Q_1 :
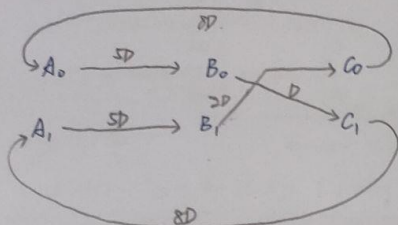
(a)

unfolding factor = 2.

$A_0 \xrightarrow{5D} B_0 \xrightarrow{D} C_1 \xrightarrow{8D} A_1 \xrightarrow{5D} B_1 \xrightarrow{2D} C_0 \xrightarrow{8D} A_0$.

$A_0 \longrightarrow B_{(0+10)\%2}$ with $\left[\frac{10+0}{2}\right]$ delay

$B_0 \longrightarrow C_1$ with $\left[\frac{3+0}{2}\right]$ delay

$\vdots$

$C_0 \longrightarrow A_0$ with $\left[\frac{16+0}{2}\right]$ delay

unfolding factor = 3.

$A_0 \xrightarrow{3D} B_1 \xrightarrow{D} C_1 \xrightarrow{5D} A_1 \xrightarrow{3D} B_2 \xrightarrow{D} C_2 \xrightarrow{6D} A_2$

$\xrightarrow{4D} B_0 \xrightarrow{D} C_0 \xrightarrow{5D} A_0$.
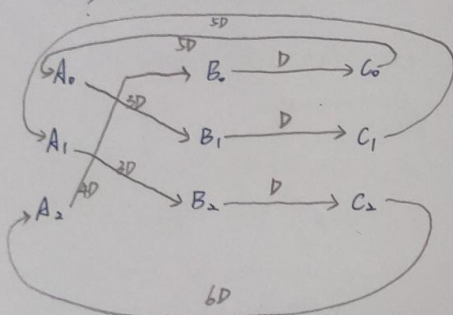
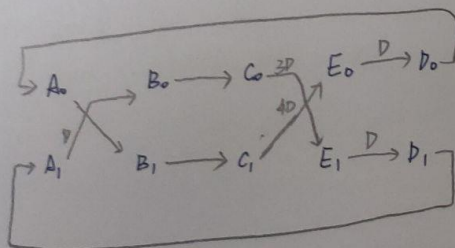$A_0 \longrightarrow B_{(0+10)\%3}$ with $\left[\frac{0+10}{3}\right]$ delay

$B_1 \longrightarrow C_{(1+3)\%3}$ with $\left[\frac{1+3}{3}\right]$ delay

$\vdots$

$C_0 \longrightarrow A_{(0+16)\%3}$ with $\left[\frac{0+16}{3}\right]$ delay

(b) unfolding factor = 2.

$A_0 \longrightarrow B_1 \longrightarrow C_1 \xrightarrow{4D} E_0 \xrightarrow{D} D_0 \longrightarrow A_0$. : Loop 1

$A_1 \xrightarrow{D} B_0 \longrightarrow C_0 \xrightarrow{3D} E_1 \xrightarrow{D} D_1 \longrightarrow A_1$: Loop 2.

$A_0 \longrightarrow B_{(0+1)\%2}$ with $\left[\frac{0+1}{2}\right]$ delay

$B_1 \longrightarrow C_{(1+0)\%2}$ with $\left[\frac{1+0}{2}\right]$ delay

$\vdots$

$D_0 \longrightarrow A_{(0+0)\%2}$ with $\left[\frac{0+0}{2}\right]$ delay

$A_1 \longrightarrow B_{(1+1)\%2}$ with $\left[\frac{1+1}{2}\right]$ delay

$B_0 \longrightarrow C_{(0+0)\%2}$ with $\left[\frac{0+0}{2}\right]$ delay

$\vdots$

$D_1 \longrightarrow A_{(1+0)\%2}$ with $\left[\frac{1+0}{2}\right]$ delay

unfolding factor = 6

$A_0 \longrightarrow B_1 \longrightarrow C_1 \xrightarrow{2D} E_0 \xrightarrow{D} D_1$

$\longrightarrow A_1 \longrightarrow B_2 \longrightarrow C_2 \xrightarrow{3D} E_0 \longrightarrow D_2$

$\longrightarrow A_2 \xrightarrow{D} B_0 \longrightarrow C_0 \xrightarrow{3D} E_1 \xrightarrow{D} D_0 \longrightarrow A_0.$
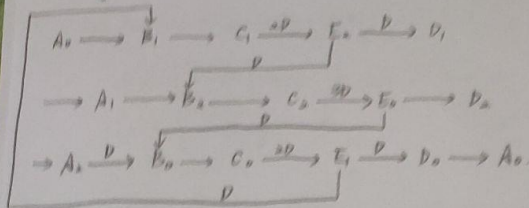
$A_0 \longrightarrow B_{(0+1)\%3}$ with $\left[\frac{0+1}{6}\right]$ delay

$B_1 \longrightarrow C_{(1+0)\%3}$ with $\left[\frac{1+0}{6}\right]$ delay

$\vdots$

$D_0 \longrightarrow A_{(0+0)\%3}$ with $\left[\frac{0+0}{6}\right]$ delay
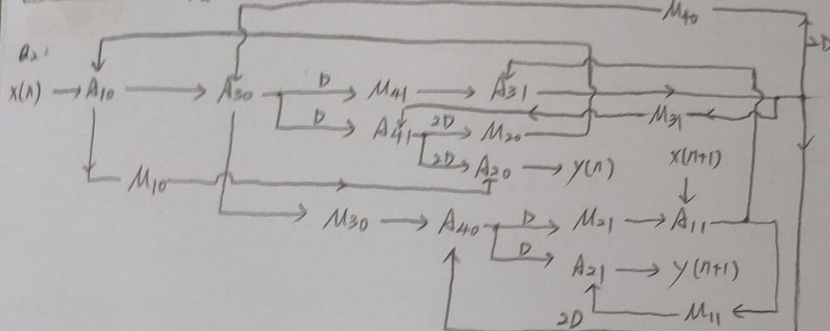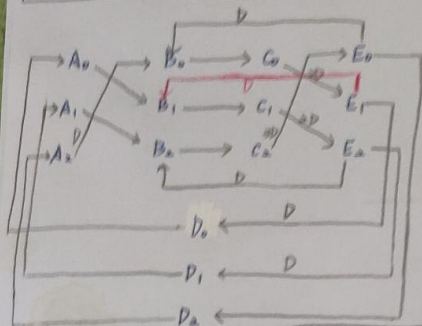
node delay transfer.

A_{41}
A_{31}
A_{30}

Q3

(a)

$$T_a = \frac{(C_m + \eta C_a) \cdot V_0}{K(V_0 - V_t)^2} = T_b = \frac{(C_m + 2 C_a) \cdot V_0 \cdot \beta}{k \cdot (\beta V_0 - V_t)^2}$$

$$\frac{17.4}{3.5^2} = \frac{12.4\beta}{(4\beta - 0.5)^2} \Rightarrow \beta = 0.7702 \text{ or } 0.0203$$

$\because \beta \cdot V_0 > 1.2 \qquad \therefore \beta = 0.0203 \text{ (不合)}$
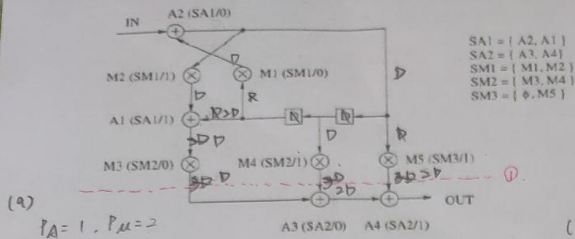
$\therefore \beta = 0.7702$

(b)

$$P_a = (8C_m + \eta C_a) \cdot 4^2 \cdot f$$

$$P_b = (8C_m + \eta C_a) \cdot (4\beta)^2 f$$

$$(1) \quad \frac{P_b}{P_a} = \beta^2 = 0.5931$$

power saving $= 40.69\%$

Q4. For the design shown below.

SA1 = { A2, A1 }
SA2 = { A3, A4 }
SM1 = { M1, M2 }
SM2 = { M3, M4 }
SM3 = { 0, M5 }

(a)

$P_A = 1$, $P_M = 2$

$N w(e) - P_U + V - U \geq 0$ (folding equation)

$DF(A_2 \to M_5) = 2 \cdot 0 - 1 + 1 - 0 = 0 \cdots (1) + 2 \Rightarrow 2$

$DF(A_2 \to M_4) = 2 \cdot 1 - 1 + 1 - 0 = 2 \cdots (2) + 2 \Rightarrow 4$

$DF(A_2 \to M_1) = 2 \cdot 2 - 1 + 0 - 0 = 3 \cdots (3) - 2 \Rightarrow 1$

$DF(A_2 \to A_1) = 2 \cdot 2 - 1 + 1 - 1 = 4 \cdots (4) + 2 \Rightarrow 6$

$DF(A_3 \to M_3) = 2 \cdot 0 - 1 + 1 - 0 = 0 \cdots (5) \quad \Rightarrow 0$

$DF(M_1 \to A_3) = 2 \cdot 0 - 2 + 0 - 0 = -2 \cdots (6) + 2 \Rightarrow 0$

$DF(M_2 \to A_1) = 2 \cdot 0 - 2 + 1 - 1 = -2 \cdots (7) + 2 \Rightarrow 0$

$DF(A_1 \to M_3) = 2 \cdot 0 - 1 - 0 - 1 = -2 \cdots (8) + 2 \Rightarrow 0$

$DF(M_3 \to A_3) = 2 \cdot 0 - 2 + 0 - 0 = -2 \cdots (9) + 6 - 2 - 2 \Rightarrow 0$

$DF(A_3 \to A_4) = 2 \cdot 0 - 1 + 1 - 0 = 0 \cdots (10) \quad \Rightarrow 0$

$DF(M_4 \to A_3) = 2 \cdot 0 - 2 + 0 - 1 = -3 \cdots (11) + 6 - 2 \Rightarrow 4$

$DF(M_5 \to A_4) = 2 \cdot 0 - 2 + 1 - 1 = -2 \cdots (12) + 6 - 2 \Rightarrow 2$

∵ (6),(7),(8),(9),(11),(12) 未满足条件 (≥ 0)

∴ not a valid folding

(b)

using retiming

① using pipeling to add 3D.

② using Node delay transfer to make sure

$DF(U \overset{0}{\to} V) \geq 0$.

过程如上图

(c) $N = 2$.

$T\ input : u(folding\ order) + P_U$

$T\ output : u + P_U + max_V \{ DF(U \to V) \}$

Node	Tinput → Toutput	
A_1	2 →	2
A_2	1 →	1
A_3	1 →	1
A_4	2 →	X
M_1	2 →	2
M_2	3 →	3
M_3	2 →	2
M_4	3 →	4
M_5	3 →	5
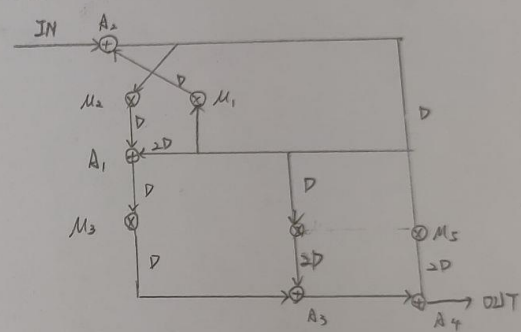
Cycle	A_1	A_2	A_3	A_4	M_1	M_2	M_3	M_4	M_5	# live
0										0
1		X					X	X		0
2	X							X		1 + 0 = 1
3										1 + 0 = 1
4										3 + 1 = 4
5										3 + 1 = 3
6										1 + 4 = 5
7										1 + 3 = 4

∴ At least, we need 5 regs.

Q4
(c)

cycle	input	R_1	R_2	R_3	R_4	R_5	OUT
0							
1	A_2						
2		A_2					
3	$M_4 M_5$		A_2				
4			M_5	A_2	M_4		M_4
5				M_5	A_2		M_5
6						A_2	
7						A_2	A_2

Q3

(a)

$$T_a = \frac{(C_m + 7C_a) \cdot V_0}{k(V_0 - V_t)^2} = T_b = \frac{(C_m + 2C_a) \cdot V_0 \cdot \beta}{k \cdot (\beta V_0 - V_t)^2}$$

$$\frac{17.4}{3.5^2} = \frac{12.4\beta}{(4\beta - 0.5)^2} \Rightarrow \beta = 0.7702 \text{ or } 0.0203$$

$\beta V_0 \ge 1.2$ ∴ $\beta = 0.0203$ (不合)