

1.

$$IC = 5,000,000,000$$

$$20 \text{ Hz} = 2 \times 10^9 \text{ Hz}$$

$$CT = \frac{1}{2 \times 10^9} \text{ sec}$$

$$\begin{aligned} CPI &= 7 \cdot 0.45 + 11 \cdot 0.1 + 8 \cdot 0.1 + 8 \cdot 0.2 + 8 \cdot 0.15 \\ &= 7 \cdot 0.45 + 11 \cdot 0.1 + 8 \cdot 0.45 \\ &= 3.15 + 1.1 + 7.6 \\ &= 4.25 + 7.6 \\ &= 7.85 \end{aligned}$$

$$\begin{aligned} ET &= IC \cdot CPI \cdot CT \\ &= 5 \cdot 10^9 \cdot \frac{1}{2 \times 10^9} \cdot 7.85 \\ &= 2.5 \cdot 7.85 \\ &= 19.625 \end{aligned}$$

bgt : 6 cycles

50% bne \rightarrow bse

	# of instructions	percentage
R-type	35	$\frac{35}{90} = 0.38888 \dots$
LW	10	$\frac{10}{90} = 0.11111 \dots$
SW	10	$\frac{10}{90} = 0.11111 \dots$
BNE	10	$\frac{10}{90} = 0.11111 \dots$
BEQ	15	$\frac{15}{90} = 0.16666 \dots$
BGT	10	$\frac{10}{90} = 0.11111 \dots$
	90	

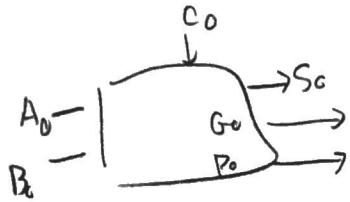
$$IC_{old} = 5 \times 10^9$$

$$\begin{aligned} IC_{new} &= 5 \times 10^9 \times \frac{90}{70} \\ &= 45 \times 10^8 \\ &= 4.5 \times 10^9 \end{aligned}$$

	Latency	percentage.
R - 7P	7	38.89%
LW	11	11.11
SW	8	11.11
BIN E	8	11.11
BFQ	8	16.67
BOT	6	11.11

$$\begin{aligned}
 CPI_{\text{new}} &= 7 \cdot 0.3889 + 11 \cdot 0.1111 + 8 \cdot 0.1111 + 8 \cdot 0.1111 \\
 &\quad + \dots + 8 \cdot 0.1667 + 6 \cdot 0.1111 \\
 &= 7 \cdot 0.3889 + 8 \cdot 0.1667 + \frac{16}{33} \cdot 0.1111 \\
 &= 2.7222 + 1.3336 + 3.6663 \\
 &= 7.7222
 \end{aligned}$$

$$\begin{aligned}
 ET_{\text{new}} &= IC \cdot CPI \cdot CT \\
 &= 4.5 \cdot 10^7 \cdot 7.7222 \cdot \frac{1}{2 \times 10^9} \\
 &= 2.25 \cdot 7.7222 = 17.37495
 \end{aligned}$$



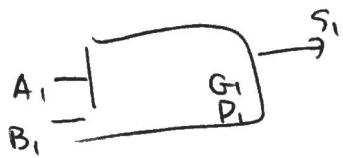
$$G_0 = A_0 \cdot B_0$$

(2T)

$$P_0 = A_0 \oplus B_0$$

(4T)

$$C_1 = G_0 + P_0 C_0$$



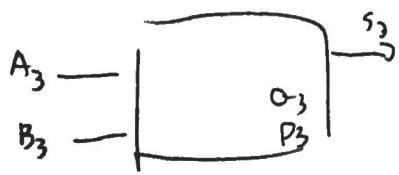
$$C_2 = G_1 + P_1 C_1$$

$$= G_1 + P_1 G_0 + P_1 P_0 C_0$$



$$C_3 = G_2 + P_2 C_2$$

$$= G_2 + P_2 G_1 + P_2 P_1 G_0 + P_2 P_1 P_0 C_0$$



$$C_4 = G_3 + P_3 C_3$$

$$= G_3 + P_3 G_2 + P_3 P_2 G_1 + P_3 P_2 P_1 G_0$$

$$+ P_3 P_2 P_1 P_0 C_0$$

$$G_d = \frac{G_3 + P_3 G_2 + P_3 P_2 G_1 + P_3 P_2 P_1 G_0}{18T}$$

$$\frac{\frac{G_3}{2T} + \frac{P_3 G_2}{4T} + \frac{P_3 P_2 G_1}{4T} + \frac{P_3 P_2 P_1 G_0}{4T}}{18T}$$

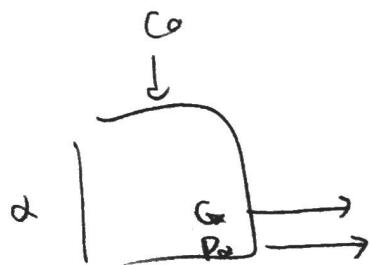
$$\frac{\frac{G_3}{2T} + \frac{G_2}{4T} + \frac{P_2 G_1}{4T} + \frac{P_2 P_1 G_0}{4T}}{18T}$$

$$\frac{\frac{G_3}{2T} + \frac{G_2}{4T} + \frac{G_1}{4T} + \frac{G_0}{4T}}{18T}$$

$$P_d = \frac{P_3}{4T} \frac{P_2}{4T} \frac{P_1}{4T} \frac{P_0}{4T}$$

$$\frac{P_3}{4T} \frac{P_2}{4T} \frac{P_1}{4T} \frac{P_0}{4T}$$

$$11T$$

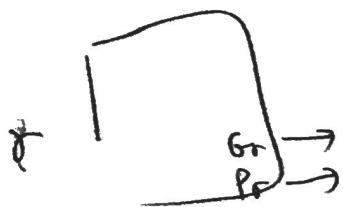


$$C_4 = G_\alpha + P_\alpha C_0$$



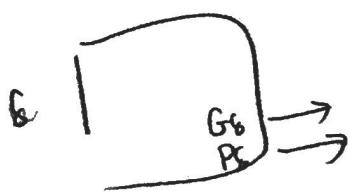
$$C_8 = G_\beta + P_\beta C_4$$

$$= G_\beta + P_\beta G_\alpha + P_\beta P_\alpha C_0$$



$$C_{12} = G_\gamma + P_\gamma C_8$$

$$= G_\gamma + P_\gamma G_\beta + P_\gamma P_\beta G_\alpha + P_\gamma P_\beta P_\alpha C_0$$



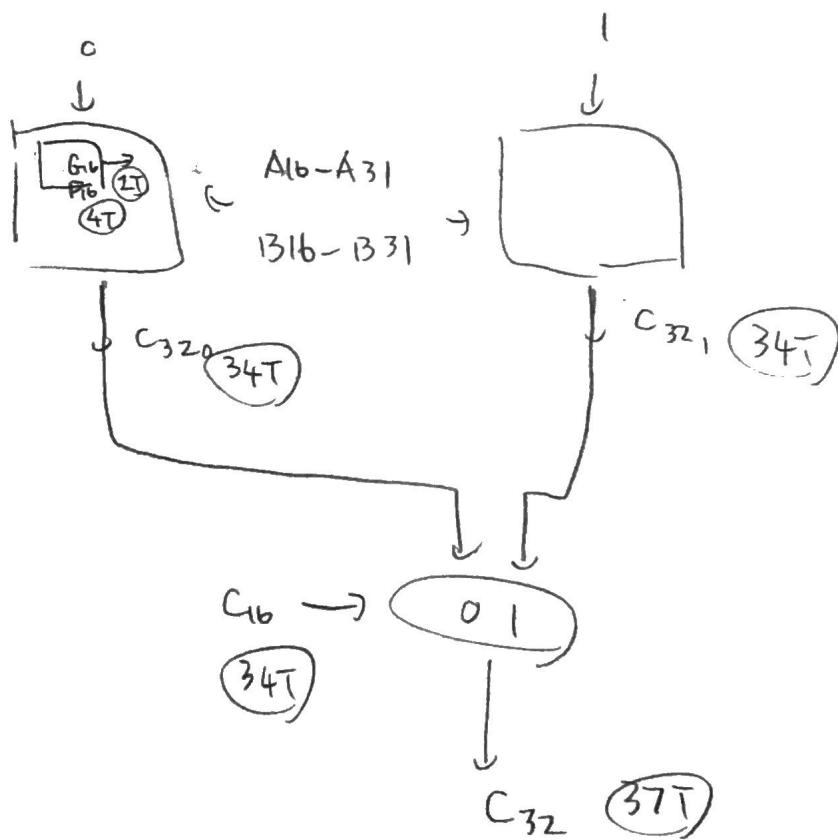
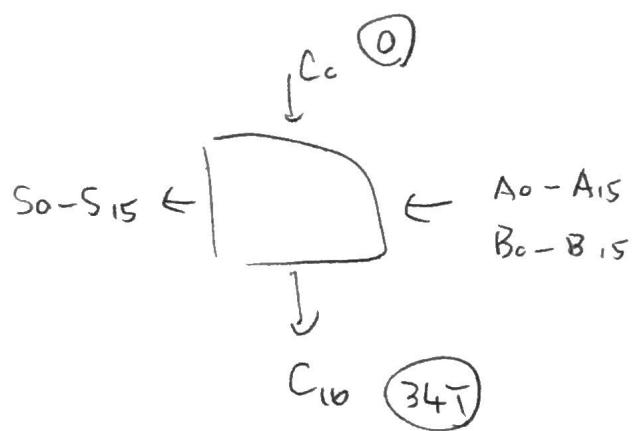
$$C_6 = G_\epsilon + P_\epsilon C_{12}$$

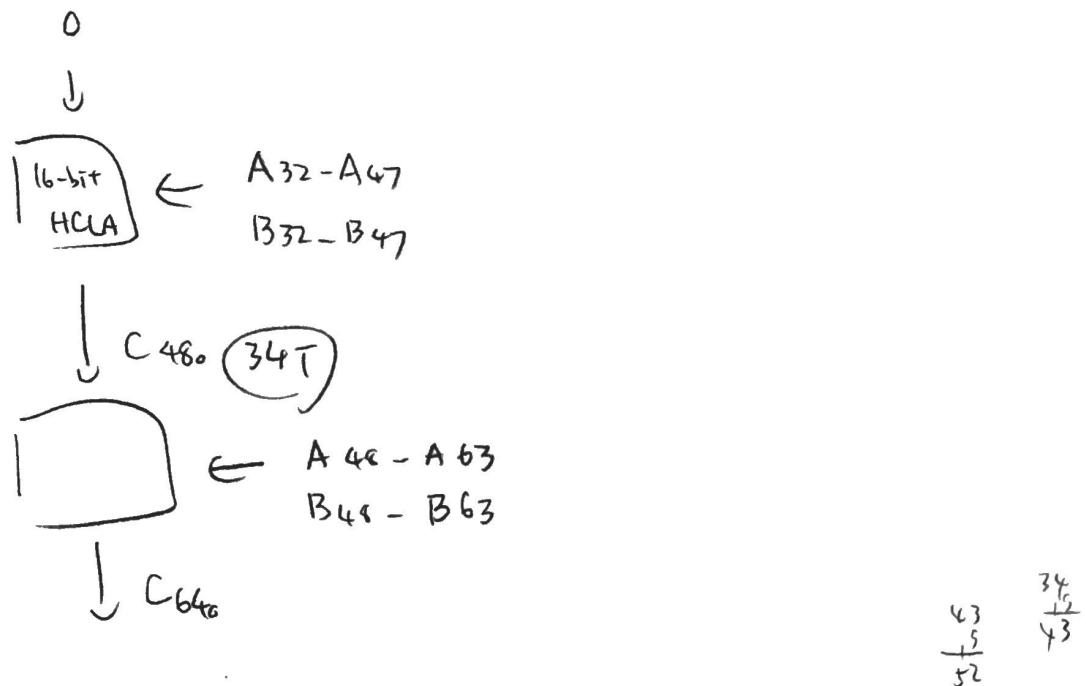
$$= \frac{G_\epsilon}{18T} + \frac{P_\epsilon G_\alpha}{11T} + \frac{P_\epsilon P_\alpha G_\beta}{11T} + \frac{P_\epsilon P_\beta G_\alpha}{11T}$$

$$+ \frac{P_\epsilon P_\beta P_\alpha G_\alpha}{11T} + \frac{P_\epsilon P_\beta P_\alpha G_\beta}{11T} + \frac{P_\epsilon P_\beta P_\alpha C_0}{11T}$$

$$\underline{\underline{25T}} \quad \underline{\underline{20T}}$$

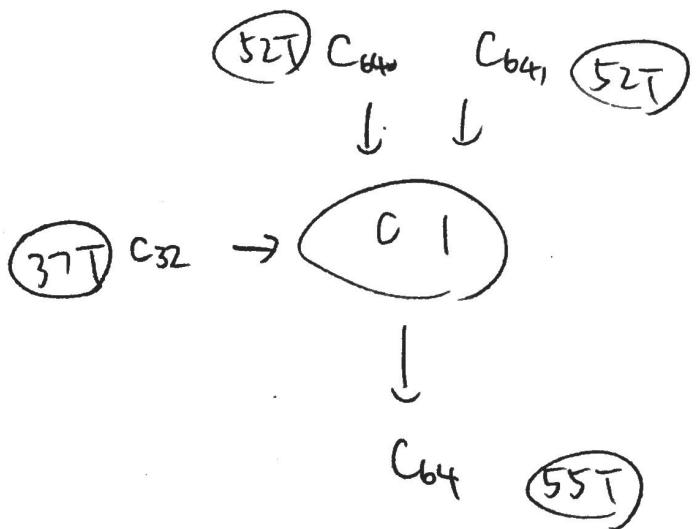
(34T)

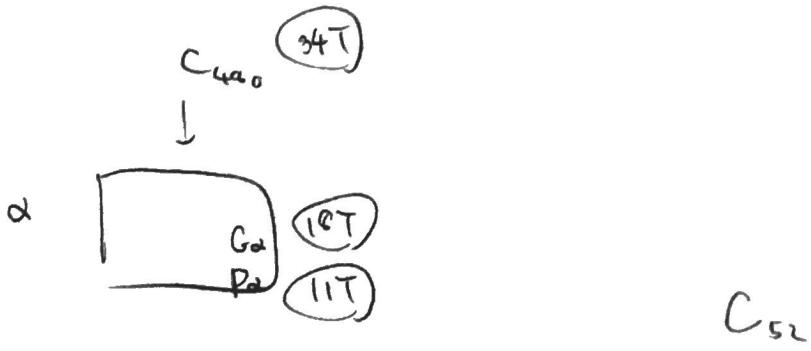




$$C_{640} = \frac{G_\alpha + P_\alpha G_\beta + P_\alpha P_\beta G_\beta + P_\alpha P_\beta P_\beta G_\alpha + P_\alpha P_\beta P_\beta P_\alpha G_{480}}{18T \overline{1T} \overline{18T} \overline{1T} \overline{1T} \overline{18T} \overline{1T} \overline{1T} \overline{1T} \overline{18T} \overline{1T} \overline{1T} \overline{1T} \overline{1T} \overline{1T} \overline{1T} \overline{1T} \overline{34T}}$$

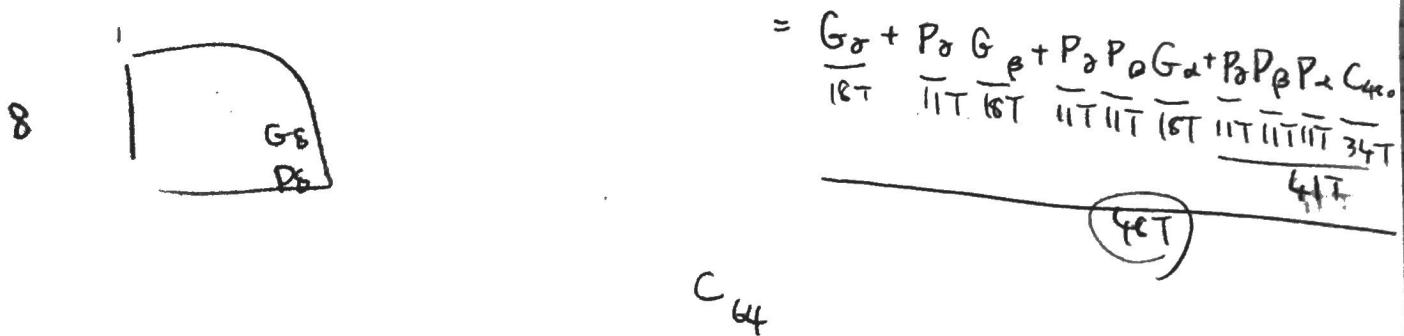
$52T$

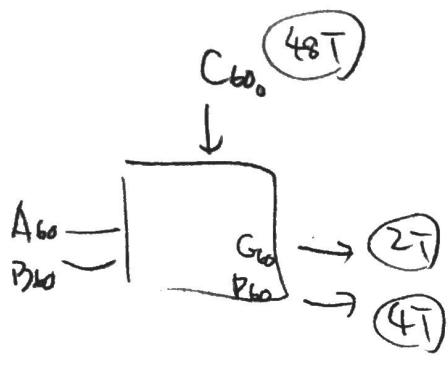




$$C_{60} = G_\gamma + P_\gamma C_{56}$$

$$= \frac{G_\gamma}{18T} + \frac{P_\gamma G_\beta}{11T} + \frac{P_\gamma P_\alpha G_\alpha}{11T 18T} + \frac{P_\gamma P_\beta P_\alpha}{11T 11T 18T} \frac{C_{440}}{34T}$$





$$C_{60_0}$$



$$C_{61_0}$$



$$\frac{55}{62}$$

$$C_{63_0} = G_{62} + P_{62} C_{62}$$

$$= G_{62} + P_{62} G_{61} + P_{62} P_{61} G_{60} + \cancel{P_{62} P_{61} P_{60} C_{60}}$$

$$\frac{17}{55}$$

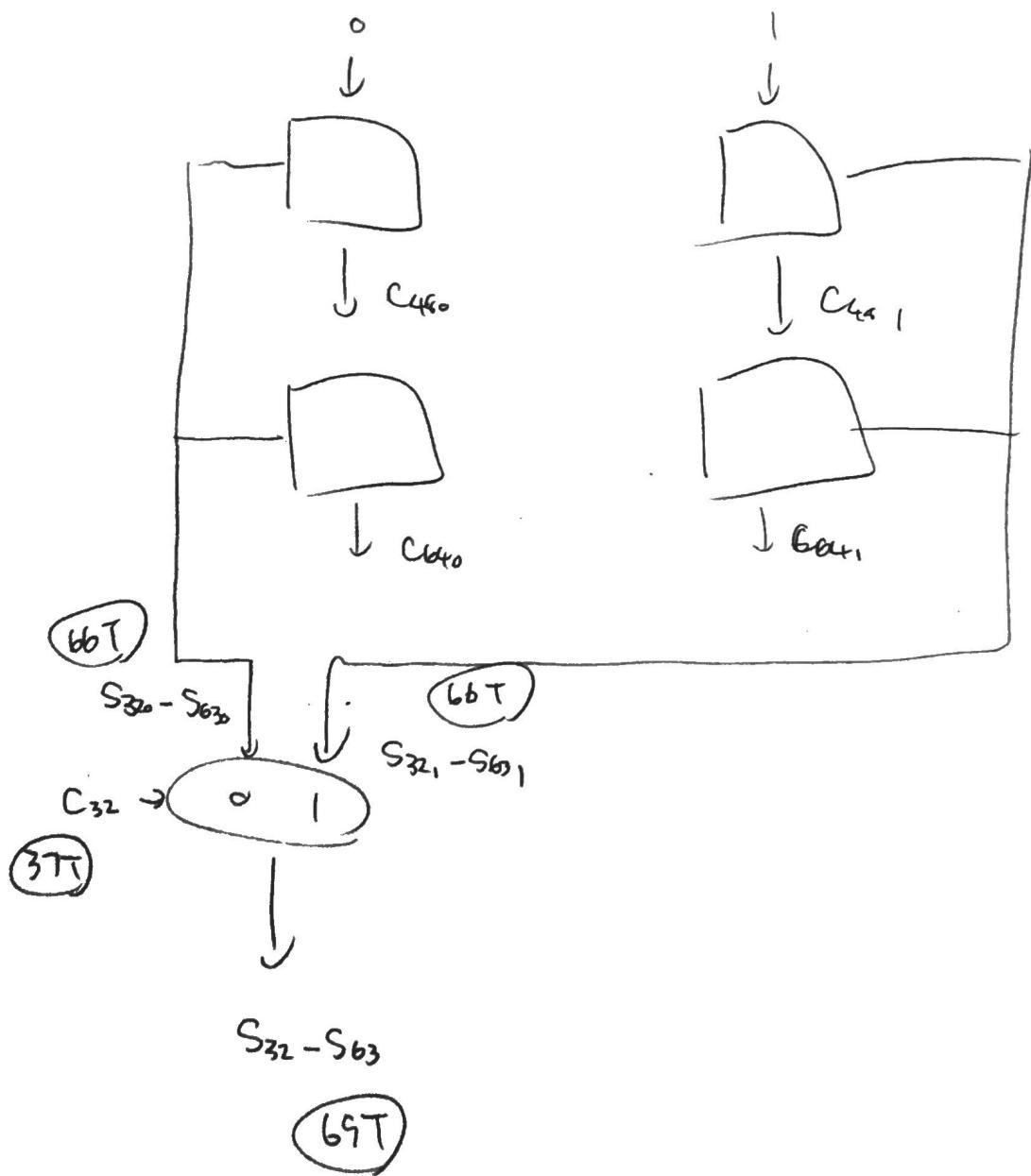


$$62T$$

$$C_{64_0}$$

$$S_{63_0} = \left(\frac{A_{63}}{0} \oplus \frac{B_{63}}{0} \right) \oplus \frac{C_{63}}{62T}$$

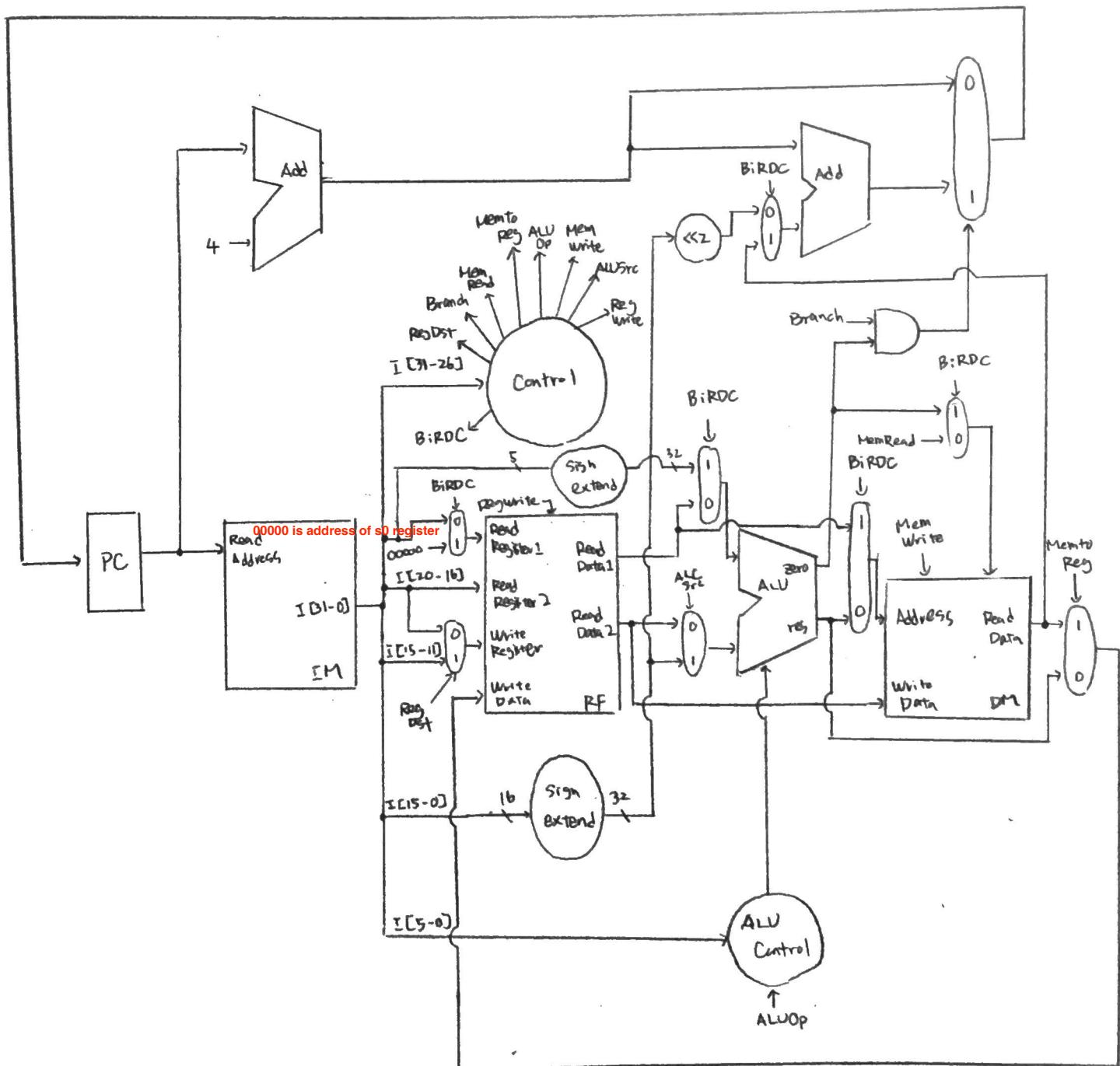
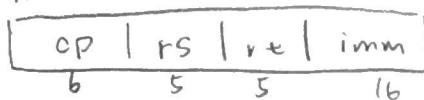
$$66T$$



3. BIRD

if (R[RT] == SE(RS))

$$PC = PC + 4 + M [R [\$50]]$$



Main Controller

Input or Output	Signal Name	R-format	lw	sw	beq	bird
Input	op	000000	100011	101011	000100	111111
Outputs	RegDst	1	0	x	x	x
	ALUSrc	0	1	1	0	0
	MemtoReg	0	1	x	x	x
	RegWrite	1	1	0	0	0
	MemRead	0	1	0	0	1
	MemWrite	0	0	1	0	0
	Branch	0	0	0	1	1
	ALUDP	10	00	00	01	01
	BIRPC	0	0	0	0	1

ALU Controller

Opcode	ALUDP	instruction	function	ALU Action	ALU Ctrl
lw	00	load word		add	010
sw	00	store word		add	010
beq	01	branch equal		subtract	110
R-type	10		add	add	010
			subtract	subtract	110
			AND	AND	000
			OR	OR	001
			SLT	SLT	111
			xxxxxx	Subtract	110
bird	01	branch immediate			