Mechatronic System Instrumentation
- MECH 421 -

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Course Summary

MECH 421 is about "Control and Instrumentation"

Control and Instrumentation are complementary

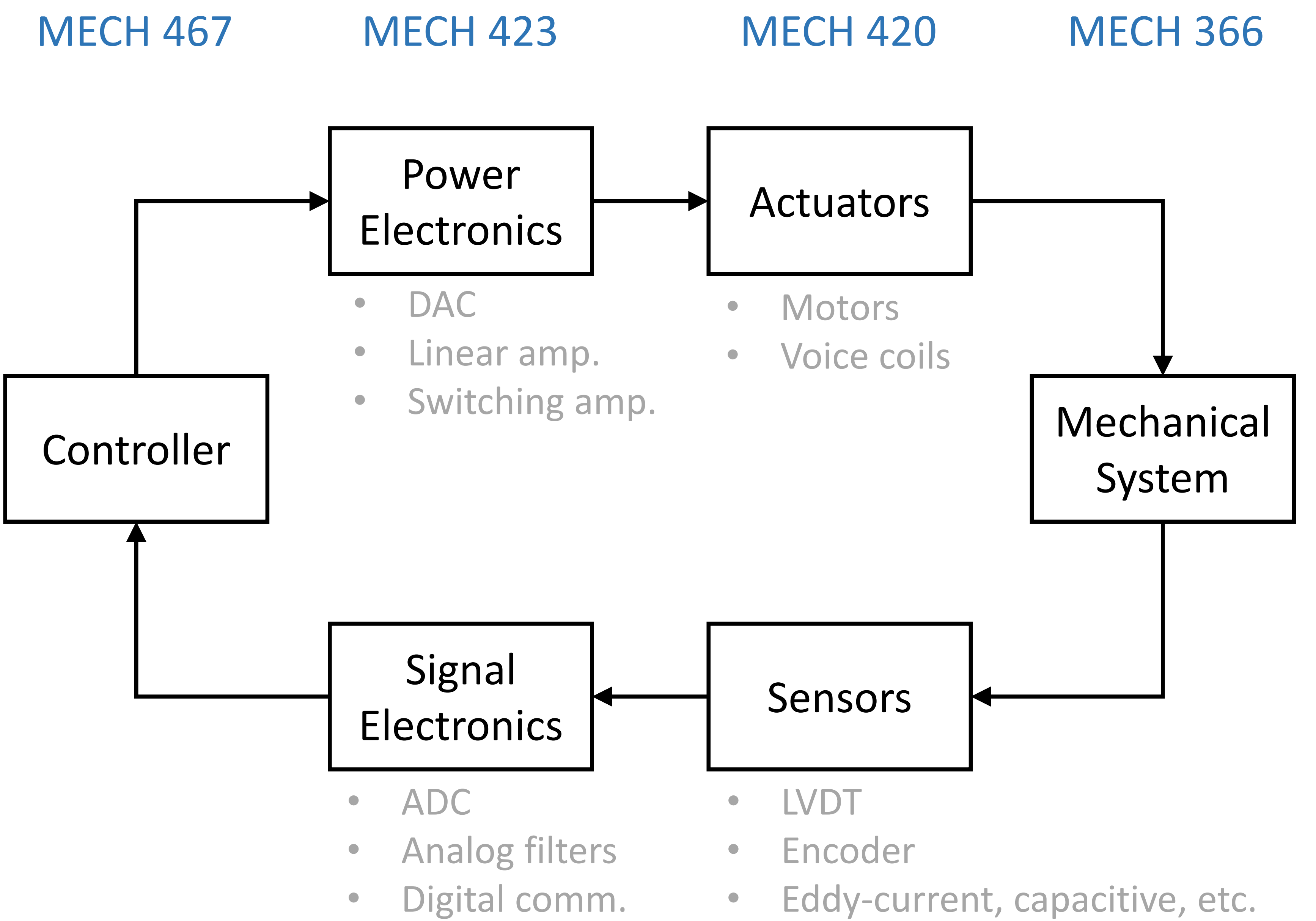
- **Control**
  :Theoretical knowledge to design and analyze mechatronic systems

- **Instrumentation**
  :Hardware-oriented knowledge to realize mechatronic systems

We need to understand these two to interconnect various subsystems, such as controller, sensors, actuators, and mechanical systems.

Circuits and electronics are "glue" between the subsystems.

Proposed Goal



Proposed Contents

Circuits

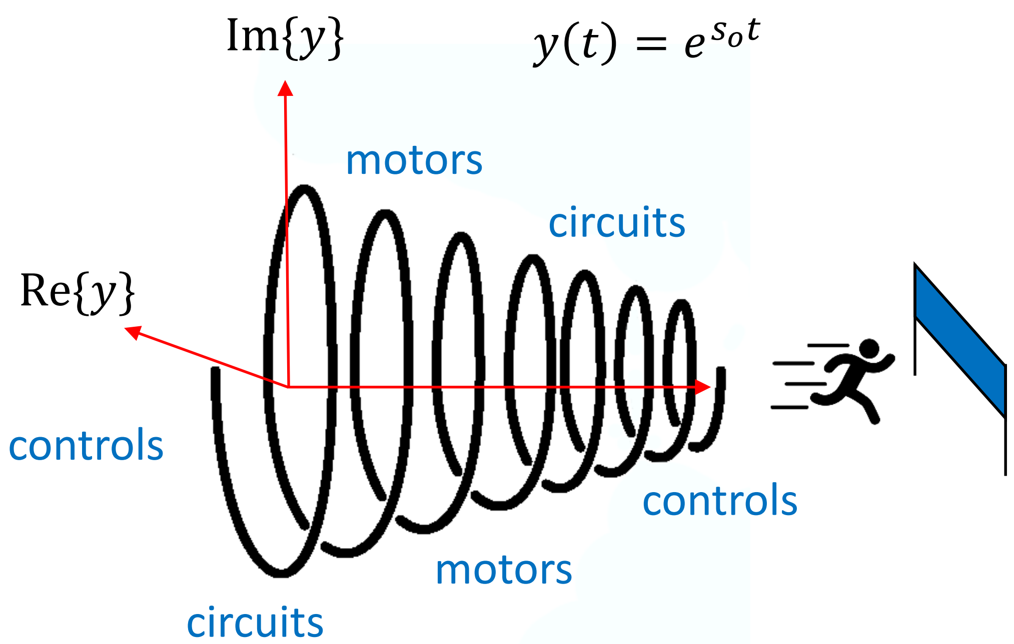
- Linear circuits
- Op-amp circuits
- Power amplifier
- Differential measurement

Controls

- LTI systems
- Loop shaping
- Digital control
- Noise Filtering

Motors

- Brushed dc motor
- Brushless dc motor



Course Schedule (Tentative)

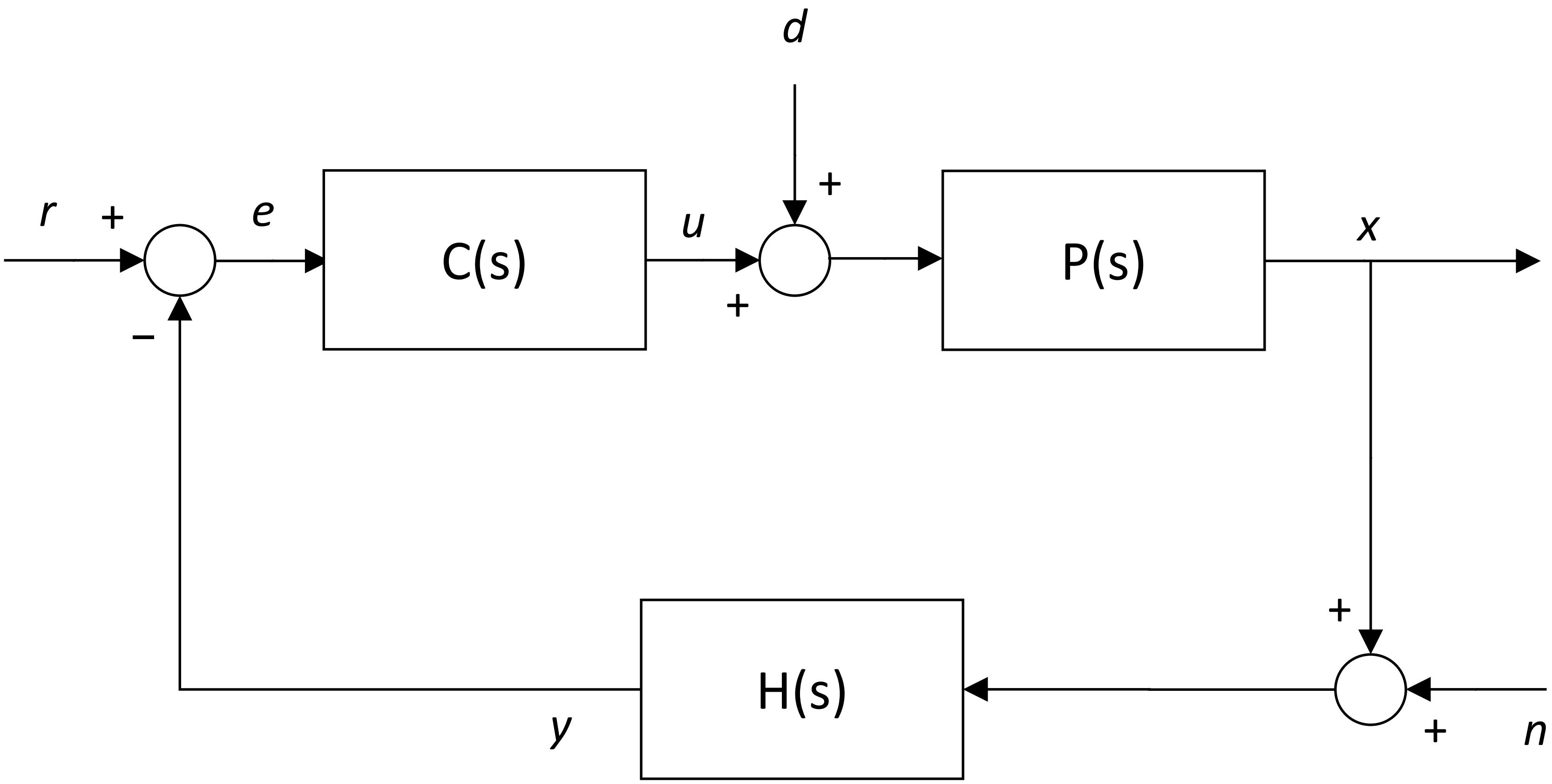
Week	Date	Lecture	HW Out	Prelab Out	Lab	
1	Jan 11	Feedback system				
	Jan 15	LTI systems review	1			
2	Jan 18	Op-amp static model				
	Jan 22	Op-amp dynamic model	2			
3	Jan 25	Loop shaping, 2^{nd} order systems and others				
	Jan 29	Crossover frequency and phase margin		1		
4	Feb 1	Brushed DC motor				
	Feb 5	Voltage-controlled brushed DC motor	3			
5	Feb 8	Current-controlled brushed DC motor			1	
	Feb 12	Transconductance amplifier		2		
6	Feb 15	**Midterm Break**				
	Feb 19					
7	Feb 22	Differential measurement			2	
	Feb 26	Op-amp non-idealities	4			
8	Mar 1	**Mid-term quiz**				
	Mar 5	Feedback and stability – Nyquist	5	~~3~~		
9	Mar 8	Lead controller design				
	Mar 12	PI controller design	~~5~~	3		
10	Mar 15	Digital control, ADC: sampling, ~~aliasing~~, quantization			~~3~~	
	Mar 19	DAC: reconstruction, delay, etc.	6			
11	Mar 22	Digital control design via approximate mapping				
	Mar 26	Digital control design based on ZOH equivalent		~~4~~	3	
12	Mar 29	~~Brushless DC motor~~				
	Apr 2	~~Brushless DC motor commutation~~	7			
13	Apr 5	Introductory power electronics			~~4~~	Design Problem
	Apr 9	~~Electromagnetic interference reduction techniques~~	~~8~~			
14	Apr 12	Summary of the course				

Course Schedule (Tentative)

	Week	Date	Lecture	HW Out	Prelab Out	Lab	
Control	1	Jan 11	Feedback system				
		Jan 15	1st-order, 2nd-order, fractional-order integrator	1			
	2	Jan 18	LTI system review				
Circuit		Jan 22	Zero dynamics / op-amp terminal relations	2			
	3	Jan 25	Op-amp circuits - statics				
		Jan 29	Op-amp circuits - dynamics		1		
Motor	4	Feb 1	Brushed DC motor				
		Feb 5	Voltage-controlled brushed DC motor	3			
	5	Feb 8	Current-controlled brushed DC motor			1	
		Feb 12	Transconductance amplifier		2		
	6	Feb 15	**Midterm Break**				
		Feb 19					
Circuit	7	Feb 22	Differential measurement			2	
		Feb 26	Op-amp non-idealities	4			
	8	Mar 1	**Mid-term quiz**				
Control		Mar 5	2nd-order system review	5	~~3~~		
	9	Mar 8	Motion control design via loop shaping				
		Mar 12	PID control design– Kp, PI, Lead, LPF	~~5~~	3		
	10	Mar 15	PID control – Sensitivity functions, anti-windup, impedance			~~3~~	
		Mar 19	Feedback & stability (demo)	6			
	11	Mar 22	Digital control system: ADC, DAC (PAM, PWM), delay, etc.				
		Mar 26	Digital control design via approximate mapping		~~4~~	3	
	12	Mar 29	Stability assessment of LTI feedback systems				
		Mar 31	Nyquist test	7			
Circuit	13	Apr 9	Linear power amplifier			~~4~~	Design Problem
		Apr 12	Switching power amplifier (power electronics)	~~8~~			
	14	Apr 14	Summary of the course				

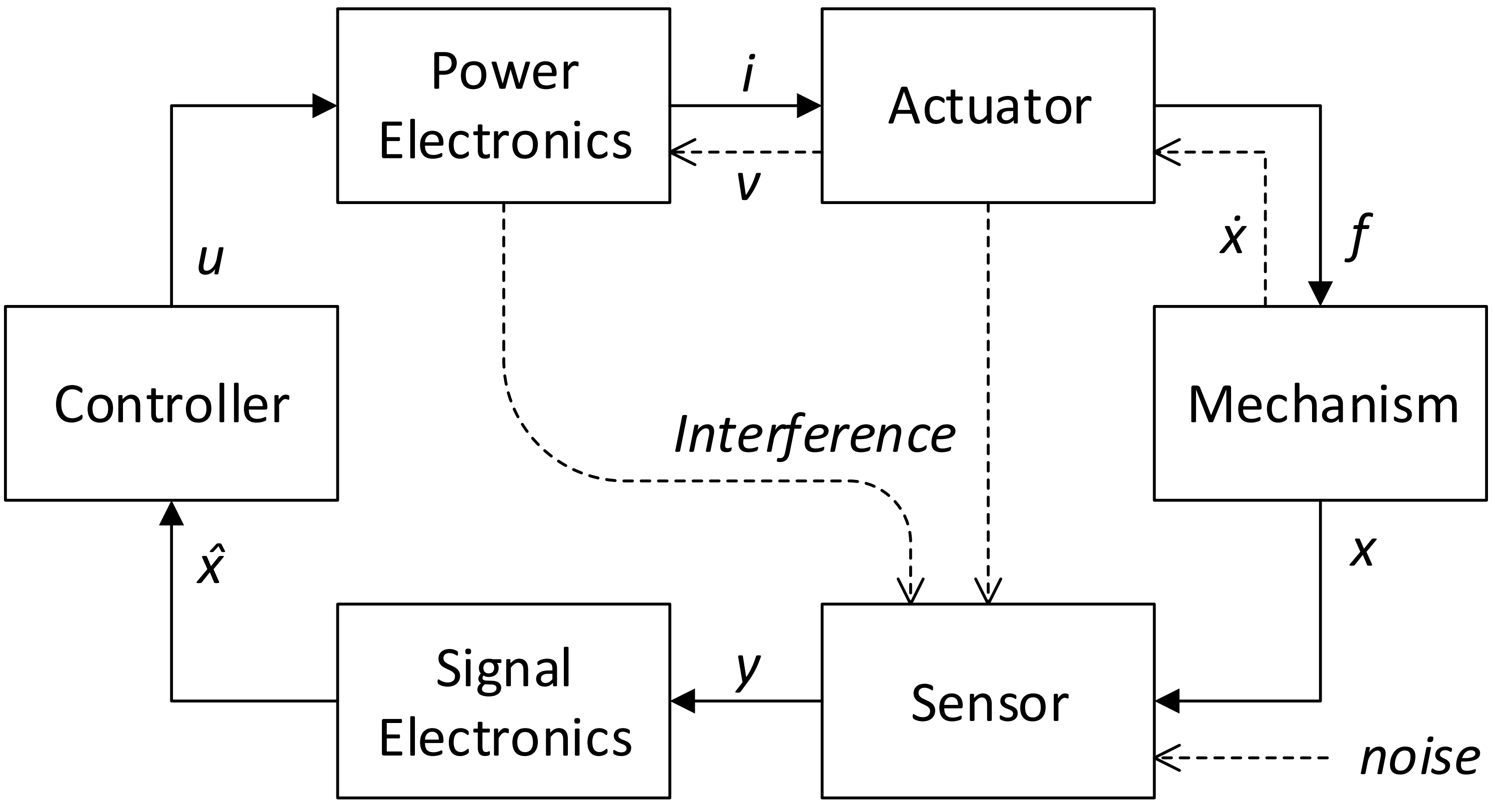
Course Review

Control View Point



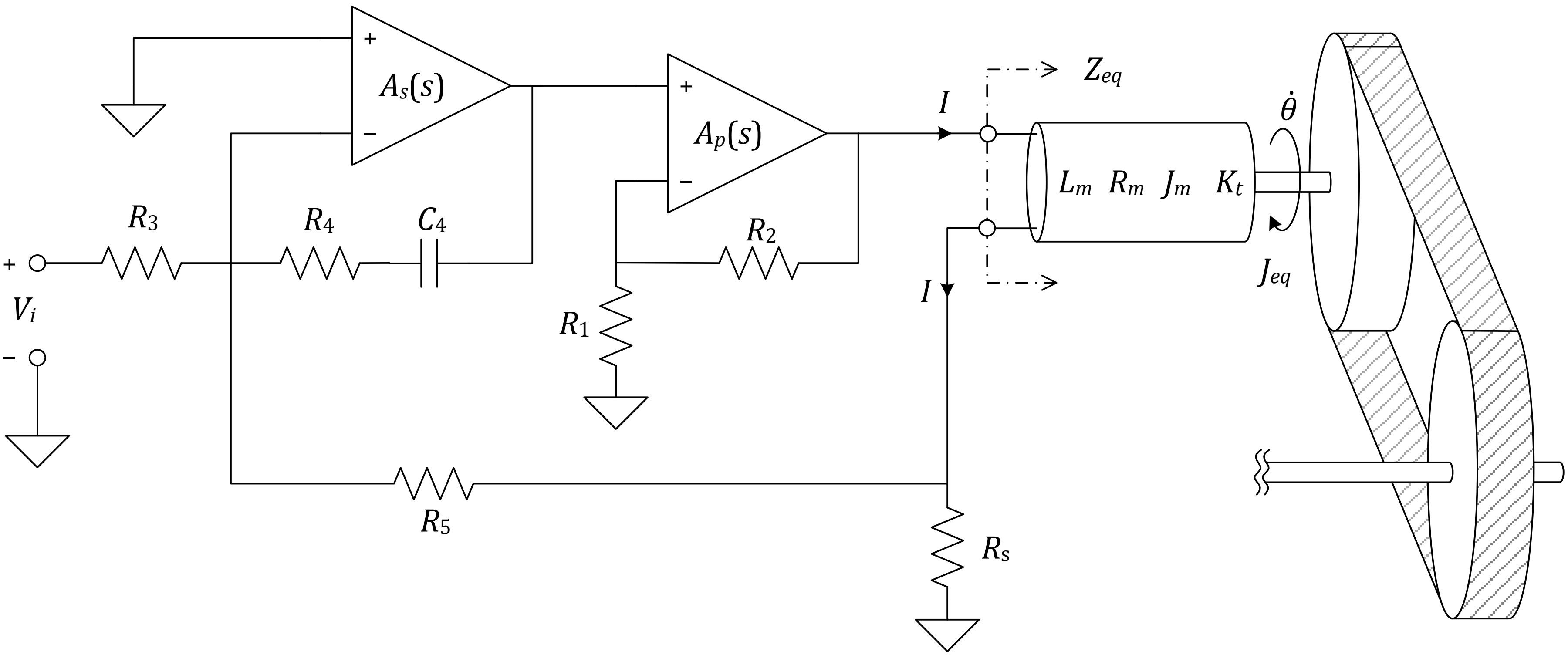
Course Review

Instrumentation View Point



Course Review

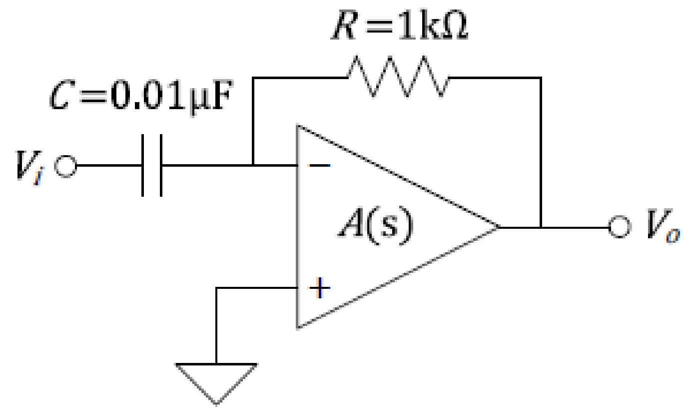
Instrumentation View Point



Course Review

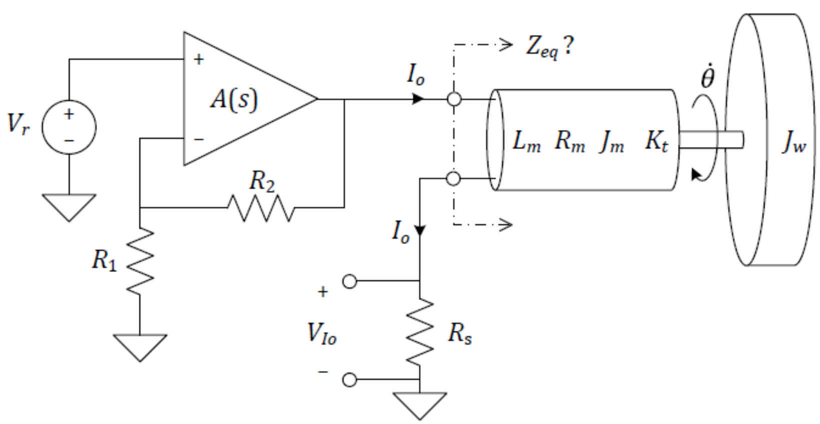
Op-Amp Circuits

- Op-amp as a feedback system
- Op-amp dynamics (frequency vs. time)
- Gain and bandwidth
- Input/output impedance
- Non-idealities (offset voltage, bias current)
- Datasheet reading



DC Motor

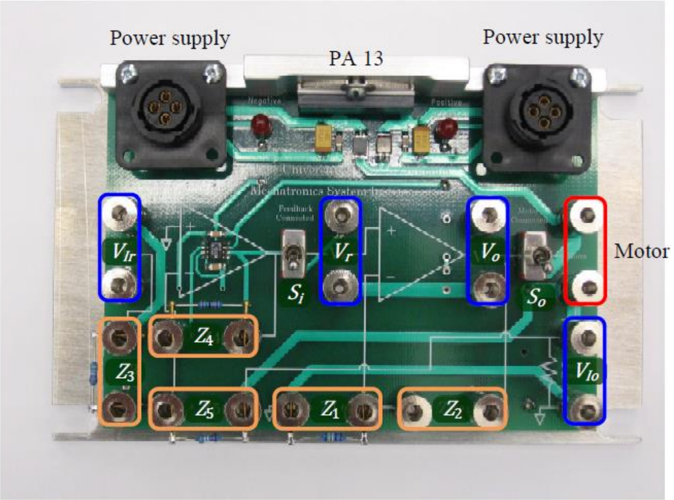
- $\tau = K_t i$
- $e = K_t \dot{\theta}$
- Apparent impedance (elec. & mech.)
- Torque control = Current control
- Motivation for VCCS

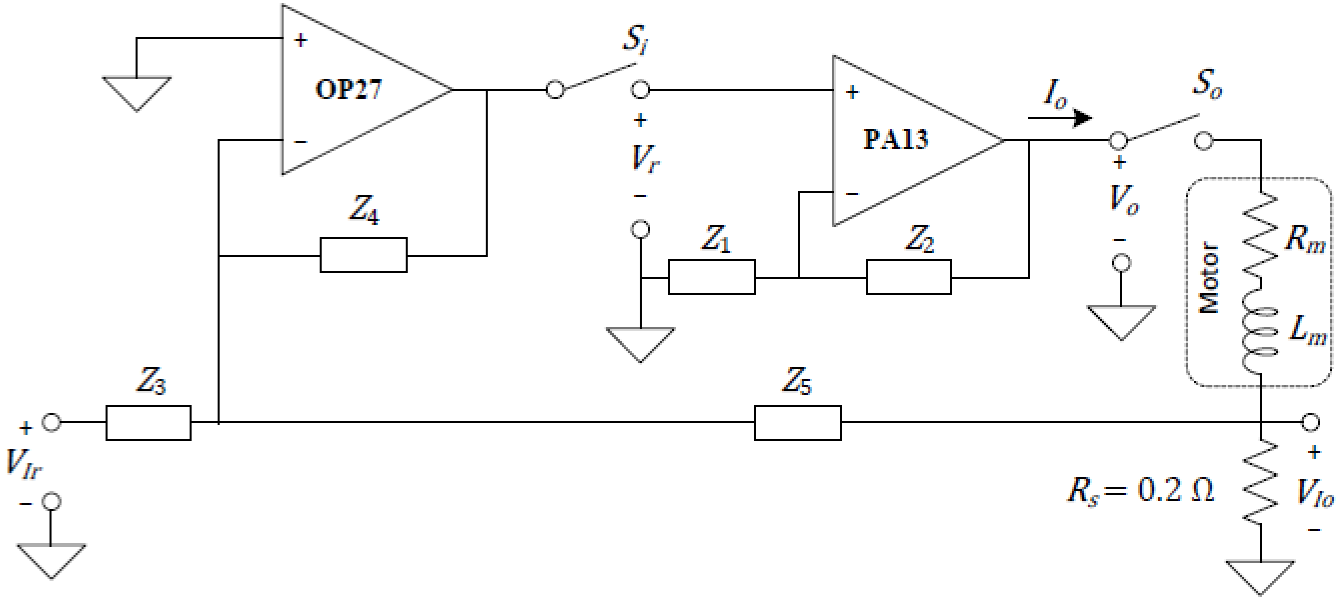


Course Review

Power Amplifier

- Transconductance amplifier (VCCS)
- Analog control design & implementation
- Design based on datasheet FRF
- $i \approx G_m u$ makes life easier

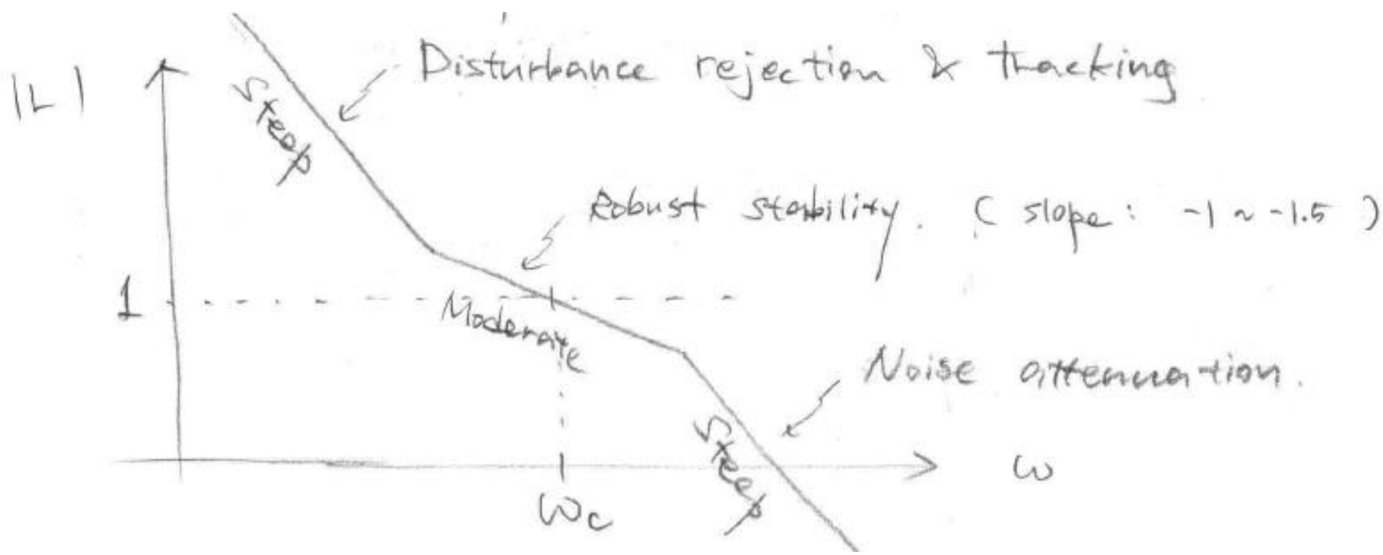




Course Review

Loop Shaping

- Loop Transmission (L.T.) and Loop Return Ratio $L(s)$
- Bode plot of $L(j\omega)$
- Crossover frequency ω_c → Closed-loop bandwidth $\omega_h \approx \omega_c$
- Phase margin ϕ_m → Closed-loop damping ratio $\zeta \approx \phi_m/100$
- Nyquist test: $Z = N + P$



Course Review

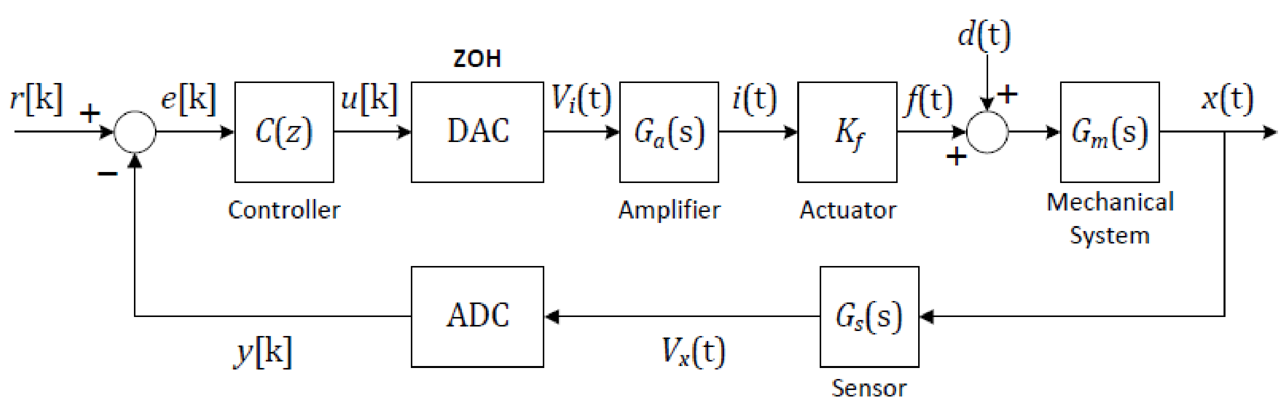
Digital Control

Indirect design via Discrete-time Approximation

- Plant including DAC delay: $P(s)e^{-\frac{sT}{2}}$
- CT Controller $C(s)$ for $P(s)e^{-\frac{sT}{2}}$
- Find DT Controller via numerical approximation (backward, forward, Tustin)

Direct design via Discrete-time Equivalents

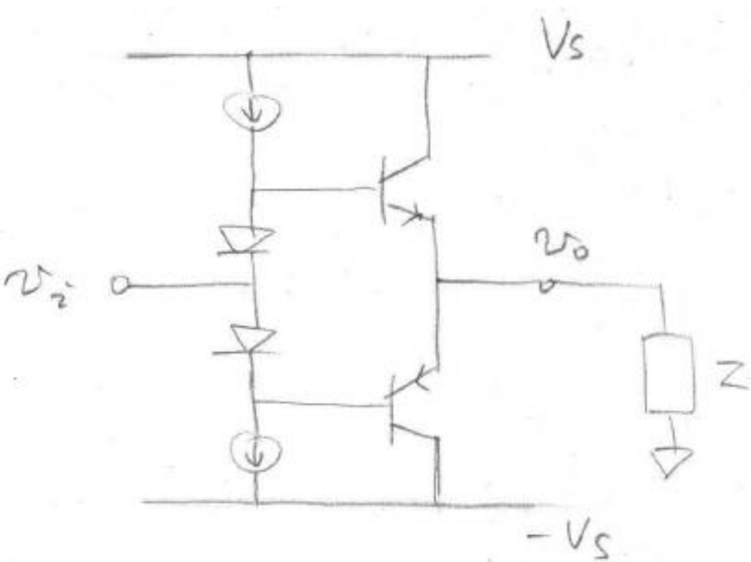
- Zero-order hold equivalent: $P_{zoh}(z) = (1 - z^{-1})\mathcal{Z}\{\frac{P(s)}{s}\}$



Course Review

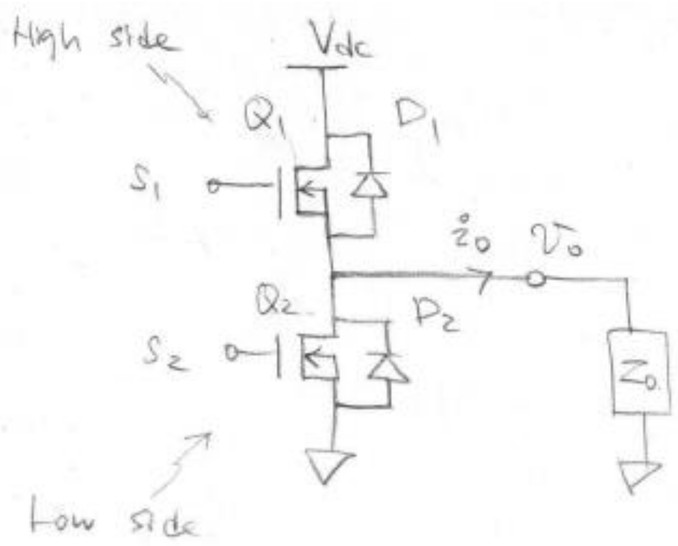
Linear Amplifier

- BJT
- Push-pull stage
- Power dissipation



Switching Amplifier

- MOSFET
- Half-bridge stage
- H-bridge inverter
- Current ripples



Course Evaluation

MECH 421 201 2020W › Modules

2020W2

- Home
- Zoom
- Syllabus
- Announcements
- Assignments
- Discussions
- Quizzes
- Grades
- People
- Chat
- Modules
- Pages
- Files
- My Media
- Media Gallery
- Library Online Course Reserves
- Course Evaluation

Collapse All

▾ Lectures

- Lecture 1
- Lecture 2
- Lecture 3
- Lecture 4
- Lecture 5
- Lecture 6
- Lecture 7
- Lecture 8
- Lecture 9
- Lecture 10