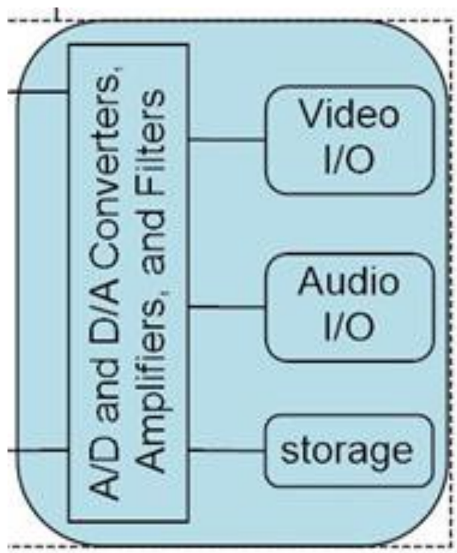
Pre-work Question for KI3

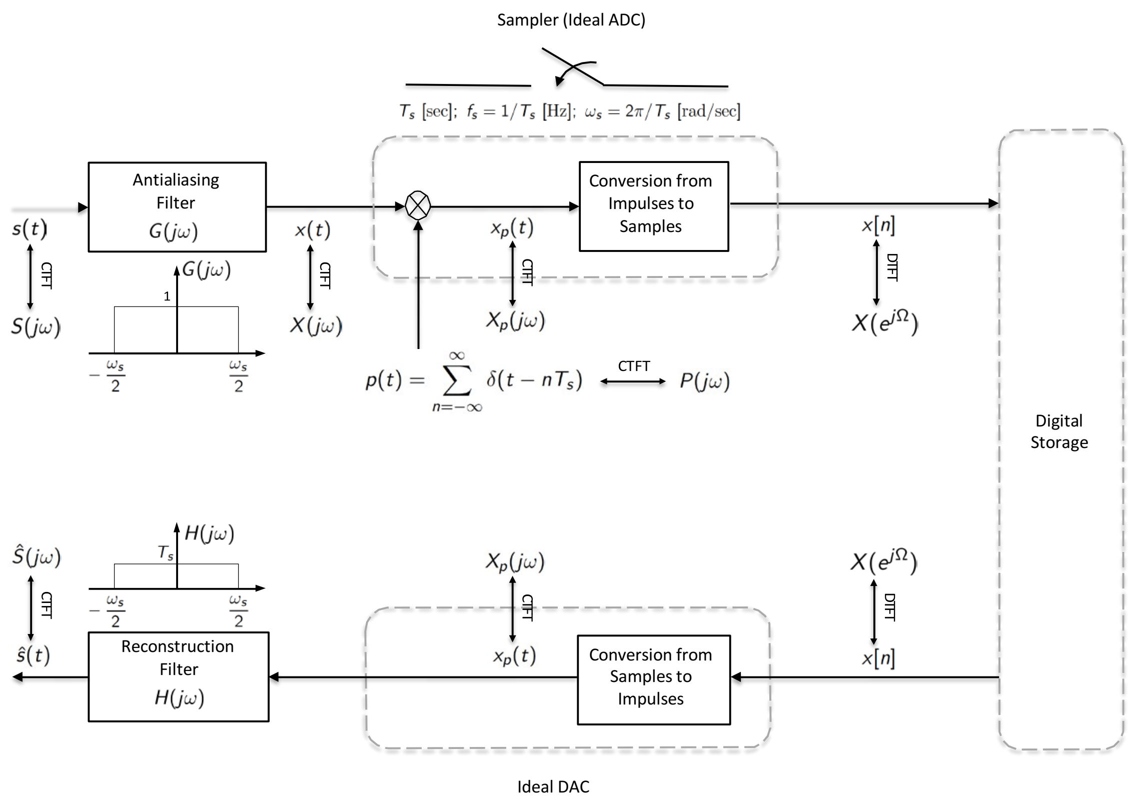
In this KI, we will analyze the analog-to-digital convertor (A/D), the digital-to-analog convertor (D/A) and the digital storage module of a cell phone. The block diagram is shown below in blue.



`

Linear Systems (ECE 311)

The figure below shows the idealized block diagram of the KI-3 system from the perspective of ECE 311. The signals involved in this system and their spectra are identified on the figure.



1. Single Tone. Suppose that the signal to be processed is $s(t) = \cos(\omega_0 t)$. Assume, for now, that the antialiasing filter $G(j\omega)$ is not there. In other words, $x(t) = s(t)$. Consider the following three sampling regimes:

1) $\omega_s = 2.5\omega_0$

2) $\omega_s = 2\omega_0$

3) $\omega_s = 1.5\omega_0$

In each case, determine mathematical expressions for the signals listed below, and sketch the signals:

- $s(t)$ and $S(j\omega)$
- $X(j\omega)$
- $P(j\omega)$
- $X_p(j\omega)$
- $X(e^{j\Omega})$

- $\hat{s}(t)$ and $\hat{S}(j\omega)$

Show sufficient details on your sketches to convey the patterns accurately. The plots will show the progres- sion of signals (and their spectra) from continuos-time to discrete-time, and vice versa, in each sampling regime. In which case(s) does aliasing occur? Identify the aliasing effect (if any) on your plots. Compare $s(t)$ and $S(j\omega)$ with $\hat{s}(t)$ and $\hat{S}(j\omega)$, respectively, in each case. If you were to play $s(t)$ and $\hat{s}(t)$ over a speaker, what would you hear in each case?

Note: The signal $x[n]$ is in discrete time. Its spectrum $X(e^{j\Omega})$ is a discrete-time Fourier transform (DTFT) of $x[n]$ and is a function of the normalized frequency $\Omega = 2\pi\omega/\omega_s$ [rad].

2. Superposition of Tones. Consider now a superposition of two tones. Let $s(t) = \cos(\omega_0 t) + \cos(\omega_1 t)$, where $\omega_1 = 1.8\omega_0$.

A. Without the antialiasing filter. Assume that the antialiasing filter $G(j\omega)$ is not there, that is $x(t) = s(t)$. Consider the following three sampling regimes:

1) $\omega_s = 4\omega_0$ 2) $\omega_s = 2.8\omega_0$ 3) $\omega_s = 2.2\omega_0$

In each case, sketch the signals listed below:

- $S(j\omega)$
- $X(j\omega)$
- $X_p(j\omega)$
- $X(e^{j\Omega})$
- $\hat{S}(j\omega)$

Show sufficient details on your sketches to convey the patterns accurately. In which case(s) does aliasing occur? Identify the aliasing effect (if any) on your plots. Compare $S(j\omega)$ with $\hat{S}(j\omega)$ in each case. If you were to play $s(t)$ and $\hat{s}(t)$ over a speaker, what would you hear in each case?

- **B. With the antialiasing filter.** Assume now that the antialiasing filter $G(j\omega)$, as described in the figure, is in place. Consider the same three sampling regimes as in 2-A. In each case, sketch the signals listed below:

  - $S(j\omega)$
  - $X(j\omega)$
  - $X_p(j\omega)$
  - $X(e^{j\Omega})$
  - $\hat{S}(j\omega)$

  Show sufficient details on your sketches to convey the patterns accurately. Does aliasing occur in any of the cases? Compare $S(j\omega)$ with $\hat{S}(j\omega)$ in each case. If you were to play $s(t)$ and $\hat{s}(t)$ over a speaker, what would you hear in each case?

Electronics (ECE 331)

The following questions serve as prework questions to be answered before the commencement of KI 3. All questions pertain to the comparator circuit illustrated in Fig. 1. You have learned the characteristics of an ideal Op-Amp (Operational Amplifier) before. Here, you can treat the Op-Amp in Fig. 1 as an Op-Amp close to ideal, where it has a very high voltage gain, Av; its input impedance is infinity; its output impedance is zero; and the output swings from –Vee to +Vcc. The output Vo = Av*(V^+ - V^-). Since its voltage gain, Av, is very high, the output, Vo, swings to either –Vee or +Vcc as soon as input difference changes the sign. An additional tutorial of working of comparators is also provided in the following Youtube video (https://www.youtube.com/watch?v=7beZocF34AU).

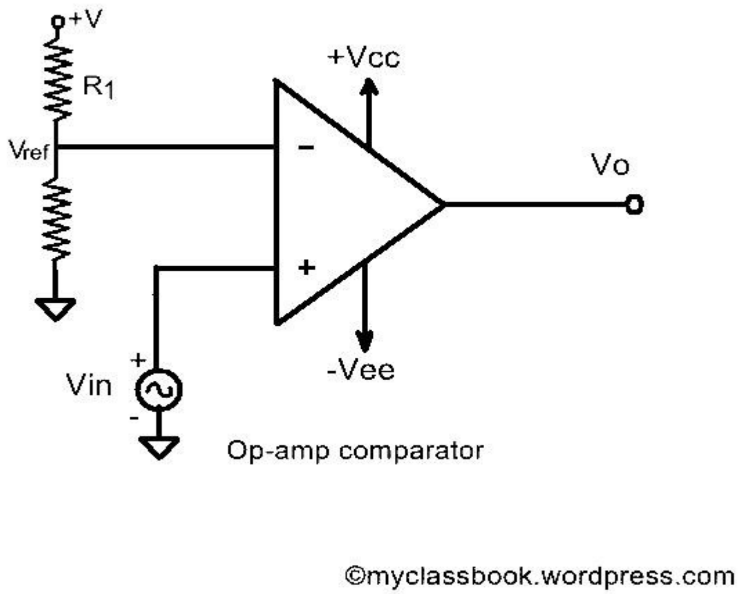


Fig. 1: Basic circuit schematic of a comparator. V_{ref} is the reference voltage to which V_{in} is being compared.

Questions:

1) Assuming that the input (V_{in}) is a sinusoidal input with amplitude 5V and frequency 1 kHz. Assuming the reference DC voltage (V_{ref}) is 2.5V. Sketch the output of the OPAMP as a function of time for one full cycle of the input.
2) How does the sketch change if the input is a triangular wave with same amplitude and frequency?

Electromagnetics (ECE 341)

In KI2, we discussed both the audio and video output aspects. We have discussed the audio input section in the above questions. Another important aspect is storage. There are a variety of storage methods, but we will focus on hard-disk drives (HDDs) and magnetic tapes.

1) Hard-disk drives: A picture of a hard disk drive is shown below. The part that stores data is labeled as #4 and is called the platter. A platter is made of a hard material such as glass or aluminum coated with a thin layer of metal which can be magnetized or demagnetized. What kind of magnetic material (hard or soft) do you think this metal is and why?

To read data, hard drives make use of a part called a head, labeled #6 in the diagram above. The head is basically a piece of metal that's wrapped in wire. When a reading data from the disk the arm, #2 above, will move the head to a specific location on the disk while the disk is spinning at several thousand revolutions per minute (RPM). What happens in the head component which allows the rest of the computer to process the data (hint: it processes the data as an electrical signal)?

2) Writing Data: To write data, the process above goes in reverse. Using electromagnetic principles, explain this operation.

References/Resources:

B. M. Notaros, "*Electromagnetics*," PEARSON Prentice Hall, 2010.

http://rack1.ul.cs.cmu.edu/rotaryvoicecoil/

https://www.extremetech.com/computing/88078-how-a-hard-drive-works

http://www.explainthatstuff.com/harddrive.html

http://www.learnabout-electronics.org/ac_theory/transformers04.php

http://video_demos.colostate.edu/controls/index.html