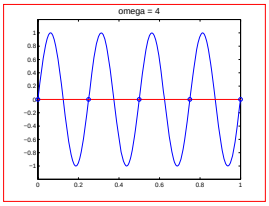
- Previous Lecture:
  - Working with sound files
- Today's Lecture:
  - Frequency computation
  - Touchtone phone
- Announcement:
  - Section in the computer lab this week
  - Prelim 3 tonight 7:30-9pm
    - A-F in Kimball B11
    - G-L Ives 305
    - M-R in Upson B17
    - S-Z in Olin 255

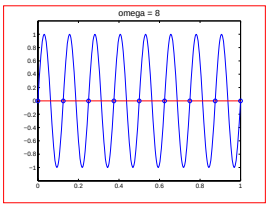
A "pure-tone" sound is a sinusoidal function

$$y(t) = \sin(2\pi\omega t)$$

ω = the frequency

Higher frequency means that y(t) changes more rapidly with time.





Still looking at the time domain

$$y(t) = \sin(2\pi \cdot 4t)$$

$$y(t) = \sin(2\pi \cdot 8t)$$

Digitize for Graphics

```
% Sample "Rate"
  n = 200
% Sample times
  tFinal = 1;
  t = 0:(1/n):tFinal
% Digitized Plot…
  omega = 8;
  y= sin(2*pi*omega*t)
  plot(t,y)
```

Digitize for Sound

```
% Sample Rate
  Fs = 32768
% Sample times
  tFinal = 1;
  t = 0:(1/Fs):tFinal
% Digitized sound…
  omega = 800;
  y= sin(2*pi*omega*t);
  sound(y,Fs)
```


Adding Sinusoids

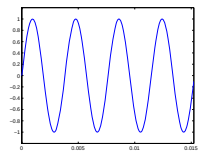
```
Fs = 32768; tFinal = 1;
t  = 0:(1/Fs):tFinal;

C3  = 261.62;
yC3 = sin(2*pi*C3*t);
A4  = 440.00;
yA4 = sin(2*pi*A4*t);
y   = (yC3 + yA4)/2;

sound(y,Fs)
```


Adding Sinusoids

C3:



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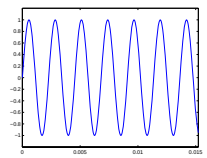
A4:



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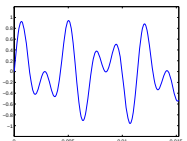
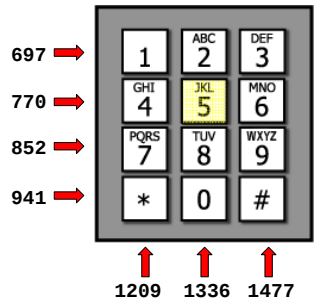


A frequency is associated with each row & column.

So two frequencies are associated with each button.



"5"-Button corresponds to (770,1336)

Each button has its own 2-frequency "fingerprint"!

Signal for button 5:

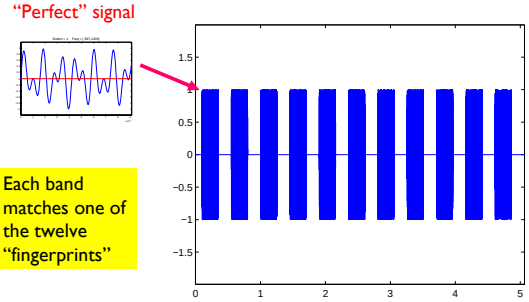
```
Fs = 32768;
tFinal = .25;
t  = 0:(1/Fs):tFinal;

yR = sin(2*pi*770*t);
yC = sin(2*pi*1336*t)
y  = (yR + yC)/2;

sound(y,Fs)
```


What does the signal look like for a multi-digit call?

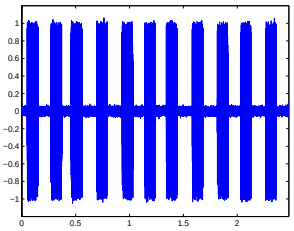
"Perfect" signal



Each band matches one of the twelve "fingerprints"

Buttons pushed at equal time intervals

"Noisy" signal



Each band approximately matches one of the twelve "fingerprints." There is noise between the button pushes.

Buttons pushed at unequal time intervals

The Segmentation Problem

When does a band begin?

When does a band end?

Somewhat like the problem of finding an edge in a digitized picture.

Fourier Analysis

Once a band is isolated, we know it is the sum of two sinusoids:

What are the two frequencies?

Use Fourier analysis to find out.