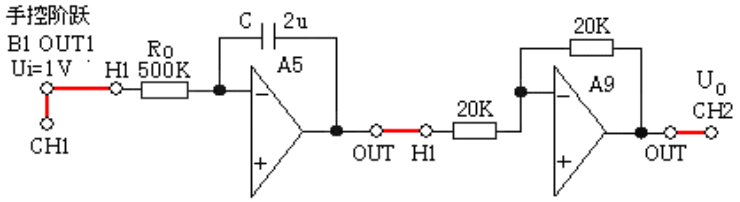
×0.632

T

1.1.1.3

1-1-3

$$G(S)=\frac{U_O(S)}{U_i(S)}=\frac{1}{TS} \qquad T_i=R_0C \qquad U_0(t)=\frac{1}{Ti}t$$



1-1-3

1-1-3

a

1	A5	S5 S11 S12

b

1	Ui	B1	OUT1 H1
2		A5	OUT H1
3		B1	OUT1 CH1
4		A9	OUT CH2

1

0

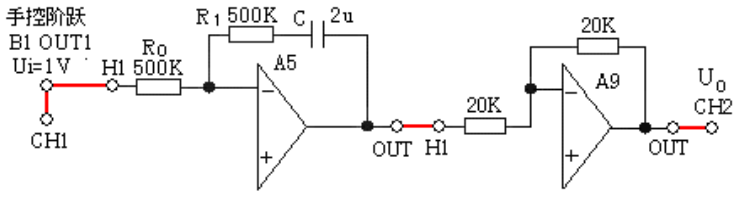
0 Ti

Ti

Ti 1

1.1.1.4

1-1-4 .



1-1-4

$$G(S)=\frac{U_O(S)}{U_i(S)}=K(1+\frac{1}{TiS}) \qquad K=\frac{R_1}{R_0} \qquad T_i=R_1C$$

$U_O(t)=K \quad 1+\frac{1}{T}t$

1 1-1-4

a

1	A5	S5 S6 S7

b

1	Ui	B1 OUT1	H1
2		A5 OUT	H1
3		B1 OUT1	CH1
4		A9 OUT	CH2

2

0 0

Ti

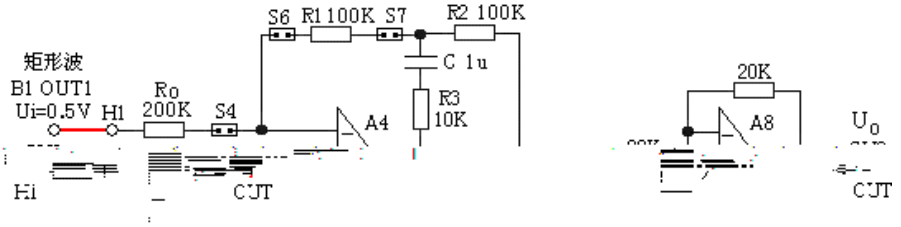
Ti

Ti 1

K×

1.1.1.5

1-1-5



1-1-5

+

$$G(S)=\frac{U_O(S)}{U_i(S)}=K(\frac{1+TS}{1+\tau S})$$

$$T_D=(\frac{R_1R_2}{R_1+R_2}+R_3)C \qquad \tau=R_3C \qquad K=\frac{R_1+R_2}{R_0}$$

$$K_D=\frac{(R_1 // R_2)+R_3}{R_3} \qquad T_D=K_D\times\tau=0.06S$$

$$U_0(t)=KT\delta(t)+K$$

1 1-1-5

a

1	A4	S4 S6 S7

2

b

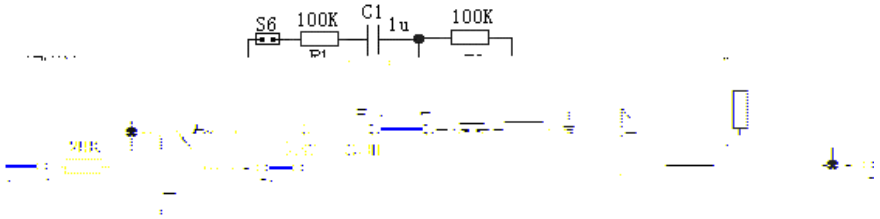
1	Ui	B1 OUT1	H1
2		A4 OUT	H1
3		A8 OUT	CH2

Uo 1.1V 0.5V
0.632

KD=6 1-1-5 $T_D = K_D \times \tau = 0.06S$
A D
Tek

1.1.1.6 PID

PID 1-1-6



1-1-6 PID

$$G(S) = \frac{U_O(S)}{U_i(S)} = K_P + \frac{K_P}{T_i S} + K_P T_d S$$

T_d $(\frac{R_1 R_2}{R_1 \quad R_2} \quad R_3)C_2$, $T_i = (R_1 + R_2)C_1$, $K_P = \frac{R_1 + R_2}{R_0}$

K_D $\frac{(R_1 // R_2) \quad R_3}{R_3}$

$\tau = R_3 C_2$ $T_d = K_D \times \tau$

$$U_0(t) = K_p T_D \delta(t) + K_P + \frac{K_p}{T} t$$

1 1-1-6

a b

1	A4	S4 S6

1 Ui

2

Ti 1-1-12

A4 S7 A8 Uo

1.6V 0.3V=Kp*Ui 0.632

KD=6 1-1-6 $T_d = K_D \times \tau = 0.06S$

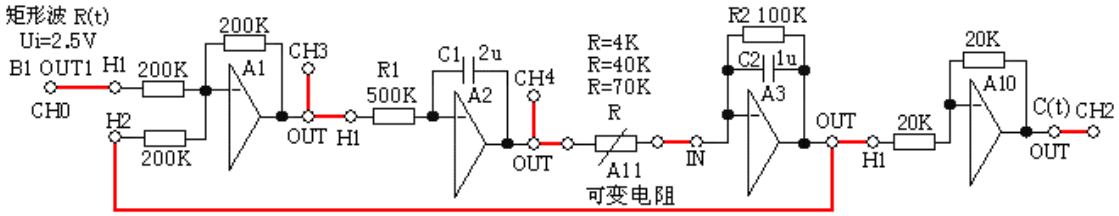
A D

Tek

1.1.2

1-1-7 A2 A3

Ti=R1*C1=1 T=R2*C2=0.1



1-1-7

$$G(S) = \frac{K}{TiS(TS+1)} = \frac{K}{S(0.1S+1)} \qquad K = \frac{R_2}{R} = \frac{100k}{R}$$

$$\phi(s) = \frac{\omega_n^2}{S^2 + 2\xi\omega_n S + \omega_n^2} = \frac{10K}{S^2 + 10S + 10K}$$

1-1-7 A3 R

K

1 1-1-7

a

1	A1	S4 S8
2	A2	S5 S11 S12
3	A3	S8 S11

b

1		B1 OUT1 H1
2		A1 OUT H1
3		A3 OUT H2
4		A3 OUT H1
5	4K	A11
6	40K 70K	A2 OUT A3 IN
7		A10 OUT CH2

CH4 .

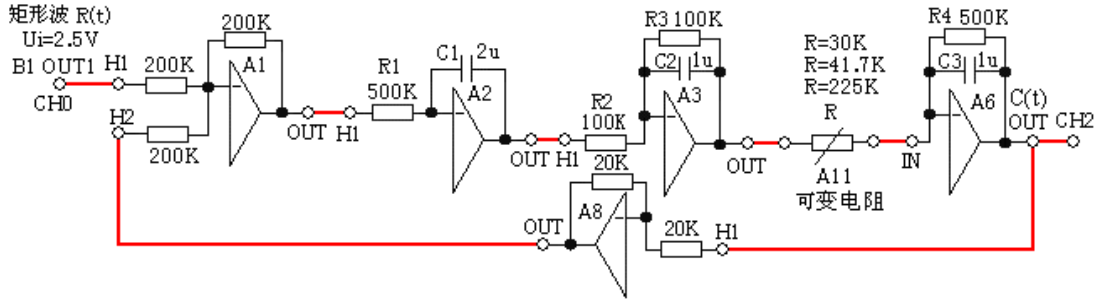
2

A11 4K 40K 70K

K A10 C(t)

1.1.3

1-1-8 A2 A3
A6 Ti=R1*C1=1 A3 T1=R3*C2=0.1
K1=R3/R2=1 A6 T2=R4*C3=0.5 K=R4/R=500K/R



1-1-8

$$G(S)=\frac{K}{S(0.1S+1)(0.5S+1)}=\frac{K}{0.05S^3+0.6S^2+S}$$

$$\phi(S)=\frac{K}{S(0.1S+1)(0.5S+1)+K}=\frac{K}{0.05S^3+0.6S^2+S+K}$$

1-1-8 A11 K=16.7 K=12
K=2.22 A6 H1 IN
1 1-1-8
a b

1	A1	S4 S8
2	A2	S5 S11 S12
3	A3	S3 S8 S11
4	A6	S9 S10

2

1		B1 OUT1 H1
2		A1 OUT H1
3		A2 OUT H1
4		A6 OUT H1
5		A8 OUT H2
6	225K	A11
7	41.7K 30K	A3 OUT A6 IN
8		A6 OUT CH2

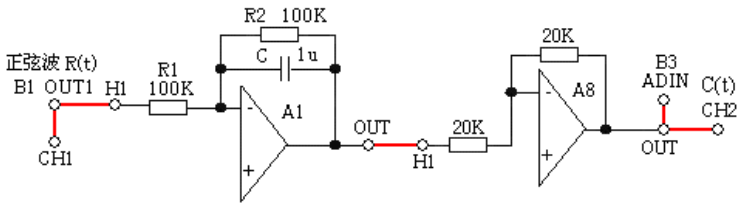
A6 C t

1.2

1.2.1

1-2-1

$\omega = 1/T$



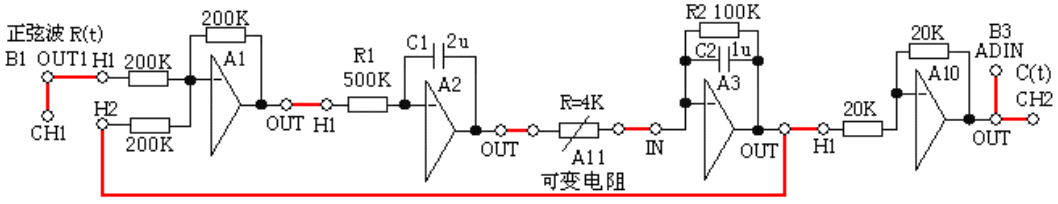
1-2-1

1-2-1 K=1 T=0.1 $\omega = 1/T = 0.1\text{rad/s}$

1 1-2-1

a b

2



1-2-2

1-2-2 A2

Ti=R1*C1=1

A3 T=R3*C2=0.1 K=R3/R

K=25 R=4K

1 ω_r $L(\omega_r)$

2

1.2.2

a

1	A1	S4 S8
2	A2	S5 S11 S12
3	A3	S8 S11

b

1		B1 OUT1 H1
2		A1 OUT H1
3		A3 OUT H1
4 5	4K	A11 A2 OUT A3 IN
6		A3 OUT H2
7		A10 OUT ADIN
8		A1 H1 CH1
9		A10 OUT CH2

2

-

r r)

L ω ω_r

$L(\omega_r)$

φ ω

φ

r L r)

r

L φ Im Re

1.2.3

1 1-2-2

ω_c γ

2

ω_c γ

1 1.2.2

2

-

ω_C

L ω $L(\omega) = 0$

ω_C

ω_C

ω_C

L φ Im Re

-

-

1.3

1.3.1

1 $L(\omega)$ $\varphi(\omega)$

,

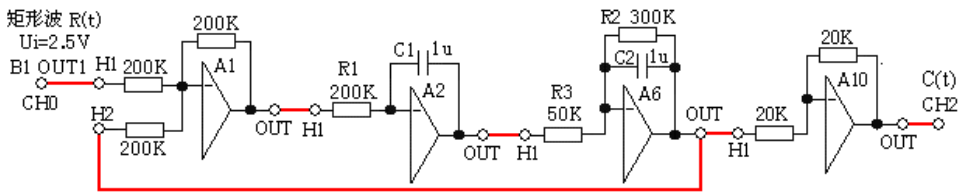
2 Mp

t_P

3 ,

Mp t_P

1 1-3-1



1-3-1

1-3-1

$$G(S)=\frac{6}{0.2S(1+0.3S)}$$

1 1-3-1

a b

1	A1	S4 S8
2	A2	S4 S11

1		B1 OUT1	H1
2		A1 OUT	H1
3		A2 OUT	H1
4		A6 OUT	H2
5		A6 OUT	H1
6		A10 OUT	CH2
7		A10 OUT	ADIN

3	A6	S3 S8 S10

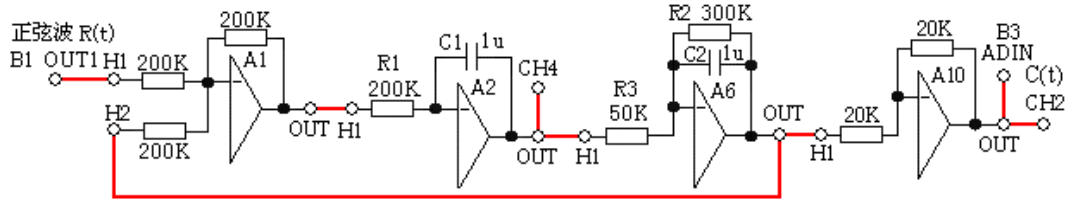
2

Mp= 59% tp= 0.336S ts= 1.8S(Δ =5)

2

1-3-2 1-3-1

A10 OUT ADIN



1-3-2

1

2

-

L $L(\omega)=0$ ω

$L(\omega)=0$ $\omega_c=9.28rad/s$ φ

ω $\varphi=161^\circ$

$\gamma=180^\circ-161^\circ=19^\circ$

1.2.3

9.44rad/s 19 °

3

°

2 °

$\varphi_m=\gamma'-\gamma+\quad=52^\circ-19^\circ+9^\circ=42^\circ \quad Sin\varphi_m=0.67$

Δ $\gamma(\omega_C \quad \omega_C')$ 5 ~10 °

$$a=\frac{1+\sin\varphi_m}{1-\sin\varphi_m}=\frac{1+0.67}{1-0.67}=5$$

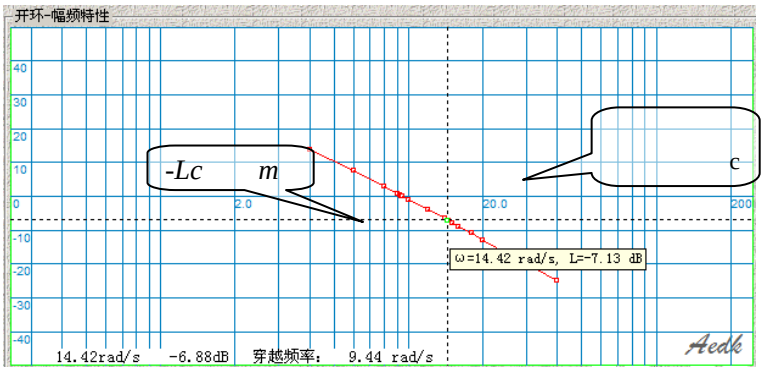
φ_m

$$L_C(\varphi_m)=10\lg a=10\lg 5=7dB$$

L $L(\omega)=-7dB$ ω

$L(\omega)=-7dB$ ω_m=14.4 rad/s 1-3-3

ω_c'



1-3-3

$$T=\frac{1}{\omega_m\sqrt{a}}=\frac{1}{14.4\times 2.24}=0.031$$

C=1u R4=155K R5=38.7K

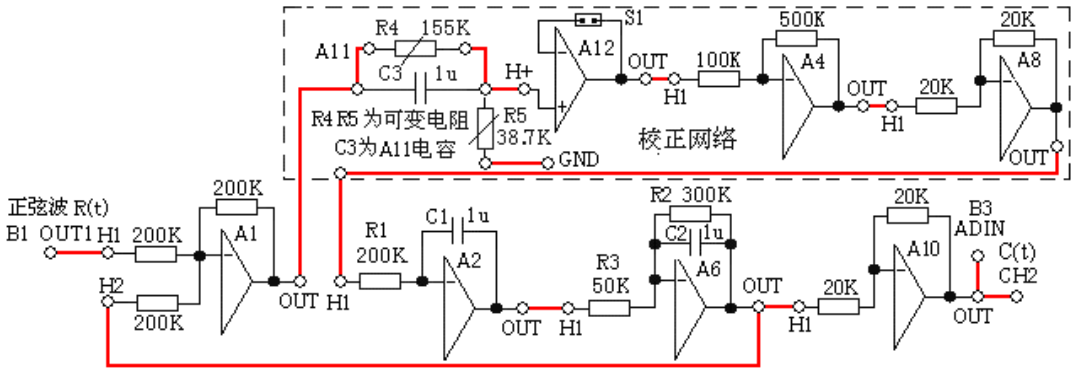
3-3-7

a

a a=5 5 A4

4

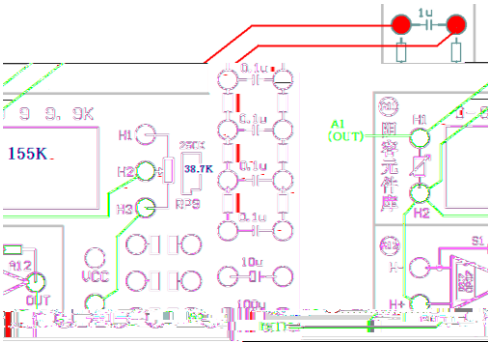
1-3-4



1-3-4

1-3-7

$$G(S)=\frac{1}{5}\times\frac{1+0.155S}{1+0.031S}\times\frac{30}{0.2S(1+0.3S)}$$



1-3-5

1 1-3-4 1-3-5

a b

1		B1 OUT1 H1	
2 3	155K	A11 A1 OUT A12 H+	
4 5	1u	A11 1u	
6 7	38.7K	A11 A12 H+ GND	
8		A12 OUT H1	1-3-8
9		A4 OUT H1	
10		A8 OUT H1	
11		A2 OUT H1	

2

2

L

$L(\omega)=0$

ω $L(\omega)=0$

$\omega_c=14.42rad/s$ φ

ω

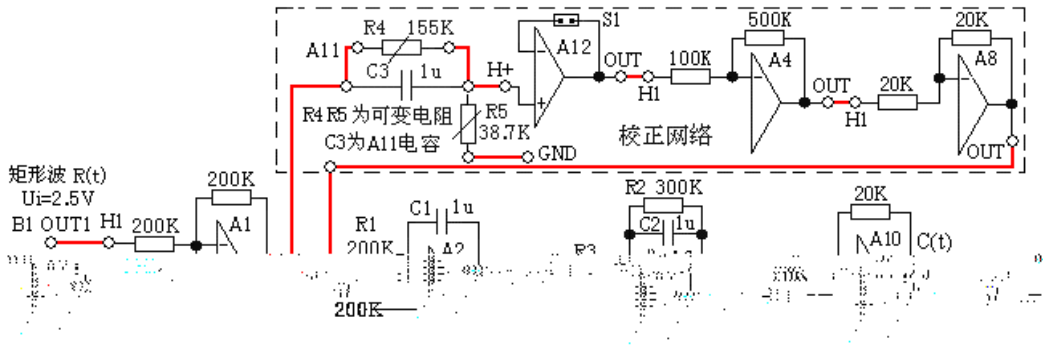
$\varphi=125^\circ$ $\gamma=180^\circ-125^\circ=55^\circ$ 1.2.3

14.42 rad/s $\gamma=180^\circ-125^\circ=55^\circ$

5

1-3-6 1-3-4

A10 OUT ADIN



1-3-6

1

2

1

Mp= 18.1%　　ts= 0.38S(Δ =5　)　　tp=0.2S

1.3.2

1　　$L(\omega)$　　$\varphi(\omega)$

,

2　　Mp

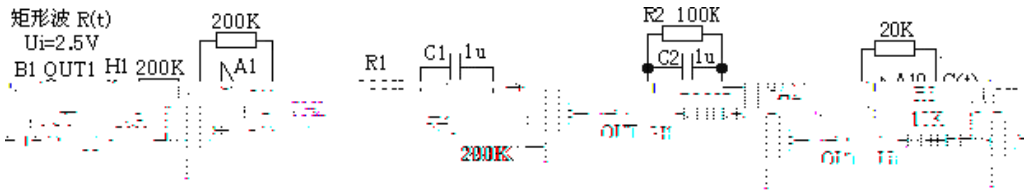
tP

3　　,

Mp　　tP

1

1-3-7



1-3-7

1-3-7

$$G(S)=\frac{10}{0.2S(1+0.1S)}$$

1　　1-3-7

a

1	A1	S4　S8
2	A2	S4　S11
3	A3	S1　S8　S11

b

1		B1　OUT1	H1
2		A1　OUT	H1
3		A2　OUT	H1
4		A3　OUT	H2
5		A3　OUT	H1
6		A10　OUT	CH2
7		A10　OUT	ADIN

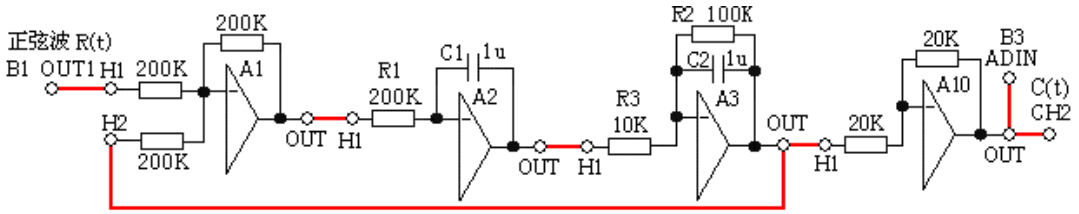
2

Mp= 50 % ts= 0.78S(Δ =5) tp= 0.15S

2

1-3-8 1-3-7

A10 OUT ADIN



1-3-8

1

2

_____ _____

-

L $L(\omega)=0$ ω

$L(\omega)=0$ $\omega_c=20.38rad/s$ φ

ω $\varphi=154^\circ$

20.38rad/s $26^\circ\gamma=180^\circ-154^\circ=26^\circ$

1.2

3

ω_C' $\varphi(\omega_C')$

$\gamma'=\gamma(\omega_C')+\varphi(\omega_C')$ $\varphi(\omega_C')=-11^0$ $\gamma(\omega_C')=52^0+11^0=63^0$

φ $\varphi(\omega)=63^0-180^0=-117^0$

ω $\varphi(\omega)=-117^0$ ω =6.29 rad/s

1-3-17

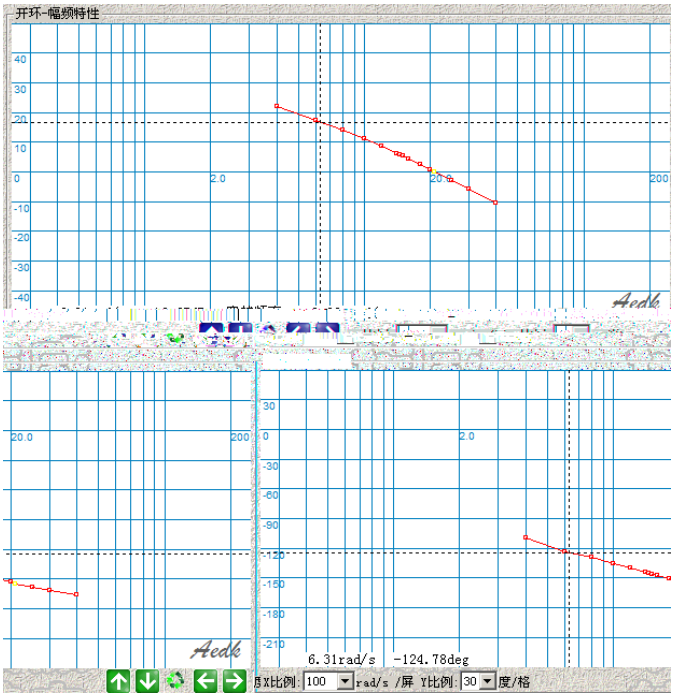
L ω =6.29 rad/s

$L(\omega_C')=-16.3dB$

$-20lgb=L(\omega_C')$ $b=0.15$

$T=\frac{1}{0.1\omega_C'\times b}=10.34$ C=10u R4=159K R5=875K

$$G_C(S)=\frac{1+1.59S}{1+10.34S}$$



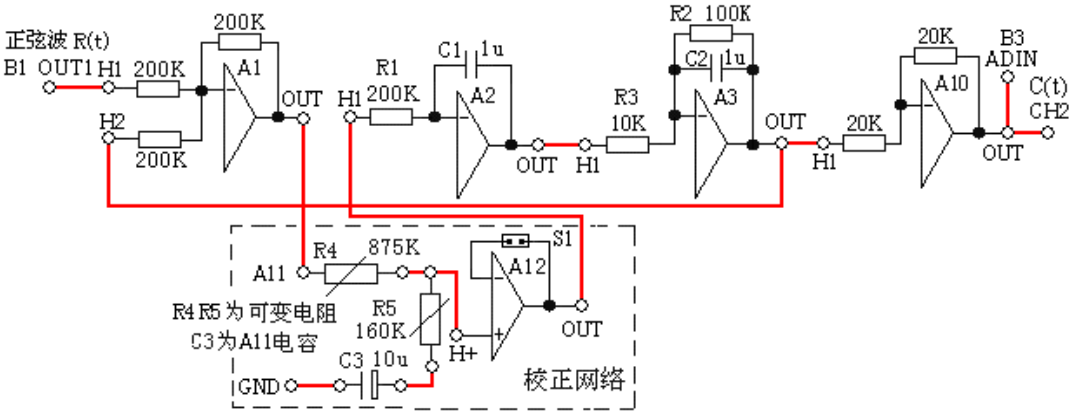
1-3-17

4

1-3-9

1-3-18

$$G(S)=\frac{1+1.59S}{1+10.34S}\times\frac{10}{0.2S(1+0.1S)}$$



1-3-9

1-3-10

2

2

L $L(\omega) = 0$ ω

$L(\omega) = 0$

1.3.3

1 Mp ,

2 Mp tP

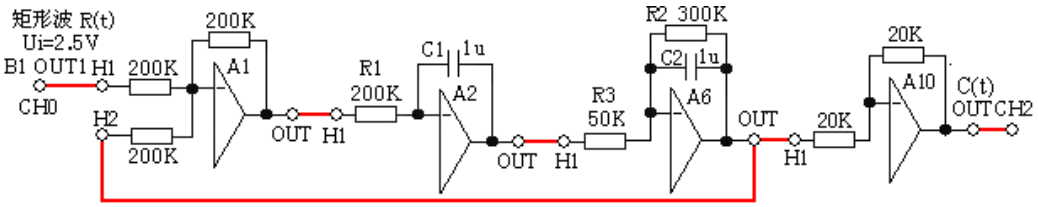
3 Mp ,

Mp tP

1

1-3-12

1-3-12 $$G(S)=\frac{6}{0.2S(1+0.3S)}$$



1-3-12

1 1-3-12

a b

1		B1 OUT1 H1
2		A1 OUT H1
3		A2 OUT H1
4		A6 OUT H2
5		A6 OUT H1
6		A10 OUT CH2

1	A1	S4 S8
2	A2	S4 S11
3	A6	S3 S8 S10

2

Mp= 59% tp= 0.336S n=10 =0.1667

2

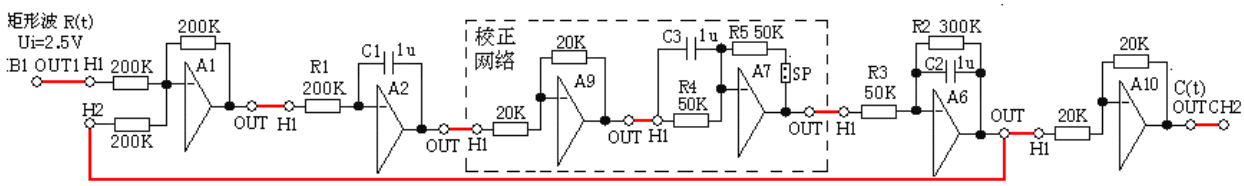
-

0467

Td=0.05 Kd=1 C3=1u R4=50K R5=50K

1-3-13

$$G(S)=\frac{6}{0.2S(1+0.3S)}\times(1+0.05S)$$



1-3-13 -

1 1-3-13

a

1	A1	S4 S8
2	A2	S4 S11
3	A6	S3 S8 S10
4	A7	S3 S1 S10 SP

b

1		B1 OUT1 H1
2		A1 OUT H1
3		A2 OUT H1
4		A9 OUT H1
5		A7 OUT H1
6		A6 OUT H1
7		A6 OUT H2
8		A10 OUT CH2

2

_____ _____ 1

Mp=28 % tp= 0.3S

1.3.4

1 Mp ,

2 Mp tP

3 Mp ,

Mp tP

1

1-3-14

1-3-14

1-3-14 $G(S)=\frac{6}{0.2S(1+0.3S)}$

A2 Ti=R1*C1=0.2S

A6 T=R2*C2=0.3S K=R2/R3=6

1 1-3-14

a b

1		B1 OUT1 H1
2		A1 OUT H1
3		A2 OUT H1
4		A6 OUT H2
5		A6 OUT H1
6		A10 OUT CH2

1	A1	S4 S8
2	A2	S4 S11
3	A6	S3 S8 S10

2

Mp= 59% tp= 0.336S *n=10* *=0.16767*

2

1-3-14

1-3-15 A2 R7/R4

A7

$$K_x = K \div K_a = R6 \div R5$$

1-3-14 Ti = 0.2S K =6 $G_a(S)$

Ta

$\xi = \frac{1}{2}\sqrt{Ti/KT_a}$ $G_a(S)$ $T_a = 0.052$

1-3-14 T=0.3S K =6

$G_a(S)$ Ta=0.052 3-3-17 a=0.795

R7=10K R4=10K÷0.795=12.6K R4 A11

K=6 a=0.795 $G_a(S)$

Ka=1.04 K=6

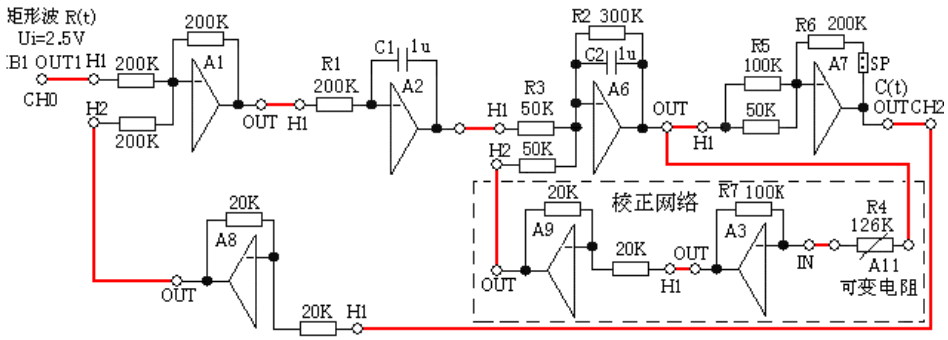
$K_X = K \div K_a$ $K_x = K \div K_a = 6 \div 1.04 = 5.77$

A7 R6=200K R5=200K÷5.77=34.7K

R5=100K 50K=33.3K

3

1-3-15



1-3-15

1 1-3-15

a b

2

1

1-3-34

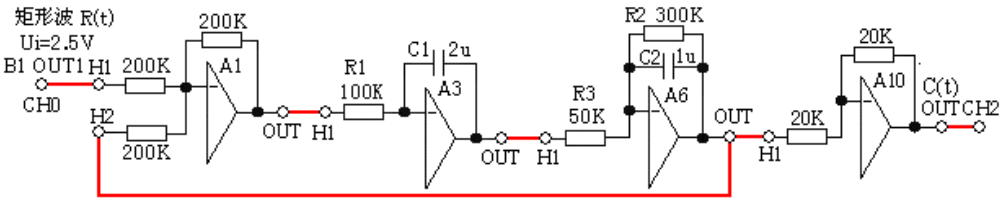
Mp=28 % tp= 0.16S

1.3.5

1 Mp ,

2 Mp tP

3



1-3-16

1-3-16 A5

Ti=R1*C1=0.2S

A6 T=R2*C2=0.3S K=R2/R3=6

$$G(S)=\frac{6}{0.2S(1+0.3S)}=\frac{100}{S^2+3.33S}$$

$$\omega_n=10 \qquad \xi=0.1665$$

$$M_P=e^{-\frac{\xi\pi}{\sqrt{1-\xi^2}}}\times 100\%=59\% \qquad t_p=\frac{\pi}{\omega_n\sqrt{1-\xi^2}}=0.32$$

1 1-3-16

a b

1	r(t)	B1 OUT1 H1
2		A1 OUT 3 H1
3		A3 OUT H1
4		A6 OUT H2
5		A6 OUT H1
6		A10 OUT CH2

2

1	A1	S4 S8
2	A3	S3 S11 S12
3	A6	S3 S8 S10

Mp= 57.2 % tp= 0.332S ts= 1.8S(Δ =5)

2

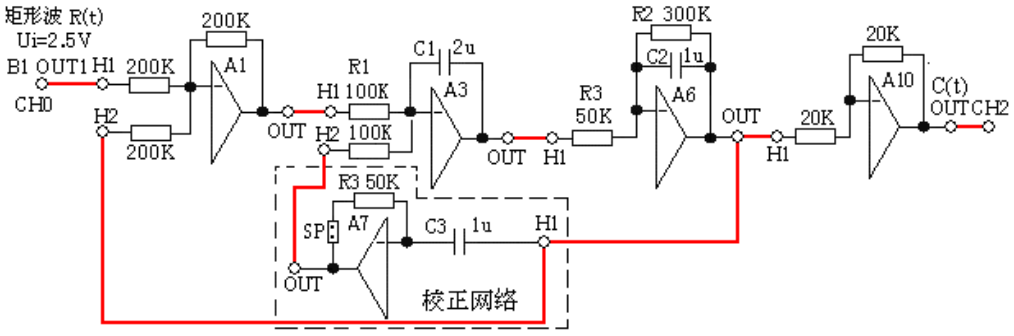
$$\xi_t \geq 0.4$$

1-3-16 Ti = 0.2S $\omega_n=10$

$\xi=0.1665$ 3-3-22 Kf=0.0467

C3=1u Kf =0.0467 3-3-25

R3=46.7K R3=50K 1-3-17



1-3-17

1 1-3-17

a

1	A1	S4 S8
2	A3	S3 S11 S12
3	A6	S3 S8 S10
4	A7	S1 S10 SP

b

1	r(t)	B1 OUT1 H1
2		A1 OUT 3 H1
3		A3 OUT H1
4		A6 OUT H2
5		A6 OUT H1
6		A6 OUT H1
7		A7 OUT H2
8		A10 OUT CH2

2

1

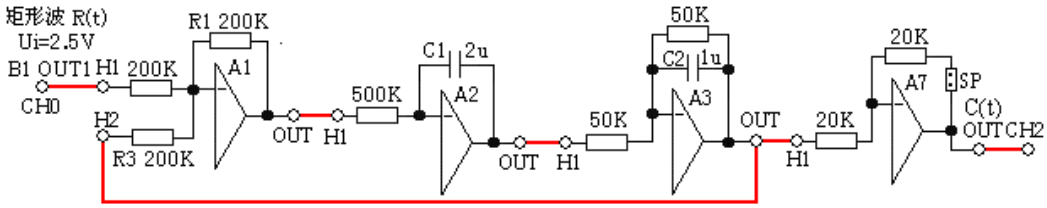
1-3-40

Mp= 23.1 % tp= 0.36S

1.3.6

1

1-3-18



1-3-18

1 1-3-18

1		B1 OUT1 H1

a

b

1	A1	S4 S8
2	A2	S5 S11 S12
3	A3	S2 S7 S11
4	A7	S2 S9 SP

2		A1	OUT	H1
3		A2	OUT	H1
4		A3	OUT	H1
5		A3	OUT	H2
6		A7	OUT	CH2

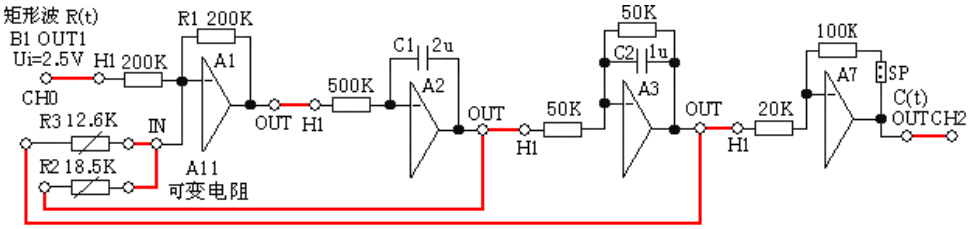
2

2

1-3-18 M_P

t_P 1-3-19

K1=-10.8=R1/R2 R1=200K R2=9.3K K2=15.8=R1/R3 R1=100K R3=6.3K



1-3-19

1 1-3-19

a b

1	A1	S4 S8
2	A2	S5 S11 S12
3	A3	S2 S7 S11
4	A7	S2 S11 SP

1		B1	OUT1	H1
2		A1	OUT	H1
3		A2	OUT	H1
4		A3	OUT	H1

5

6 R2= [redacted]

2

1

1-3-49

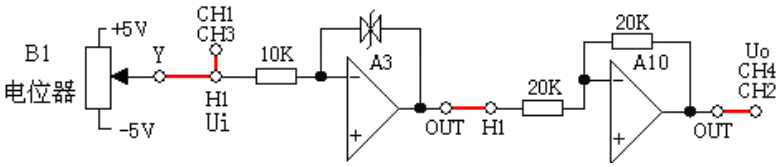
Mp 20% tp=0.36S

1.4

1.4.1

1.4.1.1

1 1-4-1



1-4-1

X-Y

1 1-4-1

a b

	1		B1 Y H1
	2		A3 OUT H1
	3/4		A3 H1 CH3 CH1
	5/6	×1	A10 OUT CH4 CH2

1	A3	S1 S13

2

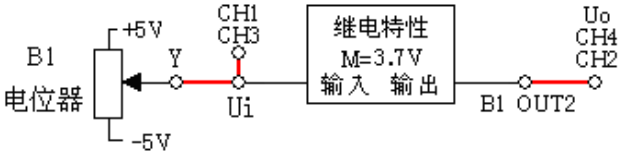
_____ - _____ _____

B1

-5V~+5V

2

1-4-2



.

1-4-2

1 1-4-2

1/2		B1 Y B2 CH3 CH1
3/4		B1 OUT2 B2 CH4 CH2

2 X-Y

_____ - _____ _____ _____

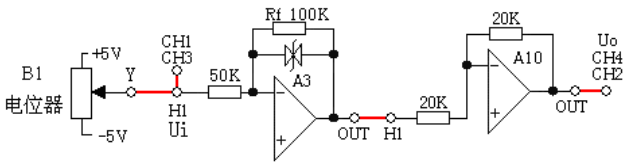
B1

-5V~+5V

1.4.1.2

1

1-4-3



1-4-3

1 1-4-3

a b

1		B1 Y H1
2		A3 OUT H1
3		A3 H1 CH3
4	×1	A10 OUT CH4

1	A3	S2 S8 S13

2

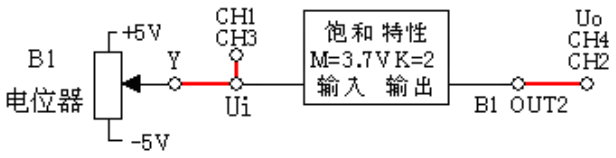
\- B1

-5V~+5V

X-Y

2

1-4-4



1-4-4

1 1-4-4

1/2		B1 Y B2 CH3 CH1
3/4		B1 OUT2 B2 CH4 CH2

2

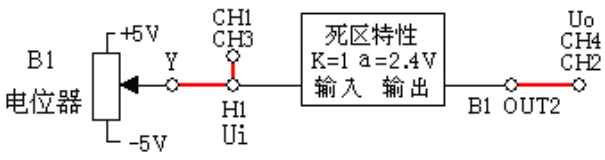
\- B1

-5V~+5V

X-Y

1.4.1.3

1-4-5



1-4-5

1 1-4-5

1/2		B1 Y B2 CH3 CH1
3/4		B1 OUT2 B2 CH4 CH2

2

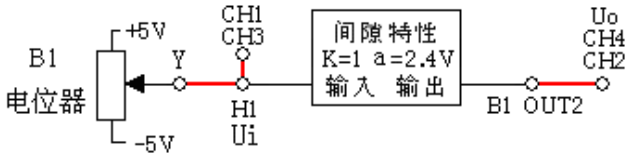
-

B1 -5V~+5V

X-Y

1.4.1.4

1-4-6



1-4-6

1 1-4-6

3	A3	S2 S11 S12

1		B1 OUT1	H1
2		A8 OUT	H1
3		A1	CH3 X
4		B1 OUT2	H1
5		A2 OUT	H1
6		A3 OUT	H2
7		A3 OUT	CH2
8		A2	CH4 Y

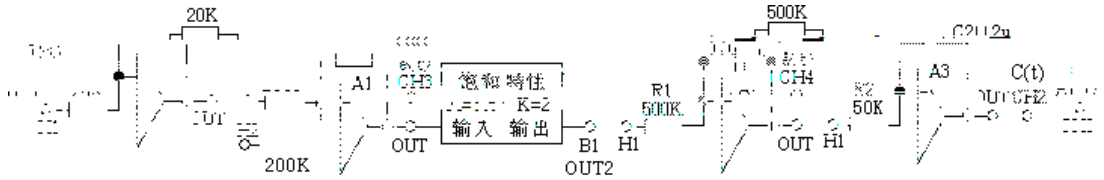
2

-

X-Y

1.4.2.2

1-4-8



1-4-8

1 1-4-8

a b

1	A1	S4 S8
2	A2	S5 S10 S11
3	A3	S2 S11 S12

1		B1 OUT1	H1
2		A8 OUT	H1
3		A1	CH3 X
4		B1 OUT2	H1
5		A2 OUT	H1
6		A3 OUT	H2
7		A3 OUT	CH2
8		A2	CH4 Y

2

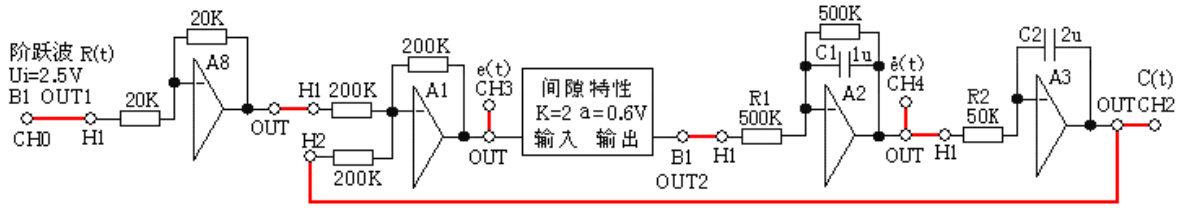
-

X-Y

MP(%) t_P

1.4.2.3

1-4-9



1-4-9

1 1-4-9

a b

1	A1	S4 S8
2	A2	S5 S10 S11
3	A3	S2 S10 S11

2

-

1		B1 OUT1	H1
2		A1	CH3 X
3		B1 OUT2	H1
4		A2 OUT	H1
5		A3 OUT	H1
6		A3 OUT	H2
7		A3 OUT	CH2
8		A2	CH4 Y

X-Y

1.4.3

$$G(S)=\frac{K_1K_2}{TiS(T_1S+1)(T_2S+1)}$$

1

CH1

CH2 CH3 CH4 CH3 X CH4 Y

2 CH3 $\dot{e}$

CH4

X-Y

A

T A

3 X-Y

e-e

4

k

e-e

1.4.3.1

1-4-10

1-4-10

1 1-4-10

a b

1	A1	S4 S8
2	A2	S5 S10 S11 S12
3	A3	S5 S11 S12
4	A6	S9 S10

1		B1 OUT1 H1
2		A8 OUT H1
3		X
4		B1 OUT2 H1
5		A9 OUT H1
6 7	500K	A11 A2 OUT A6 IN
8		A6 OUT H1
9		A3 OUT H2
10		A3 OUT CH2
11		A6 Y

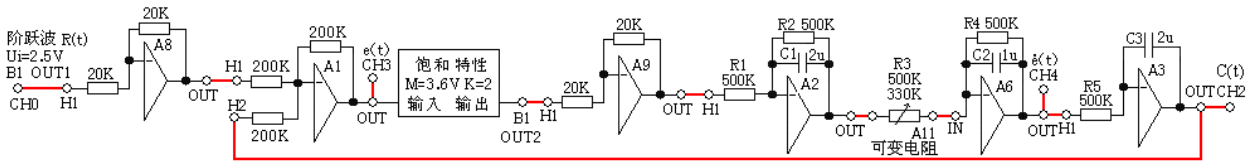
2

_____ - _____ _____

X-Y

1.4.3.2

1-4-11



1-4-11

1 1-4-11

a

1	A1	S4 S8
2	A2	S5 S10 S11 S12
3	A3	S5 S11 S12
4	A6	S9 S10

b

1		B1 OUT1 H1
2		A8 OUT H1
3		X
4		B1 OUT2 H1
5		A9 OUT H1
6		A11
7	330K 500K	A2 OUT A6 IN
8		A6 OUT H1
9		A3 OUT H2
10		A3 OUT CH2
11		A6 Y

2

-

R3=500K G

MP(%)

k=2 K2 R3

A11 330K K=1.51 G

1-4-35

R3 500K K=3 k G