Keine Zeit für Experimente?

Teil 2: Graphische und physikalische Modellierung, und Hardwareanbindung

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„The middle ages revealed what happens to thinking without experimentation; during this century we witness the results of experimenting without thinking. “

Arthur Schopenhauer (1788-1860)

“Experimenting *does* improve learning outcome, if supported by a *didactic* framework.”

Experiments are time consuming.

1. Prep work (instructor)
2. Pre-experiment → Very important
3. Experiment ← Typically over-emphasized
4. Post-experiment → Immensely important
5. Evaluation

We support you
Experiment implementation: The sky’s the limit

Hardware connectivity

Symbolic
- Simulink and Simscape blocks
- MATLAB function
- Symbolic

Numeric
- Optimization
- Control System

Graphic, physical Modeling
- StateFlow
- Simscape
- Simulink

MATLAB
- Publishing
The solution landscape: a matter of perspective

MATLAB (symbolic)

```matlab
%% Analyze system response in time domain
% Create symbolic objects
clear all; clc;
syms R L C U(t)
% Define first and second derivatives for Do
D2U = diff(U);
```

MATLAB (numeric)

```matlab
%% Convert differential equation to set of first order equations
[V,V] = odeToVectorField(RLC_DE, U00, U0t);
% Convert symbolic expression to MATLAB function (and file)
M = matlabFunction(V, 'file', 'RLC_DE.m', 'vars', ['t', 'Y', 'Y', 'R', 'L'],
% Plot results
```

Simulink

```matlab
% Convert symbolic expression to Simscape equation
S = simscapeEquation(RLC_DE);
```

MATLAB and H/W

```matlab
%% Create a measurement session and configure
% Use the Digilent Analog Discovery
s = dag.createSession('digitronic');
s.addAnalogOutputChannel('AD1', 'Voltage');
s.addAnalogInputChannel('AD1', 'Voltage');
```
RLC series circuit: problem statement

\[ \begin{align*}
\text{Kirchhoff's Laws} \\
L \frac{d^2 u_c}{dt^2} + R \frac{du_c}{dt} + u_c &= u_i \\
L C s^2 u_c + R C s u_i + u_c &= u_i \\
H_1(s) &= \frac{u_c}{u_i} = \frac{1}{L C s^2 + R C s + 1}
\end{align*} \]

\[ \begin{align*}
\text{Newton's Laws} \\
m \frac{d^2 x}{dt^2} + b \frac{dx}{dt} + k x &= f \\
m s^2 x + b s x + k x &= F \\
H_2(s) &= \frac{X}{F} = \frac{1}{ms^2 + bs + k}
\end{align*} \]
RLC series circuit: solution and analysis

From \( H(s) \):

\[
U_C = \frac{1}{s^2 + \frac{R}{L} s + \frac{1}{LC}} \cdot U_i.
\]

* natural: \( s^2 + \frac{R}{L} s + \frac{1}{LC} = 0 \)

\[
\omega_{nc} = \frac{R}{2L} \pm \sqrt{\frac{1}{4LC} - \frac{R^2}{4L^2}}
\]

\[
\Rightarrow u_C(t) = A e^{-\alpha t} \cdot \sin(\omega_d t + \phi)
\]

\( u_C(t) \) natural

\( g(u_i) \) forced

SYSTEM BEHAVIOR:

1. Step response:

\[
uc \uparrow \quad \text{t}
\]

2. Frequency response:

\[
\omega \quad \text{H}(\omega)
\]

\[-\pi \quad \text{H}(\omega) \uparrow]

\[
-x \quad \text{H}(\omega) \downarrow
\]
Resources to get you started

>> doc

Central info/code hub

Online Course Materials
Hardware for experiments

- Find hardware for your application
- ...and request additional hardware

Support package only req’d
- Raspberry Pi
- Arduino
- LEGO Mindstorms
- Samsung Galaxy, iPhone
- NXT and EV3
- ...plus many more

Additional toolboxes req’d
- Digilent’s Analog Discovery
- Microsoft Kinect
- Altera DE2-115
- Freescale Freedom
- NI CompactDAQ
- ...plus many more
Key takeaways

- Experiments can foster the learning progress. Use with care.

- Experiments develop competences.

- Use our tools and materials: they are validated and help save time.