Sampling

\[ x(t) = \cos(2\pi 1500t) \]
\[ t = T_n \]

\[ x[n] = \cos(2\pi \cdot 1500 \cdot T_n) \]
\[ f_s = 8000 \text{ Hz} \]
\[ T_s = \frac{1}{f_s} = \frac{1}{8000} \text{ sec} \]

\[ x[n] = \cos(2\pi \cdot 1500 \cdot \frac{1}{8000} n) \]

**Shannon Sampling Theorem**

\[ f_s > 2f_{\text{max}} \rightarrow f_{\text{max}} < f_s/2 \]

\[ f_s = 2f_{\text{max}} \]
\[ f_s = 8000 \text{Hz} \]
\[ f_{\text{max}} = \frac{f_s}{2} \]
\[ f_s = \frac{1}{T_s} \]

**Time domain**

- \( x(t) \)
- Sampling
- Frequency domain
- \( 0 \)
- \( T_s \)
- \( 2T_s \)
- \( 3T_s \)
- \( 4T_s \)

**Frequency domain**

- \( 2A \)
- \( -f_s \)
- \( f_s \)
- \( 2f_s \)

**Sampled sinewave**

- \( 2A \)
- \( -f_o \)
- \( -f_s \)
- \( f_s \)
- \( 2f_s \)

D-to-C only reconstructs frequencies between \( \frac{-f_s}{2} \) and \( \frac{f_s}{2} \)
Normalized frequency
\[ x[n] = x(nT) = \cos(2\pi f_s nT) = \cos(\omega_n nT) \]
\[ \omega_n = \omega f_s \]
\[ f = \omega / (2\pi) = f_s / f_s \]
\[ x[n] = \cos(2\pi fn) = \cos(n\omega) \]

Sampling: Aliasing
\[ f_s \leq f_s < 1.5 f_s \]
\[ 1 \leq f_s < 1.5 \]

Sampling: Folding
\[ \frac{f_s}{2} < f_s < f_s \]
\[ 0.5 < f_s < 1 \]

Shannon Sampling Theorem
\[ f_{\text{max}} < \frac{1}{2} \]

Over-sampling
\[ f_{\text{input frequency}} \]
\[ f_{\text{oversampled}} = f_s - f_{\text{input frequency}} \]
\[ 8700 - 8000Hz = 800Hz \]

Folding
\[ f_{\text{input frequency}} \]
\[ f_{\text{oversampled}} = f_s - f_{\text{input frequency}} \]
\[ 5600 - 8000Hz = 2400Hz \]
**Vary Sample rate**

\[ x(t) = \cos(2\pi 1200t) \]

\[ t = T_n \quad \text{vary} \quad T_n \]

\[ x[n] = \cos(2\pi \cdot 1200 \cdot T_n) \]

**Sampling: Composite Signal**

\[ x(t) = \cos(2\pi 1200t) + \cos(2\pi 600t) \]

\[ x[n] = \cos(2\pi \cdot 1200 \cdot T_n) + \cos(2\pi \cdot 600 \cdot T_n) \]

\[ f_s = 3800\text{Hz} \]

**Sampling: Composite Signal**

\[ x(t) = \cos(2\pi 1200t) + \cos(2\pi 600t) \]

\[ x[n] = \cos(2\pi \cdot 1200 \cdot T_n) + \cos(2\pi \cdot 600 \cdot T_n) \]

\[ f_s = 2200\text{Hz} \]
**Psychophysics**

the relationship between physical stimuli and what you perceive

absolute thresholds, discrimination thresholds, and scaling.

Threshold: the point of intensity that you can just detect the presence of, or difference in, a stimulus.

- **absolute threshold** — the level at which the subject is able to detect the presence of the stimulus (50%)
- **difference threshold** — the difference between two stimuli of differing intensities you can detect (50%)

adjust one stimulus until it is perceived as the same as the other, describe the magnitude of the difference between two stimuli detect a stimulus against a background.

discrimination experiments -- what point the difference between two stimuli is detectable.

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**Psychophysics: Vision**

**Color Matching**

Bipartite white screen

Turn knobs for R, G, & B until combined light matches color of test light.

---

**Sampling: Composite Signal**

\[
x(t) = \cos(2\pi t \cdot 1200) + \cos(2\pi t \cdot 600)
\]

\[
x[n] = \cos(2\pi \cdot 1200 \cdot T_n) + \cos(2\pi \cdot 600 \cdot T_n)
\]

\[f_s = 1000\ Hz\]

---

**Resampling**

Resized (nearest-Neighbor) no pre-blur

Resized (nearest-Neighbor) with pre-blur

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http://en.wikipedia.org/wiki/Psychophysics

http://www.ling.upenn.edu/courses/ling525/color_vision.html
By exaggerating contrast along edges in the image, the edges stand out more, making them appear sharper.
Psychoacoustics: Sound Masking

Broadband white noise tends to mask all frequencies, and is approximately linear in that masking. By linear you mean that if you raise the white noise by 10 dB, you have to raise everything else 10 dB to hear it. -- http://hyperphysics.phy-astr.gsu.edu/hbase/sound/mask.html

You know I can’t hear you when the water is running!
This statement carries the essentials of the conventional wisdom about sound masking. Low-frequency, broad banded sounds (like water running) will mask higher frequency sounds which are softer at the listener’s ear (a conversational tone from across the room).

The following MATLAB function performs a simple psychoacoustic test. It creates bandlimited noise, centered at 1000 Hz and also creates a sinusoid. It then plays the noise alone and then the noise plus the sinusoid. Try different values of f and A to see whether you can detect the sinusoid. For a particular value of f we’ll call $A_{\text{min}}(f)$ the minimum amplitude at which the frequency f sinusoid could still be heard. Plot several values on the graph of f vs. $A_{\text{min}}$ to determine a simple masking curve.

A typical masking experiment might proceed as follows. A short, about 400 msec, pulse of a 1,000 Hz sine wave acts as the target, or the sound the listener is trying to hear. Another sound, the masker, is a band of noise centered on the frequency of the target (the masker could also be another pure tone). The intensity of the masker is increased until the target cannot be heard.

mask.m plays noise, then noise plus a sinewave of amplitude A and frequency f. You are supposed to determine the smallest amplitude that you can hear the sinewave over the noise. Repeat this for several values of f, and plot f vs. $A_{\text{min}}$.

mask.m is linked to the course webpage. http://ssi.www.media.mit.edu/courses/ssi/y05/ps4/mask.m

Tip:
In mask.m change
```
sound(wf,22050)
A
%add so you get feedback of A
%pause
%comment out, so you don’t wait
sound(wf+s,22050)
```

>> f=1000; for A=0.01:.01:.1; mask(f,A); end

Press cmd+. to stop when you detect sinewave.

<table>
<thead>
<tr>
<th>f</th>
<th>$A_{\text{min}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>0.0003</td>
</tr>
<tr>
<td>500</td>
<td>0.0003</td>
</tr>
<tr>
<td>750</td>
<td>0.0006</td>
</tr>
<tr>
<td>825</td>
<td>0.03</td>
</tr>
<tr>
<td>900</td>
<td>0.19</td>
</tr>
<tr>
<td>1000</td>
<td>0.215</td>
</tr>
<tr>
<td>1100</td>
<td>0.19</td>
</tr>
<tr>
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<tr>
<td>1500</td>
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<tr>
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<tr>
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<td>0.0004</td>
</tr>
<tr>
<td>10000</td>
<td>0.0007</td>
</tr>
</tbody>
</table>

Minimum audible sinusoid amplitude with noise centered at 1000Hz (A=1)