

Doing Packed Decimal Arithmetic in Assembler

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Section Preview

☐ Packed Decimal

- ◆ Zoned Decimal Format
- ◆ Packed Decimal Format
- ◆ DC and DS for Zoned and Packed Type Data
- ◆ Packed Decimal Instruction Set: PACK, UNPK, ZAP, CP, AP, SP, MP, DP
- ◆ Arithmetic Concerns
 - ✗ Significant Digits
 - ✗ Keeping Track of Decimal Points
- ◆ Packed Decimal Arithmetic - An Example
- ◆ Rounding
- ◆ Summary

Zoned Decimal

❑ When you key in numeric characters, they are stored in memory in a format called "zoned decimal":

- ◆ Each numeric character, 'n', is stored in a byte with the hex digits 'Fn'
- ◆ For example, '1562' will be stored in memory as

F1 F5 F6 F2

- ◆ The left half of any byte (the 'F's above) is called the zone portion of the byte
- ◆ The right half is called the numeric portion
- ◆ So if the data in a field is all numeric characters we say the field is in zoned decimal format

Zoned Decimal Data and Signs

❑ Traditionally, the sign of a zoned number (if any) is represented in the zone portion of the right most byte of the field

- ◆ Hex digits 'A', 'C', 'E', and 'F' represent a positive sign (memory device: 'FACE')
- ◆ Hex digits 'B' and 'D' indicate a negative number:

F1 F5 F6 C2

F1 F5 F6 D2

❑ This came about, historically, from the days of punched cards

- ◆ To enter a signed number into a card, the keypuncher would key in the digits, backspace, and then overpunch a plus or a minus sign
- ◆ The resulting hole combinations were mapped into the hex characters we now use today

Packed Decimal

- ☐ The CPU cannot perform arithmetic operations on zoned decimal data
 - ◆ There are no machine instructions to add, subtract, multiply, or divide zoned decimal fields

- ☐ Your program must convert zoned decimal data into one of the formats that the CPU has arithmetic instructions for:
 - ◆ Packed Decimal
 - ◆ Binary Integer
 - ◆ Floating Point

- ☐ At this point in the course, we discuss packed decimal data and instructions
 - ◆ Later we discuss binary integer data and instructions
 - ◆ We will not discuss floating point in this course

Packed Decimal Format

- ❑ Packed decimal data is a string of bytes such that each byte contains two digits except the right most hex digit, which represents the sign of the number:

DD DD DD DD DS

- ❑ Packed decimal fields may be any length from one byte to 16 bytes

- ♦ Thus the range of values is:

- 9,999,999,999,999,999,999,999,999,999
to
+ 9,999,999,999,999,999,999,999,999,999

- ♦ Note that commas are not stored in the data, nor are decimal points

- ❑ Whenever the CPU executes a packed decimal instruction, it (the CPU) checks the operands are valid packed decimal format

- ♦ Each digit in the range 0-9

- ♦ The sign digit one of hex 'A' through 'F'

- ❑ If the data fails the test, a data exception occurs (program data interruption) that ultimately leads to an Abend

Packed Decimal Instructions

- ❑ So to perform arithmetic on numeric data, you must first convert the data into one of the valid formats and then use the appropriate instructions

- ❑ There are two instructions for converting data between zoned decimal format and packed decimal format:

PACK — convert from zoned to packed

UNPK — convert from packed to zone

- ❑ There is a small number of instructions available to work with packed decimal data; among them are:

AP — Add Packed

SP — Subtract Packed

MP — Multiply Packed

DP — Divide Packed

CP — Compare Packed

ZAP — Zero and Add Packed

- ❑ Packed decimal instructions are discussed in a separate chapter in the POO

Packed Decimal Instructions - Format

- ❑ All packed decimal instructions can work with the first and second operands being of different lengths!

- ◆ This requires the instructions to carry two length codes: one for each operand
- ◆ In explicit style, this shows up as:

$xP \quad D_1(L_1, B_1), D_2(L_2, B_2)$

- ◆ And in the machine format, the second byte (the length code for Storage / Storage instructions) uses the first half byte for the length of the first operand, and the second half byte for the length of the second operand:



- ◆ As before, the length codes are stored as one less than the actual length of the operands
-
- ❑ Packed decimal instructions belong to the class of instructions known as "Storage / Storage, two length codes"

DC For Zoned Decimal Type Data

Rules for DCs With Zoned Decimal Type Data

◆ Value right-justified in storage

- X Pad on left with zoned zeros (X'F0'), if necessary
- X Truncate on left, if necessary
- X May only contain decimal characters (0-9) and possibly a leading plus or minus sign (which is stored as an overpunch in the rightmost byte)
- X Decimal points considered documentation only

◆ Maximum length attribute: 16

Examples

<u>Definition as coded</u>			<u>Assembled Value</u>	<u>Length Attribute</u>
FLD1	DC	ZL3'452'	_____	_____
	DC	Z'1239'	_____	_____
ANY	DC	Z'-92.45'	_____	_____
	DC	ZL2'8724'	_____	_____
XX	DC	ZL4'-34'	_____	_____

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Examples

<u>Definition as coded</u>			<u>Assembled Value</u>	<u>Length Attribute</u>
FLD1	DC	ZL3'452'	<u>4 5 2</u>	<u>3</u>
	DC	Z'1239'	<u></u>	<u></u>
ANY	DC	Z'-92.45'	<u></u>	<u></u>
	DC	ZL2'8724'	<u></u>	<u></u>
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ANY	DC	Z'-92.45'	<u></u>	<u></u>
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ANY	DC	Z'-92.45'	<u>9 2 4 N</u>	<u>4</u>
	DC	ZL2'8724'	<u></u>	<u></u>
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	DC	Z'1239'	<u>1 2 3 9</u>	<u>4</u>
			hex: F9 F2 F4 D5	
ANY	DC	Z'-92.45'	<u>9 2 4 N</u>	<u>4</u>
	DC	ZL2'8724'	<u></u>	<u></u>
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			hex: F9 F2 F4 D5	
ANY	DC	Z'-92.45'	<u>9 2 4 N</u>	<u>4</u>
	DC	ZL2'8724'	<u>2 4</u>	<u>2</u>
XX	DC	ZL4'-34'	<u></u>	<u></u>

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			hex: F9 F2 F4 D5	
ANY	DC	Z'-92.45'	9 2 4 N	4
	DC	ZL2'8724'	2 4	2
XX	DC	ZL4'-34'	0 0 3 M	4

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			hex: F9 F2 F4 D5	
ANY	DC	Z'-92.45'	9 2 4 N	4
	DC	ZL2'8724'	2 4	2
			hex: F0 F0 F3 D4	
XX	DC	ZL4'-34'	0 0 3 M	4

DC For Packed Decimal Type Data

Rules for DCs With Packed Decimal Type Data

◆ Value right-justified in storage

- ✗ Pad on left with binary zeros, if necessary
- ✗ Truncate on left, if necessary
- ✗ Value may only contain decimal characters (0-9), possibly a decimal point, and possibly a leading plus or minus sign (assembled sign placed in the rightmost hex digit)
 - Decimal points considered documentation only

◆ Maximum length attribute: 16

Examples

<u>Definition as coded</u>			<u>Assembled Value (Hex)</u>	<u>Length Attribute</u>
NO1	DC	P'13'		
	DC	P'1.3'		
XYZ	DC	PL3'456'		
EXTR1	DC	PL2'34345'		
	DC	P'-3'		
	DC	3P'13'		

DC For Packed Decimal Type Data

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Examples

<u>Definition as coded</u>			<u>Assembled Value (Hex)</u>	<u>Length Attribute</u>
NO1	DC	P'13'	01 3C	2
	DC	P'1.3'		
XYZ	DC	PL3'456'		
EXTR1	DC	PL2'34345'		
	DC	P'-3'		
	DC	3P'13'		

DC For Packed Decimal Type Data

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NO1	DC	P'13'	01 3C	2
	DC	P'1.3'	01 3C	2
XYZ	DC	PL3'456'		
EXTR1	DC	PL2'34345'		
	DC	P'-3'		
	DC	3P'13'		

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<u>Definition as coded</u>			<u>Assembled Value (Hex)</u>	<u>Length Attribute</u>
NO1	DC	P'13'	01 3C	2
	DC	P'1.3'	01 3C	2
XYZ	DC	PL3'456'	00 45 6C	3
EXTR1	DC	PL2'34345'		
	DC	P'-3'		
	DC	3P'13'		

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◆ Maximum length attribute: 16

Examples

<u>Definition as coded</u>			<u>Assembled Value (Hex)</u>	<u>Length Attribute</u>
NO1	DC	P'13'	01 3C	2
	DC	P'1.3'	01 3C	2
XYZ	DC	PL3'456'	00 45 6C	3
EXTR1	DC	PL2'34345'	34 5C	2
	DC	P'-3'		
	DC	3P'13'		

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Examples

<u>Definition as coded</u>			<u>Assembled Value (Hex)</u>	<u>Length Attribute</u>
NO1	DC	P'13'	01 3C	2
	DC	P'1.3'	01 3C	2
XYZ	DC	PL3'456'	00 45 6C	3
EXTR1	DC	PL2'34345'	34 5C	2
	DC	P'-3'	3D	1
	DC	3P'13'		

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NO1	DC	P'13'	01 3C	2
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XYZ	DC	PL3'456'	00 45 6C	3
EXTR1	DC	PL2'34345'	34 5C	2
	DC	P'-3'	3D	1
	DC	3P'13'	01 3C 01 3C 01 3C	2

More on Zoned and Packed Data Types

- ☐ You may code DS statements for Z and P type data also

- ☐ Coding a field with a data type of Z or P does not guarantee the data in the field will always be of that type
 - ◆ If you code a DC, the Assembler will ensure data is initialized properly
 - ◆ But other instructions, MVC for example, can overlay any field with data of any type
 - ◆ Similarly, describing a field in a record as any data type does not cause conversion when data is read into that area

- ☒ GET always brings in data as it is really formatted on the tape or disk or other media

- ☐ In practice, people seldom code the Z data type in programs
 - ◆ Most often a field containing character digits is described as character type: C

PACK

PACK COMPFL, ZNFLD

ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

--	--	--	--	--	--

PACK COMPFL+2 (4) , ZNFLD+1 (2)

COMPFL:

--	--	--	--	--	--

PACK FLDX, FLDX

PACK FLDA (1) , FLDA (1)

FLDA:

67

FLDA:

--

Machine Instruction

**Storage / Storage
Two length codes**

☐ Operands in PACK instructions are not checked for validity

PACK

PACK **COMPFL, ZNFLD**



ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

--	--	--	--	--	--

PACK **COMPFL+2 (4) , ZNFLD+1 (2)**

COMPFL:

--	--	--	--	--	--

PACK **FLDX, FLDX**

PACK **FLDA (1) , FLDA (1)**

FLDA:

67

FLDA:

--

Machine Instruction

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PACK

PACK **COMPFL, ZNFLD**




ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

					F
--	--	--	--	--	---



PACK **COMPFL+2 (4) , ZNFLD+1 (2)**

COMPFL:

--	--	--	--	--	--

PACK **FLDX, FLDX**

PACK **FLDA (1) , FLDA (1)**

FLDA:

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FLDA:

--

Machine Instruction

**Storage / Storage
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PACK

PACK COMPFL, ZNFLD




ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

					6F
--	--	--	--	--	----



PACK COMPFL+2 (4) , ZNFLD+1 (2)

COMPFL:

--	--	--	--	--	--

PACK FLDX, FLDX

PACK FLDA (1) , FLDA (1)

FLDA:

67

FLDA:

--

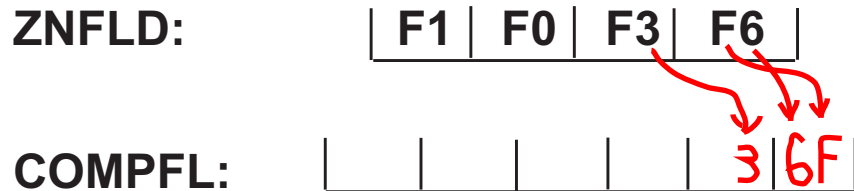
Machine Instruction

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Two length codes**

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PACK COMPFL, ZNFLD

PACK COMPFL+2 (4) , ZNFLD+1 (2)



PACK FLDX, FLDX

PACK FLDA (1) , FLDA (1)



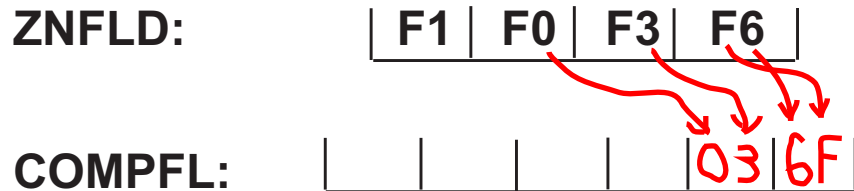
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PACK COMPFL, ZNFLD

PACK COMPFL+2 (4) , ZNFLD+1 (2)



PACK FLDX,FLDX

PACK FLDA (1) , FLDA (1)



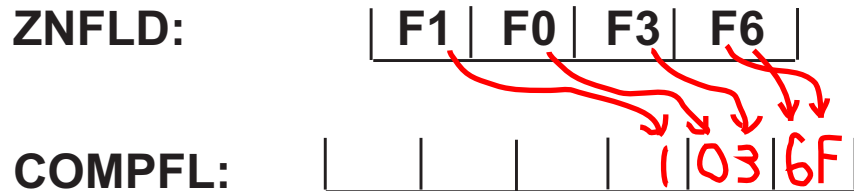
Machine Instruction

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PACK **FLDX, FLDX**

PACK **FLDA (1) , FLDA (1)**



Machine Instruction

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Two length codes**

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PACK

PACK COMPFL, ZNFLD




ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

00	00	00	01	03	6F
----	----	----	----	----	----



PACK COMPFL+2 (4) , ZNFLD+1 (2)

COMPFL:

--	--	--	--	--	--

PACK FLDX, FLDX

PACK FLDA (1) , FLDA (1)

FLDA:

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FLDA:

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PACK COMPFL, ZNFLD




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F1	F0	F3	F6
----	----	----	----

COMPFL:

00	00	00	01	03	6F
----	----	----	----	----	----



PACK COMPFL+2 (4) , ZNFLD+1 (2)

FOF3

COMPFL:

--	--	--	--	--	--

PACK FLDX, FLDX

PACK FLDA (1) , FLDA (1)

FLDA:

67

FLDA:

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Machine Instruction

Storage / Storage
Two length codes

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PACK

PACK COMPFL, ZNFLD

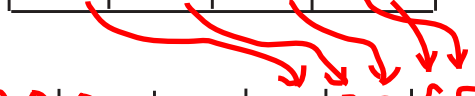


ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

00	00	00	01	03	6F
----	----	----	----	----	----



PACK COMPFL+2(4), ZNFLD+1(2)

COMPFL:

					F
--	--	--	--	--	---

FOF3



PACK FLDX, FLDX

PACK FLDA(1), FLDA(1)

FLDA:

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FLDA:

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Machine Instruction

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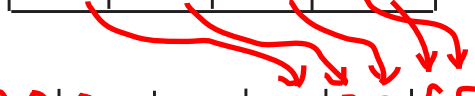


ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

00	00	00	01	03	6F
----	----	----	----	----	----



PACK COMPFL+2(4), ZNFLD+1(2)

COMPFL:

					3F
--	--	--	--	--	----

FOF3



PACK FLDX, FLDX

PACK FLDA(1), FLDA(1)

FLDA:

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FLDA:

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Machine Instruction

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Two length codes

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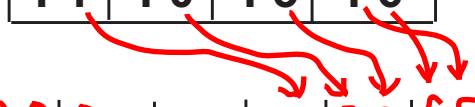


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F1	F0	F3	F6
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COMPFL:

00	00	00	01	03	6F
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PACK COMPFL+2(4), ZNFLD+1(2)

COMPFL:

—	—	00	00	00	3F
--------------	--------------	----	----	----	----

FOF3



PACK FLDX, FLDX

PACK FLDA(1), FLDA(1)

FLDA:

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FLDA:

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Machine Instruction

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PACK

PACK COMPFL, ZNFLD

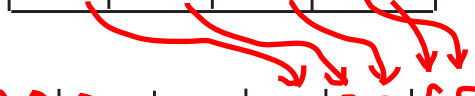


ZNFLD:

F1	F0	F3	F6
----	----	----	----

COMPFL:

00	00	00	01	03	6F
----	----	----	----	----	----



PACK COMPFL+2(4), ZNFLD+1(2)

COMPFL:

—	—	00	00	00	3F
---	---	----	----	----	----

FOF3



PACK FLDX, FLDX


PACK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

76



Machine Instruction

Storage / Storage
Two length codes

❑ Operands in PACK instructions are not checked for validity

UNPK

UNPK ZNFLD , COMPU

COMPU:

06	10	2C
----	----	----

ZNFLD:

--	--	--	--	--	--

UNPK FLDA (1) , FLDA (1)

FLDA:

67

FLDA:

--

Machine Instruction

**Storage / Storage
Two length codes**

☐ **Operands in UNPK instructions are not checked for validity**

UNPK

UNPK ZNFLD, COMPU



COMPU: | 06 | 10 | 2C |

ZNFLD: | | | | | | |

UNPK FLDA(1), FLDA(1)

FLDA: | 67 |

FLDA: | |

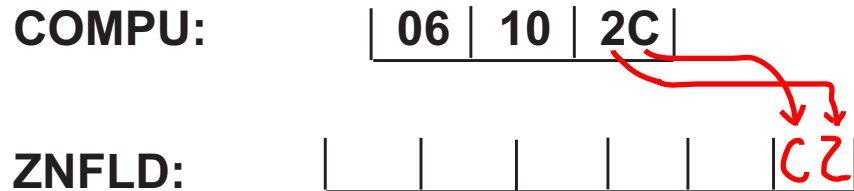
Machine Instruction

**Storage / Storage
Two length codes**

☐ Operands in UNPK instructions are not checked for validity

UNPK

UNPK ZNFLD, COMPU



UNPK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

--

Machine Instruction

Storage / Storage
Two length codes

☐ Operands in UNPK instructions are not checked for validity

UNPK

UNPK ZNFLD, COMPU



COMPU:

06	10	2C
----	----	----

ZNFLD:

				F	0	C	Z
--	--	--	--	---	---	---	---



UNPK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

--

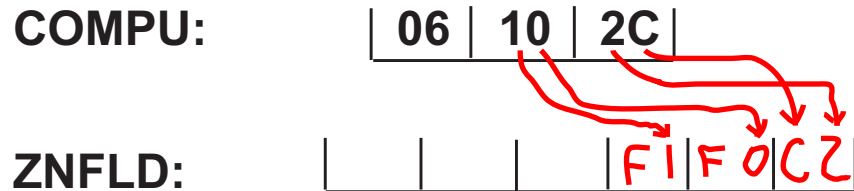
Machine Instruction

**Storage / Storage
Two length codes**

☐ Operands in UNPK instructions are not checked for validity

UNPK

UNPK ZNFLD, COMPU



UNPK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

--

Machine Instruction

**Storage / Storage
Two length codes**

☐ Operands in UNPK instructions are not checked for validity

UNPK

UNPK ZNFLD, COMPU



COMPU:

06	10	2C
----	----	----

ZNFLD:

		F6	F1	F0	CZ
--	--	----	----	----	----



UNPK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

--

Machine Instruction

**Storage / Storage
Two length codes**

☐ Operands in UNPK instructions are not checked for validity

UNPK

UNPK ZNFLD, COMPU



COMPU:

06	10	2C
----	----	----

ZNFLD:

	F	O	F	G	F	I	F	O	C	Z
--	---	---	---	---	---	---	---	---	---	---



UNPK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

--

Machine Instruction

**Storage / Storage
Two length codes**

☐ Operands in UNPK instructions are not checked for validity

UNPK

UNPK ZNFLD, COMPU



COMPU:

06	10	2C
----	----	----

ZNFLD:

F0	F0	F6	F1	F0	C2
----	----	----	----	----	----



UNPK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

--

Machine Instruction

**Storage / Storage
Two length codes**

☐ Operands in UNPK instructions are not checked for validity

UNPK

UNPK ZNFLD, COMPU



COMPU:

06	10	2C
----	----	----

ZNFLD:

F0	F0	F6	F1	F0	C2
----	----	----	----	----	----



UNPK FLDA(1), FLDA(1)

FLDA:

67

FLDA:

76



Machine Instruction

Storage / Storage
Two length codes

☐ Operands in UNPK instructions are not checked for validity

ZAP

ZAP  FLD1, FLD2

Machine Instruction

Storage / Storage
Two length codes

Before

FLD1: | 12 | 34 | 56 | 78 | 9F |

FLD2 | 80 | 27 | 3C |

After

FLD1: | 00 | 00 | 80 | 27 | 3C |

☐ The condition code is set after the operation:

00	Result is zero
01	Result is negative
10	Result is positive
11	Overflow; high order digits have been lost

◆ May follow with something like these extended mnemonic branch instructions:

BZ	ZERO_VALUE
BM	NEGATIVE_VALUE
BP	POSITIVE_VALUE
BO	OVERFLOW

☐ A program data exception occurs if the second operand (only) is not correct packed decimal format

☐ This instruction is used to move packed decimal data to larger fields

◆ For example, to set up MP or DP correctly

CP

CP FLDA,FLDB

Machine Instruction

Storage / Storage
Two length codes

☐ The condition code is set after the compare operation:

00 Both operands are equal
01 First operand is low
10 First operand is high
11 -- does not apply to CP instruction --

- ◆ Usually follow a 'CP' instruction with some conditional branch instruction ('BC' or 'BCR', or an extended mnemonic branch instruction)

Note: this is a signed decimal compare:

If	FLDA:	<table border="1"><tr><td>01</td><td>0C</td></tr></table>	01	0C	and	FLDB:	<table border="1"><tr><td>02</td><td>0D</td></tr></table>	02	0D
01	0C								
02	0D								
Then	CP	FLDA,FLDB		will indicate	FLDA > FLDB				
But	CLC	FLDA,FLDB		will indicate	FLDA < FLDB				

- ☐ If the fields are of different lengths, the compare proceeds as if the shorter were extended on the left with zeros
- ☐ A program data exception occurs if both operands are not in the packed decimal format

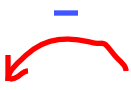
AP, SP

AP FLDA, FLDB



AP FLDA, FLDA

SP FLDA, FLDB



SP FLDA, FLDA

Machine Instructions

Storage / Storage
Two length codes

❑ The condition code is set after either operation:

00	Result is zero
01	Result is negative
10	Result is positive
11	Overflow; high order digits have been lost

♦ May follow an 'AP' or 'SP' instruction with something like these extended mnemonic branch instructions:

BZ	ZERO_RESULT
BM	NEGATIVE_RESULT
BP	POSITIVE_RESULT
BO	OVERFLOW

❑ A program data exception occurs if both operands are not in the packed decimal format

MP

MP  MPLCAND, MPLIER

Machine Instruction

Storage / Storage
Two length codes

Rules

- ◆ Both operands must be valid packed decimal data (otherwise, a data exception)
- ◆ Second operand 8 bytes or less (otherwise, a specification exception)
- ◆ First operand longer than second operand (otherwise, a specification exception)
- ◆ First operand must have at least as many bytes of leading zeros as the total length of the second operand (otherwise, a data exception)

Example:

MPLCAND: | 00 | 01 | 2C |

MPLIER: | 00 | 5C |

Will not work



☐ The condition code is not set after an MP operation

DP

DP DIVIDEND, DIVISOR

Machine Instruction

**Storage / Storage
Two length codes**

Rules

- ◆ Both operands must be valid packed decimal data (otherwise, a data exception)
- ◆ Second operand 8 bytes or less (otherwise, a specification exception)
- ◆ First operand longer than second operand (otherwise, a specification exception)
- ◆ Leftmost digit in dividend must be zero (otherwise, a decimal divide exception)
- ◆ If dividing by zero, a decimal divide exception occurs
- ◆ If not enough room for quotient, a decimal divide exception occurs; to test:
 - ✗ align the left most digit of the divisor to the second digit of the dividend, padding the divisor to the left and right with zeros to match the length of the dividend
 - ✗ if the divisor, so aligned, is less than or equal to the dividend, the divide won't work (decimal exception)

DP, p.2.

Example

DIVIDEND:

01	52	03	62	7C
----	----	----	----	----

DIVISOR:

00	34	5C
----	----	----

doing the alignment test yields:

0	1	5	2	0	3	6	2	7
0	0	0	3	4	5	0	0	0

000345000 < 015203627

so divide won't work

But

- ♦ lop off the left most byte of the divisor, and, voilà:

0	1	5	2	0	3	6	2	7
0	3	4	5	0	0	0	0	0

034500000 > 015203627

therefore, OK!

in other words, in this case you could code:

DIVIDEND, DIVISOR+1 (2)

DP, p.3.

DP DIVIDEND, DIVISOR

Before the divide:

DIVIDEND:

dd	dd	dd	dd	ds
----	----	----	----	----

DIVISOR:

dd	ds
----	----

After the divide:

DIVIDEND:

qq	qq	qs	rr	rs
----	----	----	----	----

 - quotient - - rem -

DIVISOR:

dd	ds
----	----

 unchanged

Notes

- ♦ The length of the remainder equals the length of the divisor
- ♦ The quotient occupies the rest of the dividend field
- ♦ Be careful, after a divide, of code like:

AP FLDA, DIVIDEND

X The field DIVIDEND, in its entire length, no longer contains valid packed decimal data

X Use something like this:

AP FLDA, DIVIDEND(3)

DP, p.4.

Notes, continued

- ♦ The remainder is not additional decimal places, but rather an integer less than the divisor, for example:

		347		<— quotient
divisor —>	123) 42765		<— dividend
		369		
		586		
		492		
		945		
		861		
		84		<— remainder

- ♦ The condition code is not set after a DP instruction
- ♦ The test for a decimal divide is really trying to ensure there is enough room in the dividend field for the full quotient and the remainder
 - ✗ A reliable way to do this is to define the dividend field large enough to hold the greatest number of digits you actually expect in the dividend plus enough bytes for the remainder
 - Since the size of the remainder is the length of the divisor, it is a good idea to keep the divisor defined as small as possible (yet large enough to hold the largest expected value)
 - ✗ As you reach the limits (16 byte dividend or 8 byte divisor or numbers close together in length) you might have to programmatically test each situation

Arithmetic Concerns

- ❑ There are a number of issues the programmer needs to remember when working with arithmetic data in Assembler language programs

Programmer responsibilities

- ◆ Ensure data in the proper format for each instruction
 - ◆ Plan enough room for significant digits in the result field
 - ◆ Keep track of decimal point location
-
- ❑ The first point relates to knowing when to
 - ◆ PACK data not already packed
 - ◆ ZAP data to a larger field to satisfy MP and DP criteria
 - ◆ Use a subset of a field to satisfy DP criteria
-
- ❑ We discuss significant digits and keeping track of the decimal point on the following pages ...

Significant Digits

- ❑ To ensure arithmetic operations allow enough room in the result field, you must plan for the worst possible case (largest possible result)
 - ◆ Do this by "playing computer" and keeping track of result digits, especially significant digits (non-leading-zero digits)
 - ◆ As you plan your operations you may find you need to change the definitions of the work fields you are doing your calculations in (usually need to increase the size) or to ZAP data into larger fields before performing certain operations

- ❑ The result of AP and SP operations may contain at most one more significant digit than the longer of the two numbers

e.g.: DD DD DS + DD DS

 yields, at most, 0D DD DD DS

- ◆ Although repeated add or subtract instructions can create larger results (ultimately, you need to know your data)

Significant Digits, 2

- ❑ For MP operations, the largest possible number of significant digits in the product is the sum of the significant digits in the multiplier and the multiplicand

e.g.: DD DD DS * DD DS

yields, at most, 0D DD DD DD DS

- ◆ However, recall the multiplicand must have at least as many bytes of leading zeros as total length of the multiplier, so we need to set up something like:

e.g.: 00 00 DD DD DS * DD DS

yields, at most, 0D DD DD DD DS

- ❑ For DP instructions, the largest possible number of significant digits in the quotient is
(the number of significant digits in the dividend) minus
(the number of significant digits in the divisor) plus 1

e.g.: DD DD DS / DD DS

yields, at most, DD DS

- ◆ Remember the special testing for divide exception also

Keeping Track of Decimal Points

- ❑ **Decimal points are only assumed**
 - ◆ **You are responsible for keeping track of where they belong and of making any necessary adjustments**
- ❑ **AP, SP, and CP instructions must have the same number of assumed decimal positions in both operands before performing the operation**

For example, given

FLDA: 00 DD DS **FLDB:** 00 00 DS

- ◆ Before we can add these numbers:

ZAP **FLDC,FLDB** so FLDC: 00 00 00 00 DS

MP	FLDC,P1000	if P1000:	01 00 0C
-----------	-------------------	------------------	-----------------

then FLDC:

<u>00</u>	<u>00</u>	<u>0D</u>	<u>00</u>	<u>0C</u>
		^		

- ◆ Then we can add the fields:

AP **FLDA,FLDC**

Keeping Track of Decimal Points, 2

- ❑ MP produces a product such that the number of assumed decimal places equals the sum of the decimal positions in the two operands

For example, given

FLD1: 00 00 0D DD DS

FLD2: $\frac{DD \quad DS}{\wedge}$

then

MP FLD1,FLD2

yields

FLD1: 00 DD DD DD DS

Keeping Track of Decimal Points, 3

- ❑ DP must always have the divisor adjusted to be treated as if it were an integer

- ◆ That is, having no digits to the right of the decimal point

- ❑ The dividend must be adjusted in parallel with the divisor, logically shifting divisor and dividend decimal places in tandem:

$$\begin{array}{r} \text{DD DD} \\ \text{^} \\ \hline \text{DD D} \\ \text{^} \end{array} \longrightarrow \begin{array}{r} \text{DDD D} \\ \text{^} \\ \hline \text{DDD} \\ \text{^} \end{array}$$

- ◆ If the divisor has more significant decimal places to the right of the decimal point than the dividend, you must multiply the dividend (number on top) by 10^n , where 'n' is the number of decimal positions in the divisor (the number on the bottom) minus the number of decimal positions in the dividend

- ✗ The number of assumed decimal positions in the quotient will equal the number of decimal positions in the dividend after the adjustment

- ✗ To carry extra decimal positions (for example, for rounding or for extra precision in the fractional part), multiply the dividend by 10 for each extra decimal position you want to carry (before you do the DP)

- ✗ Also, any such multiplication may require the dividend field to be larger

Packed Decimal Arithmetic - An Example

❑ To put all this in perspective, let's look at a concrete example

❑ Given fields LM, LN, HI, HK, and JR coming in as zoned decimal numbers as follows

- ◆ LM is an integer, up to three digits long
- ◆ LN, HK, and JR contain five digits, including two digits to the right of the decimal point
- ◆ HI is three digits long, all three being to the right of the decimal point
- ◆ The definition for these fields, in an Assembler program might look like this:

LM	DS	CL3	999
LN	DS	CL5	999V99
HK	DS	CL5	999V99
JR	DS	CL5	999V99
HI	DS	CL3	V999

- ◆ Code the instructions to calculate the value of

$$\frac{(LM + LN) * HI}{HK - JR}$$

- ◆ Remember to check you are not dividing by zero (if you find you are, branch to a routine called ZERODIVIDE, which will be written later)
- ◆ The result is to be placed into a field called FINAL_RESULT, in edited zoned decimal format for display on a terminal or in a report

Packed Decimal Arithmetic - An Example, 2

- ❑ Since each of the input fields is in zoned format, the first step is to **PACK** each of the numbers

- ◆ Where should we **PACK** them?

- ✗ Better define some work fields to hold the packed decimal version of these fields

- ✗ What should we call these fields, and how big should they be?

- Note that we can make a reasonable guess on the sizes of these fields; later, if we find we need to change the size, we can

- ❑ On this page, code the instructions that define work fields to hold packed decimal versions of our numbers, and the **PACK** instructions themselves:

```
PACK
PACK
PACK
PACK
PACK
.
.
.
PACKLM    DS    PL
PACKLN    DS    PL
PACKHK    DS    PL
PACKJR    DS    PL
PACKHI    DS    PL
```

Packed Decimal Arithmetic - An Example, 2

- ❑ Since each of the input fields is in zoned format, the first step is to **PACK** each of the numbers


- ◆ Where should we **PACK** them?

- ✗ Better define some work fields to hold the packed decimal version of these fields

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- Note that we can make a reasonable guess on the sizes of these fields; later, if we find we need to change the size, we can

- ❑ On this page, code the instructions that define work fields to hold packed decimal versions of our numbers, and the **PACK** instructions themselves:

```
PACK  PACKLM,LM      00  dd  d|s    
PACK  
PACK  
PACK  
PACK  
PACK  
.  
.  
.  
PACKLM  DS  PL3  
PACKLN  DS  PL  
PACKHK  DS  PL  
PACKJR  DS  PL  
PACKHI  DS  PL
```


Packed Decimal Arithmetic - An Example, 2

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```

PACK  PACKLM,LM      00    dd    d|s
PACK  PACKLN,LN      dd    d|d    ds
PACK
PACK
PACK
.
.
.
PACKLM  DS  PL3
PACKLN  DS  PL3
PACKHK  DS  PL
PACKJR  DS  PL
PACKHI  DS  PL
    
```

Packed Decimal Arithmetic - An Example, 2

- ❑ Since each of the input fields is in zoned format, the first step is to **PACK** each of the numbers

- ◆ Where should we **PACK** them?

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- ❑ On this page, code the instructions that define work fields to hold packed decimal versions of our numbers, and the **PACK** instructions themselves:

```
PACK  PACKLM,LM      00    dd    d|s
PACK  PACKLN,LN      dd    d|d    ds
PACK  PACKHK,HK      dd    d|d    ds
PACK
PACK
.
.
.
PACKLM  DS  PL 3
PACKLN  DS  PL 3
PACKHK  DS  PL 3
PACKJR  DS  PL
PACKHI  DS  PL
```

Packed Decimal Arithmetic - An Example, 2

- ❑ Since each of the input fields is in zoned format, the first step is to **PACK** each of the numbers

- ◆ Where should we **PACK** them?

- ✗ Better define some work fields to hold the packed decimal version of these fields

- ✗ What should we call these fields, and how big should they be?

- Note that we can make a reasonable guess on the sizes of these fields; later, if we find we need to change the size, we can

- ❑ On this page, code the instructions that define work fields to hold packed decimal versions of our numbers, and the **PACK** instructions themselves:

```
PACK  PACKLM,LM      00    dd    d|s
PACK  PACKLN,LN      dd    d|d    ds
PACK  PACKHK,HK      dd    d|d    ds
PACK  PACKJR,JR      dd    d|d    ds
PACK
.
.
.
PACKLM  DS  PL3
PACKLN  DS  PL3
PACKHK  DS  PL3
PACKJR  DS  PL3
PACKHI  DS  PL
```

Packed Decimal Arithmetic - An Example, 2

- ❑ Since each of the input fields is in zoned format, the first step is to **PACK** each of the numbers

- ◆ Where should we **PACK** them?

- ✗ Better define some work fields to hold the packed decimal version of these fields

- ✗ What should we call these fields, and how big should they be?

- Note that we can make a reasonable guess on the sizes of these fields; later, if we find we need to change the size, we can

- ❑ On this page, code the instructions that define work fields to hold packed decimal versions of our numbers, and the **PACK** instructions themselves:

```

PACK  PACKLM,LM      00    dd    d|s
PACK  PACKLN,LN      dd    d|d    ds
PACK  PACKHK,HK      dd    d|d    ds
PACK  PACKJR,JR      dd    d|d    ds
PACK  PACKHI,HI      |dd    ds
.
.
.
PACKLM  DS      PL 3
PACKLN  DS      PL 3
PACKHK  DS      PL 3
PACKJR  DS      PL 3
PACKHI  DS      PL 2
    
```

Packed Decimal Arithmetic - An Example, 3

☐ Now, what should we do next? We have two choices:

- ◆ The add ($LM + LN$)
- ◆ The subtract ($HK - JR$)

☐ Remember that we want to check that we don't divide by zero

- ◆ It turns out it is more efficient to check for this before we do all the rest of the calculations only to find out we can't do the divide

☐ On this page, code the instructions to do the subtract and branch to ZERODIVIDE if the result is zero:

Packed Decimal Arithmetic - An Example, 3

❑ Now, what should we do next? We have two choices:

- ◆ The add ($LM + LN$)
- ◆ The subtract ($HK - JR$)

❑ Remember that we want to check that we don't divide by zero

- ◆ It turns out it is more efficient to check for this before we do all the rest of the calculations only to find out we can't do the divide

❑ On this page, code the instructions to do the subtract and branch to ZERODIVIDE if the result is zero:

SP PACKHK,PACKJR dd d|d ds 

Packed Decimal Arithmetic - An Example, 3

❑ Now, what should we do next? We have two choices:

- ◆ The add ($LM + LN$)
- ◆ The subtract ($HK - JR$)

❑ Remember that we want to check that we don't divide by zero

- ◆ It turns out it is more efficient to check for this before we do all the rest of the calculations only to find out we can't do the divide

❑ On this page, code the instructions to do the subtract and branch to ZERODIVIDE if the result is zero:

```
SP    PACKHK,PACKJR    dd  d|d  ds
BZ    ZERODIVIDE
```

Packed Decimal Arithmetic - An Example, 4

☐ Now we can do the add: LM + LN

- ◆ Remember that both fields must have the same number of implied decimal places
- ◆ Since LM is '999' and LN is '999V99', you need to do some work preparatory to doing the addition

☐ On this page, write the code to add LM and LN:

Packed Decimal Arithmetic - An Example, 4

❑ Now we can do the add: LM + LN

- ◆ Remember that both fields must have the same number of implied decimal places
- ◆ Since LM is '999' and LN is '999V99', you need to do some work preparatory to doing the addition

❑ On this page, write the code to add LM and LN:

```
MP      PACKLM,P100          dd  d|0  0s
```

Packed Decimal Arithmetic - An Example, 4

□ Now we can do the add: LM + LN

- ◆ Remember that both fields must have the same number of implied decimal places
- ◆ Since LM is '999' and LN is '999V99', you need to do some work preparatory to doing the addition

□ On this page, write the code to add LM and LN:

MP	PACKLM,P100	dd	d 0	0s
AP	PACKLM,PACKLN	dd	d d	ds

Packed Decimal Arithmetic - An Example, 4

❑ Now we can do the add: LM + LN

- ◆ Remember that both fields must have the same number of implied decimal places
- ◆ Since LM is '999' and LN is '999V99', you need to do some work preparatory to doing the addition

❑ On this page, write the code to add LM and LN:

```
MP      PACKLM,P100          dd  d|0  0s
AP      PACKLM,PACKLN        dd  d|d  ds
```

but because of MP rules, need to go back and redefine PACKLM as PL4:

```
PACKLM  DS      PL4
P100    DC      P'100'
```

Packed Decimal Arithmetic - An Example, 4

□ Now we can do the add: LM + LN

- ◆ Remember that both fields must have the same number of implied decimal places
- ◆ Since LM is '999' and LN is '999V99', you need to do some work preparatory to doing the addition

□ On this page, write the code to add LM and LN:

```
MP      PACKLM,P100          dd  d|0  0s
AP      PACKLM,PACKLN        dd  d|d  ds
```

but because of MP rules, need to go back and redefine PACKLM as PL4:

```
PACKLM  DS      PL4
P100    DC      P'100'
```

then ...

```
PACK    PACKLM,LM           gives  00  00  dd  d|s
```

Packed Decimal Arithmetic - An Example, 4

□ Now we can do the add: LM + LN

- ◆ Remember that both fields must have the same number of implied decimal places
- ◆ Since LM is '999' and LN is '999V99', you need to do some work preparatory to doing the addition

□ On this page, write the code to add LM and LN:

```
MP      PACKLM,P100      dd  d|0  0s
AP      PACKLM,PACKLN    dd  d|d  ds
```

but because of MP rules, need to go back and redefine PACKLM as PL4:

```
PACKLM  DS      PL4
P100    DC      P'100'
```

then ...

```
PACK    PACKLM,LM      gives  00  00  dd  d|s
MP      PACKLM,P100    gives  00  dd  d|0  0s
```

Packed Decimal Arithmetic - An Example, 4

❑ Now we can do the add: LM + LN

- ◆ Remember that both fields must have the same number of implied decimal places
- ◆ Since LM is '999' and LN is '999V99', you need to do some work preparatory to doing the addition

❑ On this page, write the code to add LM and LN:

```
MP      PACKLM,P100      dd  d|0  0s
AP      PACKLM,PACKLN    dd  d|d  ds
```

but because of MP rules, need to go back and redefine PACKLM as PL4:

```
PACKLM  DS      PL4
P100    DC      P'100'
```

then ...

```
PACK    PACKLM,LM      gives  00  00  dd  d|s
MP      PACKLM,P100    gives  00  dd  d|0  0s
AP      PACKLM,PACKLN  gives  0d  dd  d|d  ds
```



Packed Decimal Arithmetic - An Example, 5

☐ Now we're ready for the multiply: $(LM + LN) * HI$

- ◆ Plan the size of the product field, and how many implied decimal places will there be?
- ◆ Do you need to define a new work field, or can you use the field that currently holds the sum of $LM + LN$?
- ◆ Remember to ensure you have enough leading zeros in the first operand

☐ On this page, code the instructions necessary to do the multiply:

Packed Decimal Arithmetic - An Example, 5

□ Now we're ready for the multiply: $(LM + LN) * HI$

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- ♦ Do you need to define a new work field, or can you use the field that currently holds the sum of $LM + LN$?
- ♦ Remember to ensure you have enough leading zeros in the first operand

□ On this page, code the instructions necessary to do the multiply:

To multiply PACKLM (which contains $LM + LN$) times PACKHI, PACKLM must have as many leading bytes of zeros as the length of PACKHI (which is two bytes long), so we must redefine PACKLM again:

```
PACKLM  DS      PL6
```


Packed Decimal Arithmetic - An Example, 5

□ Now we're ready for the multiply: $(LM + LN) * HI$

- ♦ Plan the size of the product field, and how many implied decimal places will there be?
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```
PACKLM DS PL6
```

- so now our instructions and their results:

```
PACK PACKLM,LM      00  00  00  00  dd  d|s
```

Packed Decimal Arithmetic - An Example, 5

□ Now we're ready for the multiply: $(LM + LN) * HI$

- ◆ Plan the size of the product field, and how many implied decimal places will there be?
- ◆ Do you need to define a new work field, or can you use the field that currently holds the sum of $LM + LN$?
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```
PACKLM DS PL6
```

- so now our instructions and their results:

PACK	PACKLM,LM	00	00	00	00	dd	d s
MP	PACKLM,P100	00	00	00	dd	d 0	0s

Packed Decimal Arithmetic - An Example, 5

□ Now we're ready for the multiply: $(LM + LN) * HI$

- ♦ Plan the size of the product field, and how many implied decimal places will there be?
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To multiply PACKLM (which contains $LM + LN$) times PACKHI, PACKLM must have as many leading bytes of zeros as the length of PACKHI (which is two bytes long), so we must redefine PACKLM again:

```
PACKLM DS PL6
```

- so now our instructions and their results:

PACK	PACKLM,LM	00	00	00	00	dd	d s
MP	PACKLM,P100	00	00	00	dd	d 0	0s
AP	PACKLM,PACKLN	00	00	0d	dd	d d	ds

Packed Decimal Arithmetic - An Example, 5

□ Now we're ready for the multiply: $(LM + LN) * HI$

- ◆ Plan the size of the product field, and how many implied decimal places will there be?
- ◆ Do you need to define a new work field, or can you use the field that currently holds the sum of $LM + LN$?
- ◆ Remember to ensure you have enough leading zeros in the first operand

□ On this page, code the instructions necessary to do the multiply:

To multiply PACKLM (which contains $LM + LN$) times PACKHI, PACKLM must have as many leading bytes of zeros as the length of PACKHI (which is two bytes long), so we must redefine PACKLM again:

```
PACKLM DS PL6
```

- so now our instructions and their results:

PACK	PACKLM,LM	00	00	00	00	dd	d s
MP	PACKLM,P100	00	00	00	dd	d 0	0s
AP	PACKLM,PACKLN	00	00	0d	dd	d d	ds
MP	PACKLM,PACKHI	00	dd	dd	dd	dd	ds

Packed Decimal Arithmetic - An Example, 6

☐ We're finally ready to do the divide:

$$\frac{(LM + LN) * HI}{(HK - JR)}$$

- ◆ Plan the result: how big is the remainder, how big is the quotient (that is, how many bytes long are these fields?)
- ◆ Remember to adjust when divisor has decimal places; how many decimal places will the quotient have?
- ◆ Remember to avoid dividing by zero

☐ On this page, write the instruction(s) necessary to accomplish the divide:

Packed Decimal Arithmetic - An Example, 6

□ We're finally ready to do the divide:

$$\frac{(\text{LM} + \text{LN}) * \text{HI}}{(\text{HK} - \text{JR})}$$

- ◆ Plan the result: how big is the remainder, how big is the quotient (that is, how many bytes long are these fields?)
- ◆ Remember to adjust when divisor has decimal places; how many decimal places will the quotient have?
- ◆ Remember to avoid dividing by zero

□ On this page, write the instruction(s) necessary to accomplish the divide:

First, in terms of our data fields, we are trying to divide PACKLM by PACKHK, where the contents of the fields look like this:

```
PACKLM:  00  dd  dd | dd  dd  ds
          -----
PACKHK:           dd  d|d  ds
```

we have to move both fields' implied decimal position to the right two places, so we are dividing by an integer; since PACKLM has more decimal places than PACKHK we don't need to multiply; but after this divide we see that there would be a remainder of 3 bytes and a quotient of 3 bytes; since the dividend value can have 9 digits (5 bytes) and the divisor is 3, re-size PACKLM:

```
PACKLM  DS      PL8
```

Packed Decimal Arithmetic - An Example, 6

□ We're finally ready to do the divide:

$$\frac{(\text{LM} + \text{LN}) * \text{HI}}{(\text{HK} - \text{JR})}$$

- ◆ Plan the result: how big is the remainder, how big is the quotient (that is, how many bytes long are these fields?)
- ◆ Remember to adjust when divisor has decimal places; how many decimal places will the quotient have?
- ◆ Remember to avoid dividing by zero

□ On this page, write the instruction(s) necessary to accomplish the divide:

Now the operands for our divide look like this:

```
PACKLM:  00  00  00  dd  dd  dd  d|d  ds
          -----
PACKHK:               dd  dd  ds
```

Then after the divide we will have this:

```
PACKLM:  00 qq  qq  q|q  qs  rr rr rs
          -----
          ---- quotient ---- | - rem -
```

Packed Decimal Arithmetic - An Example, 6

☐ We're finally ready to do the divide:

$$\frac{(\text{LM} + \text{LN}) * \text{HI}}{(\text{HK} - \text{JR})}$$

- ◆ Plan the result: how big is the remainder, how big is the quotient (that is, how many bytes long are these fields?)
- ◆ Remember to adjust when divisor has decimal places; how many decimal places will the quotient have?
- ◆ Remember to avoid dividing by zero

☐ On this page, write the instruction(s) necessary to accomplish the divide:

So now we can safely do the divide:

```
DP      PACKLM,PACKHK  00 qq qq q|q qs | rr rr rs
```


Packed Decimal Arithmetic - An Example, 6

□ We're finally ready to do the divide:

$$\frac{(LM + LN) * HI}{(HK - JR)}$$

- ◆ Plan the result: how big is the remainder, how big is the quotient (that is, how many bytes long are these fields?)
- ◆ Remember to adjust when divisor has decimal places; how many decimal places will the quotient have?
- ◆ Remember to avoid dividing by zero

□ On this page, write the instruction(s) necessary to accomplish the divide:

So then we have:

```

PACK  PACKLM,LM          00 00 00 00 00 00 dd d|s
PACK  PACKLN,LN          dd d|d ds
PACK  PACKHK,HK          dd d|d ds
PACK  PACKJR,JR          dd d|d ds
PACK  PACKHI,HI          |dd ds
SP    PACKHK,PACKJR      dd d|d ds
BZ    ZERODIVIDE
MP    PACKLM,P100        00 00 00 00 00 dd d|0 0s
AP    PACKLM,PACKLN      00 00 00 00 0d dd d|d ds
MP    PACKLM,PACKHI      00 00 00 dd dd | dd dd ds
DP    PACKLM,PACKHK      00 qq qq q|q qs| rr rr rs
    
```

Packed Decimal Arithmetic - An Example, 7

□ Finally, we're ready to display the result by editing the quotient into the field `FINAL_RESULT`

◆ Here we just demonstrate the necessary code and data areas

✕ Intricacies of the ED instruction and edit patterns is grist for a different session some other day

```
      MVC    FINAL_RESULT,EDPAT1
      ED     FINAL_RESULT,PACKLM+1

EDPAT1 DC    X'4020206B2021204B2020'
```

Packed Decimal Arithmetic - An Example, Summary

- ☐ Consolidate all the code from the example on this one page, for reference and discussion

```

*   Pack incoming fields
      PACK  PACKLM,LM           00 00 00 00 00 00 DD DS
      PACK  PACKLN,LN           DD DD DS   (2 dec pos)
      PACK  PACKHK,HK           DD DD DS   (2 dec pos)
      PACK  PACKJR,JR           DD DD DS   (2 dec pos)
      PACK  PACKHI,HI           DD DS      (3 dec pos)

*   PACKHK = (HK-JR), result has 2 dec pos
      SP    PACKHK,PACKJR
      BZ    ZERODIVIDE          don't divide by zero

*   adjust PACKLM to contain 2 implied decimal places
      MP    PACKLM,P100         00 00 00 00 00 DD D0 0S

*   PACKLM = (LM+LN), result still has 2 dec pos
      AP    PACKLM,PACKLN       00 00 00 00 0D DD DD DS

*   PACKLM = (LM+LN)*HI, 5 dec pos
      MP    PACKLM,PACKHI       00 00 00 DD DD DD DD DS

*   PACKLM = ((LM+LN)*HI)/(HK-JR), quot. has 3 dec pos
      DP    PACKLM,PACKHK       00 DD DD DD DS|DD DD DS
*                                     --quotient---- --rem---

      MVC   FINAL_RESULT,EDPAT1
      ED    FINAL_RESULT,PACKLM+1

*
.
.
.
PACKLM     DS      PL8
PACKLN     DS      PL3
PACKHK     DS      PL3
PACKJR     DS      PL3
PACKHI     DS      PL2
FINAL_RESULT DS CL10
EDPAT1     DC      X'4020206B2021204B2020'
P100       DC      P'100'

```

Rounding

□ To "round a number to 'n' decimal places" means dropping all digits after the n^{th} decimal place, perhaps doing some adjustment in the n^{th} position

- ◆ Round up - if the truncated portion is not zero, add 1 to the n^{th} position

Round 215.73 up to units: \rightarrow 216

- ◆ Round down - truncate with no adjustment

Round 215.73 down to tenths: \rightarrow 215.7

- ◆ Half-adjust - add '5' to the $(n+1)^{\text{st}}$ position then truncate

✗ If the sum carries into the n^{th} position, you have automatically rounded up

✗ If the sum doesn't carry into the n^{th} position, you have automatically rounded down

- ◆ Half-adjust 215.73 to units:

$$\begin{array}{r} 215.73 \\ + \quad 5 \\ \hline 216.23 \end{array} \quad \text{therefore, value is 216}$$

- ◆ Half the time, half-adjusting results in rounding up; half the time it results in rounding down

Rounding, 2

□ The effect is slightly different for negative numbers:

- ◆ Half-adjust -215.73 to units:

$$\begin{array}{r} -215.73 \\ + \quad 5 \\ \hline -215.23 \end{array} \quad \text{therefore, value is } -215$$

- ◆ Makes sense to add five to the absolute value of a number (or add -5 to a negative number and +5 to a positive one)

□ Rounding only makes sense if the value being rounded has more significant positions than the rounding precision

- ◆ Therefore, in planning calculations where rounding is to take place, you need to allow for carrying enough positions (at least one more position than the precision of the rounding)
- ◆ For example, if rounding to hundredths, plan calculations to allow for results to thousandths

Rounding - An Example

- ❑ To see how one might deal with the need to round a calculation, recall our example

- ◆ Calculating

$$\frac{(LM+LN) * HI}{(HK-JR)}$$

✗ produced a quotient in the eight byte field PACKLM

✗ the remainder was three bytes, the quotient five bytes, with three implied decimal positions:

```
PACKLM:      00 DD DD DD DS DD DD DS
               ^
             ----- Quotient ----- --- Rem. ---
```

- ❑ Suppose now the requirement is to half-adjust the result to two decimal places

- ◆ First, we need to add '5' to the last digit in the quotient:

```
AP      PACKLM(5) , P5
```

- ◆ where P5 is defined as:

```
P5      DC      P ' 5 '
```

Rounding - An Example, p.2.

- ❑ If the quotient could be negative, we actually need to have some code like this:

```
CP      PACKLM(5),P0
BL      SUB5
AP      PACKLM(5),P5
B       COMMON
SUB5    SP      PACKLM(5),P5
COMMON  ...
```

- ❑ This certainly takes care of the first part of half-adjusting
 - ◆ But the result is still five bytes with three implied decimal positions:

```
PACKLM:    00 DD DD DS DD DS
              ^
          ----- Quotient ----- --- Rem. ---
```

- ◆ How to now get rid of the undesired third decimal position?
- ◆ There are three possibilities

- ✗ Divide PACKLM by 10 (with all the complications of DP)
- ✗ Use the MVO instruction (an older, cumbersome style)
- ✗ Use the SRP instruction (described on the next page)

SRP - Shift and Round Packed

- ❑ The best option for solving our rounding problem is the SRP instruction

Syntax

SRP FLDA,3,5

- ◆ Shift the contents of FLDA left 3 decimal digits (no rounding)

SRP FLDA,61,5

- ◆ Shift the contents of FLDA right 3 decimal digits after adding 5 to the last digit to be shifted out
- ◆ If FLDA is not a valid packed decimal number, a data exception occurs

Machine Instruction

**Storage / Storage
one length code**

... and some mysteries ...

SRP, continued

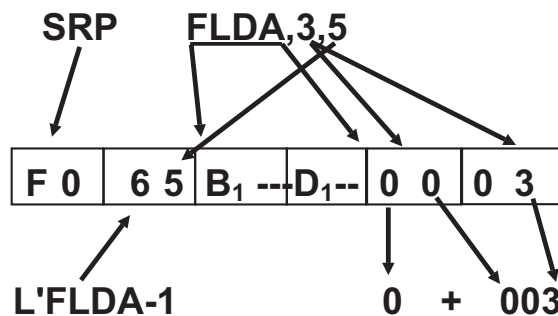
□ The explicit form of the SRP instruction is

SRP D1(L1,B1),D2(B2),I3

♦ In machine format:

F 0	L ₁ I ₃	B ₁ ---D ₁ ---	B ₂ ---D ₂ ---
-----	-------------------------------	--------------------------------------	--------------------------------------

♦ Looking at a specific example:



= 00 00 00 03₁₆

= 0000 0000 0000 0000 0000 0000 0000 0011

shift specification

Shift specification

- ♦ Left shift: specify number of digits to shift (0 to 31)
- ♦ Right shift: specify 64-(number of digits to shift)

SRP - Shift Specifications

<u>Binary</u>	<u>Dec</u>	<u>Shift</u>	<u>Binary</u>	<u>Dec</u>	<u>Shift</u>
000000	0	none	100000	32	right 32
000001	1	left 1	100001	33	right 31
000010	2	left 2	100010	34	right 30
000011	3	left 3	100011	35	right 29
000100	4	left 4	100100	36	right 28
000101	5	left 5	100101	37	right 27
000110	6	left 6	100110	38	right 26
000111	7	left 7	100111	39	right 25
001000	8	left 8	101000	40	right 24
001001	9	left 9	101001	41	right 23
001010	10	left 10	101010	42	right 22
001011	11	left 11	101011	43	right 21
001100	12	left 12	101100	44	right 20
001101	13	left 13	101101	45	right 19
001110	14	left 14	101110	46	right 18
001111	15	left 15	101111	47	right 17
010000	16	left 16	110000	48	right 16
010001	17	left 17	110001	49	right 15
010010	18	left 18	110010	50	right 14
010011	19	left 19	110011	51	right 13
010100	20	left 20	110100	52	right 12
010101	21	left 21	110101	53	right 11
010110	22	left 22	110110	54	right 10
010111	23	left 23	110111	55	right 9
011000	24	left 24	111000	56	right 8
011001	25	left 25	111001	57	right 7
011010	26	left 26	111010	58	right 6
011011	27	left 27	111011	59	right 5
011100	28	left 28	111100	60	right 4
011101	29	left 29	111101	61	right 3
011110	30	left 30	111110	62	right 2
011111	31	left 31	111111	63	right 1

☐ Possible values in six bits as unsigned binary integer

Rounding - An Example, p.3.

□ Now, to handle the half adjust situation we just code this:

```
SRP      PACKLM(5) , 63 , 5
```

Summary

- ❑ Coding in Assembler is part understanding the instructions
 - ◆ And part knowing your data
 - ◆ And part knowing how to string together a series of instructions to accomplish a particular task
- ❑ In this session we have focused on the issues around doing packed decimal arithmetic calculations, including
 - ◆ Allowing enough room for sufficient precision
 - ◆ Keeping track of implied decimal points
 - ◆ Avoiding division by zero
 - ◆ Rounding the results of calculations
- ❑ The important thing here has been the process, so when you must do numeric calculations follow these guidelines as they apply to the problem you are faced with

Good luck. Don't panic!

Contact us for a copy of the Assembler program used to test lecture points.