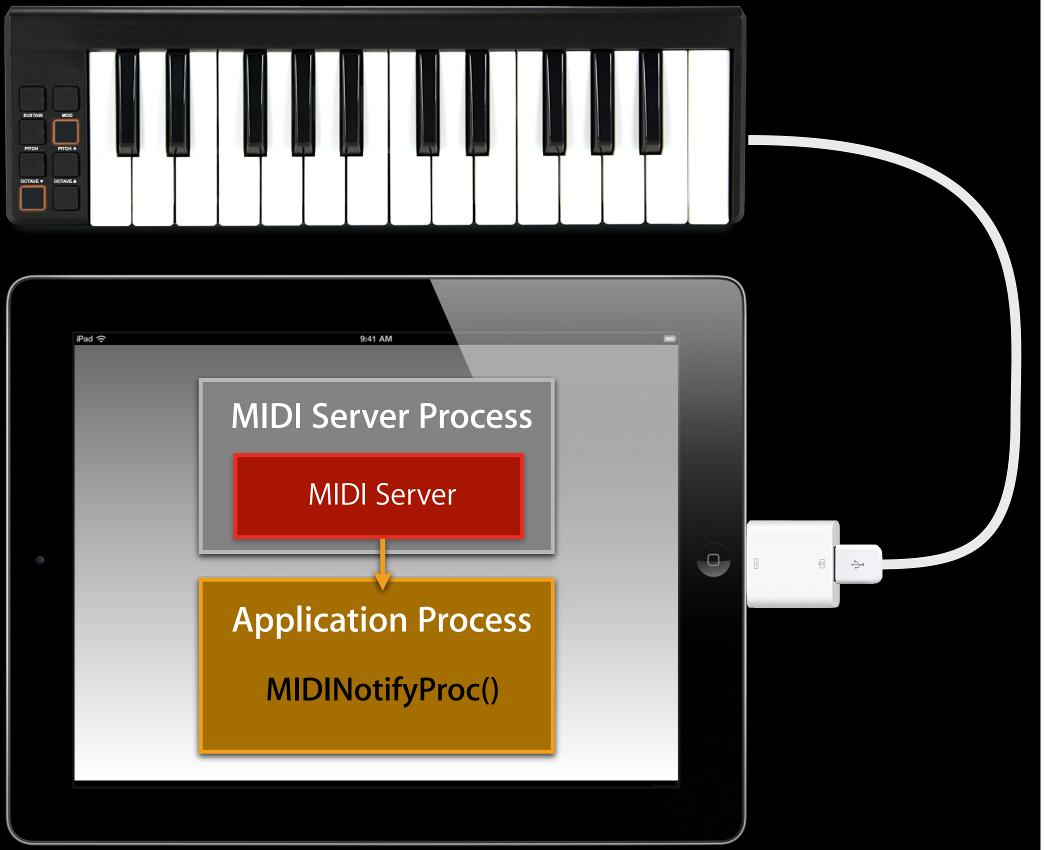


CoreMIDI Properties

- Properties can get information about devices, entities, or endpoints
  - Name
  - Manufacturer
  - Unique ID
  - Offline state
  - Receive and transmit channels
  - Current patch
  - MIDI settings
    - Supports General MIDI
    - Supports MMC
    - Receives/transmits clock

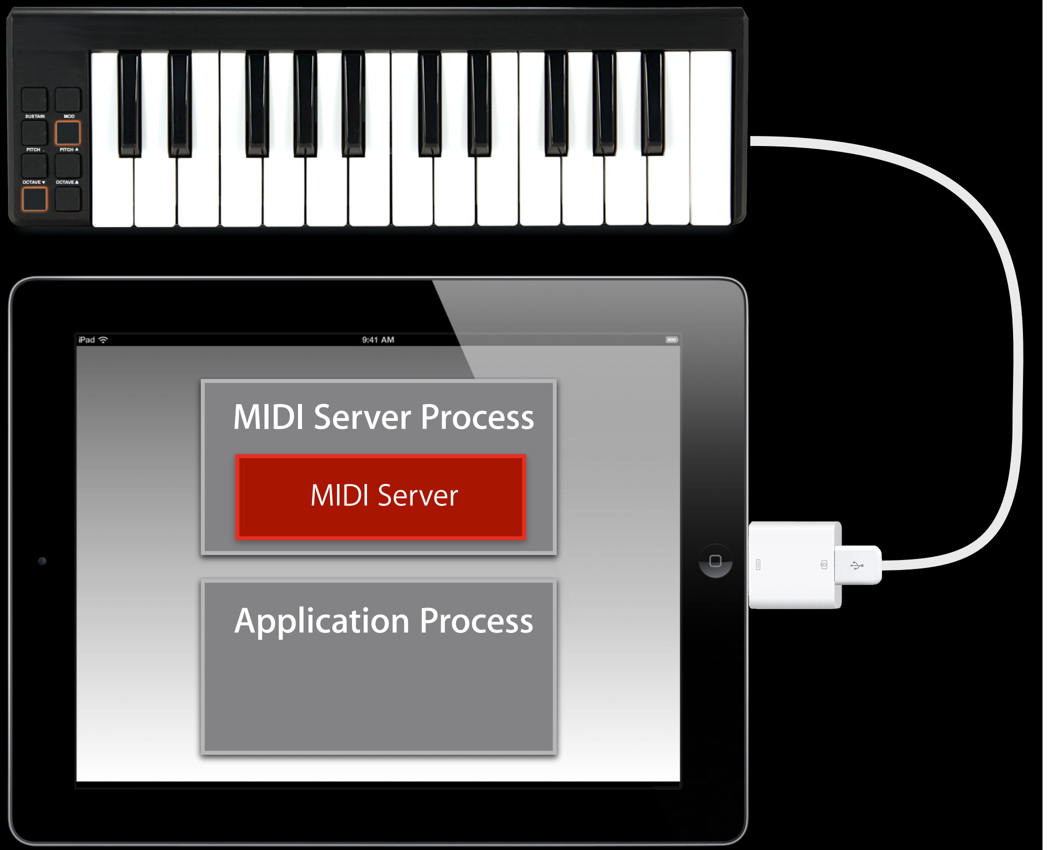
Creating a MIDIClient

```
void MIDINotificationHandler(const MIDINotification *inMsg, void *inRefCon)
{
    switch (inMsg->messageID) {
        case kMIDIMsgPropertyChanged:
            ...
        break;
    }
}
```

```
MIDIClientRef midiClient;
OSStatus result = MIDIClientCreate(CFSTR(“My Client”),
                                   MIDINotificationHandler,
                                   NULL, &midiClient);
```

Getting MIDI Data

- Application needs to create a MIDI input port
- MIDI Server calls application's MIDIReadProc() when MIDI messages are received
- Provides a packet list of MIDI events



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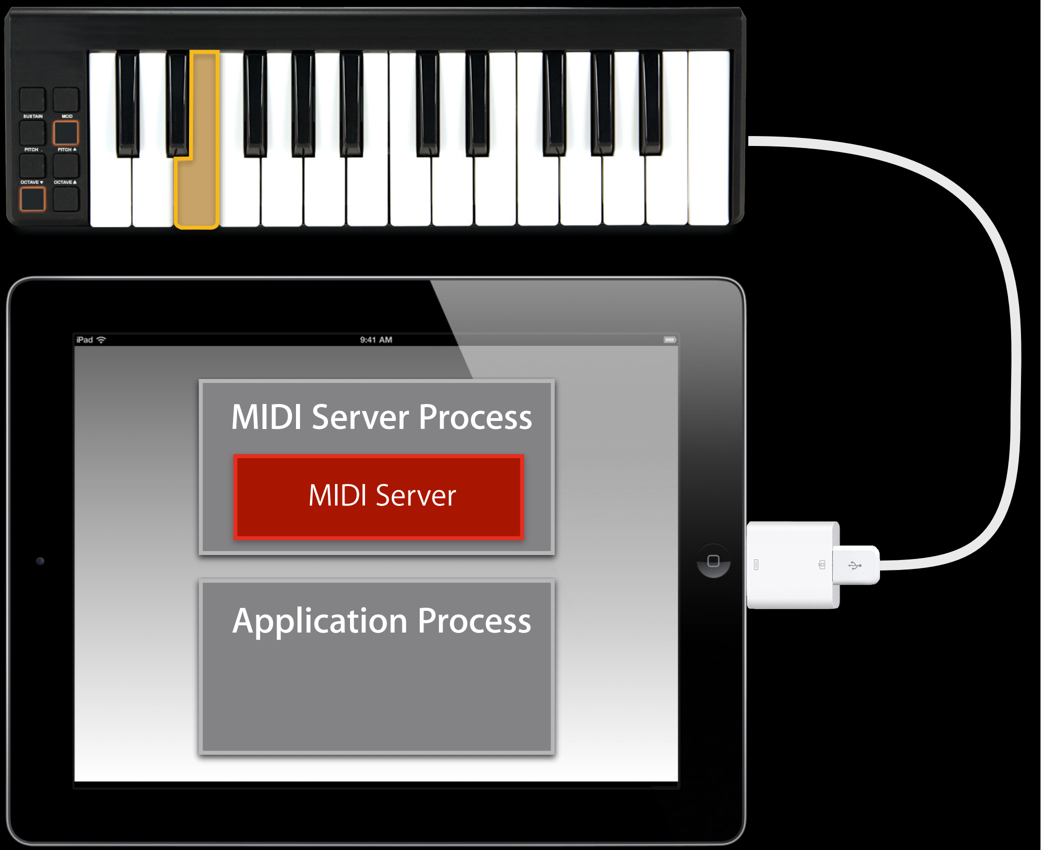

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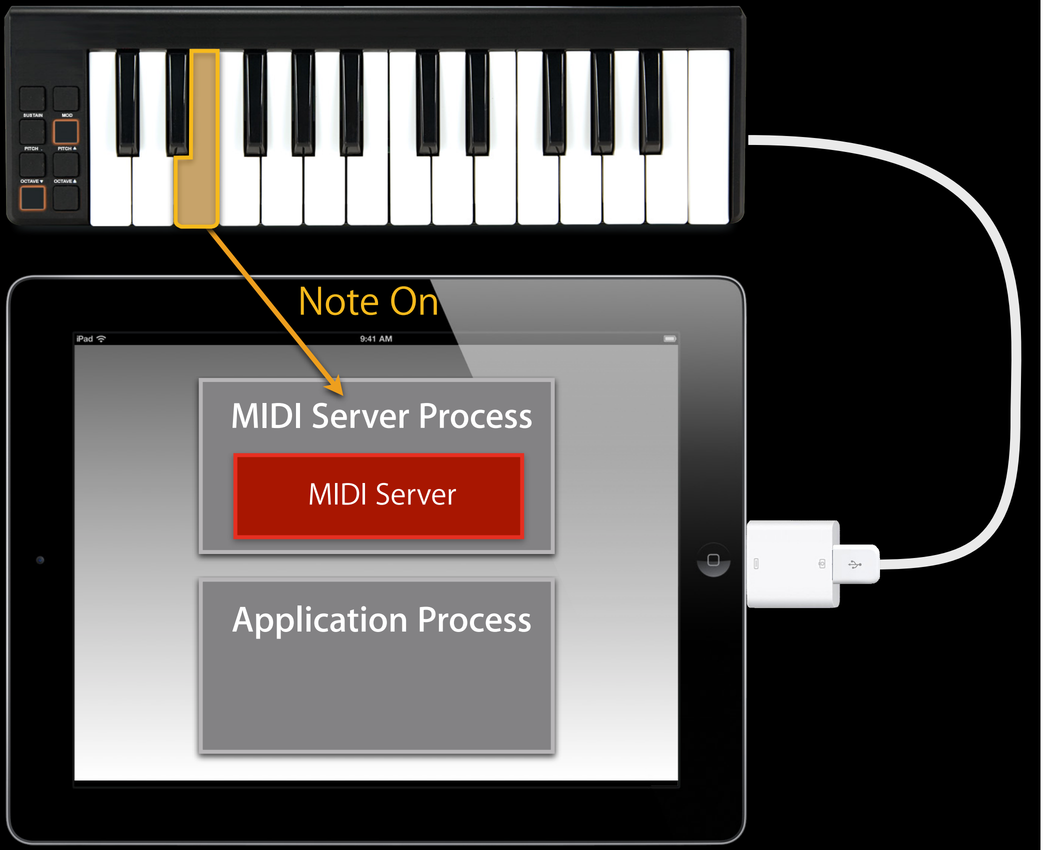

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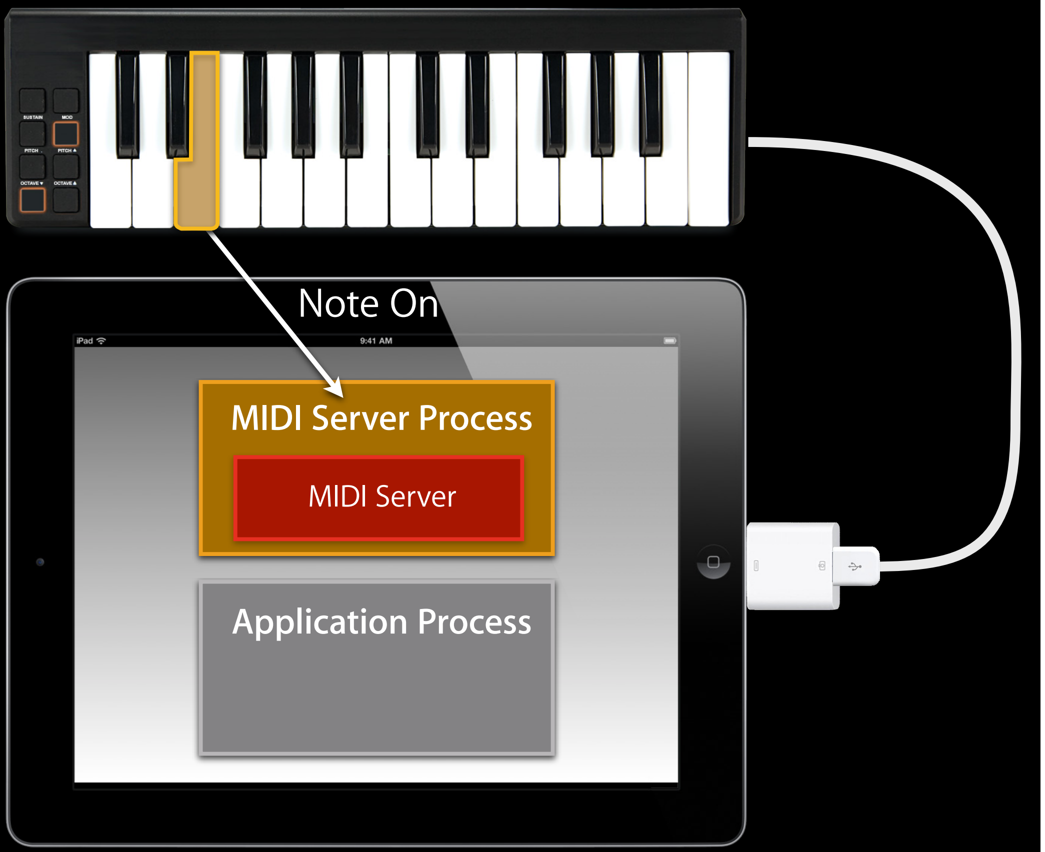

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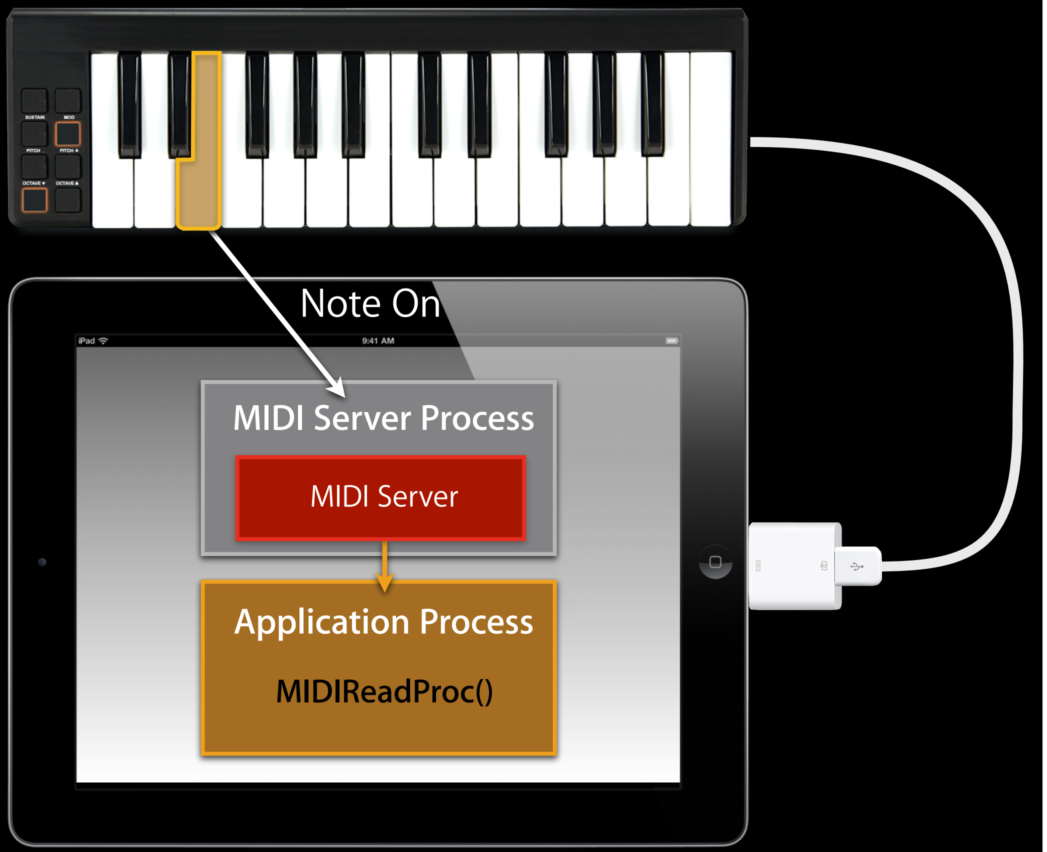
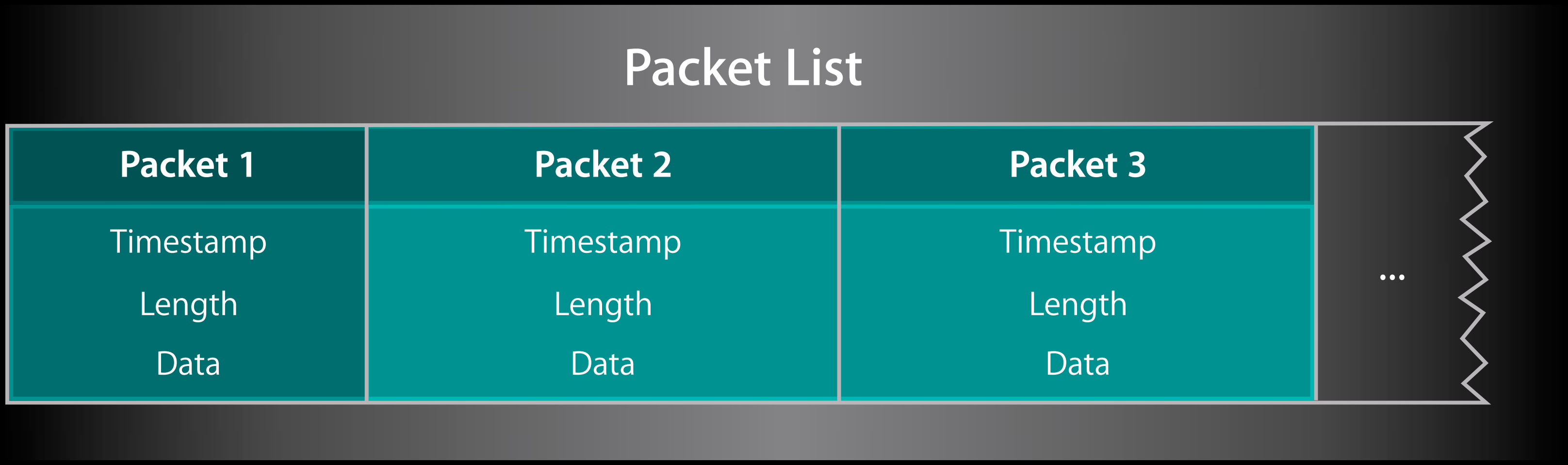


MIDI Packets

Anatomy of a MIDIPacket



```
p1=PacketList[0]   p2=MIDIPacketNext(p1)  p3=MIDIPacketNext(p2)
```

Getting MIDI Data

Creating a port

```
void MIDIInputPortHandler(const MIDIPacketList *inPackets,
                          void *inRefCon, void *srcRefCon) {
    const MIDIPacket *pkt = &(inPackets->packet[0];
    for (int i = 0; i < inPackets->numPackets; pkt = MIDIPacketNext(pkt)) {
        ...  // process packets
    }
}
```

```
MIDIPortRef midiInputPort;
OSStatus result = MIDIInputPortCreate(midiClient, CFSTR(“InputPort”),
                              MIDIInputPortHandler, NULL, &midiInputPort);
```

Sending MIDI Data

- Use MIDISend( ) to send a packet list of MIDI Data
- Use MIDIOutputPortCreate( ) to create an output port
- Specify the destination for the data

```
MIDISend(MIDIPortRef port,
         MIDIEndpointRef dest,
         const MIDIPacketList *packets)
```

Using Networked MIDI Connections

```
#import <CoreMIDI/MIDINetworkSession.h>

MIDINetworkSession *session = [MIDINetworkSession defaultSession];
session.enabled = YES;
session.connectionPolicy = MIDINetworkConnectionPolicy_Anyone;
```

```
MIDINetworkHost *host = [MIDINetworkHost hostWithName: @“My Session”
                                              address: @“myhost.acme.com”
                                                 port: 5004];


[MIDINetworkConnection connectWithHost: host];
```

The Music Sequencer

Doug Scott
Core Audio Engineering

Demo

Playing MIDI files in your app

Doug Scott
Core Audio Engineering

The Music Sequencing API

- Declared in <AudioToolbox/MusicPlayer.h>

The Music Sequencing API

- Declared in <AudioToolbox/MusicPlayer.h>
- MusicSequence
    - Tempo track
    - Event tracks

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The Music Sequencing API

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- MusicSequence
  - Tempo track
  - Event tracks
- MusicTrack
  - MIDI events
  - AU Parameter automation data
  - User data events
- MusicPlayer

The Music Sequencing API

MusicSequence

- Add, remove, merge MusicTracks
- Read and write MIDI files
- Beats/time conversion

The Music Sequencing API

MusicTrack

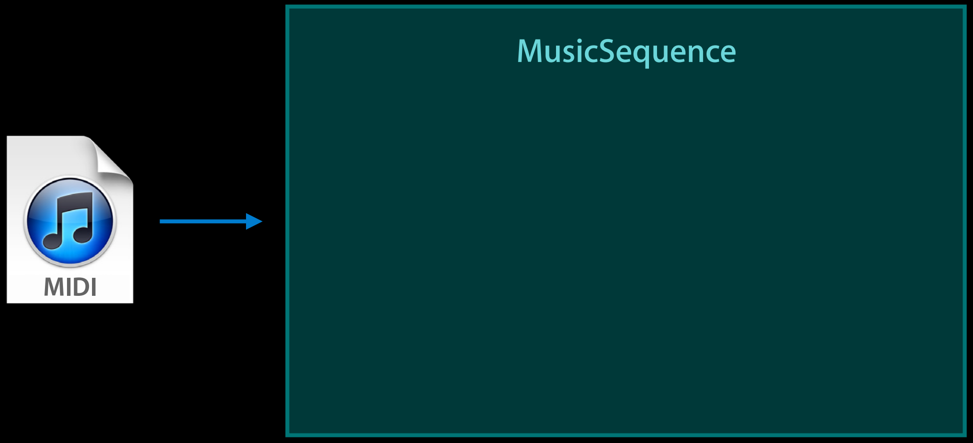
- Add, move, clear music events
- Mute, solo, looping, etc.
- Associate events with a destination
    - Audio Units (instruments, sound effects, etc.)
    - MIDI devices
- Supports event iteration

The Music Sequencing API

MusicPlayer

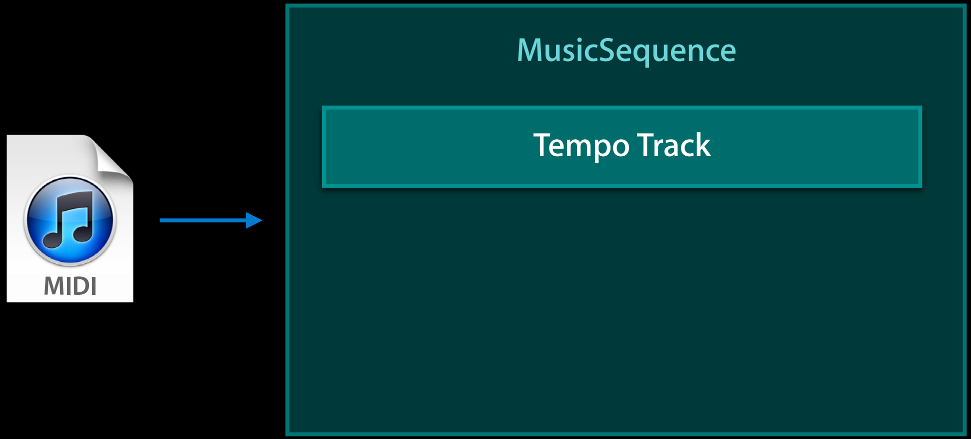
- Playback controls
- Host time to beats and vice versa

Loading a MIDI File—An Easy Use Pattern



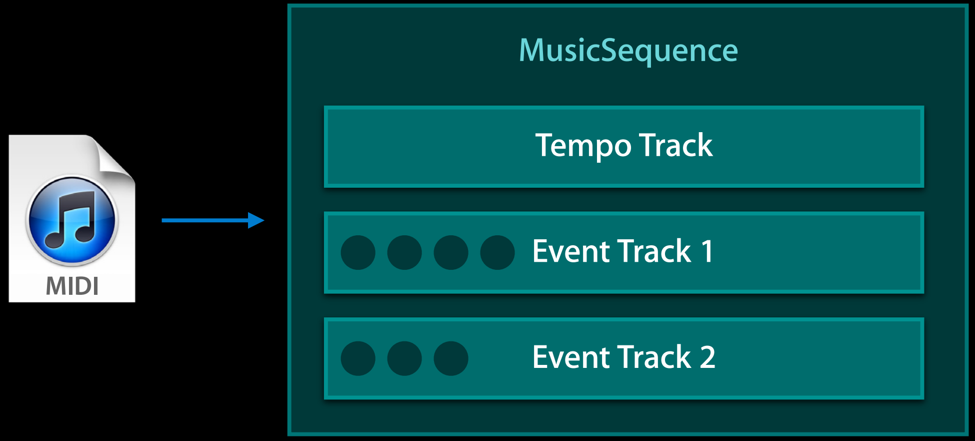
```
MusicSequence mySequence = ...
CFURLRef inPathToMIDIFile = ...
MusicSequenceFileLoad(mySequence, inPathToMIDIFile, 0,
                      kMusicSequenceLoadSMF_ChannelsToTracks);
```

Loading a MIDI File



- Loads file’s tempo events if present
- Otherwise, creates a default tempo

Loading a MIDI File



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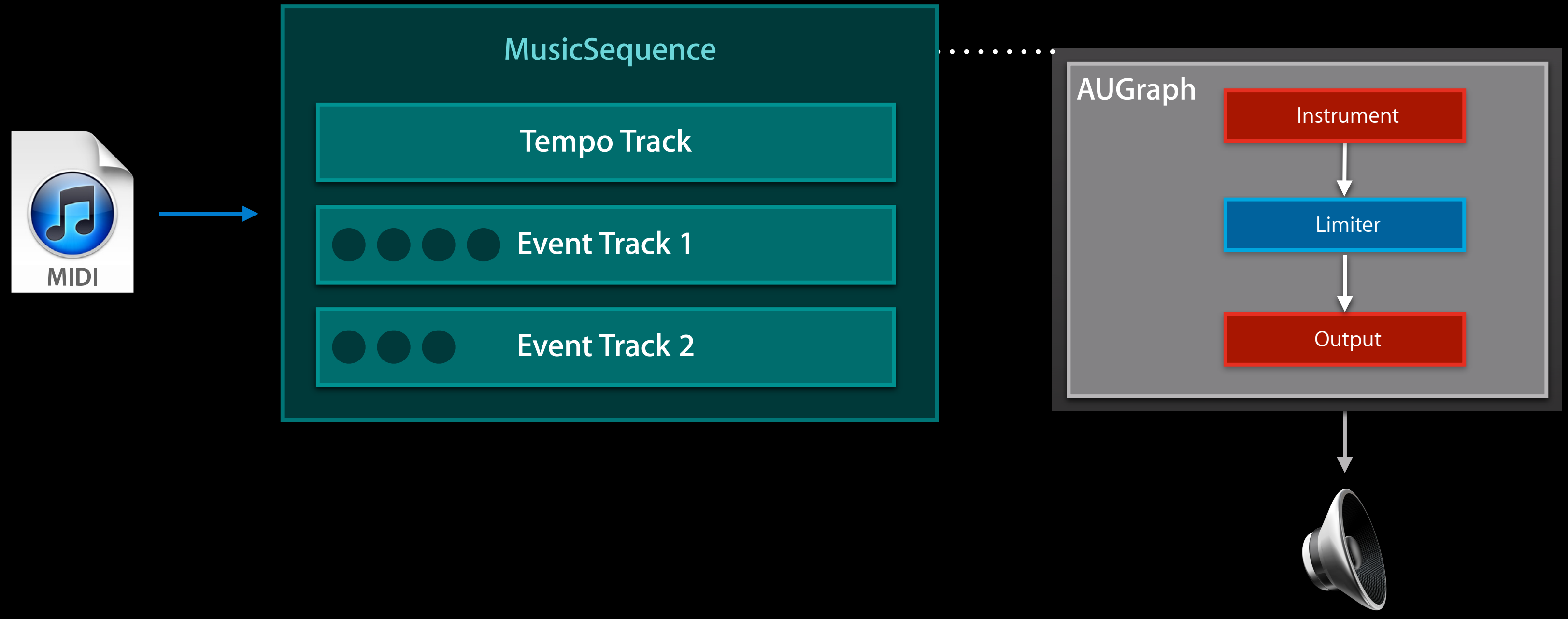
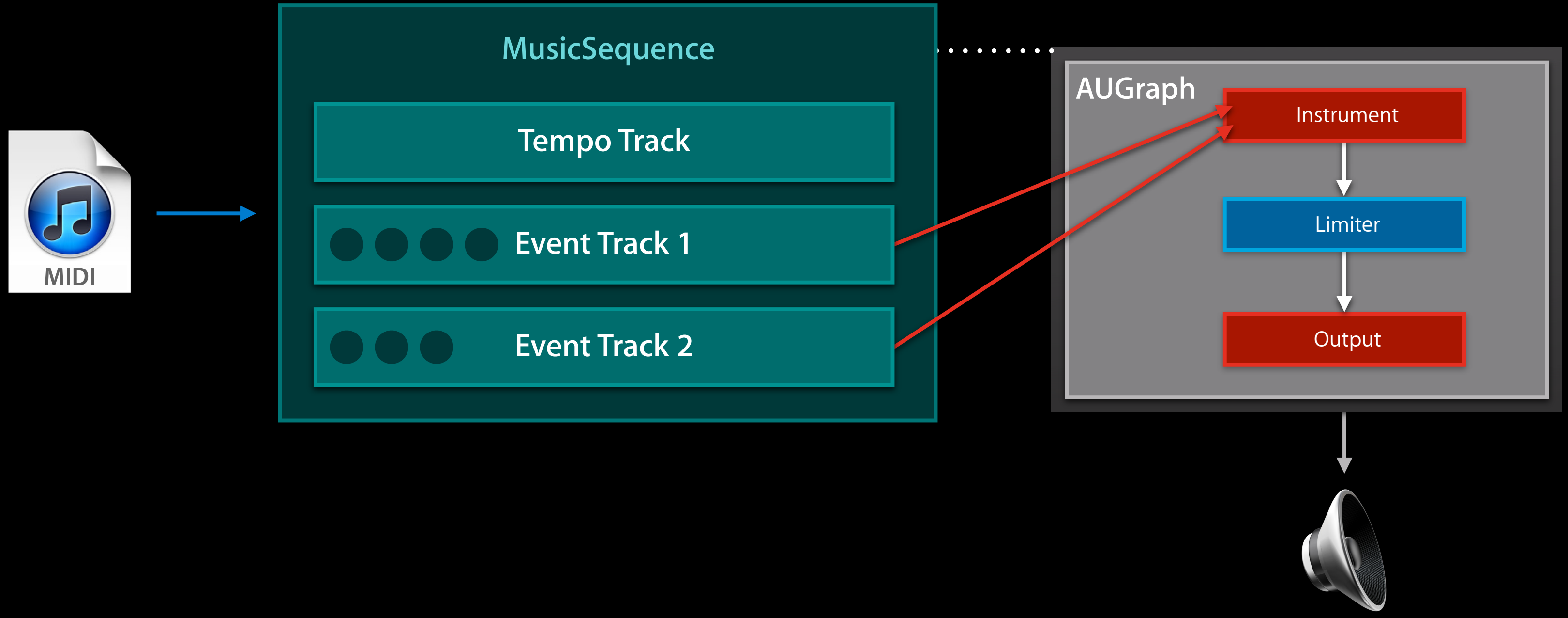
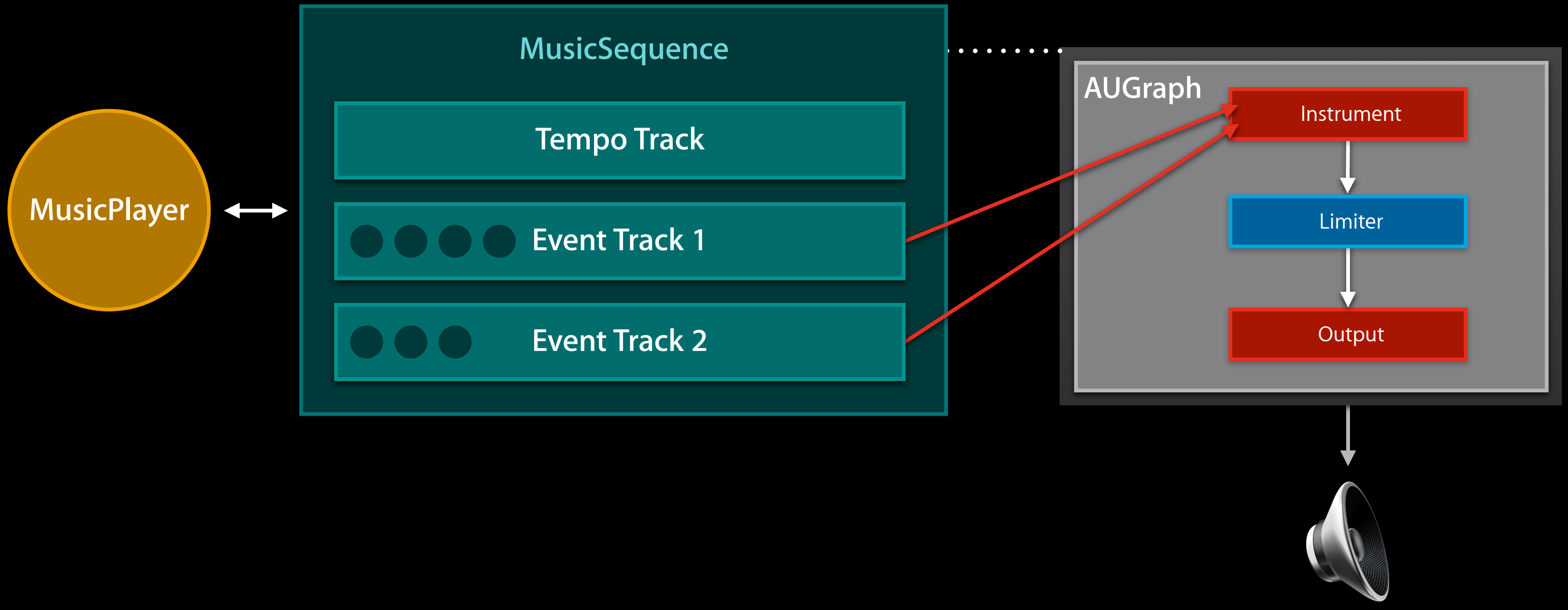


Loading a MIDI File



Playing the Sequence



```
MusicPlayerSetSequence(myMusicPlayer, mySequence);
MusicPlayerStart(myMusicPlayer);
MusicPlayerSetPlayRateScalar(myMusicPlayer, 1.0);
```

Creating a Custom Sequence

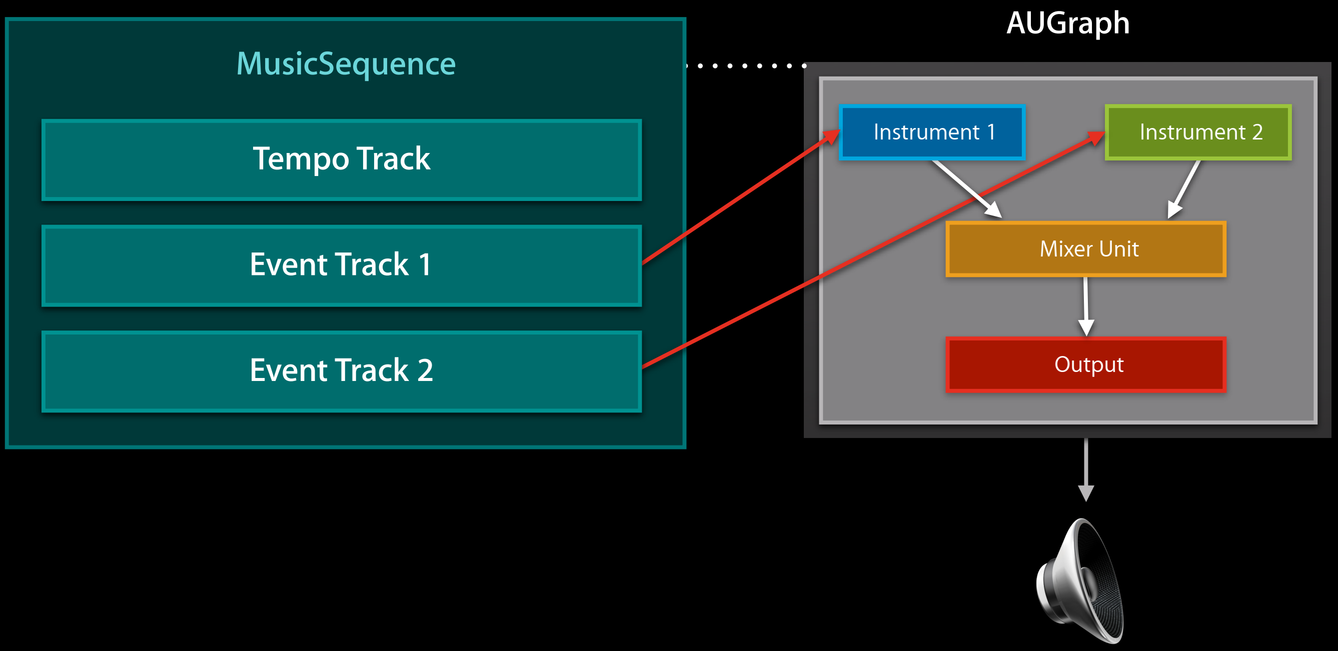
Complex usage pattern

- MIDI recorder/sequencer app
- Play a MIDI sequence with multiple instruments
- AU parameter automation data

Creating a Custom Sequence

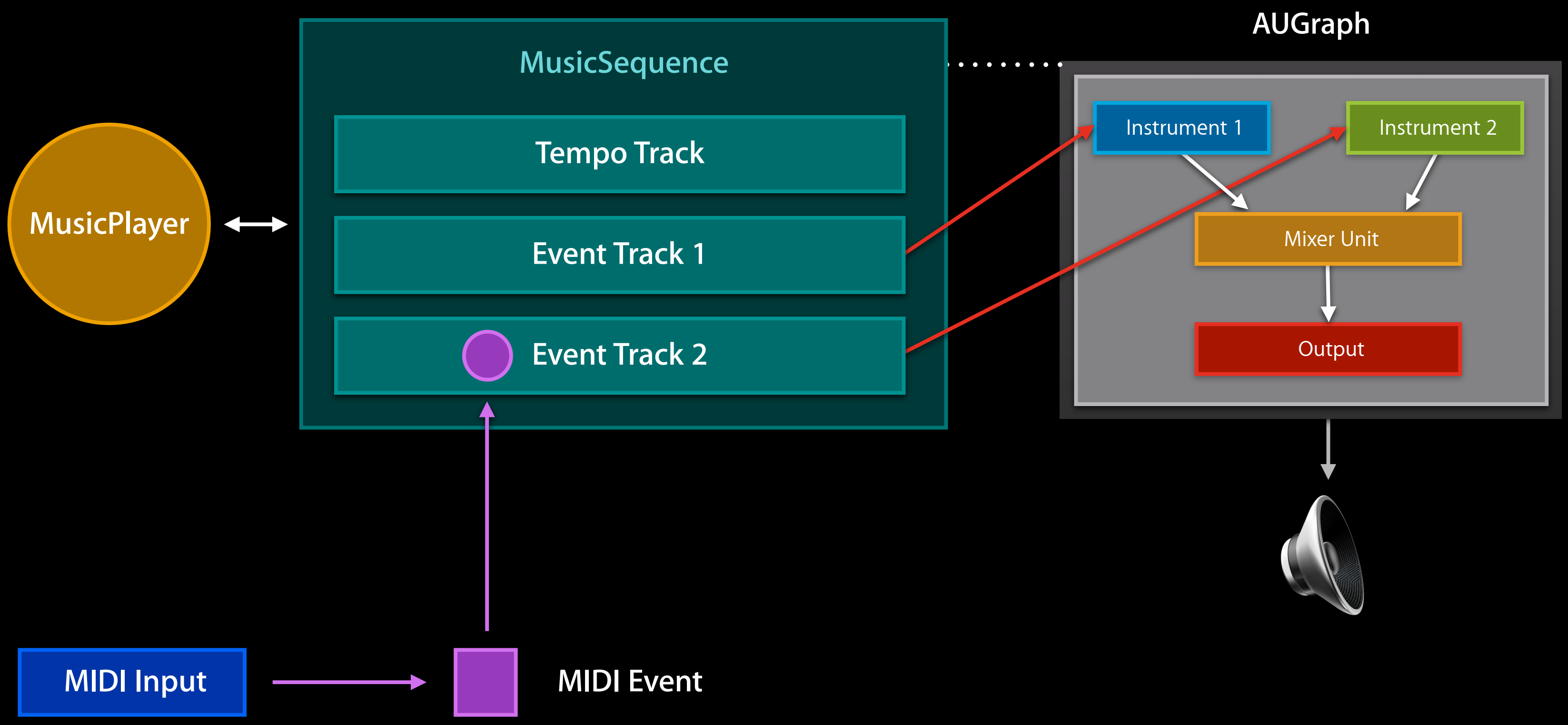
- Create an empty sequence
- Create a custom AUGraph
- Add tracks to sequence
- Add events to tracks
- Target tracks to graph nodes or MIDI endpoints

An Example of a Custom Sequence



• The two event tracks send their events to different instruments

Adding a Live Event to a Track



Summary

Technologies for music applications

- Audio Units
- AUSampler
- CoreMIDI
- Music sequencing

Related Sessions

Audio Session Management for iOS	Marina Wednesday 11:30 AM

Labs

Audio Lab	Graphics & Media Lab C Wednesday 2:00PM

More Information

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Media Technologies Evangelist
evershen@apple.com

Documentation and Sample Code
iPhone Dev Center
http://developer.apple.com/iphone

Audio Unit Hosting Guide for iPhone OS
WWDC attendee website

Apple Developer Forums
http://devforums.apple.com

WWDC2011