Lecture 10 - Module 2

Today:
* Composing blocks (continued)
* Design procedure
* Design examples

Note 20

\[ f(\cdot) \rightarrow g(\cdot) \]

\[ \begin{array}{c}
\text{in} \\
\text{mid}_{L} \\
\text{mid}_{R} \\
\text{out}
\end{array} \]

\[ f(\cdot) \rightarrow g(\cdot) \]

\[ U_{\text{mid},L} = U_{\text{th},g} \quad \text{in general} \]

\[ U_{\text{mid},L} = \frac{R_{\text{th},g} \cdot V_{\text{th},g}}{R_{\text{th},g} + R_{\text{th},f}} + \frac{R_{\text{th},f}}{R_{\text{th},g} + R_{\text{th},f}} \cdot V_{\text{th},g} \]

Ideal isolation:
From perspective of block \( f \) see an open-circuit, i.e., \( R_{\text{th},g} = \infty \) (or \( R_{\text{th},g} = 0 \) as drive output with voltage source).

From perspective of block \( g \) see a voltage source, i.e., \( R_{\text{th},f} = 0 \).

\[ \begin{array}{c}
V_{\text{th},g} \\
\text{R}_{\text{th},g} \\
\text{mid}_{L} \\
\text{mid}_{R} \\
\text{R}_{\text{th},f} \\
\text{V}_{\text{th},g}
\end{array} \]

\[ U_{\text{mid},L} = U_{\text{mid},R} \quad \text{goal:} \]

\[ U_{\text{mid},L} = \frac{V_{\text{th},g}}{R_{\text{th},g}} \]

\[ U_{\text{mid},R} = V_{\text{th},f} = U_{\text{mid},L} \]
Example 1: Want this:

\[ V_{in} \xrightarrow{R_1, R_2} V_{mid} \xrightarrow{A_v=10} V_{out} = 10 \cdot V_{mid} \]

Implement:

\[ V_{in} \xrightarrow{R_1, R_2} V_{mid} \]

\[ I^+ = 0 \quad (G_{\text{gain}}=1) \]

\[ V_{mid,L} = V_{mid,R} \]

\[ A_v = \frac{V_{out}}{V_{mid,L}} = 10 \]

Verify:

\[ V_{mid,L} = \frac{R_2}{R_2 + R_1} V_{in} \]

Example 2:

\[ V_{in} \xrightarrow{\text{Sensor}} V_{mid} \xrightarrow{-3} V_{out} \]

Implement:

\[ V_{in} \xrightarrow{R_{\text{th, sensor}}} V_{mid,L} \xrightarrow{R_{1} = R} V_{mid,R} \]

\[ I^+ = 0 \quad I = \frac{V_{mid,R}}{R} \]

\[ V_{mid,L} = V_{\text{th, sensor}} - R_{\text{th, sensor}} \cdot \frac{V_{mid,L}}{R} \]

\[ V_{out} = -3 \cdot V_{mid,R} \]

Verify:

\[ V_{mid,L} = V_{\text{th, sensor}} \]

\[ V_{out} = -\frac{R_2}{R_1} \cdot V_{in} \]

Solution:

\[ I = \frac{V_{\text{th, sensor}}}{R_{\text{th, sensor}}} \]

\[ V_{out} = -3 \cdot V_{mid,L} \]

\[ I = \frac{-3 \cdot V_{\text{th, sensor}}}{R_{\text{th, sensor}}} \]
Design procedure:

Step 1: Specification
Concretely (re)state your goal for the design. (most often from a word specification)

Step 2: Strategy
Describe (often as a block diagram) the strategy to achieve this goal.

L> often review what you can measure vs. what you wanted to know.
L> what is the relationship between the two (e.g. touch / no-touch)

Step 3: Implementation
Implement the components within the strategy.

L> Remind yourself of the blocks you know that can provide the wanted function (or be adopted to provide this function)
L> Think about how to modify/adapt the blocks (iteration #1000)

Step 4: Verification/Analysis
Does the implementation in step 3 satisfy the specification in step 1?
L> check for block to block connections.
Example design #1: ("Countdown timer")

1. Push button
2. Turn on timer
3. Compare the output of the timer with 2 seconds

Diagram:

Steps: Build a circuit that after a button is pressed measures 2s and then applies 2V across an LED. (I assume you can press the button only once)

Step 2: (strategy) Push button → turn-on timer → Timer → 2s → Compare 2V across LED

Step 3: (implementation) 1. Turn on a timer: → switch
2. Timer:
   \[ I_c = C \frac{dV}{dt} \]
   \[ V_c(t) = \frac{I_s}{C} \cdot t + V_c(0) \]

Together:

Diagram: Circuit diagram showing the connections and components.
step 4: (Verify)

\[ I_1 = 0 \text{ (switch off)} \]
\[ I_1' = I_s \text{ (switch on)} \]

KCL: \( I_s = \Sigma I \) (always)

Before the button is pushed, \( s_1 = \text{on} \quad \text{wire} \)

\[ I_s = \frac{I_c}{C} \quad \text{Vtime} = 0 \]

\[ I_c = C \frac{d\text{Vtime}}{dt} = 0 \]

when push the button, \( s_1 = \text{off} \quad \text{oc} \quad @t = t_0 \)

\[ \text{Vtime} (t_0) = 0 \]

\[ \text{Vtime} (t) = \frac{I_s}{C} \cdot (t - t_0) + \text{Vtime} (t_0) \]

\[ \text{Vtime} (t) = \frac{I_s}{C} \cdot (t - t_0) \]

\[ \text{Vtime} (t) = \frac{I_s}{C} \cdot 2s = \text{Vref}, \quad t = t_0 + 2s \]