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

Voltage Divider:

\[ V_{R2} = V_S \left( \frac{R_2}{R_1+R_2} \right) \]

Voltage Summer:

\[ V_{\text{out}} = V_1 \left( \frac{R_2}{R_1+R_2} \right) + V_2 \left( \frac{R_1}{R_1+R_2} \right) \]

Unity Gain Buffer:

\[ \frac{v_{\text{out}}}{v_{\text{in}}} = 1 \]

Inverting Amplifier:

\[ v_{\text{out}} = v_{\text{in}} \left( \frac{-R_f}{R_i} \right) + V_{\text{REF}} \left( \frac{R_f}{R_i} + 1 \right) \]

Non-inverting Amplifier:

\[ v_{\text{out}} = v_{\text{in}} \left( 1 + \frac{R_{\text{top}}}{R_{\text{bottom}}} \right) - V_{\text{REF}} \left( \frac{R_{\text{top}}}{R_{\text{bottom}}} \right) \]

Transresistance Amplifier:

\[ v_{\text{out}} = i_{\text{in}} (-R) + V_{\text{REF}} \]
Artificial Neuron

- Neurons in our brain are interconnected.
- The output of a single-neuron is dependent on inputs from several other neurons.
- This idea is represented with vector-vector multiplication – the output is a linear combination of several inputs.
- An artificial neuron circuit must perform addition.
\[ \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \]

V_{out} = - \frac{R_2}{R_1} \cdot V_{in} (when R_1 and R_2 are the same)

\[ V_{out_i} = -\frac{R_3}{R_1} \cdot V_{in} - \frac{R_3}{R_2} \cdot V_2 \]
Cascading Blocks

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

$U_{\text{mid} R} = V_{\text{th} f}$

Before connection
After Connection

\[ V_{\text{midk}} = \frac{R_{\text{tg}}}{R_{\text{tg}} + R_{\text{ths}}} \cdot V_{\text{ths}} + \frac{R_{\text{ths}}}{R_{\text{ths}} + R_{\text{tg}}} \cdot V_{\text{tg}} \]

If \( R_{\text{ths}} = 0 \) or \( R_{\text{tg}} \to \infty \) is o.c.

Ideal isolation:

From perspective of block f: see an open circuit; \( R_{\text{tg}} \equiv \text{O.C.} \)

From perspective of block g: see a Voltage Source \( R_{\text{ths}} = 0 \)
Unity Gain Buffer

\[ U^+ = U^- \]
\[ V_{\text{in}} = V_{\text{out}} \]

Allows us to isolate circuits

Speaker Design

\[ V_{\text{speaker}} = \frac{V_{\text{DAC}}}{126} \]

\[ I^+ = 0 \quad \Rightarrow \quad U^+ = V_{\text{DAC}} \]
\[ V_{\text{out}} = V_{\text{speaker}} = U^- \quad \Rightarrow \quad U^+ = U^- \]

\[ V_{\text{DAC}} = V_{\text{speaker}} \]
Example 1

Want this:

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

Implement:

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

Verify:

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

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

Want this:

\[ V_{\text{in}} \rightarrow \text{Sensor} \rightarrow \text{Op Amp} \rightarrow V_{\text{out}} \]

\[
R_s = R, \quad \frac{R_f}{R} = 3R
\]

\[ V_{\text{out}} = V_{\text{in}} \left( -\frac{R_f}{R_s} \right) \]

Before connection:

\[ U_{\text{midL}} = V_{\text{thS}} \]

Solution:

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

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

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

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

- **Touch/no touch** → **Convert touch to capacitance** → **Convert capacitance to voltage** → **Voltage**

**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.
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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)?
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 → > → Apply 2V

time since button pressed

2 sec
Step 3 (Implementation): Implement the components described in your strategy

Turn on circuit:

Timer:

$$I_c = C \frac{dV_c}{dt}$$

$$V_c(t) = \frac{I_s}{C} \cdot t + V_c(0)$$

$$V_{time}$$

Together:
Step 4: Verify:

\[ I_1 = 0 \quad (o.c. \text{ def.}) \]
\[ I_2 = -I_s \quad (\text{clem. def}) \]
\[ I_1 + I_2 = 0 \quad (\text{KCL}) \]
\[ 0 + (-I_s) = 0 \times (\text{violation}) \]

Revise:
Before button is pushed: $S_1$ is **on**.

- $V_{\text{time}} = ?$
- $V_1 = 0$ (wire def.)
- $V_{\text{time}} = V_1 = 0$
- $I_C = C \frac{dV_{\text{time}}}{dt} = 0$
- $KCL$

\[
I_S = I_{\text{sw}} + I_C
\]

\[
I_S = I_{\text{sw}}
\]
When you push the button: $S_1$ is off

@ $t = t_0$

$V_{\text{time}}(t_0) = 0$

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

$V_{\text{time}}(t_0 + 2\tau) = V_{\text{ref}}$