**Signal:** A function of time that contains in it some sort of desired information.

**Communications:** The signal is sent by a human and received by a human.

**Signal Processing:** The signal is sent by nature and received by a human.

Most real-world signals are continuous time: Audio, radio, bioelectric, ECG, EKG.

**Discrete:** Sample continuous-time signal \( x(t) \) by setting \( t = nT_s \) for some small \( T_s \).

Example: \( x(t) = \cos(2\pi 60t) \rightarrow x[n] = x(t = 0.001n) = \cos(0.12\pi n) \) (discrete-time).

**Q:** WHAT do we want to do with a signal \( x(t) \)? **A:** Filter it. **Q:** What does that mean? **A:** Alter its spectrum. **Q:** What’s a spectrum? **A:** It’s same as the output of a prism:

If \( x(t) \) is periodic with period \( T \) (this means that \( x(t) = x(t + T) \) for all \( t \)), then:

\[
x(t) = c_0 + c_1 \cos\left(\frac{2\pi}{T} t + \theta_1\right) + c_2 \cos\left(\frac{4\pi}{T} t + \theta_2\right) + c_3 \cos\left(\frac{6\pi}{T} t + \theta_3\right) + \ldots
\]

This is the Fourier series expansion of \( x(t) \). Filtering means to alter the \( \{c_n\}, \{\theta_n\} \).

The spectrum of \( x(t) \) is the sinusoids in the Fourier series (like output of a prism).

**Q:** WHY do we want to filter \( x(t) \)? **A:** To do any of the following (all in EECs 206):

1. To reduce noise in the signal by decreasing \( \{c_n\} \) for large \( n \) (low-pass filter);
2. To detect edges in the signal by increasing \( \{c_n\} \) for large \( n \) (high-pass filter);
3. To eliminate interference by decreasing \( \{c_n\} \) for ONE \( n \) (notch or band-reject filter);
4. To dereverberate \( x(t) \) (eliminate undesired echoes present in \( x(t) \)) (echo cancellation):
   - Examples: Multipath in cellular phones, water column in seismic processing.
5. To reverberate \( x(t) \) (add in desired echoes of \( x(t) \) for a fuller sound) (reverberator):
   - Example: Make a lousy singer sound better (the "singing in bathroom effect").

**Q:** HOW do we filter \( x(t) \)? **A:** By sampling it and passing \( x[n] \) through a system.

Example: Input samples \( x[n] \) through this system to get output samples \( y[n] \):

\[
x[n] \rightarrow [y[n] - 1.84y[n-1] + 0.98y[n-2] = x[n] - 1.86x[n-1] + x[n-2]] \rightarrow y[n].
\]

This eliminates 60 Hz interference in a signal \( x(t) \) sampled with \( T_s = 0.001 \) second.

**Q:** Where did THAT equation come from?! **A:** Stay tuned to EECs 206!

**Q:** How do we know what this filter does? **A:** Compute its frequency response.

**Q:** How do we design this filter? **A:** By using its transfer function (poles & zeros).

**Topics in EECs 206 and Why We Will Be Studying Them:**

1. **Signal properties:** Energy, power, mean, variance, statistics; for detection.
2. **Sinusoids:** Building blocks of signal spectrum and Fourier series; musical tones.
3. **Complex numbers:** Math tool for manipulating sinusoids—easier than trigonometry!
4. **Line spectra:** Graphical picture of spectrum of sum of sinusoids. Simple version of:
5. **Fourier Series:** Writing a periodic signal \( x(t) \) as sum of sinusoids (see above).
6. **Sampling:** Can’t process \( x(t) \) itself; CAN process the samples \( x[n] \) of \( x(t) \).
7. **Discrete Fourier Transform:** Writing a periodic signal \( x[n] \) as a sum of sinusoids.
8. **Systems:** What we use to perform signal processing on \( x[n] \) (see example above).
9. **Frequency Response:** What a given system will do to the spectrum of \( x[n] \).
10. **z-transforms:** Math tool for systems—easier than doing things directly.
11. **Transfer functions:** Best way to represent systems—get other ways from it.
12. **Poles and zeros:** Use to design systems having a desired frequency response.