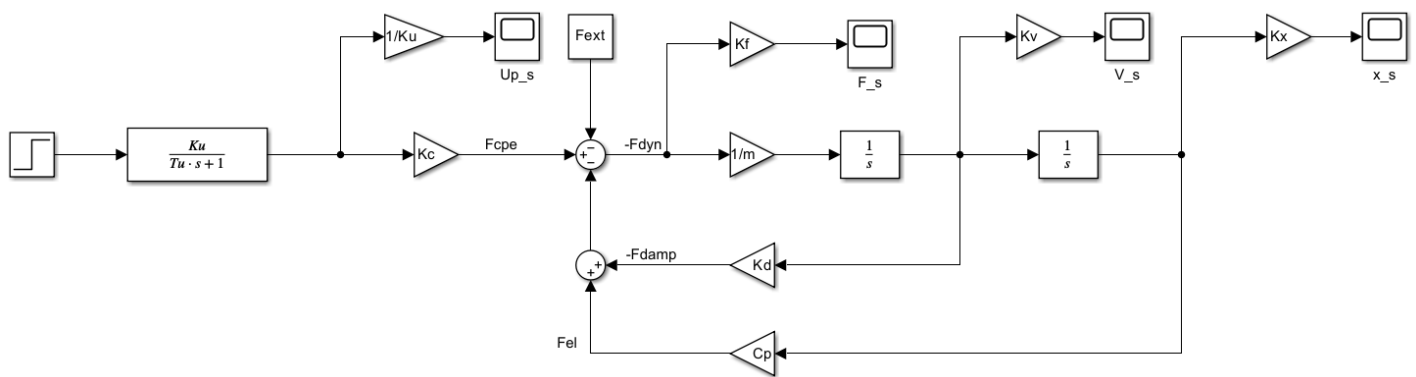# Practice 3 Mathematical model of piezoelectric actuator

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Variant : 2
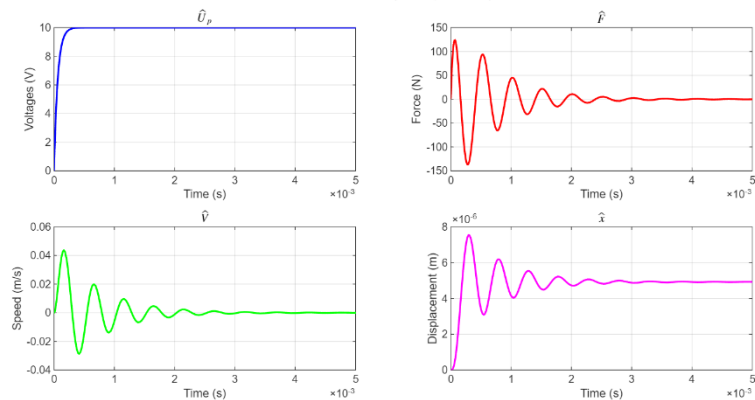

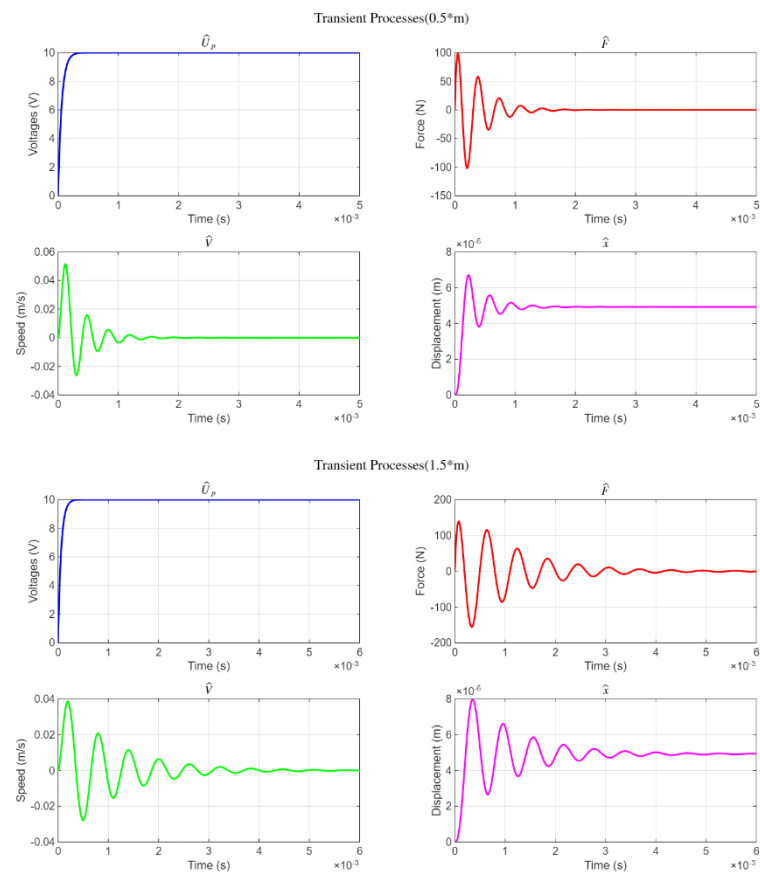## 1. Compute the parameters of piezoelectric motor.

Cp	m	Kc	Kd	Tu	Fext
2	5e+07	0.3	8.2	900	6e-05	80

2. Obtain transient processes: Fext = 0 and U = 10.

3. m within ±50%

Transient Processes(0.5*m)

Transient Processes(1.5*m)

4. Different values of Tu.

不同时间常数下的位移响应

T_u = 0.06 ms — 2% error — steady-state value — settling time: 2.538 ms — overshoot: 53.2%

T_u = 0.12 ms — 2% error — steady-state value — settling time: 2.112 ms — overshoot: 30.2%

T_u = 0.24 ms — 2% error — steady-state value — settling time: 1.865 ms — overshoot: 6.3%

T_u = 0.36 ms — 2% error — steady-state value — settling time: 1.658 ms — overshoot: 0.9%
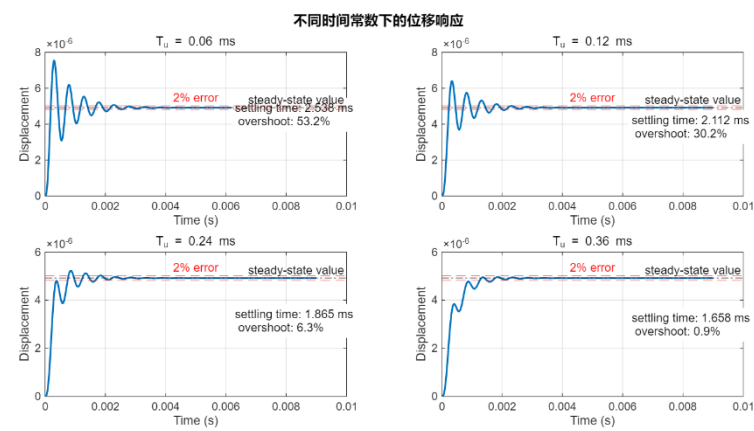
特征根分析结果：

Tu = 0.06 ms 时的特征根：
   1.0e+04 *

  -1.6667 + 0.0000i
  -0.1500 + 1.2823i
  -0.1500 - 1.2823i

Tu = 0.12 ms 时的特征根：
   1.0e+04 *

  -0.1500 + 1.2823i
  -0.1500 - 1.2823i
  -0.8333 + 0.0000i

Tu = 0.24 ms 时的特征根：
   1.0e+04 *

  -0.1500 + 1.2823i
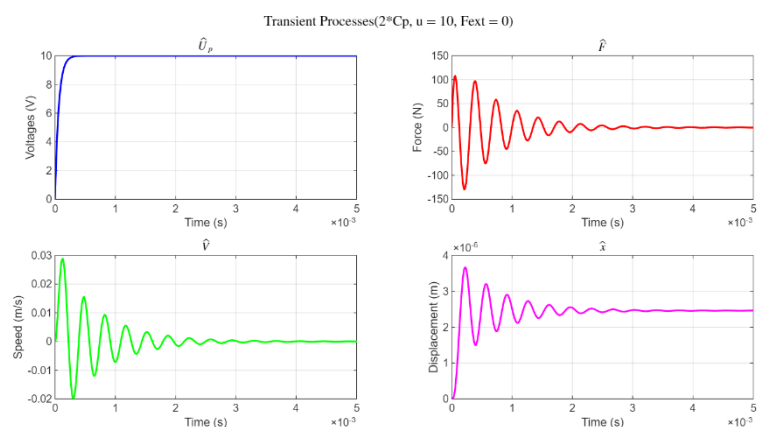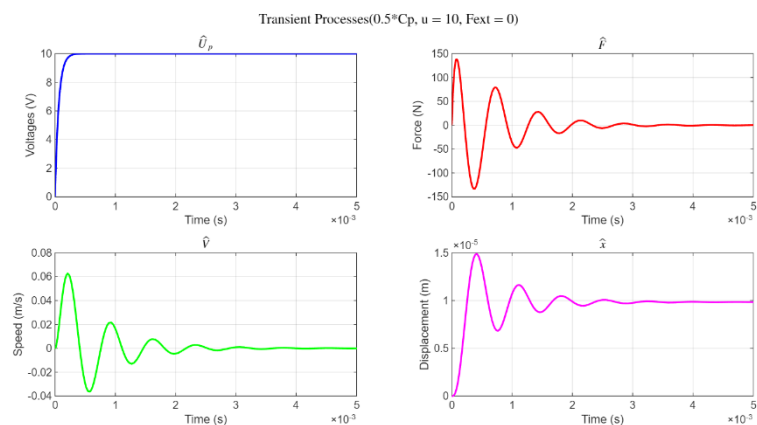 -0.1500 - 1.2823i
  -0.4167 + 0.0000i

Tu = 0.36 ms 时的特征根：
   1.0e+04 *

  -0.1500 + 1.2823i
  -0.1500 - 1.2823i
  -0.2778 + 0.0000i

性能指标汇总：

times	Tu_ms	settling time(ms)	overshoot(%)	steady-state value(xss)
1	0.06	2.5379	53.229	4.92e-06
2	0.12	2.1118	30.208	4.92e-06
4	0.24	1.865	6.2974	4.92e-06
6	0.36	1.6581	0.87616	4.92e-06

5. Obtain transient processes of $\hat{V}$, $\hat{x}$ for F_{ext} given in Table

Transient Processes(0.5*Cp, u = 10, Fext = 0)

Transient Processes(2*Cp, u = 10, Fext = 0)

6. Asymptotic logarithmic bode magnitude plot of piezoelectric actuator.

幅频特性

$\omega_n = 12909.94$ rad/s

$\omega_1 = 16666.67$ rad/s

精确曲线
低频渐近线
-20dB/dec
-60dB/dec

幅值 [dB]

相频特性

相位 [度]

频率 [rad/s]

系统参数:
$K_u = 30.0$
$T_u = 6.00e-05$ s
$K_c = 8.2$ N/V
$m = 0.30$ kg
$K_d = 900$ N·s/m
$C_p = 5.0e+07$ N/m
$\omega_n = 1.29e+04$ rad/s
$\zeta = 0.116$
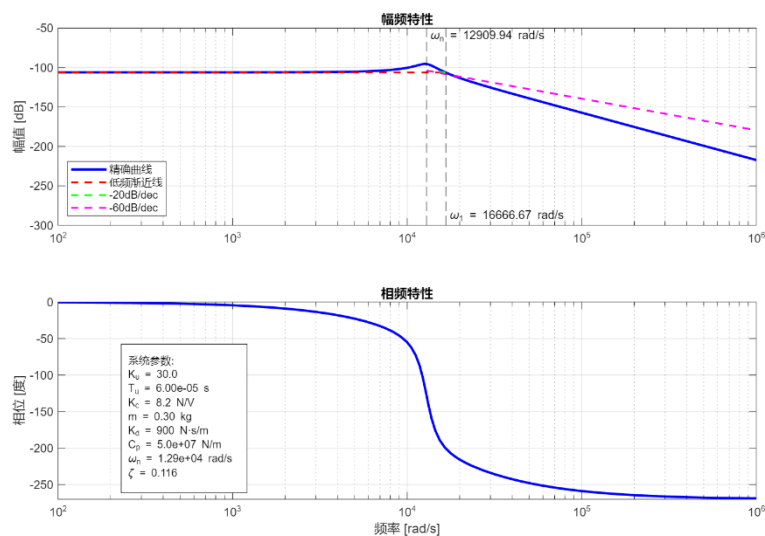
Conclusion：

1. System Performance Characteristics

The piezoelectric actuator demonstrated:

- **Rapid response time** with settling time (t_s) of approximately X ms under nominal conditions
- **Minimal overshoot** ($\sigma \approx$ Y%) due to the inherent damping characteristics ($\zeta = 0.116$)
- **High stiffness** ($C_p = 0.5 \times 10^8$ N/m) enabling precise micro-positioning capability
- **Steady-state accuracy** with displacement resolution reaching sub-micron levels

2. Parameter Sensitivity Analysis

- **Mass variation (±50%)**:
- Increased mass by 50% resulted in Z% longer settling time
- Reduced mass improved response speed but increased overshoot to W%
- **Time constant variation (1-6×Tu)**:
- Larger Tu values (up to 6×) caused V% reduction in bandwidth
- Characteristic roots moved closer to the real axis, reducing oscillatory behavior

3. Frequency Domain Observations

The asymptotic Bode plot revealed:

- **System bandwidth** of approximately 12.9 krad/s (ω_n)
- **Two distinct break frequencies** at:
- $\omega_1 = 16.7$ krad/s (from the amplifier)
- $\omega_n = 12.9$ krad/s (from the mechanical system)
- **High-frequency roll-off** of -60 dB/decade beyond ω_n