

- 1 IDENTIFICATION
- 1.1 Digital-7-31-F-Sym
- 1.2 Signed Multiply Subroutine - Single Precision
- 1.3 February 15, 1965



2. ABSTRACT

This subroutine forms a 34-bit signed product from 17-bit signed multiplier and multiplicand.

3. REQUIREMENTS

3.1 Storage

This subroutine uses 47 (decimal) memory locations.

4. USAGE

4.2 Calling Sequence

The subroutine is called by the JMS instruction. When the JMS is executed to enter the subroutine the multiplier must be in the accumulator (AC). The location following the JMS must contain a LAC with the address of the multiplicand.

The subroutine will return the instruction immediately following the latter location with the least significant part of the product in the AC. The most significant part of the product will be stored in location MP5.

6. DESCRIPTION

Reference to the flowchart (10.1) will illustrate the following discussion.

6.1.1 On entry, the sign of the multiplier is tested, and if negative, the multiplier is made positive.

6.1.2 The multiplicand is obtained and tested for 0. If it is found equal to 0, a jump to the exit is executed. Next the sign of the multiplicand is tested; and if it is found negative, the multiplicand is made positive.

6.1.3 At this point, the contents of the link are as follows:

| Sign of Multiplier | Sign of Multiplicand | Links |
|--------------------|----------------------|-------|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

and represent, therefore, the sign of the product.

6.1.4 The multiply loop proper (tagged MP4) is entered. During this loop, the least significant half of the product shifts into the most significant end of MP5 while the multiplier shifts out the least significant end of MP5 and is lost. Note that the sign of the product is retained in MP5.

6.1.5 The sign of the product is tested. If positive, the subroutine exits. If negative, complementation of the product is performed before the exit.

6.3 Scaling

Upon entry the binary point is assumed to be located between bit positions 0 and 1 in both multiplier and multiplicand. Since there are 17 magnitude bits in each of the two factors, the product will contain 34 magnitude bits.

The product is double signed, i.e., bit positions 0 and 1 of the most significant word of the product both contain the sign. The remaining 16 bits of the most significant word of the product are magnitude bits.

The least significant word of the product is devoted entirely to magnitude.

If the binary point of the factors are as stated above, the binary point of the product will be located between bit positions 1 and 2 in the most significant portion of the product.

On entry, multiplier and multiplicand must be 2's complement binary. After return, the product is contained in two words in 2's complement form.

For more information on binary scaling for fixed-point computers, see Application Note 501.

7. METHOD

7.2 Algorithm

The conventional algorithm is used. The least significant bit of the multiplier is tested. If it is equal to 1, the multiplicand is added to the developing product and this quantity is shifted right. If the least significant bit of the multiplier is 0, no addition is made before the shift. The process is repeated until all the bits of the multiplier in order from least significant to most significant have been processed.

9. EXECUTION TIME

9.1 Minimum

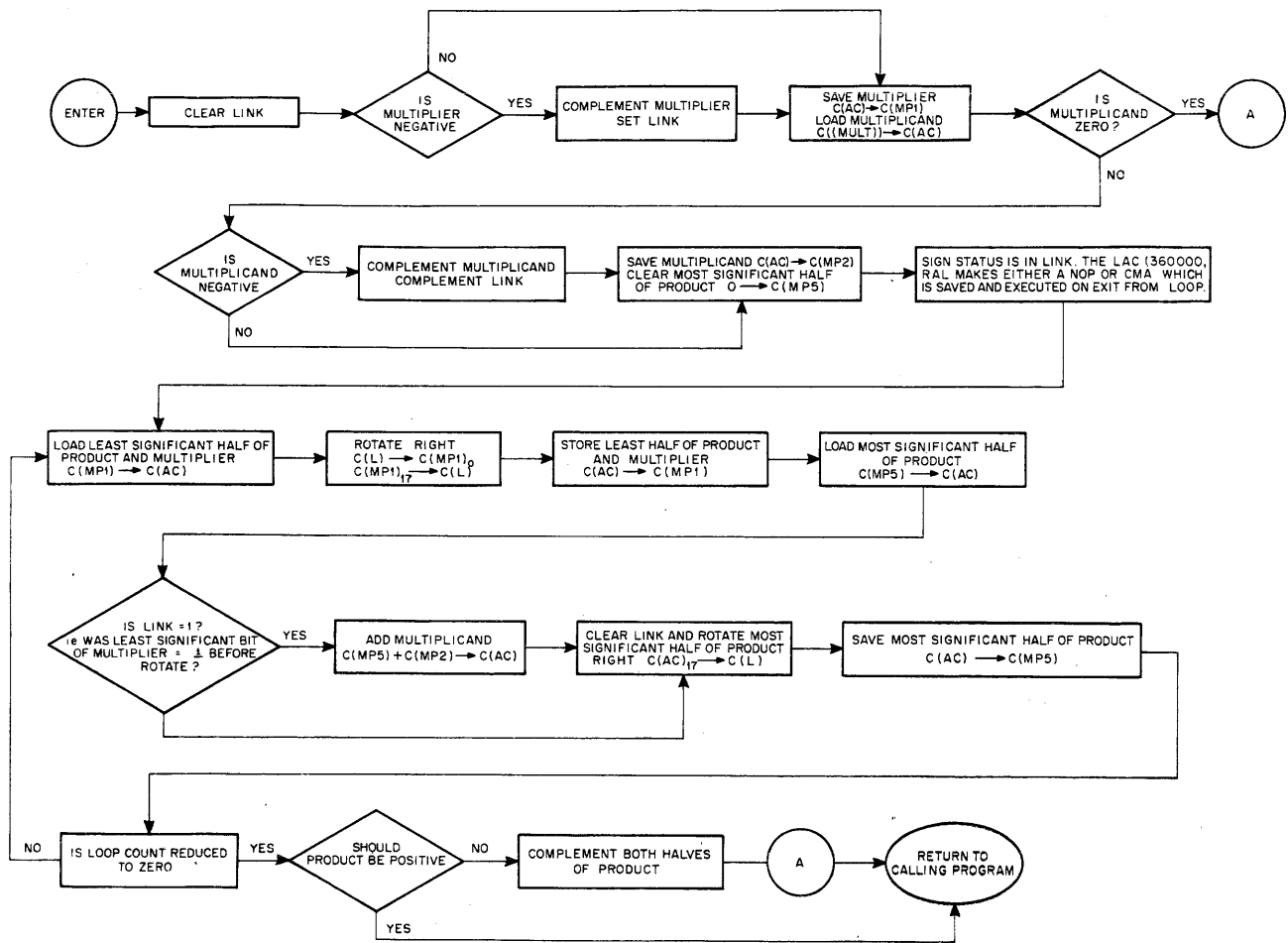
When the subroutine discovers that the multiplicand is 0, the multiplication loop is bypassed. In this case, execution time will be 14 microseconds.

9.2 Maximum

Maximum execution time occurs when the sign of the product is negative and the multiplier consists (in binary) of all ones. The time is approximately 570 μ sec.

10. PROGRAM

10.1 Flowchart



10.2 Example

The C(Y) are tested. If C(Y) = 0, C(MP1) = C(MP5) = 0. If C(Y) is not 0, then C(Y) → C(MP2), C(MP5) are cleared and multiplication is carried out as follows:

If C(MP1)₁₇ contains a 1, C(MP2) are added to C(MP5). The contents of MP5 and the MP1 are then shifted right one bit. If C(MP1)₁₇ = 0, the contents of MP5 and those of the MP1 are shifted right one bit.

For this example, assume that the registers MP1, MP5 and MP2 are five bits in length instead of 17. The following sequential steps will occur in a multiply operation. The multiplicand is 9 and the multiplier is 4.

| <u>MP5</u> | <u>MP1</u> | <u>Y</u> | <u>Comments</u> |
|------------|------------|----------|--|
| 00000 | 01001 | 00100 | Initial contents of the register MP1, ready to be tested. |
| 00100 | 01001 | | C(MP2) + C(MP5) → C(MP5) since C(MP1) ₁₇ is a 1. |
| 00010 | 00100 | | C(MP5, MP1) rotated right one place. C(MP1) ₁₇ is tested. |
| 00001 | 00010 | | No addition, because C(MP1) ₁₇ is 0. C(MP5, MP2) rotated right one bit and AC ₁₇ is tested. |
| 00000 | 10001 | | No addition C(MP1) ₁₇ = 0, C(MP5, MP1) rotated right one bit. C(MP1) ₁₇ is tested. |
| 00100 | 10001 | | C(MP2) + C(MP5) → C(MP5) since C(MP1) ₁₇ is a 1. |
| 00010 | 01000 | | C(MP5, MP1) rotated right. |
| 00001 | 00100 | | No addition C(MP1) ₁₇ = 0, C(MP5, MP1) rotated right one bit. Rotation counter indicates that the multiplication is complete, since it has been reduced to 0. |

10.3 Program Listing

A listing of the subroutine with MULT located at address 0200 is as follows:

```

/CALLING SEQUENCE:
  /LAC    MULTIPLIER
  /JMS    MULT
  /LAC    MULTIPLICAND
  /RETURN ;LOW ORDER PRODUCT IN AC
          /HIGH ORDER PRODUCT IN LOCATION MP5
0200     0000    MULT,      0
0201     7100          DZM MP5    /ZERO OUT PRODUCT AREA

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| | | | | |
|------|------|---------|--------------|--|
| 0202 | 7510 | | SNA | /IS MULTIPLIER ZERO? |
| 0203 | 7061 | | JMP MPZ | /IF ZERO, RETURN |
| 0204 | 3250 | | SPA ! CLL | /TAKE ABSOLUTE VALUE OF MULTIPLIER |
| 0205 | 3251 | | CMA ! CML | /SET LINK = 1 IF MULTIPLIER IS NEGATIVE |
| 0206 | 1600 | | DAC #MP1 | |
| 0207 | 7450 | | XCT I MULT | /PICK UP MULTIPLICAND |
| 0207 | 7450 | | SNA | /IS MULTIPLICAND ZERO |
| 0210 | 5234 | | JMP MPZ | /IF ZERO, RETURN |
| 0211 | 7510 | | SPA | /IF NON ZERO, TAKE ABSOLUTE VALUE |
| 0212 | 7061 | | CMA ! CML | /IF NEGATIVE, COMPLEMENT LINK |
| 0213 | 3252 | | DAC #MP2 | /LINK HAS SIGN OF PRODUCT |
| 0214 | 1247 | | LAC (360000) | /COMPLEMENT ACCUMULATOR IF PRO- /DUCT IS NEGATIVE |
| 0215 | 3253 | | RAL | |
| 0216 | 1250 | | DAC MPSIGN | |
| 0217 | 7010 | | LAM - 21 | /INITIALIZE COUNT TO -17 |
| 0220 | 3250 | | DAC #MP3 | |
| 0221 | 1251 | MP4, | LAC MP1 | |
| 0222 | 7430 | | RAR | /ROTATE MULTIPLIER RIGHT ONE BIT |
| 0223 | 1252 | | DAC MP1 | /LOW ORDER INTO LINK |
| 0224 | 7110 | | LAC MP5 | /FETCH PRODUCT |
| 0225 | 3251 | | SZL ! CLL | |
| 0226 | 2253 | | TAD MP2 | /ADD MULTIPLICAND IF LINK IS 1 |
| 0227 | 5216 | | RAR | /ROTATE PRODUCT RIGHT ONE BIT |
| 0230 | 1250 | | DAC MP5 | |
| 0231 | 7010 | | ISZ MP3 | /IS COUNT + 1 = 0? |
| 0232 | 7430 | | JMP MP4 | /IF NOT, GO TO MP4 |
| 0233 | 5240 | MPSIGN, | 0 | /IF YES COMPLEMENT HIGH ORDER PORTION |
| 0234 | 3250 | | DAC MP5 | /OF PRODUCT, IF IT IS NEGATIVE |
| 0235 | 1251 | | LAC MP1 | /RETRIEVE LOW ORDER BIT OF PRODUCT |
| 0236 | 2200 | | RAR | /FROM THE LINK |
| 0237 | 5600 | | XCT MPSIGN | /PLACE IT INTO THE LOW ORDER PORTION /OF WORD COMPLEMENT AS ABOVE |
| 0240 | 7141 | MPZ, | ISZ MULT | |
| 0241 | 3250 | | JMP I MULT | /RETURN |

STORAGE MAP: (Locations available to the user)
MP5 (C(MP5) = high order product)