Welcome to EECS 16A!
Designing Information Devices and Systems I

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Module 2
Lecture 12
Design Procedure and Examples (Note 20)
Today
Design Procedure

Step 1 (Specification): Concretely restate the goals for the design.

Frequently, a design prompt will include a lot of text, so we’d like to restate all of the most important features of our design. We’ll refer to these specifications later to determine if our design is complete.

Step 2 (Strategy): Describe your strategy (often in the form of a block diagram) to achieve your goal. To do this, start by thinking about what you can measure vs. what you want to know.

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Touch/no touch ➔ Convert touch to capacitance ➔ Convert capacitance to voltage ➔ Voltage
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Step 3 (Implementation): Implement the components described in your strategy. This is where pattern matching is useful: remind yourself of blocks you know, (ex. voltage divider, inverting amplifier) and check if any of these can be used to implement steps of your strategy.
Design Procedure

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**Step 4 (Verification):** Check that your design from Step 3 does what you specified in Step 1. Check block-to-block connections, as these are the most common point for problems. Does one block load another block causing it to behave differently than expected? Are there any contradictions (ex. a voltage source with both ends connected by a wire, or a current source directed into an open circuit)?
Cascading Blocks

We want blocks \( f(x) \) and \( g(x) \) to keep their functionality.

\[ f(x) \quad \text{mid}_L \quad g(h) \quad \text{out} \]

\[ R_{thf} \quad U_{midL} \quad R_{thg} \quad U_{midR} \]

\[ V_{thf} = U_{midL} \quad U_{midL} = V_{thf} \quad \text{before connection} \]

[Diagram showing connections and voltage nodes]
After Connection

\[ V_{midh} = \frac{R_{thg}}{R_{thg} + R_{thf}} \cdot V_{thf} + \frac{R_{thf}}{R_{thf} + R_{thg}} \cdot V_{thg} \]

If \( R_{thf} = 0 \) or \( R_{thg} \rightarrow \infty \) is o.c.

Ideal isolation:

From perspective of block f: See an open circuit;
\[ R_{thg} \equiv \text{O.C.} \]

From perspective of block g: See a voltage source
\[ R_{thf} = 0 \]
Unity Gain Buffer

- Allows us to isolate circuits

Vin \rightarrow + \rightarrow V_{out}

U^+ = V_{in}
U^- = V_{out}

Gain (GR)

U^+ = U^-
Vin = V_{out}

Speaker Design

Vspeaker = \frac{V_{DAC}}{126}

loading

V_{DAC} \rightarrow + \rightarrow V_{sp}

R_{sp}

V_{DAC} \rightarrow + \rightarrow V_{sp}

R_{sp}

I^+ = 0 \Rightarrow U^+ = V_{DAC}
V_{out} = Vspeaker = U^- \Rightarrow U^+ = U^-

V_{DAC} = Vspeaker
Example 1

Want this:

\[ V_{in} \rightarrow \frac{R_2}{R_1 + R_2} \rightarrow U_{mid} \rightarrow AV = 10 \rightarrow V_{out} \]

Implement:

Verifying:

\[ U_{mid} = \frac{R_2}{R_1 + R_2} \cdot V_{in} \]

\[ U_{mid} = U_{mid} \cdot R \Rightarrow AV = \frac{V_{out}}{U_{mid} \cdot R} = 10 \]
Example 2

Want this: \[ V_{in} \rightarrow \text{Sensor} \rightarrow U_{mid} \rightarrow -3 \rightarrow V_{out} \]

Before connection

\[ U_{midh} = V_{thh} \]

When connected:

\[ U_{midh} = \frac{R}{R+R_{thh}} \cdot V_{thh} \neq V_{thh} \]

Solution: ?

Buffer!
\[ V_{thS} = V_{midL} \]

\[ V_{midL} = V_{midR} \]

\[ U^+ = U^- = 0 \]

\[ V_{out} = V_{thS} \left( -\frac{3R}{R} \right) \]
Example 3

Your boss comes to you and asks you to build a countdown timer that will turn on a Light Emitting Diode (LED) two seconds after a button is pressed. She tells you that the LED will emit light when 2V is applied across it.

Step 1 (Specification): Build a circuit that measures 2s after a button is pressed and then applies 2V across a LED. Assume the button is pressed only once.

Step 2 (Strategy): Describe your strategy.

Push button → Turn-on timer → Timer → \( \geq 2\) sec → Apply 2V
Step 3 (Implementation): Implement the components described in your strategy.

Turn on circuit:

Timer:

\[ I_c = C \frac{dV_c}{dt} \]
\[ V_c(t) = \frac{I_s}{C} t + V_c(0) \]
\[ V_{time} \]

Together:

\[ V_{ref} = V_{time}(2s) \]
Step 4: Verify:

\[ I_1 = 0 \quad \text{(o.c. def.)} \]
\[ I_2 = -I_s \quad \text{(clem. def)} \]
\[ I_1 + I_2 = 0 \quad \text{(KCL)} \]
\[ 0 + (-I_s) = 0 \quad \text{(violation)} \]
Before button is pushed: \( S_i \) is on.

\[ U_{\text{time}} = ? \]

\[ U_i = 0 \text{ (wire def.)} \]

\[ U_{\text{time}} = U_i = 0 \]

\[ I_c = C \frac{dU_{\text{time}}}{dt} = 0 \]

KCL:

\[ I_s = I_{\text{sw}} + I_c \]

\[ I_s = I_{\text{sw}} \]
When you push the button: $S_g$ is off.

At $t = t_0$

$V_{time} (t_0) = 0$

$V_{time} (t) = \frac{I_s (t - t_0)}{C} + 0$

$V_{time} (t_0 + 2s) = V_{ref}$