SFWR ENG 3DX4 Summary

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Course: SFWR ENG 3DX4

Math objects made using [MathType](); graphs made using [Winplot]().

Table of Contents

Note: the following summaries may be useful:

- SFWR ENG 2MX3
- ENGINEER 3N03
- TRON 3TA4

I may review to clarify or correct, but mostly I will omit those things.

Introduction to Systems

Systems can be represented by **block diagrams** to make it easier to marginalize the different parts of the systems.

Laplace

Useful for…

Time begins when your signal begins

$$h(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$$

Initial conditions:

- $c(0)$

Time domain (t): variables are <u>lower case</u>, e.g. $f(t)$
Frequency domain (s): variables are <u>upper case</u>, e.g. $F(s)$

Transfer function:

When doing the inverse Laplace, it's useful to break your fractions up so that you can

Strictly Stable: it will eventually get back to the initial position
Marginally Stable:
Unstable: it will progressively get worse

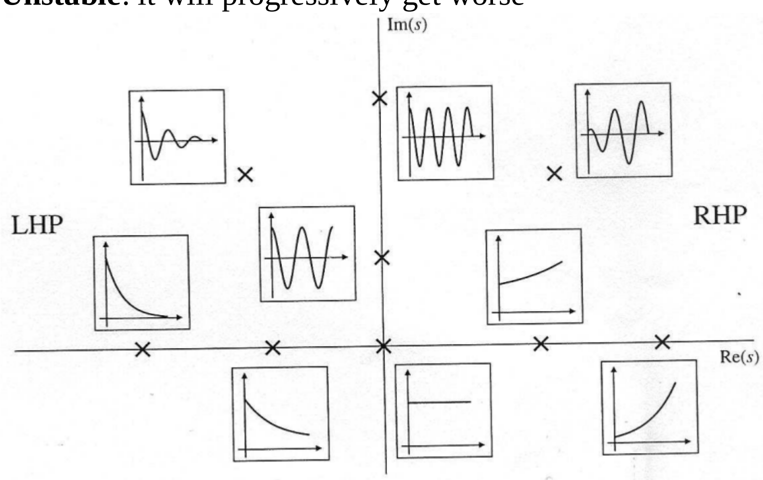


Figure 2.5 from Dorf and Bishop, *Modern Control Systems (10th Edition)*, Prentice-Hall, 2004.

Transfer Functions

Electrical

Component stuff

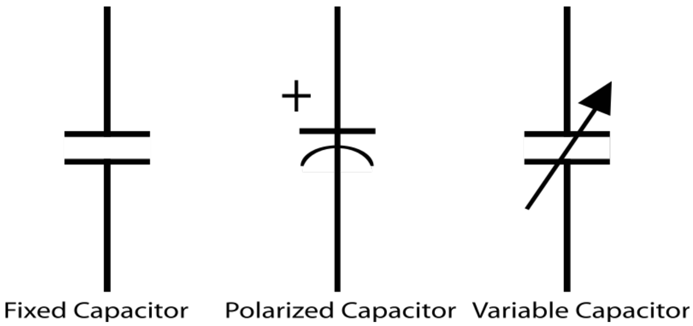
Impedence:

$Z_R = R$

$Z_L = sL = j\omega L$

$Z_C = \frac{1}{sC} = \frac{-j}{\omega C}$

Polarized capacitors: Z is positive when current is going from − to +, but negative from + to −

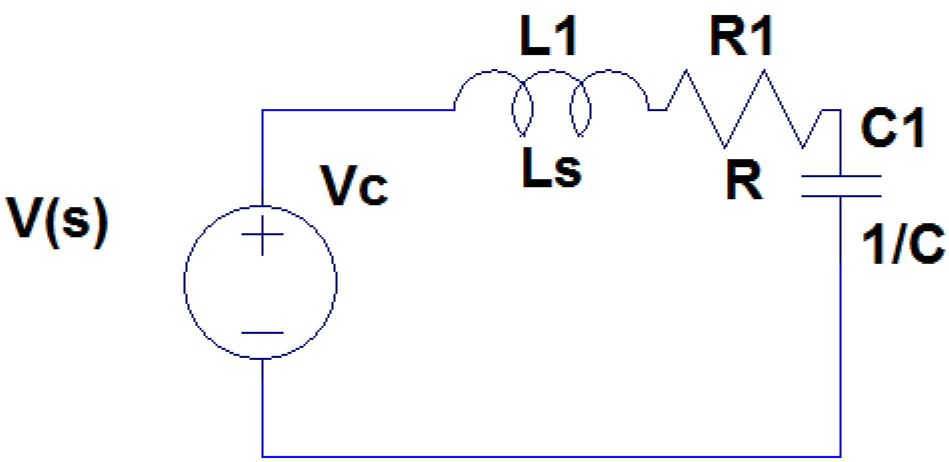


admittance:

$Y(s) = \frac{I(s)}{V(s)} = \frac{1}{R} = G$

$V_c(s) = I(s)\frac{1}{Cs}$

$I(s) = \frac{V(s)}{L_s + R + \frac{1}{Cs}}$



Mesh Analysis

Add the voltages, where V = IZ

Cramer's Rule

$$x_1 = \frac{\det(A_1)}{\det(A)}, x_2 = \frac{\det(A_2)}{\det(A)}, \ldots, x_n = \frac{\det(A_n)}{\det(A)}$$

$$V_C(s) = \overbrace{H(s)}^{\substack{\text{transfer} \\ \text{function}}} \frac{1}{Cs}$$

OP-Amps

Mechanical

Translational systems:
Rotational Systems:

Newton's Second Law of Motion: $\Sigma f = Ma$

$$Z_m(s) = \frac{F(s)}{X(x)}$$

$$\begin{aligned} f(t) &= Ma(t) \\ &= M\frac{\mathrm{d}^2 x}{\mathrm{d}t^2} \end{aligned}$$

Translational Systems

Spring

Spring is like a capacitor

Force displacement: $f(t) = Kx(t)$

Viscous Damper

Using viscous fluid to slow something down

Viscous Damper is like a resistor

Force displacement: $f(t) = f_v \frac{\mathrm{d}x(t)}{\mathrm{d}t}$

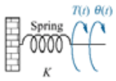
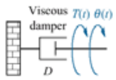
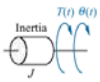
Mass

Mass is like a inductor

Force displacement: $f(t) = M\frac{\mathrm{d}^2 x(t)}{\mathrm{d}t^2}$

Rotational Systems

Impedence: $Z_m(s) = \dfrac{T(s)}{\theta(s)}$

Component	Torque-angular velocity	Torque-angular displacement	Impedance $Z_M(s) = T(s)/\theta(s)$
	$T(t) = K\int_0^t \omega(\tau)\,d\tau$	$T(t) = K\theta(t)$	K
	$T(t) = D\omega(t)$	$T(t) = D\dfrac{d\theta(t)}{dt}$	Ds
	$T(t) = J\dfrac{d\omega(t)}{dt}$	$T(t) = J\dfrac{d^2\theta(t)}{dt^2}$	Js^2

Signals

Transducer: anything that converts energy to electrical energy
Transmitter: long distances

Unstable systems have ∞ steady state error
Steady-state error [e_∞]:

$$e_\infty = \lim_{t\to\infty} e(t)$$

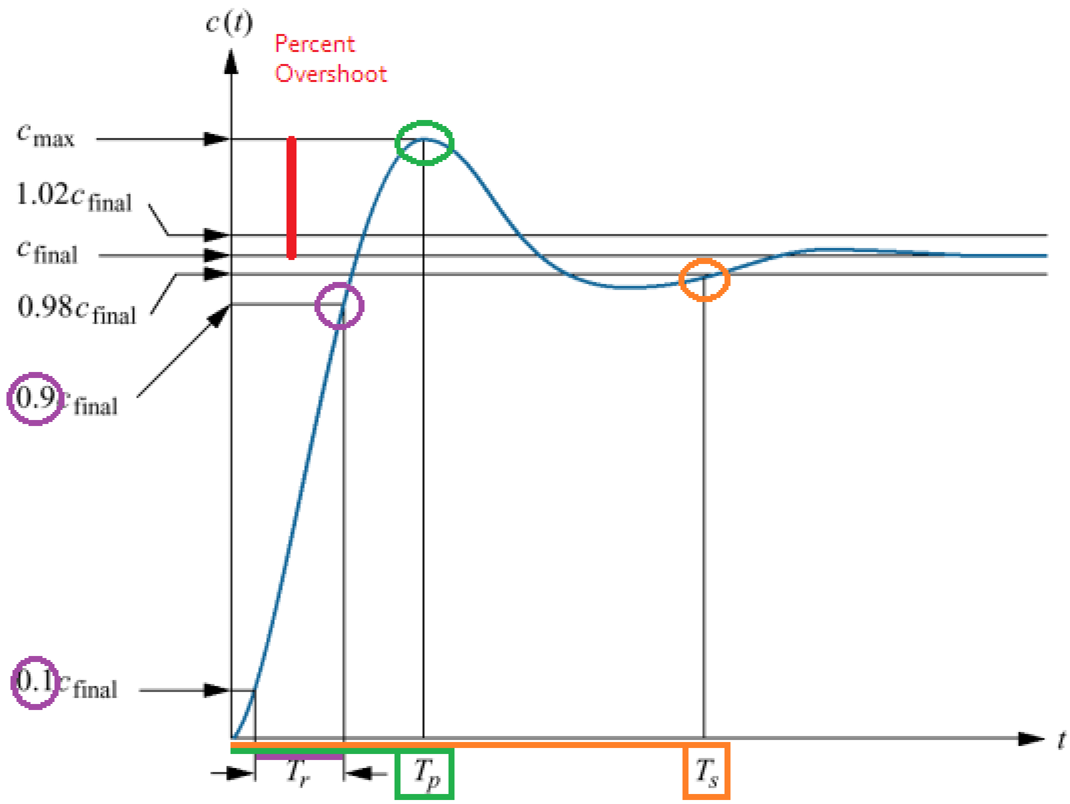
Final value theorem: finds steady state error

$$\lim_{x\to\infty} f(t) = \lim_{x\to 0} sF(s)$$

So $e_\infty = \lim_{x\to 0} sF(s)$ and you're given F(s), so just multiply by s and find the limit.

Rise time [T_r]: time between 10% and 90% of final value (c_{final})
Peak time [T_p]: time it takes to get to highest peak ($c_{\max}$)
Settling time [T_s]: how long it takes to get to the steady state within ±2%
Percent overshoot [%OS]: how much further is the peak from the final

$$\%\text{OS} = \frac{c_{\max} - c_{\text{final}}}{c_{\text{final}}} \times 100\%$$



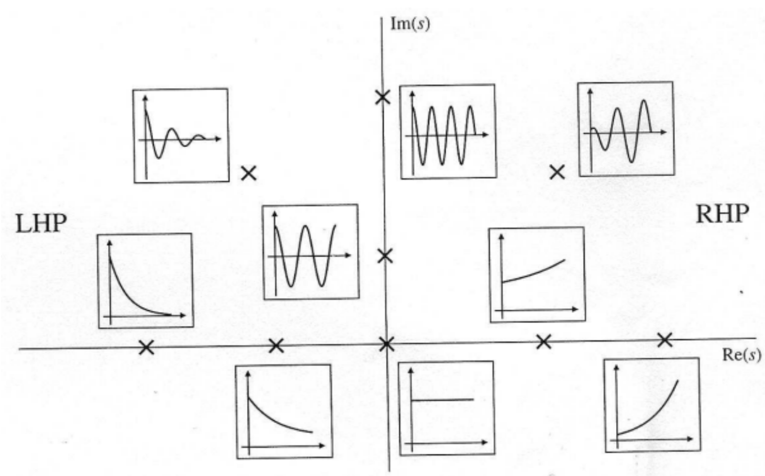


Figure 2.5 from Dorf and Bishop, *Modern Control Systems (10th Edition)*, Prentice-Hall, 2004.

Non-/Linear Systems

- Op Amps are linear
- If you don't have enough voltage, your motor magnets won't have enough power to switch poles, so they require a minimum voltage

You can't model non-linear systems, until you linearize it. To do this, we find the slope and approximate the equation of the line, using y=mx+b

Proportional-Integral-Derivative (PID):
If your gears are vibrating, your PID is probably too high

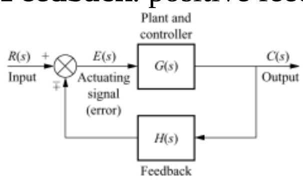
Block Diagrams

A way of representing a system

Summing junction: could be an X or +, but usually an X in this course

Cascade: subsystems in series are multiplied
Parallel: parallel subsystems have a *summing junction* at the end, so you just add everything together

Feedback: positive feedback is bad



Positive: $\dfrac{G(s)}{1-G(s)H(s)}$

Negative: $\dfrac{G(s)}{1+G(s)H(s)}$

Simplification:

State Space Equations

Yeah, you think you know them from 2MX3, but you don't really know them. Apparently the ABCD variables actually have names.

- **System Matrix [A]**:
- **Input Matrix [B]**:
- **Output Matrix [C]**:
- **Feedforward Matrix [D]**:

Transfer Function -> State Space

Phase Variable Approach:
The *n* state variables will consist of:

- *y*
- the derivatives of *y*