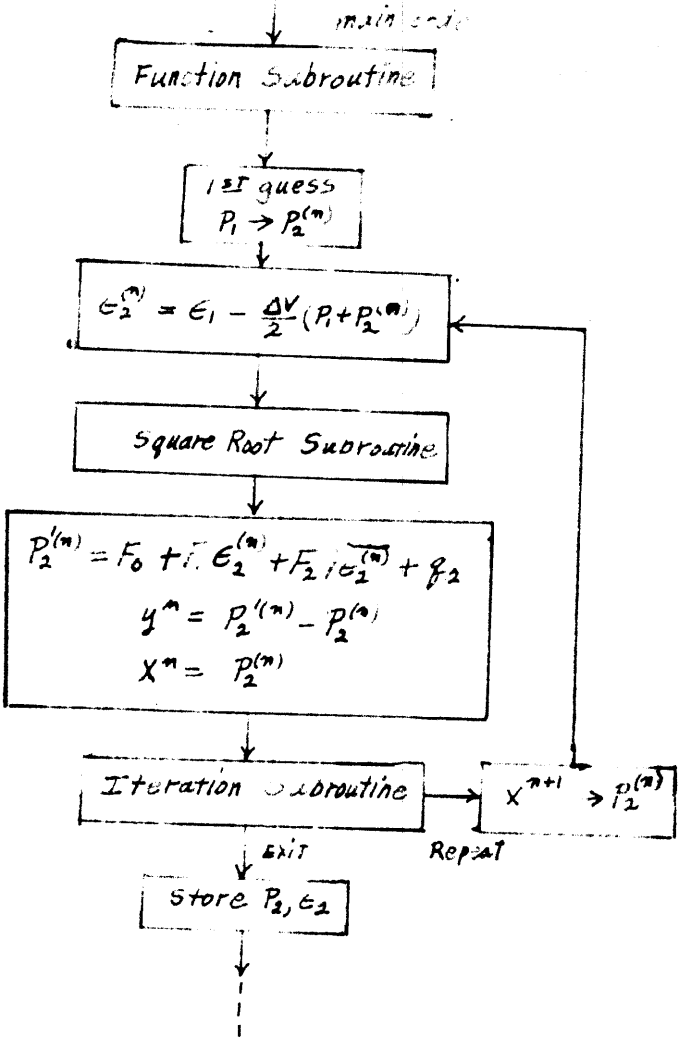
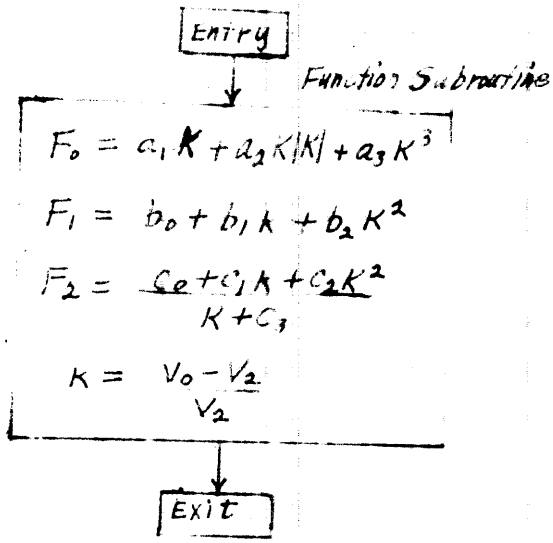
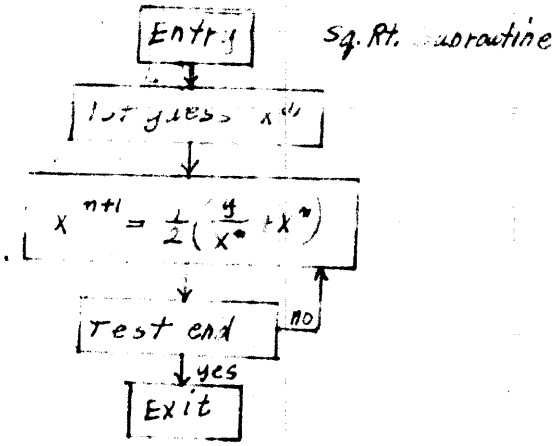
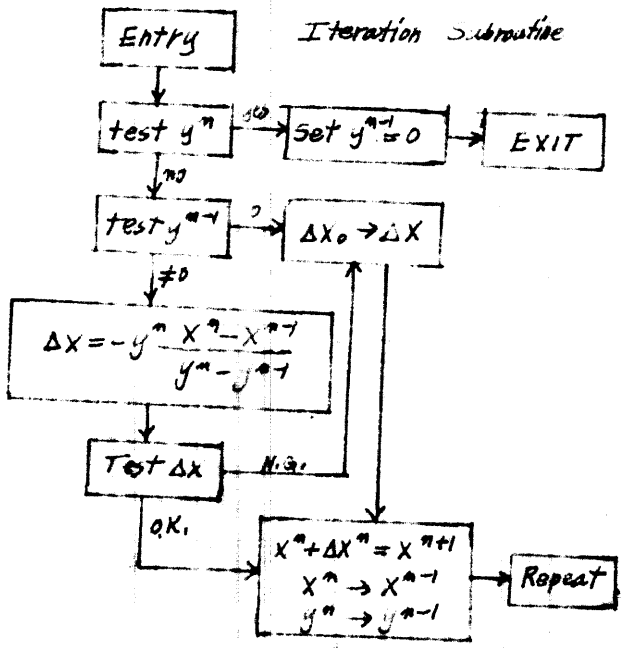
Example Problem to Study "Stretch" Addressing







Note: This flow diagram represents part of a typical calculation semi-quantitatively. A number of special cases usually found have been omitted for simplicity.



HGK Jan '57

Instructions 704 Type Instrs. with minimal register

Main Program:

Loc.	op.	addr.	indx.	
1.0	TSX	2.0		C
1.1	CA	$\mathcal{L}(P_1)$		
1.2	ST	$\mathcal{L}(P_2)$		
1.3	CS	$\mathcal{L}(P_1)$		
1.4	FS	$\mathcal{L}(P_2)$		
1.5	FD	$\mathcal{L}(2)$		
1.6	FM	$\mathcal{L}(\Delta x)$		
1.7	FA	$\mathcal{L}(\epsilon_1)$		
1.8	ST	$\mathcal{L}(\epsilon_2)$		
1.9	TSX	3.0		C
1.10	FM	$\mathcal{L}(F_2)$		
1.11	FA	$\mathcal{L}(F_0)$		
1.12	FA	$\mathcal{L}(\mu_2)$		
1.13	ST	$\mathcal{L}(T3)$		
1.14	CA	$\mathcal{L}(\epsilon_2)$		
1.15	FM	$\mathcal{L}(F_1)$		
1.16	FA	$\mathcal{L}(T5)$		
1.17	ST	$\mathcal{L}(T5)$		
1.18	FS	$\mathcal{L}(P_2)$		
1.19	ST	$\mathcal{L}(y)$		
1.20	CA	$\mathcal{L}(P_2)$		
1.21	ST	$\mathcal{L}(x)$		
1.22	TSX	4.0		C
1.23	Ty	1.2		(Argument)
1.24	CA	$\mathcal{L}(P_2)$		
1.25	ST	$\mathcal{L}(P_2)'$		A
1.26	CA	$\mathcal{L}(\epsilon_2)$		
1.27	ST	$\mathcal{L}(\epsilon_2)'$		A

Function Subroutine

2.0	CA	$\mathcal{L}(1.0)$	
2.1	FS	$\mathcal{L}(V_2)$	
2.2	FD	$\mathcal{L}(V_2)$	
2.3	ST	$\mathcal{L}(\mu)$	
2.4	FM abs.	$\mathcal{L}(a_3)$	
2.5	FA	$\mathcal{L}(a_2)$	
2.6	FM abs	$\mathcal{L}(\mu)$	
2.7	FA	$\mathcal{L}(a_1)$	
2.8	FM	$\mathcal{L}(\mu)$	
2.9	ST	$\mathcal{L}(F_0)$	
2.10	CA	$\mathcal{L}(b_0)$	
2.11	FM	$\mathcal{L}(\mu)$	
2.12	FA	$\mathcal{L}(b_1)$	
2.13	FM	$\mathcal{L}(\mu)$	
2.14	FA	$\mathcal{L}(b_0)$	
2.15	ST	$\mathcal{L}(F_1)$	
2.16	CA	$\mathcal{L}(C_3)$	
2.17	FA	$\mathcal{L}(a)$	
2.18	ST		

Loc.	op.	addr.	indx.	
2.19	CA	$\mathcal{L}(C_2)$		
2.20	FM	$\mathcal{L}(\mu)$		
2.21	FA	$\mathcal{L}(C_1)$		
2.22	FM	$\mathcal{L}(\mu)$		
2.23	FA	$\mathcal{L}(C_0)$		
2.24	FD	$\mathcal{L}(T5)$		
2.25	ST	$\mathcal{L}(F_2)$		
2.26	T	1		C

Sq-Root

3.0	ST	$\mathcal{L}(y)$	
3.1	AR	1	
3.2	FA	$\mathcal{L}(0)$	
3.3	ST	$\mathcal{L}(x)$	
3.4	CA	$\mathcal{L}(y)$	
3.5	FD	$\mathcal{L}(x)$	
3.6	ST	$\mathcal{L}(T5)$	
3.7	FA	$\mathcal{L}(x)$	
3.8	FM	$\mathcal{L}(\frac{1}{2})$	
3.9	ST	$\mathcal{L}(x^{n+1})$	
3.10	FS	$\mathcal{L}(x^n)$	
3.11	FS	$\mathcal{L}(\delta)$	
3.12	TM	3.16	
3.13	CA	$\mathcal{L}(x^{n+1})$	
3.14	ST	$\mathcal{L}(x)$	
3.15	Ty	3.4	
3.16	CA	$\mathcal{L}(x^{n+1})$	
3.17	T	1	C

Iteration Subroutine

4.0	CA	$\mathcal{L}(\delta)$	
4.1	Sub.	$\mathcal{L}(y)$	
4.2	TM	2	C
4.3	CA	$\mathcal{L}(y^{n+1})$	
4.4	TZ	4.25	
4.5	CA	$\mathcal{L}(y^n)$	
4.6	FS	$\mathcal{L}(y^{n-1})$	
4.7	ST	$\mathcal{L}(T5)$	
4.8	CA	$\mathcal{L}(x^n)$	
4.9	FS	$\mathcal{L}(x^{n+1})$	
4.10	ST	$\mathcal{L}(T5)$	
4.11	CA	$\mathcal{L}(x^n)$	
~~4.12~~	~~FS~~	~~$\mathcal{L}(x^{n+1})$~~	
~~4.13~~	~~ST~~	~~$\mathcal{L}(T2)$~~	
~~4.14~~	~~CA~~	~~$\mathcal{L}(C_0)$~~	
4.12	FM	(T5)	
4.13	FD	(T5)	
4.14	ST	$\mathcal{L}(\Delta x)$	
4.15	MAP		
4.16	FS	$\mathcal{L}(\delta)$	
4.17	TM	4.25	
4.18	CA	$\mathcal{L}(x^n)$	
4.19	ST	$\mathcal{L}(x^{n+1})$	
4.20	CA	$\mathcal{L}(y^n)$	
4.21	ST	$\mathcal{L}(y^{n+1})$	
4.22	CA	$\mathcal{L}(\Delta x)$	
4.23	FA	$\mathcal{L}(x^n)$	
4.24	T	1	C
4.25	CA	$\mathcal{L}(\Delta x)$	
4.26	ST	$\mathcal{L}(\Delta x)$	
4.27	T	4.18	

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DATE	Oct 10, '57
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CODE: SIMPLE MESH CALC.
(Evaluating 2-D Hydro. gradient)

	Loc.	Op.	I_1	I_2	Addr.
	1	Load II		ℓ	0
	2	Load II		k	0
(B)	3	Load II		j	0
(A)	4	Fl. Load	j		$\mathcal{I}(x_1)$
	5	Fl. Add-	j		$\mathcal{I}(x_3)$
a	6	Fl. Store			R_1
	7	Fl. Load	j		$\mathcal{I}(y_2)$
	8	Fl. Add-	j		$\mathcal{I}(y_4)$
b	9	Fl. Store			R_2
	10	Fl. Load	j		$\mathcal{I}(x_2)$
	11	Fl. Add-	j		$\mathcal{I}(x_4)$
c	12	Fl. Store			R_3
	13	Fl. Load	j		$\mathcal{I}(y_1)$
	14	Fl. Add-	j		$\mathcal{I}(y_3)$
d	15	Fl. Store			R_4
	16	Load Index	p		j, m
	17	Load Index	q		j, n
	18	Fl. Load	p		$\mathcal{I}(P_1)$
	19	Fl. Add-	q		$\mathcal{I}(P_1-1)$
p	20	Fl. Store			R_5
	21	Fl. Load	q		$\mathcal{I}(P_1)$
	22	Fl. Add-	p		$\mathcal{I}(P_1-1)$
q	23	Fl. Store			R_6
	24	Fl. Load	ℓ		$\mathcal{I}(r_1)$
	25	Fl. Add	ℓ		$\mathcal{I}(r_2)$
	26	Fl. Add	ℓ		$\mathcal{I}(r_3)$
	27	Fl. Add	ℓ		$\mathcal{I}(r_4)$
	28	Add Exp Im-			2
R	29	Fl. Store			R_7
	30	Fl. Load			R_3
	31	Fl. Mpy			R_4
	32	Fl. Store			R_8
	33	Fl. Load			R_1
	34	Fl. Mpy			R_2
D	35	Fl. Add-			R_8
	36	Fl. MPY			R_7

"Raw" Arith.

	Loc.	Op.	I_1	I_2	Addr.
RD	37	Fl. Store			R_8
	38	Fl. Load			R_4
	39	Fl. Mpy			R_6
	40	Fl. Store			R_9
	41	Fl. Load			R_2
	42	Fl. Mpy			R_5
	43	Fl. Add-			R_9
A	44	Fl. Store			R_9
	45	Fl. Load			R_3
	46	Fl. Mpy			R_6
	47	Fl. Store			R_{10}
	48	Fl. Load			R_6
	49	Fl. Mpy			R_1
B	50	Fl. Add-			R_{10}
	51	Fl. Div.			R_8
H_{ij}	52	Fl. Sto.-	k		$\mathcal{I}(h_1)$
	68	Fl. Load			R_9
	54	Fl. Div.			R_8
G_{ij}	55	Fl. Sto.-	k		$\mathcal{I}(g_1)$
	56	Incr.	ℓ		1
	57	Incr.	k		2
	58	Incr.	j		1
	59	Compare II		j	$\mathcal{I}(J)$
	60	Branch No (UI)			(A)
	61	SWAP Direct			m / n
	62	Compare II		k	$\mathcal{I}(K)$
	63	Branch No (UI)			(B)
	64	(Next)			

Indices

1	j
2	k
3	ℓ
4	p
5	q
6	m
7	n
Elim	J
Elim	K

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Example of Full Word Code (Los Alamos Sept 16 Version assumed)

CODE: SIMPLE MESH CALC.

DATE	Oct 1, 1957
DRAWN	HGK
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	Loc.	OP.	I	OA	SA	Pre Post
	1	Load I	ℓ	0		
	2	Load I	k	0		
(b)	3	Load I	j	0		
(x)	4	Fl. Load	j	$I(x_1)$		
a	5	Fl. Add −	j	$I(x_2)$	R_1	Post
	6	Fl. Load	j	$I(y_2)$		
b	7	Fl. Add −	j	$I(y_4)$	R_2	Post
	8	Fl. Load	j	$I(x_3)$		
c	9	Fl. Add −	j	$I(x_4)$	R_3	Post
	10	Fl. Load	j	$I(y_1)$		
d	11	Fl. Add −	j	$I(y_3)$	R_4	Post
	12	Fl. Load	j, m	$I(P_i)$		
p	13	Fl. Add −	j, n	$I(P_i-1)$	R_5	Post
	14	Fl. Load	j, n	$I(P_i)$		
q	15	Fl. Add −	j, m	$I(P_i-1)$	R_6	Post
	16	Fl. Add	ℓ (bdk)	$I(r_1)$	$I(r_2)$	Pre
	17	Fl. Add	ℓ	$I(r_3)$		
	18	Fl. Add	ℓ	$I(r_4)$		
R	19	Decr. Exp		2	R_7	Post
	20	Fl. Load		R_3		
	21	Fl. Mpy		R_4	R_8	Post
	22	Fl. Mpy		R_2	R_1	Pre
D	23	Fl. Add −		R_8		
EB	24	Fl. Mpy		R_7	R_8	Post
	25	Fl. Load		R_4		
	26	Fl. Mpy		R_6	R_9	Post
	27	Fl. Mpy		R_1	R_2	Pre
A	28	Fl. Add −		R_9	R_9	Post
	29	Fl. Load		R_4		
	30	Fl. Mpy		R_6	R_{10}	Post
	31	Fl. Mpy		R_1	R_6	Pre
B	32	Fl. Add −		R_{10}		
H	33	Fl. Div −	k (SA)	R_8	$I(h_1)$	Post
	34	Fl. Load		R_9		
G	35	Fl. Div −	k (SA)	R_8	$I(g_1)$	Post
	36	Incr. I	ℓ	1		

"Raw" Arith

Loc.	OP.	I	OA	SA	Pre Post
37	Incr I.	k	2		
38	I Br NG	j	(a)		
39	SWAP		(m)	I(m)	
40	Br VG	k	(b)		
41	(Next)				

Indices

1	i
2	k
3	ℓ
4	p
5	q
6	m
7	n

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List of OPERATIONS for half word scheme Oct 14, '57

DATE
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Direct Index Arith.

1. Load Index
2. Store Index
3. Add Index
4. Sub. Index
5. Compare Index.

Immediate Index Arith.

1. Imm. Load
2. Imm. Add
3. Imm. Compare

Indirect Addressing

1. Load I Indirect
2. Rename Index II/I

Geometric Addressing

1. Load I geom.

Transmit Operations

1. Transmit
2. Swap

Floating Point

1. Load N/U
2. Add N/U
3. Add double N/U
4. Add Mem. N/U
5. Add Mantissa N/U
6. Add SUB) N/U
7. Augment N/U
8. Interchange Aug N/U
9. Mpy N/U
10. Divide N/U
11. Interchange Div N/U
12. Divide Double N/U
13. Store N/U
14. Round & Store N/U
15. Set Exp. & Store N/U
16. Mpy Cumulative N/U
17. Add Exponent
18. Add Exponent Imm.
19. Store Remainder
20. Store & Borrow
21. Load D
22. Compare
23. Square Root & Store
24. offset Mantissa
(8 not assigned)

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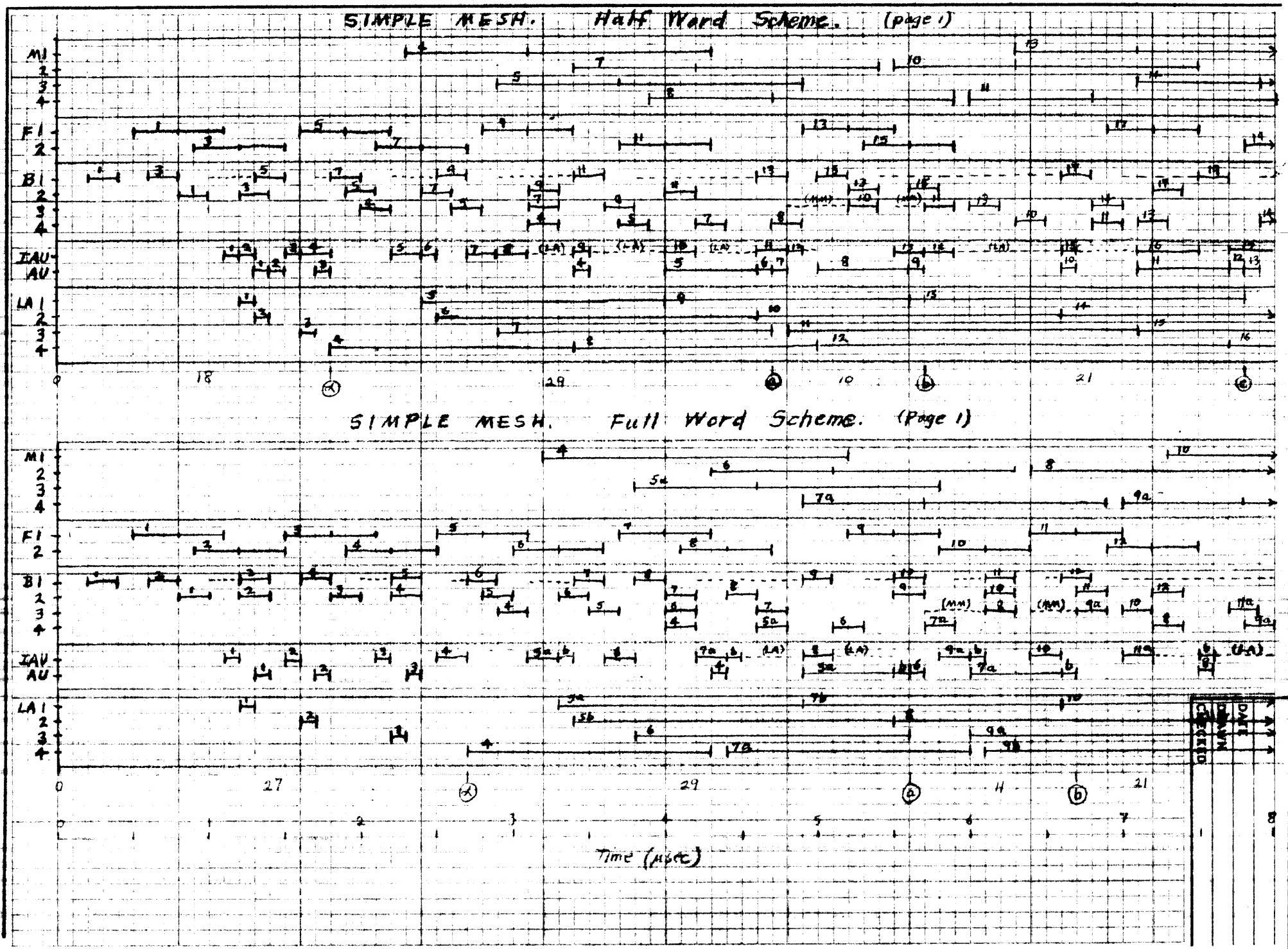
IBM CALCULATOR FLOW CHART



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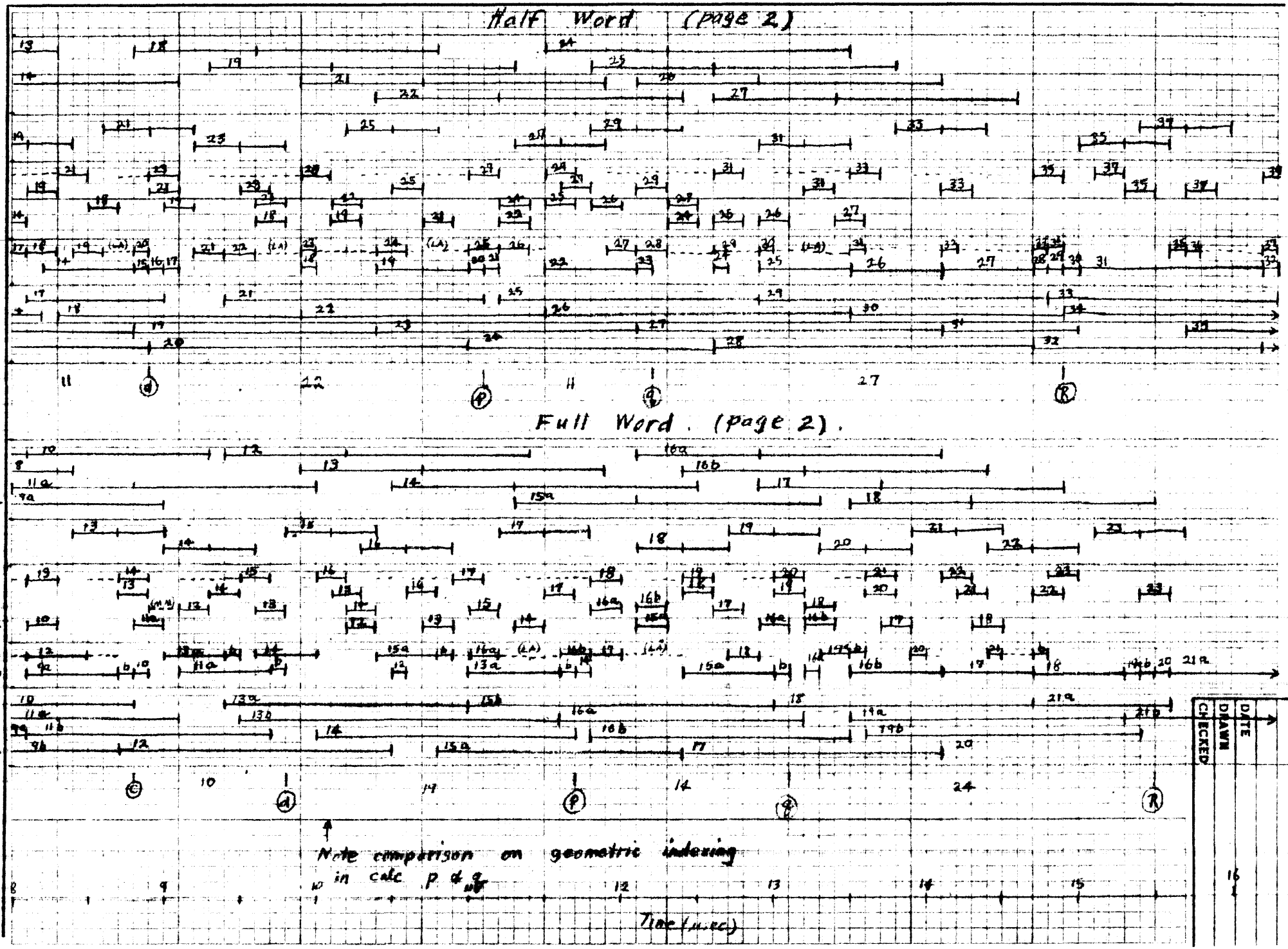
IBM CALCULATOR FLOW CHART



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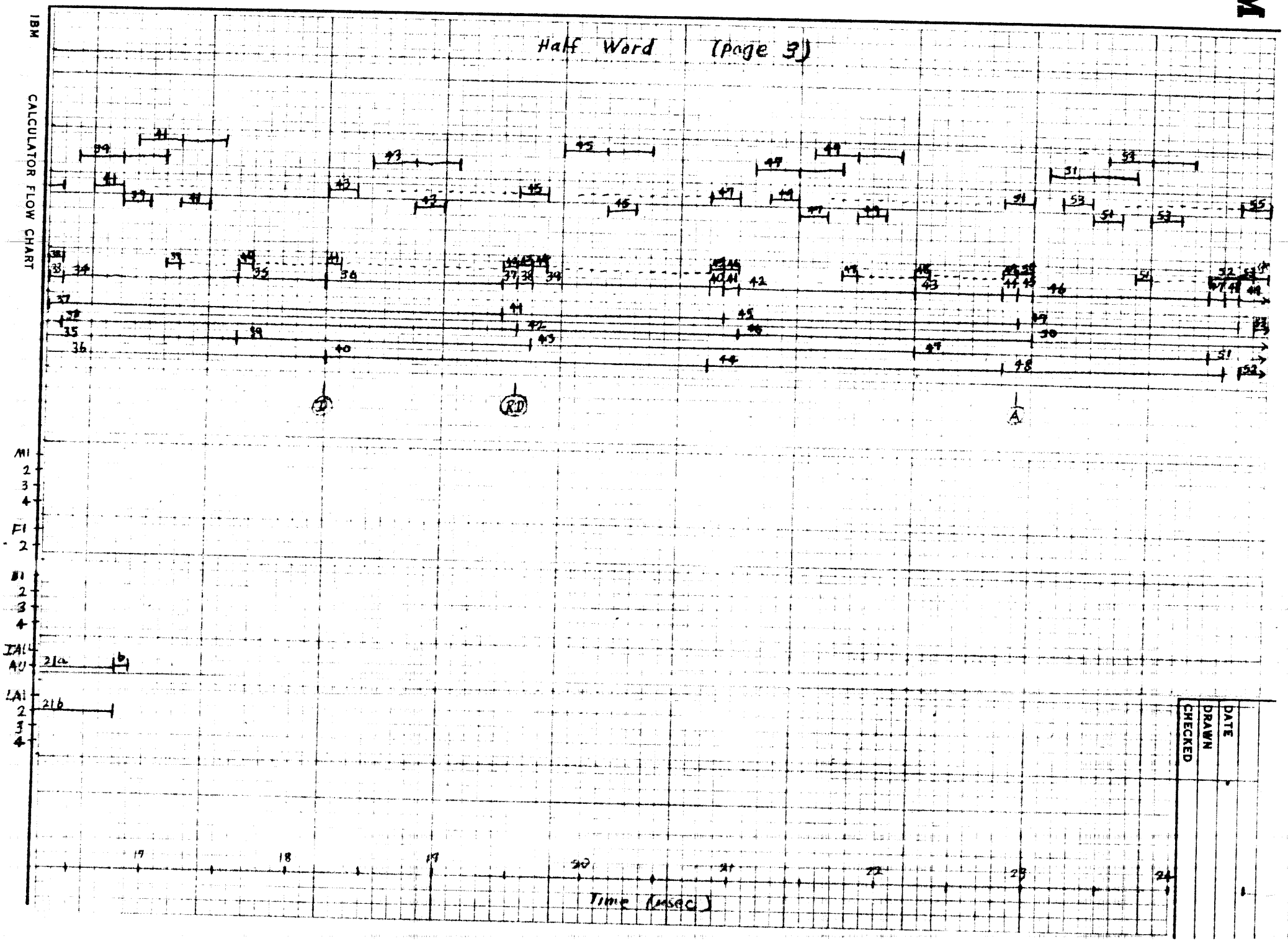
IBM CALCULATOR FLOW CHART

Half Word (page 3)



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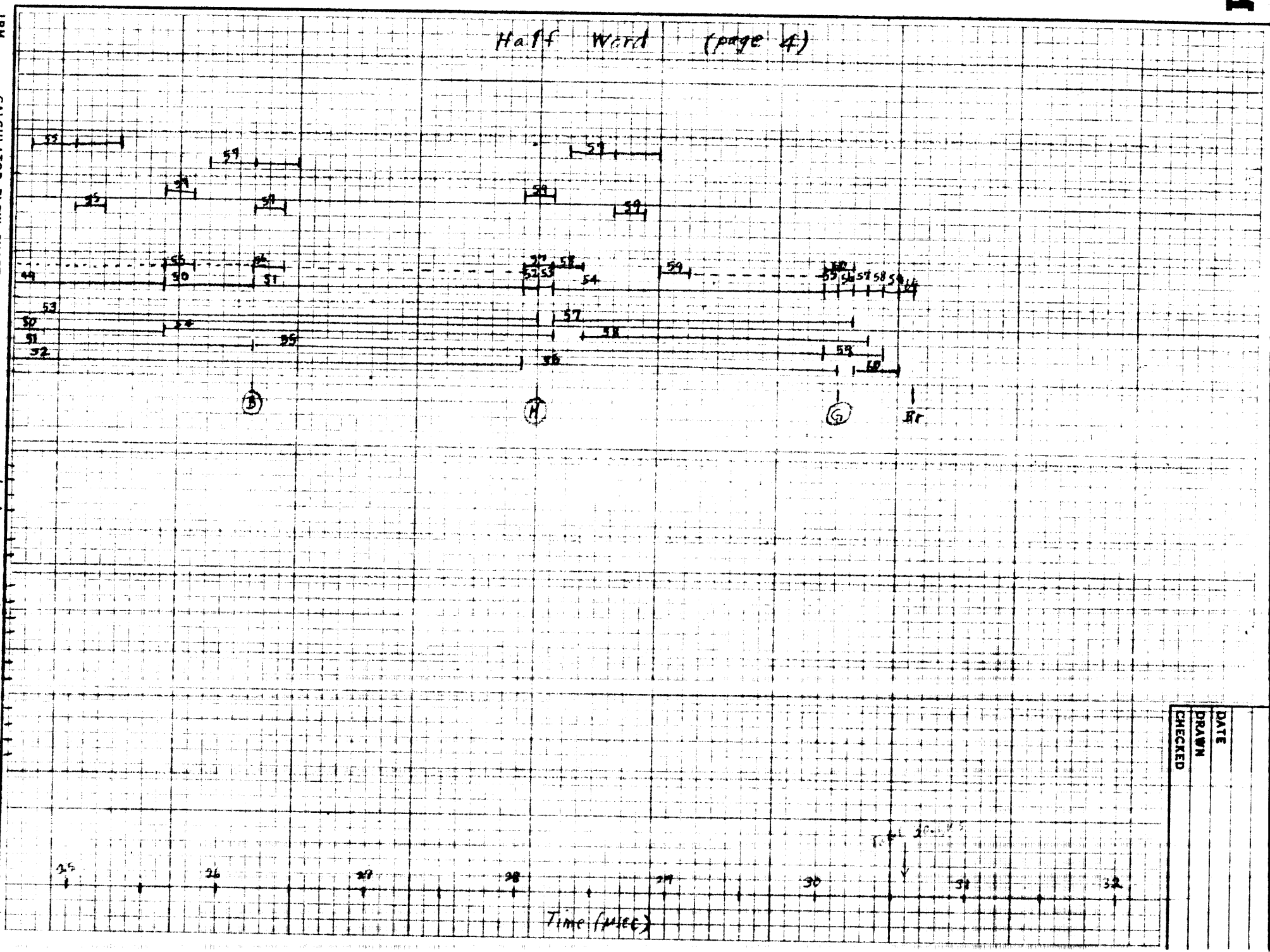

DATE	
DRAWN	
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DATE
DRAWN
CHECKED

	1 Instr. No. 1–6	2. Op. Type 7–12	3 Op. Location 13–18	4 Index I 19–24	5 Index J 25–30	6 Address 31–36	7 Spec. Types 37–42
Load #	1		201	13		0	
Load C	2		202	11		14	
Load C	3		203	12		14	
FL Load	4		204			0	
FL Load D	5		205				

Example of Chain Indexing

DATE	Oct 14, '57
DRAWN	HGK
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Full Word

Loc	OP	I	OA	SA	Pre Post
1	Load I	j	I(J₀)		
2	Load I	i	I(I₀)		
3	Load I	r	I(R₀)		
4	Fl. Load		0		
5	[Fl. Add]	i, j, r	I(Xₐₐ)		
6	I Br R	r	5	1	
7	Br V Gn	r	5	I	
8	Fl. Store	i, j	I(Xₐₐ)		
9	I Br R	i	4	1	
10	I Br R	j	4	I	

Indices & Index quantities:

J_0, I_0, R_0, R_1, R_2, R_3

i, j, r

Code : 10 full wds

Ind. : 9 full wds

Half Word

Loc	OP	I_1	I_2	Addr.
1	Load II		o	I(J-2)
2	Load II		j	I(I)
3	Load II		n	I(I-2)
4	Load II o		i	1
5	Load II		r+3	R_0
6	Load I geo.	m		i, j
7	Load II		ℓ	3
8	Load None	r+3	r	0
9	Load II	r+1	r+2	1
10	Load II	r+1	r+3	2
11	Fl. Load			0
12	Load I geo.	k		m, r
13	[Fl. Add]	k		I(Xₐₐ)
14	Incr	k		1
15	Count+B No.		r+2	13
16	Count+B No.		ℓ	8
17	Fl. Store	m		I(Xₐₐ)
18	Incr	j		I(I)
19	Count+B No.	n		6
20	Incr	j		I(I)
21	Count+B No.	o		6

Indices & Index quantities:

V's : I, R_0, R_1, R_2, R_3

C's : I-2, I-2, R_0, R_1, R_2, R_3

R's : R_0, R_1, R_2, R_3

i, j, k, ℓ, m, n, o

r, r+1, r+2, r+3

Code : 10.5 full wds,

Ind : 13 full wds.

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DATE Oct 7, 59
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Matrix Multiply Loops
using half word op scheme
(no Count+Br type ops.)

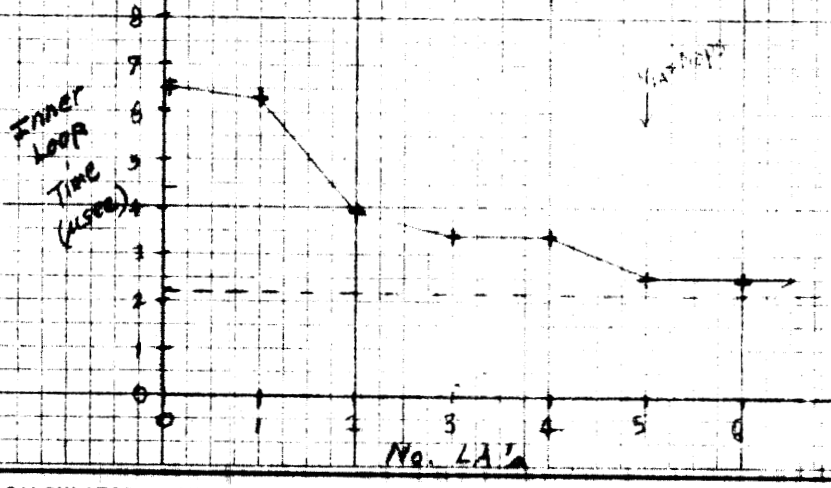
$A \times B = C$

$a_{00}\cdots \times b_{00} \cdots = c_{00}\cdots$

N x N Matrices stored Row-wise

LOC.	Op.	I_1	I_2	Addr.
1	Load I		j	0
2	Load II		i	0
3	Load I		ℓ	I(N)
4	Fl. Load			0
5	Fl. Load D	i		$I(a_{ik})$
6	Fl. Cum. Mpy	j		$I(b_{00})$
7	Incr I	i		1
8	Add II		j	I(N)
9	Count Br. No.		ℓ	5
10	Fl. Store	i		$I(C_0) - N$
11	Add II		j	$I[-N(N-1)+1]$
12	Compare I		j	I(N)
13	Branch No			2
14	Exit			

Results of hand-timed simulation



Time (μsec)	No. LAP's
6.5	0
6.3	1
3.9	2
3.4	3
2.5	5
2.5	6

(12 Aug 64)

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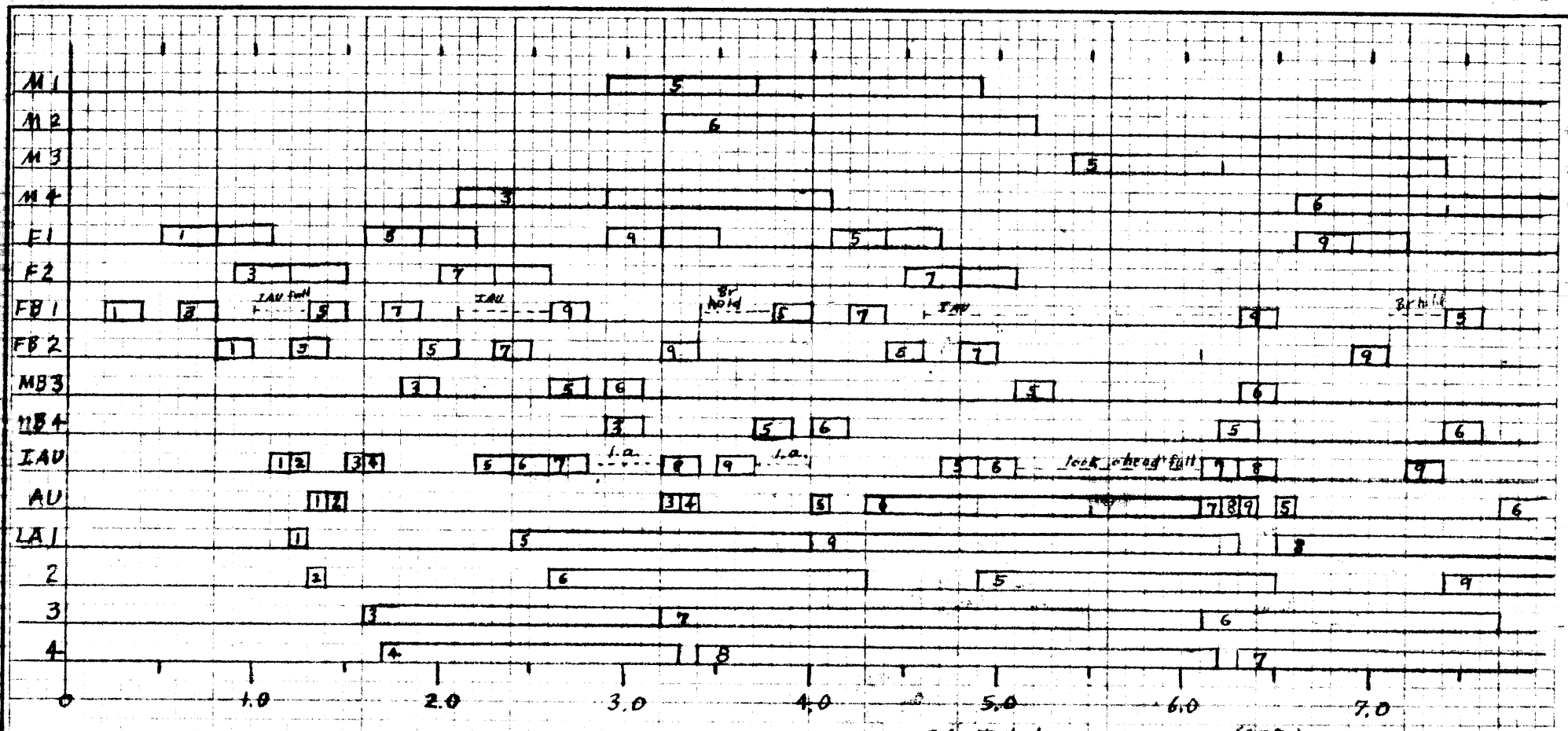
IBM CALCULATOR FLOW CHART



3.4 Total 2.2 AU (65%)

Note: I(M) was taken as M-4 in instr. #3 but as a fast register in instr. #8

Timing Chart, Multiply

DATE Oct 7, 57

DRAWN HAK

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