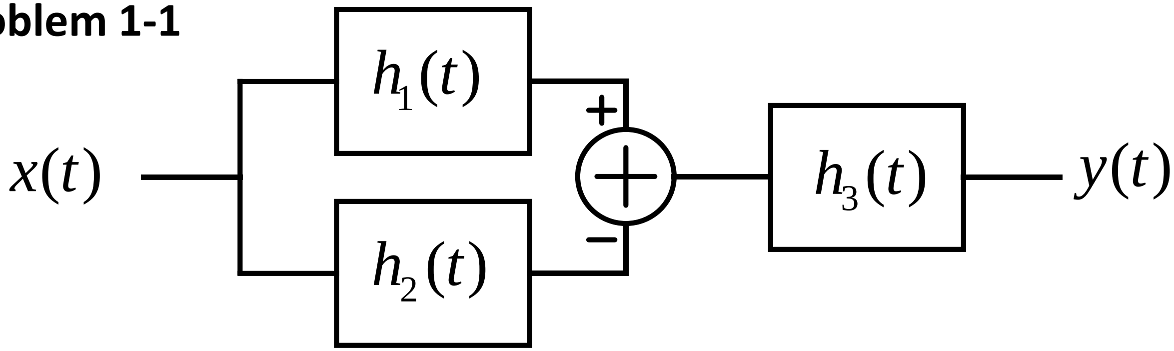
Problem 1 CT LTI Causal Feedforward and Feedback System

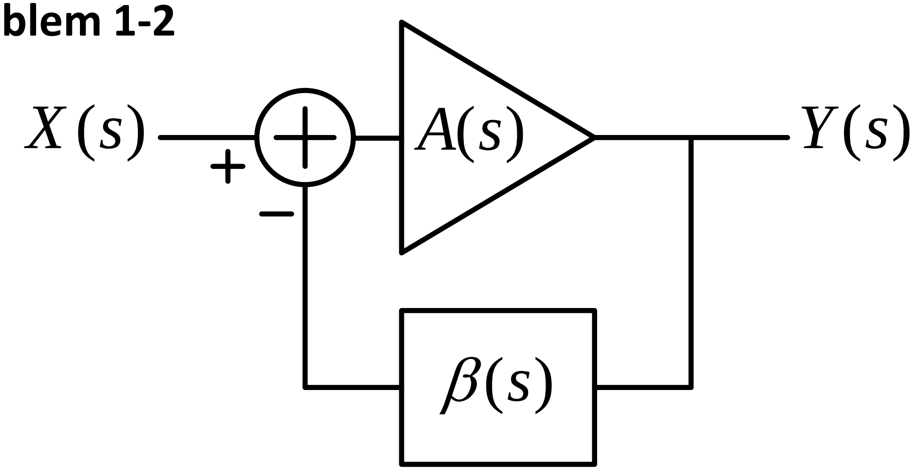
Problem 1-1



$$h_1(t) = \delta(t)$$
$$h_2(t) = u(t)$$
$$h_3(t) = e^{-t}u(t) \; .$$

(1) Please find the impulse response of the system (i.e. h(t)). (2.5%)
(2) Please find the transfer function of the system (i.e. H(s)). (2.5%)

Problem 1-2



$$A(s) = \left(1 + \frac{1}{s}\right) \times \frac{1}{s}$$
$$\beta(s) = 4$$

(1) Please find the impulse response of the system (i.e. h(t)). (2.5%)
(2) Please find the transfer function of the system (i.e. H(s)). (2.5%)

Problem 2 CT LTI System

Given the impulse response of an CT LTI system, $h(t) = e^{-t}u(t) + e^{-2t}u(t)$.

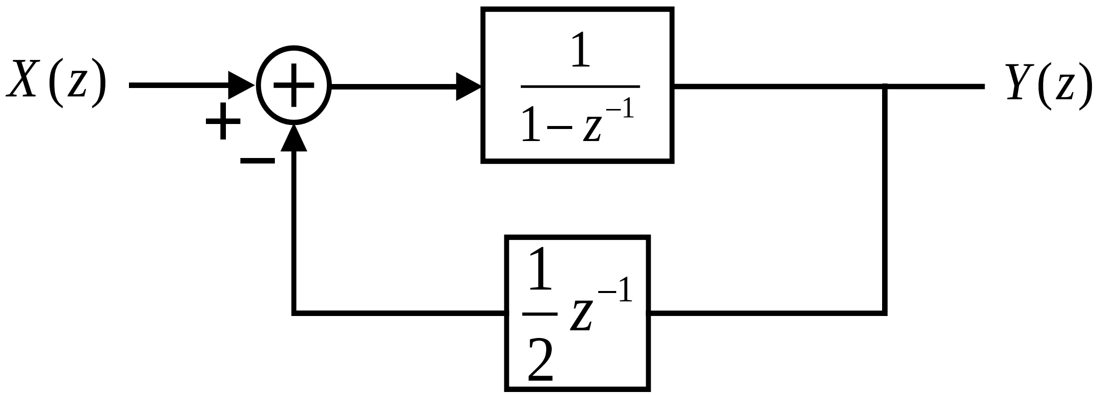
(1) Please find the transfer function (i.e. H(s)). (2.5%)
(2) Please find the differential equation. (2.5%)
(3) Is it causal? Is it stable?(2. 5%)
(4) Please plot the pole-zero plot and find the R.O.C. (2. 5%)

Problem 3 CT LTI System

Given the transfer function of an CT LTI system, $H(s) = \dfrac{s-1}{(s+1)(s+2)}$.

(1) Please find the impulse response (i.e. H[n]). (2.5%)
(2) Please find the differential equation. (2.5%)
(3) Please plot the pole-zero plot. (2. 5%)
(4) If it is causal and stable, what is the R.O.C. (2. 5%)

Problem 4   DT LTI Causal Feedback System



Assuming it is a causal, please answer the following questions.

(1) Please find the impulse response (i.e. h[n]). (2.5%)

(2) Please find the transfer function (i.e. H(z)). (2.5%)

(3) Plot the pole-zero plot. (2.5%)

(4) Find the R.O.C. of H(z). (2.5%)

Problem 5 DT LTI System

Given the impulse response of an DT LTI system, $h[n] = (0.1)^n u[n] + 2(-0.9)^n u[n]$.

(1) Please find the transfer function (i.e. H(z)). (2.5%)
(2) Please find the difference equation. (2.5%)
(3) Is it causal? Is it stable?(2. 5%)
(4) Please plot the pole-zero plot and find the R.O.C. (2. 5%)

Problem 6 DT LTI Causal System

Problem 6-1

Given the difference equation of an DT LTI Causal system, $8y[n]-2y[n-1]-y[n-2]=8x[n]$.

(1) Please find the transfer function (i.e. H(z)). (2.5%)

(2) When the input is $x[n]=\delta[n]+\frac{1}{4}\delta[n-1]$, what is the output y[n]?(2.5%)

Problem 6-2

Given the difference equation of an DT LTI Causal system, $y[n]=3x[n]+6x[n-1]+9x[n-2]$.

(1) Please find the transfer function (i.e. H(z)). (2.5%)

(2) When the input is $x[n]=u[n]-u[n-1]$, what is the output y[n]?(2.5%)

Problem 7 DT LTI FIR System

Given the difference equation of an DT LTI system, $y[n] = x[n] + x[n-1] + x[n-2] + x[n-3]$.

(1) Please find the impulse response (i.e. h[n]). (2.5%)
(2) Please find the transfer function (i.e. H(z)). (2.5%)
(3) Plot the pole-zero plot and find the R.O.C. of H(z). (2.5%)
(4) Draw the implementation of this DT LTI System. (2.5%)

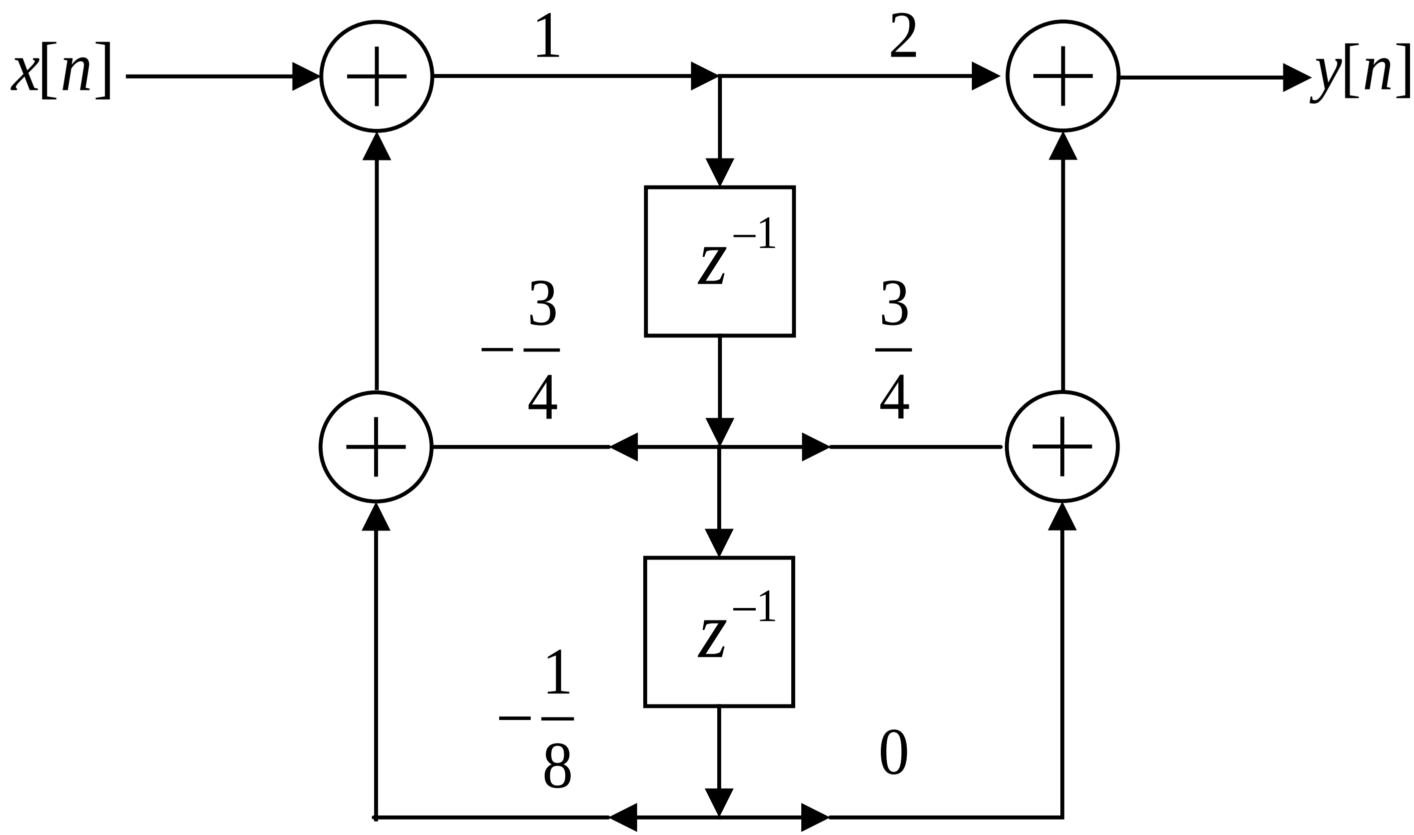
Problem 8 DT LTI System

Given the difference equation of an DT LTI Causal system,

$$y[n]-\frac{5}{6}y[n-1]+\frac{1}{6}y[n-2]=2x[n]-\frac{5}{6}x[n-1].$$

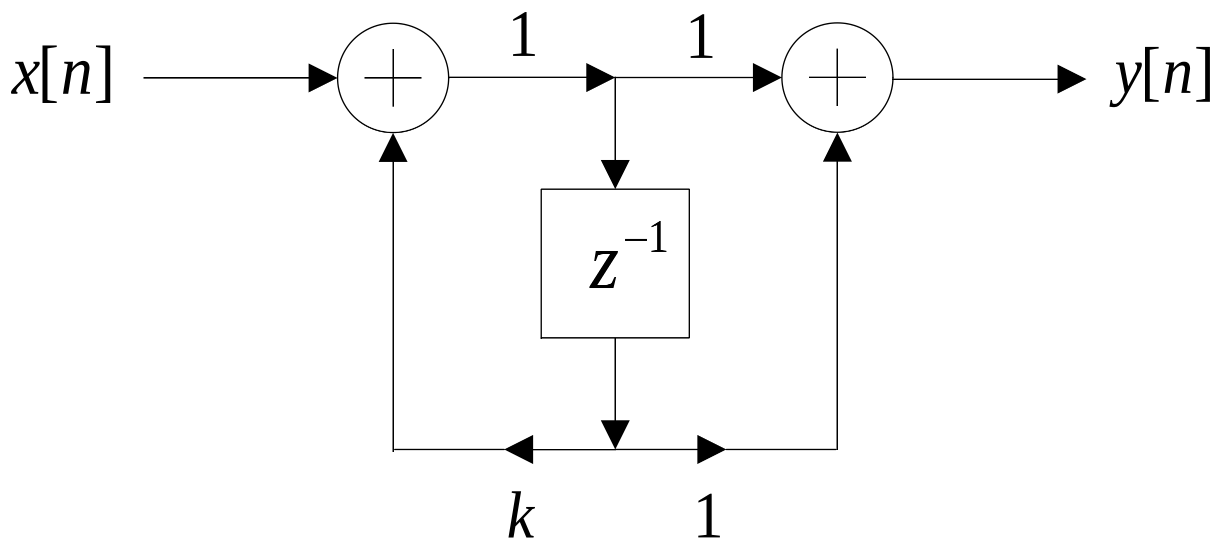
(1) Please find the impulse response (i.e. h[n]). (2.5%)
(2) Please find the transfer function (i.e. H(z)). (2.5%)
(3) Plot the pole-zero plot and find the R.O.C. of H(z). (2.5%)
(4) Draw the direct form II implementation of this DT LTI System. (2.5%)

Problem 9 DT LTI Causal System



(1) Please find the difference equation. (2.5%)
(2) Please find the transfer function (i.e. H(z)). (2.5%)
(3) Is the system stable? (2. 5%)
(4) Please find the impulse response(i.e. h[n])). (2. 5%)

Problem 10   DT LTI Causal System



(1) Please find the difference equation. (2.5%)
(2) Please find the transfer function (i.e. H(z)). (2.5%)
(3) If the system is stable, what is the range of k? (2. 5%)
(4) When k is 0.5, please find the impulse response(i.e. h[n])). (2. 5%)

CTFT

$$x(t) = \int_{-\infty}^{+\infty} \underbrace{\boxed{\int_{-\infty}^{+\infty} x(t)\, e^{-j2\pi f t}\, dt}}_{X(f)} e^{+j2\pi f t}\, df$$

DTFT

$$x[n] = \int_{-\frac{1}{2}}^{+\frac{1}{2}} \underbrace{\boxed{\sum_{n=-\infty}^{+\infty} x[n]\, e^{-j2\pi f n}}}_{X(f)} e^{+j2\pi f n}\, df$$

CTFS

$$x(t) = \sum_{k=-\infty}^{+\infty} \frac{1}{T} \underbrace{\boxed{\int_0^T x(t)\, e^{-j\frac{k2\pi t}{T}}\, dt}}_{X[k]} e^{+j\frac{k2\pi t}{T}}$$

DTFS

$$x[n] = \sum_{k=0}^{N-1} \frac{1}{N} \underbrace{\boxed{\sum_{n=0}^{N-1} x[n]\, e^{-j\frac{k2\pi n}{N}}}}_{X[k]} e^{+j\frac{k2\pi n}{N}}$$

$x_1(t) \overset{CTFT}{\Leftrightarrow} X_1(f)$

$x_1[n] = x_1(nT_s)$

$x_1[n]$ ②

$\xrightarrow{DTFT}$

$\tilde{X}_1(\hat{f})$

$$\tilde{X}_1(\hat{f}) = f_s \sum_{m=-\infty}^{+\infty} X_1(f - mf_s)$$

$$x_p(t) = x_1(t) * \sum_{\ell=-\infty}^{+\infty} \delta(t - \ell T)$$

$$x_p[n] = x_1[n] * \sum_{\ell=-\infty}^{+\infty} \delta[n - \ell N]$$

$$X_p(k) = X_1\left(f = k\frac{1}{N}\right)$$

$$\tilde{X}_p[k] = \tilde{X}_1\left(\hat{f} = k\frac{1}{N}\right)$$

$x_p[n] = x_p(nT_s)$

$$\tilde{X}_p[\hat{k}] = f_s \times \sum_{m=-\infty}^{+\infty} \cancel{X}_p[n - mN]$$

$x_p(t) \overset{CTFS}{\longleftrightarrow} X_p[k]$

$x_p[n] \overset{DTFS}{\longleftrightarrow} \tilde{X}_p[k]$

Table 01 CTFT Basic Function

$x(t)=\int_{-\infty}^{+\infty} X(f)e^{+j2\pi ft}\,df$	$X(f)=\int_{-\infty}^{+\infty} x(t)e^{-j2\pi ft}\,dt$
$rect(t)$	$sinc(f)$
$sinc(t)$	$rect(f)$
$\delta(t)$	1
1	$\delta(f)$
$u(t)$	$\frac{1}{j2\pi f}+\frac{1}{2}\delta(f)$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$
$e^{+j2\pi f_o t}$	$\delta(f-f_o)$
$e^{-j2\pi f_o t}$	$\delta(f+f_o)$

Table 02 DTFT Basic Function

$x[n]=\int_{-\frac{1}{2}}^{+\frac{1}{2}} X(f)e^{+j2\pi fn}df$	$X(f)=\sum_{n=-\infty}^{+\infty} x[n]e^{-j2\pi fn}$
$x[n]=\begin{cases} 1, \lvert n\rvert \le M \\ 0, else \end{cases}$	$X(f)=\frac{sin((2M+1)\pi f)}{sin(\pi f)}$
$x[n]=\frac{sin(K\pi n)}{\pi n}$	$X(f)=\begin{cases} 1, \lvert f\rvert \le K/2 \\ 0, else \end{cases}$
$\delta[n]$	1
1	$\delta(f)$
$u[n]$	$\frac{1}{1-e^{-j2\pi f}}+\frac{1}{2}\delta(f)$
$a^n u[n]$	$\frac{1}{1-ae^{-j2\pi f}}$
$e^{+j2\pi f_o n}$	$\delta(f-f_o)$
$e^{-j2\pi f_o n}$	$\delta(f+f_o)$

Table 03 CTFS Basic Function

$x(t)=\frac{1}{T}\sum_{k=-\infty}^{+\infty} X[k]e^{+j\frac{k2\pi t}{T}}$	$X[k]=\int_0^T x(t)e^{-j\frac{k2\pi t}{T}}dt$
$x(t)=\sum_{n=-\infty}^{+\infty}\delta(t-nT)$	$X[k]=1$
$x(t)=e^{+j\frac{m2\pi t}{T}}$	$X[k]=T\delta[k-m]$
$x(t)=e^{-j\frac{m2\pi t}{T}}$	$X[k]=T\delta[k+m]$

Table 04 DTFS Basic Function

$x[n]=\frac{1}{N}\sum_{k=0}^{N-1}X[k]e^{+j\frac{k2\pi n}{N}}$	$X[k]=\sum_{n=0}^{N-1}x[n]e^{-j\frac{k2\pi n}{N}}$
$x[n]=\sum_{l=-\infty}^{+\infty}\delta[n-lN]$	$X[k]=1$
$x[n]=e^{+j\frac{m2\pi n}{N}}$	$X[k]=N\delta[k-m]$
$x[n]=e^{-j\frac{m2\pi n}{N}}$	$X[k]=N\delta[k+m]$

Table 05 CTFT Basic Property

$x(t)=\int_{-\infty}^{+\infty} X(f)e^{+j2\pi ft}df$	$X(f)=\int_{-\infty}^{+\infty} x(t)e^{-j2\pi ft}dt$
$ax(t)+by(t)$	$aX(f)+bY(f)$
$x(t-t_0)$	$e^{-j2\pi ft_0}X(f)$
$e^{+j2\pi f_0 t}x(t)$	$X(f-f_0)$
$x(t)*y(t)$	$X(f)\times Y(f)$
$x(t)\times y(t)$	$X(f)*Y(f)$
$\frac{d}{dt}x(t)$	$j2\pi fX(f)$
$\int_{-\infty}^{t} x(\tau)d\tau$	$X(f)\times\left(\frac{1}{j2\pi f}+\frac{1}{2}\delta(f)\right)$
$-j2\pi tx(t)$	$\frac{d}{df}X(f)$
$x(at)$	$\frac{1}{\lvert a\rvert}X(\frac{f}{a})$
$x^*(t)=x(t) \longleftrightarrow X^*(f)=X(-f)$	
$\int_{-\infty}^{+\infty}\lvert x(t)\rvert^2dt=\int_{-\infty}^{+\infty}\lvert X(f)\rvert^2df$	

Table 06 DTFT Basic Property

	$x[n]=\int_{-\frac{1}{2}}^{+\frac{1}{2}} X(f)e^{+j2\pi fn}df$	$X(f)=\sum_{n=-\infty}^{+\infty} x[n]e^{-j2\pi fn}$
✗	$ax[n]+by[n]$	$aX(f)+bY(f)$
✓	$x[n-n_0]$	$e^{-j2\pi fn_0}X(f)$
✓	$e^{+j2\pi f_0 n}x[n]$	$X(f-f_0)$
✓	$x[n]*y[n]$	$X(f)\times Y(f)$
✓	$x[n]\times y[n]$	$X(f)*Y(f)$
✓	$x[n]-x[n-1]$	$\left(1-e^{-j2\pi f}\right)X(f)$
✓	$\sum_{m=-\infty}^{n} x[m]$	$X(f)\times\left(\frac{1}{1-e^{-j2\pi f}}+\frac{1}{2}\delta(f)\right)$
✓	$-j2\pi nx[n]$	$\frac{d}{df}X(f)$
✓	$x[\frac{n}{p}]$	$X(pf)$
✓	$x^*[n]=x[n] \longleftrightarrow X^*(f)=X(-f)$	
	$\sum_{n=-\infty}^{+\infty}\lvert x[n]\rvert^2=\int_{-\frac{1}{2}}^{+\frac{1}{2}}\lvert X(f)\rvert^2 df$	

Table 07 CTFS Basic Property

$x(t)=\frac{1}{T}\sum_{k=-\infty}^{+\infty} X[k]e^{+j\frac{k2\pi t}{T}}$	$X[k]=\int_0^T x(t)e^{-j\frac{k2\pi t}{T}}dt$
$ax(t)+by(t)$	$aX[k]+bY[k]$
$x(t-t_0)$	$e^{-j\frac{k2\pi t_0}{T}}X[k]$
$e^{+j2\pi f_0 t}x(t)$	$X[k-Tf_0]$
$x(t)*y(t)$	$X[k]\times Y[k]$
$x(t)\times y(t)$	$\frac{1}{T}X[k]*Y[k]$
$\frac{d}{dt}x(t)$	$j\frac{k2\pi}{T}X[k]$
$x(at)$	$\frac{1}{a}X[k]$
$x^*(t)=x(t) \longleftrightarrow X^*[k]=X[-k]$	
$\int_0^T \lvert x(t)\rvert^2 dt=\frac{1}{T}\sum_{k=-\infty}^{+\infty}\lvert X[k]\rvert^2$	

Table 08 DTFS Basic Property

$x[n]=\frac{1}{N}\sum_{k=0}^{N-1}X[k]e^{+j\frac{k2\pi n}{N}}$	$X[k]=\sum_{n=0}^{N-1}x[n]e^{-j\frac{k2\pi n}{N}}$
$ax[n]+by[n]$	$aX[k]+bY[k]$
$x[n-n_0]$	$e^{-j\frac{k2\pi n_0}{N}}X[k]$
$e^{+j2\pi f_0 n}x[n]$	$X[k-Nf_0]$
$x[n]*y[n]$	$X[k]\times Y[k]$
$x[n]\times y[n]$	$\frac{1}{N}X[k]*Y[k]$
$x[n]-x[n-1]$	$\left(1-e^{-j\frac{k2\pi}{N}}\right)X[k]$
$x[\frac{n}{p}]$	$X[k]$
$x^*[n]=x[n] \longleftrightarrow X^*[k]=X[-k]$	
$\sum_{n=0}^{N-1}\lvert x[n]\rvert^2=\frac{1}{N}\sum_{n=0}^{N-1}\lvert X[k]\rvert^2$	

CT LTI system

$$\delta(t) \longrightarrow \boxed{\begin{array}{c}\text{CT}\\ \text{LTI}\end{array}} \longrightarrow h(t)$$

time response $$x(t) \longrightarrow \boxed{\begin{array}{c}\text{CT}\\ \text{LTI}\end{array}} \longrightarrow y(t) = h(t) * x(t)$$

Bode

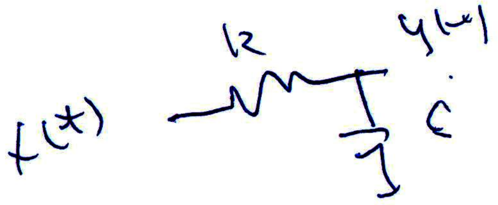
$$e^{+j2\pi f t} \longrightarrow \boxed{\begin{array}{c}\text{CT}\\ \text{LTI}\end{array}} \longrightarrow y(t) = H(j2\pi f) \cdot e^{+j2\pi f t}$$

plot

$$\cos(2\pi f t + \theta) \longrightarrow \boxed{\begin{array}{c}\text{CT}\\ \text{LTI}\end{array}} \longrightarrow y(t) = |H(j2\pi f)| \cos(2\pi f t + \theta + \angle H(j2\pi f))$$

Pole-Zero plot $$e^{+st} \longrightarrow \boxed{\begin{array}{c}\text{CT}\\ \text{LTI}\end{array}} \longrightarrow H(s)\, e^{+st}$$

②



$$y'(t) + \frac{1}{RC} y(t) = \frac{1}{RC} x(t)$$

R.L.C
s domain

$H(t) = \frac{Y(s)}{X(s)}$

$H(s)$

$s = j2\pi f$

LT

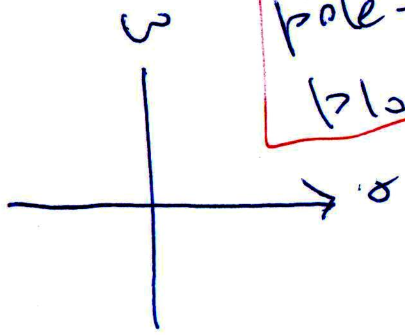
$H(j2\pi f)$

$s = \sigma + j\omega$

$h(t)$

$\boxed{\text{Bode plot}}$

$\boxed{\text{pole-zero plot}}$

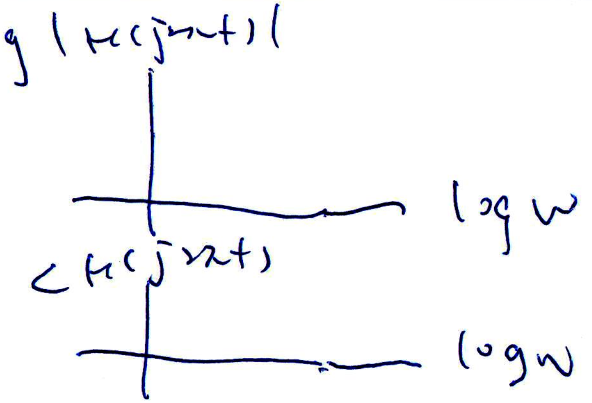


s plane

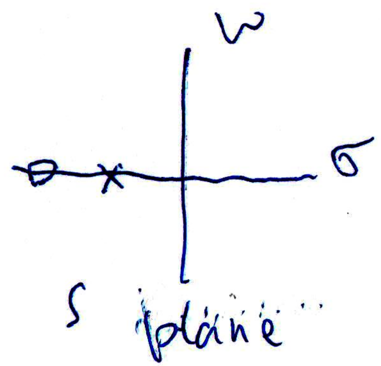
③

Bode plot

$\cos 2\pi f t \rightarrow \boxed{\text{LTI}} \rightarrow |H(j2\pi f)| \cos(2\pi f t + \angle H(j2\pi f))$



Pole - Zero Plot



$H(s) = \frac{1}{s+a}$

$Re\{s\} > Re\{-a\}$: $h(t) = e^{-at} u(t)$

$Re\{s\} < Re\{-a\}$: $h(t) = -e^{-at} u(-t)$

Nyquist stability Criteria (causal)

stable ⇔ 所有的 pole 都在左半平面

BIBO Stability

$\int_{-\infty}^{+\infty} |h(t)| dt < \infty$ 絕對可積分

收斂区间包含虚軸

傅立葉轉換存在

causal 收斂区间在最右边 pole 的右边

BIBO Stability + causal

所有 pole 在左半平面

收斂区间在最右边的右边

(4)

Table 11 LT Basic Function

$h(t)=\frac{1}{j2\pi}\int_{\sigma-j\infty}^{\sigma+j\infty}H(s)e^{+st}ds$	$H(s)=\int_{-\infty}^{+\infty}h(t)e^{-st}dt$ $ROC: R_x$
$h(t)=e^{-at}u(t)$	$H(s)=\frac{1}{s+a}$ $ROC: Re\{s\}>-Re\{a\}$
$h(t)=-e^{-at}u(-t)$	$H(s)=\frac{1}{s+a}$ $ROC: Re\{s\}<-Re\{a\}$
$h(t)=te^{-at}u(t)$	$H(s)=\frac{1}{(s+a)^2}$ $ROC: Re\{s\}>-Re\{a\}$
$h(t)=-te^{-at}u(-t)$	$H(s)=\frac{1}{(s+a)^2}$ $ROC: Re\{s\}<-Re\{a\}$
$h(t)=\delta(t)$	$H(s)=1$ $ROC: all\ s-plane$
$h(t)=\frac{d}{dt}\delta(t)$	$H(s)=s$ $ROC: all\ s-plane$
$h(t)=u(t)$	$H(s)=\frac{1}{s}$ $ROC: Re\{s\}>0$
$h(t)=\cos(\omega_o t)u(t)$	$H(s)=\frac{s}{s^2+\omega_o^2}$ $ROC: Re\{s\}>0$
$h(t)=\sin(\omega_o t)u(t)$	$H(s)=\frac{\omega_o}{s^2+\omega_o^2}$ $ROC: Re\{s\}>0$
$h(t)=e^{-at}\cos(\omega_o t)u(t)$	$H(s)=\frac{s+a}{(s+a)^2+\omega_o^2}$ $ROC: Re\{s\}>-a$
$h(t)=e^{-at}\sin(\omega_o t)u(t)$	$H(s)=\frac{\omega_o}{(s+a)^2+\omega_o^2}$ $ROC: Re\{s\}>-a$

(5)

Table 15 LT Basic Property

$h(t)=\frac{1}{j2\pi}\int_{\sigma-j\infty}^{\sigma+j\infty}H(s)e^{+st}ds$	$H(s)=\int_{-\infty}^{+\infty}h(t)e^{-st}dt \quad ROC: R_h$
$ah_1(t)+bh_2(t)$	$aH_1(s)+bH_2(s) \quad ROC: R_{h_1}\cap R_{h_2}$
$h_1(t)*h_2(t)$	$H_1(s)H_2(s) \quad ROC: R_{h_1}\cap R_{h_2}$
$h(t-a)$	$e^{-as}H(s) \quad ROC: R_h$
$e^{at}h(t)$	$H(s-a) \quad ROC: R_h+Re\{a\}$
$\frac{d}{dt}h(t)$	$sH(s) \quad ROC: R_h$
$\int_{-\infty}^{t}h(\tau)d\tau$	$\frac{1}{s}H(s) \quad ROC: R_h\cap Re\{s\}\gtrless 0$
$-th(t)$	$\frac{d}{ds}H(s) \quad ROC: R_h$

DT LTI system

Time Response

$$\delta[n] \xrightarrow{} \boxed{\text{DT LTI}} \xrightarrow{} h[n]$$

$$x[n] \xrightarrow{} \boxed{\text{DT LTI}} \xrightarrow{} y[n] = h[n] * x[n]$$

Freq Response

Bode plot

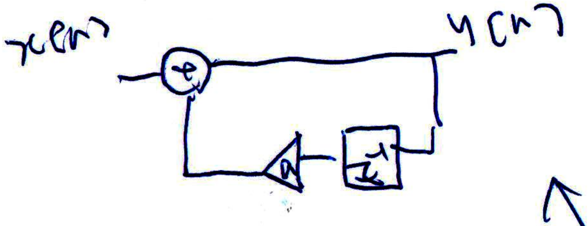
$$e^{+j2\pi fn} \xrightarrow{} \boxed{\text{DT LTI}} \xrightarrow{} H(e^{j2\pi f}) \cdot e^{+j2\pi fn}$$

$$\cos(2\pi fn + \theta) \xrightarrow{} \boxed{\text{DT LTI}} \xrightarrow{} |H(e^{j2\pi f})| \cos\left(2\pi fn + \theta + \angle H(e^{j2\pi f})\right)$$

Pole-zero plot

$$z^n \xrightarrow{} \boxed{\text{DT LTI}} \xrightarrow{} H(z)\, z^n$$

2



$y[n] + a\,y[n-1] = x[n]$

z domain

$H(z) = \dfrac{Y(z)}{X(z)}$

$H(z)$

z^{-1}

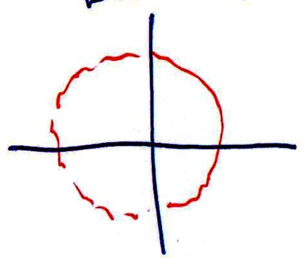
$z = e^{sT_s}$

$z = e^{j2\pi f}$

$h[n]$

$H(e^{j2\pi f})$

$Im\{z\}$



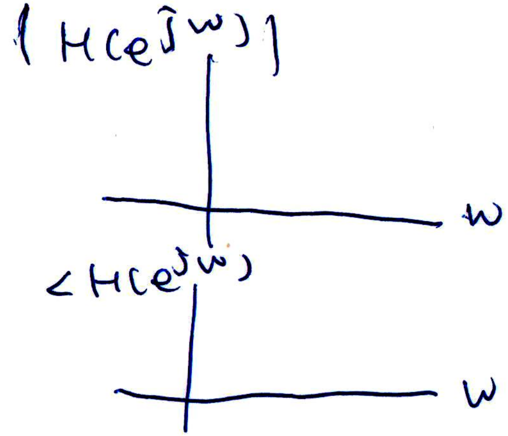
$Re\{z\}$

z-plane

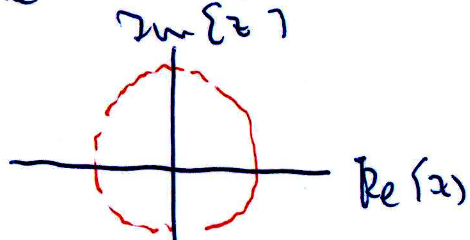
Bode Plot

③

$$\cos(2\pi f n) \longrightarrow \boxed{\begin{matrix}DT\\LTI\end{matrix}} \longrightarrow |H(e^{j2\pi f})| \cos(2\pi f n + \angle H(e^{j2\pi f}))$$



Pole-Zero plot



Nyquist stability (causal)

stable $\longleftrightarrow$ 所有的pole要在單位圓內

BIBO stability

$\sum_{n=-\infty}^{+\infty} |h[n]| < \infty$ absolutely summable

收斂區間包含單位圓

DTFT存在

$$H(z) = \frac{1}{1-az^{-1}}$$

$|z|>|a|$: $h(n) = a^n u(n)$

$|z|<|a|$: $h(n) = -a^n u(-n-1)$

causal 收斂區間在最外面pole的外面

BIBO stability + causal

所有pole要在單位圓內

收斂區間在最外面pole的外面

Table 12 ZT Basic Function

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$h[n]=\frac{1}{j2\pi}\oint_c H(z)z^{n-1}dz$	$H(z)=\sum_{n=-\infty}^{+\infty} h[n]z^{-n}$ $ROC: R_x$
$h[n]=a^n u[n]$	$H(z)=\frac{1}{1-az^{-1}}$ $ROC: \|z\|>\|a\|$
$h[n]=-a^n u[-n-1]$	$H(z)=\frac{1}{1-az^{-1}}$ $ROC: \|z\|<\|a\|$
$h[n]=(n+1)a^n u[n]$	$H(z)=\frac{1}{(1-az^{-1})^2}$ $ROC: \|z\|>\|a\|$
$h[n]=-(n+1)a^n u[-n-1]$	$H(z)=\frac{1}{(1-az^{-1})^2}$ $ROC: \|z\|<\|a\|$
$h[n]=\delta[n]$	$H(z)=1$ $ROC: all\ z-plane$
$h[n]=\delta[n-n_o]$	$H(z)=z^{-n_o}$ $ROC: all\ z-plane$
$h[n]=u[n]$	$H(z)=\frac{1}{1-z^{-1}}$ $ROC: \|z\|>1$
$h[n]=\cos(\omega_o n)u[n]$	$H(z)=\frac{1-\cos(\omega_o)z^{-1}}{1-2\cos(\omega_o)z^{-1}+z^{-2}}$ $ROC: \|z\|>1$
$h[n]=\sin(\omega_o n)u[n]$	$H(z)=\frac{\sin(\omega_o)z^{-1}}{1-2\cos(\omega_o)z^{-1}+z^{-2}}$ $ROC: \|z\|>1$
$h[n]=a^n\cos(\omega_o n)u[n]$	$H(z)=\frac{1-a\cos(\omega_o)z^{-1}}{1-2a\cos(\omega_o)z^{-1}+a^2z^{-2}}$ $ROC: \|z\|>a$
$h[n]=a^n\sin(\omega_o n)u[n]$	$H(z)=\frac{a\sin(\omega_o)z^{-1}}{1-2a\cos(\omega_o)z^{-1}+a^2z^{-2}}$ $ROC: \|z\|>a$

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Table 16 ZT Basic Property

$h[n]=\frac{1}{j2\pi}\oint_c H(z)z^{n-1}dz$	$H(z)=\sum_{n=-\infty}^{+\infty} h[n]z^{-n}$ $ROC: R_h$
$ah_1[n]+bh_2[n]$	$aH_1(z)+bH_2(z)$ $ROC: R_{h_1}\cap R_{h_2}$
$h_1[n]*h_2[n]$	$H_1(z)H_2(z)$ $ROC: R_{h_1}\cap R_{h_2}$
$h[n-n_o]$	$z^{-n_o}H(z)$ $ROC: R_h$
$a^n h[n]$	$H(\frac{z}{a})$ $ROC: \|a\| R_h$
$h[n]-h[n-1]$	$(1-z^{-1})H(z)$ $ROC: R_h$
$\sum_{m=-\infty}^{n} h[m]$	$\frac{1}{1-z^{-1}}H(z)$ $ROC: R_h \cap \|z\| \gtrless 1$
$nh[n]$	$-z\frac{d}{dz}H(z)$ $ROC: R_h$