Consolidated Engineering Corporation
Computer Division
Mathematics Section

CODED BY: K. L. Austin

SUBROUTINE: Floating Decimal Arithmetic

PROBLEM: To evaluate the expression U op V = Y where U and V are given in floating decimal form. The answer, Y, is to be in floating decimal form. op may be any one of the arithmetic operations; addition, subtraction, multiplication, or division.

METHOD OF SOLUTION:

The mantissas and exponent indices of U and V are separated, the appropriate operation is performed and the result is assembled with its proper exponent index.

NOTES: 1. The floating form of U, V and Y are represented symbolically as:

$U = U_{man} + U_{exp}$ (U_{man} = 8 digit mantissa of U. U_{exp} = 2 digit exponent index of U.)

$V = V_{man} + V_{exp}$

$Y = Y_{man} + Y_{exp}$

Actual exponent +50

50 = 0

Where the non-zero numbers have mantissas of the form $.X_1 X_2 X_3 X_4 X_5 X_6 X_7 X_8$, $X_1 \neq 0$ and a floating decimal zero is of the form .0000000000. The exponent indices range from 1 - 99 inclusive.

2. The computer will halt if:

(1) op = division and $V_{man} = 0$

(2) $Y_{exp} \geq 100$

3. $Y = Y_{man} + Y_{exp}$ will be = 0 if:

(1) $Y_{exp} \leq 0$

(2) $|Y_{man}| = 0$

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Computer Division
Mathematids Section

ACCURACY: Y_{man} is rounded to 8 digits for all op.

FORMAT: The subroutine is stored in relative positions 0000-0079. Exit from the subroutine is at position 0077. Entry position of the separate operations are:

0000	Subtraction
0002	Addition
0003	Multiplication
0005	Division

The result, Y, is stored in the A-register and also in position 4008.

CYCLE CONSTRUCTION:

No major looping is used in the coding of the problem. One simple loop is used for the separation of the mantissa and exponent indices of U and V. (commands 0008-0015)

SUBROUTINE ENTRY AND EXIT:

The subroutine is coded for entry via a cub R command to one of the relative positions 0000, 0002, 0003, or 0005. As an alternative entry method, the subroutine exit address may be stored in the R-register in position $R_1R_2R_3R_4$ by the main routine and subroutine entered via a cub command.

The exit is formed by the subroutine and stored in position 4004 as a cu($R_1R_2R_3R_4$) command.

CAUTION: A cub R x entry command must not be executed from the 7000 loop. ~~why not~~

INSERTIONS FROM THE MAIN ROUTINE:

(A) = 0

(4008) = U

(4007) = V $= \pm .\underbrace{xxxxxxxx}_{\text{mantissa}}\ \underbrace{kk}_{\text{exponent index}}$

sign of mantissa

2/10/54-mjm

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Mathematics Section

REGISTER AND LOOP CONDITIONS:

1. Used by the subroutine: loop 7; the A, R, and B registers and the special counter; positions 4008, 4007, 4006, 4005, 4004.
2. After the subroutine:

   (A) = Y (4008) = Y

   (R) = Y_{man} (4004) = exit command = cu($R_1R_2R_3R_4$)

   (B) $\neq$ 0

COMMENTS:

This subroutine may also be used for Fixed to Floating Form conversion. To convert a group of numbers to floating form which have N places to the left of the decimal point and 8 - N places to the right; the exponent N + 50 is appended to the right of the number and the number is added, by use of this subroutine, to 0.

Example:

Fixed decimal number	Appended decimal point marker	Result on addition to 0.	
0 0 0.0 1 3 4 5	53	.1 3 4 5 0 0 0 0	49
1 3 4.7 1 6 4 0	53	.1 3 4 7 1 6 4 0	53
0 2 1.0 0 4 1 3	53	.2 1 0 0 4 1 3 0	52
0 0 0.0 0 0 0 1	53	.1 0 0 0 0 0 0 0	46
0 0 0.1 0 0 0 2	53	.1 0 0 0 2 0 0 0	50

STORAGE:

0000 – 0018: mantissa and exponent separation--operation entry and exit preparation.

0019 0000 08 0001

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Mathematics Section

STORAGE (CONT'D):

0020 – 0026	op = division
0027 – 0035	op = multiplication
0036	50×10^{-10}
0037 – 0039	part of normalization
0040 – 0059	op = addition
0060 – 0079	normalization

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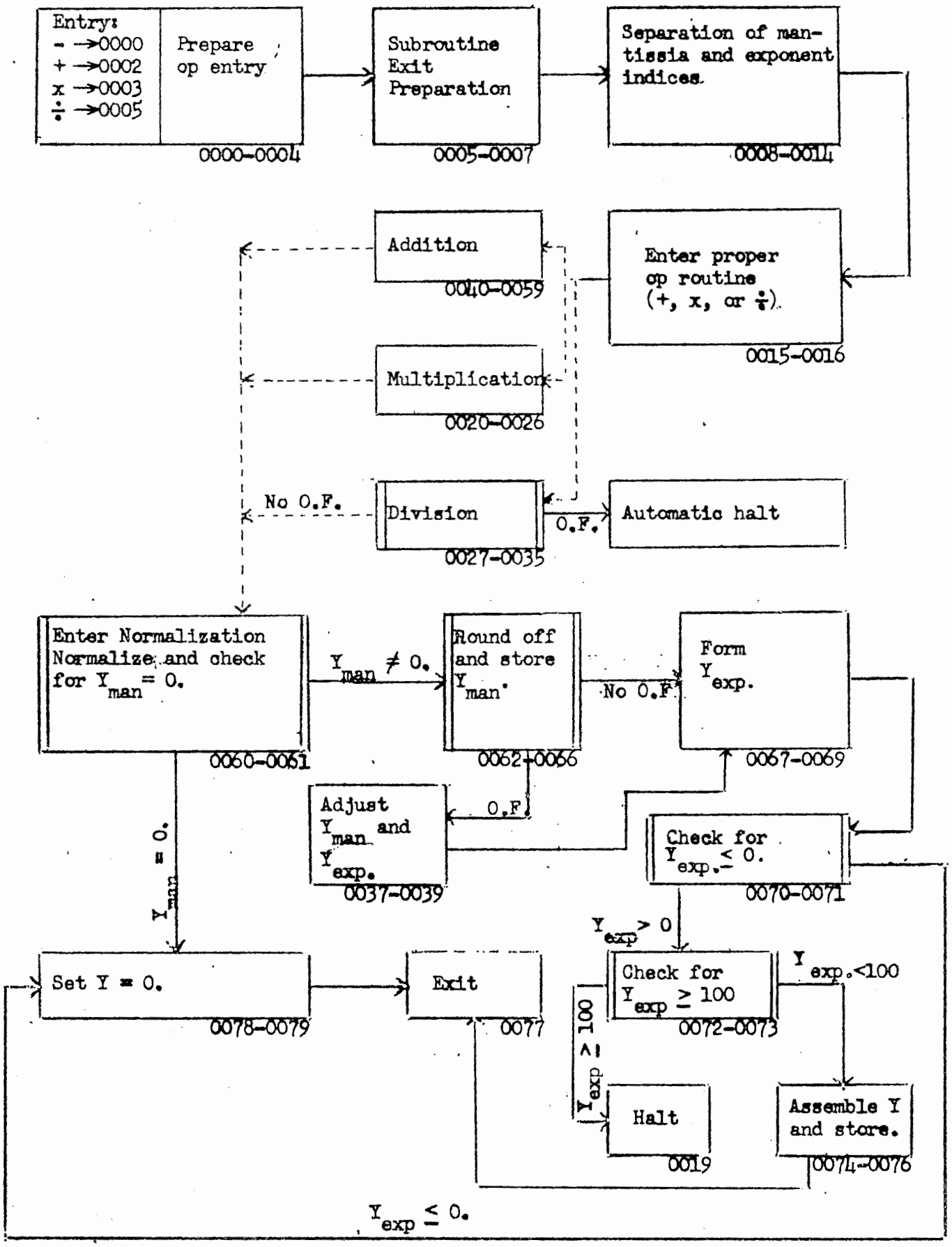
FLOW CHART:



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INSTRUCTION LIST

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	Numerical Code			cc/cu Returns	Call Number	Instruction			Immediate Effect	Continuity
s	Spare	Order	Address			s	Order	Address		
0	0001	65	4007		0000		csu	4007	$(A)_a = -V$ } change sign of V	Subtraction entry.
0	0000	02	4007		0001		tmc	4007		
0	0001	74	7017		0002		ad	7017	$(A)_a$ = 0000000020	Addition entry.
0	0001	74	7018		0003		ad	7018	$(A)_a$ = { cub 20 on op = x cub 40 on op = - or + }	Multiplication entry.
0	0000	02	7016		0004		tmc	7016		
0	0001	74	7017		0005		ad	7017	$(A)_a$ = 0000000cu (Division entry)	
0	0000	14	0004		0006		sl	0004		Subroutine exit
0	0000	02	4004		0007		tmc	4004		preparation.
0	0000	72	7019		0008		B	7019	$(B)_a = 1$	
1	0000	64	4007	7014→	0009	1	ca	4007	(B) = 1, $(A)_a$ = (u); (B) = 0, $(A)_a$ = V.	Separate mantissia and
0	0000	13	0002		0010		sr	0002	$(A)_a = U_{man}; V_{man}$	exponents of U and V and
1	0000	02	4007		0011	1	tmc	4007	store mantissias	store.
0	0000	14	0002		0012		sl	0002	$(A)_a = U_{exp}; V_{exp}$	
1	0000	12	4005		0013	1	tmh	4005	store exponents	
0	0000	22	7009		0014		B⁻	7009		
0	0000	72	7019		0015		B	7019	$(B)_a$ = 0001.	
2	0000	30	0027		0016	2	[cub cu	0027] 00	exit to operation entry	
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Numerical Code			cc/cs Returns	Cell Number	Instruction			Immediate Effect	Continuity
s	Spare	Order	Address			s	Order	Address		
0	0000	00	0020		0017					Constants
2	0000	30	0020		0018					
0	0000	08	0001	0073 →	0019					
									Multiplication	
0	0001	74	4006	0016 →	0020		ad	4006	$(A)_a = V_{exp} + U_{exp}$	Form and store partial
0	0000	75	7036		0021		su	7036	$(A)_a = V_{exp} + U_{exp} - 50$	Y_{exp}
0	0000	02	4006		0022		tmc	4006		
0	0000	64	4008		0023		ca	4008	$(A)_a = U_{man}$	
0	0000	60	4007		0024		mh	4007	$(A)_a = (U_{man})(V_{man})$	Form Y_{man}
0	0000	14	0003		0025		sl	0003		
2	0000	30	0060		0026	2	cub	0060	exit to normalisation	
									Division	
0	0001	64	4006	0016 →	0027		ca	4006	$(A)_a = U_{exp}$	Form and store partial
0	0000	74	7036		0028		ad	7036	$(A)_a = U_{exp} + 50$	Y_{exp}
0	0000	75	4005		0029		su	4005	$(A)_a = U_{exp} - V_{exp} + 50$	
0	0000	12	4006		0030		tmh	4006		
0	0000	13	0005		0031		sr	0005	? ←	
0	0000	64	4008		0032		ca	4008	$(A)_a = U_{man}$	

9/9/53-mm

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	Numerical Code			cc/cn Returns	Coil Number	Instruction			Immediate Effect	Continuity
s	Spare	Order	Address			s	Order	Address		
0	0000	13	0001		0033		sr	0001		
0	0000	61	4007		0034		div	4007	$(A)_a = U_{man} \div V_{man}$	
2	0000	30	0060		0035	2	cub	0060	exit to normalization	
0	0000	00	0050		0036					
0	0000	32	0000	0066 →	0037		B+		$(B)_a = 2$	Used by normalization
0	0000	14	0007		0038		sl	0007	$(A)_a = \pm 0010000000$ only for 9999's	routine for correction
2	0000	30	0064		0039	2	cub	0064		when round off overflows.
									Addition	
0	0001	75	4006	0016 →	0040		su	4006	$(A)_a = V_{exp} - U_{exp}$	
0	0000	13	0001		0041		sr	0001		
0	0000	73	7055		0042		sgc	7055		O.F. : $U \geq V$
0	0000	28	7059		0043		cc	7059		
0	0000	04	7048	7059 →	0044		Z	7048		O.F. : difference of expo
										nents ≥ 10
0	0000	64	7058		0045		ca	7058	$(A)_a = 00000sr000$	Alter shift right command
0	0000	14	0001		0046		sl	0001	$(A)_a = 0000sr(V_{exp} - U_{exp})$	
0	0000	02	7051		0047		tmc	7051		

9/9/53-mm

Consolidated Engineering Corp.
Computer Division

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	Numerical Code			cc/cu Returns	Cell Number	Instruction			Immediate Effect	Continuity
	Spare	Order	Address			1	Order	Address		
1	0000	64	4004	7044→	0048	1	ca	4004	(B) = 1, $(A)_a = V_{exp}$; B = 0, $(A)_a$ = exit command.	
1	0000	02	4005		0049	1	tmc	4005		Adjust smaller mantissia
1	0000	64	4007		0050	1	ca	4007	(B) = 1, $(A)_a = U_{man}$; (B) = 0, $(A)_a = V_{man}$.	for addition.
0	0000	13	0010		0051		[sr	0010]		
0	0000	23	0000		0052		round	off		
1	0000	02	4007		0053	1	tmc	4007		
0	0000	64	4008		0054		ca	4008	$(A)_a = U_{man}$	U_{man} + V_{man}
0	0000	74	4007		0055		ad	4007		
0	0000	14	0001		0056		sl	0001		
2	0000	30	0060		0057	2	cub	0060	exit to normalization	
0	0000	01	3000		0058		00000	sr 000		
0	0000	22	7044	7043→	0059		B⁻	7044		
									normalization	
				0026						
0	0001	72	7069	0035→	0060		B	7069	$(B)_a$ = .0001	
				0057						
0	0000	15	7078		0061		spl	7078	$(A)_a$ = normalized Y_{man}	
0	0000	13	0002		0062		sr	0002		Normalize Y_{man}.
	9/9/53-mm									

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s	Numerical Code: Spare	Order	Address	cc/cc Returns	Cell Number	Instruction: s	Order	Address	Immediate Effect	Continuity
0	0000	23	0000		0063		ro			
0	0000	12	4008	0039 →	0064		tmh	4008		
0	0000	13	0008		0065		sr	0008		
2	0000	04	0037		0066	2	%	0037		
0	0000	11	0000		0067		B→A		$(A)_a = 1 \times 10^{-10}$ ≈ 2×10^{-10}	
0	0000	74	4006		0068		ad	4006	$(A)_a = (A)_b$ + partial Y_{exp}	Form Y_{exp}
0	0000	17	0001		0069		spc	0001	$(A)_a = (A)_b$ - normalizing factor	
0	0000	73	7060		0070		sgc	7060		Check for $Y_{exp} \leq 0$.
0	0000	28	7078		0071		cc	7078		
0	0000	13	0002		0072		sr	0002		Check for $Y_{exp} \geq 100$
2	0000	04	0019		0073	2	%	0019		
0	0000	64	4008		0074		ca	4008	$(A)_a = Y_{man}$	
0	0000	14	0002		0075		sl	0002	$(A)_a = Y_{man} + Y_{exp}$	Form and store $Y_{exp}+Y_{man}$
0	0001	12	4008	7079 →	0076		tmh	4008		
0	0000	20	4004		0077		cu	4004		Subroutine exit
0	0000	02	4008	7061 7071 →	0078		tmc	4008		
0	0000	20	7076		0079		cu	7076		$Y = 0$.