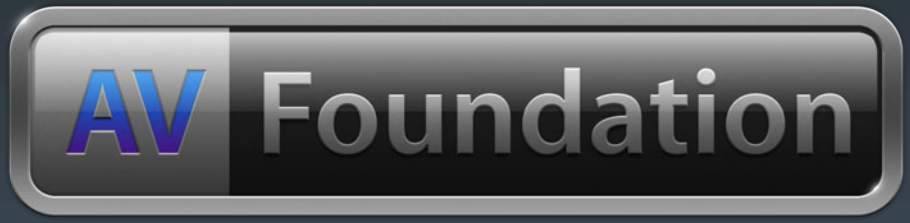
AV Foundation

Real-time media effects and processing during playback

Session 517

Simon Goldrei
Media Systems


AV Foundation

Agenda

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- Synchronizing an AVPlayer with a custom timeline

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- Synchronizing an AVPlayer with a custom timeline
- Real-time audio effects and processing

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- Real-time video effects and processing

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- Synchronizing an AVPlayer with a custom timeline
- Real-time audio effects and processing
- Real-time video effects and processing

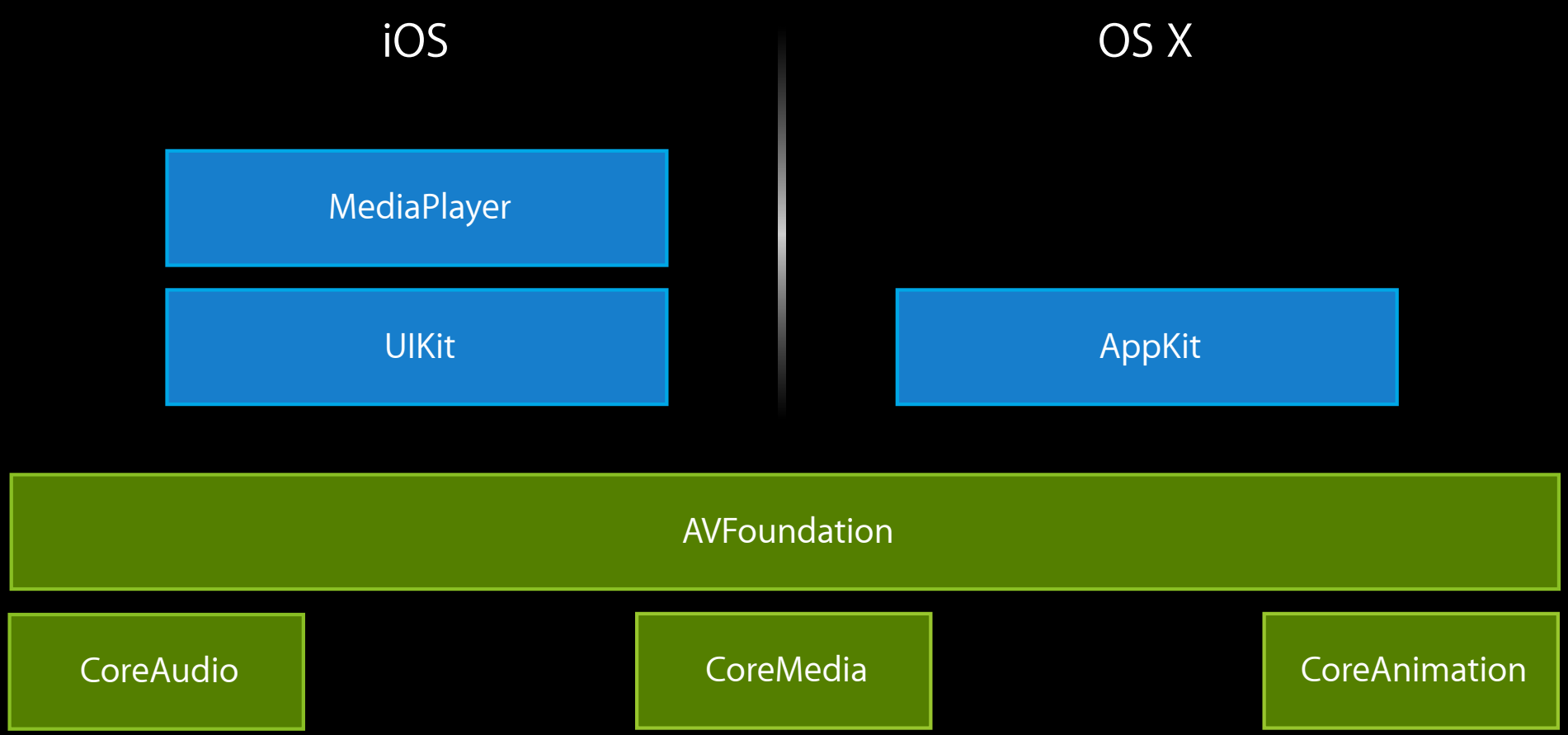
Stay in A/V Sync

Prerequisites

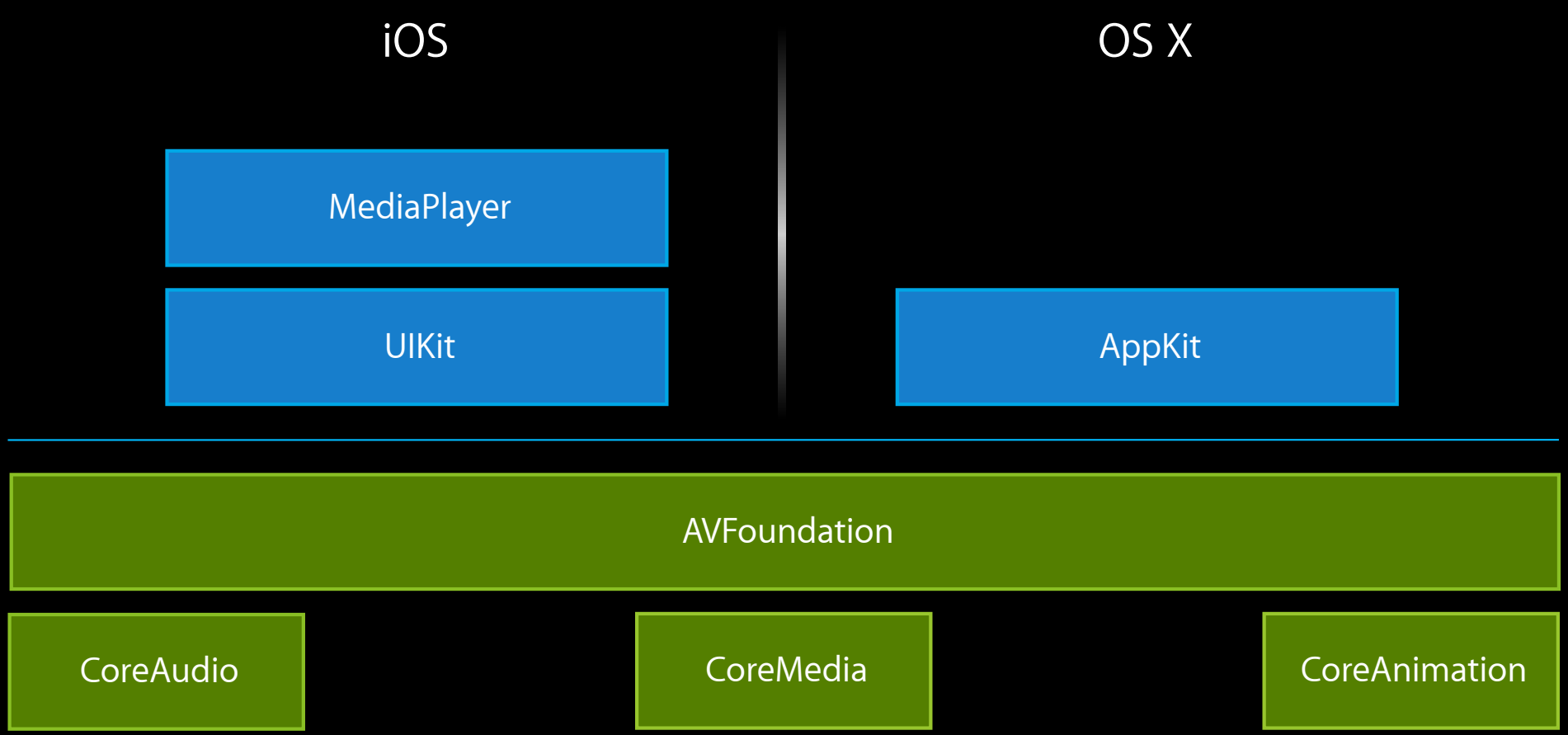
AVFoundation 2010 or 2011

- AVFoundation playback classes
  - AVAsset, AVAssetTrack
  - AVPlayerItem, AVPlayerItemTrack
  - AVPlayer

Where Is AV Foundation



Where Is AV Foundation



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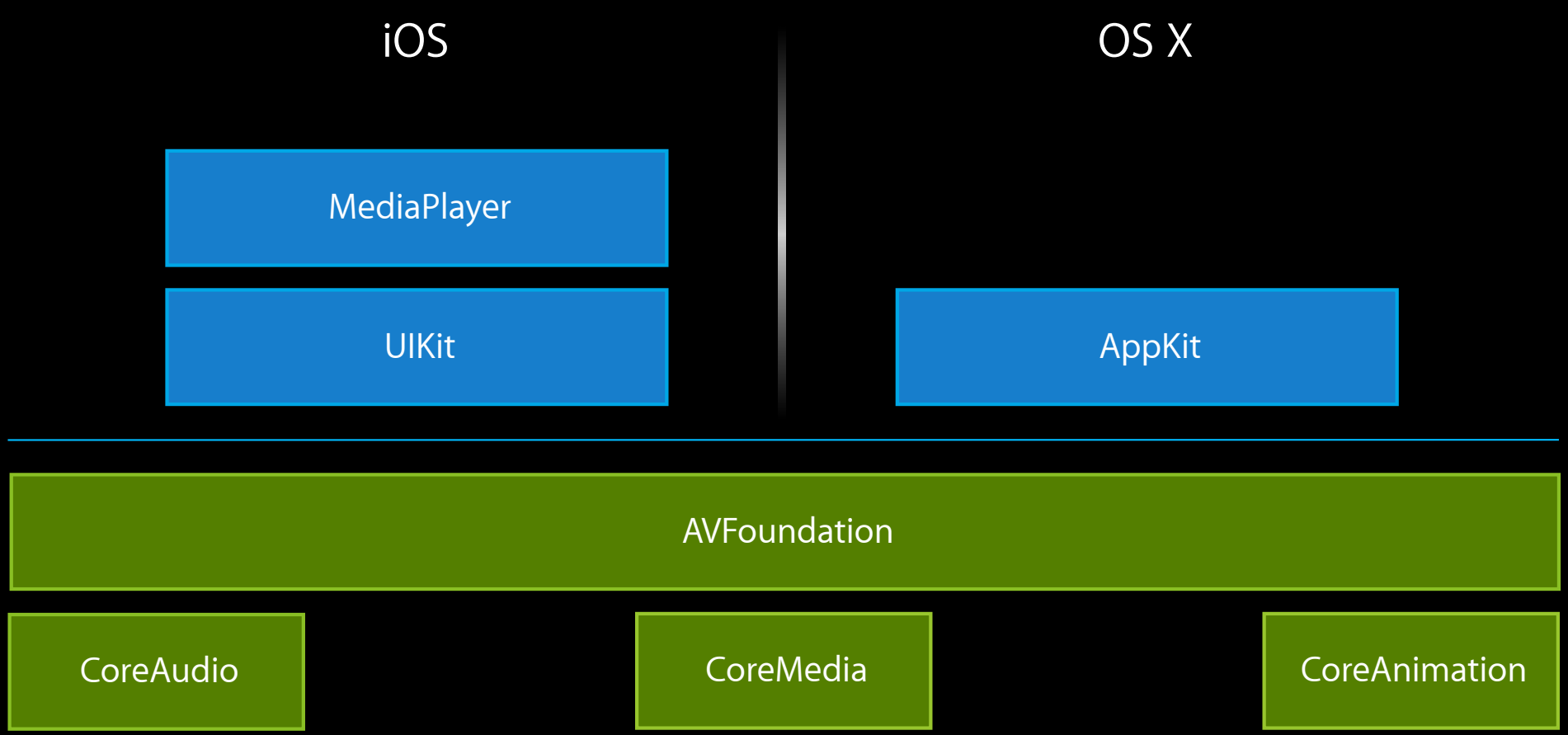

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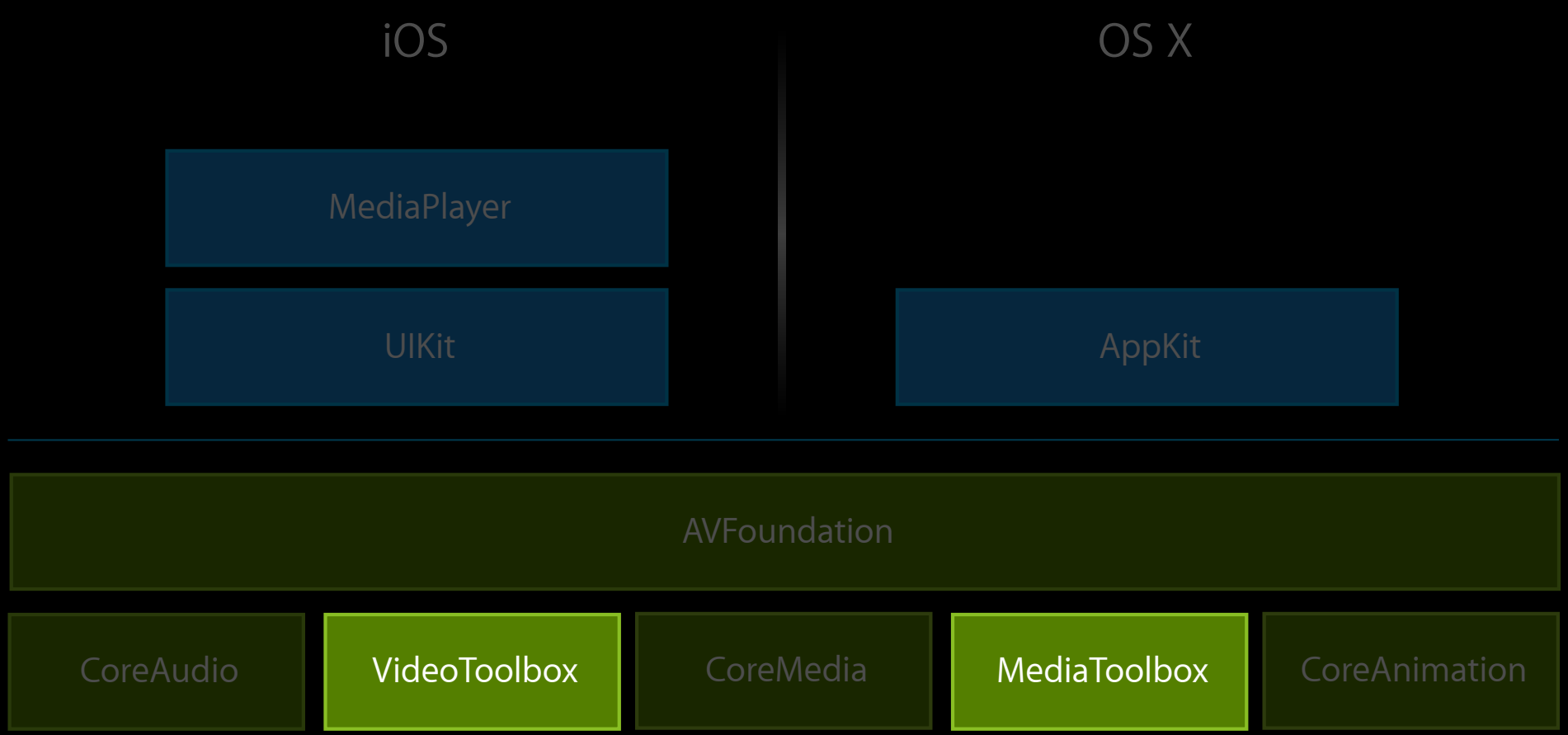
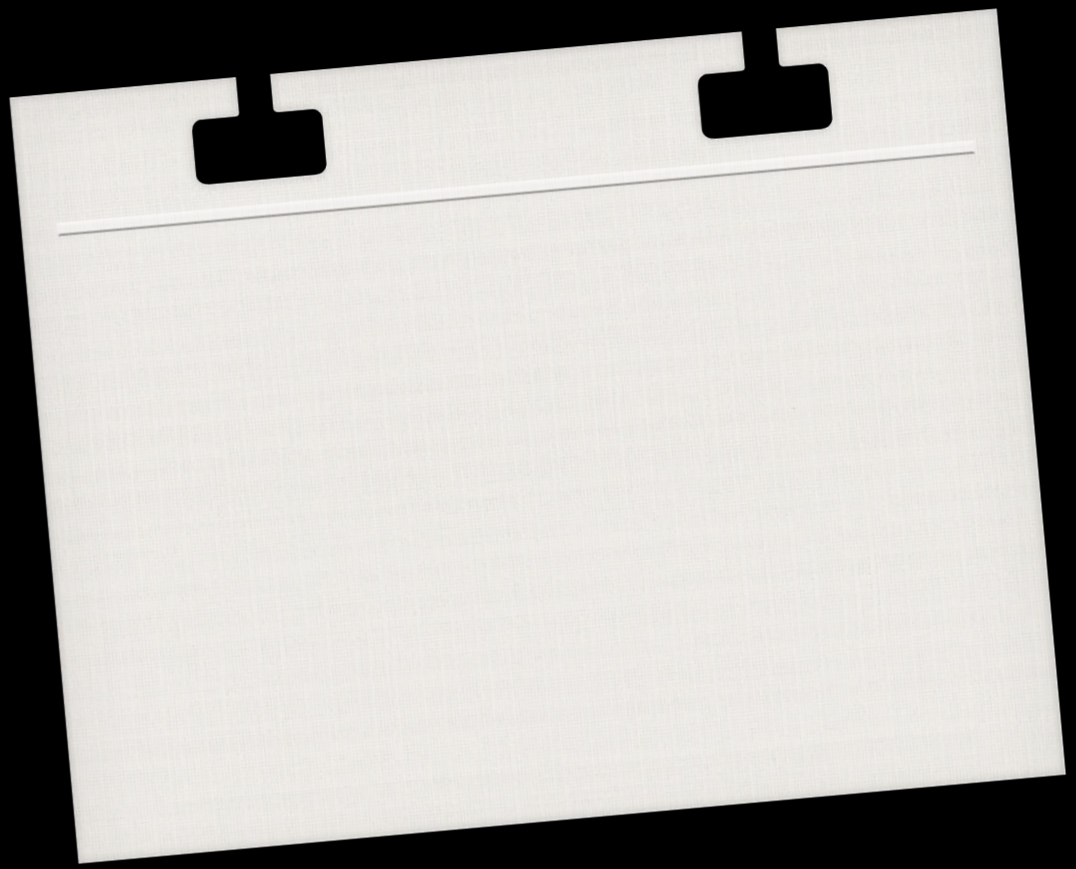


Playback Update

Playback in Four Easy Steps



Playback in Four Easy Steps

Playback in Four Easy Steps

- Create your AVURLAsset
- Load @"tracks" asynchronously

Playback in Four Easy Steps

- Create your AVURLAsset
- Load @"tracks" asynchronously
- Create AVPlayerItem

Playback in Four Easy Steps

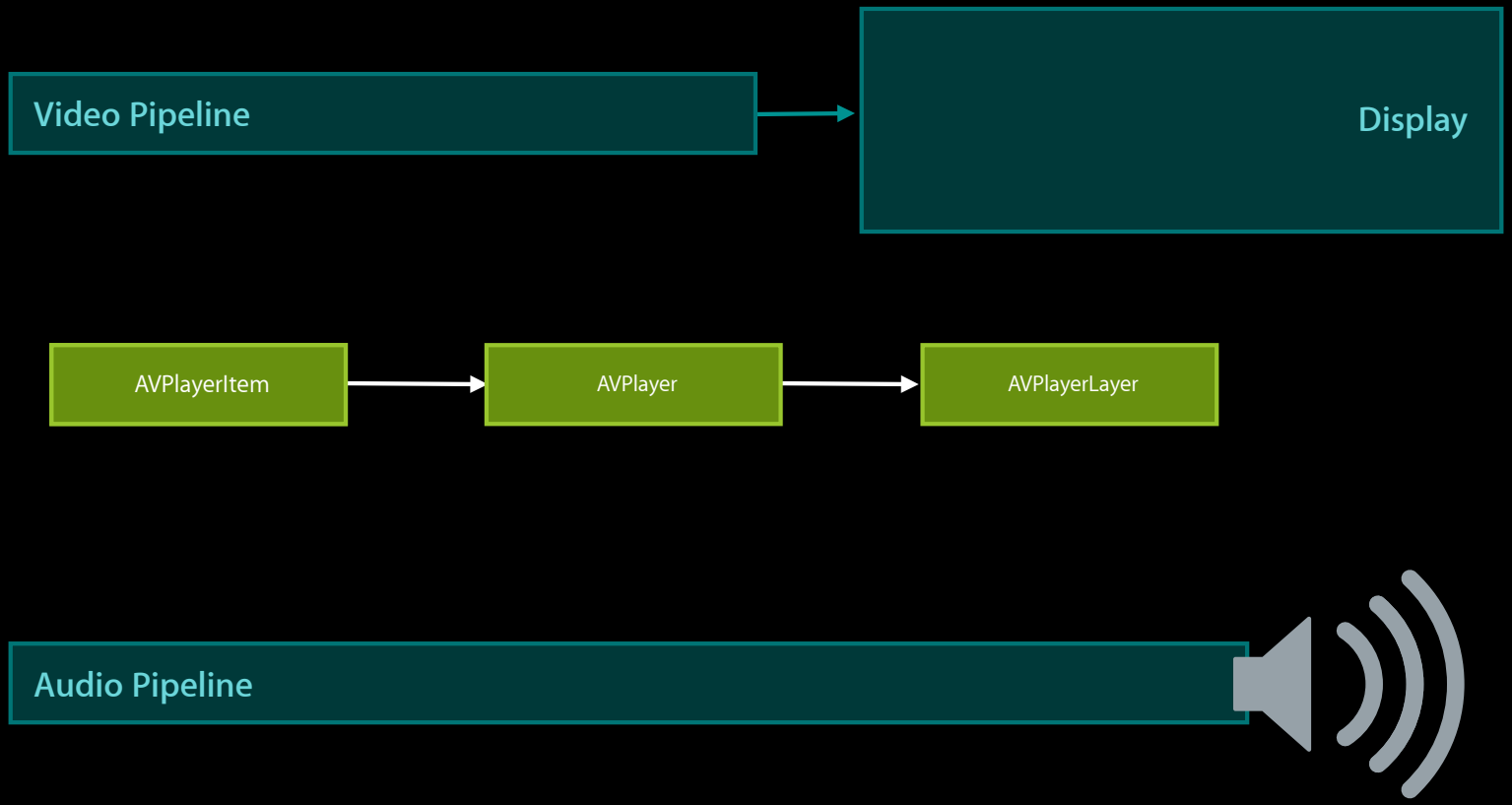
- Create your AVURLAsset
- Load @"tracks" asynchronously
- Create AVPlayerItem
- Create AVPlayer with your item

Playback in Three Easy Steps

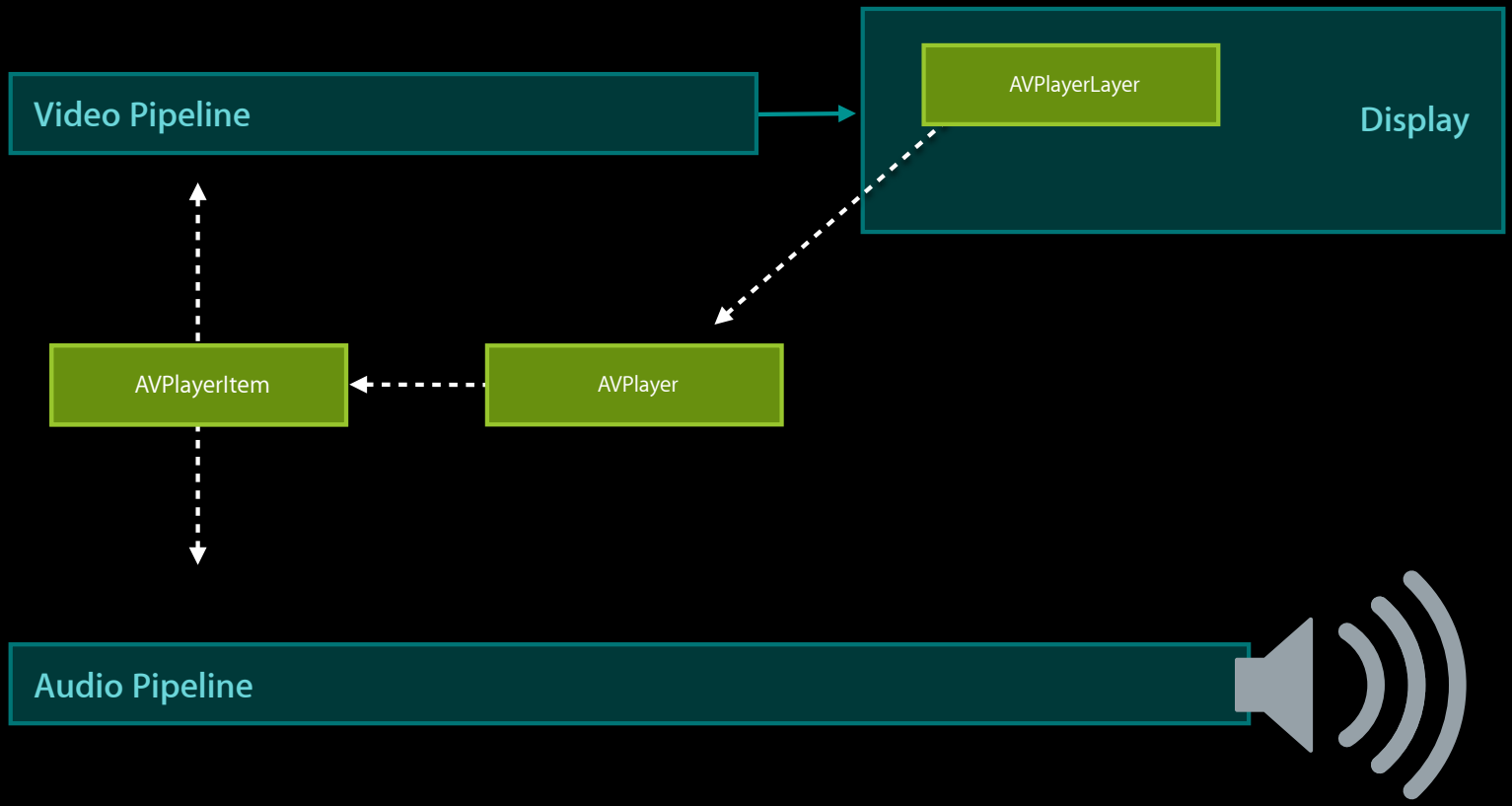
Customizing Playback

Synchronization primitives

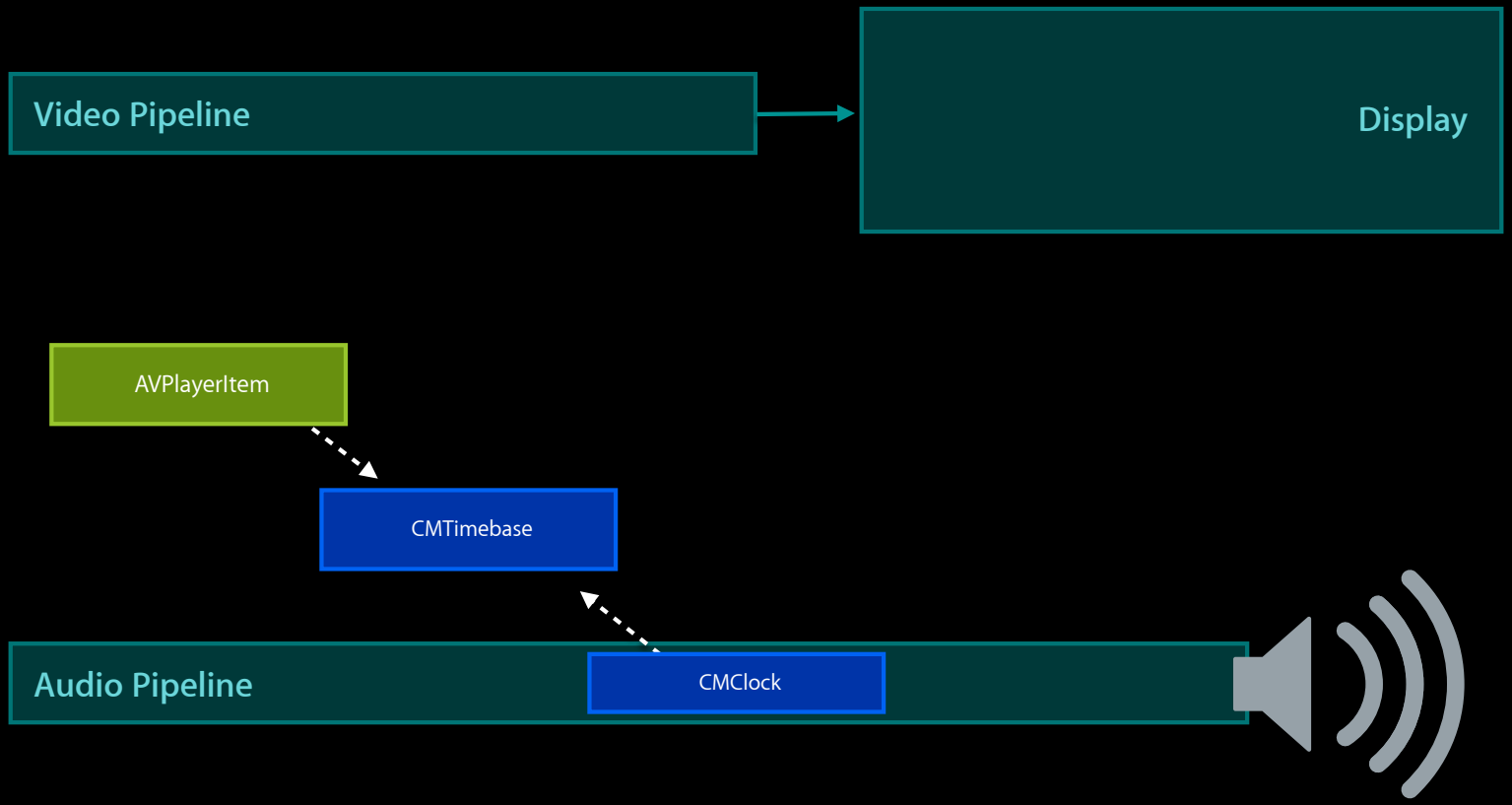
Playback Circa 2011



Playback Circa 2011



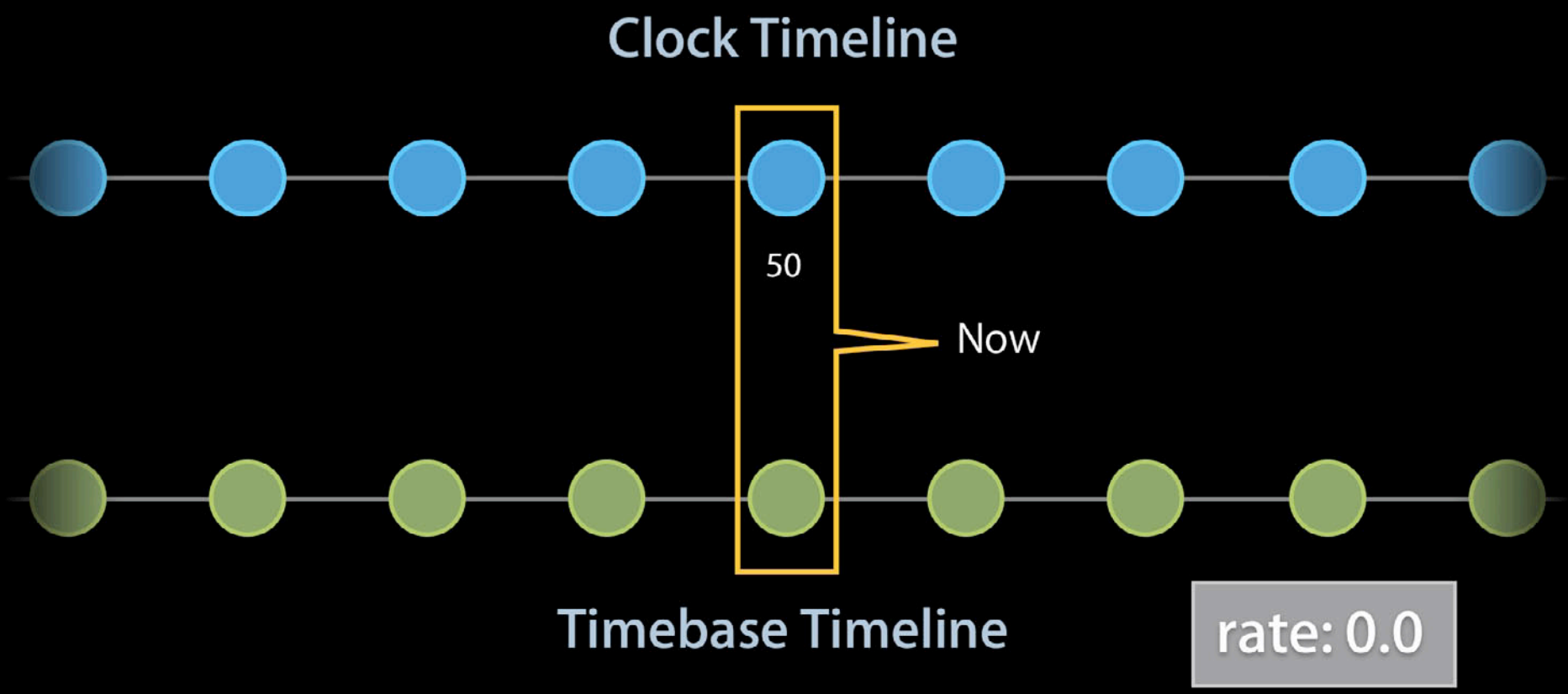
Keep It in Sync



CMClock and CMTimebase

- CMClock
  - A source of time measurement
    - Host time clock
    - Audio device clock
- CMTimebase
  - Rate with respect to time
  - Controlled by your application
  - Slaved to a master

CMClock and CMTimebase



CMClock and CMTimebase

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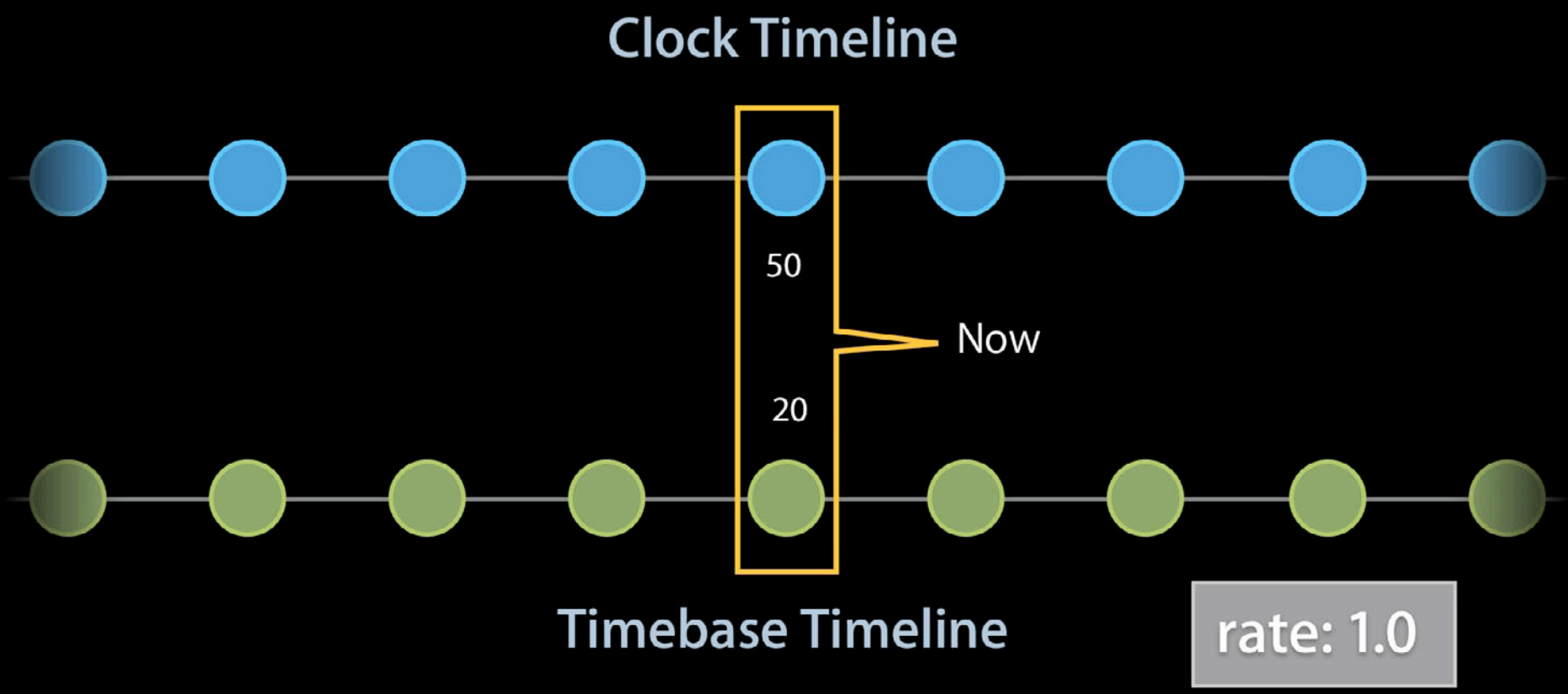

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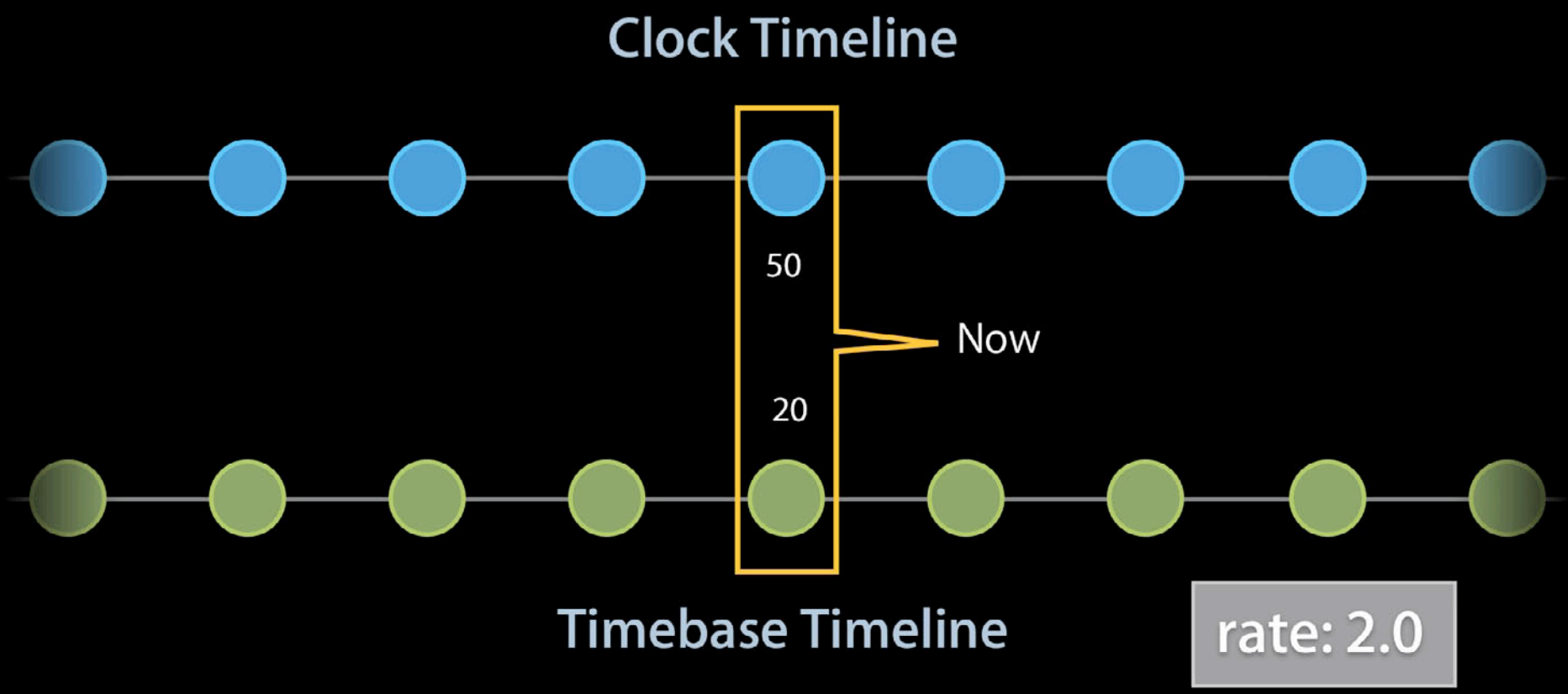

CMClock and CMTimebase

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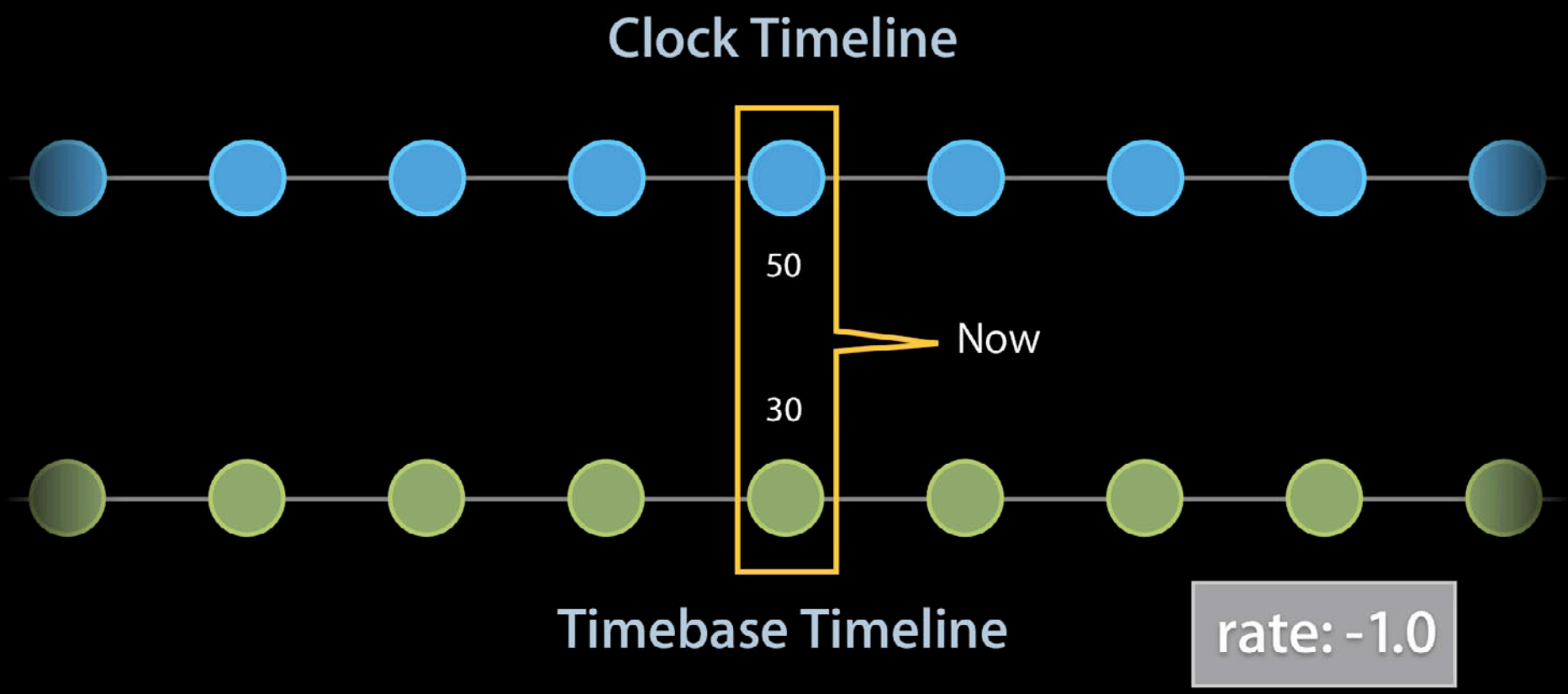


CMClock and CMTimebase

Audio Clock

CMAudioClock.h

```
OSStatus CMAudioClockCreate( CFAllocatorRef allocator,
                             CMClockRef *clockOut );
```

Audio Device Clock

CMAudioDeviceClock.h

```
OSStatus CMAudioDeviceClockCreate( CFAllocatorRef allocator,
                                   CFStringRef deviceUID,
                                   CMClockRef *clockOut );
```

Host Time Clock

CMSync.h

```
CMClockRef CMClockGetHostTimeClock( void );
```

CMTimebase

AVPlayerItem.h

```
@property (nonatomic, readonly) CMTimebaseRef timebase;
```

CMTimebase

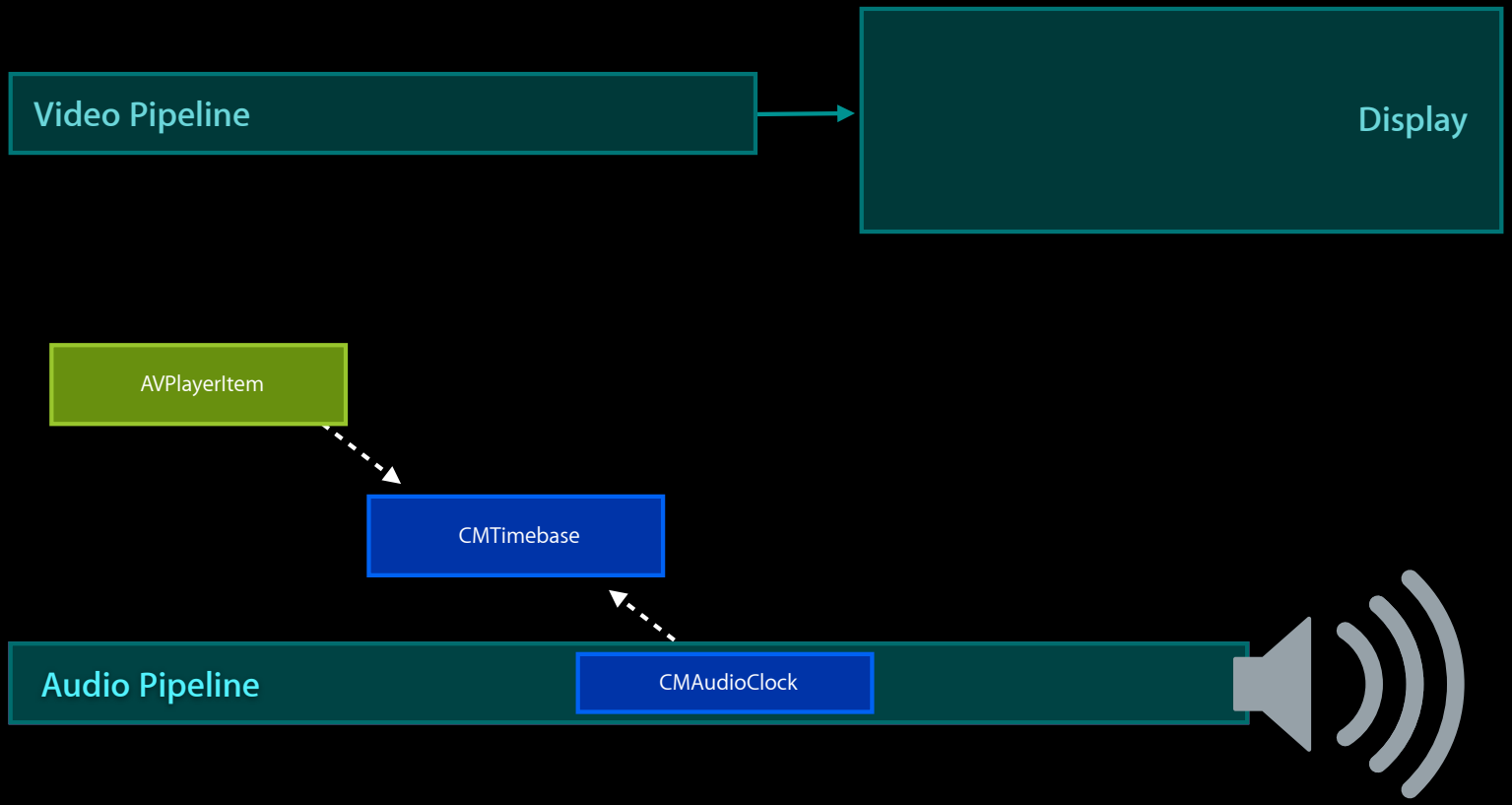
CMSync.h

```
OSStatus CMTimebaseCreateWithMasterClock( CFAllocatorRef allocator,
                                          CMClockRef masterClock,
                                          CMTimebaseRef *timebaseOut );
```

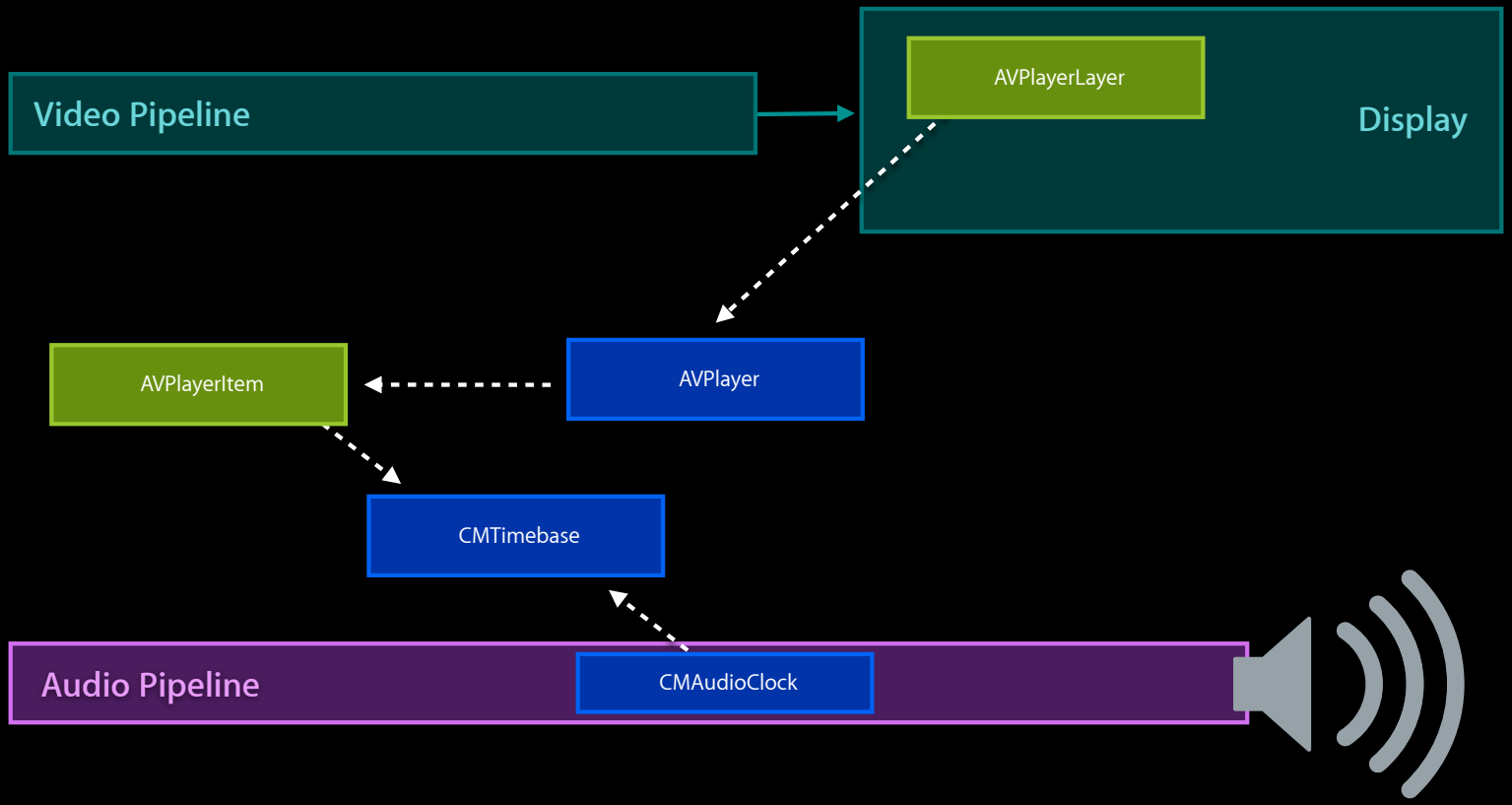
Synchronizing AVPlayer

Synchronizing AVPlayer with a custom timeline

Synchronizing Video to Custom Audio



Synchronizing Video to Custom Audio



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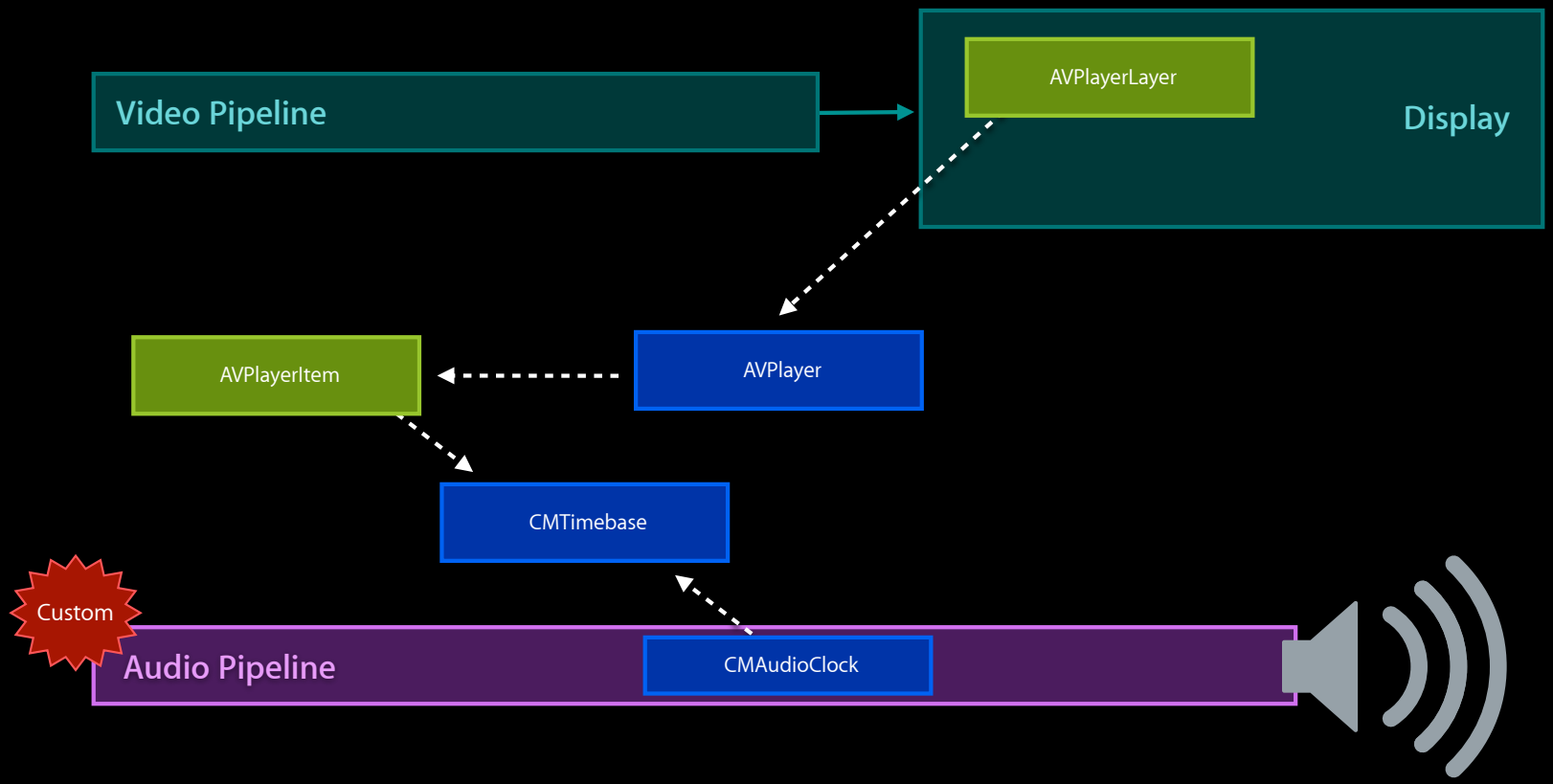

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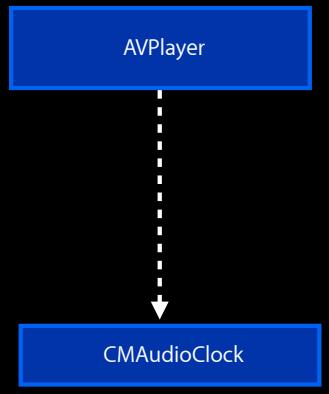


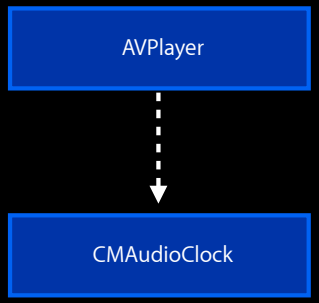
Synchronizing with AVPlayer

- Stay in sync

```
@property (nonatomic, retain) CMClockRef masterClock
```

- Start in sync

```
– setRate:(float)rate time:(CMTime)itemTime atHostTime:
(CMTime)hostClockTime
```



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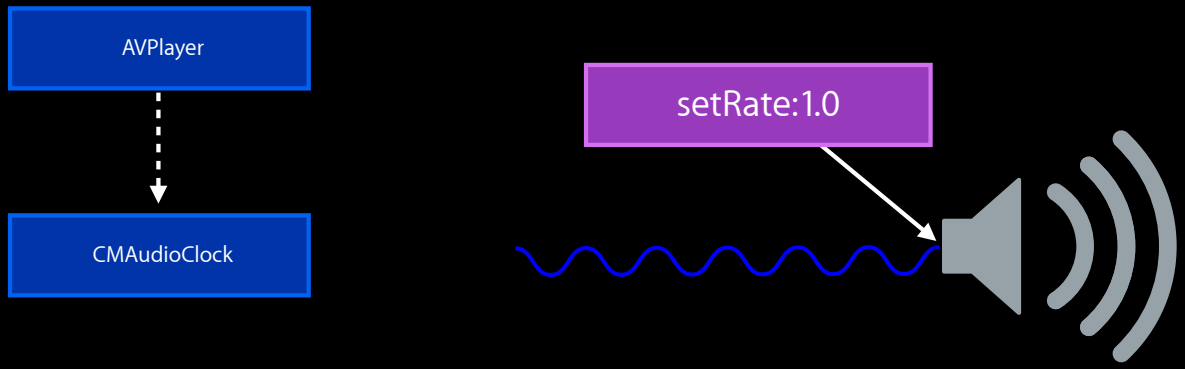

Synchronizing with AVPlayer

```
CMTime CMClockMakeHostTimeFromSystemUnits( uint64_t hostTime );

- setRate:(float)rate time:(CMTime)itemTime
                atHostTime:(CMTime)hostClockTime;
```

Synchronizing with AVPlayer

```
CMTime CMClockMakeHostTimeFromSystemUnits( uint64_t hostTime );

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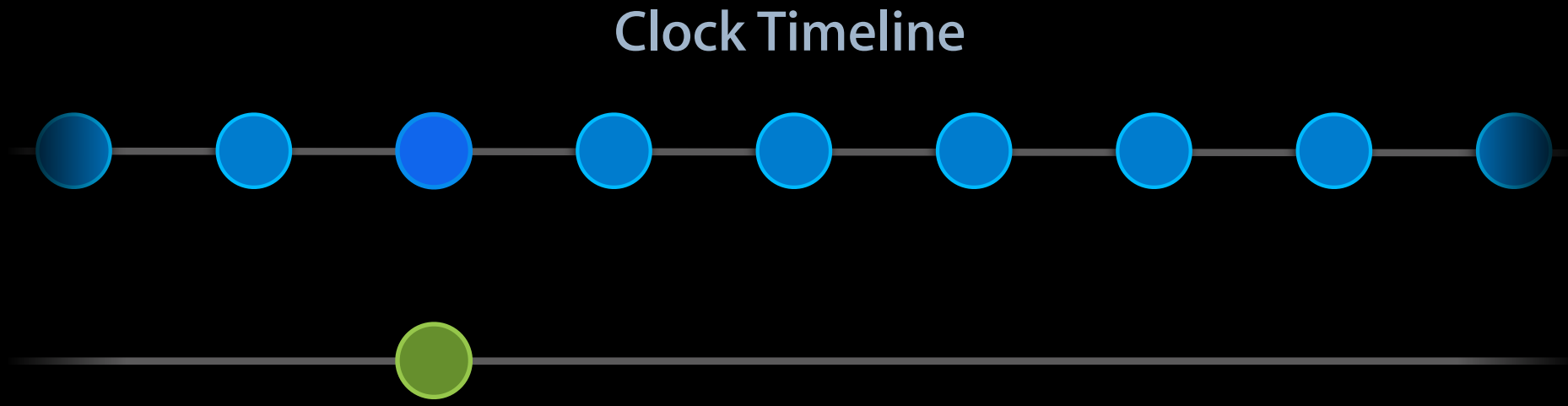

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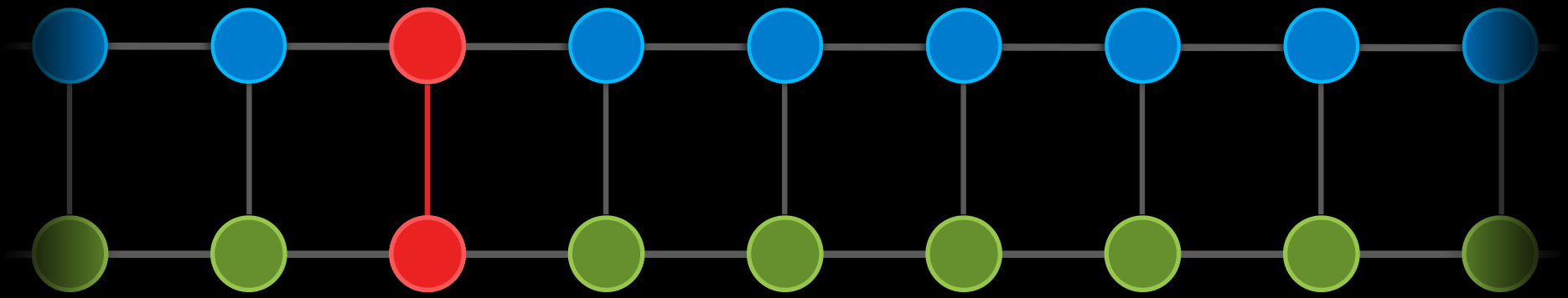
Clock Timeline



Timebase Timeline

Synchronizing with AVPlayer

Priming ahead of some future time

```
- prerollAtRate:(float)rate
        completionHandler:(void (^)(BOOL finished))completionHandler

- cancelPendingPrerolls
```

Synchronizing Video to Custom Audio

```
CMClockRef audioClock = NULL;
OSStatus err = CMAudioClockCreate(kCFAllocatorDefault, &audioClock);
if (err == noErr) {
    [myPlayer setMasterClock:audioClock];
    [myPlayer prerollAtRate:1.0 completionHandler:^(BOOL finished){
        if (finished) {
            // Calculate future host time here
            [myPlayer setRate:1.0 time:newItemTime atHostTime:hostTime];
        }
        else {
                // Preroll interrupted or cancelled
        }
    }];
}
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        else {
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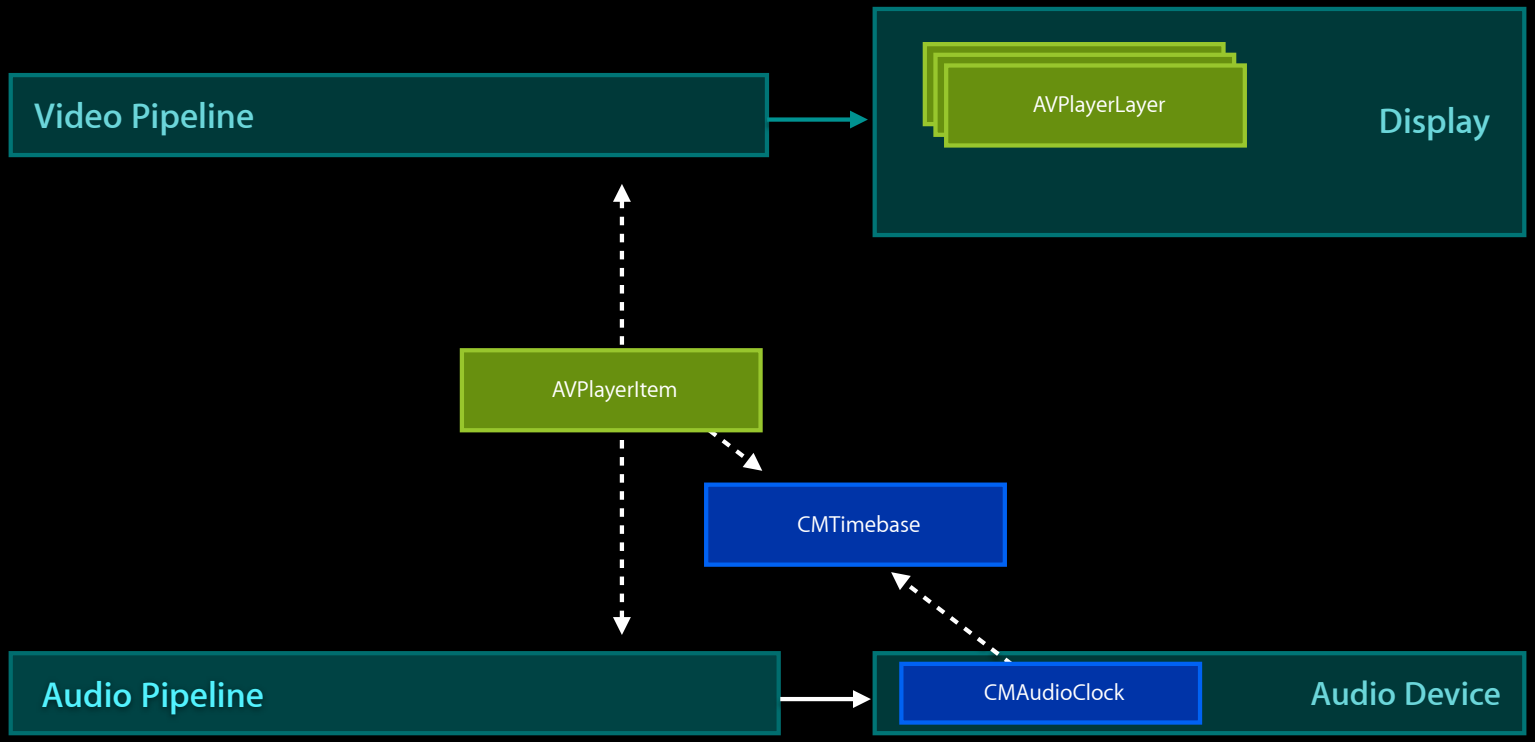
        }
    }];
}
```

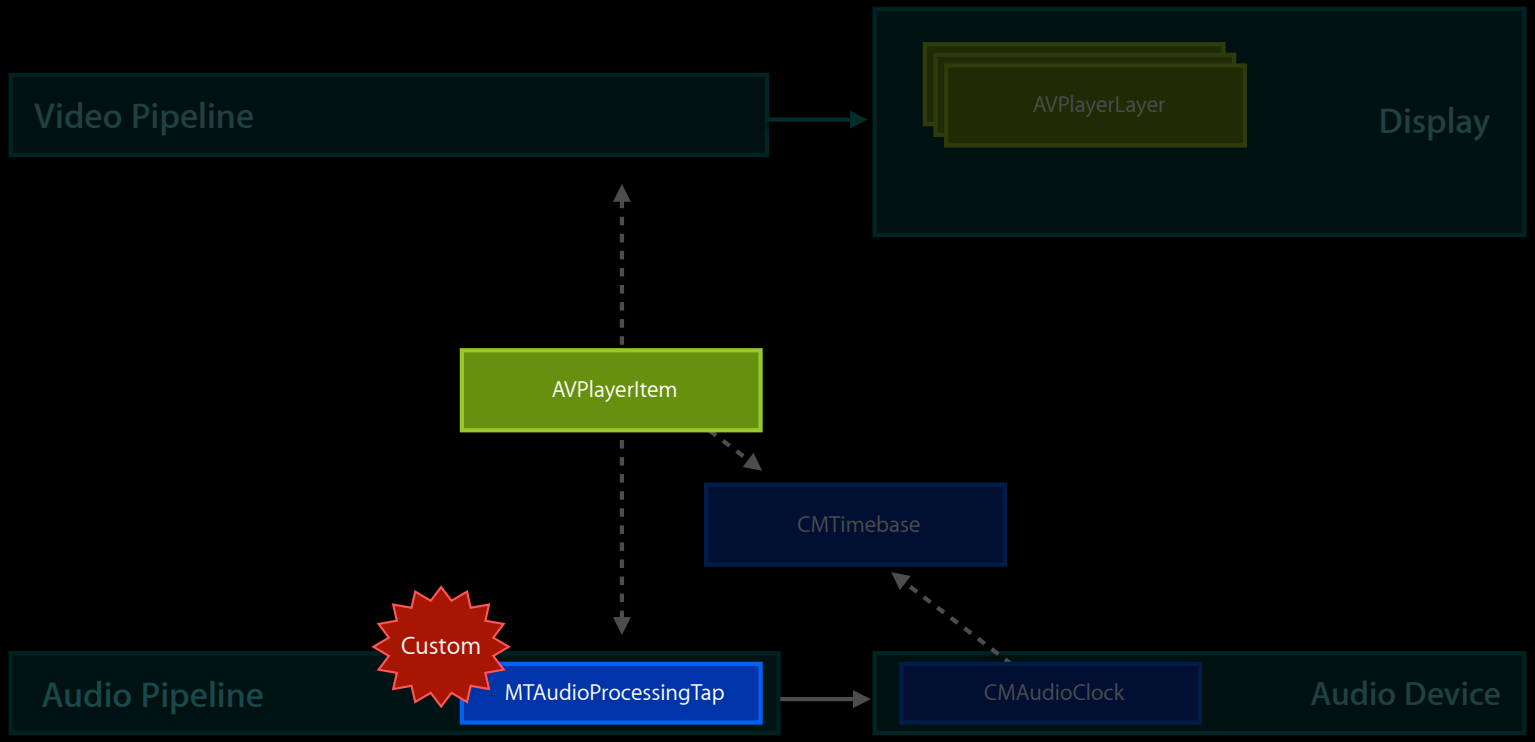
Real-Time Audio Effects and Processing

Audio effects for audiovisual media

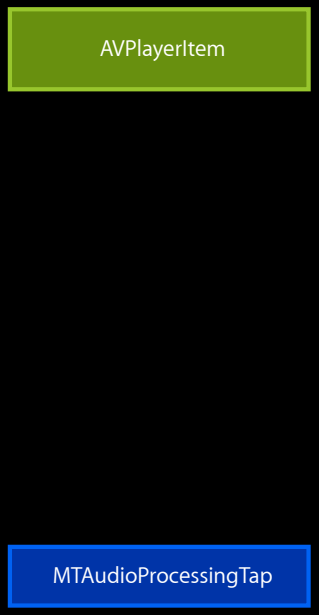
Real-Time Audio Processing



Real-Time Audio Processing

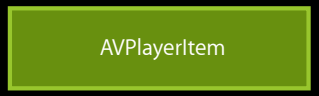


Real-Time Audio Processing



Real-Time Audio Processing

MTAudioProcessingTap



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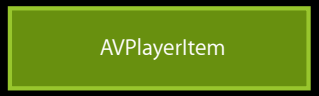

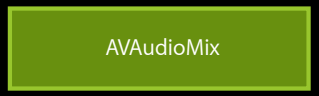

Real-Time Audio Processing

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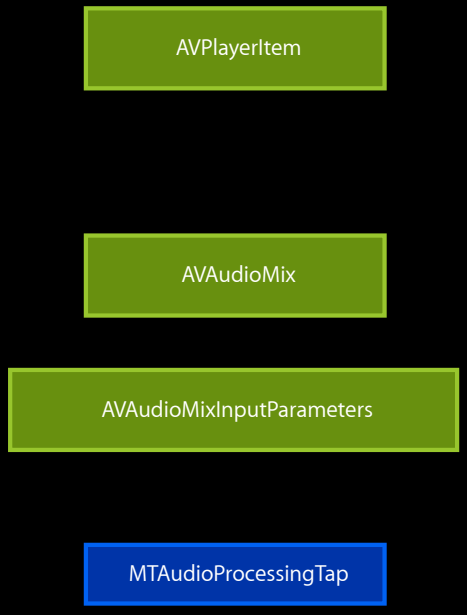

Real-Time Audio Processing

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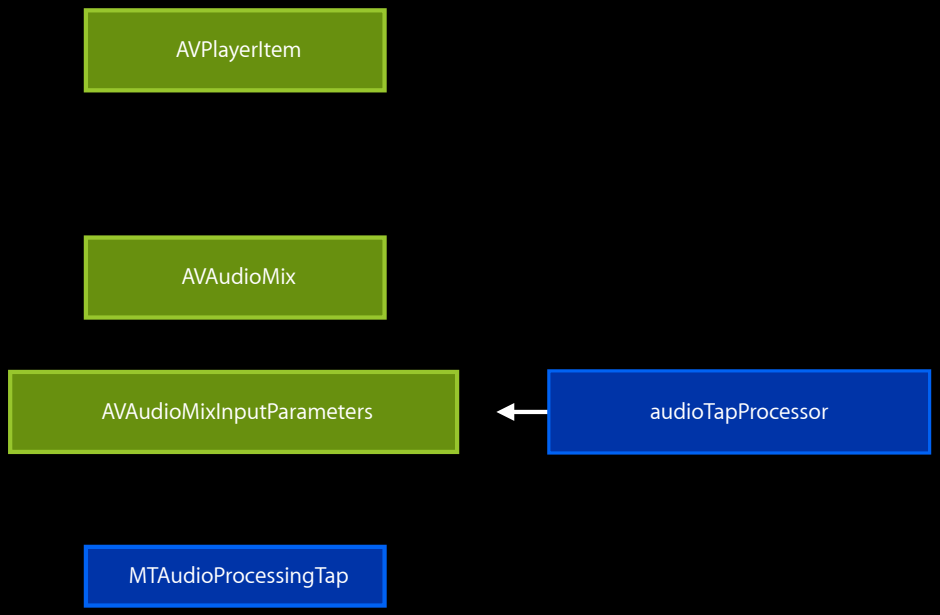
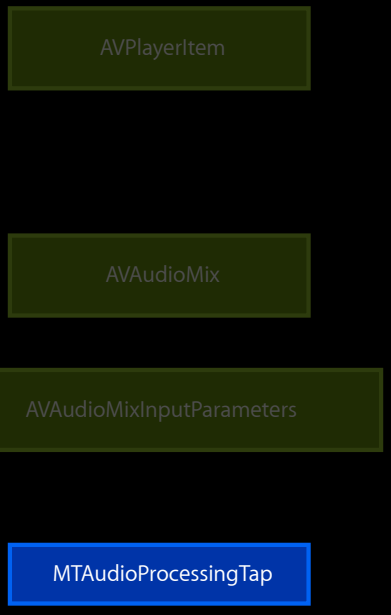


Real-Time Audio Processing

MTAudioProcessingTap



MTAudioProcessingTap

Creation

```
OSStatus
MTAudioProcessingTapCreate( CFAllocatorRef allocator,
                            const MTAudioProcessingTapCallbacks *callbacks,
                            MTAudioProcessingTapCreationFlags flags,
                            MTAudioProcessingTapRef *tapOut );
```

- Manage with CFRetain and CFRelease

MTAudioProcessingTap

Creation

```
OSStatus
MTAudioProcessingTapCreate( CFAllocatorRef allocator,
                            const MTAudioProcessingTapCallbacks *callbacks,
                            MTAudioProcessingTapCreationFlags flags,
                            MTAudioProcessingTapRef *tapOut );


typedef struct {
    int version;
    void *clientInfo;
    MTAudioProcessingTapInitCallback init;
    MTAudioProcessingTapFinalizeCallback finalize;
    MTAudioProcessingTapPrepareCallback prepare;
    MTAudioProcessingTapUnprepareCallback unprepare;
    MTAudioProcessingTapProcessCallback process;
} MTAudioProcessingTapCallbacks;
```

MTAudioProcessingTap

Lifecycle callbacks

```
typedef void
( *MTAudioProcessingTapPrepareCallback ) (
  MTAudioProcessingTapRef tap,
  CMItemCount maxFrames,
  const AudioStreamBasicDescription
    *processingFormat );
```

MTAudioProcessingTapCallbacks
version
clientInfo
init
finalize
prepare
unprepare
process

MTAudioProcessingTap

Lifecycle callbacks

```
typedef void
( *MTAudioProcessingTapUnprepareCallback ) (
  MTAudioProcessingTapRef tap );
```

MTAudioProcessingTapCallbacks

- version
- clientInfo
- init
- finalize
- prepare
- unprepare
- process

MTAudioProcessingTap

Lifecycle callbacks

```
typedef void
( *MTAudioProcessingTapProcessCallback ) (
  MTAudioProcessingTapRef tap,
  CMItemCount numberFrames,
  MTAudioProcessingTapFlags flags,
  AudioBufferList *bufferListInOut,
  CMItemCount *numberFramesOut,
  MTAudioProcessingTapFlags *flagsOut );
```

MTAudioProcessingTapCallbacks
version
clientInfo
init
finalize
prepare
unprepare
process

MTAudioProcessingTap

Lifecycle callbacks

```
typedef void
( *MTAudioProcessingTapProcessCallback ) (
  MTAudioProcessingTapRef tap,
  CMItemCount numberFrames,
  MTAudioProcessingTapFlags flags,
  AudioBufferList *bufferListInOut,
  CMItemCount *numberFramesOut,
  MTAudioProcessingTapFlags *flagsOut );
```

MTAudioProcessingTapCallbacks
version
clientInfo
init
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prepare
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process

MTAudioProcessingTap

```
MTAudioProcessingTapGetSourceAudio( MTAudioProcessingTapRef tap,
                                    CMItemCount numberFrames,
                                    AudioBufferList *bufferListInOut,
                                    MTAudioProcessingTapFlags *flagsOut,
                                    CMTimeRange *timeRangeOut,
                                    CMItemCount *numberFramesOut );
```

MTAudioProcessingTap

- Processing callback constraints
  - Don’t:
    - Acquire locks
    - Allocate or deallocate memory
  - Do:
    - Be efficient
    - Consider CMSimpleQueue

Your Processing Callback

```
void myProcessCallback(MTAudioProcessingTapRef tap,
                       CMItemCount numberFrames,
                       MTAudioProcessingTapFlags flags,
                       AudioBufferList *bufferListInOut,
                       CMItemCount *numberFramesOut,
                       MTAudioProcessingTapFlags *flagsOut)
{
 CMTimeRange timeRange;
 OSStatus err = MTAudioProcessingTapGetSourceAudio( tap,
                                                    numberFrames,
                                                    bufferListInOut,
                                                    flagsOut,
                                                    &timeRange,
                                                    numberFramesOut );
```

Your Processing Callback

```
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                       CMItemCount numberFrames,
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                       MTAudioProcessingTapFlags *flagsOut)
{
 CMTimeRange timeRange;
 OSStatus err = MTAudioProcessingTapGetSourceAudio( tap,
                                                    numberFrames,
                                                    bufferListInOut,
                                                    flagsOut,
                                                    &timeRange,
                                                    numberFramesOut );
```

```
    ...

    for (CMItemCount i = 0; i < bufferListInOut->mNumberBuffers; i++)
    {
        AudioBuffer* pBuffer = &bufferListInOut->mBuffers[i];
        UInt32 cSamples = numberFrames *
                  ( _isNonInterleaved ? 1 : pBuffer->mNumberChannels);

        float* pData = (float *) pBuffer->mData;

        for (UInt32 j = 0; j < cSamples; j++) {

               // do something with each sample

      }
    }
}
```

```
    ...

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}
```

```
    ...

    for (CMItemCount i = 0; i < bufferListInOut->mNumberBuffers; i++)
    {
        AudioBuffer* pBuffer = &bufferListInOut->mBuffers[i];
        UInt32 cSamples = numberFrames *
                  ( _isNonInterleaved ? 1 : pBuffer->mNumberChannels);

        float* pData = (float *) pBuffer->mData;

        for (UInt32 j = 0; j < cSamples; j++) {

               // do something with each sample

      }
    }
}
```

Demo

AudioTapProcessor: using Audio Units

AudioProcessingTap Demo

Using Audio Units

- Discover and create audio unit using

```
AudioComponentDescription
```

- Set the render callback on the audio unit

```
kAudioUnitProperty_SetRenderCallback

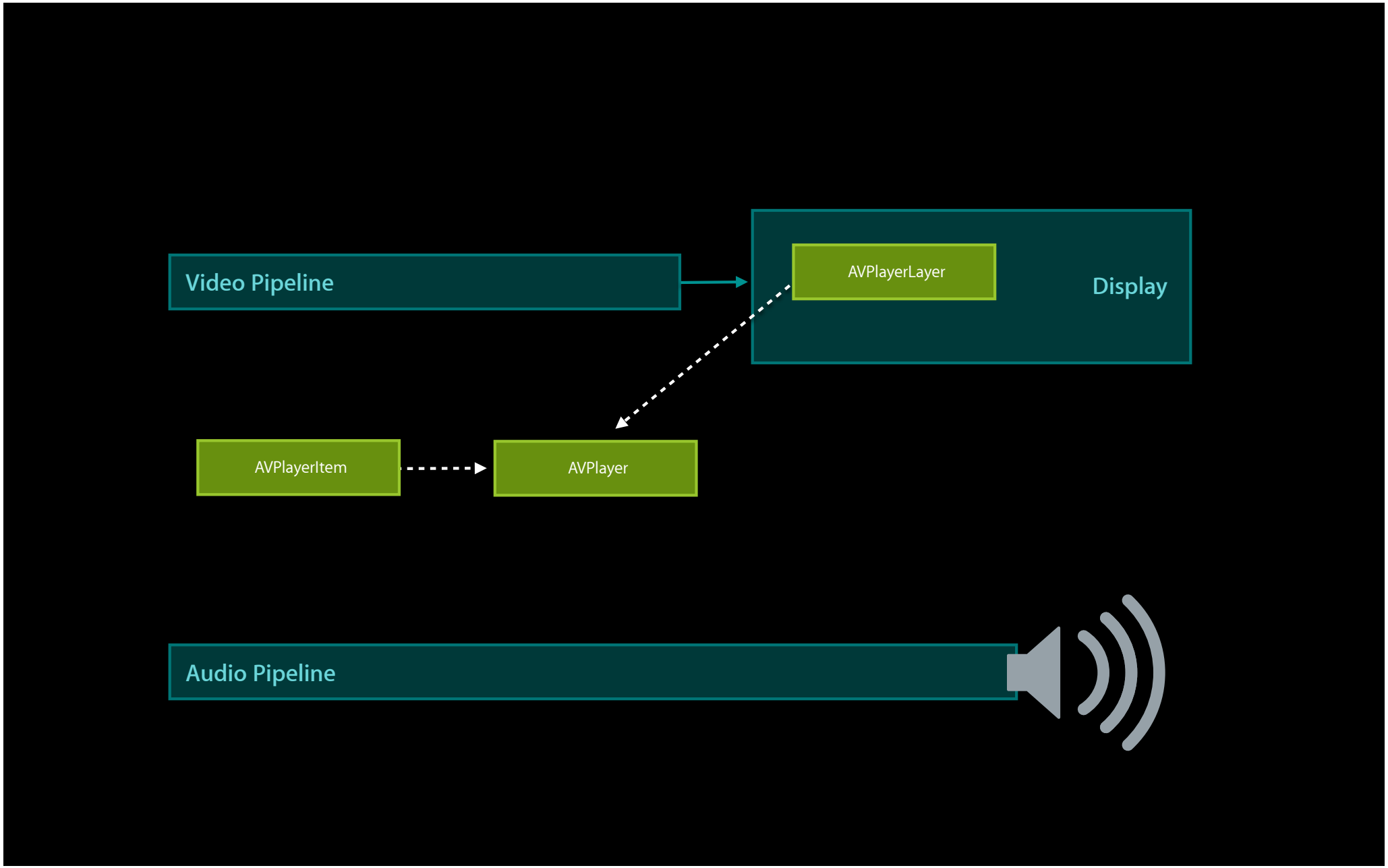
OSStatus myAudioUnitRenderCallback(
      void *inRefCon, ..., UInt32 inNumberFrames, AudioBufferList *ioData)
{
  return MTAudioProcessingTapGetSourceAudio( inRefCon,
                                             inNumberFrames,
                                             ioData,
                                            NULL, NULL, NULL);
}
```

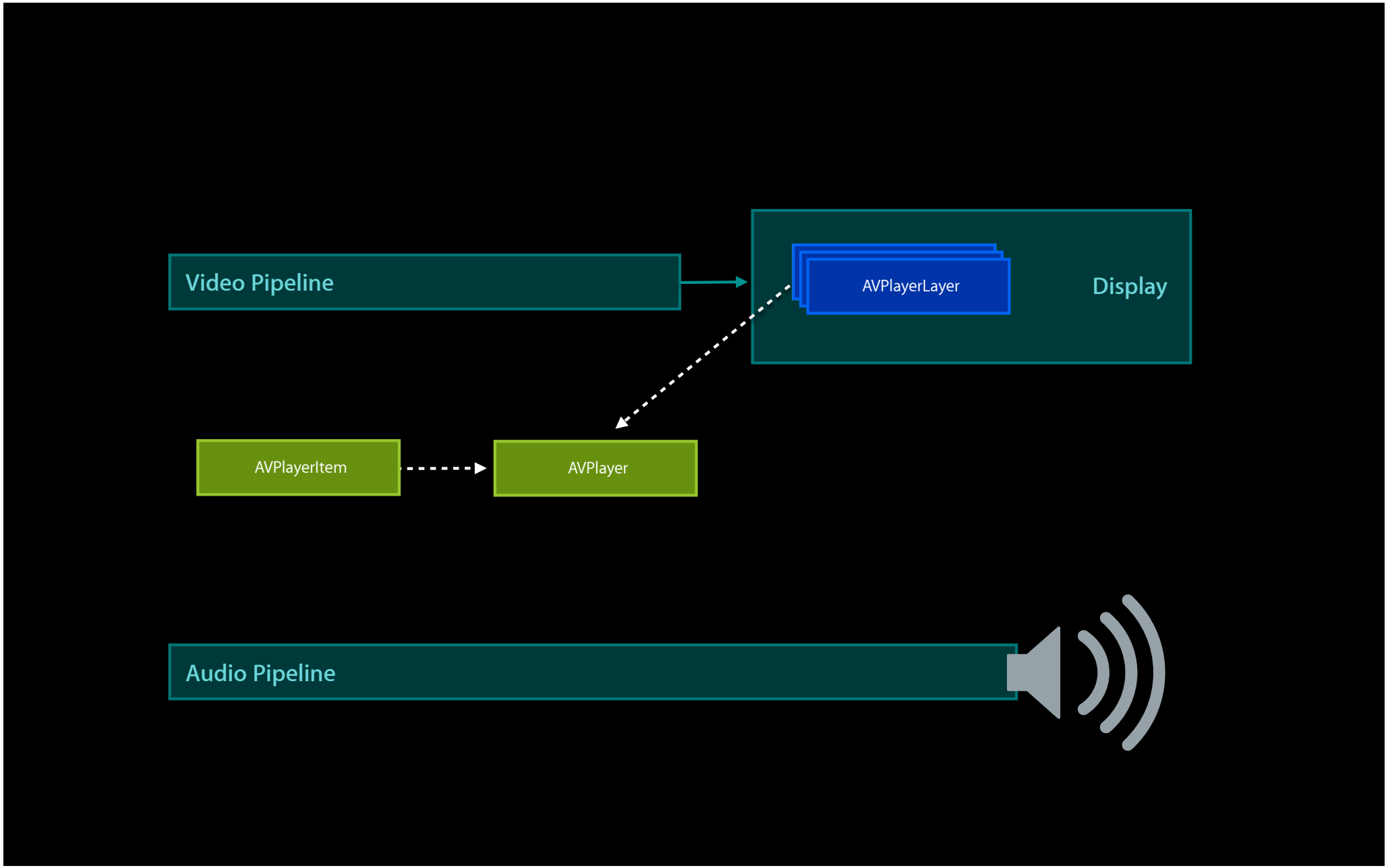
Real-Time Video Effects and Processing

Real-Time Video Effects and Processing

Goals of real-time video output

- Decoded video images during playback
- Output ahead of display-time
  - Custom manipulation
- Maintain A/V sync
  - Timestamped images


Video Pipeline
AVPlayerLayer
Display
AVPlayerItem
AVPlayer
Audio Pipeline


Video Pipeline
AVPlayerLayer
Display
AVPlayerItem
AVPlayer
Audio Pipeline

AVPlayerLayer

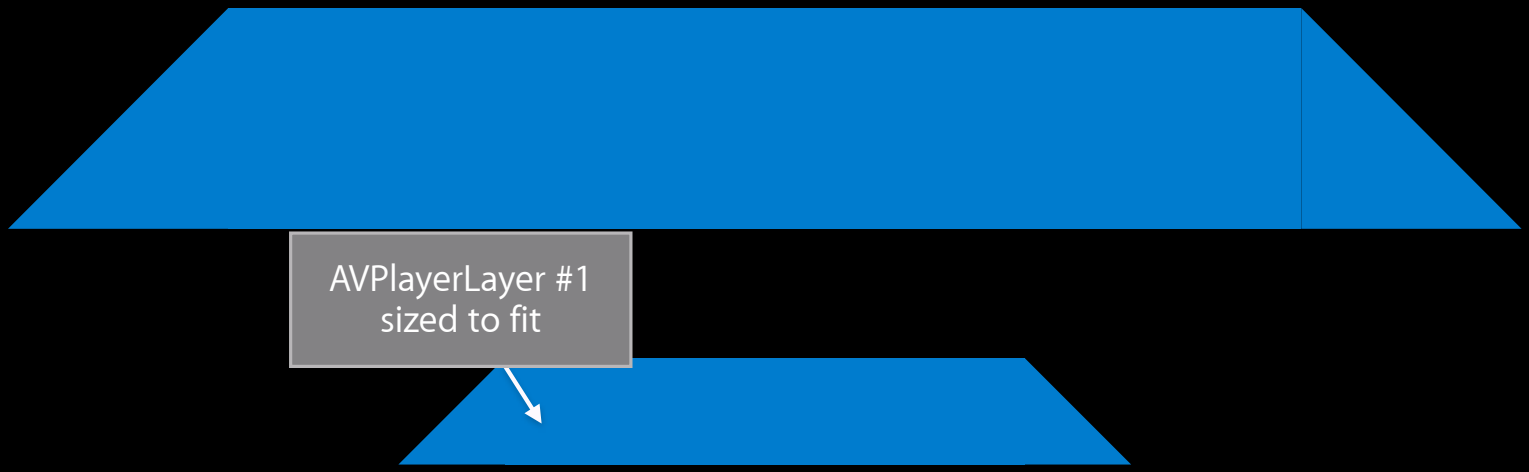
- New support
  - Multiple AVPlayerLayers to one AVPlayer
- Advantages
  - Automatic A/V sync
  - Easy to use

Demo

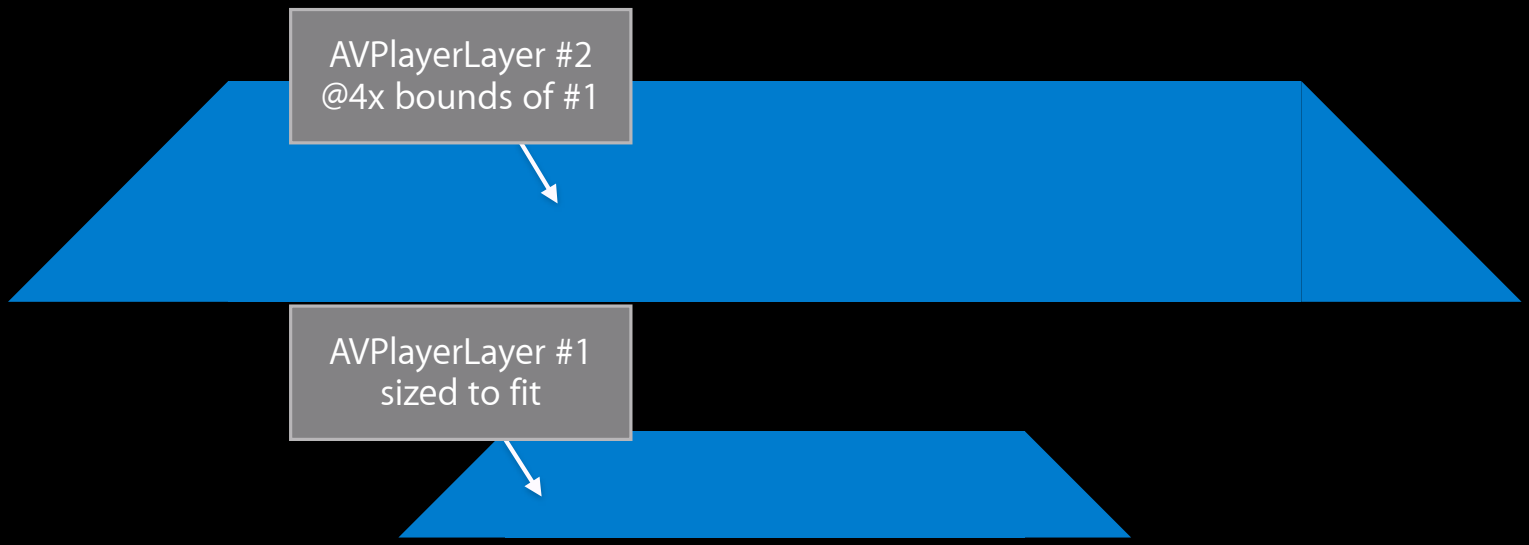
AVLoupe

AVLoupe: How It Works

AVLoupe: How It Works

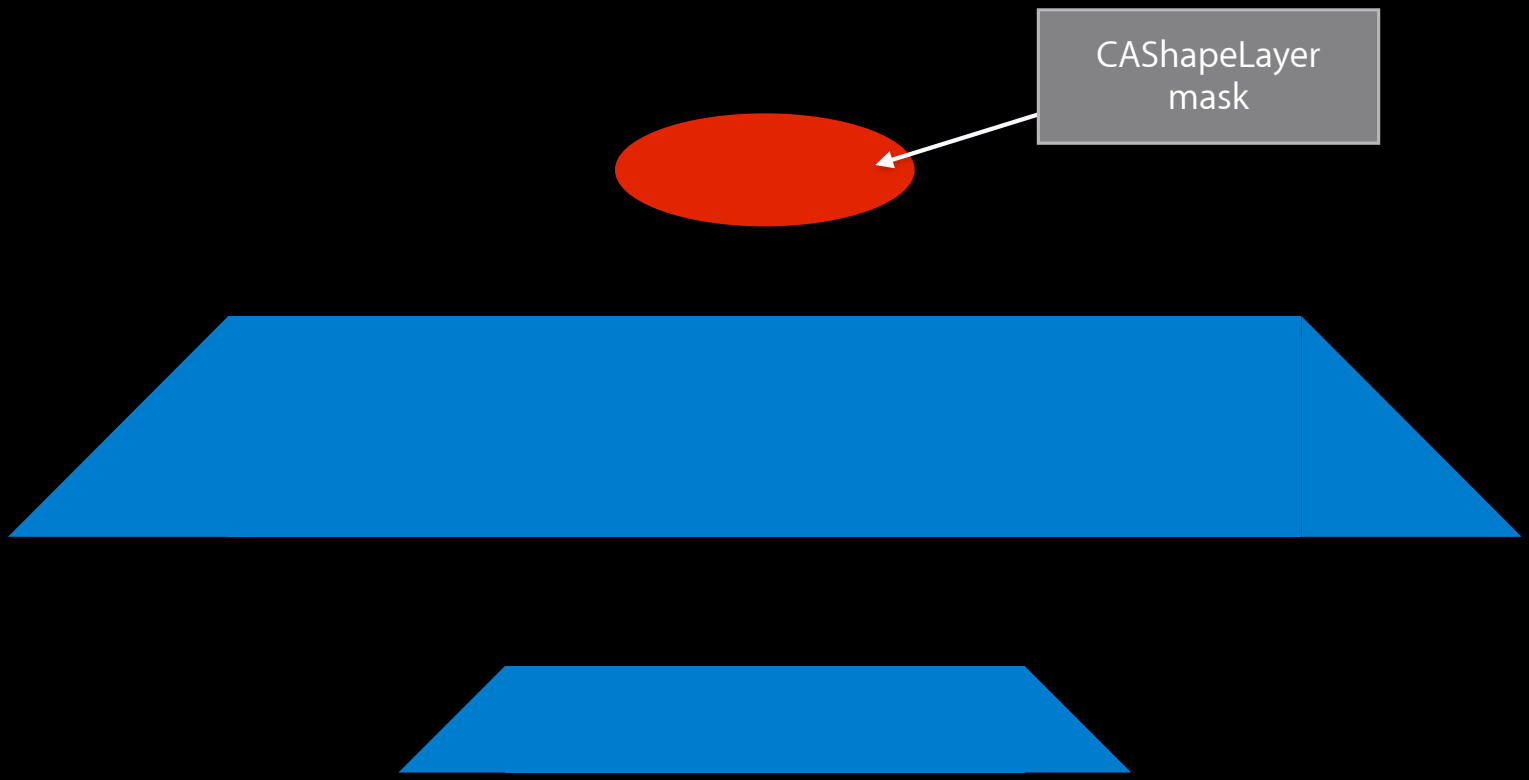


AVLoupe: How It Works

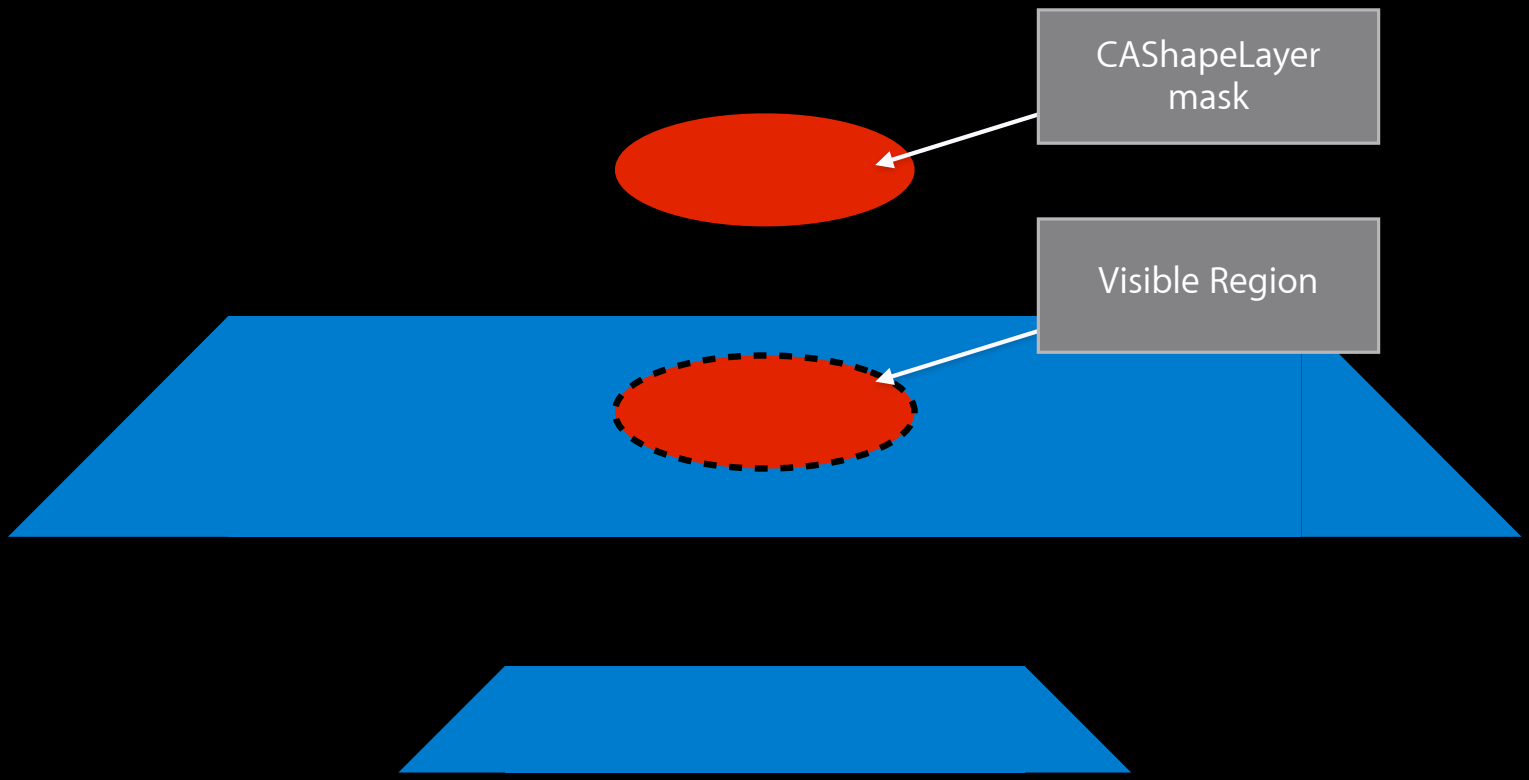


AVLoupe: How It Works

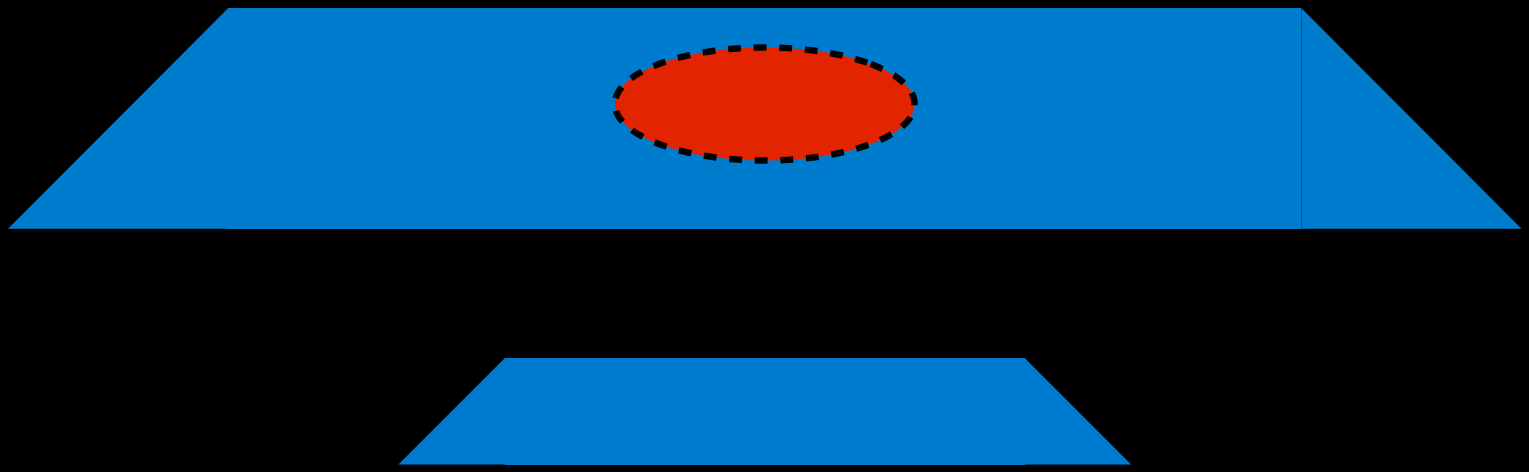
AVLoupe: How It Works



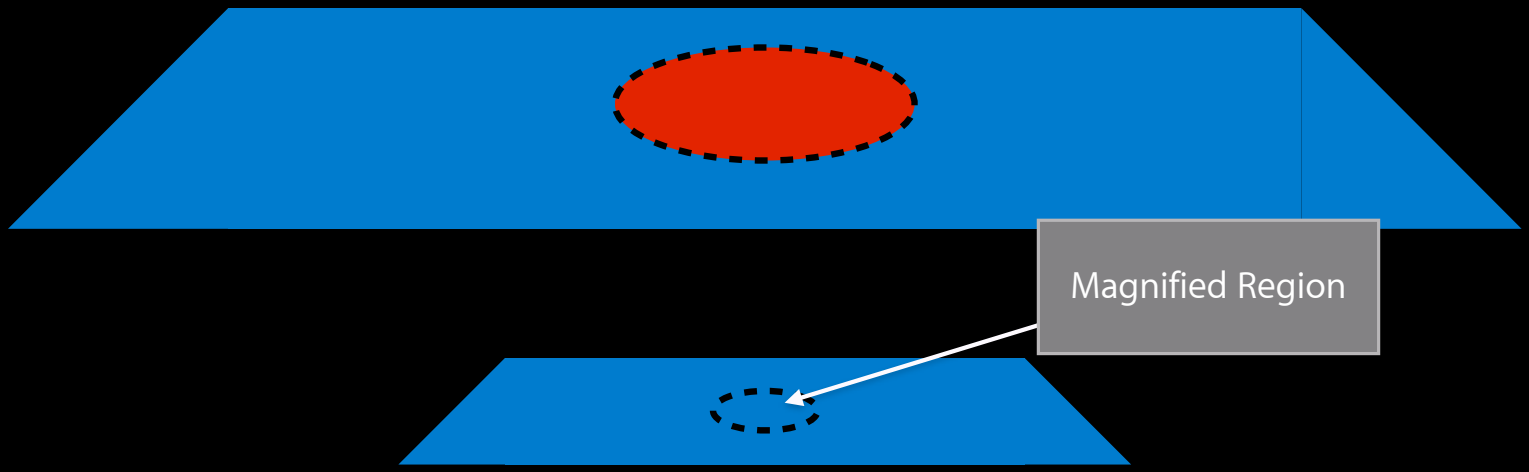
AVLoupe: How It Works



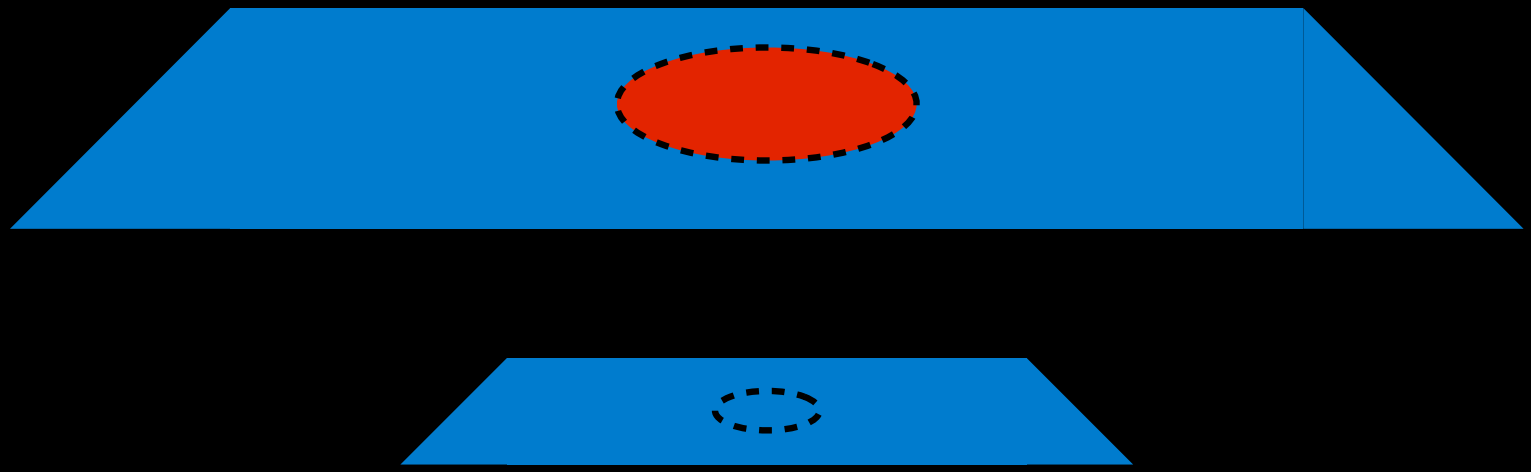
AVLoupe: How It Works



AVLoupe: How It Works

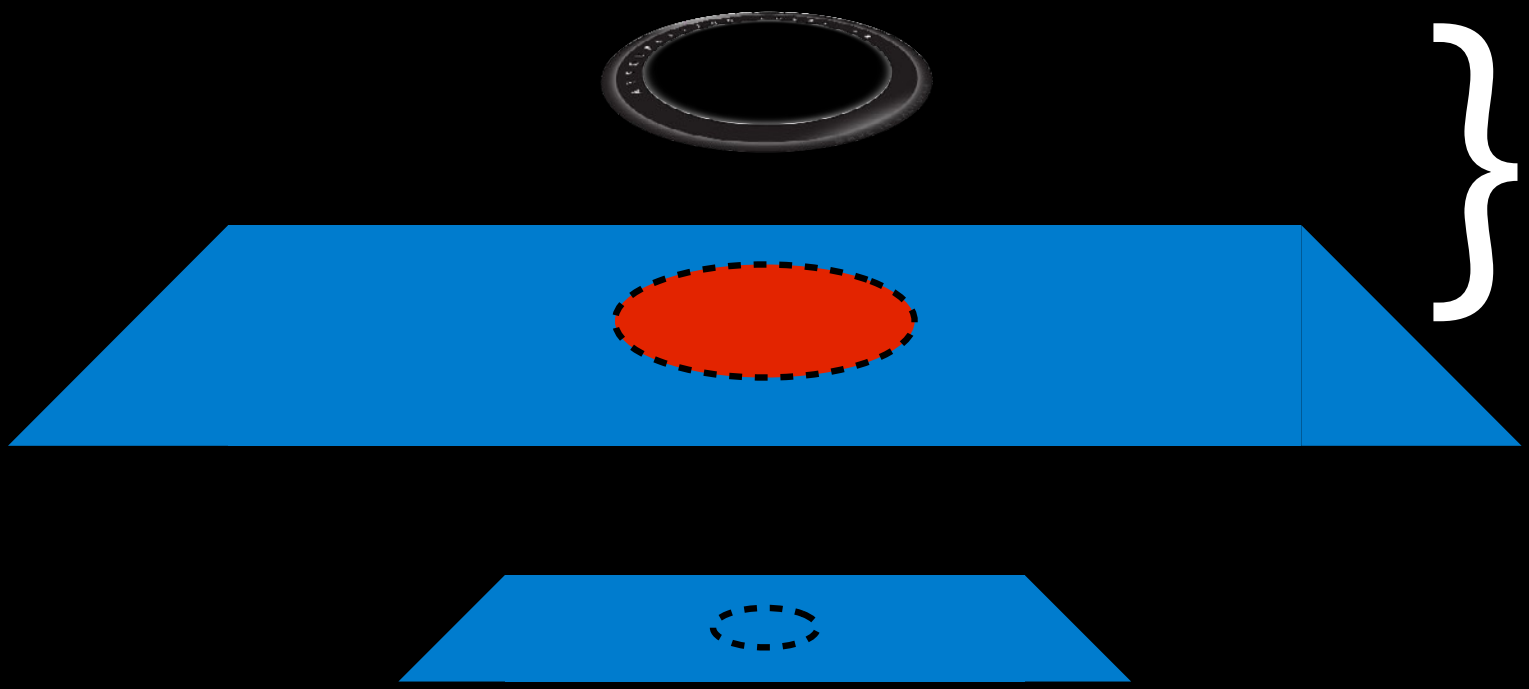


AVLoupe: How It Works



AVLoupe: How It Works

UIImageView
+
UIPanGestureRecognizer



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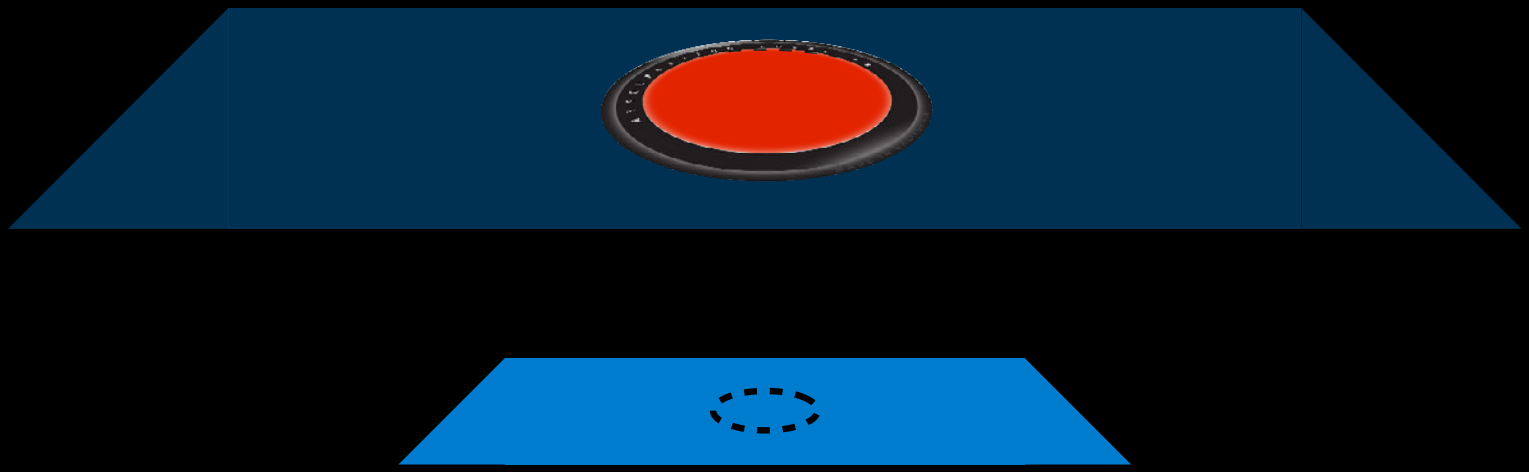
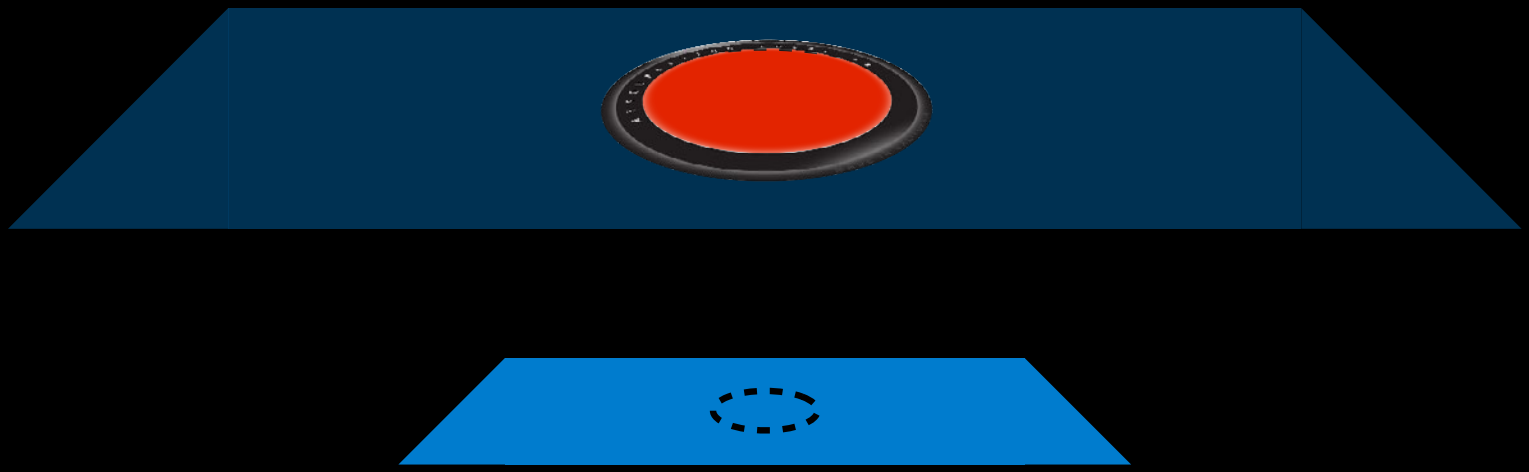


AVLoupe: How It Works



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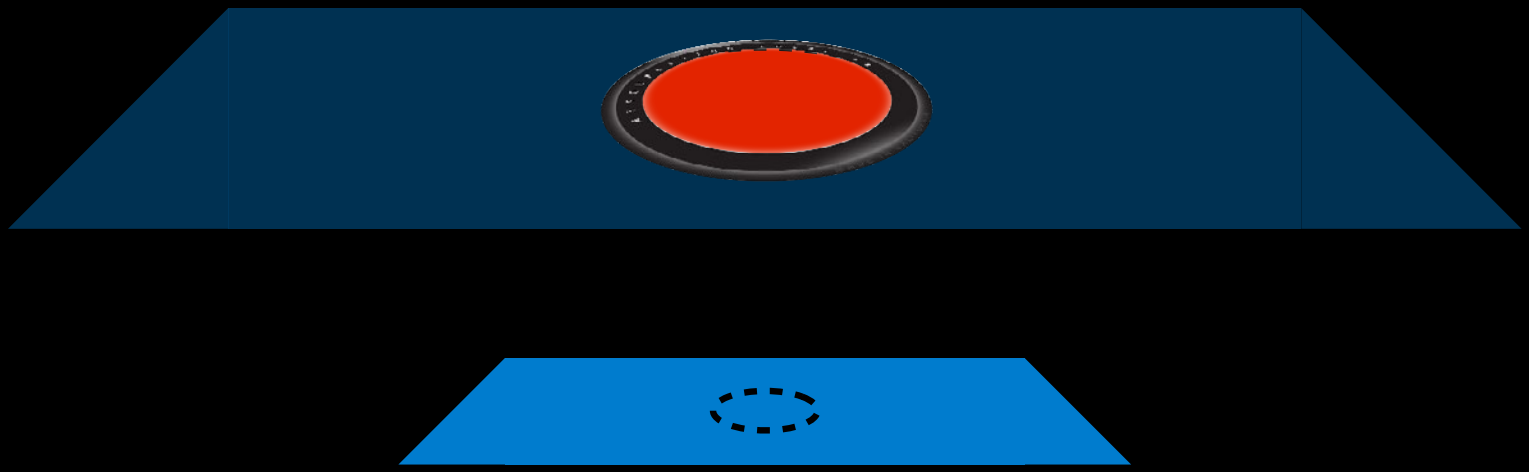
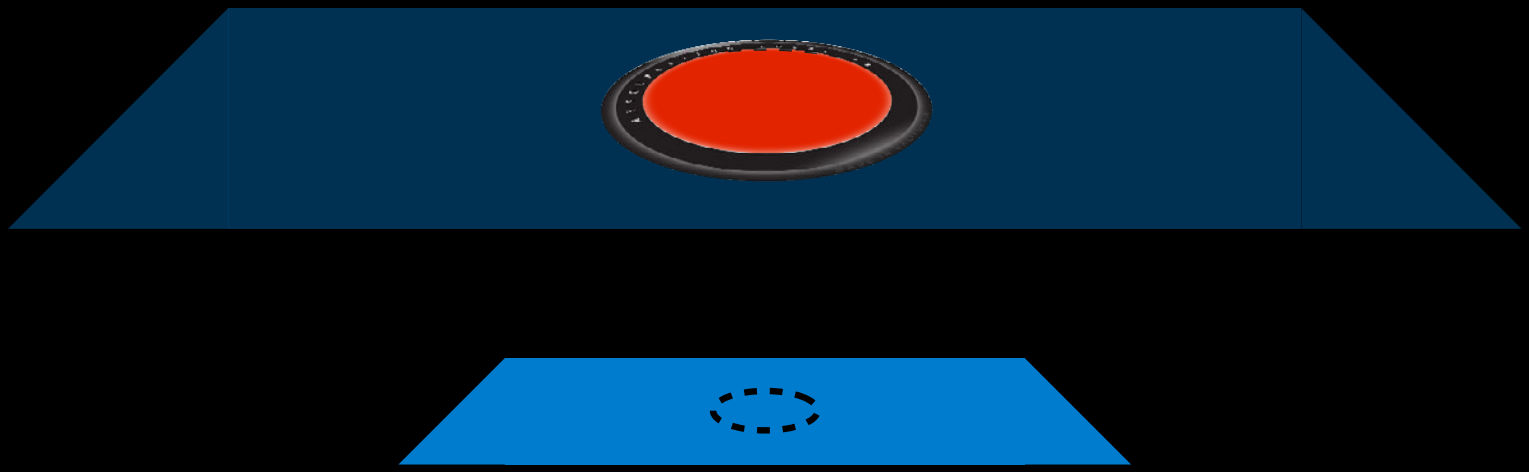


AVLoupe: How It Works



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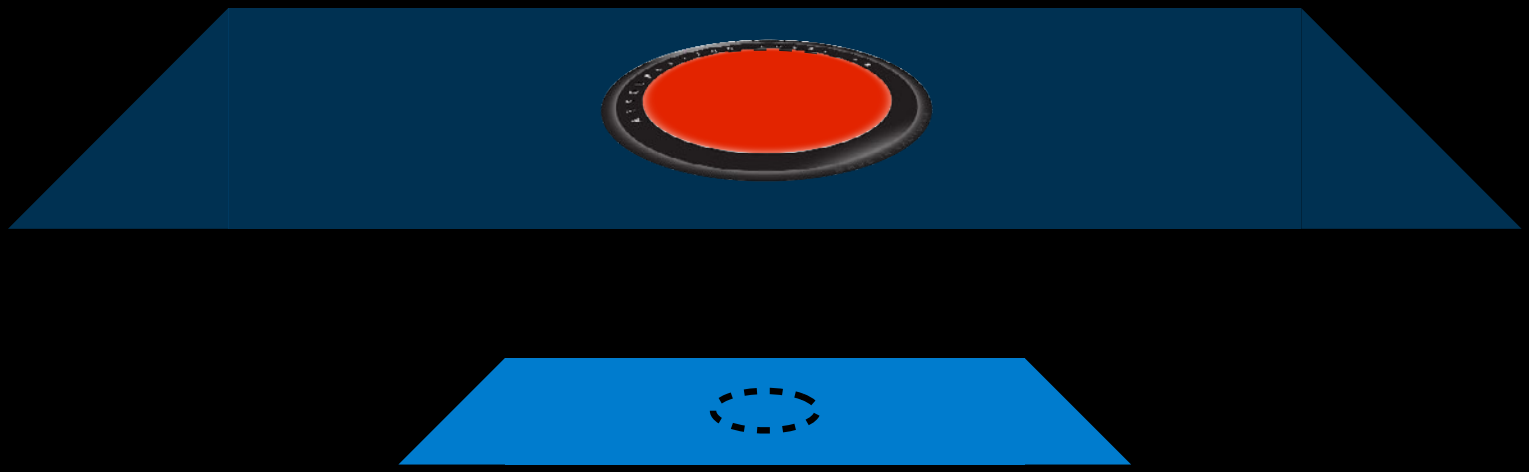

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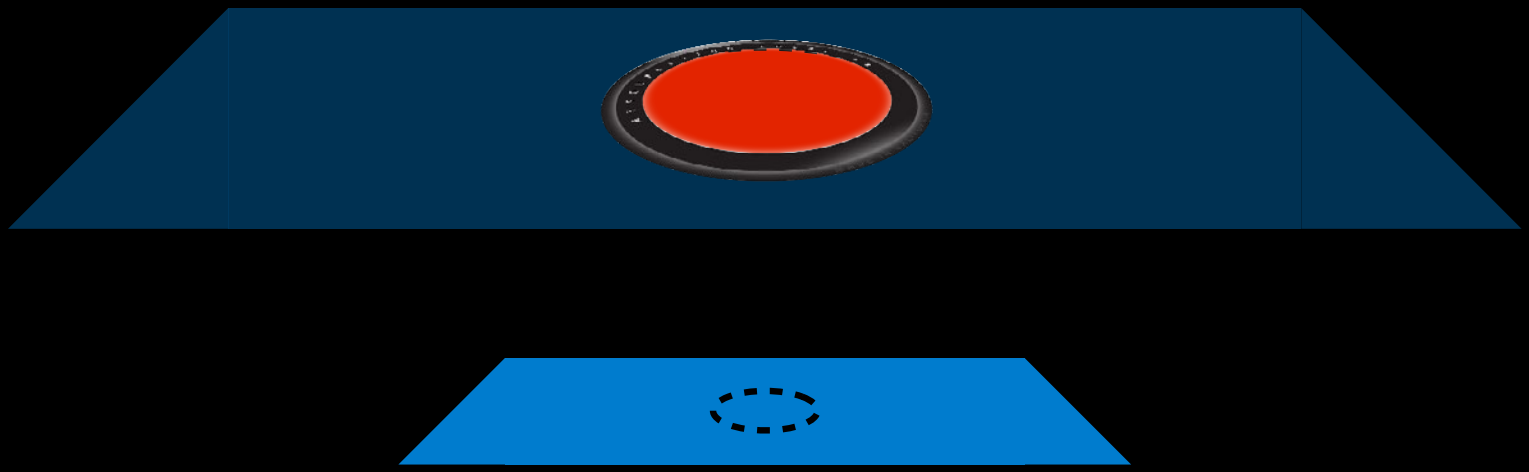
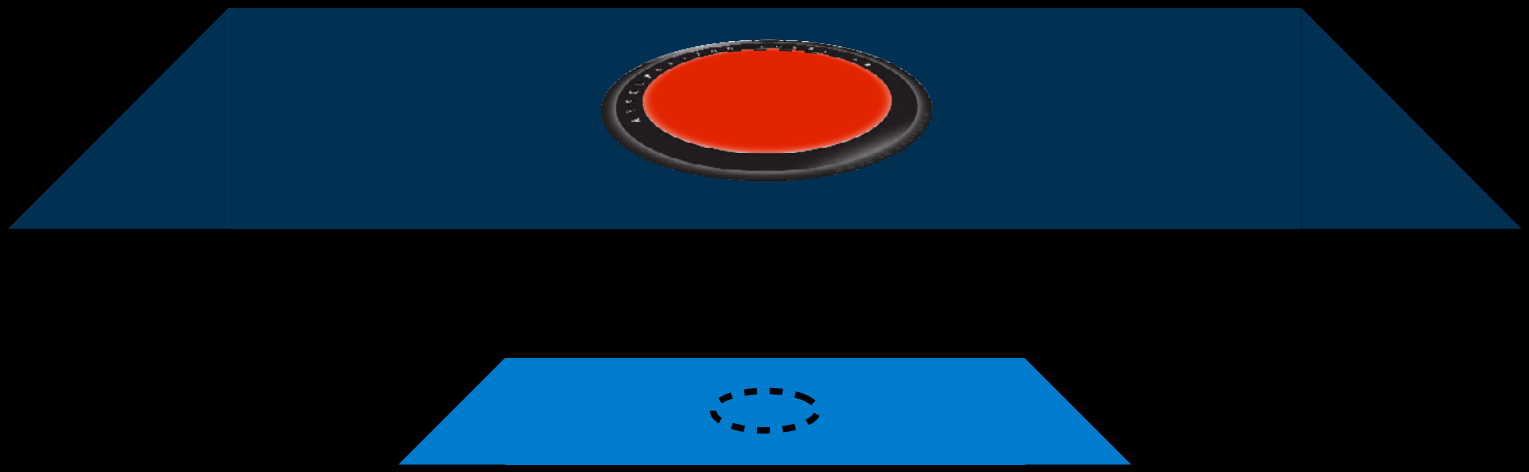
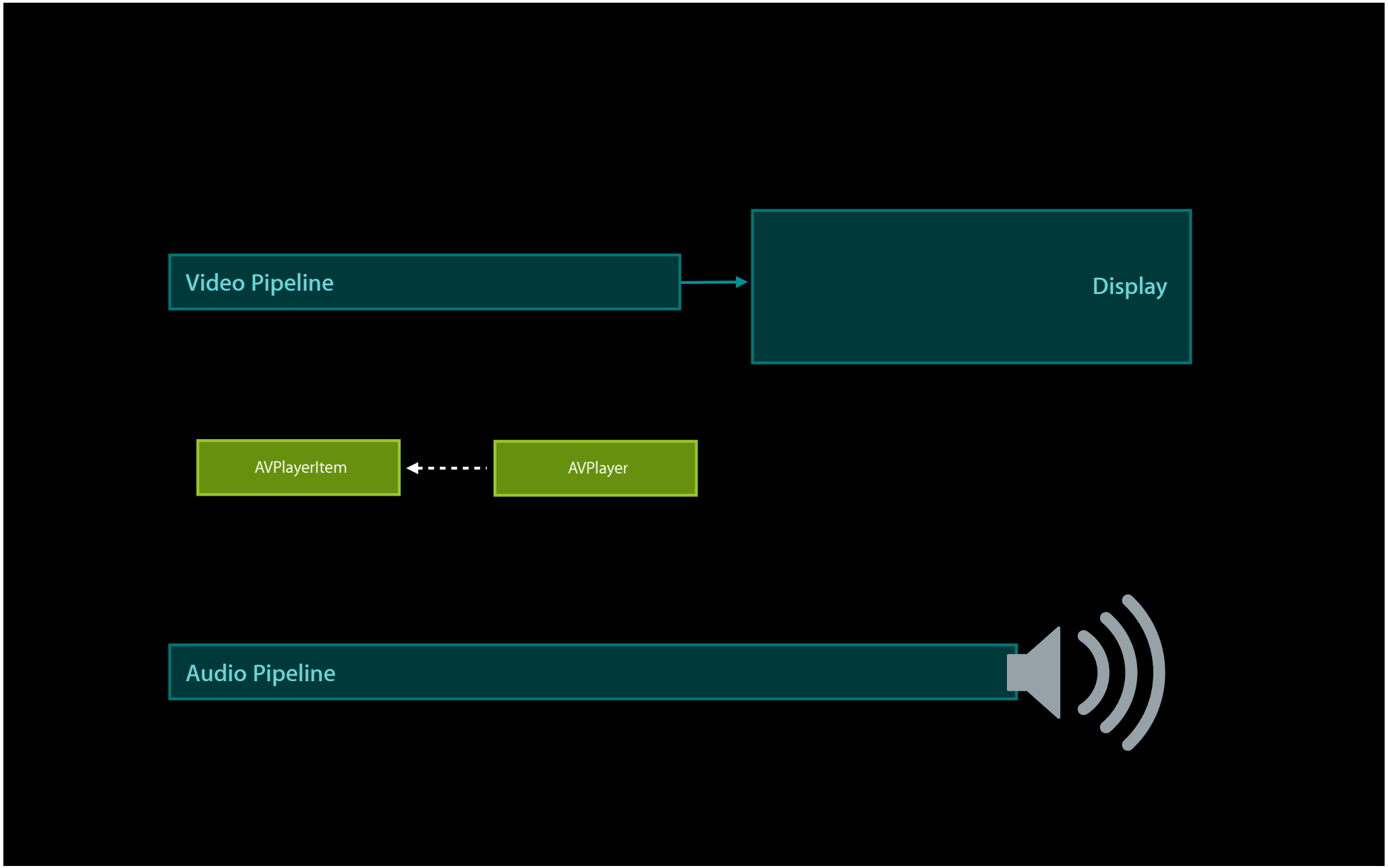
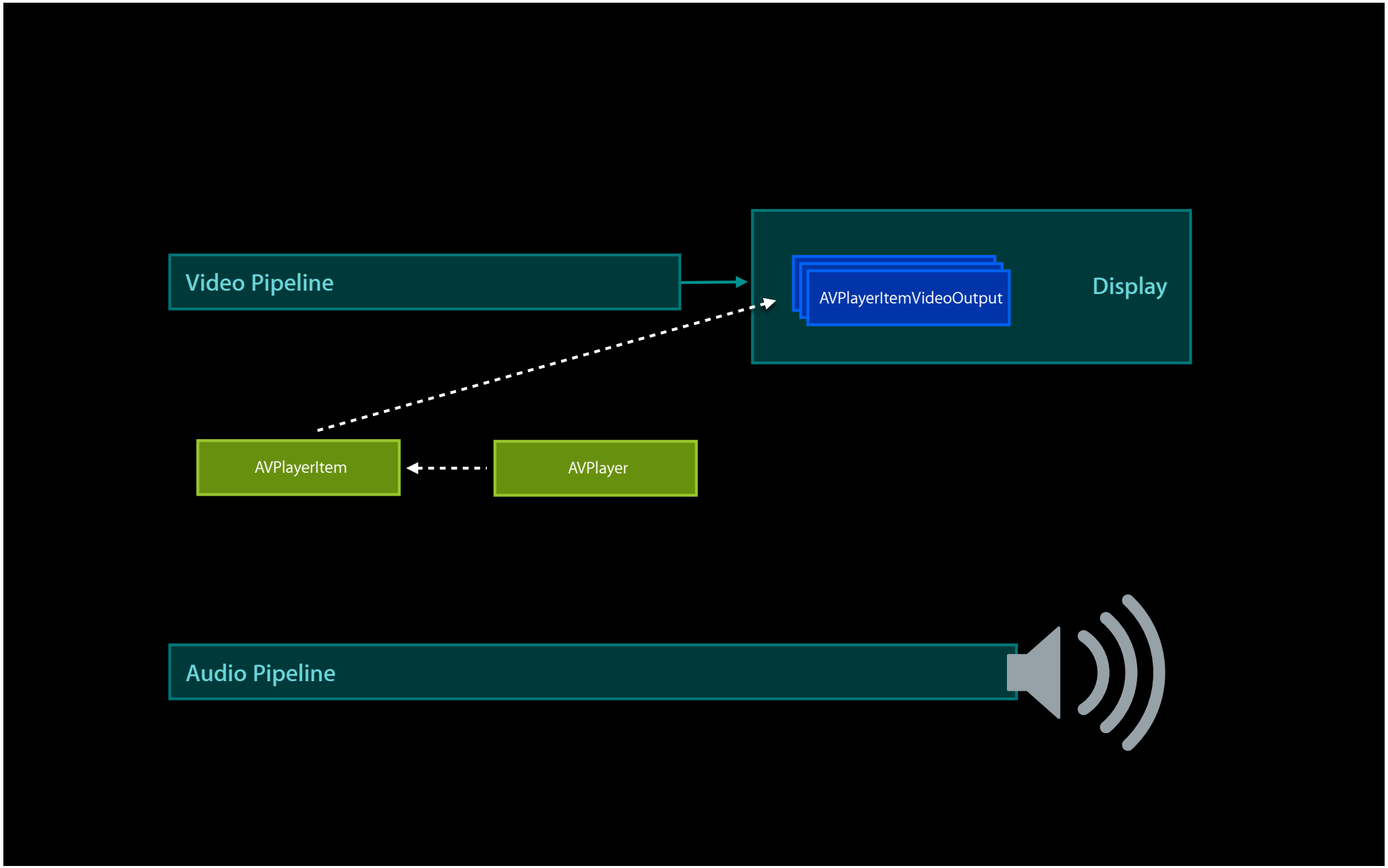


AVLoupe: How It Works




Video Pipeline
Display
AVPlayerItem
AVPlayer
Audio Pipeline


Video Pipeline
AVPlayerItemVideoOutput
Display
AVPlayerItem
AVPlayer
Audio Pipeline

AVPlayerItemVideoOutput

Getting video images in real time

- Custom presentation
  - OpenGL
  - CoreGraphics
- Video processing
  - Effects
  - Analysis

AVPlayerItemVideoOutput

Pulling images from a dynamic model

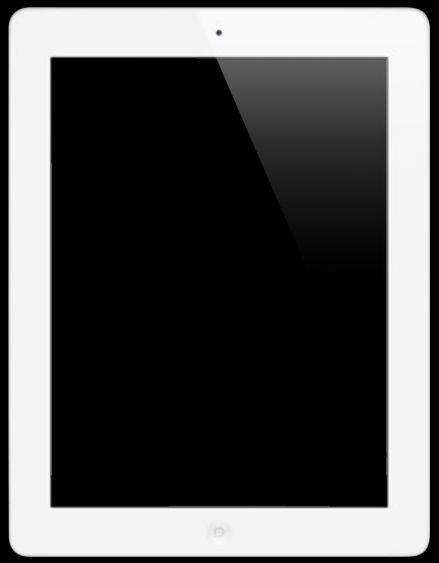
- Emits best available image for an item time

```
hasNewPixelBufferForItemTime:
copyPixelBufferForItemTime:itemTimeForDisplay:
```

- Call for each vertical sync
  - OS X
    - CVDisplayLink
    - CAOpenGLLayer
  - iOS
    - CADisplayLink
    - GLKitView or GLKitViewController

AVPlayerItemVideoOutput

Pulling images from a dynamic model

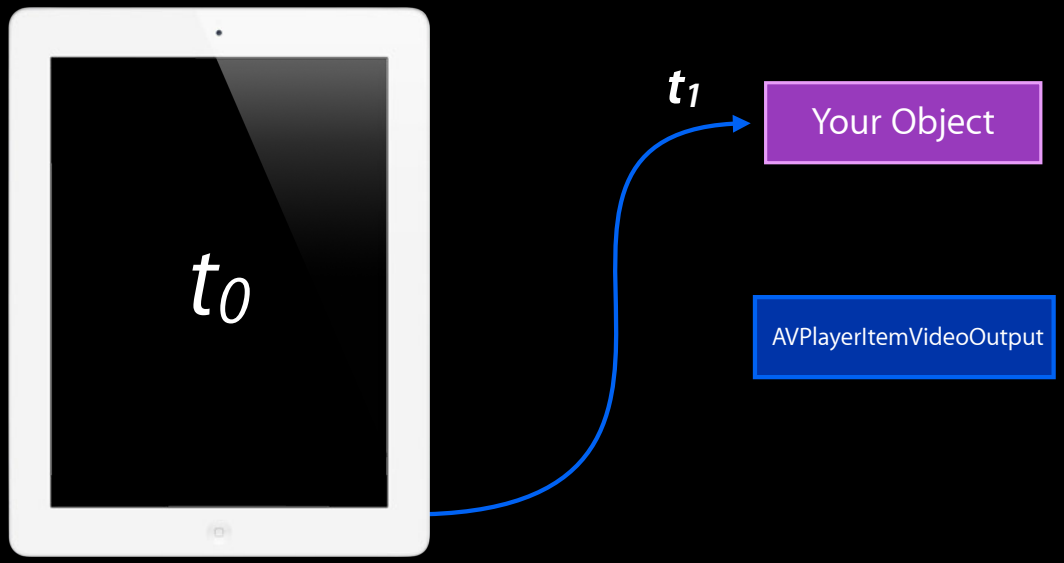


Your Object

AVPlayerItemVideoOutput

AVPlayerItemVideoOutput

Pulling images from a dynamic model



AVPlayerItemVideoOutput

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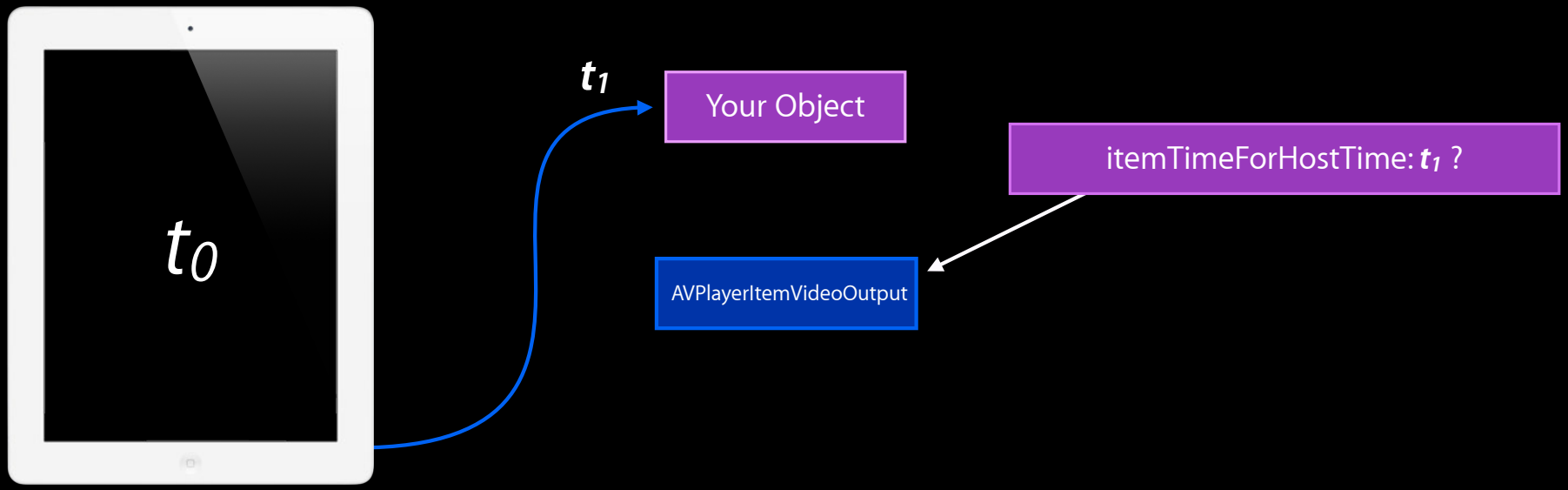

AVPlayerItemVideoOutput

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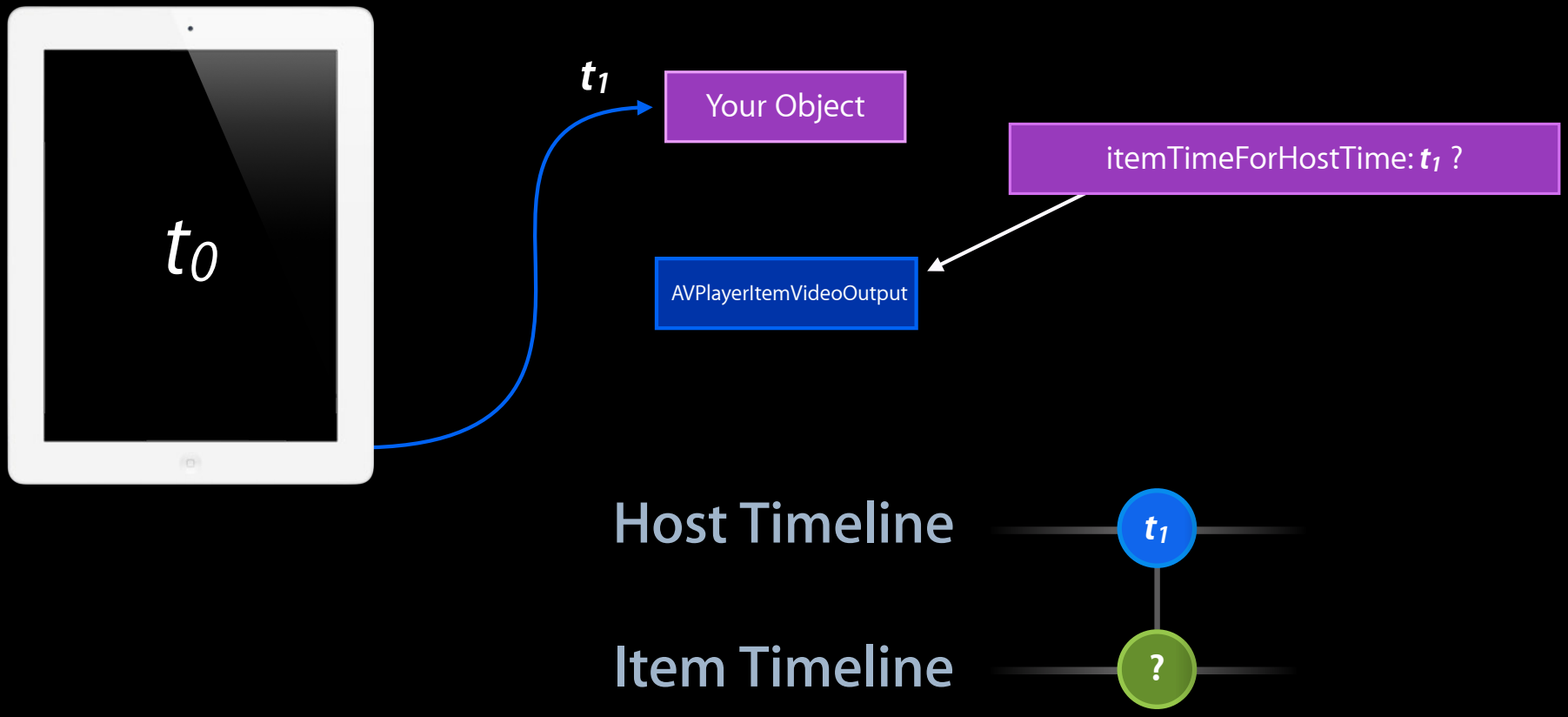
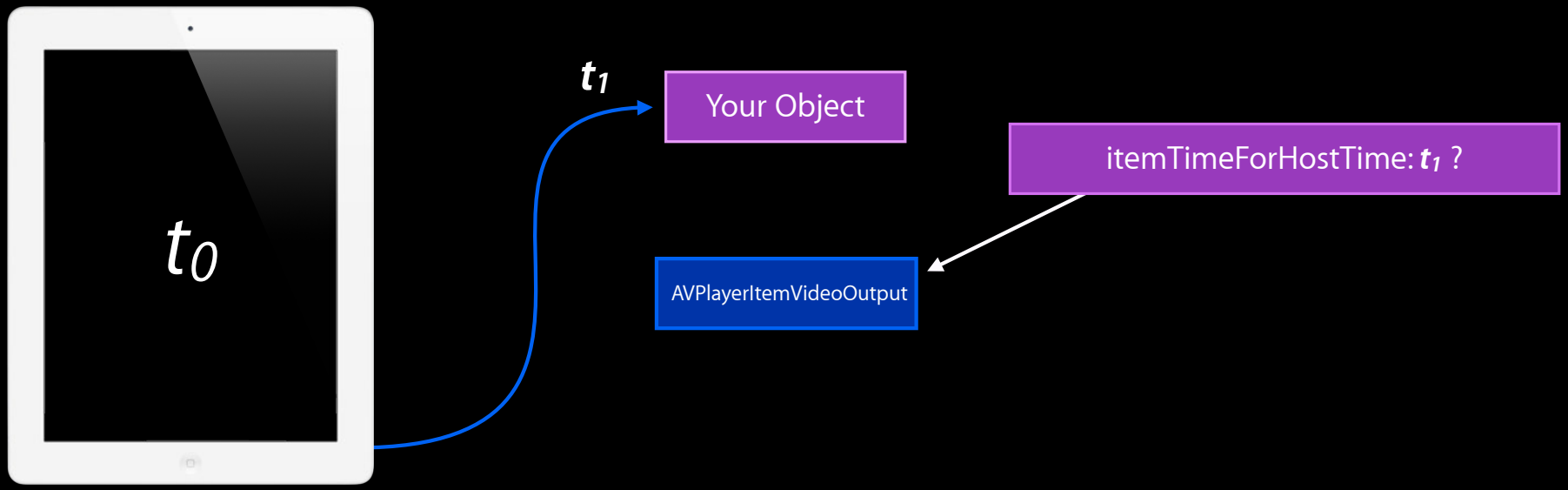


AVPlayerItemVideoOutput

Pulling images from a dynamic model



AVPlayerItemVideoOutput

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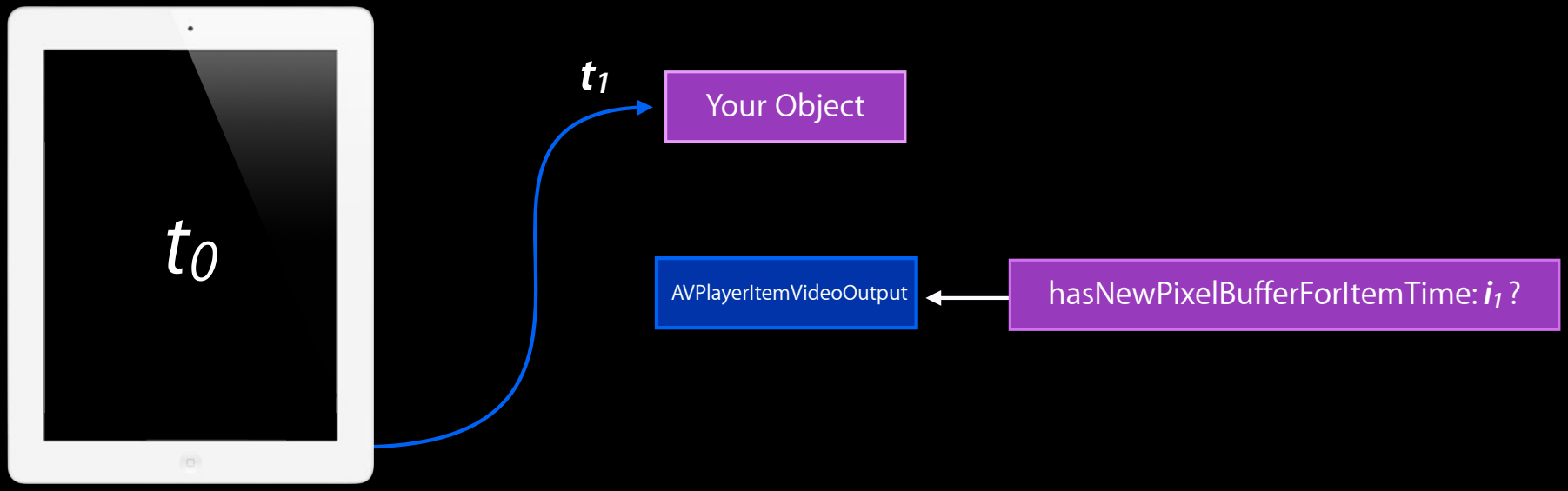
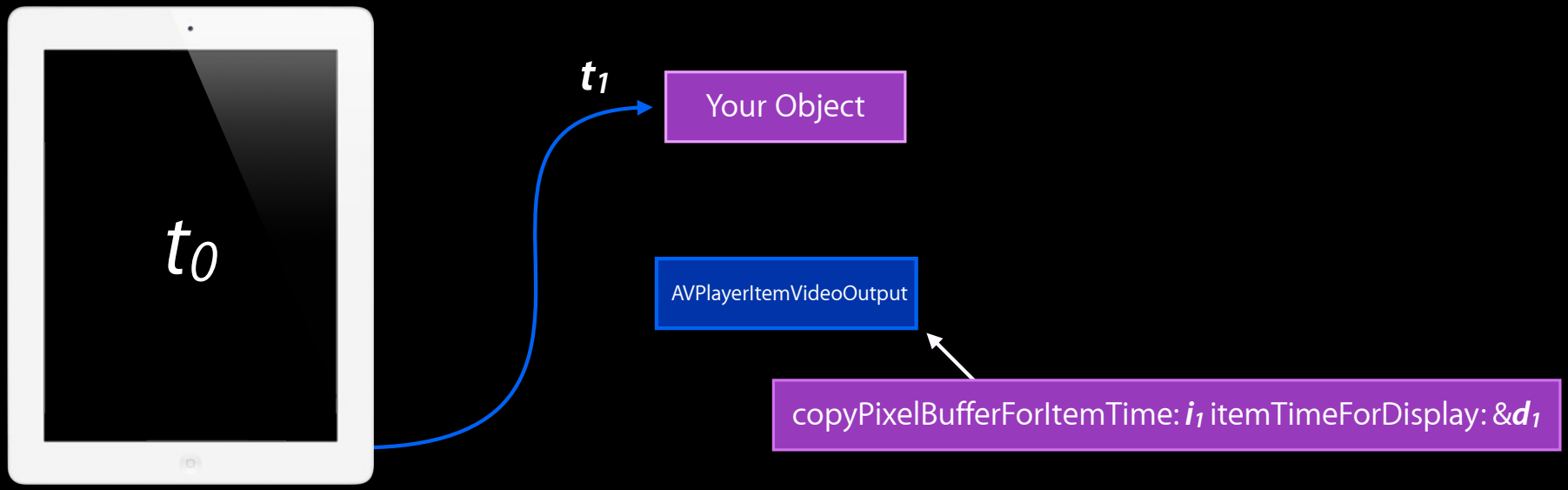


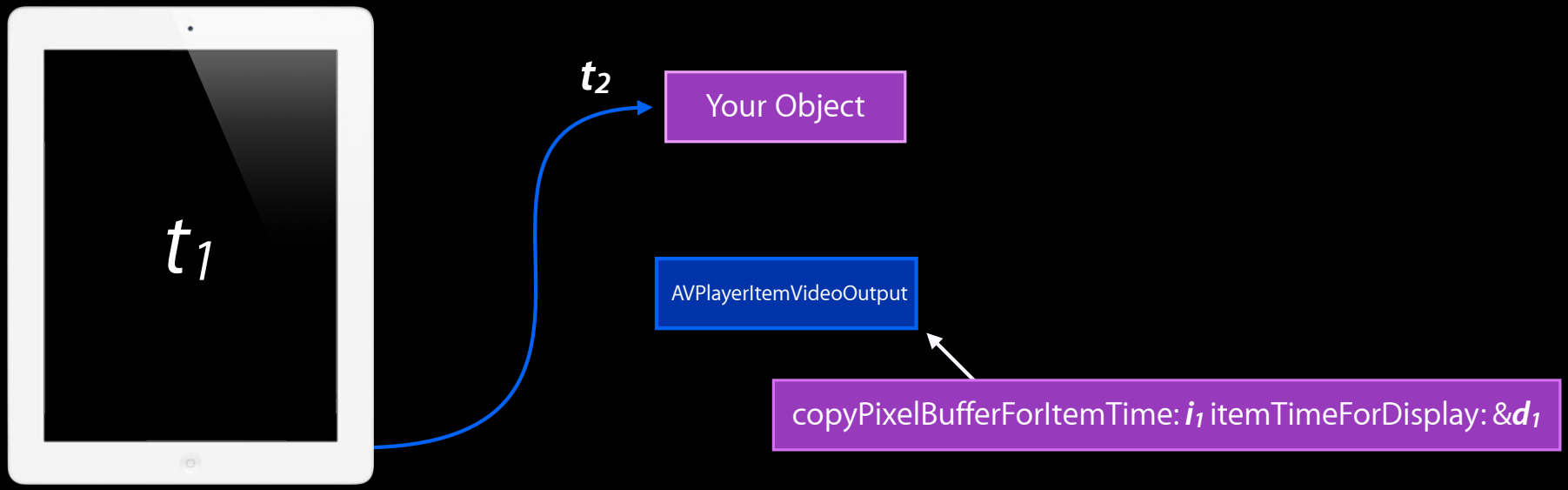
AVPlayerItemVideoOutput

Pulling images from a dynamic model



AVPlayerItemVideoOutput

Pulling images from a dynamic model



CADisplayLink

```
_displayLink = [CADisplayLink displayLinkWithTarget:self
                                           selector:@selector(mySelector:)];

[_displayLink setFrameInterval:1];
[_displayLink setPaused:YES];
[_displayLink addToRunLoop:[NSRunLoop currentRunLoop]
                   forMode:NSDefaultRunLoopMode];
```

CADisplayLink

```
- (void)mySelector:(CADisplayLink *)sender
{
  CFTimeInterval nextOutputTime = [sender timestamp] + [sender duration];
  CMTime itemTime = [_pixelBufferOutput itemTimeForTimeStamp:nextOutputTime];
  if ([_pixelBufferOutput isNewOutputAvailable:itemTime]) {
    CVPixelBufferRef pixBuff = NULL;
    [_pixelBufferOutput copyPixelBuffer:&pixBuff forTime:outputMediaTime];

    glActiveTexture(GL_TEXTURE0);
    CVOpenGLESTextureCacheCreateTextureFromImage(..., &_lumaTexture );
    glBindTexture(...);

    glActiveTexture(GL_TEXTURE1);
    CVOpenGLESTextureCacheCreateTextureFromImage(..., &_chromaTexture);
    glBindTexture(...);

    CVBufferRelease(pixBuff);
   }
}
```

CADisplayLink

```
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    glBindTexture(...);

    glActiveTexture(GL_TEXTURE1);
    CVOpenGLESTextureCacheCreateTextureFromImage(..., &_chromaTexture);
    glBindTexture(...);

    CVBufferRelease(pixBuff);
   }
}
```

AVPlayerItemVideoOutput

Meeting the deadline

- You can pull ahead of playhead
- Images not pulled before deadline are discarded

AVPlayerItemVideoOutput

Save power when paused

- Go to sleep
- Request wakeup when output will change
  - `requestNotificationOfMediaDataChangeWithAdvanceInterval:`
  - Delegate callback
    - `outputMediaDataWillChange:`

Video on a Texture

- AVPlayerItemVideoOutput
- OpenGL ES 2.0 game with GLKit
- Real-time chroma key effect
  - Fragment shader
- Video texture atlas

Demo

MagicCube

Summary

Summary

- A/V Sync is the key goal
  - Tell AVFoundation which clock to sync to
  - Be efficient with the audio processing callback
  - Use system services to remain in sync when using an AVPlayerItemVideoOutput

More Information

Eryk Vershen
Media Technologies Evangelist
evershen@apple.com

Documentation
AV Foundation Programming Guide
http://developer.apple.com/library/ios/#documentation/AudioVideo/Conceptual/AVFoundationPG

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

Sample Code
Available on session website

Related Sessions

What's New in Camera Capture	Presidio Thursday 10:15AM
Multiplayer Gaming with Game Center	Pacific Heights Thursday 10:15AM
Building Game Center Games for OS X	Pacific Heights Thursday 11:30AM

Labs

Core Animation Lab	Graphics Media & Games Lab C Thursday 11:30AM
AV Foundation Lab	Graphics Media & Games Lab C Thursday 2:00PM
Game Design Lab	Graphics Media & Games Lab A Thursday 2:00PM
iOS Camera Capture Lab	Graphics Media & Games Lab D Thursday 2:00PM


WWDC2012