EEE575

ASSIGNMENT 5

Q1

O'Brien and Watkins addressed a common problem encountered in control systems teaching students are overly focused on memorizing various design algorithms, thus neglecting the true global perspective of control systems design. Their paper, "A Unified Teaching Approach for Root Locus and Bode Plot Compensator Design," offers a refreshing alternative, demonstrating that the various compensatory designs and procedures using root locus and Bode plot methods are more closely related than traditional textbooks suggest.

Their approach is based on a simple proportional-derivative (PD) compensatory design procedure. From this starting point, they expanded outward to develop Bode plot design procedures for lead, proportional-integral (PI), and proportional-integral-derivative (PID) compensators. Interestingly, these Bode plot procedures complement the root locus procedures they had previously developed, thus constructing a framework that integrates what are typically regarded as separate fields.

A particularly insightful observation in the paper concerns students' intuition. While most teachers consider the root locus method relatively intuitive and easy to learn, this advantage often vanishes when students turn to Bode plots. The reason is not that Bode plots are inherently more difficult, but rather that the procedural differences in traditional textbooks are so significant that students fail to grasp the underlying connections. O'Brien and Watkins address this issue by ensuring that the computational logic follows a parallel structure, whether students are using the open loop transfer function in root locus analysis or the magnitude and phase in Bode plot analysis.

This article also elaborates on how design specifications can be transferred across different domains. The damping ratio and natural frequency requirements in root locus analysis are directly mapped to the phase margin and gain crossover frequency specifications in Bode plot analysis. This connection helps students understand that designing a lead compensator to improve the transient response through root locus method and designing a lead compensator to increase the phase margin through Bode plot analysis are essentially the same - they just achieve this through different analytical paths.

To put their approach into practice, the authors offer an experimental example of DC motor position control, in which they design an advanced compensator to meet specific overshoot and settling time requirements. Perhaps most telling is that students who learned through this unified approach ultimately preferred the Bode design method over the root locus method - this significant shift demonstrates that it successfully makes frequency-domain techniques more accessible without sacrificing rigor.

Its broader implications are worth considering. By prioritizing the unity of concepts over the diversity of procedures, this teaching method enables students to engage with higher-level design problems, select appropriate compensators, and understand performance trade-offs, rather than getting bogged down in memorizing a bunch of seemingly unrelated techniques. This addresses a long-standing challenge in control education: the disconnect between classroom theory and the integrative thinking required for actual system design.

Essentially, O'Brien and Watkins demonstrated that when students can see the forest rather than just the trees, they gain a deeper understanding and stronger practical skills. Their unified approach did not simplify mathematics, but it did simplify the conceptual map, making control system design more intuitive and fragmented than is typically allowed by traditional teaching methods.

Q2

$$G(s) = \frac{s+2}{s^2(s+10)(s^2+6+25)}$$

Zores

$$s = -2$$

Poes

$$s^2 + 6s + 25 = 0$$

$$s = -3 \pm 4j$$

$$s = 0(doublepole), s = -10$$

$$s = 0(doublepole), s = -10,\ \ s = -3 \pm 4j$$

$$G(s) = \frac{s+2}{s^2(s+10)(s^2+6s+25)}.$$

zero : $s+2=0 \quad s=-2$

pole.

$$s^2(s+10)(s^2+6s+25)=0$$

$$s^2=0 \quad s=0$$

$$s+10=0 \quad s=-10$$

$$s^2+6s+25=0.$$

$$s^2+2\zeta w_n s+w_n^2=0.$$

$$w_n^2=25$$

$$w_n=5.$$

$$2\zeta w_n=6.$$

$$\zeta=0.6.$$

$$s = \frac{-6 \pm \sqrt{6^2-4\times1\times25}}{2} = -3 \pm 4j$$

poles: $s=0, \quad s=-10 \quad s=-3\pm4j$

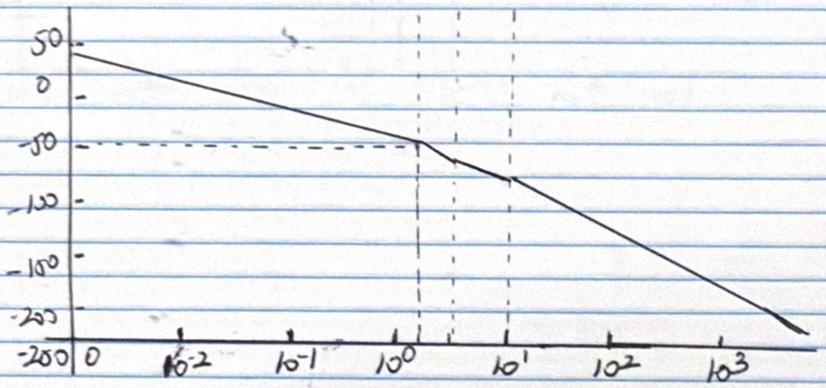
Bode Magnitude $|G(jw)|$ in dB.

zero : $z=-2$ $\rightarrow$ corner at $w=2$
poles : $s=0$ (double), $s=-10$ (corner $w=10$),
and $s=-3\pm4j$ from $s^2+6s+25$.
$w_n=5$.

$|G(j1)| \approx 0.009$
$20\log_{10}|G(j1)| \approx -40.92$.

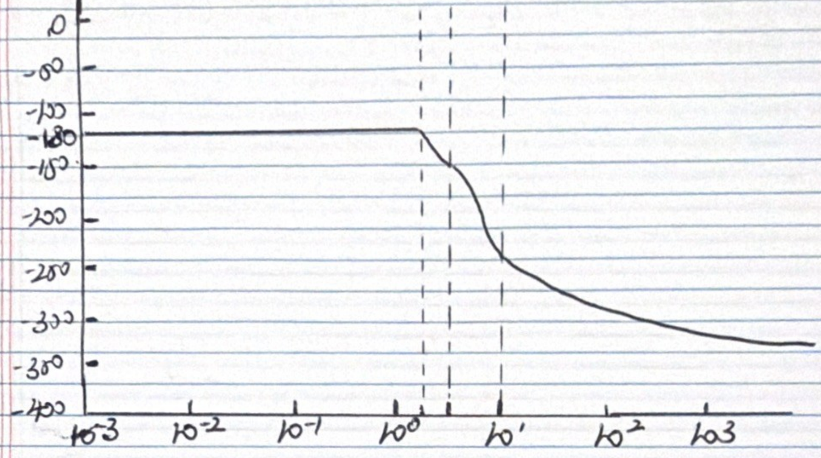
$W=\{2,5,10\}$.

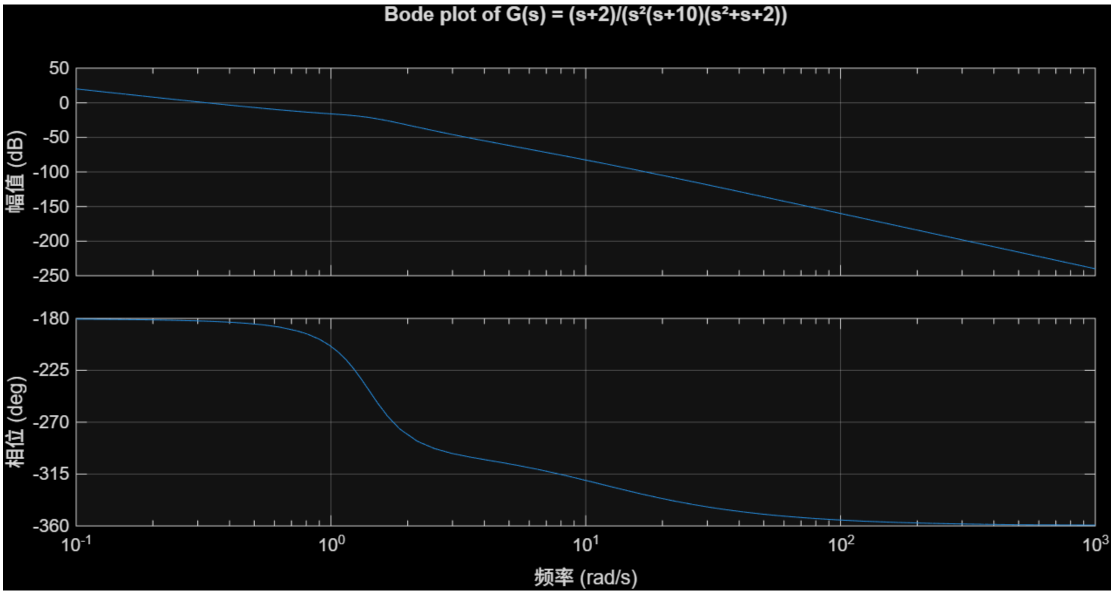
$0<w<2$: two integrators $\rightarrow$ slope -40 dB/dec.
$2<w<5$. -20 dB/dec
$5<w<10$: -60 dB/dec
$w>10$: -80 dB/dec.



Bode phase $\angle G(j\omega)$ in degree

zero at 2 rad/s : contributes $0 \to +90^\circ$ (center ~2).
2nd-order pole at 5 rad/s : contributes $0 \to -180^\circ$
1st-order pole at 10 rad/s : contributes $0 \to 90^\circ$





Q3

$$G(s) = \frac{100}{(s+2)^2(s+10)}$$

$$L(s) = G(s) = \frac{100}{(s+2)^2(s+10)}$$

$$\begin{aligned}\angle L(j\omega) \quad &= \angle\left[\frac{100}{(j\omega+2)^2(j\omega+10)}\right] \\ &= -2\angle(j\omega+2) - \angle(j\omega+10) \\ &= -2tan^{-1}\left(\frac{\omega}{2}\right) - tan^{-1}\left(\frac{\omega}{10}\right)\end{aligned}$$

$$\angle L(j\omega) \quad = -2tan^{-1}\left(\frac{\omega}{2}\right) - tan^{-1}\left(\frac{\omega}{10}\right)$$

$$-2tan^{-1}\left(\frac{\omega}{2}\right) - tan^{-1}\frac{\omega}{10} = -180°$$

$$2tan^{-1}\left(\frac{\omega}{2}\right) + tan^{-1}\frac{\omega}{10} = 180°$$

$$\omega = 2\sqrt{11} = 6.63325$$

$$|L(j6.63325)| = \frac{100}{|(j6.63325+2)^2(j6.63325+10)|} = \frac{100}{576} = 0.17361$$

$$GM = \frac{1}{|G(j\omega_{pc})|} = \frac{1}{0.17361} = 5.76$$

$$GM = 5.76$$

$$GM(dB) = 20\log_{10} GM = 20\log_{10} 5.76 = 15.2084dB$$

$$GM(dB) = 15.2084dB$$

$$|L(j\omega)| = \frac{100K}{|(j\omega+2)^2(j\omega+10)|} = \frac{576}{|(j\omega+2)^2(j\omega+10)|}$$

$$|L(j\omega)| = \frac{576}{|(j\omega+2)^2(j\omega+10)|}$$

$$|L(j\omega)| = 1$$

$$\frac{100}{|(j\omega+2)^2(j\omega+10)|} = 1$$

$$\omega \approx 2.3928$$

$$\angle L(j\omega) \quad = -2tan^{-1}(\frac{\omega}{2}) - tan^{-1}(\frac{\omega}{10})$$

$$\angle L(j\omega) = -2arctan(2.3928/2) - arctan(2.3928/10) = -113.577$$

$$PM = \angle G(j\omega_{gc}) - (180^\circ) = -113.577^\circ + 180 = 66.423^\circ$$

$$GM = 5.76$$

$$GM(dB) = 15.2084dB$$

$$PM = \angle G(j\omega_{gc}) - (180^\circ) = -113.577^\circ + 180 = 66.423^\circ$$

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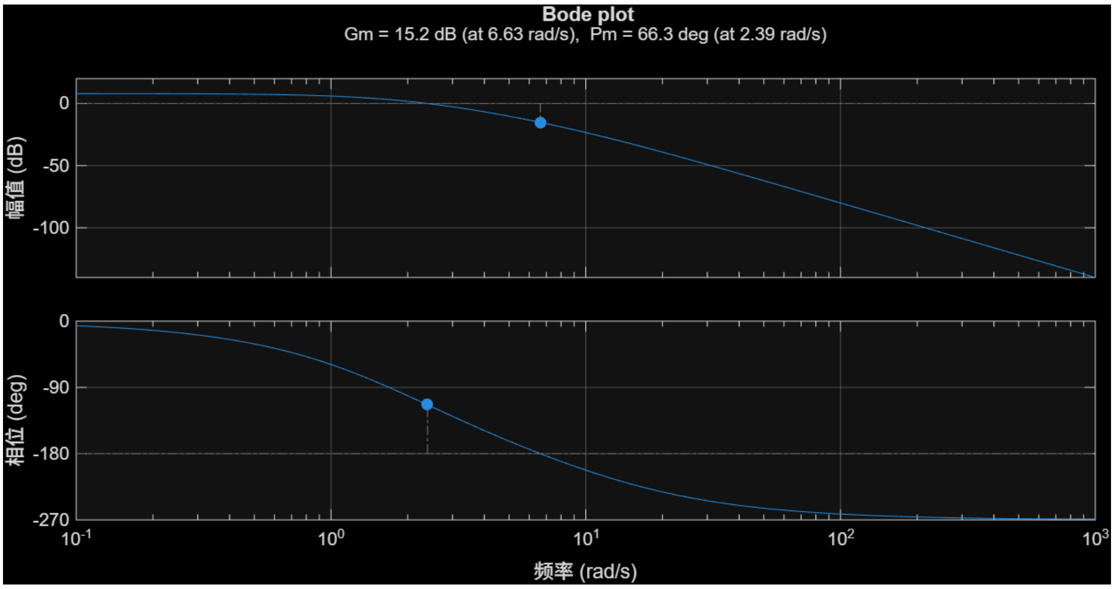
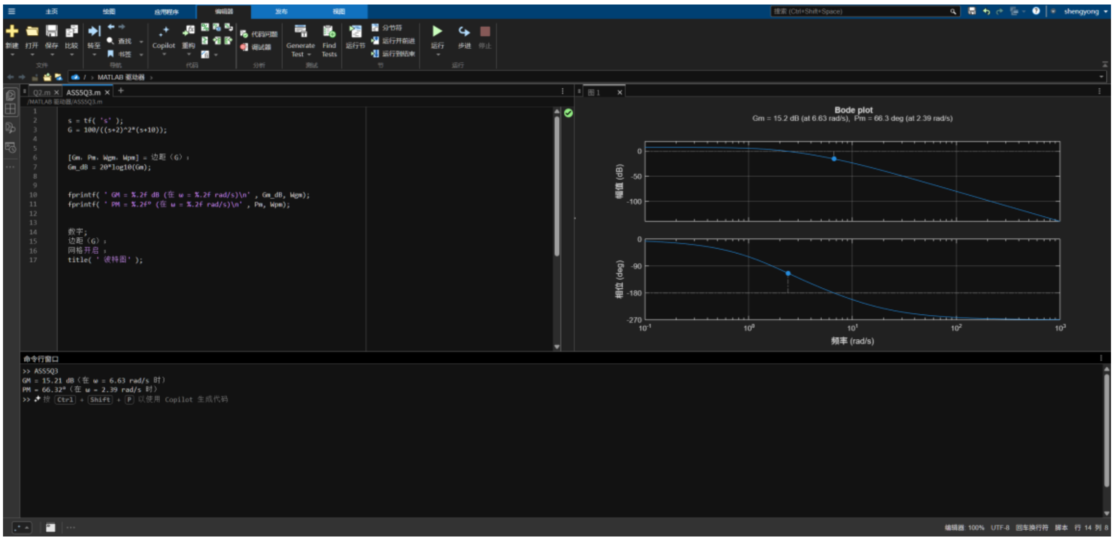
>> ASS5Q3
 GM = 15.21 dB (在 ω = 6.63 rad/s)
 PM = 66.32° (在 ω = 2.39 rad/s)
>>
```





CODE

Q2

```
s = tf('s');
G = (s+2)/(s^2*(s+10)*(s^2+s+2));
figure;
bode(G);
grid on;
title('Bode plot of G(s) = (s+2)/(s²(s+10)(s²+s+2))');
```

Q3

```
s = tf('s');
G = 100/((s+2)^2*(s+10));


[Gm, Pm, Wgm, Wpm] = margin(G);
Gm_dB = 20*log10(Gm);


fprintf(' GM = %.2f dB (在 ω = %.2f rad/s)\n', Gm_dB, Wgm);
fprintf(' PM = %.2f° (在 ω = %.2f rad/s)\n', Pm, Wpm);


figure;
margin(G);
grid on;
title(' Bode plot');
```