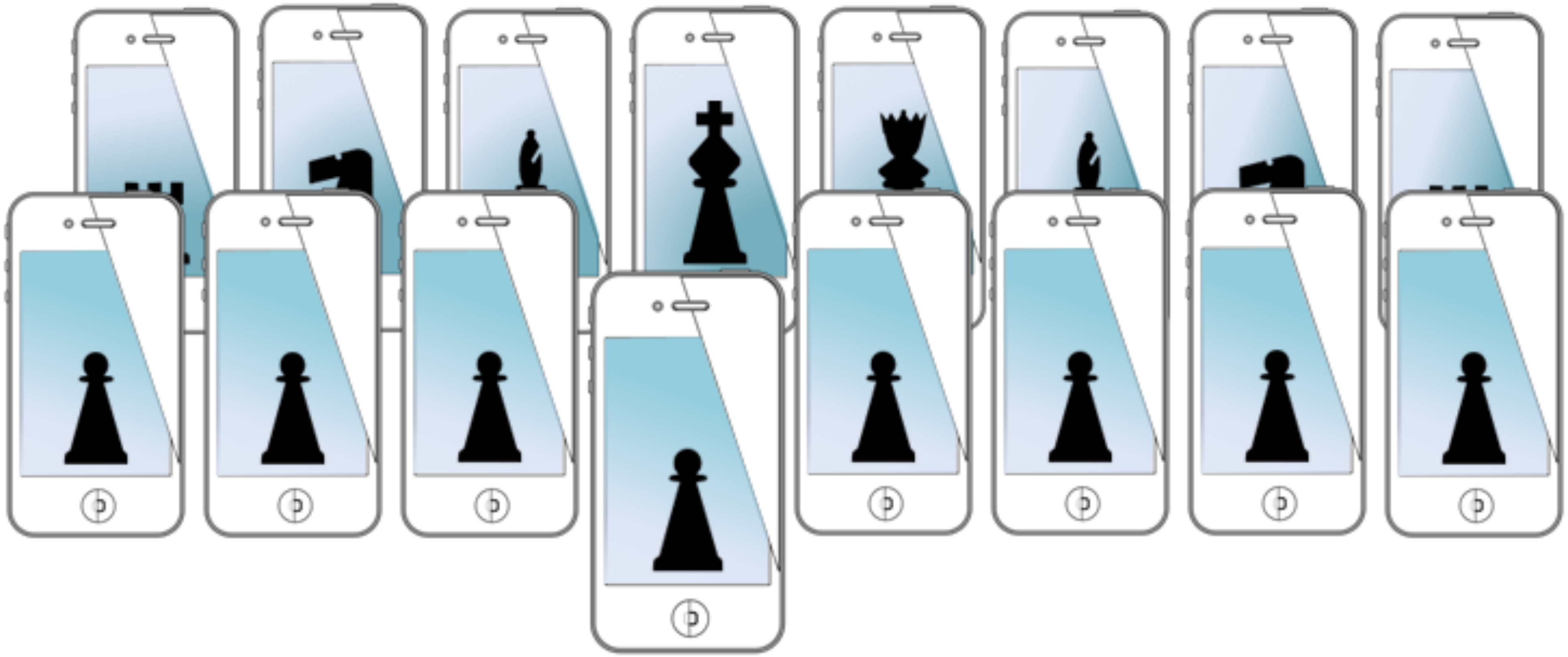
MOBILE SENSING LEARNING



CS5323 & 7323

Mobile Sensing and Learning

audio graphing, sampled data, & accelerate

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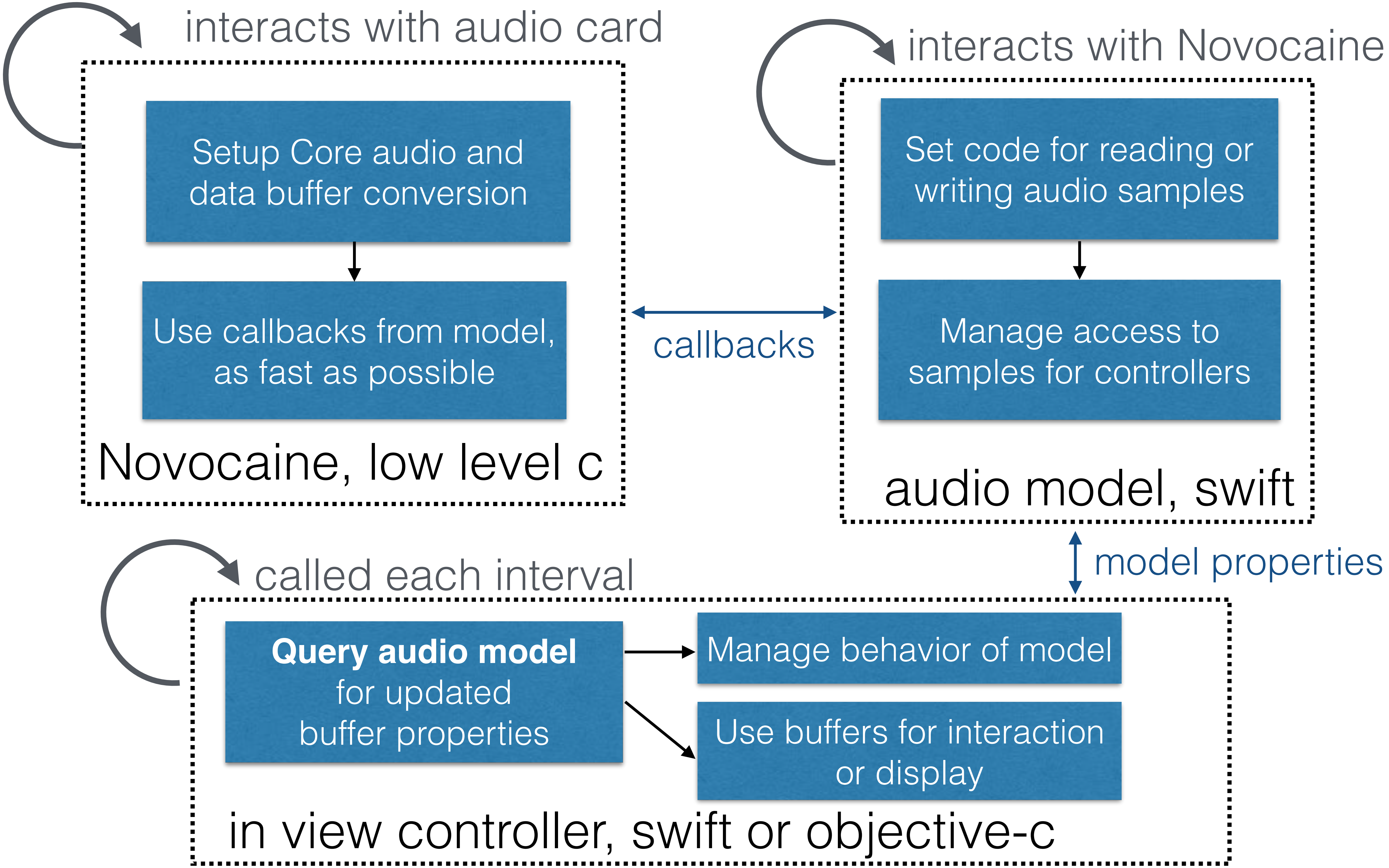
agenda and logistics

- logistics
  - flipped module on audio next time!
- agenda
  - dealing with sampled data
  - the accelerate framework
    - massive digital signal processing library
  - graphing audio fast (well, graphing anything)
    - must use lowest level graphing, Metal

review: MVC with audio



interacts with audio card

Setup Core audio and data buffer conversion

Use callbacks from model, as fast as possible

Novocaine, low level c

callbacks

interacts with Novocaine

Set code for reading or writing audio samples

Manage access to samples for controllers

audio model, swift

model properties

called each interval

Query audio model for updated buffer properties

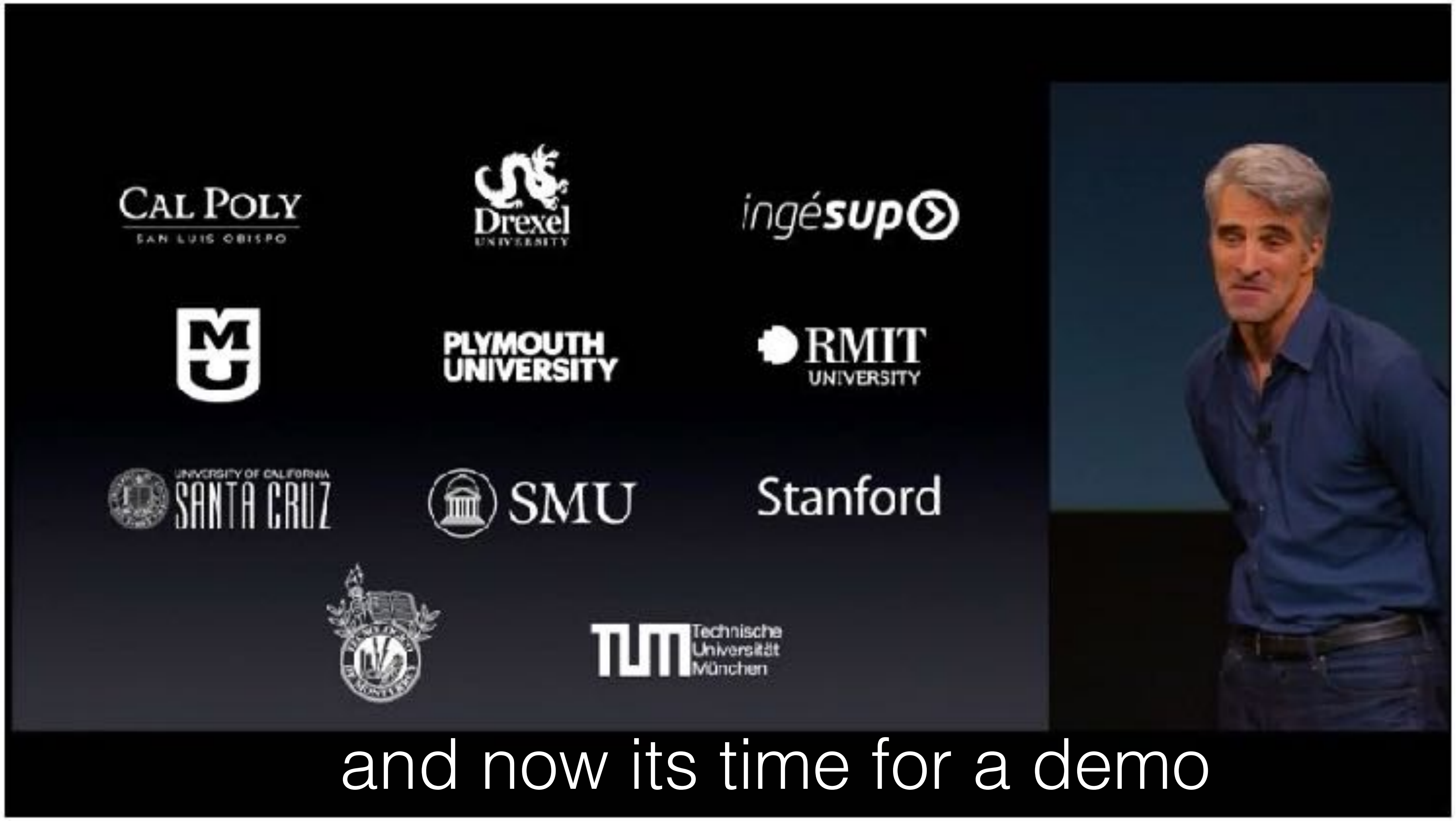
Manage behavior of model

Use buffers for interaction or display

in view controller, swift or objective-c

sample from the mic

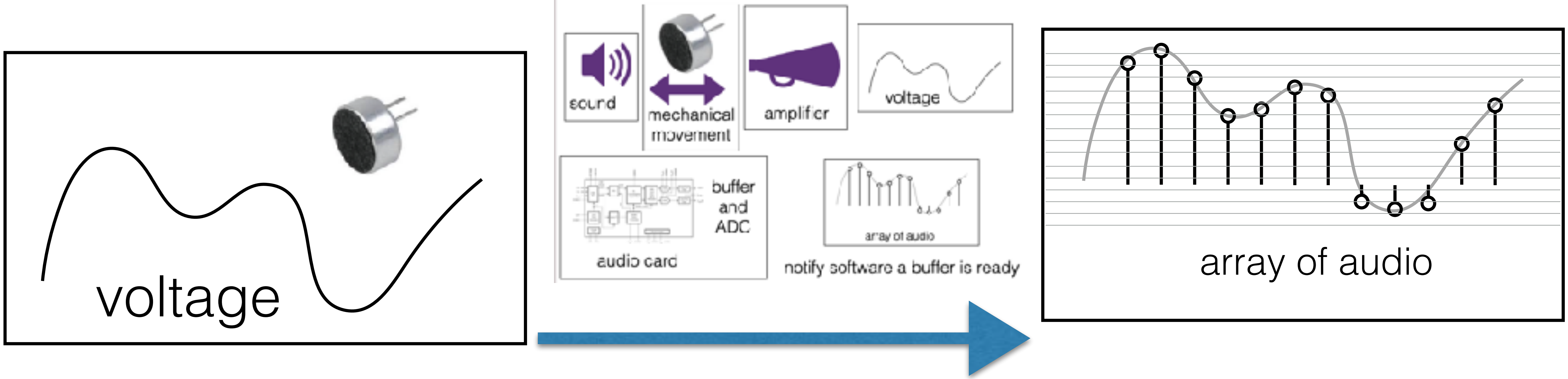
- recall: data from the microphone on novocaine



and now its time for a demo

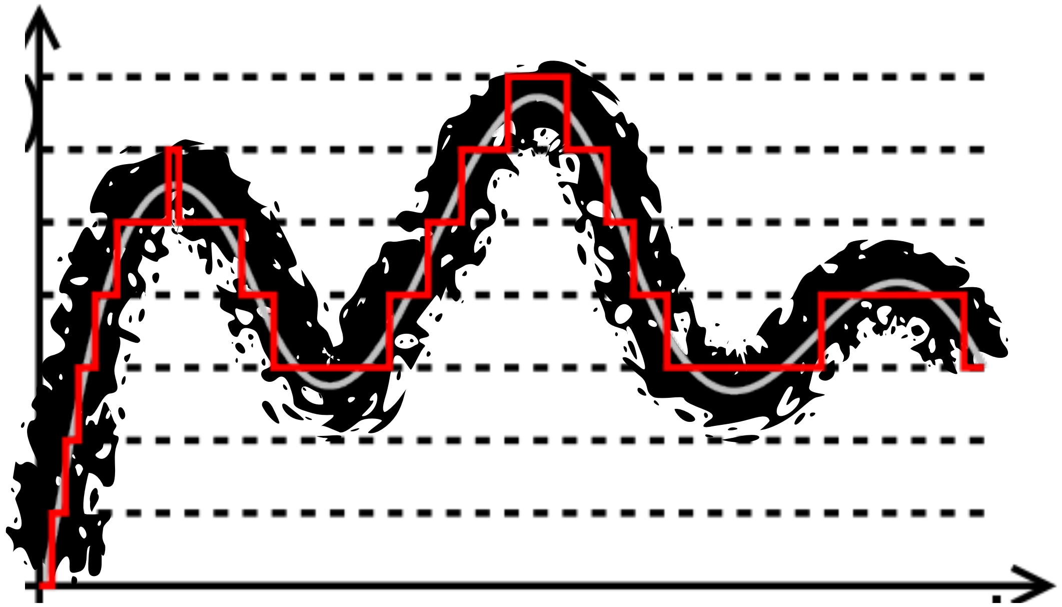
intro to sampled data

- physical processes are continuous
  - digitization **may change** how we **understand** the signal
- digitization occurs in time and amplitude
  - time: sampling
  - amplitude: quantization



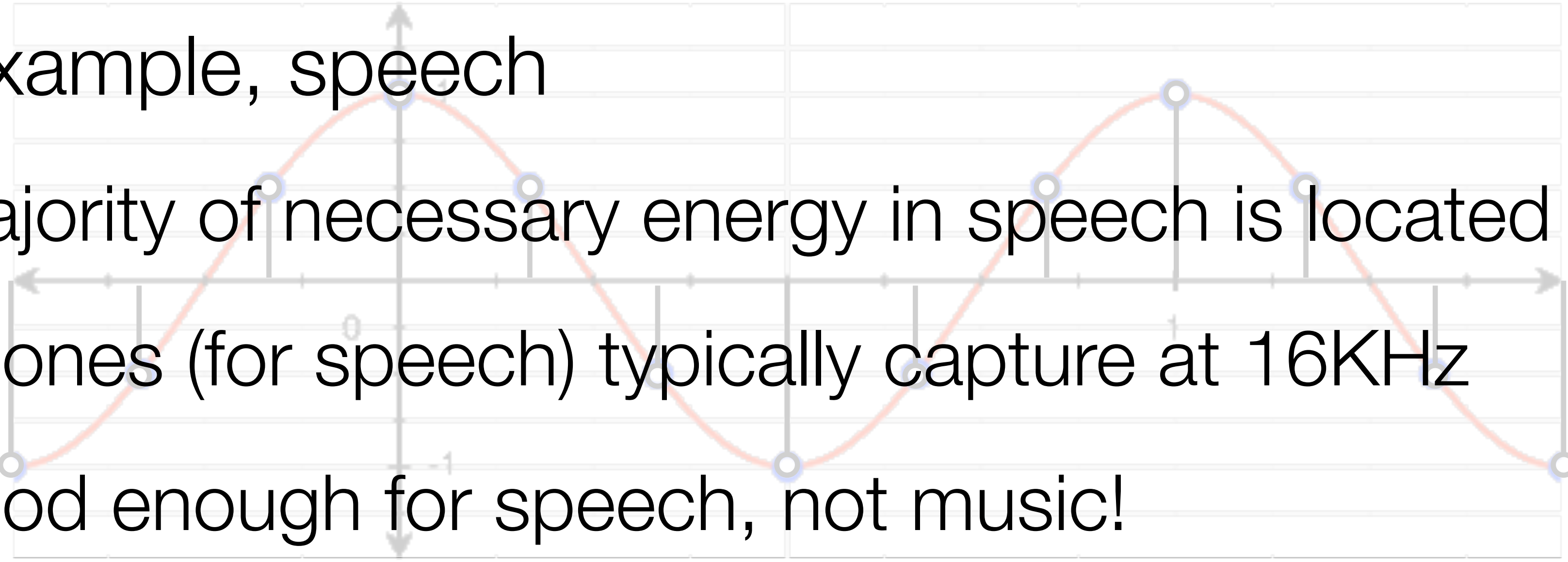
sampled data

- quantization (amplitude)
  - introduces error in estimating amplitude of a signal
  - error can be reduced by adding more "bits per sample"
- most ADCs are 16 bits, considered "good enough"
- sufficient for most uses
  - not for others!



sampling errors

- sampling in time
  - introduces errors through ‘aliasing’, limits the range of frequencies able to be accurately captured
- heuristics
  - don’t try to sample extremely small increments or values!
  - if capturing an “X”Hz signal, need to sample at least 2“X” Hz
  - changing sample rates is complicated
- for example, speech
  - majority of necessary energy in speech is located < 8000Hz
  - phones (for speech) typically capture at 16KHz
  - good enough for speech, not music!



sanity check

- I need to detect an 80Hz signal
  - what sampling rate should we use?

- I want to detect a feather dropping next to the microphone
  - can the sound be detected?

making a sine wave

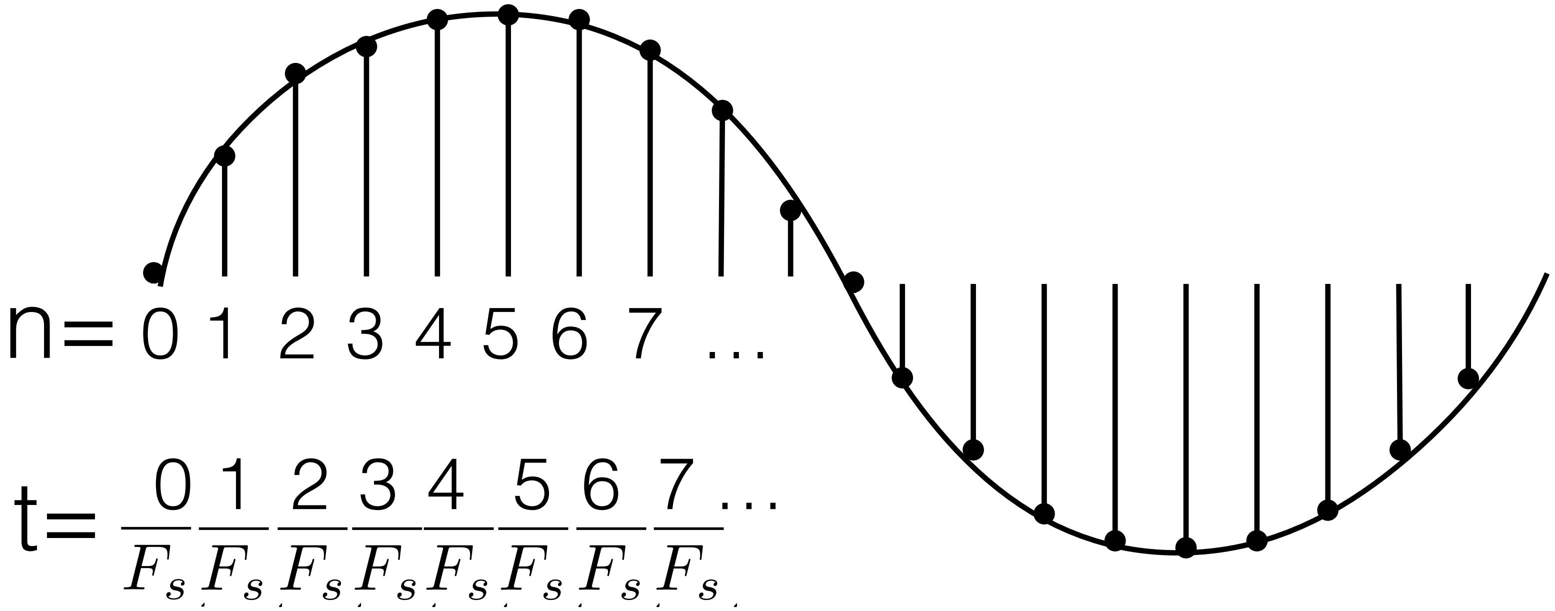
- we want to create a sine wave and play it to the speakers

$$g(t) = \sin(2\pi f t)$$ equation for sine wave

frequency in Hz

time in “seconds”

but we are working digitally, so we have an “index” in an array, not time!



n= 0 1 2 3 4 5 6 7 …
t= $\frac{0}{F_s}\frac{1}{F_s}\frac{2}{F_s}\frac{3}{F_s}\frac{4}{F_s}\frac{5}{F_s}\frac{6}{F_s}\frac{7}{F_s}\ldots$

$$g[n] = \sin\left(2\pi f\left(\frac{n}{F_s}\right)\right)$$

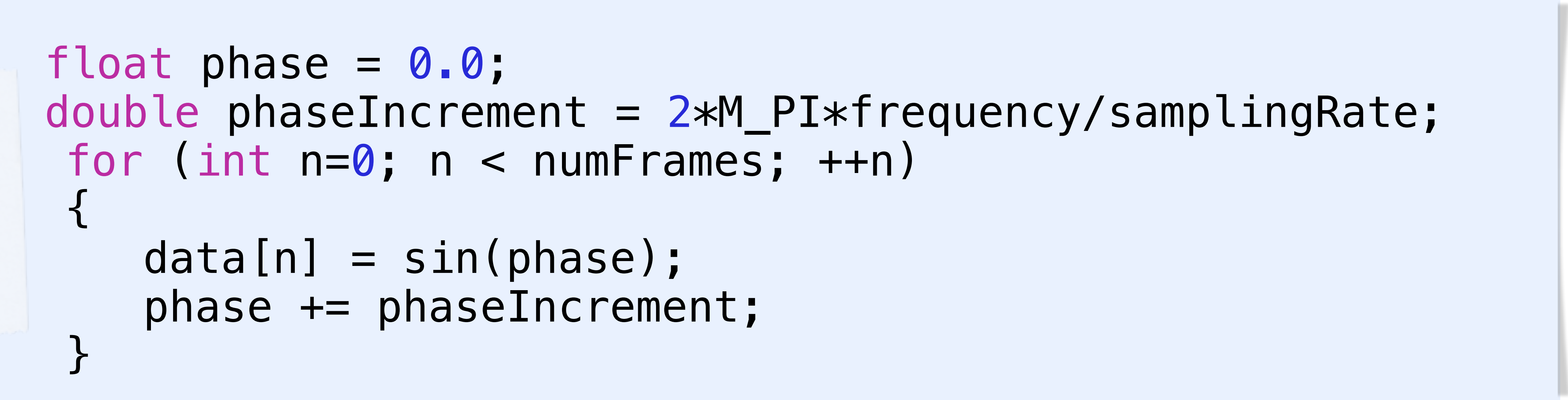
making a sine wave

$$g[n] = \sin\left(2\pi f\left(\frac{n}{F_s}\right)\right)$$

how to program this?

```
for (int n=0; n < numFrames; ++n)
 {
     data[n] = sin(2*M_PI*frequency*n/samplingRate);
 }
```

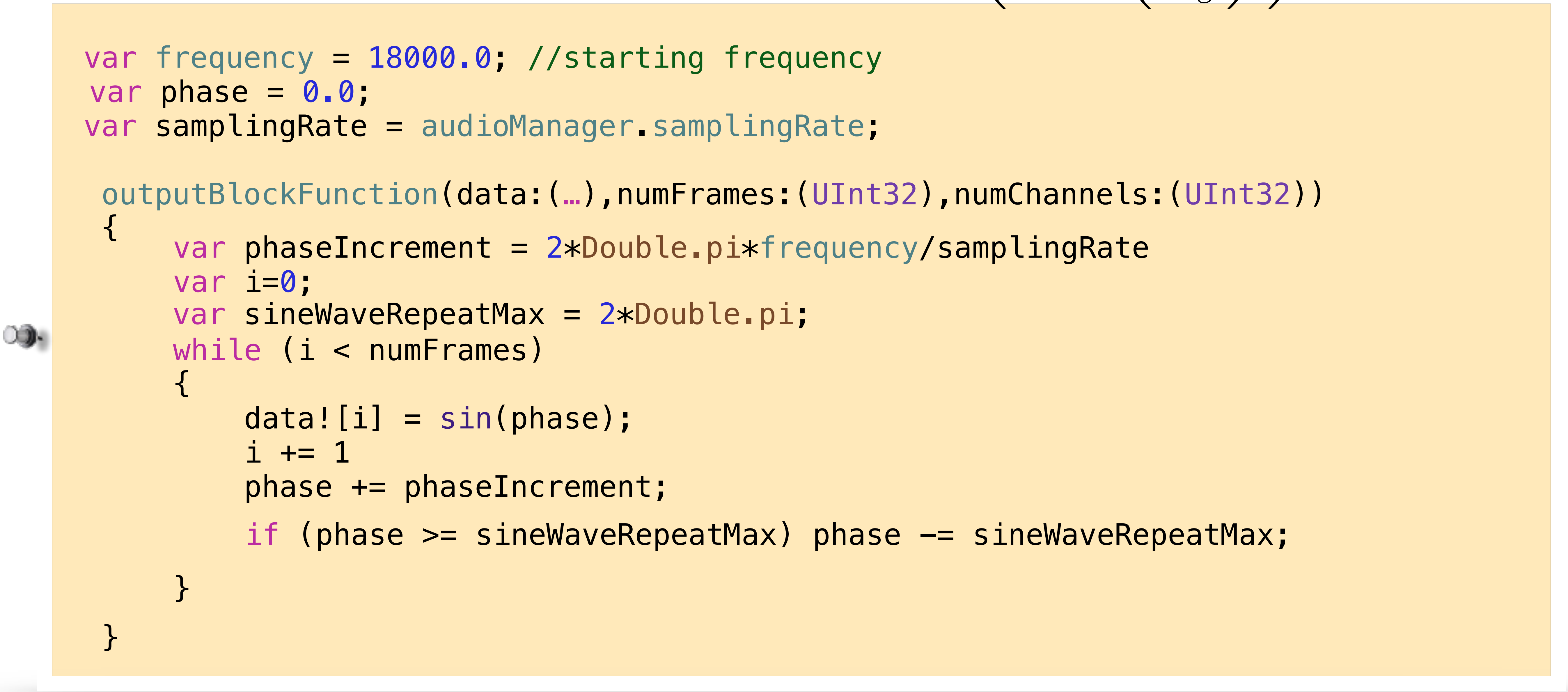
is this efficient?



```
float phase = 0.0;
double phaseIncrement = 2*M_PI*frequency/samplingRate;
 for (int n=0; n < numFrames; ++n)
 {
     data[n] = sin(phase);
     phase += phaseIncrement;
 }
```

making a sine wave

- bringing it all together $$g[n] = \sin\left(2\pi f\left(\frac{n}{F_s}\right)\right)$$



```
var frequency = 18000.0; //starting frequency
 var phase = 0.0;
var samplingRate = audioManager.samplingRate;

 outputBlockFunction(data:(…),numFrames:(UInt32),numChannels:(UInt32))
 {
     var phaseIncrement = 2*Double.pi*frequency/samplingRate
     var i=0;
     var sineWaveRepeatMax = 2*Double.pi;
     while (i < numFrames)
     {
         data![i] = sin(phase);
         i += 1
         phase += phaseIncrement;
         if (phase >= sineWaveRepeatMax) phase -= sineWaveRepeatMax;
     }
 }
```

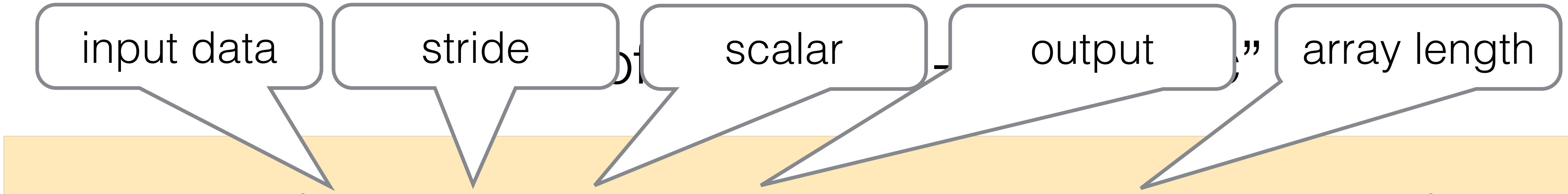
```
data: UnsafeMutablePointer<Float>?
```

play samples to speakers

- demo, play sine wave

the accelerate framework

- very powerful digital signal processing (DSP) library
  - look at vDSP Programming Guide on developer.apple.com for the complete API
- provides mathematics for performing fast DSP



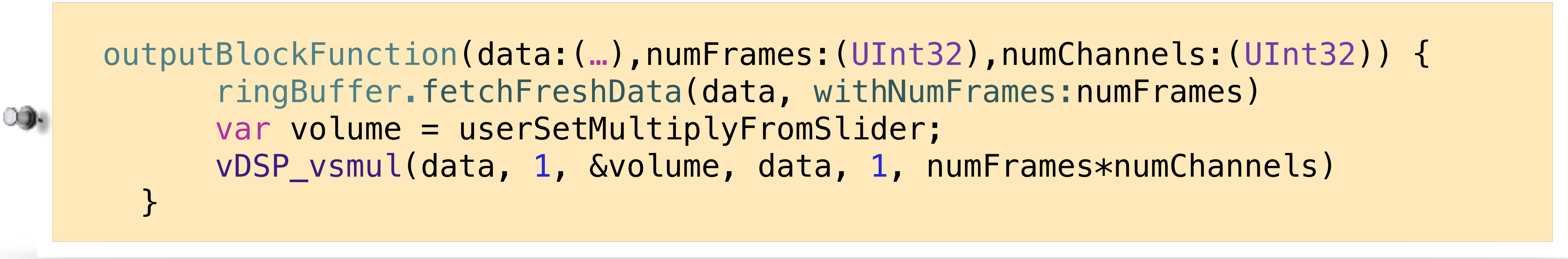
```
vDSP_vsmul(data, 1, &mult, data, 1, numFrames*numChannels);
```

```
void vDSP_vsmul (
   const float __vDSP_input1[],
   vDSP_Stride __vDSP_stride1,
   const float *__vDSP_input2,
   float __vDSP_result[],
   vDSP_Stride __vDSP_strideResult,
   vDSP_Length __vDSP_size
);
```

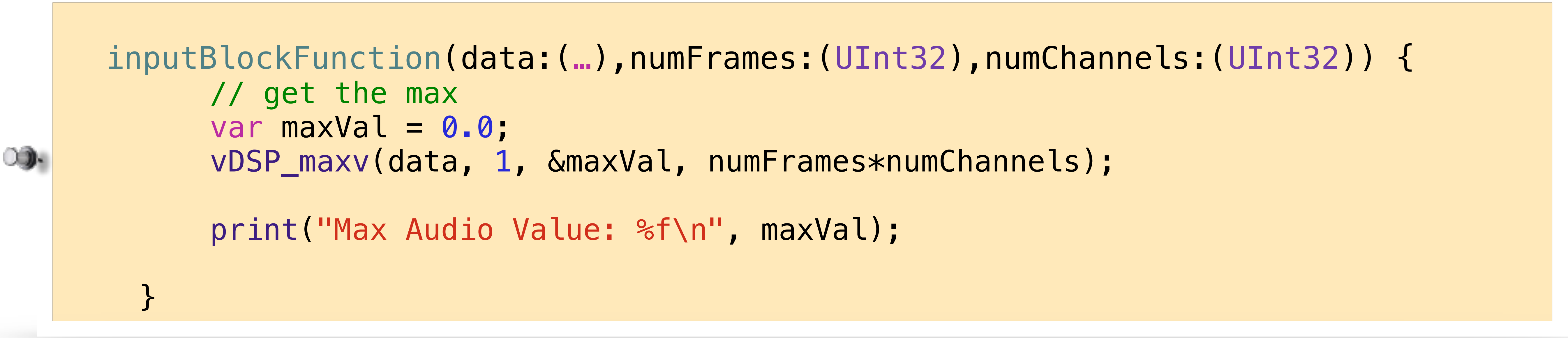
https://developer.apple.com/documentation/accelerate/1450020-vdsp_vsmul

examples

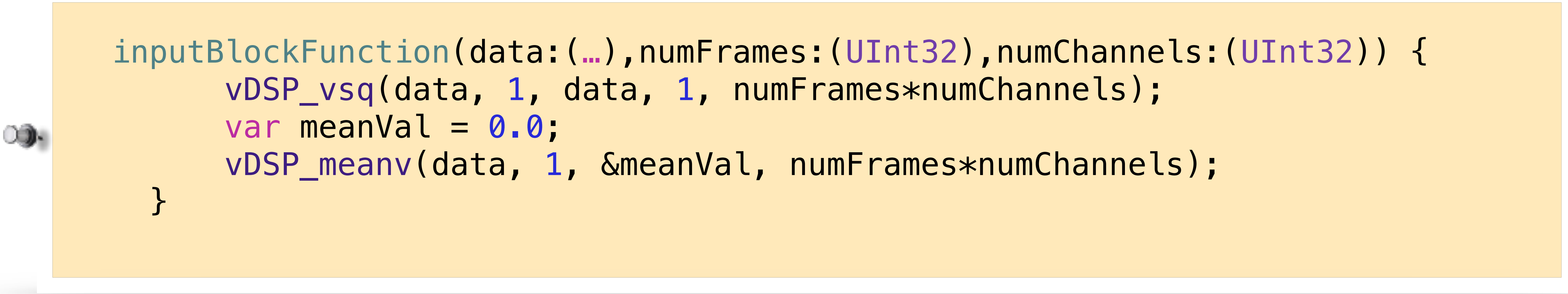
what do each of these implement?



```
outputBlockFunction(data:(…),numFrames:(UInt32),numChannels:(UInt32)) {
      ringBuffer.fetchFreshData(data, withNumFrames:numFrames)
      var volume = userSetMultiplyFromSlider;
      vDSP_vsmul(data, 1, &volume, data, 1, numFrames*numChannels)
  }
```



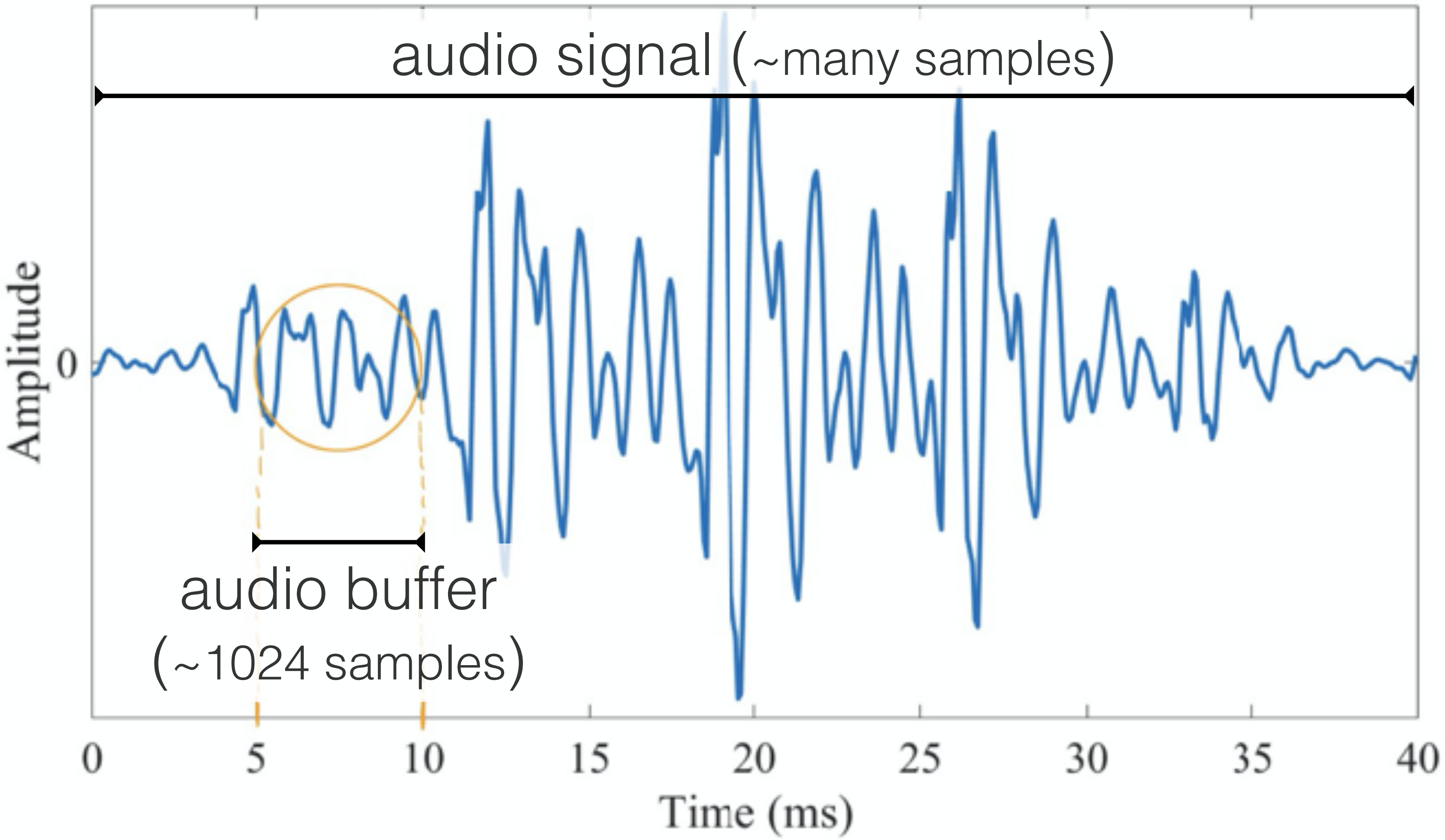
```
inputBlockFunction(data:(…),numFrames:(UInt32),numChannels:(UInt32)) {
      // get the max
      var maxVal = 0.0;
      vDSP_maxv(data, 1, &maxVal, numFrames*numChannels);

      print("Max Audio Value: %f\n", maxVal);

  }
```



```
inputBlockFunction(data:(…),numFrames:(UInt32),numChannels:(UInt32)) {
      vDSP_vsq(data, 1, data, 1, numFrames*numChannels);
      var meanVal = 0.0;
      vDSP_meanv(data, 1, &meanVal, numFrames*numChannels);
  }
```

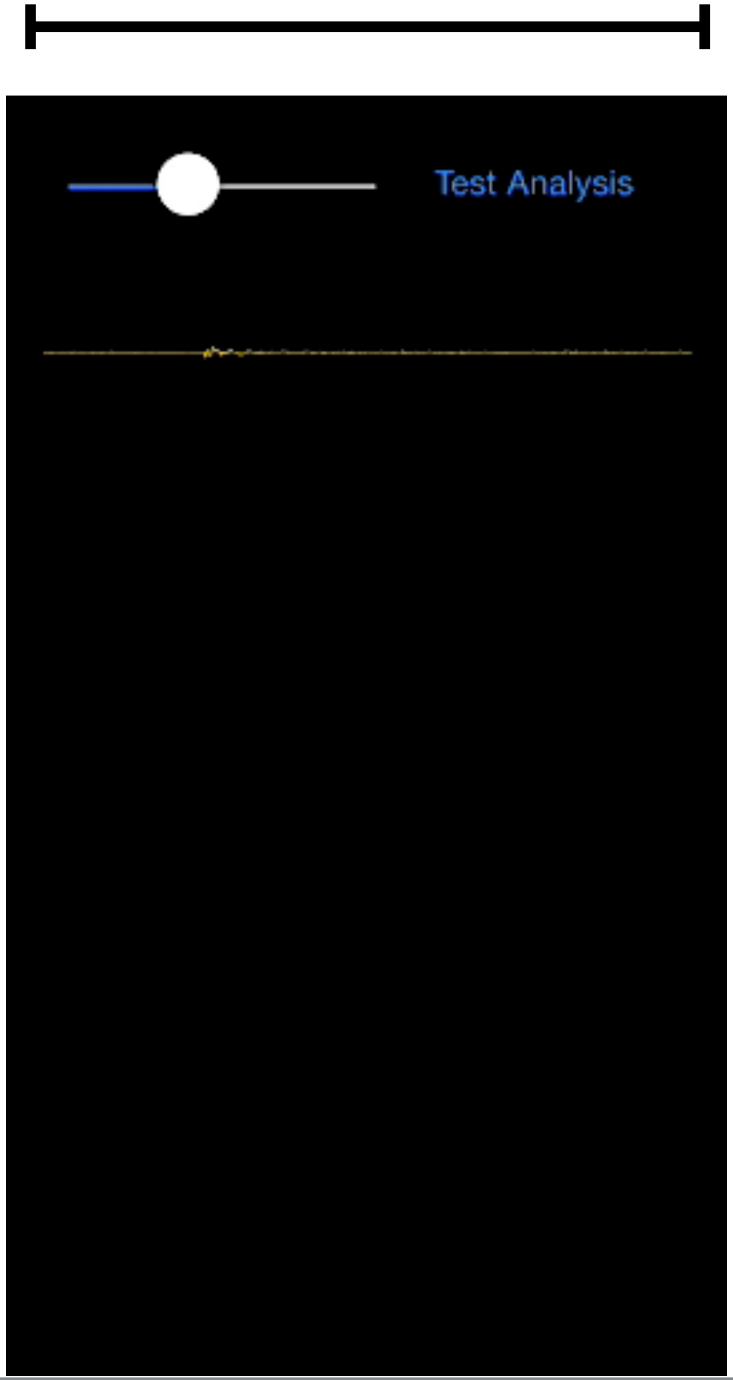
audio graphing

- we want to see the incoming samples
  - good for debugging
  - equalizers, oscilloscope type applications, etc.



how much data to show?

- sampling at 48kHz == 48000 samples per second



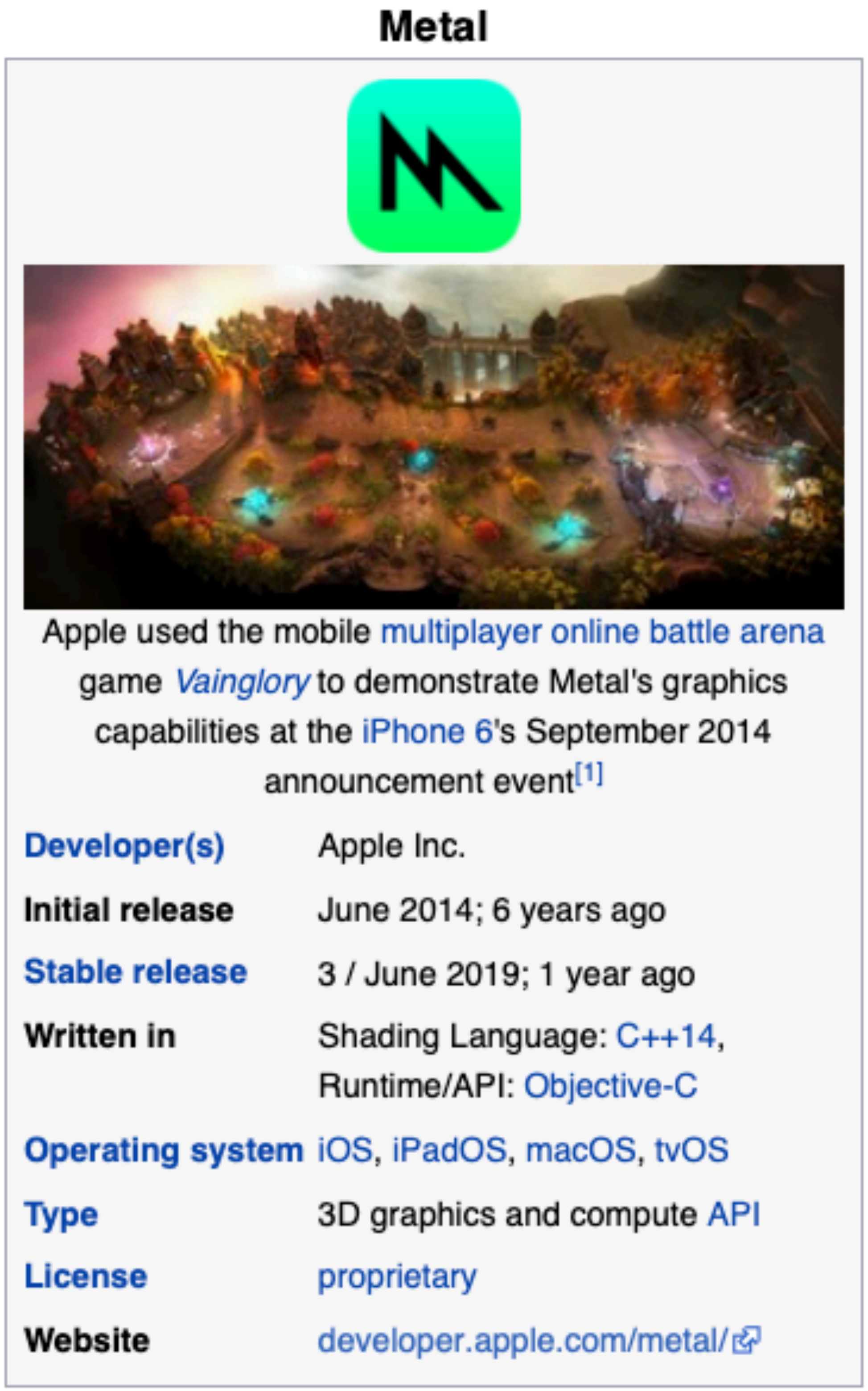
graph 0.5 second window is:
24000 samples

display is >640 pixels wide

what if we want lots of graphs?

solution

- use the GPU
- set vectors of data on a 2D plane
- let the renderer perform scaling, anti-aliasing, and bit blitting to screen
- …this is not a graphics course
- …but we need to use the Metal API

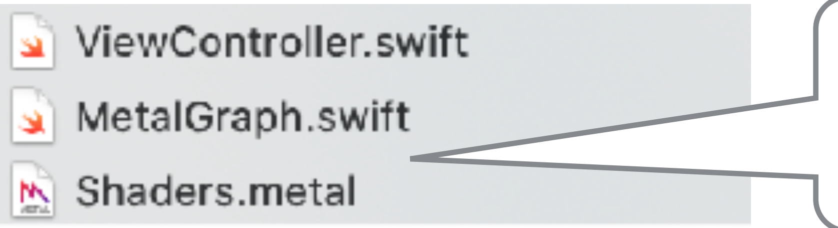


Metal

Apple used the mobile multiplayer online battle arena game *Vainglory* to demonstrate Metal's graphics capabilities at the iPhone 6's September 2014 announcement event[1]

Developer(s)	Apple Inc.
Initial release	June 2014; 6 years ago
Stable release	3 / June 2019; 1 year ago
Written in	Shading Language: C++14, Runtime/API: Objective-C
Operating system	iOS, iPadOS, macOS, tvOS
Type	3D graphics and compute API
License	proprietary
Website	developer.apple.com/metal/

the MetalGraph class


ViewController.swift
MetalGraph.swift
Shaders.metal

drag class/shaders
into project, if needed

```swift
lazy var graph:MetalGraph? = {
   return MetalGraph(mainView: self.view)
}()
```

declare and init property

```swift
 // add in a graph for displaying the audio
 graph?.addGraph(withName: "time",
          shouldNormalize: false,
         numPointsInGraph: AUDIO_BUFFER_SIZE)
```

add graph names to controller
and how many expected points in array

```swift
 // periodically, display the audio data
 graph?.updateGraph(
           data:  timeData,
           forKey: "time"
 )
```

refresh data for each
named graph key

Properties: automatic screensize (pixel) downsampling
automatic coloring based in iOS scheme,
efficient memory management through vertex buffers
adding functionality is a pain if you are new to graphics

audio graphing demo!

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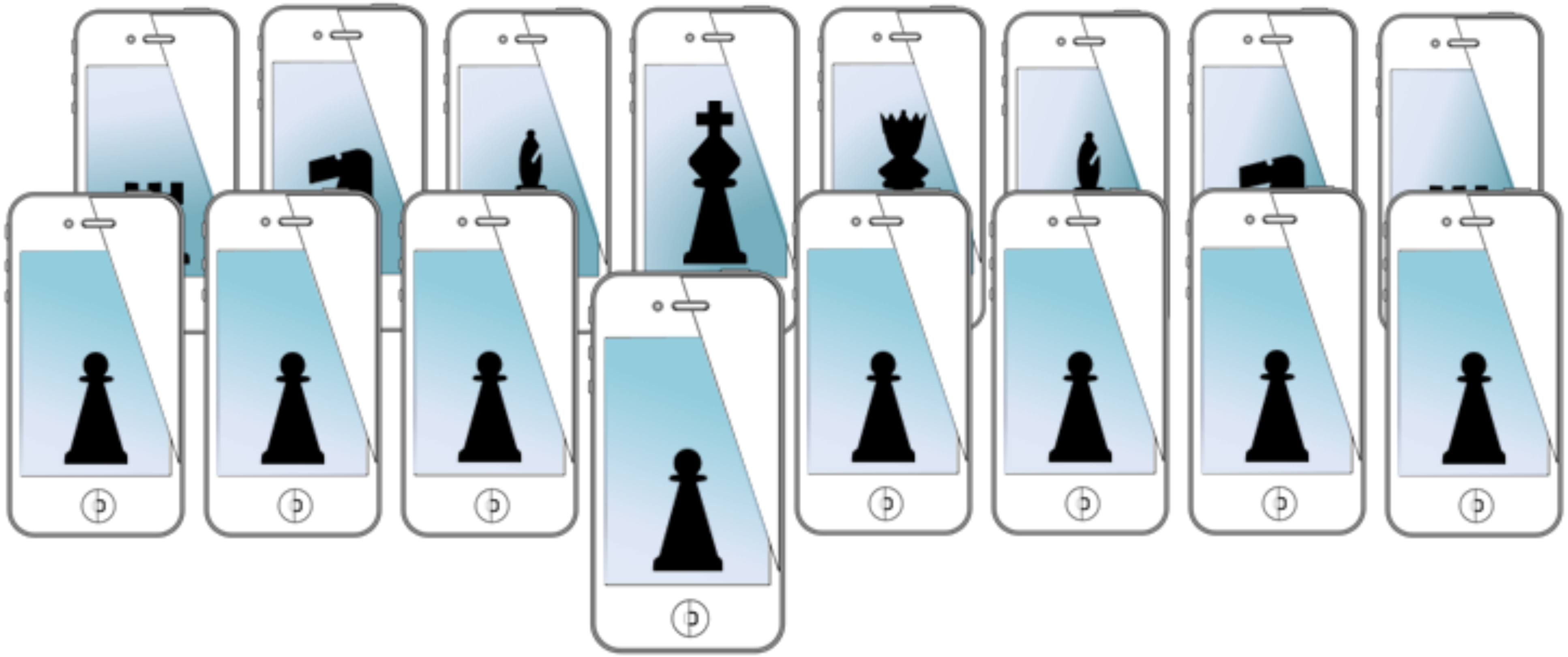

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