#### 程序代写代做 CS编程辅导



weLecture - 10

Digital Processing

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#### Transform Analysis of Linear Time-Invariant (LTI) Systems 程序代与代做 CS编程辅导



How to analyze a system given the Z-Transform and/or Fourier Transform WeChat: cstutorcs

- Analysis of LTI systems described by Difference Equations
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   Analysis of LTI systems described by Fourier Transform
- ► All-Pass and Milimail: thtore systems com

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▶ Definition: A m assessment as a stable and causal system, which a stable and causal inverse system, i.e. all poles and zer the stable and causal inverse system, i.e. all poles and zer the stable and causal inverse system.

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$$H.\text{Assign} (b_0) = \prod_{k=1}^{M} (1 - c_k z^{-1}) \\ \prod_{k=1}^{M} (1 - d_k z^{-1}) \\ \prod_{k=1}^{M} (1 - d_k z^{-1})$$

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$$H_{i}(z) = \frac{1}{b_{0}} \frac{1}{$$

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▶ Given a magnitu



$$C(z) = \underbrace{\text{Vighat: (15 tempers)}}_{A_0} \underbrace{\text{Pr(ijecto Exah) (Helps*z)}}_{D_1} \underbrace{\text{Helps*z)}}_{A_0} \underbrace{\text{Indians: (15 dkz^{-1})}}_{A_0} \underbrace{\text{Indians: (15 dkz^{-1})}_{A_0}}_{A_0} \underbrace{\text{Indians: (15 dkz^{-1})}}_{A_0} \underbrace{\text{Indians: (15 dkz^{-1})}}_{A_0} \underbrace{\text{Indians: (15 dkz^{-1})}}_{A_0} \underbrace{\text{Indians: (15 dkz^{-1})}}_{A_0} \underbrace{\text{Indians:$$

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We can uniquely determine H(z) provided that it is minimum-phase since affine zeros and poles must lie inside the unit circle.

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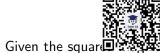
▶ We have seen the squared magnitude response (C(z)) is specified, and the corresponding M and N are fixed for a rational stable Ghdtcs usates yestem, there are finite choices of the zeros and phase responses.

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If we impose the additional restriction that the system is minimum-phase, then we sand uniquely determine the zeros.

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• Given the square during wind with the corresponding M and N, there is a unique system whose zeros and poles are all inside the unit circle.

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Therefore, the relationship between magnitude and phase for a minimum-phase system is unique.

## Revisit Example 5.10 (Lecture 9)

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Given the C(z) zero-pole plot below, find the system function H(z) that corresponds to a causa temperature temperature with real-valued time domain impulse response.



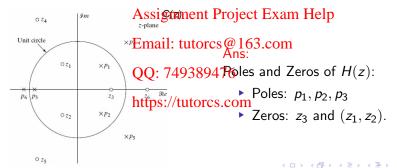
- ▶ There are 4 possible options for H(z)
- One of these options is a minimum-phase system.

## Minimum-Phase Systems Revisit Example 5.1 作序代写代做 CS编程辅导

Given the magnitude

$$C(z) = \left( \begin{array}{c} \prod_{k=1}^{M} (1 - c_k z^{-1})(1 - c_k^* z) \\ \prod_{k=1}^{M} (1 - d_k z^{-1})(1 - d_k^* z) \end{array} \right)$$

If H(z) is minimum-pWase,hWhatthto the poles and zeros of H(z)?



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▶ Where does the



imum-phase come from?

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- Given the magnitude squared function WeChat: cstutorcs

$$C(z) = A \begin{cases} b_0 \\ sign \\ a_0 \end{cases} \prod_{k=1}^{M} (1 - c_k z^{-1}) (1 - c_k^* z) \\ \prod_{k=1}^{N} (1 - d_k z^{-1}) (1 - d_k^* z) \\ Email: tutorcs@163.com \end{cases}$$

there exists a limited number of possibilities for the OO: 749389476

corresponding system function  $(H_1(z), H_2z \cdots \text{ etc.})$ 

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Given the magnitude squared function

$$C(z) = \prod_{k=1}^{M} \frac{\prod_{k=1}^{M} (1 - c_k z^{-1})(1 - c_k^* z)}{\prod_{k=1}^{N} (1 - d_k z^{-1})(1 - d_k^* z)}$$

- All of these possibilities have the same magnitude response.
- $\vdash$   $H_{min}(z)$  is one of them ment Project Exam Help
- All other possibilities for H(z) can be decomposed in to a multiplication of  $H_{min}(z)$  and a suitable  $H_{ap}(z)$ .

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 $H_1(z) = H_{min}(z)H_{ap}^1(z)$ 

https:///b(/t)O#C/5 $_{ap}$ (z)

:

$$H_k(z) = H_{min}(z)$$



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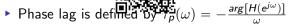
Among all these systems: that have the same magnitude squared function, the minimum-phase system has the minimum phase Assignment Project Extensy Lelp minimum energy delay.

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#### Minimum Phase Lag



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- Phase lag is defined by  $T_p(\omega) = -\frac{\arg[H(e^{j\omega})]}{\omega}$
- Recall that

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The unwrapped phased totars rolominamum-phase system

$$arg[H(e^{Q}): \frac{749389476}{arg}[H_{min}^{476}(e^{j\omega})] + arg[H_{ap}(e^{j\omega})]$$
  
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## Minimum Phase Lag

► The unwrapped are any non minimum-phase system

$$\arg[H(e^{\mathbf{I}_{ap}}, \mathbf{I}_{ap}, \mathbf$$

► Fact:  $arg[H_{ap}(e^{\mathbf{W}})]$ Chat: cotutores  $\omega \leq \pi$ . (See Lecture 09)

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#### Minimum Phase Lag

The unwrapped any non minimum-phase system  $\arg[H(e^{\underline{\mathbf{u}}},\mathbf{x},\mathbf{w})] + \arg[H_{ap}(e^{j\omega})]$ 

- ► Fact:  $arg[H_{ap}(e^{\mathbf{W}})]^{\text{Chat: cotutores}} \omega \leq \pi$ . (See Lecture 09)
- Hence,  $\arg[H(e^{i\mathbf{A}})^{\mathbf{S}}]$  Hence,  $\arg[H(e^{i\mathbf{A}})^{\mathbf{S}}]$  Hence,  $\arg[H(e^{i\mathbf{A}})^{\mathbf{S}}]$
- ► Hence,  $-\arg[H_{min}^{\text{Emajl}}]$ :  $\cot^2[H_{min}^{\text{Lorge}}]$  for  $0 \le \omega \le \pi$
- ► Phase Lag  $H(e^{i\frac{h}{h}ttps: //tutorcs.com})$  Phase Lag  $H_{min}(z)$ .
- Minimum-phase systems are minimum phase-lag systems.



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#### Minimum Group Del

▶ The group delay of any non minimum-phase system

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$$grd[H(e^{j\omega})] = grd[H_{min}(e^{j\omega})] + grd[H_{ap}(e^{j\omega})]$$
  
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► Fact:  $grd[H_{ap}(e^{j\omega})] > 0$  for  $0 \le \omega \le \pi$ . (See Lecture 09)

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#### Minimum Group Del 🔄

▶ The group delay of any non minimum-phase system

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$$grd[H(e^{j\omega})] = grd[H_{min}(e^{j\omega})] + grd[H_{ap}(e^{j\omega})]$$
  
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- ► Fact:  $grd[H_{ap}(e^{j\omega})] \ge 0$  for  $0 \le \omega \le \pi$  (See Lecture 09)
- $grd[H_{min}(e^{j\omega})]$  iq qways bes 9476  $grd[H(e^{j\omega})]$ .
- Minimum-phase systems are minimum group delay systems.
- ▶ Thus, introduces the least amount of delay to the input.

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#### Minimum Energy De ty

We define the property with the domain with th

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$$\overline{\operatorname{cstuder}}(m)|^2$$
.

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### Minimum Energy De ty

We define the property and the domain with the domain with the property and the domain with th

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$$\overline{cstvor}(m)|^2$$
.

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▶ What does *E*[*n*] Entern? thotime 1.6the onergy of *n* samples is added up.

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### Minimum Energy De ty

We define the property of impulse response (time domain) is:

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$$\overline{\operatorname{cstvor}}_{m=0}^{n} |h(m)|^{2}$$
.

#### Assignment Project Exam Help

▶ What does *E*[*n*] Engan? thto time 1.6the onergy of *n* samples is added up.

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If h[n] has all of its energy concentrated around n = 0, is this a good/bad thing? A good thing, as this will result in low delay.

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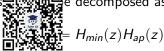


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- Given C(z), the minimum-phase system has the most amount of partial energy concentrated around n=0; i.e., the energy of the minimum Falmasie: systems i delayed the least of all systems having the same magnitude response. QQ: 749389476

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▶ Any rational sys



where  $H_{min}(z)$  is a minimum-phase system and  $H_{ap}(z)$  is an all-pass system.

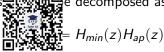
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▶ Any rational sys



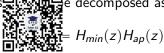
where  $H_{min}(z)$  is a minimum-phase system and  $H_{ap}(z)$  is an all-pass system.

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The magnitude response is equal to the minimum-phase response i.e. |H(3) = 4438(4) 6(why?)

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▶ Any rational sys



where  $H_{min}(z)$  is a minimum-phase system and  $H_{ap}(z)$  is an all-pass system.

#### Assignment Project Exam Help

The magnitude response is equal to the minimum-phase response i.e. |H(3) = 4438(4) 6(why?)

https://tutores.com/
$$|H_{ap}(z)|$$

given 
$$|H_{ap}(z)| = 1$$
.



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Suppose H(z) has a contract of outside the unit circle at  $z=\frac{1}{c^*}$ , |c|<1 and the poles/zeros are inside the unit circle.

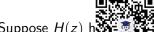
Well bit 
$$= ckt_1(t_2)t(cs^{-1} - c^*)$$

where  $H_1(z)$  is naingum who be roject Exam Help

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Suppose H(z) has a consider one unit circle at  $z=\frac{1}{c^*}$ , |c|<1 and the poles/zeros are inside the unit poles/zeros are inside the unit circle.

Well bit 
$$= ckt_1(t_2)t(cs^{-1} - c^*)$$

where  $H_1(z)$  is maining unmarked by oject Exam Help

An equivalent expression utor ds @163.com

$$\begin{array}{c} \text{QQ: } 749389476 \\ \text{H(z)} = H_1(z)(1-cz^{-1}) \\ \text{https://tutorcs.com} \end{array} \frac{(z^{-1}-c^*)}{1-cz^{-1}}.$$

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• An equivalent explanation H(z) is

$$H(z) = \frac{1}{2} \left(1 - cz^{-1}\right) \frac{(z^{-1} - c^*)}{1 - cz^{-1}}.$$

 $H_{min}(z) = H_1(z) We Chat: to statorics mum-phase$ 

(additional zero Assignmenti Project Freezo diletate reciprocal location of  $1/c^*$ ) Email: tutorcs@163.com

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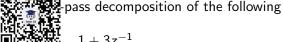
• An equivalent expression H(z) is

$$H(z_{\blacksquare 1}^{\blacksquare 1}, \overline{z_{1}^{\square 1}})(1-cz^{-1}) \frac{(z^{-1}-c^{*})}{1-cz^{-1}}.$$

- $H_{min}(z) = H_1(z)$  Per Least 1 Statement in the second of  $H_1(z)$  Per Land of  $H_2(z)$  Per Land of  $H_2(z)$
- $H_{ap}(z) = \frac{(z^{-1}-c^*)}{1-cz}$  is a part by a system.
- The added pole <a href="httphe/alltpass.system">httphe/alltpass.system</a> (inside the unit circle) must be canceled by a zero, which we have added to the minimum-phase system.



Find the minimum-plasystem:



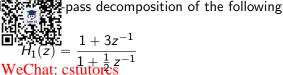
 $H_1(z) = \frac{1}{1 + \frac{1}{2}z^{-1}}$ WeChat: estutores

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Find the minimum-p



(1) What are the pole Assignment Project Exam Help

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Find the minimum-psystem:

pass decomposition of the following  $1 + 3z^{-1}$ 

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(1) What are the poleAssignment Project Exam Help Pole:  $z = -\frac{1}{2}$  and Zero: z = -3 Email: tutorcs@163.com

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Find the minimum-p

pass decomposition of the following  $H_1(z) = \frac{1+3z^{-1}}{1-z^{-1}}$ 

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- (1) What are the pole Assignment Project Exam Help Pole:  $z = -\frac{1}{2}$  and Zero: z = -3
- (2) How to create a  $\frac{1}{100}$  How to create a  $\frac{1}{100$

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Find the minimum-p

pass decomposition of the following

$$H_1(z) = \frac{1 + 3z^{-1}}{1 + \frac{1}{2}z^{-1}}$$
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- (1) What are the poleA swig nement Project Exam Help Pole:  $z = -\frac{1}{2}$  and Zero: z = -3
- (2) How to create a  $\frac{1}{100}$  How to create a  $\frac{1}{100$

$$\begin{split} & H_1(z) = 3 \frac{249389476}{3} \frac{1}{3} = 3 \frac{1}{1 + \frac{1}{2}z^{-1}} (z^{-1} + \frac{1}{3}) \\ & \text{https://ttproces.com} + \frac{1}{2}z^{-1} (z^{-1} + \frac{1}{3}) \\ & = 3 \frac{1 - (-\frac{1}{3}z^{-1})}{1 + \frac{1}{2}z^{-1}} \frac{z^{-1} + \frac{1}{3}}{1 - (-\frac{1}{3}z^{-1})} \end{split}$$

## Minimum-Phase & All-Pass Decomposition Example 5.12(a)

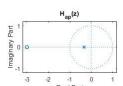
$$H_1(z) = \frac{1}{1 - \frac{1}{1 - \frac{1}{2}}} \sum_{i=1}^{n} \frac{1}{1 - \frac{1}{2}} 3 \frac{1 - (-\frac{1}{3}z^{-1})}{1 + \frac{1}{2}z^{-1}} \frac{z^{-1} + \frac{1}{3}}{1 - (-\frac{1}{3}z^{-1})}$$

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 $H_{min}(z) = 3\frac{1 + \frac{1}{3}z^{-1}}{1 + \frac{1}{2}z^{-1}}$ Email: tutores@163.com3

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 $H_{ap}(z) = \frac{z^{-1} + \frac{1}{3}}{1 + \frac{1}{2}z^{-1}}$ 

Find the minimum-psystem:

pass decomposition of the following

$$H_2(z) = \frac{\sum_{z=0}^{n} \frac{1}{2} e^{-j\pi/4} z^{-1}}{\text{WeChat: cst-utors}^{\frac{1}{2}} z^{-1}}$$

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pass decomposition of the following

## Minimum-Phase & All-Pass Decomposition Example 5.12(b)

Find the minimum-p system:

 $\frac{\sum_{i=1}^{n} \frac{3}{2} e^{-j\pi/4} z^{-1}) (1 + \frac{3}{2} e^{-j\pi/4} z^{-1})}{\text{WeChat: cstutores}^{-1}}$ 

$$H_2(z) = \frac{(1+\frac{2}{2}c+2)(1+\frac{1}{2}c+1)}{\text{WeChat: cstutors}^{\frac{1}{2}} \cdot \vec{s}^{-1}}$$

(1) What are the pole assignment Project Exam Help

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pass decomposition of the following

# Minimum-Phase & All-Pass Decomposition Example 5.12(b) 程序代写代做 CS编程辅导

Find the minimum-p system:

$$H_2(z) = \frac{\sqrt{1 + \frac{3}{2}e^{-j/4}z^{-1}})(1 + \frac{3}{2}e^{-j\pi/4}z^{-1})}{\text{WeChat: cstutors}^{\frac{1}{2}} z^{-1}}$$

(1) What are the poleAssignenealt Project Exam Help

Poles: 
$$z = 0$$
 and  $z = \frac{1}{3}$   
Zeros:  $z = -\frac{3}{2}e^{i\pi \frac{1}{2}}$  tut 2 Pres @ 163.com

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Find the minimum-personal pass decomposition of the following system:

$$H_2(z) = \frac{\sum_{1}^{n} \frac{1}{2} e^{-j/4} z^{-1} (1 + \frac{3}{2} e^{-j\pi/4} z^{-1})}{\text{WeChat: cstutors}^{\frac{1}{2}} z^{-1}}$$

- (1) What are the poleAssignment Project Exam Help Poles: z = 0 and  $z = \frac{1}{3}$  Zeros:  $z = -\frac{3}{2}e^{i\pi}$  [In all: tugorcs@163.com
- (2) How to create a minimum phase and all-pass system from H(z)?

$$H_2(z) = \frac{\frac{3}{2}e^{j\pi/4}(\frac{2}{3}e^{-j\pi/4} + z^{-1})\frac{3}{2}e^{-j\pi/4}(\frac{2}{3}e^{j\pi/4} + z^{-1})}{\frac{\text{https://tutorcs.}_1 - \frac{\pi}{3}z^{-1}}}$$
$$= \frac{9}{4}\frac{(z^{-1} + \frac{2}{3}e^{-j\pi/4})(z^{-1} + \frac{2}{3}e^{j\pi/4})}{1 - \frac{1}{\pi}z^{-1}}$$

$$H_{2}(z) = \frac{(1 + \frac{3}{2}e^{j\pi/4}z^{-1})}{1 - \frac{1}{4}z^{-1}}$$

$$= \frac{9}{4} \frac{(z^{-1} + \frac{2}{3}e^{-j\pi} \Box z^{-1})}{1 - \frac{1}{4}z^{-1}}$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{1}{3}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4})(z^{-1} + \frac{2}{3}e^{j\pi/4})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{1}{4}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{1}{4}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{1}{4}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{1}{4}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{1}{4}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

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$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{1}{4}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{2}{3}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{2}{3}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{2}{3}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

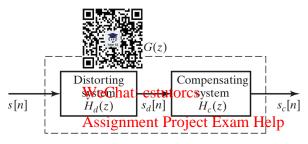
$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{2}{3}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{2}{3}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{j\pi/4}z^{-1})(1 + \frac{2}{3}e^{-j\pi/4}z^{-1})}{1 - \frac{2}{3}e^{-j\pi/4}z^{-1}} (z^{-1} + \frac{2}{3}e^{-j\pi/4}z^{-1})$$

$$= \frac{9}{4} \frac{(1 + \frac{2}{3}e^{-j\pi$$

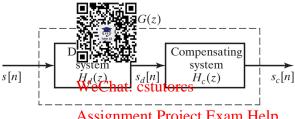
程序代写代做 CS编程辅导



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Perfect compens  $0.074cn^{-4}$ 

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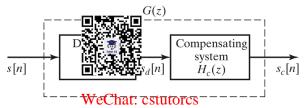


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  If  $H_d(z)$  and  $H_c(z)$  are both causal and stable, then perfect compensation is  $0.08515493894176H_d(z)$  is minimum-phase.
- If  $H_d(z)$  is non-minimum-phase, we only compensate its min phase component (why?).

#### 程序代与代做 CS编程辅导

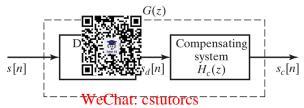


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If  $H_d(z)$  is non-minimum-phase, we only compensate its min phase componer mail: tutorcs@163.com

$$QQ_{d}^{2}(z)^{49}=89476_{d min}(z)H_{ap}(z).$$

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#### Assignment Project Exam Help

If  $H_d(z)$  is non-minimum-phase, we only compensate its min phase componer mail: tutorcs@163.com

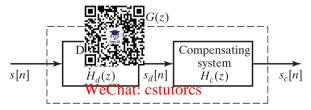
$$QQ_{d}^{2}\sqrt{2}938P_{d\,min}^{476}(z)H_{ap}(z).$$

► Choosing  $H_c(z) = \frac{\text{https://tutorcs.com}}{H_{d,min}(z)}$ , then the overall system function:

$$G(z) = H_d(z)H_c(z) = H_{ap}(z).$$



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• Choosing  $H_c(z)$  then the overall system function

QQ) 7498894716(z) = 
$$H_{ap}(z)$$
.

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▶ Magnitude is exactly compensated but phase distortions occur due to  $\angle H_{ap}(z)$ .

#### Homework

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- ▶ Read and under Marcl tall upttooks of the textbook.
- Problems related to this lecture: 5.12, 5.13, 5.14, 5.15, 5.17, Assignment Project Exam Help
   5.18, 5.19, 5.24 and 5.28.

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