THE ENGLISH ELECTRIC CO., LTD.

NELSON RESEARCH LABORATORIES

STAFFORD
MATHEMATICAL PHYSICS LABORATORY.

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Reference
Order No.

Front Sheet.

Data Sheets 1-2.

Drawing Nos. S6/10101-2.

DEUCE Subroutine No. 36 (M10D)

Report by

G.J. Hutton.

SUMMARY.

The attached document contains working details of a DEUCE Subroutine for multiplying two signed double length numbers to give a signed double length product with variable shift and round off.

The subroutine was prepared at N.R.L. and has been copied into all instruction delay lines of the N.R.L. DEUCE at Blackheath and tested in each.

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MATHEMATICAL PHYSICS LABORATORY.

NW

Description. Signed multiplication of a double length number α by a double length number β yielding a double length answer γ with variable shift and round off. It is second order.

Data. α (signed double length) $= \alpha_2 + 2^{32}\alpha_1$

β (signed double length) $= \beta_2 + 2^{32}\beta_1$

s the shift $0 \leq s \leq 32$.

N.B. With s = 32 there is no round off.

Result. $\gamma = \alpha\beta = \gamma_2 + 2^{32}\gamma_1$ γ_2, γ_1 single length.

Uses. Specially coded multiplication.

Instructions for Use.

Stores Used.	13	14	15	16	17_0	(18_2)	(18_3)	19_2	19_3
Contents at Entry.	Link	-	-	-	-	-	-	α_2	α_1
Contents at Exit.	-	β_1	-	α_1	-	(α_2)	(α_1)	-	zero

Stores Used.	20_2	20_3	21_2	21_3
Contents at Entry.	β_2	β_1	-	-
Contents at Exit.	β_2	β_1	γ_2	γ_1

Occupies. D.L.B. m.c.'s 0-31 and D.L.C m.c.'s 7, 8, (10), (11), 13, 14.

Entry. in m.c. 29.

Time.

s = 0	14 major cycles.
$1 \leq s \leq 17$	16 major cycles.
s = 18	17 major cycles.
$19 \leq s \leq 32$	18 major cycles.

Parameters.

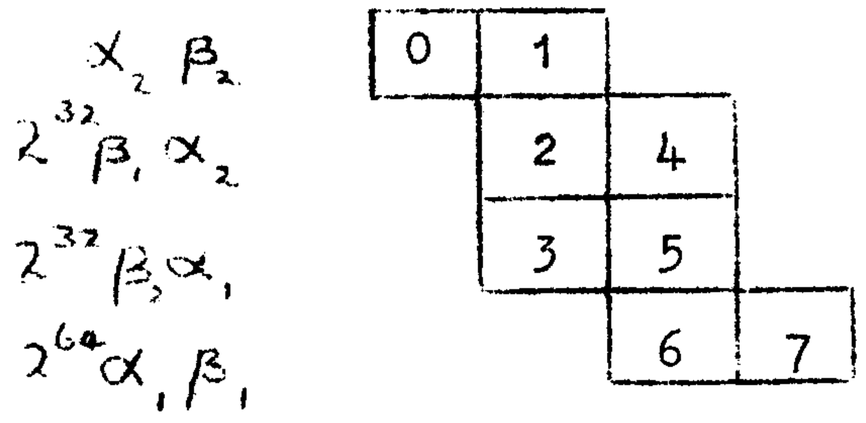
			S = 0	$1 \leq s \leq 16$	$17 \leq s \leq 32$
D.L.B.	m.c. 7	Add	$21P_{10}$	$22P_{10}+(33-2s)P_{17}$	$22P_{10}+P_{17}$
	m.c. 9	Add	$21P_{10}$	$21P_{10}$	$22P_{10}+(69-2s)P_{17}$
	m.c. 17	Add	$21P_{10}$	$22P_{10}+(33-2s)P_{17}$	$22P_{10}+P_{17}$
	m.c. 19	Add	$21P_{10}$	$21P_{10}$	$22P_{10}+(67-2s)P_{17}$
	m.c. 2	Add	$18P_{10}$ or CP_{10}	according as $18_{2,3}$ or $C_{10,11}$ is preferred as a temporary storage position.	
D.L.C.	m.c. 8	Add	$18P_5$ or CP_5		

Notation Used.

$$\alpha \times \beta = (\alpha_2 + 2^{32}\alpha_1)(\beta_2 + 2^{32}\beta_1)$$
$$= \alpha_2\beta_2 + 2^{32}(\beta_1\alpha_2 + \beta_2\alpha_1) + 2^{64}\alpha_1\beta_1$$

where $\alpha_2\beta_2$, $\beta_1\alpha_2$, $\beta_2\alpha_1$, $\alpha_1\beta_1$ are double length products.

This expression may be represented in block form as follows:-



where [0] ..... [7] represent single length numbers and [x / y] implies the operation of addition of [x] and [y]

Further, the double length result of addition of a single length number to the lower half of a doubl e length number [x / y] is considered as two component single length numbers and denoted thus [x . y | x & y]

2nd Edition.

B_{29}	$13 - I_{31}$		
B_{31}	$30 - 15$		
B_1	$B_3 - 13$	Plant link for Subroutine Mult.	
B_8	$19_2 - 16$	α_2	
B_{14}	$20_2 - 14$	β_2	
B_{16}	MULT.	(a)(b)(c) Link plants next link	
I_{30}	$B_1 - 13$	Store α	
B_2	$19 - C_{10,11}$ or $18_{2,3}$ (2 m.c.)	β_1	
B_{13}	$20_3 - 14$	(d)(e)(f) Link plants next link	
B_{16}	MULT	α_1	
I_{30}	$B_6 - 13$	(g)	
B_5	$19_3 - 16$	(h)	
B_{10}	$15 - 19_2$	β_2	
B_{12}	$21_2 - 16$	(i)(j)(k)	
B_{14}	$20_2 - 14$		
B_{16}	MULT.		
I_{30}	$30 - 21_3$		
B_3	$B_6 - 13$	Plant next link.	
B_7	$21 \begin{cases} 21 \\ \text{or} \\ 22 \end{cases}$ 25 m.c.'s	(m)	
B_9	$21 \begin{cases} 21 \\ \text{or} \\ 22 \end{cases}$		
B_{15}	$30 - 19_3$		
B_{24}	$29 - 28_2$	(n)	
B_{26}	$21_3 - 14$	(p)	
B_{30}	$14 - 17_0$		
B_{13}	$20_3 - 14$	β_1	
B_{16}	MULT	(q)(r)(s)	
I_{30}	$19 - 22$ (2 m.c.'s e,o)	(t) 19_3 is zero	
B_4	$20_3 - 27$		
	+ / −		
C_7	$0 - 0$		
C_8	$C_{10,11}$ or $18_{2,3} - 23$		
B_{11}	$16 - 27$		Sign Correction
	+ / −		
C_{13}	$0 - 0$		
C_{14}	$20 - 23$ (2 m.c.'s e,o)		
B_{17}	$21 - \begin{cases} 21 \\ \text{or} \\ 22 \end{cases}$ 25 m.c.'s	(u)	
B_{19}	$21 - \begin{cases} 21 \\ \text{or} \\ 22 \end{cases}$		
B_{23}	$17_0 - 19_2$	(v)	
B_{28}	$19 - 22$ (2 m.c.'s e,o)	19_3 is zero	
I_{31}			

MULT.

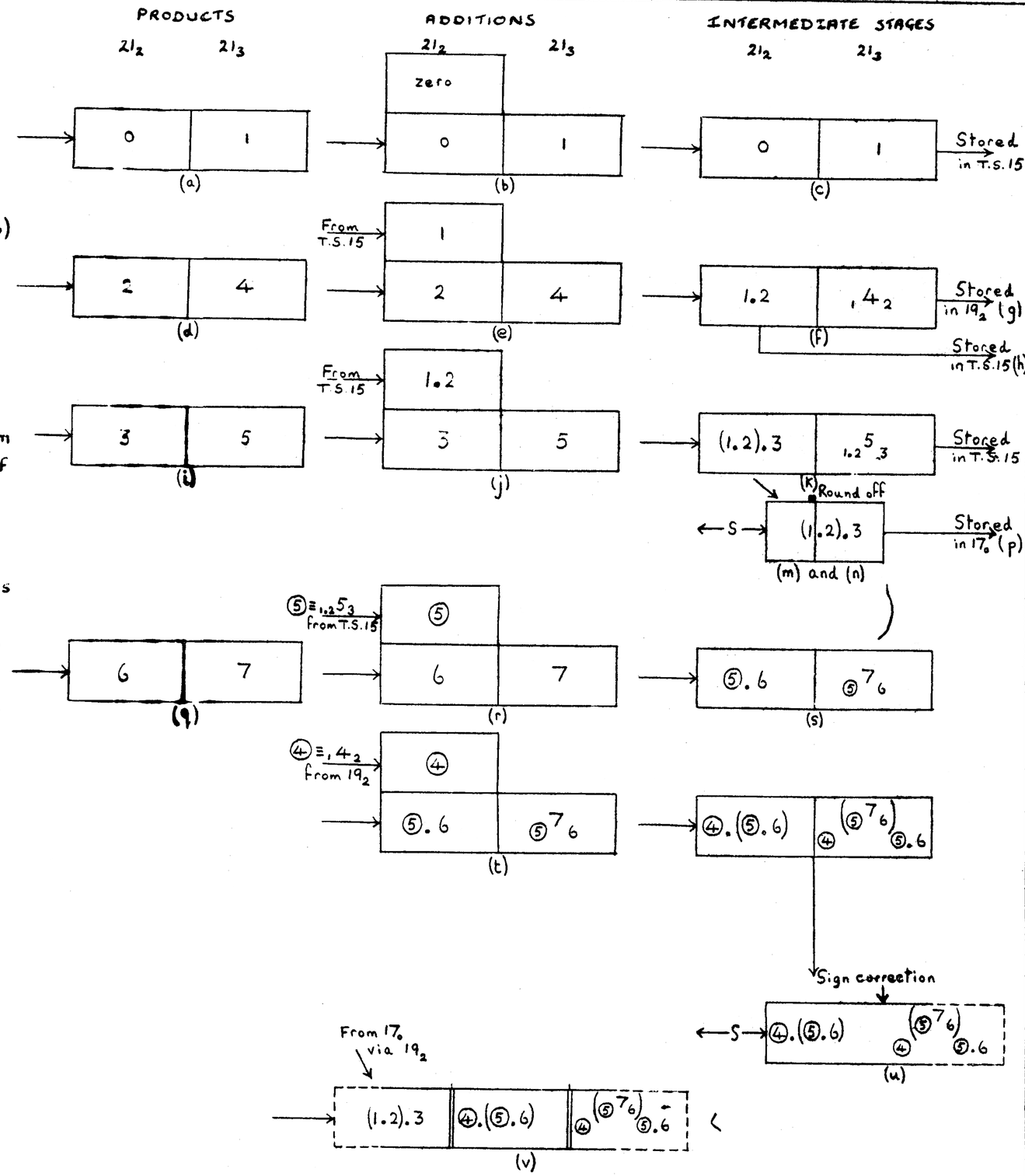
B_{16}	$30 - 21_2$
B_{18}	$14 - 21_3$
B_{21}	$0 - 24$
B_{20}	$13 - I_{30}$
B_{22}	$15 - 22$ (2 m.c.'s e,o)
B_{25}	$15 - 23_3$
B_{27}	$21_3 - 15$
I_{30}	

Note.

Mult. forms product then adds T.S. 15 into bottom half and stores top half in T.S. 15

Note.

The instructions in m.c.s 1 and 3 are obeyed twice:- once in m.c. so as a link, and once in their own positions.



It will be seen that ④ and ⑤ between them bear the correct amount of carry from the addition of 1, 2 and 3.

Flow diagram and block diagram explanation of operations carried out by subroutine M.10.D. (Double Length Mult.)

Data
File Ref. E.E.
Sheet Ref. S6/10101

NATIONAL RESEARCH LABORATORIES,
ENGLISH ELECTRIC CO. LTD.,
STAFFORD, ENGLAND.

Coding for double length multiplication Subroutine No. 36 (M10D)

D.L. B Track Card Nos.							D.L. C Track Card Nos.							D.L. Track Card Nos.							
mc	NIS	S	D	C	W	T	mc	NIS	S	D	C	W	T	mc	NIS	S	D	C	W	T	
																					Y
																					X
																					0
																					1
0	B	30	21		1	3	0							0							2
1	B	B	13		0	5	1							1							3
2	B	19		d	6	9	2							2							4
3	B	B	13		1	2	3							3							5
4	C	20	27		1	1	4							4							6
5	B	19	16		0	3	5							5							7
6	B	19	22	d	0	4	6							6							8
7	B	21		l		0	7	B	0	0		0	2	7							9
8	B	19	16		0	4	8	B		23	d	0	1	8							Y
9	B	21		l		4	9							9							X
10	B	15	19		0	0	10	Reserved } as temporary storage position if $18_{2,3}$ not used						10							0
11	C	16	27		0	0	11	Reserved }						11							1
12	B	21	15		0	0	12							12							2
13	B	20	14		0	1	13	B	0	0		0	2	13							3
14	B	20	14		0	0	14	B	20	23	d	0	1	14							4
15	B	30	19		0	7	15							15							5
16	B	30	21		0	0	16							16							6
17	B	21		l		0	17							17							7
18	B	14	21		1	1	18							18							8
19	B	21		l		2	19							19							9
20	B	13	1		8	0	20							20							Y
21	B	0	24		0	29	21							21							X
22	B	15	22	d	0	1	22							22							0
23	B	17	19		3	3	23							23							1
24	B	29	23		0	0	24							24							2
25	B	15	23		0	0	25							25							3
26	B	21	14		1	2	26							26							4
27	1	21	15		0	1	27							27							5
28	1	19	22	d	0	1	28							28							6
29	B	13	1		0	0	29							29							7
30	B	14	17		0	13	30							30							8
31	B	30	15		0	0	31							31							9