Audio Unit Extensions

Session 508

Doug Wyatt Core Audio Plumber

Audio Units

Since OS X 10.0, iOS 2.0

OS includes many units

- I/O, mixers, effects, more
- Used in higher-level API's (e.g. media playback)

3rd-party plug-ins (OS X)

Audio Unit Extensions

NEW

Full plug-in model

OS X and iOS

App Extensions -> App Store!

New API

- Modern
- Compatible

Version 3 Audio Unit API

v1: 2001

v2: 2002

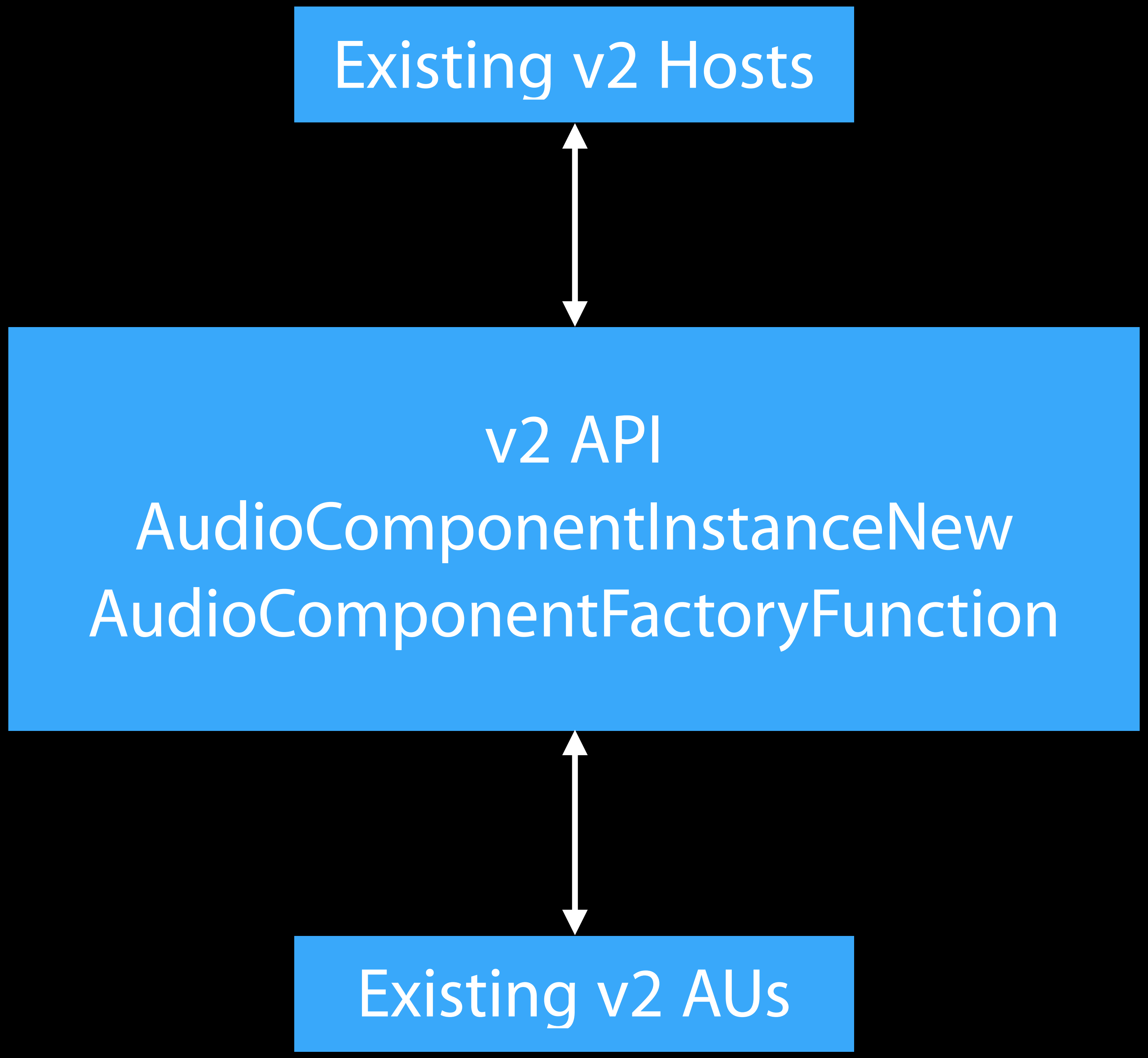
v3: AUAudioUnit class

- In AudioUnit.framework
- Objective-C / Swift

AVFoundation

AVAudioUnitComponentManager	Locate Audio Unit components	OS X 10.10+ iOS 9.0+
AVAudioUnitComponent	An Audio Unit component	OS X 10.10+ iOS 9.0+
AVAudioUnit AVAudioUnitEffect etc.	Audio Unit instance, in AVAudioEngine	OS X 10.10+ iOS 8.0+

Compatibility



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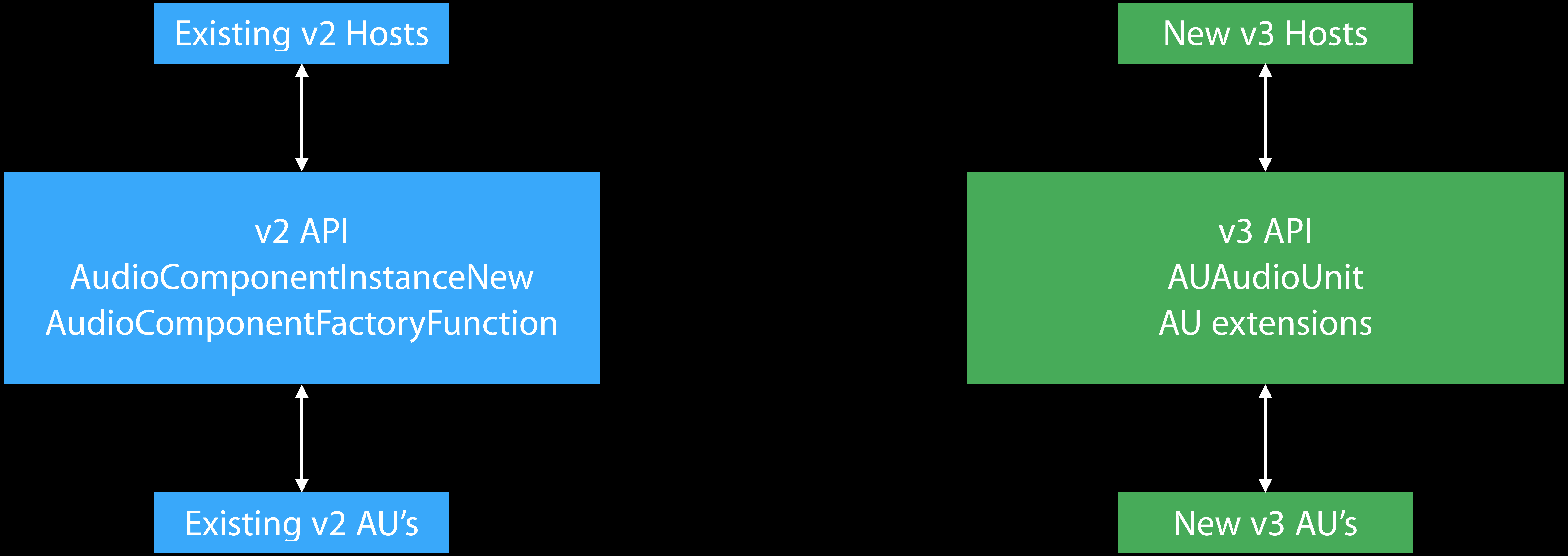

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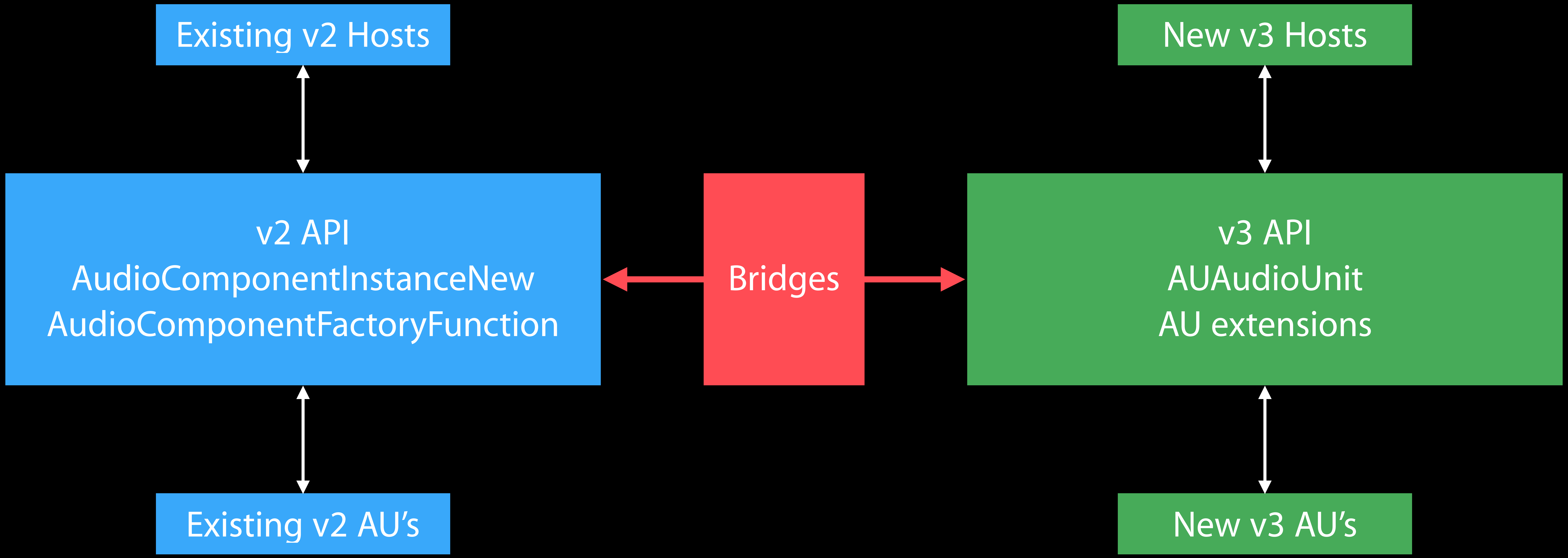

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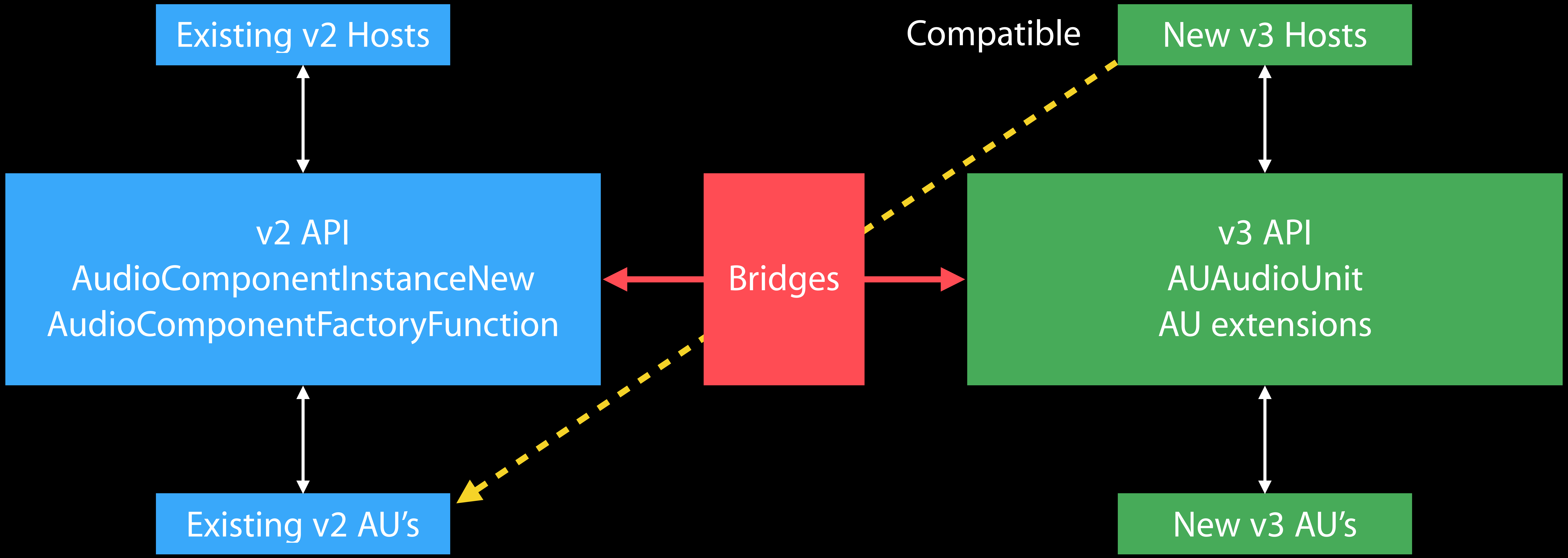

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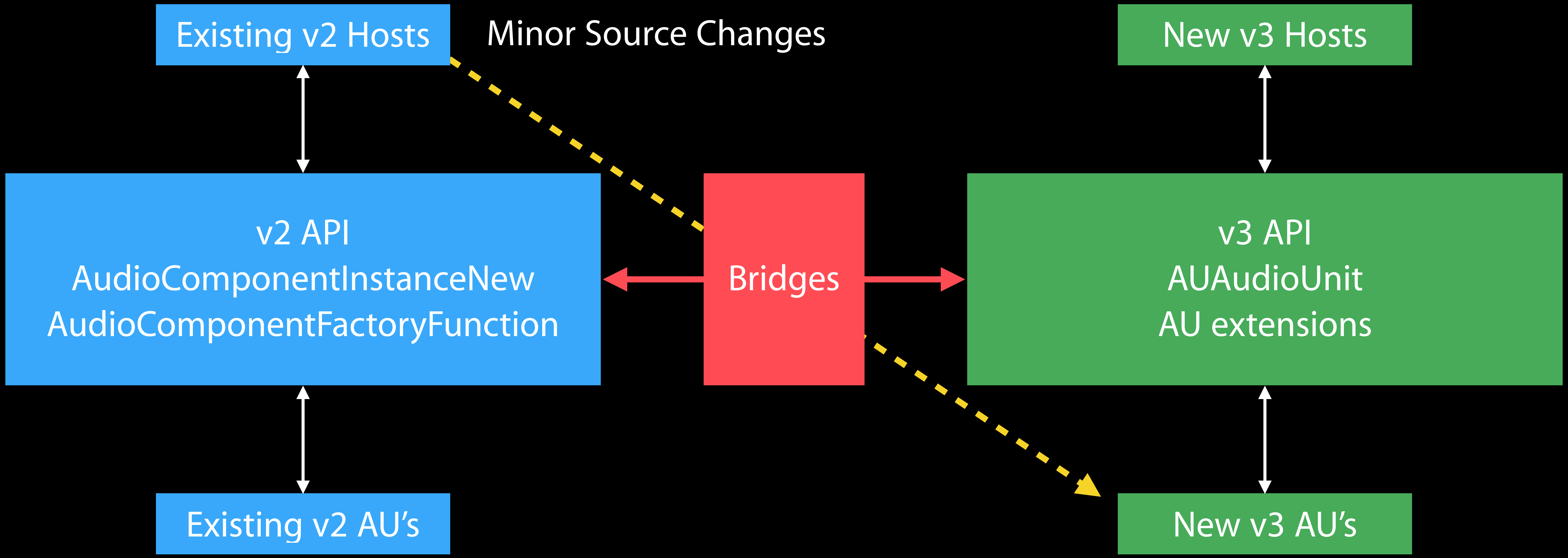


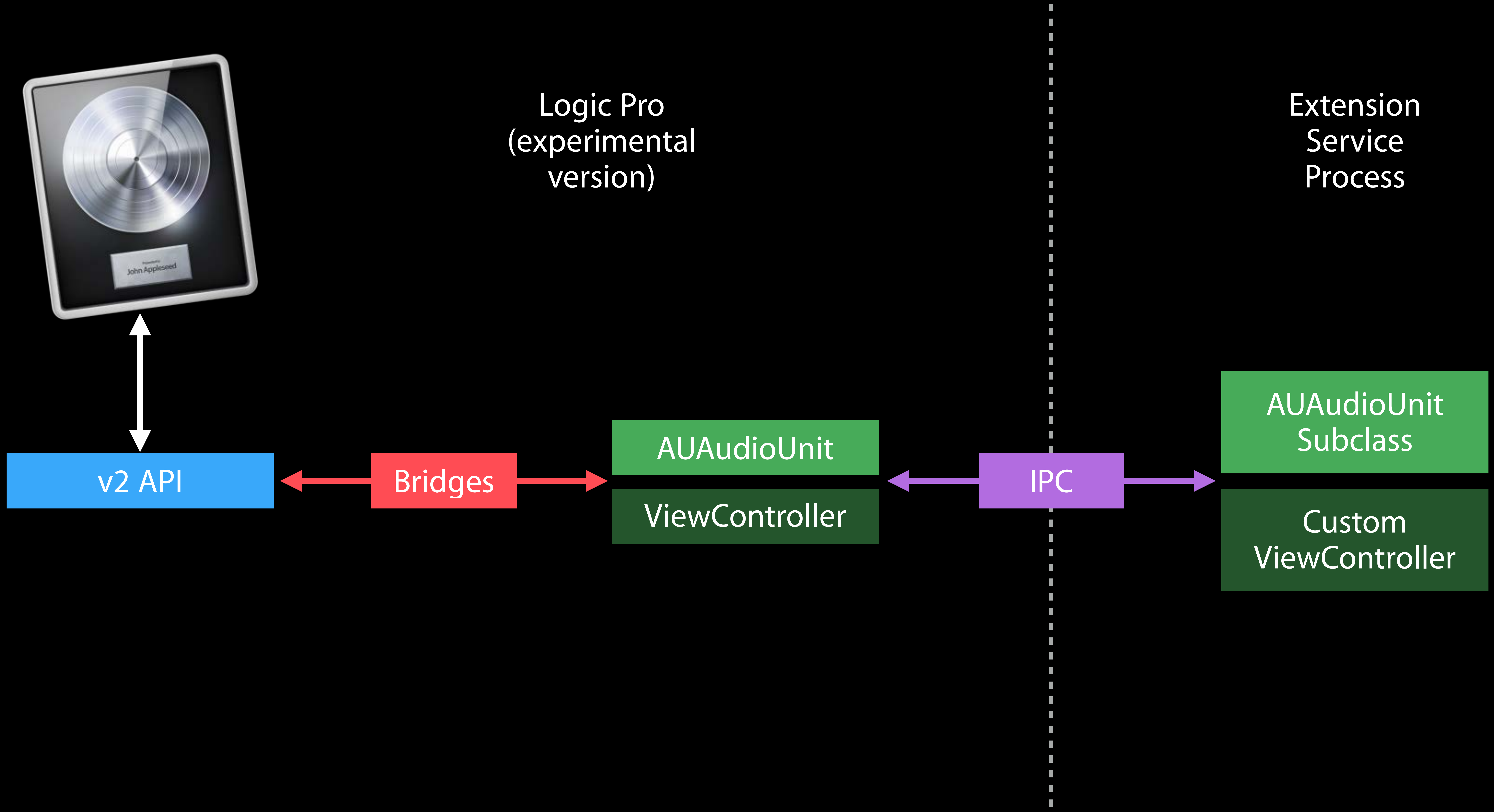
Demo

Audio Unit Extension in Logic Pro

Doug Wyatt

Core Audio Plumber

Logic Pro with AU Extension



Hosting Audio Units

Hosting Audio Units

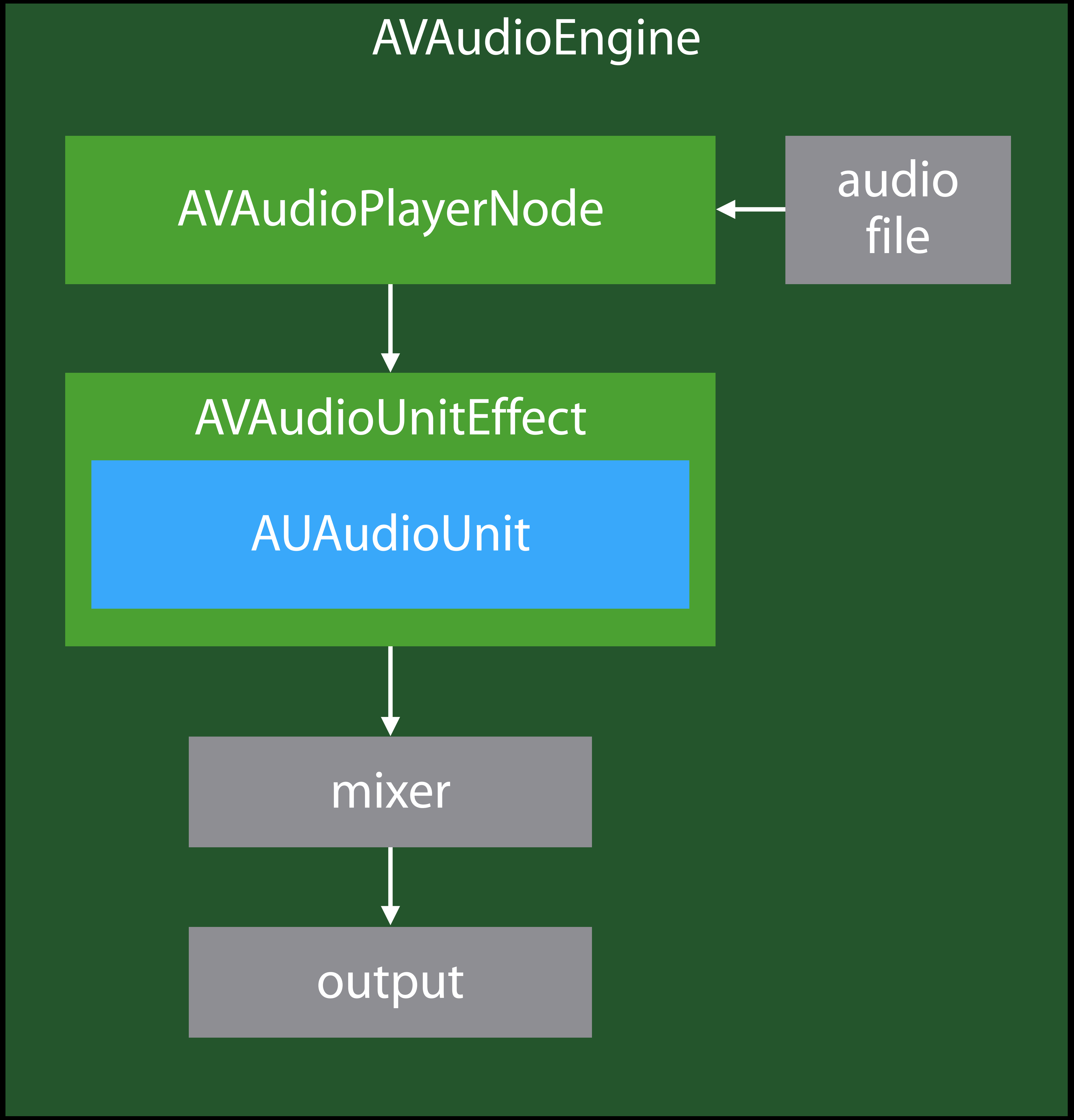
Using v3 API's

Sample Code: `AudioUnitV3Example`

AUHost shows

- Finding
- Opening
- Connecting
- Presets
- Opening AU's custom view

SimplePlayEngine



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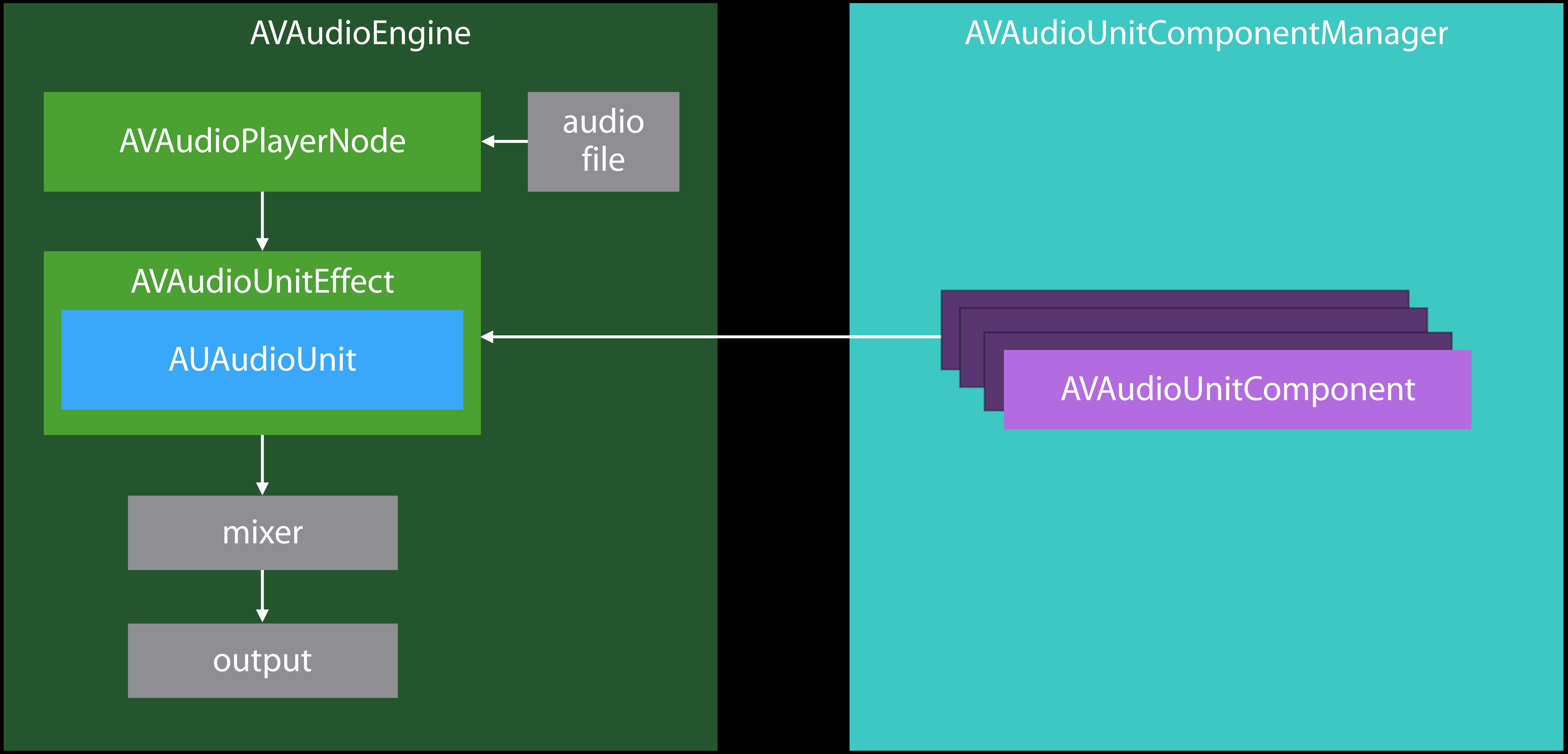

Audio Components

```
struct AudioComponentDescription {
  var componentType: OSType
  var componentSubType: OSType
  var componentManufacturer: OSType
  var componentFlags: UInt32
  var componentFlagsMask: UInt32
}
```

Finding Audio Unit Components

```
let anyEffect = AudioComponentDescription(componentType:
kAudioUnitType_Effect, componentSubType: 0, componentManufacturer:
0, componentFlags: 0, componentFlagsMask: 0)

let availableEffects: [AVAudioUnitComponent] =
AVAudioUnitComponentManager.sharedAudioUnitComponentManager().
componentsMatchingDescription(anyEffect)
```

Finding Audio Unit Components

```
let anyEffect = AudioComponentDescription(componentType:
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```
let availableEffects: [AVAudioUnitComponent] =
AVAudioUnitComponentManager.sharedAudioUnitComponentManager().
componentsMatchingDescription(anyEffect)
```

Selecting an Audio Unit

```
func selectEffectComponent(comp: AVAudioUnitComponent?,
completionHandler: () -> Void) {
  selectEffectWithComponentDescription
    (comp?.audioComponentDescription,
    completionHandler: completionHandler)
}
```

Creating an AudioUnit Instance

With AVAudioEngine

```
AVAudioUnit.instantiateWithComponentDescription(desc!, options:
[]) {
    avAudioUnit, error in
    guard let avAudioUnit = avAudioUnit else { return }
    self.effect = avAudioUnit
    self.engine.attachNode(self.effect!)
    …
```

Creating an AudioUnit Instance

With AVAudioEngine

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    …
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Creating an AudioUnit Instance

With AVAudioEngine

```
self.engine.disconnectNodeInput(self.engine.mainMixerNode)


self.engine.connect(self.player, to: self.effect!,
  format: self.file!.processingFormat)


self.engine.connect(self.effect!, to: self.engine.mainMixerNode,
  format: self.file!.processingFormat)
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Creating an AudioUnit Instance

With AVAudioEngine

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```

Creating an AudioUnit Instance

With AVAudioEngine

```
self.audioUnit = self.effect!.AUAudioUnit


if let pl = self.audioUnit!.factoryPresets {
  self.presetList = pl
}
else {
  self.presetList = [AUAudioUnitPreset]()
}
```

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With AVAudioEngine

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self.audioUnit = self.effect!.AUAudioUnit


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  self.presetList = pl
}
else {
  self.presetList = [AUAudioUnitPreset]()
}
```

Accessing an Audio Unit’s View Controller

```
playEngine.audioUnit?.requestViewControllerWithCompletionHandler {
  [weak self] viewController in
 … embed audio unit’s view controller’s view …
}
```

Demo

AUHost

Michael Hopkins
Purveyor of Pixels

Using an AudioUnit

Directly, v3 (Swift):

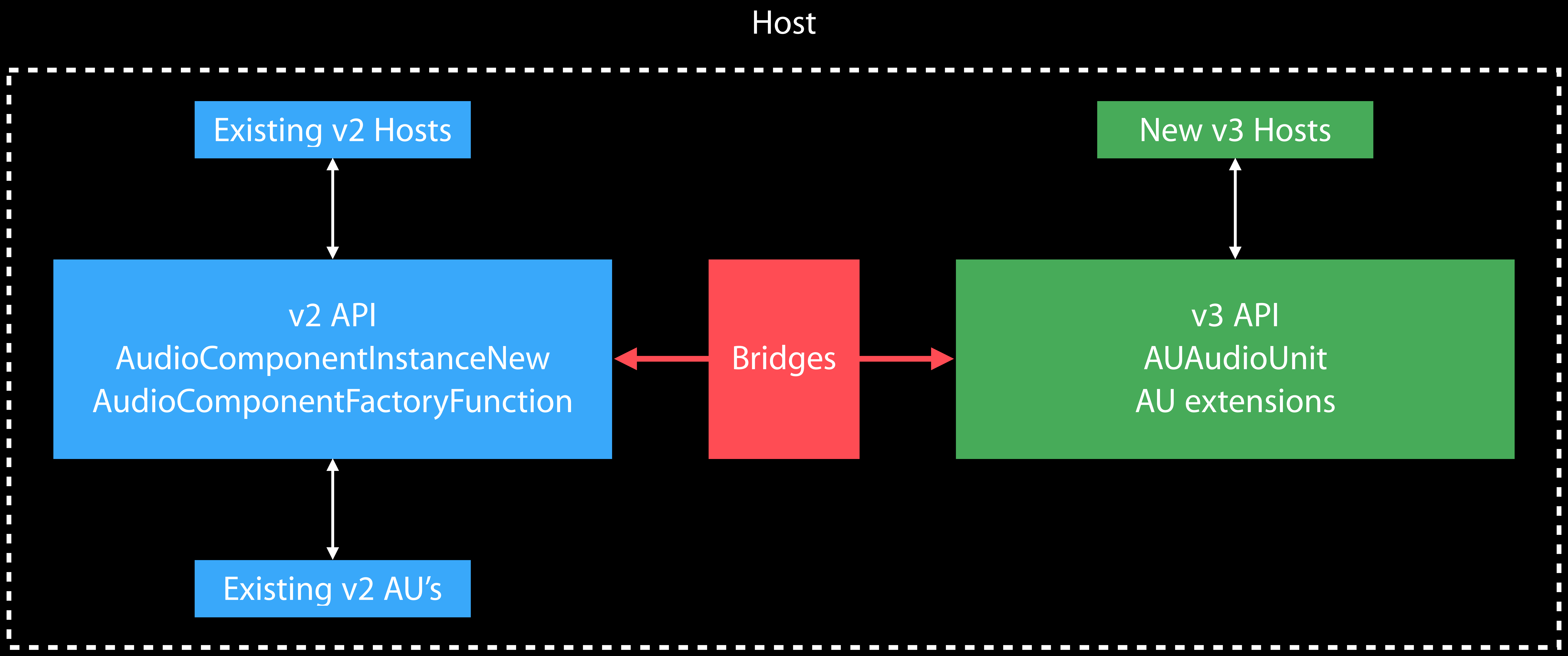
```
AUAudioUnit.instantiateWithComponentDescription(desc, options: [])
{ audioUnit, err in
        …
    }
```

Directly, v2 (C):

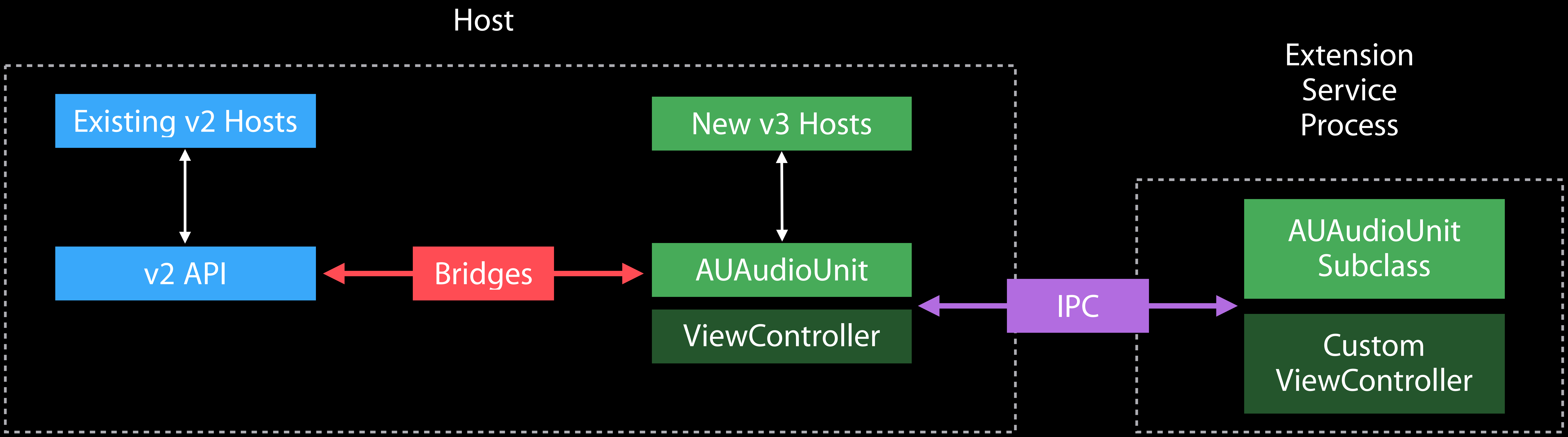
```
AudioComponentInstantiate(desc, options,
    ^(AudioComponentInstance au, OSStatus err) {
        …
    })
```

Hosting: In Versus Out of Process

v2 AU's: Always in Host's Process



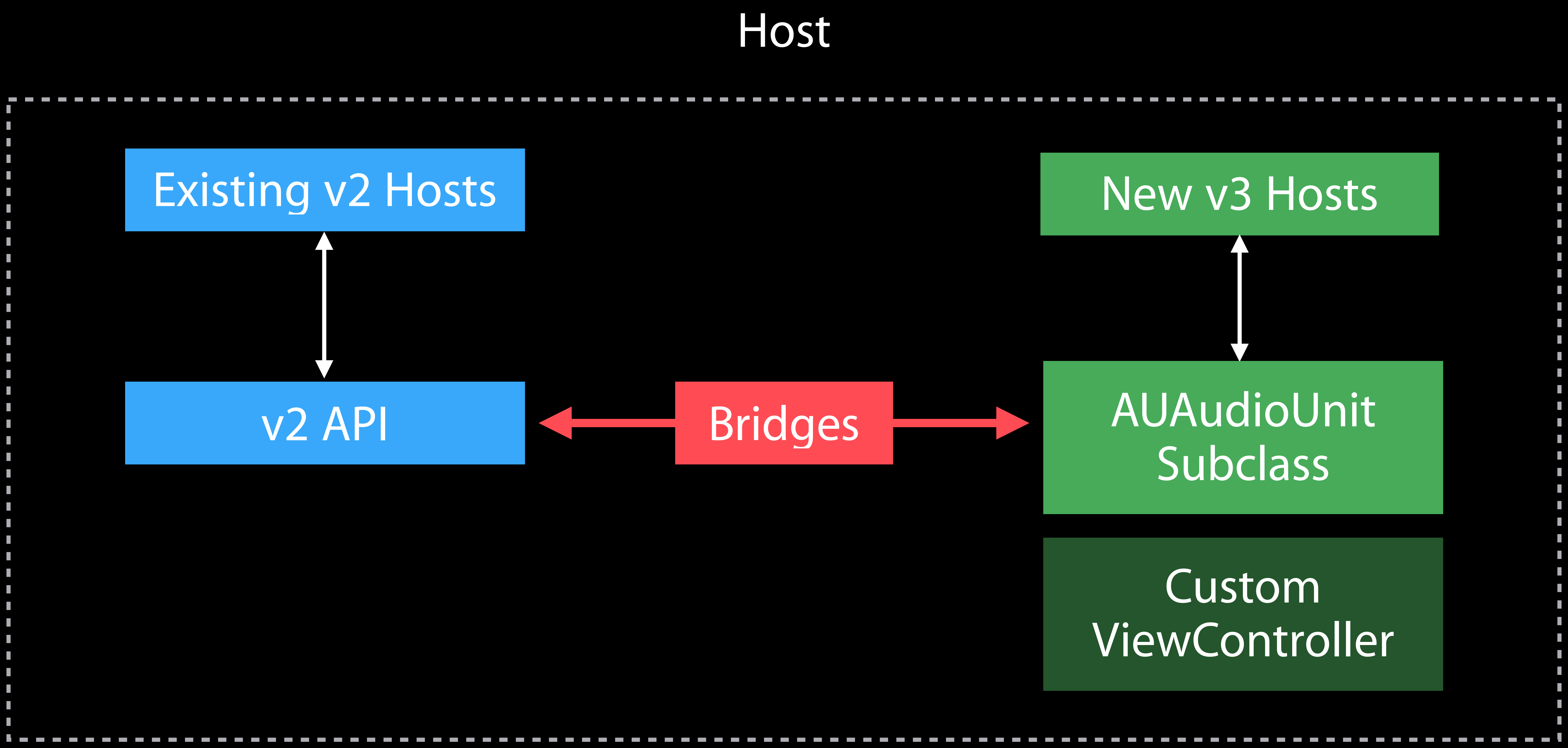
v3 AU's: Default to Separate Process



v3 AU's: Optionally In-Process

Host options: `kAudioComponentInstantiation_LoadInProcess`

AU extension plist entry: `AudioComponentBundle`



In-Process: Safety Versus Performance

Safety

- Security risk
- Misbehaving AU can crash the host

Performance

- IPC overhead ~40 µs per render cycle
- Significance depends on number of AU's and render interval
- 0.1% at 1024 frames / 44.1 kHz
- 5.5% at 32 frames / 44.1 kHz

Updating a v2 Host

If kAudioComponentFlag_RequiresAsyncInstantiation is set, use:

```
extern void AudioComponentInstantiate(
            AudioComponent                    inComponent,
            AudioComponentInstantiationOptions  inOptions,
            void (^inCompletionHandler)(
   AudioComponentInstance __nullable, OSStatus));
```

Instead of:

```
extern OSStatus AudioComponentInstanceNew(AudioComponent
inComponent, AudioComponentInstance *outInstance);
```

Updating a v2 Host

If `kAudioComponentFlag_IsV3AudioUnit` is set, use:

`kAudioUnitProperty_RequestViewController`

(also asynchronous)

Instead of:

`kAudioUnitProperty_CocoaUI`

Asynchronous Operations

Can use new methods with v2 units

Must use new methods with v3 units

Helps responsiveness

- Unblocks main thread

Don’t wait on the main thread!

- Deadlock

Creating an Audio Unit Extension

About App Extensions

.appex

App’s PlugIns directory

Runs in XPC service process

See *App Extension Programming Guide*

Creating an Audio Unit

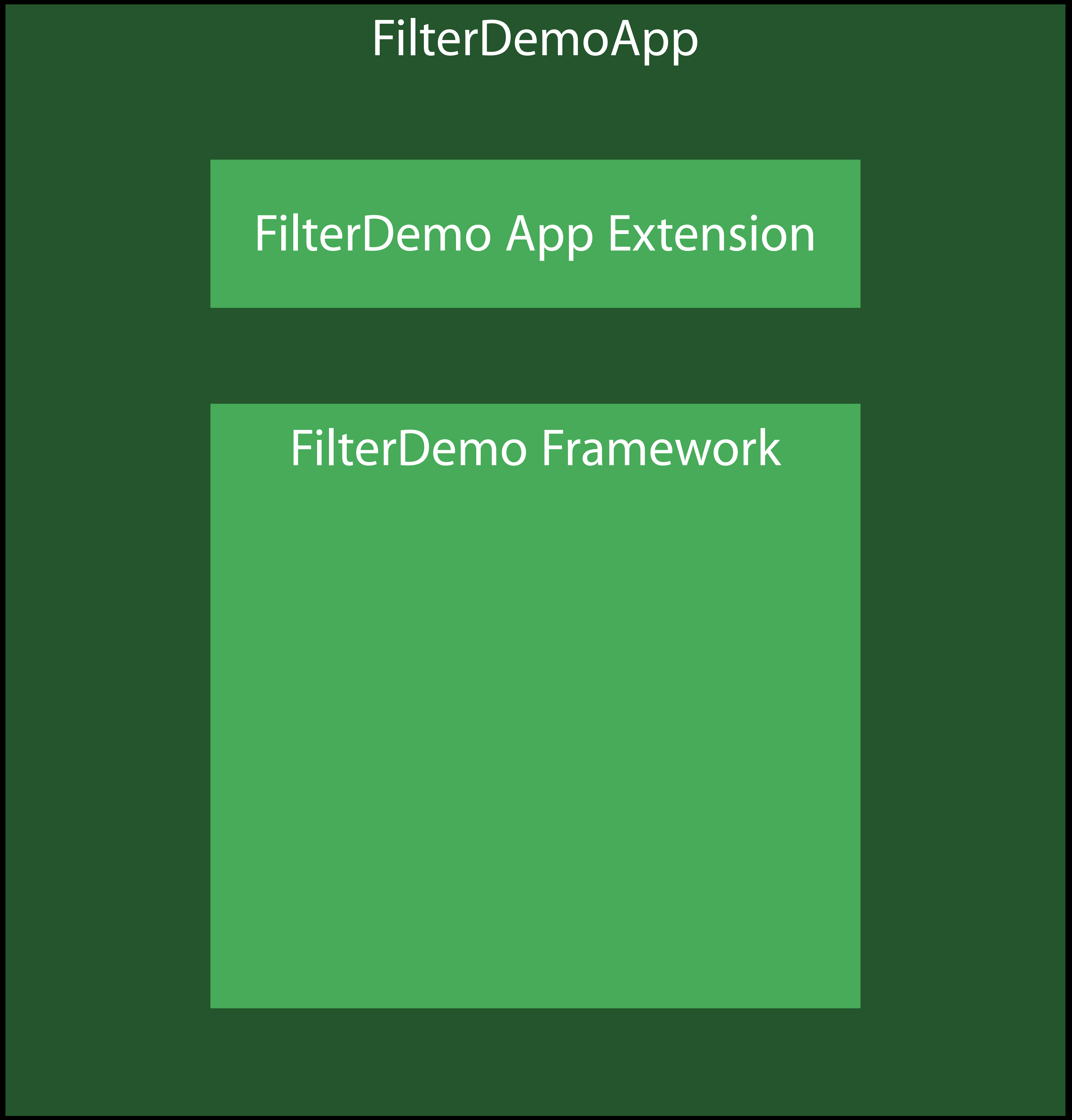
Using v3 API's

New Sample Code: `AudioUnitV3Example`

FilterDemo

FilterDemo Anatomy

- Containing app
- Extension (.appex)
- Both link framework

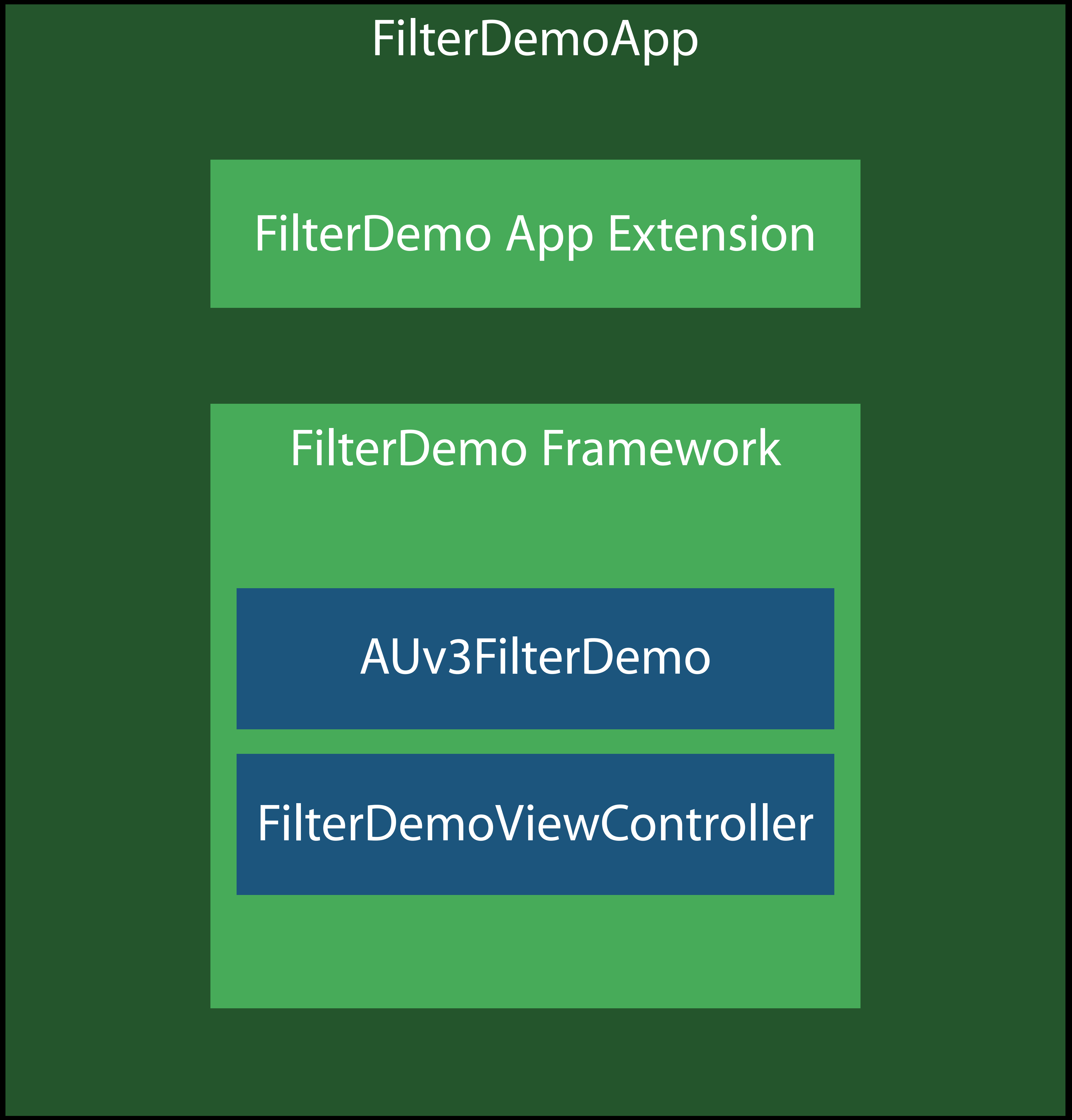


FilterDemo Anatomy

Containing app

Extension

Both link framework



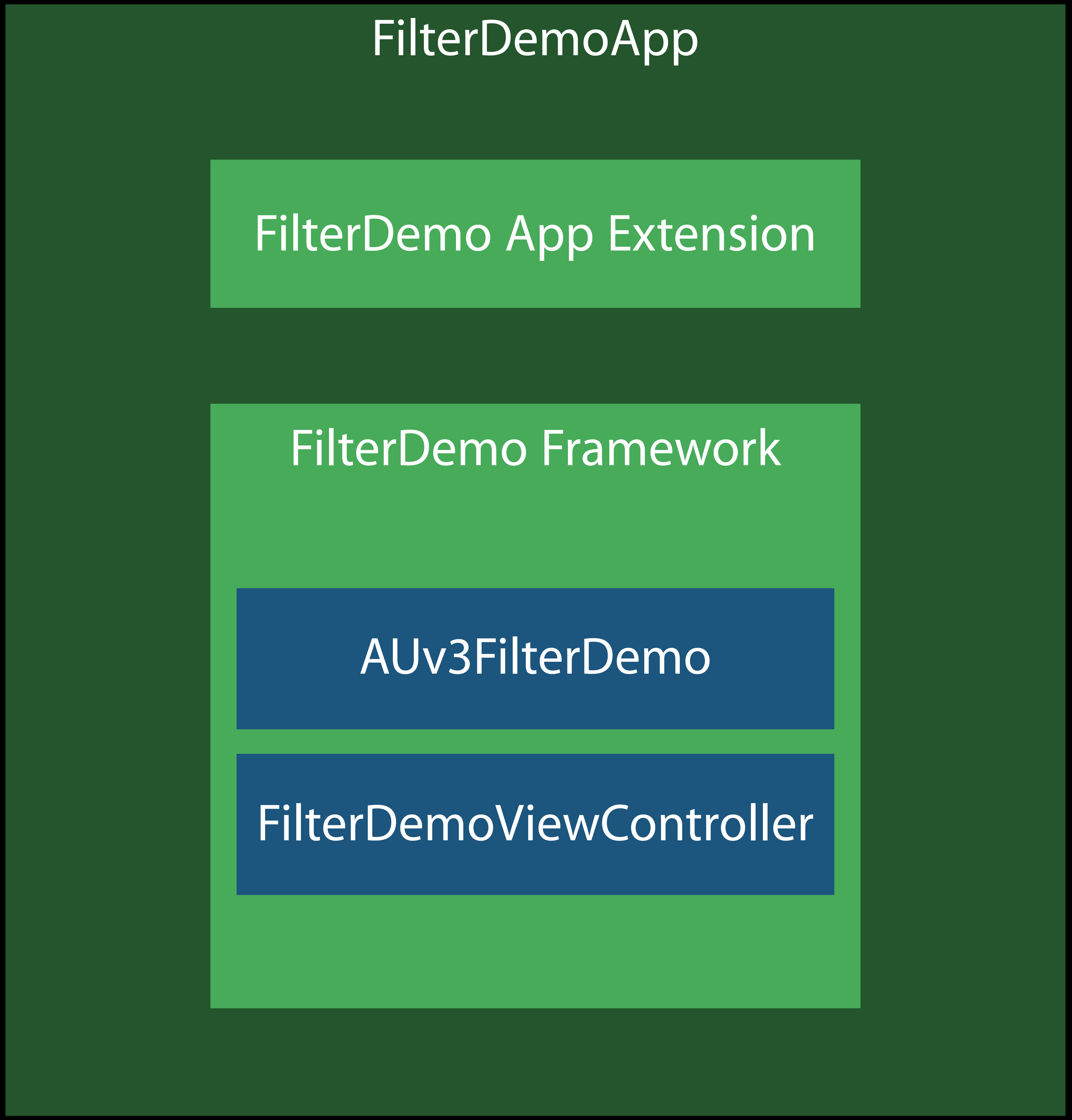
FilterDemo Anatomy

Containing app

Extension

Both link framework

- Easy development within app (no XPC)
- Code size/duplication
- On OS X, framework can be loaded into host process



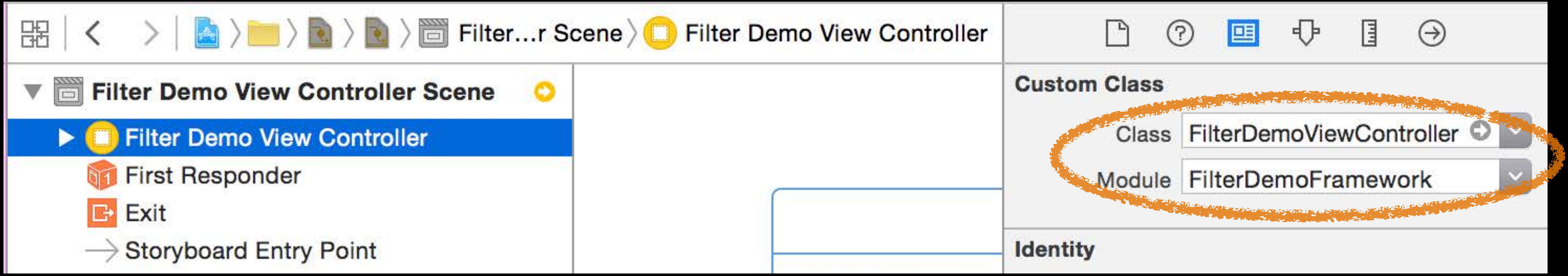
Extension's Info.plist

Comments in <AudioUnit/AUAudioUnitImplementation.h>

NSExtensionPointIdentifier	`com.apple.AudioUnit-UI`
NSExtensionMainStoryboard	MainInterface
AudioComponents	`AudioComponentDescription` (type/subtype/manufacturer), name, version, tags

Extension's MainInterface.storyboard

Entry point is a View Controller, set its Custom Class:


Filter...r Scene
Filter Demo View Controller
Filter Demo View Controller Scene
Filter Demo View Controller
First Responder
Exit
Storyboard Entry Point
Custom Class
Identity

Class FilterDemoViewController

Module FilterDemoFramework

Extension Code

```
import FilterDemoFramework

/*
  The app extension has to contain *some* code
  linking against the framework.
*/
let dummy = FilterDemoViewController.self
```

Framework: FilterDemoViewController

View controller is extension's "principal class"

Creates AUAudioUnit subclass

Creates and manages custom view

FilterDemoViewController

```
public class FilterDemoViewController : AUViewController,
  AUAudioUnitFactory, ControllerDelegate {
  public var audioUnit: AUv3FilterDemo? { … }

  public func createAudioUnitWithComponentDescription(desc:
AudioComponentDescription) throws -> AUAudioUnit {
    audioUnit = try AUv3FilterDemo(componentDescription: desc,
options: [])
    return audioUnit!
  }
}
```

FilterDemoViewController

```swift
public class FilterDemoViewController : AUViewController,
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    audioUnit = try AUv3FilterDemo(componentDescription: desc,
options: [])
    return audioUnit!
  }
}
```

Framework: AUv3FilterDemo

AUAudioUnit subclass

```
@interface AUv3FilterDemo () {
    FilterDSPKernel kernel;
    BufferedInputBus inputBus;
    AUAudioUnitBus *outputBus;
    AUAudioUnitBusArray *inputBusArray;
    AUAudioUnitBusArray *outputBusArray;
    AUParameterTree *parameterTree;
}
```

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   AUParameterTree *parameterTree;
}
```

AUv3FilterDemo

Creating bus arrays

```
inputBus.init(defaultFormat, 8);
outputBus = [[AUAudioUnitBus alloc] initWithFormat:defaultFormat
error:nil];

inputBusArray  = [[AUAudioUnitBusArray alloc]
initWithAudioUnit:self busType:AUAudioUnitBusTypeInput  busses:
@[inputBus.bus]];
outputBusArray = [[AUAudioUnitBusArray alloc]
initWithAudioUnit:self busType:AUAudioUnitBusTypeOutput busses:
@[outputBus]];
```

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```

AUv3FilterDemo

Creating parameters

```
AUParameter *cutoffParam =
  [AUParameterTree createParameterWithIdentifier:@"cutoff"
    name:@“Cutoff" address:FilterParamCutoff
    min:12.0 max:20000.0
    unit:kAudioUnitParameterUnit_Hertz unitName:nil
    flags:0 valueStrings:nil dependentParameters:nil];
AUParameter *resonanceParam =
  [AUParameterTree createParameterWithIdentifier:@"resonance"
    name:@“Resonance" address:FilterParamResonance
    …
```

AUv3FilterDemo

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AUv3FilterDemo

Creating the parameter tree

```
parameterTree = [AUParameterTree createTreeWithChildren:
  @[cutoffParam, resonanceParam]];

parameterTree.implementorValueObserver =
  ^(AUParameter *param, AUValue value) {
    filterDSPKernel->setParameter(param.address, value);
  };

parameterTree.implementorValueProvider =
  ^(AUParameter *param) {
    return filterDSPKernel->getParameter(param.address);
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AUv3FilterDemo

Creating the parameter tree

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parameterTree = [AUParameterTree createTreeWithChildren:
  @[cutoffParam, resonanceParam]];
parameterTree.implementorValueObserver =
  ^(AUParameter *param, AUValue value) {
    filterDSPKernel->setParameter(param.address, value);
  };
parameterTree.implementorValueProvider =
  ^(AUParameter *param) {
    return filterDSPKernel->getParameter(param.address);
  };
```

AUv3FilterDemo

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```

AUv3FilterDemo

Preparing to render

```
- (BOOL)allocateRenderResourcesAndReturnError:(NSError **)outError
{
  if (![super allocateRenderResourcesAndReturnError: outError]) {
    return NO; }
  inputBus.allocateRenderResources(self.maximumFramesToRender);
  kernel.init(outputBus.format.channelCount,
    outputBus.format.sampleRate);
  kernel.reset();
```

AUv3FilterDemo

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  if (![super allocateRenderResourcesAndReturnError: outError]) {
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AUv3FilterDemo

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  kernel.init(outputBus.format.channelCount,
    outputBus.format.sampleRate);
  kernel.reset();
```

AUv3FilterDemo

Cleaning up

```
- (void)deallocateRenderResources
{
  [super deallocateRenderResources];
  inputBus.deallocateRenderResources();
  …
```

AUv3FilterDemo

Rendering

```
- (AUInternalRenderBlock)internalRenderBlock
{
  // Capture properties into locals.
  __block FilterDSPKernel *state = &kernel;
  __block BufferedInputBus *input = &inputBus;
```

AUv3FilterDemo

Rendering

```
return ^AUAudioUnitStatus(
  AudioUnitRenderActionFlags *actionFlags,
  const AudioTimeStamp       *timestamp,
  AVAudioFrameCount           frameCount,
  NSInteger                   outputBusNumber,
  AudioBufferList            *outputData,
  const AURenderEvent        *realtimeEventListHead,
  AURenderPullInputBlock      pullInputBlock)
{
  …
```

AUv3FilterDemo

Rendering

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return ^AUAudioUnitStatus(
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  AURenderPullInputBlock      pullInputBlock)
{
  …
```

AUv3FilterDemo

Rendering

```
input->pullInput(&pullFlags, timestamp, frameCount, 0,
  pullInputBlock);

AudioBufferList *inAudioBufferList =
  input->mutableAudioBufferList;

state->setBuffers(inAudioBufferList, outAudioBufferList);

state->processWithEvents(timestamp, frameCount,
  realtimeEventListHead);
```

AUv3FilterDemo

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Demo

AUv3FilterDemo

Michael Hopkins
Purveyor of Pixels

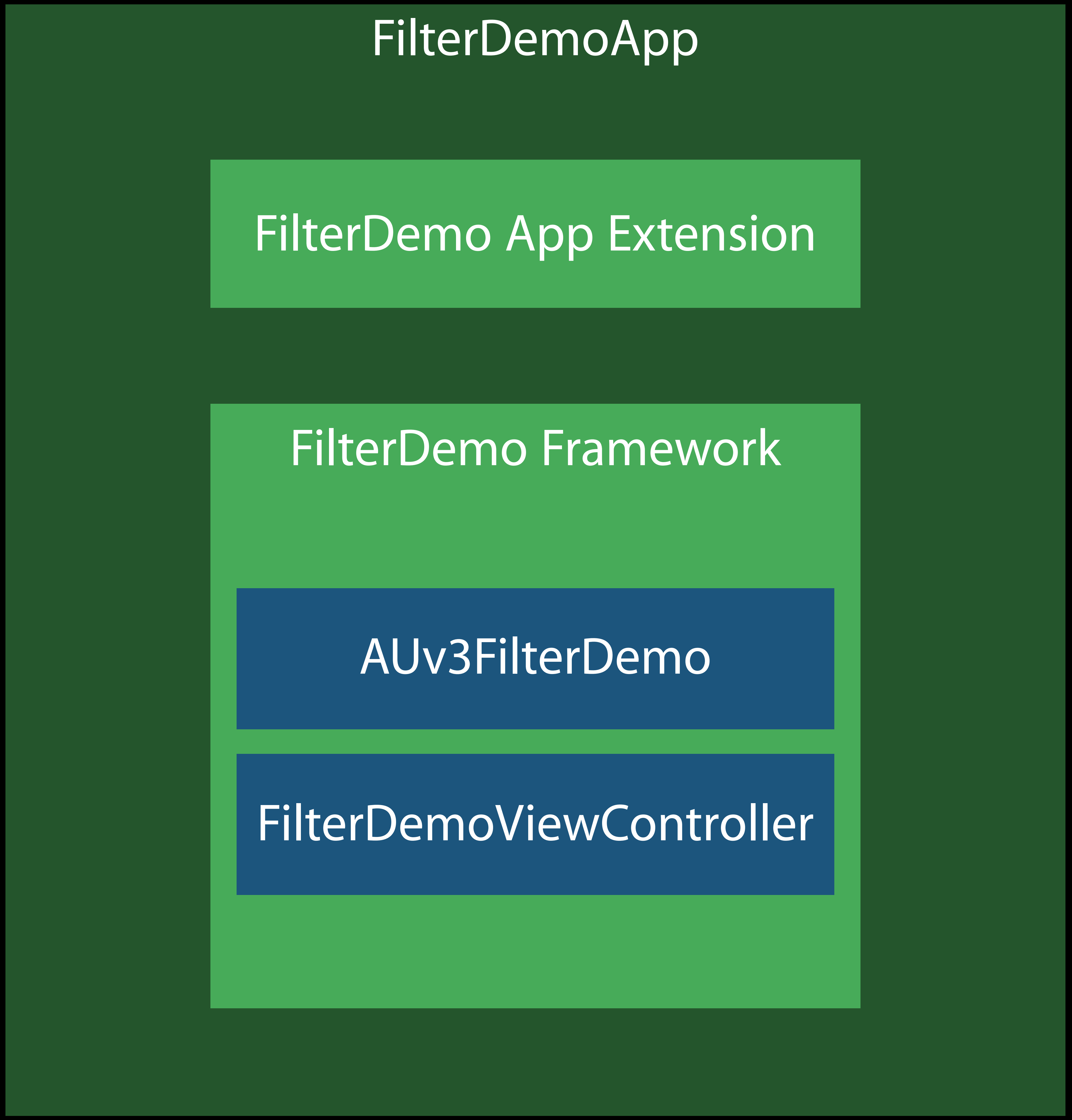
Containing App

Plug-in "vehicle"

Rapid iteration in development

Extra functionality, e.g.

- Playback engine
- Touch controller
- Documentation/help



Creating an Extension

OS X in-process framework

- Caution: Swift ABI subject to change

Xcode template planned

- For now, copy from FilterDemo

Modernized API

AUAudioUnit

Properties: v2

Scope/element based properties, `void *` access methods

- `AudioUnitGetProperty(audioUnit, propertyID, scope, element,`
  `data, dataSize)`
- `AudioUnitSetProperty`
- Awkward from Swift

Properties: v3

Dot syntax in ObjC and Swift, KVC/KVO:

```
au.maximumFramesToRender = 4096

let maxFrames = au.valueForKey(“maximumFramesToRender”) as? Int

mixerAU.addObserver(self, forKeyPath: "inputBusses", options: nil,
    context: nil)

mixerAU.inputBusses.addObserverToAllBusses(self,
    forKeyPath: "format", options: nil, context: nil)
```

Busses

Objects

- AUAudioUnitBusArray
- AUAudioUnitBus

```
let fmt: AVAudioFormat = au.inputBusses[0].format
let sampleRate: Double = fmt.sampleRate
au.outputBusses[0].name = “Reverb send”
```

Parameters: v2

Scope/element/ID

- Unweildy tuple
- Not enough bits for complex AU's

```
AudioUnitGetParameter(audioUnit, paramID, scope, element, value)
AudioUnitSetParameter(audioUnit, paramID, scope, element, value)
```

Complex AUEventListener API

AUAudioUnit.parameterTree

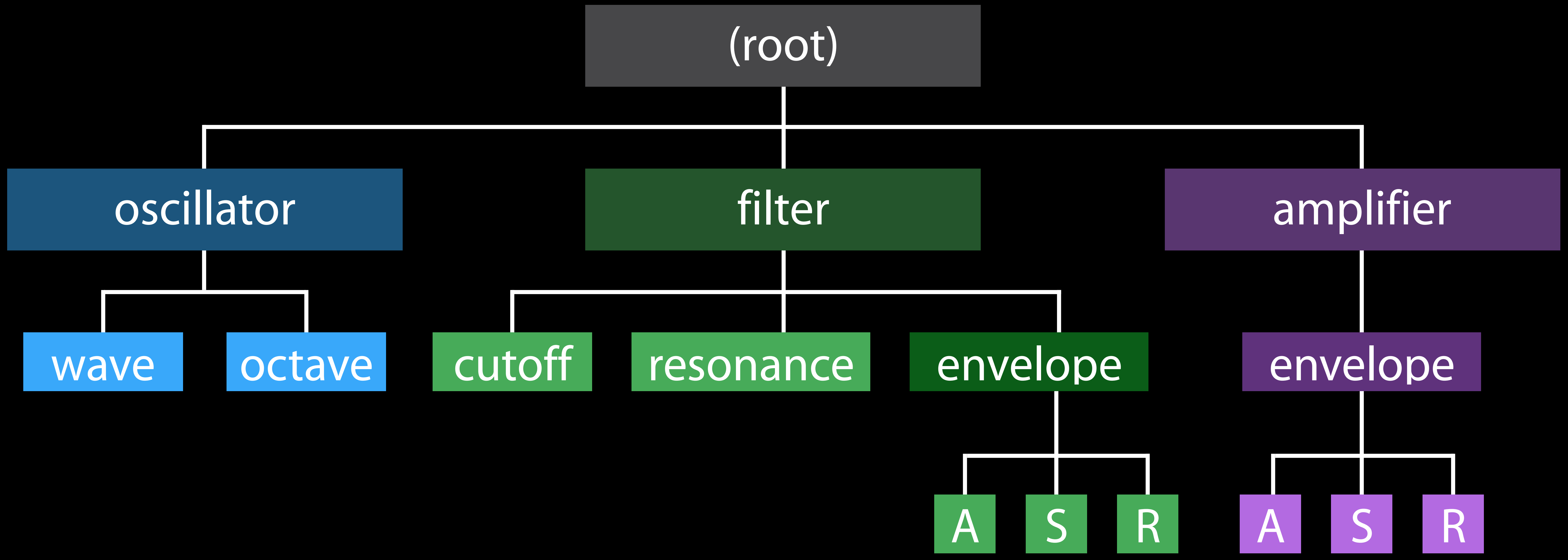
Nodes

- Groups
- Parameters
- Permanent,
  unique string ID's

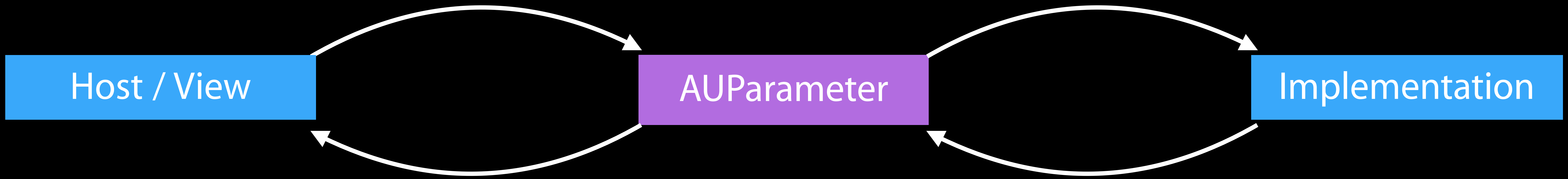
Key path (KVC)

- `oscillator.wave`
- `filter.envelope.attack`

Parameters also have numeric addresses (transient)

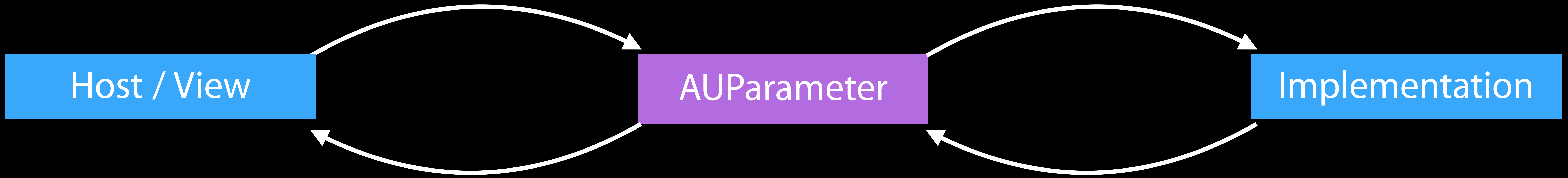


Parameter Wiring



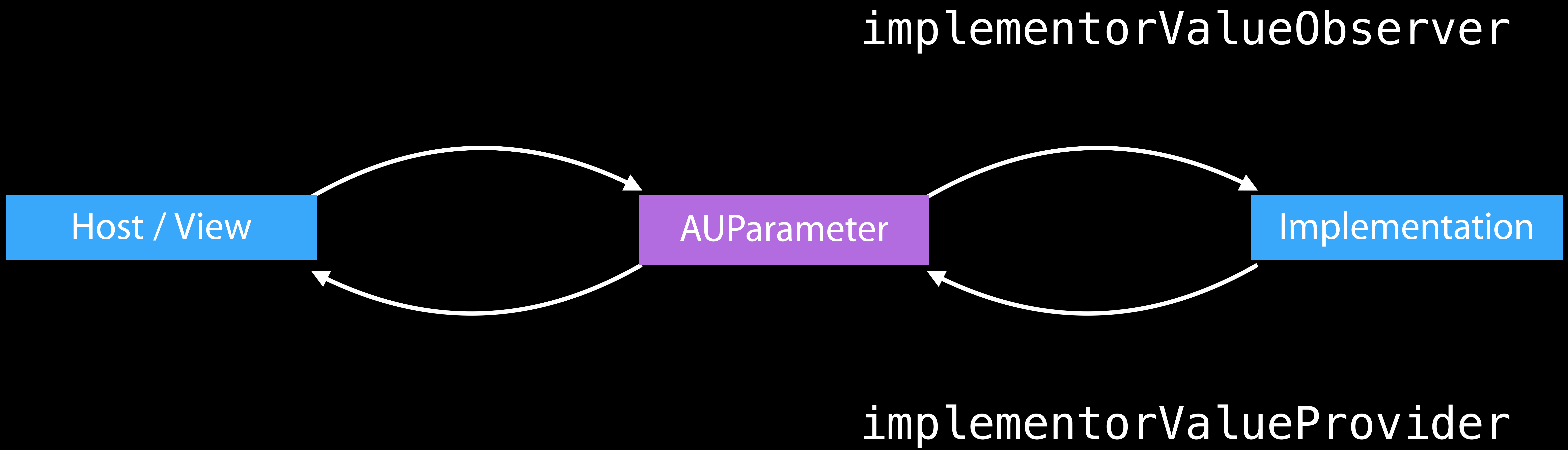
Parameter Wiring

```
   param.value = x
   param.setValue(
x, originator: token)
```

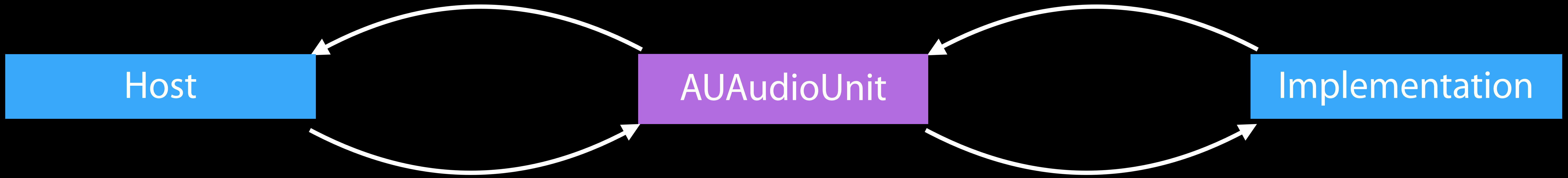


```
(^AUParameterObserver)
(AUParameterAddress
address, AUValue value)
```

Parameter Wiring

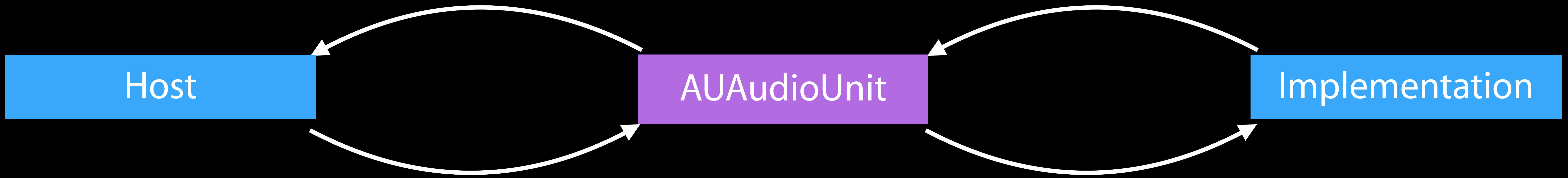


Parameter Scheduling



Parameter Scheduling

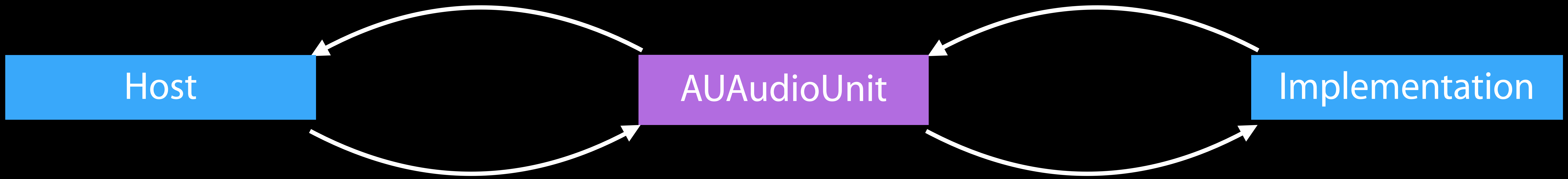
```
        doSchedule =
au.scheduleParameterBlock
```



```
doSchedule(when, rampDurationFrames,
           paramAddress,
           value)
```

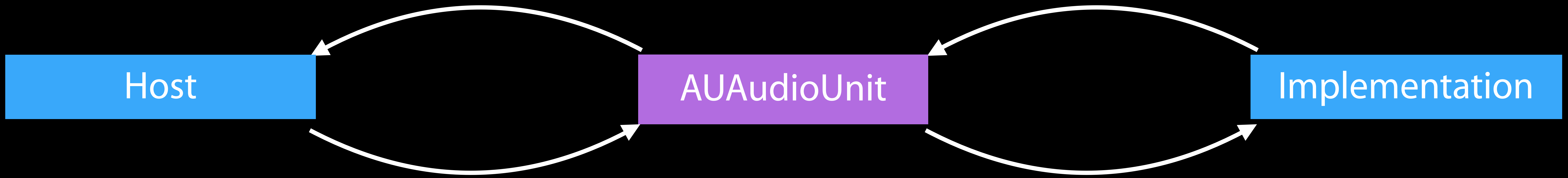
Parameter Scheduling

```
internalRender =
au.internalRenderBlock
```



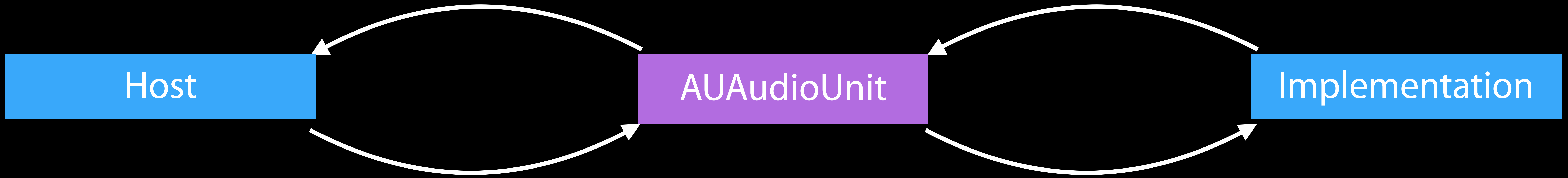
```
internalRender(… AURenderEvent
realtimeEventListHead …)
```

MIDI Events



MIDI Events

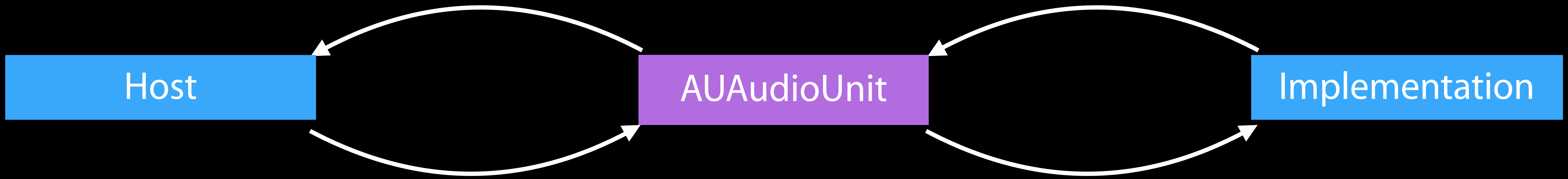
```
     scheduleMIDI =
au.scheduleMIDIEventBlock
```



```
scheduleMIDI(when, cable,
    numBytes, bytePtr)
```

MIDI Events

```
internalRender =
au.internalRenderBlock
```



```
internalRender(… AURenderEvent
realtimeEventListHead …)
```

Rendering

Pull model

v2: AU has connection or input callback

v3: Input always from callback

Otherwise, functionally identical

- Efficient bridging

Calling the Render Block

For hosts

Fetch the block when allocating render resources:

```
au.allocateRenderResources()
renderBlock = au.renderBlock
```

Call it to render:

```
renderBlock(…)
```

Render Block: Output Buffers

Host provides `AudioBufferList` for the Audio Unit's output

`bufferList.mBuffers[i].mData` can be null

- AU must replace this with an internally-owned buffer
- Buffer must remain valid until next render cycle

Render Block: Input Buffers

Host provides `AURenderPullInputBlock`

AU calls block for input

AU must supply valid `AudioBufferList` (non-null **`mData`** pointers)

Host may replace **`mData`** pointers

- Must guarantee that memory remains valid until next render cycle

Goal—Avoid copying

Rendering

Realtime thread context

- Cannot allocate memory
- Cannot make blocking calls

Using/implementing render blocks

- Never capture self: ObjC runtime unsafe
- Swift unsafe too
- To capture state: use pointer to C struct, C++ object

Apple Music Creation Apps

Audio Unit Extensions

Alec Little
Product Designer

Upcoming Support for Audio Unit Extensions

GarageBand iOS

GarageBand Mac

Logic Pro X

Mainstage

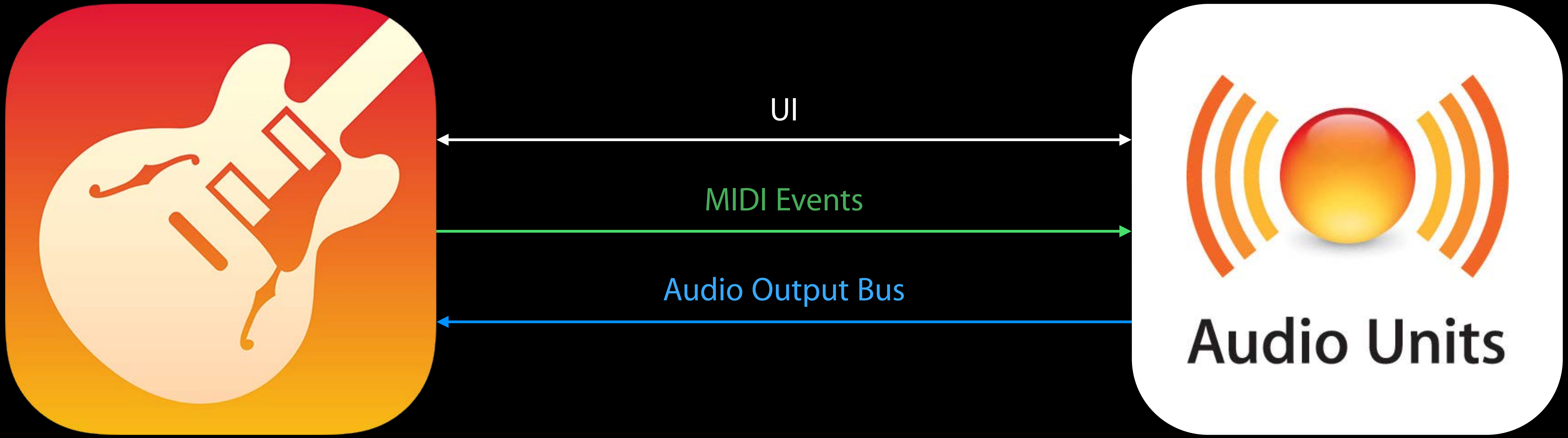
GarageBand iOS

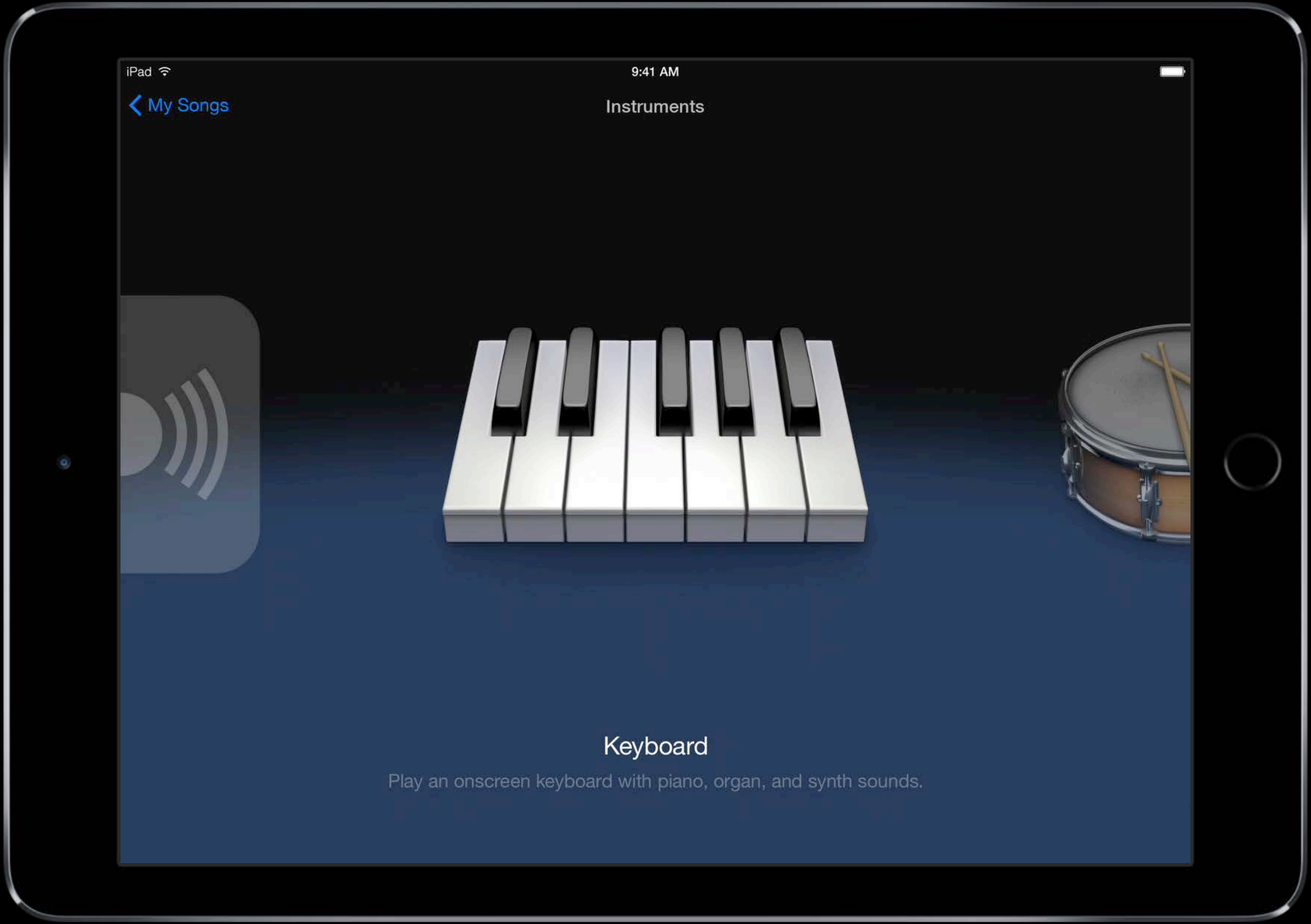
Preliminary Audio Unit Extension UI

Preliminary Audio Unit Extension UI

AU Instruments

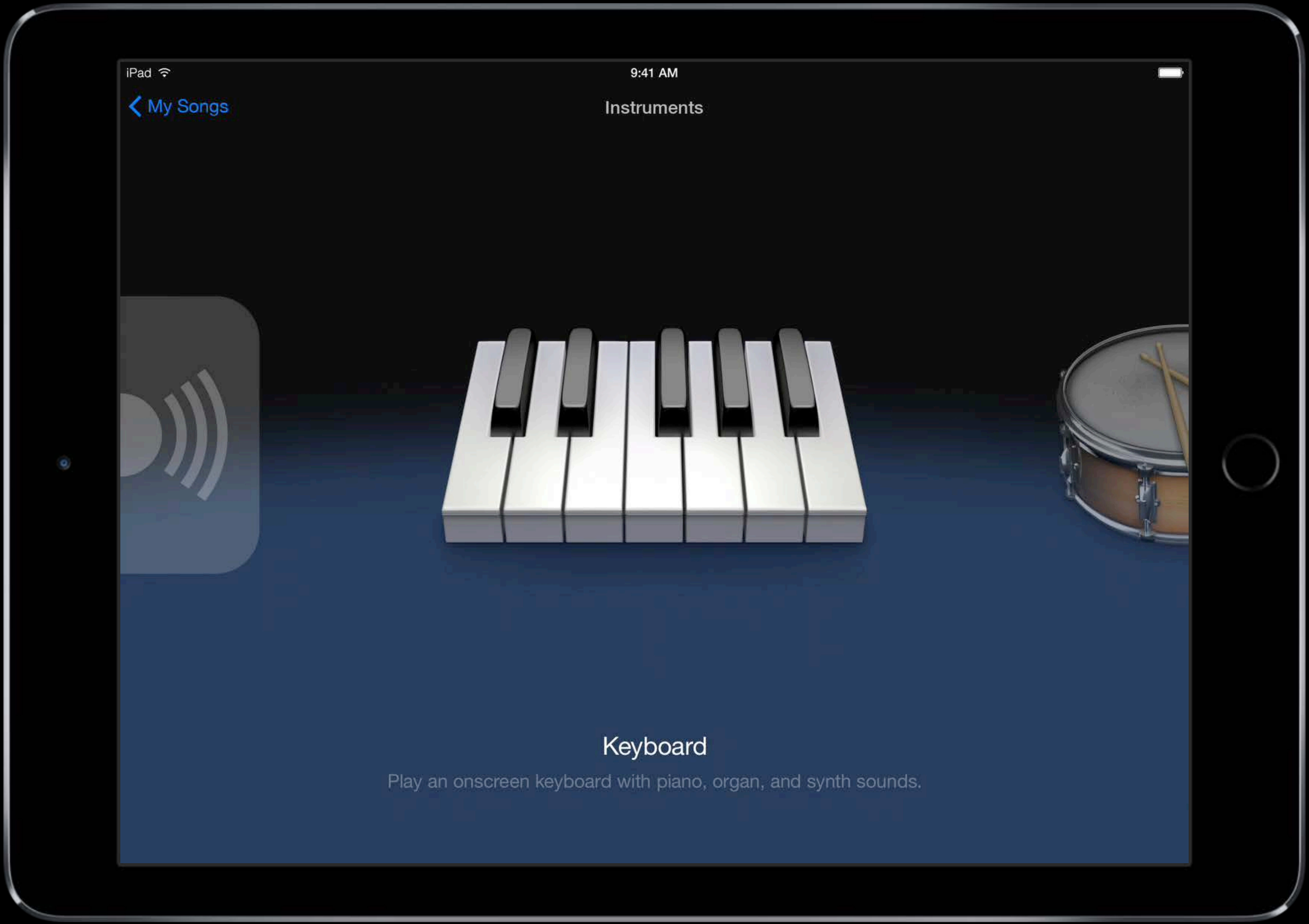
AU Instruments





Keyboard

Play an onscreen keyboard with piano, organ, and synth sounds.



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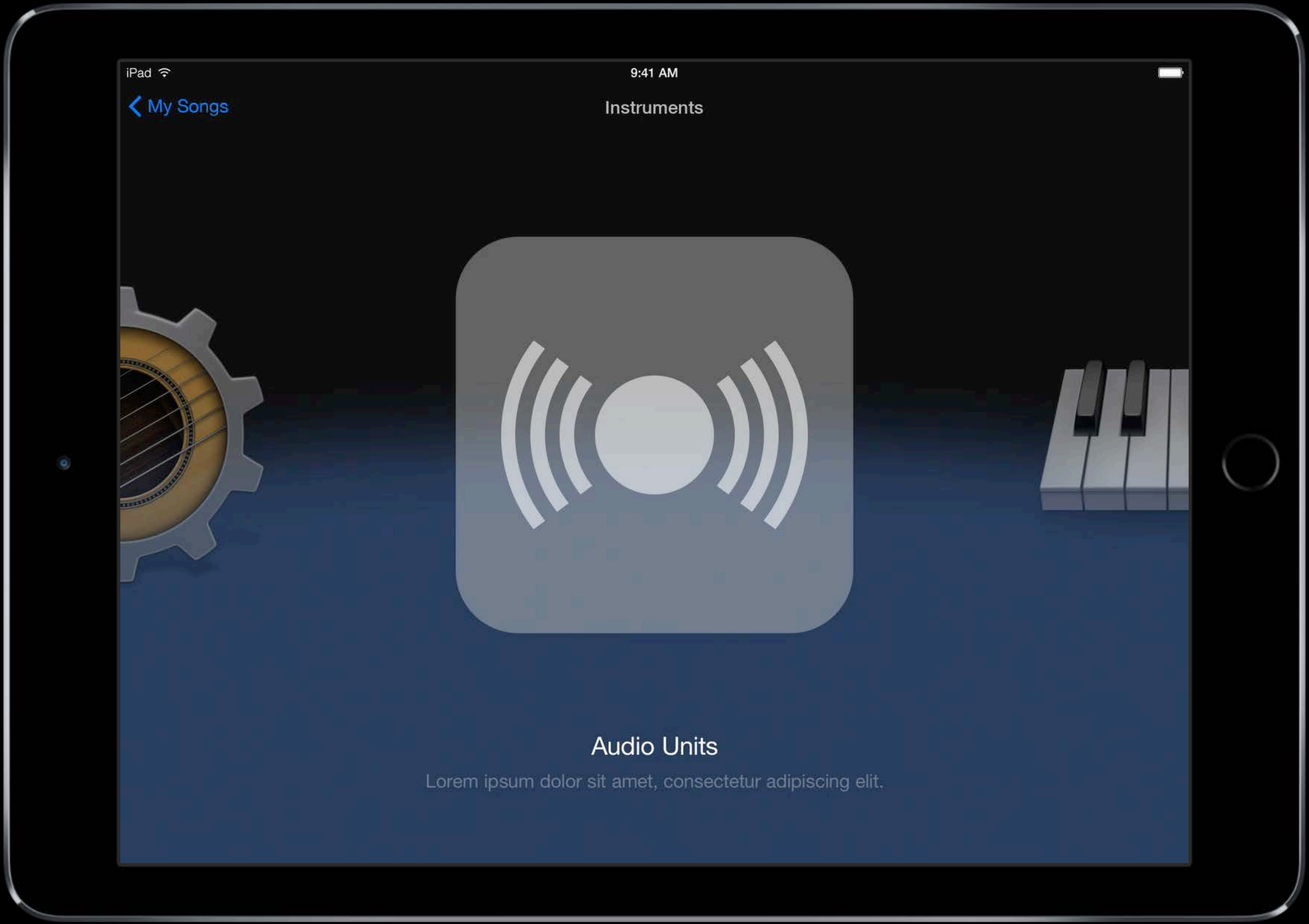
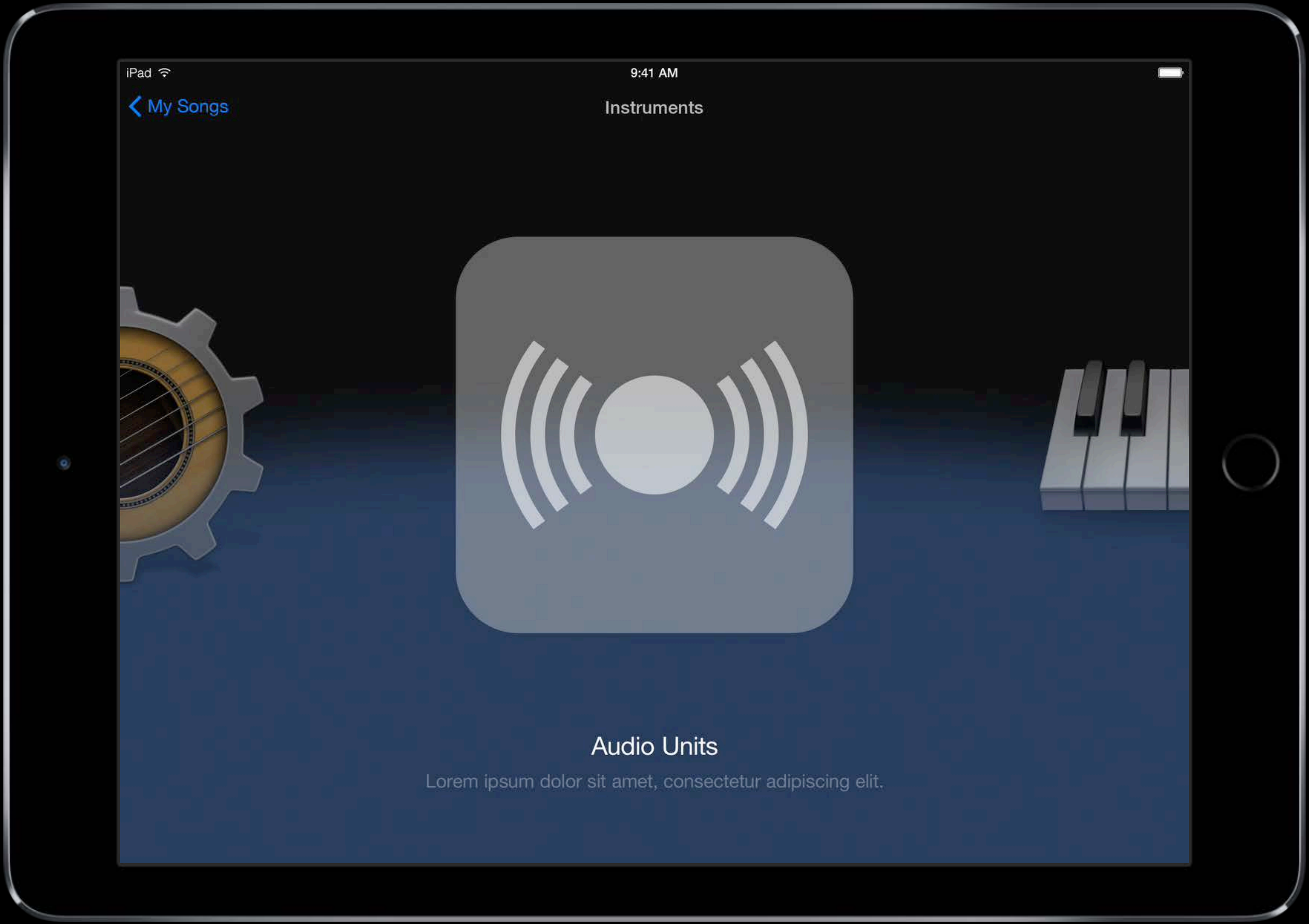


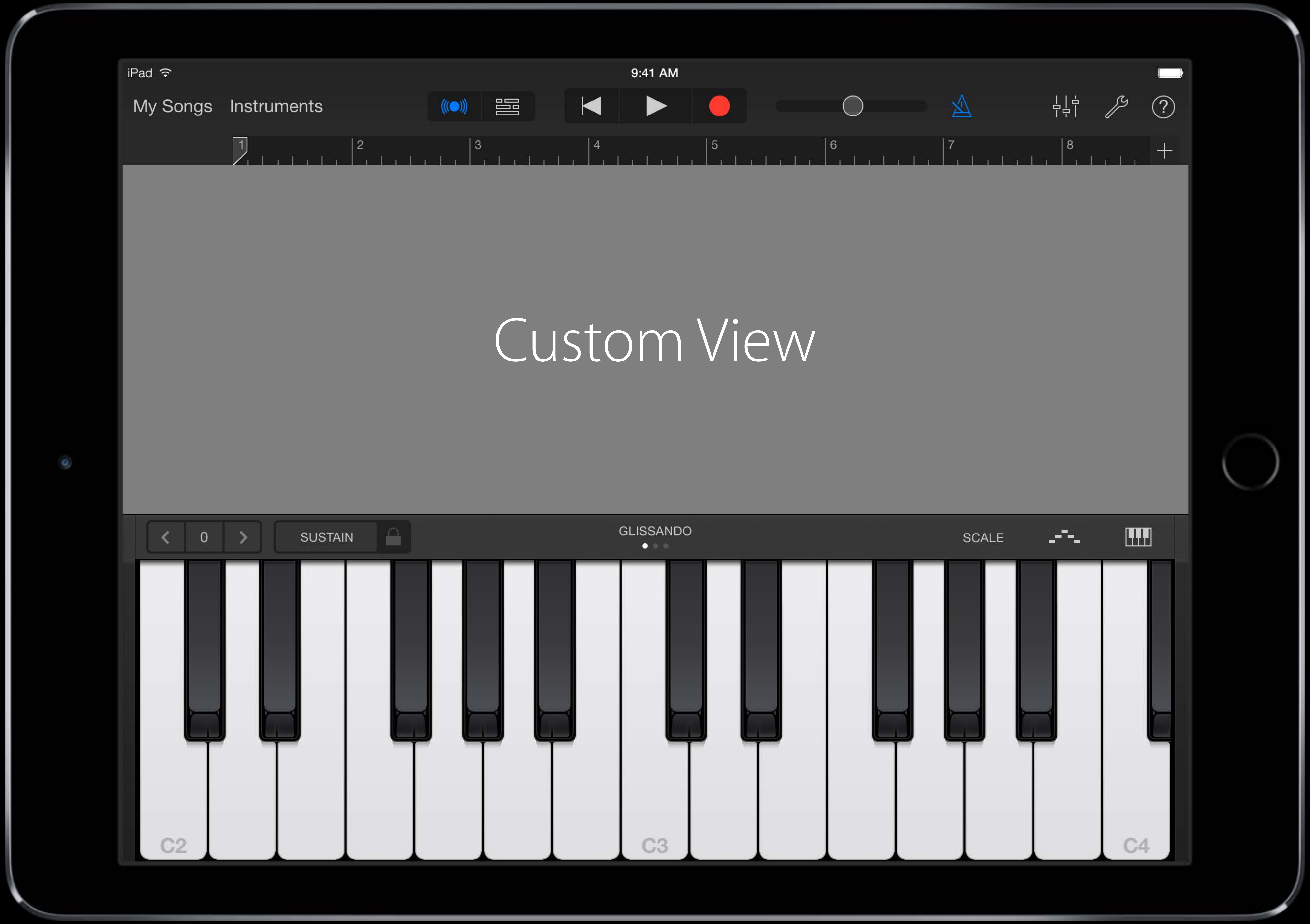
Audio Units

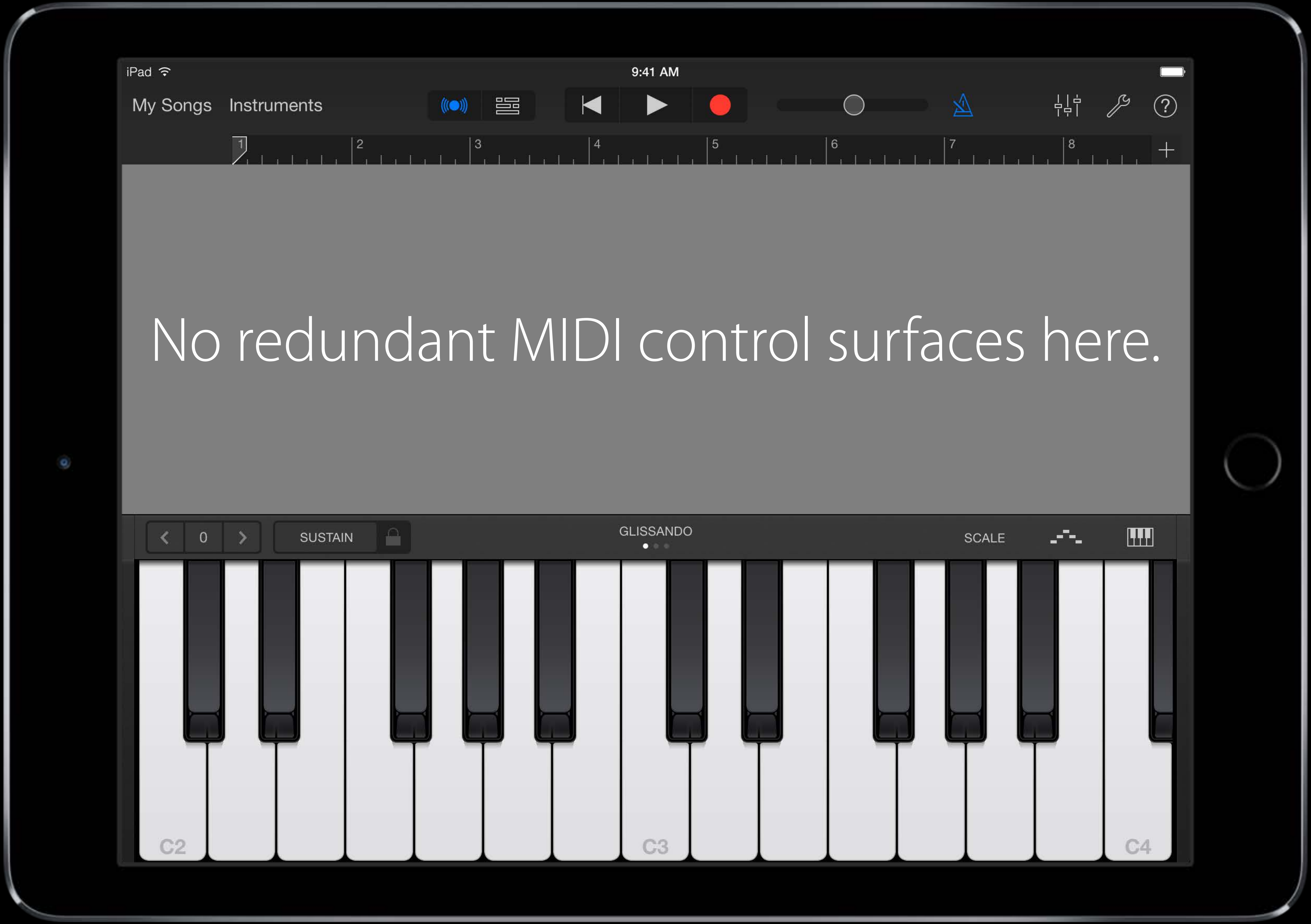
Lorem ipsum dolor sit amet, consectetur adipiscing elit.

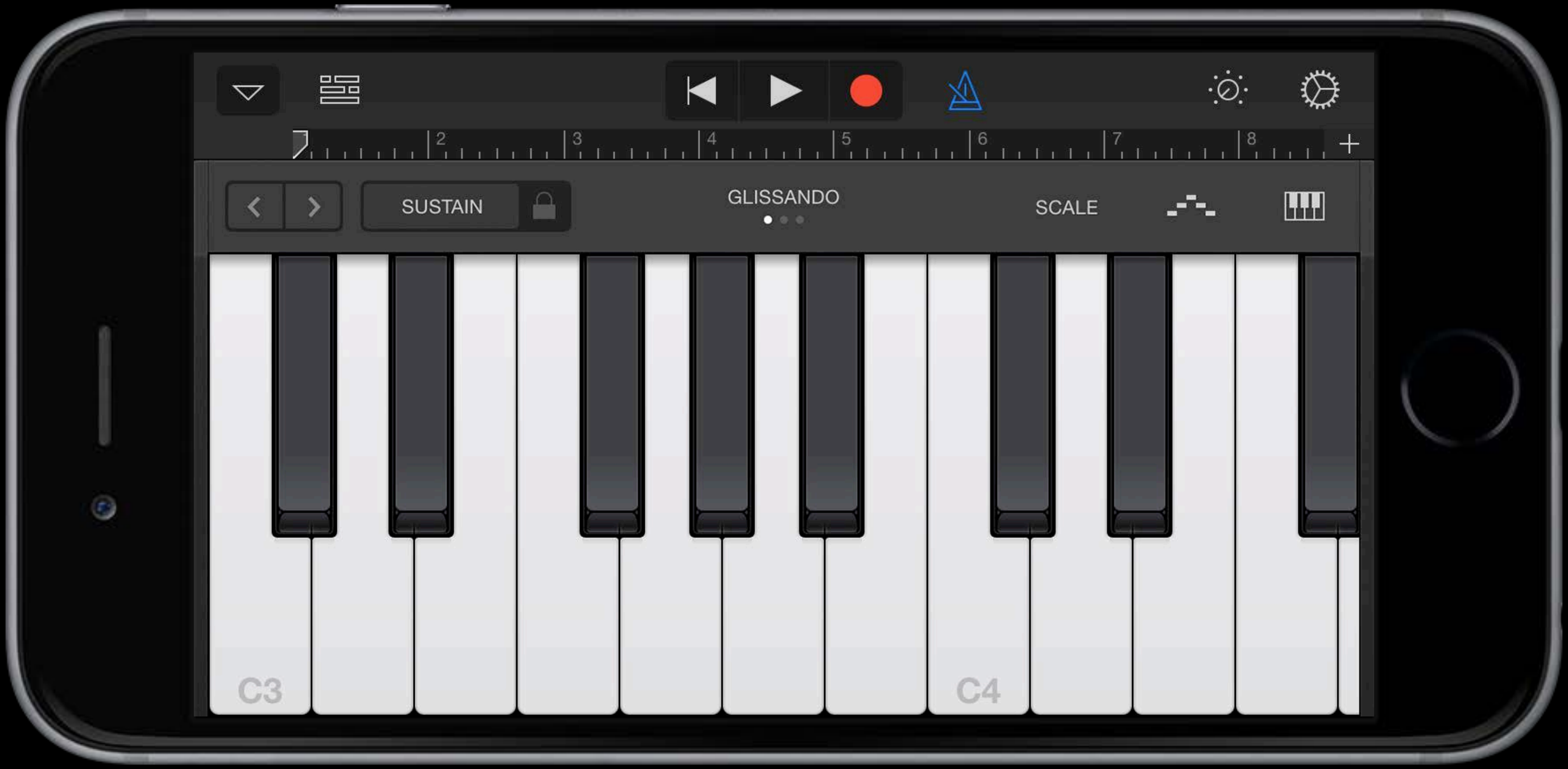


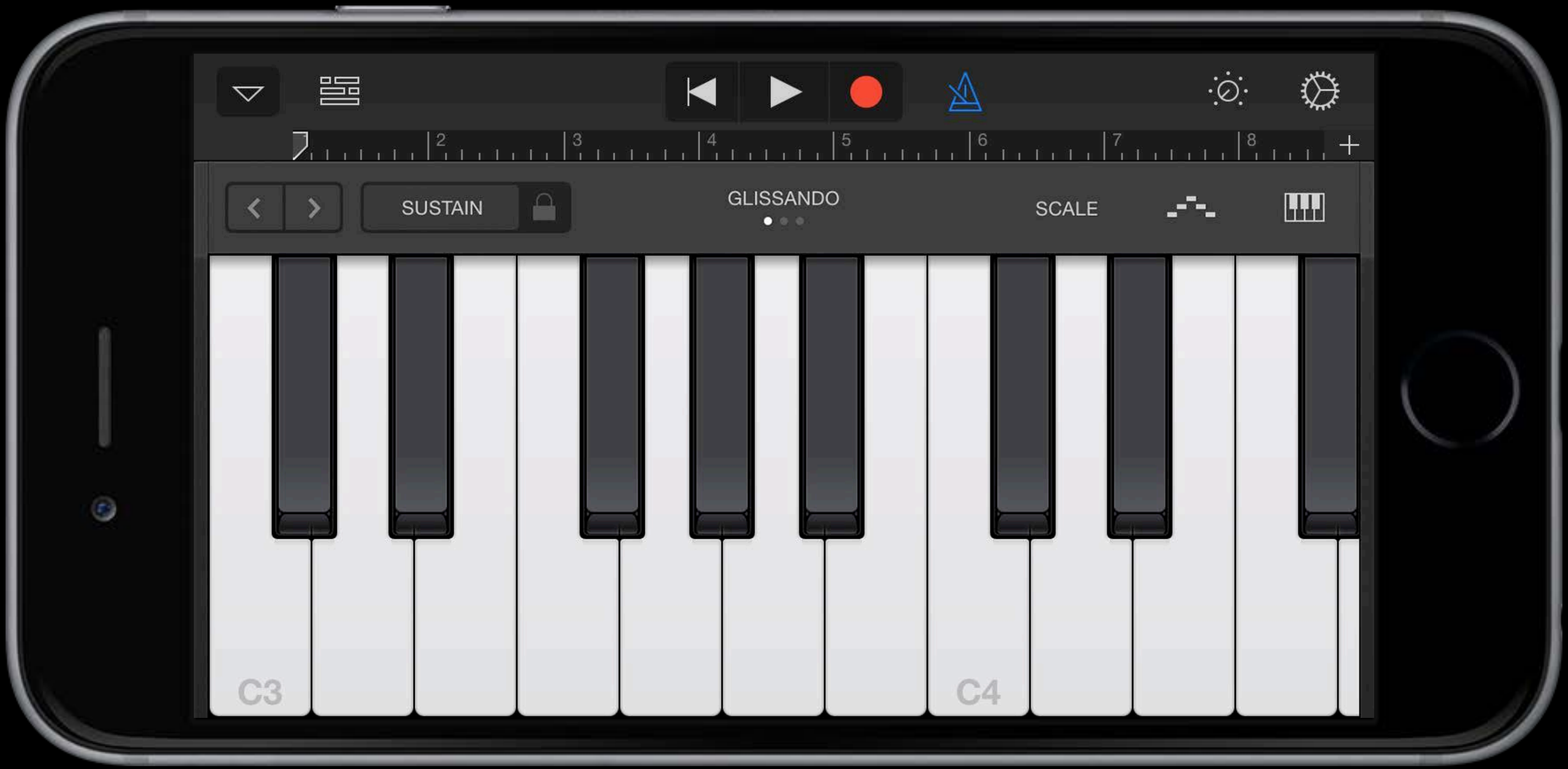
Audio Units

Lorem ipsum dolor sit amet, consectetur adipiscing elit.


iPad
9:41 AM
My Songs
Instruments
1
2
3
4
5
6
7
8
Custom View
0
SUSTAIN
GLISSANDO
SCALE
C2
C3
C4


No redundant MIDI control surfaces here.


SUSTAIN
GLISSANDO
SCALE
C3
C4


SUSTAIN
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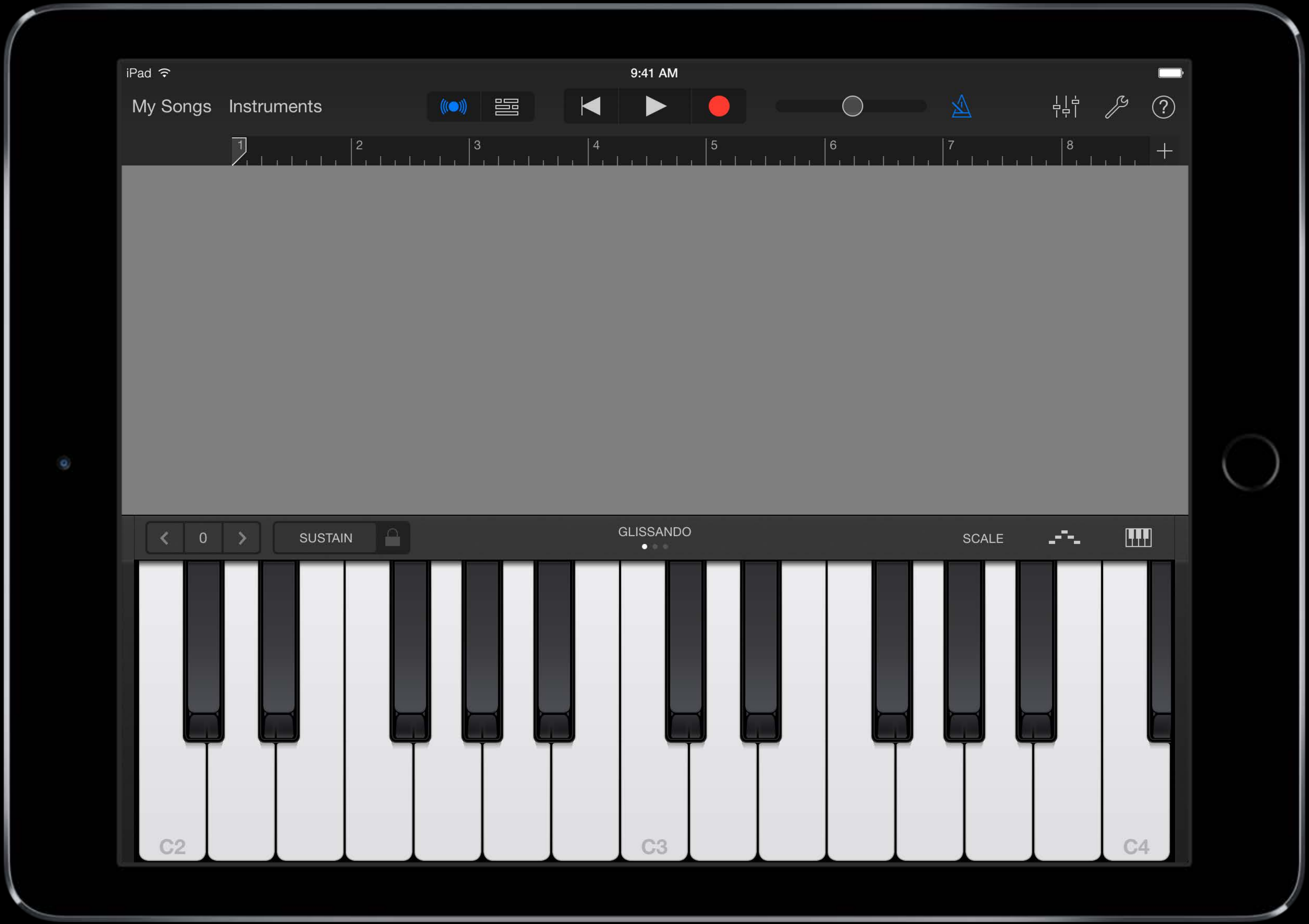
C4

GarageBand iOS Custom View

iPad Air	2048 x 670
iPhone 6+	2208 x 726
iPhone 6	1334 x 404
iPhone 5s	1136 x 350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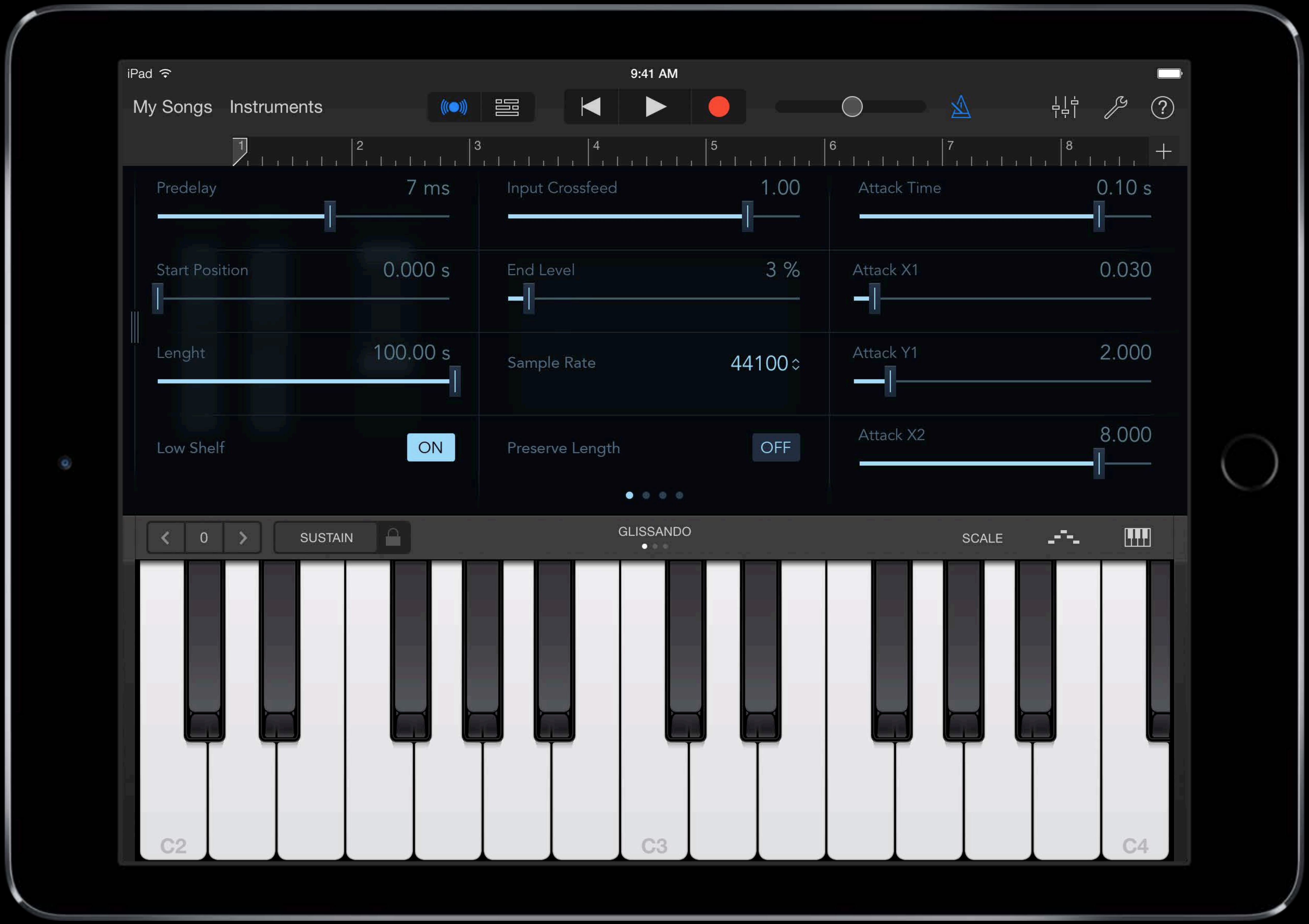
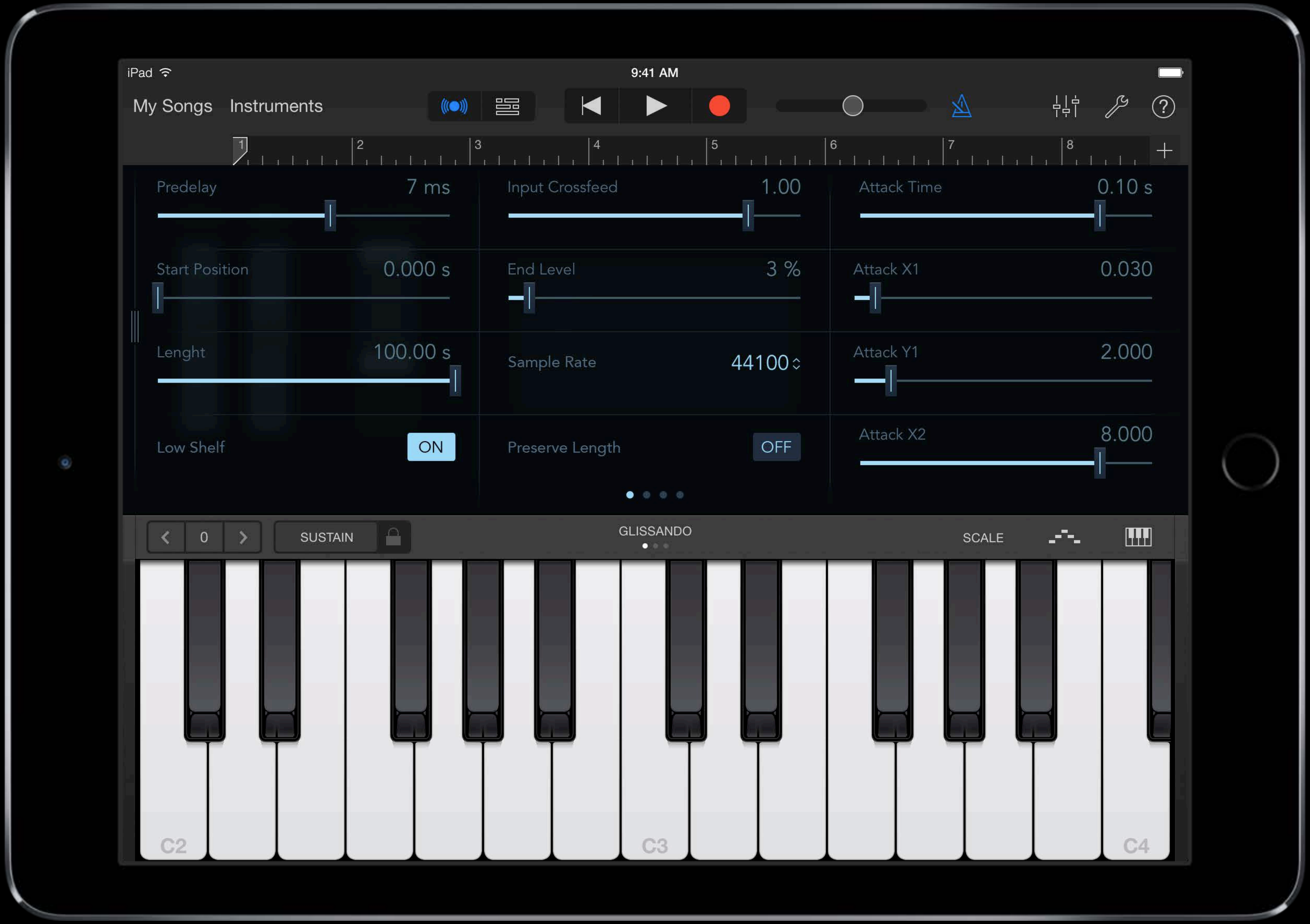


Predelay 7 ms
Input Crossfeed 1.00
Attack Time 0.10 s
Start Position 0.000 s
End Level 3 %
Attack X1 0.030
Lenght 100.00 s
Sample Rate 44100
Attack Y1 2.000
Low Shelf ON
Preserve Length OFF
Attack X2 8.000



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Apple Music Creation Apps

Audio Unit Extensions

FAQ

What About Inter-App Audio?

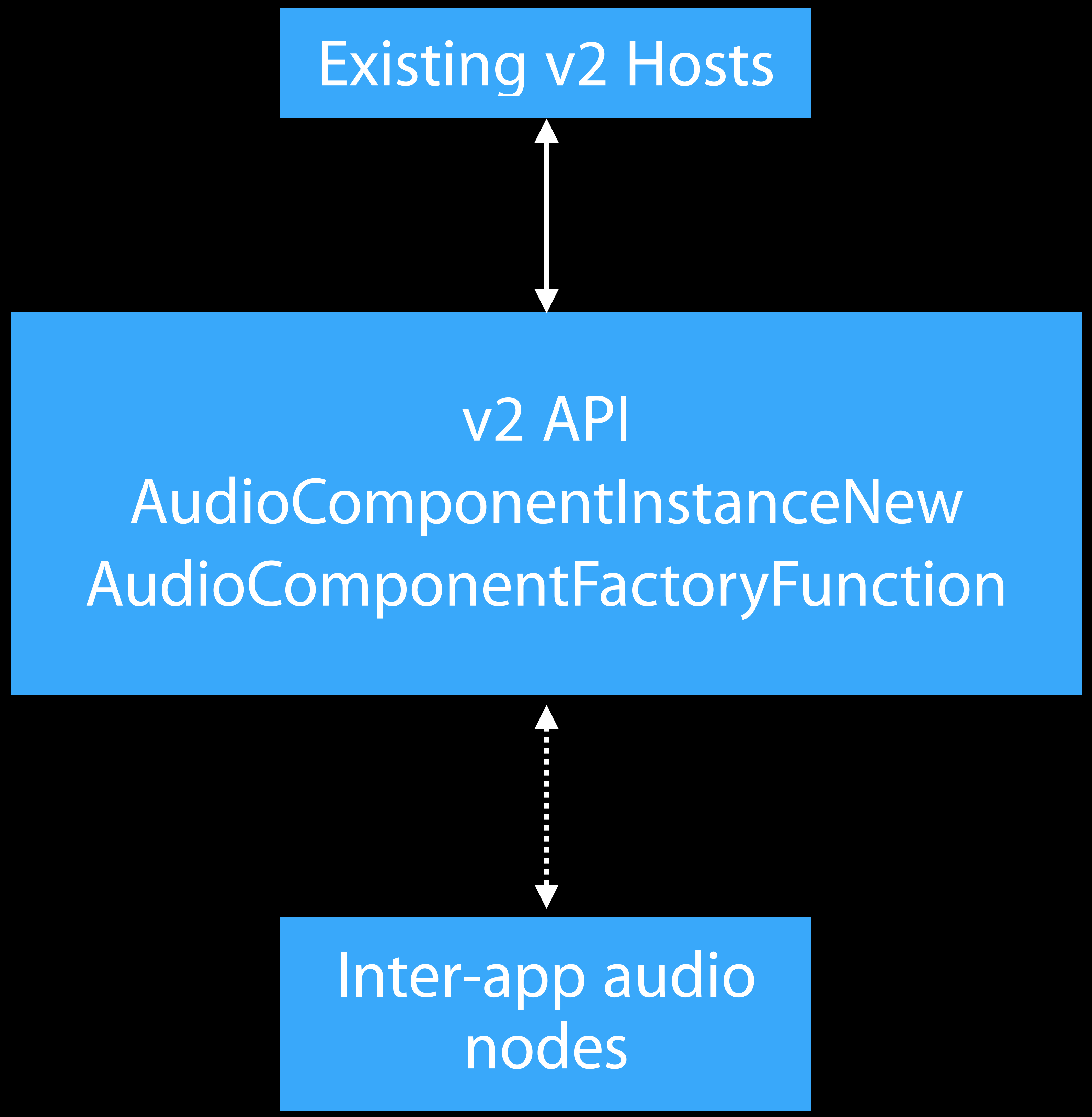
Inter-app audio uses a small subset of v2 API

No parameter support

Switching apps can be clunky

Not deprecated

Audio Unit Extensions—Inter-App Audio++



What About My v2 Host or AU?

Bridges maintain compatibility

Update to v3 when you can

v2 AU porting shortcut

- Subclass AUAudioUnitV2Bridge

Are v3 Audio Units Cross-Platform?

AUAudioUnit

- Fully portable

AUViewController

- Derives from UIViewController or NSViewController
- UI is platform-specific

Reference

Headers in AudioUnit framework—but link AudioToolbox

- AUAudioUnit.h
- AUAudioUnitImplementation.h
- AUParameters.h

CoreAudioKit framework

- AUViewController.h

AVFoundation

- AVAudioUnitComponent.h

HeaderDoc

Reference

License to use Audio Units logo

- https://developer.apple.com/softwarelicensing/agreements/audio.php

Summary

Full plug-in model on iOS

Audio Units in the iOS and OS X App Stores

`AVAudioEngine` simple host

Sample code: `AudioUnitV3Example`

Write bugs

More Information

Technical Support

Swift Language Documentation
http://developer.apple.com/swift

Apple Developer Forums
http://developer.apple.com/forums

Related Sessions

What's New in Core Audio	Nob Hill	Wednesday 4:30PM

Related Labs

Audio Lab	Graphics, Games, and Media Lab A	Thursday 1:30PM

WWDC15