EECS 16A Designing Information Devices and Systems I
Spring 2015 Note 15

Lecture notes by Dasol Yoon (03/12/2015)

Design Process

- **Step 1: Concretely state your goal for the system**
- **Step 2: Describe (e.g. with a block diagram) a strategy for achieving your goal** -Often involves reviewing what you can measure vs. what you wanted to measure, and how they relate to each other
- **Step 3: Implement the components within your strategy** -Think about what pieces you might already know how to build, or how to extend building blocks you know about
- **Step 4: Verify your design meets the original requirements** -Checking interfaces between blocks often the most critical
- **Iterate through these more than once...**

C Touchscreen Sensor Design Example:

- **Step 1: Concretely state your goal for the system** -"I want my circuit to indicate if a finger is touching the screen (at a certain position) or not"
- **Step 2: Describe a strategy for achieving your goal** -Can't measure the state of the finger directly -But do know that it can affect a capacitor in my circuit -So, let's measure this capacitance as a proxy for the finger touch -As long as we know what the capacitance should be with a finger touch
  - Checking whether the capacitance is more or less than this should tell us whether or not the finger touched
- **Step 3: Implement the components within your strategy**

See Figure 1 (a)

Functions You Know How to Build with Circuits

- comparators
- LED on/off
- Amplifier (with well-controlled gain)

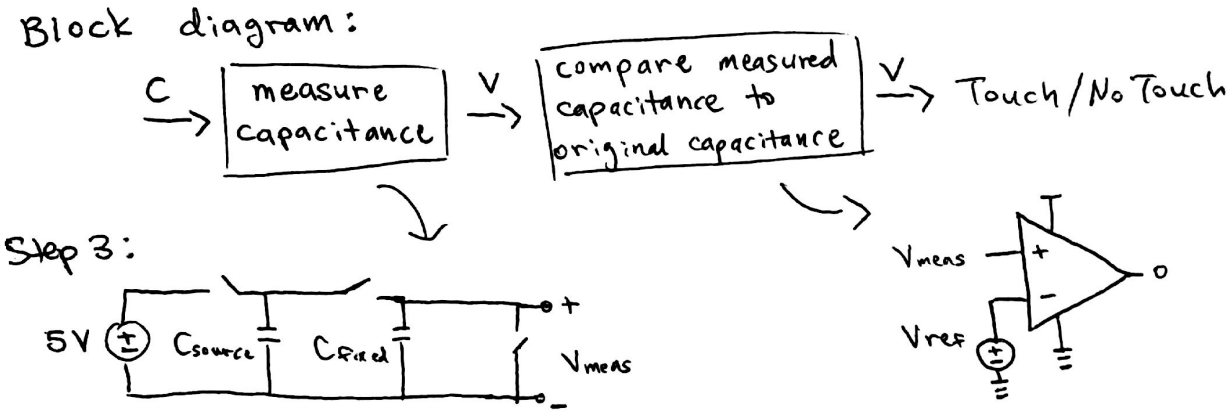

Figure 1: a

- current source -resistance measurement -voltage measurement -capacitance measurement
- adders/subtractors
- level shifter move the average of a signal
- vector multiplication
- matrix multiplication
- buffer

Global Positioning System (GPS)

- Developed by US Department of Defense, started 1973
- fully operational in 1995 -Continued improvements since then -Several other similar systems exist or in development (GLONASS, Galileo, etc.)

Key Idea Behind GPS

- Measure distance between you and some other objects in known positions
- How many known objects/positions do we need?

See Figure 2 (b)

Effect of Distance Errors We will learn in this module how to use more known positions than the bare minimum to reduce sensitivity to errors! See Figure 3 (c)

How is Distance Actually Measured?

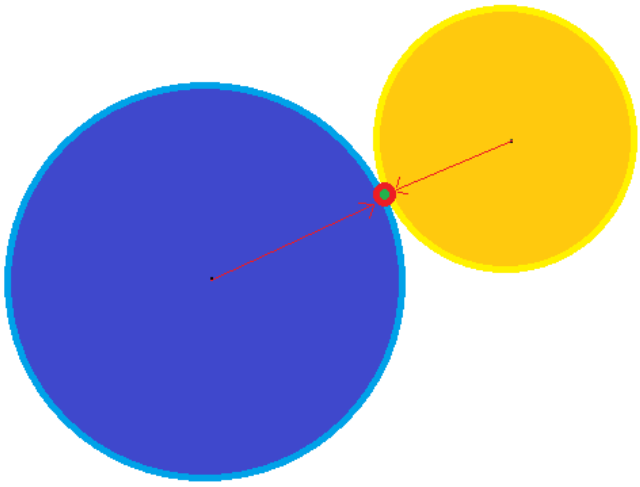

Figure 2: b

Figure 3: c

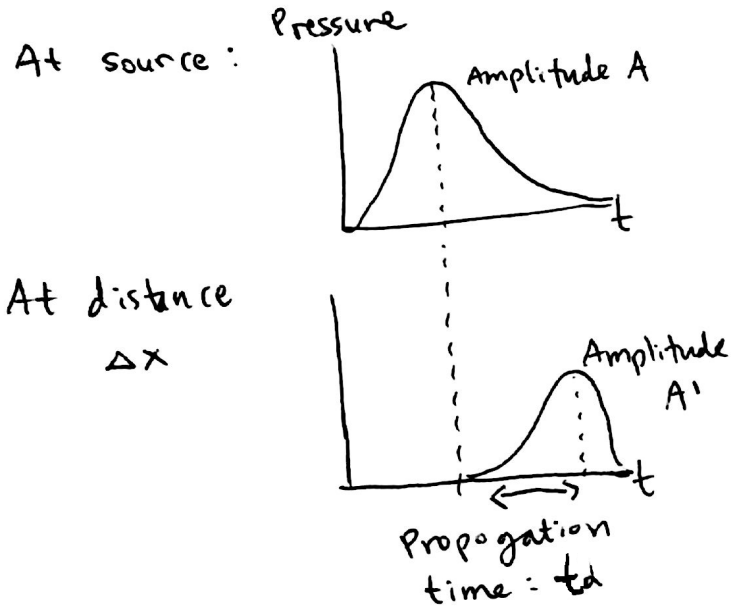

Figure 4: d

- Need a way to communicate between the known objects (beacons) and the thing you are locating (GPS receiver)
- GPS uses electromagnetic waves -In our lab we will use acoustic waves (sound waves)
- So what is a "wave"? **Waves**
  - Disturbance that travels through a "medium" from one location to another -e.g., grabbing the end of a slinky and letting it go -This disturbance has some energy associated with it
  - Our "medium" is generally air -For sound, disturbance is in the pressure of local regions of the air -(EM waves can actually travel through free space)
  - Many of the waves we will be dealing with are periodic -I.e., the disturbance behaves in a repetitive manner in time, space, or both

Important Properties of Waves

- v: velocity of wave
- $\Delta x = v_0 \cdot t_d$

See Figure 4 (d)

Important Properties of Periodic Waves

- Period = T
- frequency (f) = 1/T
- Humans can hear audio at around: 40 - 18,000 Hz

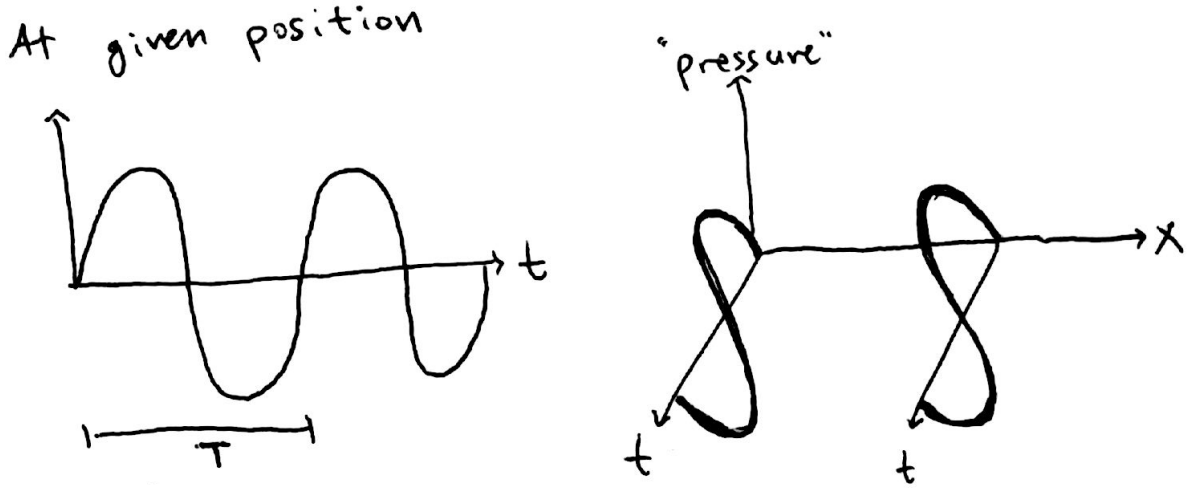

Figure 5: e

- GPS: 1.2 GHz
- $\lambda = v \cdot T = v/f$

See Figure 5 (e)

Key Idea: Cross-Correlation -Assume all beacons send only +1/-1 signals

- Beacon 1: 1 -1 1 -1 ...
- Beacon 2: 1 1 -1 -1 ...
- At Rx: $a_1 \cdot beacon_1(t + t_{p1}) + a_2 \cdot beacon_2(t + t_{p2})$

Cross-correlation: inner product

See Figure 6 (f)

$$
\begin{array}{cccccccc}
[a_1 + a_2 & -a_1 + a_2 & a_1 - a_2 & -a_1 - a_2 & a_1 + a_2 & -a_1 + a_2 & a_1 - a_2 & -a_1 - a_2] \\
[\ 1 & 1 & -1 & -1\ ] & & & & = 4a_2 \\
 & [\ 1 & 1 & -1 & -1\ ] & & & = 0 \\
 & & [\ 1 & 1 & -1 & -1\ ] & & = -4a_2 \\
 & & & [\ 1 & 1 & -1 & -1\ ] & = 0
\end{array}
$$

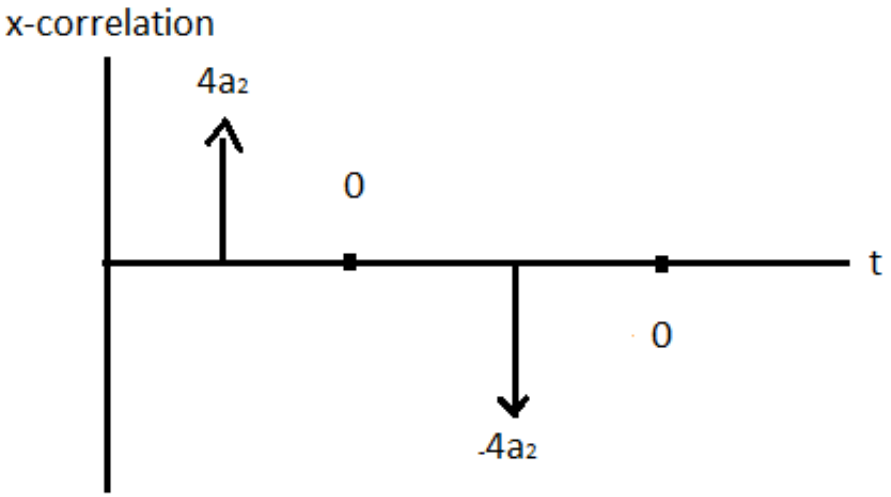

Figure 6: f