zw

1 1

1.1 I

DCT[[gA‘BIB

1.2

AoAog‘A

$$[x] = [s]\ g[1/s]\ 360[x] \tag{1}$$

oB
@A$RWFl[ADCT[[]][[@@BARWFl[]xDCT[[A]x\omega(t)ARWFl[oM(d@q[qUNNd)y_{dv}(t)$A

$$y_{dv}(t) = k'_E\omega(t) \tag{2}$$

BA$RWFl[tNd$k$'_E$B]A(2)A$RWFl[A]xdoMoAxpB$
@$A|eV[Ad@q]JbvOpgpug@BA]p\theta(t)$doMBA—eV[$oM([qNd)y_{dp}(t)$A—eV[k$_P$

$$y_{dp}(t) = k_P\theta(t) \tag{3}$$

BA1]—eV[360$x]dZbgfqA|eV[dllAeX0x360xB$
@$Axug@bBA$‘$BGBA, DCT[[$‘o‘$BP(s)Axu1ubNBA$k$_Y$ xk'_Euk_PAC(s)pAiOH‘BAP(s)‘BBAPOmCYB

1: ItB[hobNnubN

Ax‘B$P_V(s)$A

$$P_V(s) = \frac{k_A k'_E/k_E}{(1+sT_E)(1+sT_M)} = \frac{K}{(1+sT_E)(1+sT_M)} \tag{4}$$

BAu‘B$P(s)$A

$$P(s) = \frac{k_A k_P/k_E}{s(1+sT_E)(1+sT_M)} = \frac{K\ \frac{k_P}{k'_E}}{s(1+sT_E)(1+sT_M)} \tag{5}$$

BAk_AAk_Ed@qtNdAT_EdCIAT_M@BIA$K = \frac{k_A k'_E}{k_E}$BA

$$T_E \ll T_M \tag{6}$$

BAux‘BWB

$$P(s) = \frac{k_P}{sk'_E}P_V(s) \tag{7}$$

1.3 @

1.3.1 1-1

1. Axo$RWFl[pA2uBAd()dDCT[[id24VAt@NVWFl[$‘$FG)gB$

AIVXR[vCH1ACH2v[u2B

1.4 gp@

- $RWFl[tDCT[[^(VdCHSS40E2 - T0) : 1Fd^DCT[[EhCo((VdCHMS - 100V05) : 1$

- 1]5kΩ—eV[^($dYRpdqJ40S) : 110]10kΩ—eV[^($dYRpdqM22E10) : 1
- JbvO(ATdqH) :1
- fW$EIVXR[v(IWATSUDS - 5110B) : 1fWEIVXR[vv[u : 2$
- t@NVWFl[^($TEXIOFGX - 2112) : 1d()(KENWOODPS36 - 10) : 1$
- d()(PR18-1.2A) :1
- DC/DCRo[^($SUW30515C) : 1ubh[h : 1$
- WvC[
- jNbv

1.5

A1-1,1-2[hAGain5,6A7,8LB

5: 1-1(x)Gain[h

6: 1-2(u)Gain[h

7: 1-1(x)[h

8: 1-2(u)[h

A2.1A$RWFl[og‘(CH1)GlA|eV[og‘(CH2) - 15V + 15VEmRMgBl$
$reftabhomework2 - 1LB$

1.6 l@

(1)2.1
@$k_P k'_E$oBAk_PAq1]—eV[lA
$reftabhomework2-1mRMgA$y$_{dp}(t)$-15V+15VAeX0x360xlBA360x30VdolA(3)k_PA

$$k_P = \frac{y_{dp}(t)}{\theta(t)} = \frac{30[V]}{360[x]} \sim 4.8[V/rad] \tag{8}$$

BAk'_EA
reftab homework2-1]x$\omega(t)$

$$\omega(t) = \frac{2\pi}{T} = \frac{2\pi}{70.4m}[rad/s] \tag{9}$$

xBA$y_{dv}(t)$
reftab homework2-12.8[V]B]A(2)(9)k'_EA

$$k'_E = \frac{y_{dv}(t)}{\omega(t)} = \frac{2.8[V]}{\frac{2\pi}{70.4m}\ \frac{60}{2\pi}[rpm]} \sim 3.3[V/krpm] \tag{10}$$

BAJOlk$'_E = 3[V/krpm]$Aok'_ElB $k_P k'_E$pPpKvqBA

$$\frac{k_P}{k'_E} \sim 152[1/s] \tag{11}$$

B

(2)2.3
@(6)Apg$\frac{1}{T_M} \ll \frac{1}{T_E}$A(4)[hT‘AE9lBAQA$IgBA9iKA5\frac{}{T_M}\frac{1}{5T_E}$WA9mlB
(3)2.2
@A95‘8rAK,T_M,T_EA

$$K = 1\ ,\ T_E = \frac{1}{132} \sim 0.0076\ ,\ T_M = \frac{1}{28} \sim 0.036 \tag{12}$$

B
@A(8)(10)$k_p k'_E$pA(7)6,8uxZOtA(12)lg9‘Otx57d‘[h10A11LB

10: 1-2(u)ZlAlp$P_V(s)$g1-1(x)d‘
(Gain)

11: 1-2(u)ZlAlp$P_V(s)$g1-1(x)d‘
()

@10A1-2Zl1-1vBA11A1-2Zl1-1BAv XlBA1-1IVXR[vJbvOCH1ACvlBAGainABA111-2ZlT‘BAcB
@$AGain$10(12)lpP$_V(s)$gA10lOtOtmFBA(12)llAq1OlvlB]A10AvK,T_E,T_MAF$P_V(s)$B
@Lc$lpBAq\ XA1-2ZlB11ALcFnA1-2ZlvmFBlB$
@cpK,T$_E$,T_MBA$P(s)$(5)B

$$K = 1\ ,\ T_E = 0.003\ ,\ T_M = 0.03 \tag{13}$$

@A(7)5,7xuZOtAu6,8d‘B[h12A13LBA(13)l(5)$P(s)$FnLB

12: 1-1(x)ZlA(13)lp$P(s)$g1-2(u)d‘
(Gain)

13: 1-1(x)ZlA(13)lp$P(s)$g1-2(u)d‘
()

@12A13AS[hxc$lAGain1 - 11 - 2Aq1 - 1smFBA(13)lp‘FnAGainlZldA1 - 2ndmFB$

2 2

2.1 I

@pAiOHA$I[h‘[hrIB$

2.2

@pHAL14A15]c2HB

14: uQCvH

15: uQC ivfvH

@AIyAvzIlIyAvUAIyAvCs[$X\infty$oCs[$X0lBA$14v$_-v_+$u$v_- = v_+$vWBzZB
@A14zZlgoA

$$v_{out} = K_{Ca}(v_{ref}(t) - v_{in}(t)) \tag{14}$$

BA$K_{Ca}R_{1a}R_{2a}$lQCBA1A$U(s)$,$C(s)$,$R(s)$,$Y_d(s)$

$$U(s) = C(s)(R(s) - Y_d(s)) \tag{15}$$

WA(15)tvX(14)vBA$U(s)$, $R(s)$, $Y_d(s)$tvX$u(t)$, r, $y_d(t)$A$v_{in}y_d$, $v_{ref}r$, $v_{out}u$B]A14Hp1

$$C(s) = K_{Ca} \tag{16}$$

AQCpnB
@A15HARfTHslBARfTddWAdl0A

$$I(s) = sCV(s) \tag{17}$$

pBA14Llll]A15o(15)$C(s)$

$$C(s) = K_{Cb}\frac{\alpha(1+sT)}{1+s\alpha T} \tag{18}$$

B(18)AQCK_{Cb}IvfA$\alpha < 1$ivfB

2.3 @

1. A16uBApAiOH14pKAIVXR[vv[u16BA14fqlA
   reftab sositiB

16: 2u

2. Ad()d5VAt@NVWFl[$ItZbgd0VgBAg0.2Hz500Hz[hu21IAeXgCH1ACH2peaktopeakdAGainBAt@NVWFl[UoO$

3. ApAiOH15BfqlBp[pBA
   $reftabsositiBALCH1ACH2peaktopeakdB$

2.4 gp@

- fW$EIVXR[v(IWATSUDS - 5110B) : 1fWEIVXR[vv[u : 2$

- t@NVWFl[$(TEXIOFGX - 2112) : 1d()(PR18 - 1.2A) : 1$
- DC/DCRo[$(SUW30515C) : 1IyAv(AD817AN) : 3$
- R(±1%)
  :20$k\Omega$2, 300$k\Omega$2, 470$k\Omega$2, 100$k\Omega$2, 2$k\Omega$1, 7.5$k\Omega$1
- dRfT :10μF1, 1μF1
- ubh[h :1
- WvC[
- jNbv

2.5

@pAiOH1415AGain21, 22LBA23, 24LB

17:
14Gain[h

18:
15Gain[h

19: 20:
14[h 15[h

@A17, 19GainlA0xAmQCmFBA18, 20AOtT‘muQC ivfvmFB

2.6 l@

(1)2.4
@A14od(14)mFA(16)$K_{Ca}R_{1a}$, R_{2a}WB
@A14lAv_+

$$v_+ = \frac{R_{2a}}{R_{1a} + R_{2a}} v_{ref} \tag{19}$$

BAzIIyAvlzZ(19)A

$$v_+ = v_- = \frac{R_{2a}}{R_{1a} + R_{2a}} v_{ref} \tag{20}$$

BAIyAvzIlAIyAvCs[$X0oCs$[$X\infty$A14$i(t)$IyAvB]AddA

$$\frac{v_{in} - v_-}{i(t)} = R_{1a} \tag{21}$$

$$\frac{v_- - v_{out}}{i(t)} = R_{2a} \tag{22}$$

WB(21)(22)A$i(t)$A

$$\frac{v_{in} - v_-}{R_{1a}} = \frac{v_- - v_{out}}{R_{2a}} \tag{23}$$

$$\Leftrightarrow \quad v_{out} = \frac{-R_{2a}}{R_{1a}} v_{in} + \frac{R_{1a} + R_{2a}}{R_{1a}} v_- \tag{24}$$

v_{out}B(20)(24)v_-A

$$v_{out}(t) = \frac{R_{2a}}{R_{1a}}(v_{ref}(t) - v_{in}(t)) = K_{Ca}(v_{ref}(t) - v_{in}(t)) \tag{25}$$

B]A(25)Am14od(14)BAK_{Ca}
reftab sositipA

$$K_{Ca} = \frac{R_{2a}}{R_{1a}} = \frac{300k\Omega}{20k\Omega} = 15 \tag{26}$$

AmQCB

(2)2.5

@A(18)K_{Cb}, α, T15fqlWBsc$B$

@A15Oi14Hv$_{ref}$$v_{in}$AfqlA15$v_{out1}(25)v_{out}(t)Av_{ref}$$v_{in}$fqlBA$v_{out}(t)vXV_{out}(s)AcV_{out1}(s) = \frac{R_{2b}}{R_{1b}}(V_{in}(s) - V_{ref}(s))$(27)B15iAzZlpA$v_+ = 0$

$$V_- = V_+ = 0 \tag{28}$$

BA$V_-$$V_+$$v_-$$v_+$vXB2.4llAIyAvzId$I(s)$15BA$R_{3b}$, C_1HAR_{4b}, C_2Hd$I(s)$B]A(28)sRfT(17)lABAR_{3b}, C_1HA

$$\begin{aligned} I(s) &= (\frac{1}{R_{3b}} + sC_1)(V_{out1}(s) - V_-) \\ &= (\frac{1}{R_{3b}} + sC_1)V_{out1}(s) \end{aligned} \tag{29}$$

BAR_{4b}, C_2HA

$$\begin{aligned} I(s) &= (\frac{1}{R_{4b}} + sC_2)(V_- - V_{out}(s)) \\ &= -(\frac{1}{R_{4b}} + sC_2)V_{out}(s) \end{aligned} \tag{30}$$

B(29)(30)$I(s)$A(27)p$V_{out1}(s)$A

$$\begin{aligned} -(\frac{1}{R_{4b}} + sC_2)V_{out}(s) &= (\frac{1}{R_{3b}} + sC_1)V_{out1}(s) \\ \Leftrightarrow -(\frac{1}{R_{4b}} + sC_2)V_{out}(s) &= (\frac{1}{R_{3b}} + sC_1)\frac{R_{2b}}{R_{1b}}(V_{in}(s) - V_{ref}(s)) \\ \Leftrightarrow V_{out}(s) &= \frac{R_{2b}}{R_{1b}}\frac{\frac{1}{R_{3b}} + sC_1}{\frac{1}{R_{4b}} + sC_2}(V_{ref}(s) - V_{in}(s)) \end{aligned} \tag{31}$$

B

@AqAA$U(s)$, $R(s)$, $Y_d(s)$$V_{out}(s)$, $V_{ref}(s)$, $V_{in}(s)$A(31)

$$U(s) = \frac{R_{2b}}{R_{1b}}\frac{\frac{1}{R_{3b}} + sC_1}{\frac{1}{R_{4b}} + sC_2}(R(s) - Y_d(s)) \tag{32}$$

B]A(32)(15)rA$C(s)$BA(18)pA

$$\begin{aligned} K_{Cb}\frac{\alpha(1+sT)}{1+s\alpha T} &= \frac{R_{2b}}{R_{1b}}\frac{\frac{1}{R_{3b}} + sC_1}{\frac{1}{R_{4b}} + sC_2} \\ &= \frac{C_1R_{2b}}{C_2R_{1b}}\frac{\frac{C_2R_{4b}}{C_1R_{3b}}(1 + sC_1R_{3b})}{1 + s\frac{C_2R_{4b}}{C_1R_{3b}}C_1R_{3b}} \end{aligned} \tag{33}$$

B]A(33)K_{Cb}, α, TBA

reftab sositipA

$$K_{Cb} = \frac{C_1R_{2b}}{C_2R_{1b}} = \frac{10\mu F\ 100k\Omega}{1\mu F\ 470k\Omega} \sim 2.13 \tag{34}$$

$$\alpha = \frac{C_2R_{4b}}{C_1R_{3b}} = \frac{1\mu F\ 7.5k\Omega}{10\mu F\ 2k\Omega} = 0.375 \tag{35}$$

$$T = C_1R_{3b} = 10\mu F\ 2k\Omega = 0.02[s] \tag{36}$$

BATsssAPB

(3)2.3
@(16)(18)A2.4, 2.5lA1415pAiOHg$IBA1415Ig[hdLBAGain21, 22A23, 24LBA23AlSvnB$

21:
14Gain[h

22:
15Gain[h

23:
14[h

24:
15[h

@A14[h21 , 23$lSvAlB$
@$A15[h22, 24AT$‘$GainlBRAIVXR[vvlBBAlfqlAgpR$±1%elBRfTlBOvAIyAvslBAGainOtSI$lB]A22, 24vAIyAvvlB$

3 3

3.1 I

@H[vnnAIB

3.2

@[vnA1A‘B$P(s)$‘B$C(s)$[v‘B

$$G = \frac{C(s)P(s)}{1 + C(s)P(s)} \tag{37}$$

oBAP(5)

$$P(s) = \frac{K\ \frac{k_P}{k'_E}}{s(1+sT_E)(1+sT_M)} = \frac{K'}{s(1+sT_E)(1+sT_M)} \tag{38}$$

BA(11)

$$K' = 152K \tag{39}$$

BAAgl
reftab valueLBA(13),(26),(34),(35),(36),(39)QB

3: 3gl

T_E	T_M	K	K'	K_{Ca}	K_{Cb}	α	T
0.003	0.03	1	152	15	2.13	0.375	0.02

@AEX@qBnKv1A[v‘B$\frac{(s)}{}$‘A(() = 0)SB]AEX@A@BI@A
$\Phi(s) = a_n s^n + a_{n-1}s^{n-1} + c + a_1 s + a_0$
($Kv : a_i > 0 (i = 1, 2, c, n)$)
AEX
reftab LouthAEX[lABAEXOsAvZKvA

4: EX

1	a_n	a_{n-2}	a_{n-4}	c
2	a_{n-1}	a_{n-3}	a_{n-5}	c
3	x	y	z	c
c	c	c	c	c
n+1	c	c	c	c

$$x = -\frac{1}{a_{n-1}} \begin{vmatrix} a_n & a_{n-2} \\ a_{n-1} & a_{n-3} \end{vmatrix} \tag{40}$$

$$y = -\frac{1}{a_{n-1}} \begin{vmatrix} a_n & a_{n-4} \\ a_{n-1} & a_{n-5} \end{vmatrix} \tag{41}$$

$$z = -\frac{1}{a_{n-1}} \begin{vmatrix} a_n & a_{n-6} \\ a_{n-1} & a_{n-7} \end{vmatrix} \tag{42}$$

vZAlsAsOsplvZB lvZB
@AIlqBAWl$r(t)y(t)$A$e(t) = r(t) - y(t)$BA$t \to \infty e(t)$BAIlA$f(t)$vX$F(s)$B

$$\lim_{t \to +\infty} f(t) = \lim_{s \to +0} sF(s) \tag{43}$$

@AIlgu$F(s)Re[s] \geq 0 s = 01AORe[s] < 0$vgBI$F(s)$gAIlgB

3.3 @

3.3.1 3-1

1. A25HBApAiOH14gpAd()d24VAd()d5VB

25: 3-1u

2. 10]—eV[Wld(10]|eV[[$q2d$)0.8$VBIVXR$[$vCH1v$[uv_{ref}$(Wld)[qCH2v[u$v_{in}$(oM)[qAXCb‘OFFONXebvBUSBBXCb‘OF

3. ACH2v[uv_{out}(o)[qAXCb‘OFFONXebvBUSBBXCb‘OFFB

5. ApAiOH15ALl2p[$XebvLBAWld$(10]|eV[[$q2d$)5VB

3.3.2 3-2

1. A26HBApAiOH14gpAd()d24VAd()d5VB

26: 3-2u

2. 10]—eV[Wld(10]|eV[[$q2d$)0.8$VBAXCb‘OFFAd()ONBADCT$[[$nAwy$] $Ad()OFFB$

3. ApAiOH15A10]—eV[Wld(10]|eV[[$q2d$)5$VBAXCb‘OFFAd()ONBADCT$[[BA[]w]Aw B

4. AIVXR[vCH1v[uv_{ref}(Wld)[qCH2v[uv_{in}(oM)[qAXCb‘OFFONXebvBUSBBXCb‘OFFB

5. ACH2v[uv_{out}(o)[qAXCb‘OFFONXebvBUSBBXCb‘OFFB

3.3.3 2.8

1. MATLABKvOA3-1, 3-2V [VsB

2. V [VrvmFB

3.4 gp@

- $RWFl[tDCT[[^{(}VdCHSS40E2-T0):1Fd^{D}CT[[EhCo((VdCHMS-100V05):1$

- 1]5kΩ—eV[$^{(}dYRpdqJ40S):110]10k\Omega$—eV[$^{(}dYRpdqM22E10):1$
- JbvO(ATdqH) :1
- fW$EIVXR[v(IWATSUDS-5110B):1fWEIVXR[vv[u:2$
- t@NVWFl[$^{(}TEXIOFGX-2112):1d()(KENWOODPS36-10):1$
- d()(PR18-1.2A) :1
- DC/DCRo[$^{(}SUW30515C):1IyAv(AD817AN):3$
- R(±1%)
  :20kΩ2, 300kΩ2, 470kΩ2, 100kΩ2, 2kΩ1, 7.5kΩ1
- dRfT :10$\mu F1$, 1$\mu F1$
- ubh[h :1
- XCb‘ :1
- WvC[
- jNbv

3.5

@A
reftab stableLBA
reftab teijyouLB

5: 3-1(x),3-2(u)

	14H	15H
3-1(x)		
3-2(u)	s	

6: 3-1(x),3-2(u)

	14H	15H
3-1(x)	0.075	0.54
3-2(u)	s	0

@A3-1g‘LB14HAv_{in}27Av_{out}28LBA15HAv_{in}29Av_{out}30LBAl@gV [VLqB

27: 3-1(x)
14HAXebvv_{in}, v_{ref}

28: 3-1(x)
14HAXebvv_{out}, v_{ref}

29: 3-1(x)
15HAXebvv_{in}, v_{ref}

30: 3-1(x)
15HAXebvv_{out}, v_{ref}

@A3-2g‘LB
reftab stableA14H[vnsOtB15HAv_{in}31Av_{out}32LBAl@gV [VLqB

31: 3-2(u)
15HAXebvv_{in}, v_{ref}

32: 3-2(u)
15HAXebvv_{out}, v_{ref}

@A27‘32Ot$v_{in}v_{out}$olA
reftab stablenmFB

3.6 l@

(1)2.4
@Ax[vnlBAH14A$P_V(s)(4)AC(s)(16)B[v‘BG_{aV}(s)uAG_{aV}(s)(37)$pB

$$\begin{aligned} G_{aV}(s) &= \frac{C(s)P_V(s)}{1+C(s)P_V(s)} = \frac{K_{Ca}\frac{K}{(1+sT_E)(1+sT_M)}}{1+K_{Ca}\frac{K}{(1+sT_E)(1+sT_M)}} \\ &= \frac{KK_{Ca}}{T_ET_Ms^2+(T_E+T_M)s+1+KK_{Ca}} \end{aligned} \tag{44}$$

15xlB$P_V(s)(4)AC(s)(18)B[v‘BG_{bV}(s)uAG_{bV}(s)(37)$pB

$$\begin{aligned} G_{bV}(s) &= \frac{C(s)P_V(s)}{1+C(s)P_V(s)} = \frac{K_{Cb}\frac{\alpha(1+sT)}{1+s\alpha T}\frac{K}{(1+sT_E)(1+sT_M)}}{1+K_{Cb}\frac{\alpha(1+sT)}{1+s\alpha T}\frac{K}{(1+sT_E)(1+sT_M)}} \\ &= \frac{\alpha TKK_{Cb}s+\alpha KK_{Cb}}{T_ET_M\alpha Ts^3+\{\alpha T(T_E+T_M)+T_ET_M\}s^2+\{T_E+T_M+\alpha T(1+KK_{Cb})\}s+1+KK_{Cb}\alpha} \end{aligned} \tag{48}$$

@]A(48)EX@g
reftab GbVEXBA
reftab GbVx'

$$x' = -\frac{T_ET_M\alpha T(1+KK_{Cb}\alpha)-\{\alpha T(T_E+T_M)+T_ET_M\}\{T_E+T_M+\alpha T(1+KK_{Cb})\}}{\alpha T(T_E+T_M)+T_ET_M} \tag{49}$$

B

(2)2.5

@A$v_{ref}v_{in}IBAH$

@q@A
reftab GbV

reftab valuelpA

$$T_E T_M \alpha T \sim 6.8\ 10^{-7} > 0 \tag{50}$$

$$\alpha T(T_E + T_M) + T_E T_M \sim 3.4\ 10^{-4} > 0 \tag{51}$$

$$x' \sim 5.3\ 10^{-2} > 0 \tag{52}$$

$$1 + KK_{Cb}\alpha \sim 1.8 > 0 \tag{53}$$

A$G_{bV}(s)$[v‘BB
reftab stableAvB

(2)2.5
@A$v_{ref}v_{in}IBAH$
14A$v_{ref}R(s)$, $v_{in}Y_d(s)$A$Y_d(s) = R(s)G_{aV}(s)$A$e(t)$vX$E(s)$

$$\begin{aligned} E_{aV}(s) &= R(s) - Y_d(s) \\ &= R(s)(1 - G_{aV}(s)) \end{aligned} \tag{54}$$

BAvX$E_{aV}(s)$BAMXebvM$r(t) = 1$lAvX$R(s) = \frac{1}{s}$BA2.4$G_{aV}(s)$A$R(s)1A(54)IlKpBIlpABA$G$_{aV}(s)(44)$Al
reftab valueQlB

$$\begin{aligned} \lim_{t\to\infty} e(t) &= \lim_{s\to 0} sE_{aV}(s) \\ &= \lim_{s\to 0} s\ \frac{1}{s}(1 - G_{aV}(s)) \\ &= \lim_{s\to 0}(1 - G_{aV}(s)) \\ &= 1 - \frac{KK_{Ca}}{1 + KKCa} \sim 0.0625 \end{aligned} \tag{55}$$

@
reftab teijyouA0.075

$$\frac{0.075 - 0.0625}{0.0625}\ 100 = 20.0[\%] \tag{56}$$

BROelBAlelBAI[vB
@$AH15AIL$@$lvZB$E(s)to
E$_{bV}(s) = R(s)(1 - G_{bV}(s))(57)$BAvX$E_{bV}(s)$BA2.4$G_{bV}(s)AR(s)1A(57)IlKpBIlpABAG_{bV}(s)(48)$Al
reftab valueQlB

$$\begin{aligned} \lim_{t\to\infty} e(t) &= \lim_{s\to 0} sE_{bV}(s) \\ &= \lim_{s\to 0} s\ \frac{1}{s}(1 - G_{bV}(s)) \\ &= \lim_{s\to 0}(1 - G_{bV}(s)) \\ &= 1 - \frac{K\alpha K_{Cb}}{1 + K\alpha KCb} \sim 0.56 \end{aligned} \tag{58}$$

@
reftab teijyouA0.54

$$\frac{0.56 - 0.54}{0.56}\ 100 \sim 3.57[\%] \tag{59}$$

BRqlOelBAB

(3)2.6

@Au[vnlBAH14A$P(s)$(38)AC(s)(16)$B[v‘$BG_{aP}(s)uAG_{aP}(s)$(37)pB

$$\begin{aligned} G_{aP}(s) &= \frac{C(s)P(s)}{1+C(s)P(s)} = \frac{K_{Ca}\frac{K'}{s(1+sT_E)(1+sT_M)}}{1+K_{Ca}\frac{K'}{s(1+sT_E)(1+sT_M)}} \\ &= \frac{K'K_{Ca}}{T_ET_Ms^3+(T_E+T_M)s^2+s+K'K_{Ca}} \end{aligned} \tag{60}$$

@]A(44)EX@g

reftab GaVEXBq@A

reftab GaV

reftab valuelpA

$$T_ET_M = 9\ 10^{-5} > 0 \tag{45}$$

$$T_E + T_M = 0.033 > 0 \tag{46}$$

$$1 + KK_{Ca} = 16 > 0 \tag{47}$$

A$G_{aV}(s)$[v‘BB

reftab stableAvB

@AH

15xlB$P(s)$(38)AC(s)(18)$B[v‘$BG_{bP}(s)uAG_{bP}(s)$(37)pB

$$\begin{aligned} G_{bP}(s) &= \frac{C(s)P(s)}{1+C(s)P(s)} = \frac{K_{Cb}\frac{\alpha(1+sT)}{1+s\alpha T}\frac{K'}{s(1+sT_E)(1+sT_M)}}{1+K_{Cb}\frac{\alpha(1+sT)}{1+s\alpha T}\frac{K'}{s(1+sT_E)(1+sT_M)}} \\ &= \frac{K_{Cb}K'\alpha Ts + K_{Cb}K'\alpha}{T_ET_M\alpha Ts^4 + \{\alpha T(T_E+T_M)+T_ET_M\}s^3 + (T_E+T_M+\alpha T)s + (1+K'K_{Cb}\alpha T)s + K'K_{Cb}\alpha} \end{aligned} \tag{67}$$

@]A(67)EX@g

reftab GbPEXBA

reftab GbPw''', x''', y''', z'''

$$w''' = -\frac{(T_ET_M\alpha T)(1+K'K_{Cb}\alpha T) - (T_E+T_M+\alpha T)\{\alpha T(T_E+T_M)+T_ET_M\}}{\alpha T(T_E+T_M)+T_ET_M} \tag{68}$$

$$x''' = -\frac{0-(K'K_{Cb}\alpha)(\alpha T(T_E+T_M)+T_ET_M)}{\alpha T(T_E+T_M)+T_ET_M} = K'K_{Cb}\alpha \tag{69}$$

$$y''' = -\frac{(\alpha T(T_E+T_M)+T_ET_M)x''' - (1+K'K_{Cb}\alpha T)w'''}{w'''} \tag{70}$$

$$z''' = -\frac{0-x'''y'''}{y'''} = x''' \tag{71}$$

B

(4)2.7

@A2.5l$IBAH$

@q@EX[lA
reftab GbP
reftab valuelpA

$$T_E T_M \alpha T \sim 6.8\ 10^{-7} > 0 \tag{72}$$

$$\alpha T(T_E + T_M) + T_E T_M \sim 3.4\ 10^{-4} > 0 \tag{73}$$

$$w''' \sim 3.4\ 10^{-2} > 0 \tag{74}$$

$$y''' \sim 3.8\ 10^{-2} > 0 \tag{75}$$

$$z''' \sim 1.2\ 10^{2} > 0 \tag{76}$$

A$G_{bP}(s)$[v‘BB
reftab stableAvB

(4)2.7
@A2.5l$IBAH$
14A2.6$G_{aP}(s)$sUB]B
@AH15A$e(t)$vX$E(s)$

$$E_{bP}(s) \quad = \quad R(s)(1 - G_{bP}(s)) \tag{77}$$

BAvX$E_{bP}(s)$BA2.6$G_{bP}(s)$A$R(s)1A(77)IlKpBIlpABA$G$_{bP}(s)$(67)Al
reftab valueQlB

$$\begin{aligned} \lim_{t\to\infty} e(t) &= \lim_{s\to 0} sE_{bP}(s) \\ &= \lim_{s\to 0} s\ \frac{1}{s}(1 - G_{bP}(s)) \\ &= \lim_{s\to 0}(1 - G_{bP}(s)) \\ &= 1 - 1 = 0 \end{aligned} \tag{78}$$

@
reftab teijyouA0SvBB

(5)2.8
@MATLABV [VdOt27‘32LB27‘32AV [VvBnA29‘32AOtnvBAOtAV [VlOeoAV [VllBB
@A2728AmT‘vAg‘doCAXBAgpXCb‘zIOFFONuHJlBPAXCb‘OAP]B
@A27V [VvBnA$v_{in}l(V$ [$V)g‘AxBAWld0.8VvlBAWldAIyAvOaIyAv‘sKAtdEB$
@$A28qdoCAXel$v$_{ref}$Axdl0VBl0AlV [VvlBAnOexlV [VvB
@c$A3A, , nKlB$

[1] rF,uT$_{[}b]v,|$

@]A(60)EX@g
reftab GaPEXBA
reftab GaPx'',
y''

$$x'' = -\frac{T_E T_M K' K_{Ca} - T_E + T_M}{T_E + T_M} \tag{61}$$

$$y'' = -\frac{0 - x'' K' K_{Ca}}{x''} = K' K_{Ca} \tag{62}$$

B @q@EX[B
reftab GaP
reftab valuelpA

$$T_E T_M = 9\ 10^{-5} > 0 \tag{63}$$

$$T_E + T_M = 0.033 > 0 \tag{64}$$

$$x'' \sim -5.2 < 0 \tag{65}$$

$$y'' = 2280 > 0 \tag{66}$$

A$G_{aP}(s)$[v‘BsB
reftab stableAvB
@AH