

Review Questions:

Binary Integer Arithmetic

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1. Indicate the decimal value associated with each of the given bit sequences, when the bit sequence is interpreted as an integer number in each of the following representations:
 - a. Unsigned Numbers
 - b. Signed-Magnitude Numbers
 - c. Ones'-Complement Representation
 - d. Two's-Complement Representation
 - e. Saturation Arithmetic
 - f. Excess-2,047
 - g. Excess-2,048
 - (a) 101100111110₂
 - (b) 010010101100₂
 - (c) 110101110101₂
 - (d) 011100111010₂
 - (e) 101010101100₂
 - (f) 110000111010₂
 - (g) 111001111110₂
 - (h) 100110010101₂
 - (i) 001010011010₂
 - (j) 100011001100₂

2. Describe the algorithm for the addition of two Signed-Magnitude binary integers.

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3. Fill in the following table, showing the specified values for integer arithmetic of **10-bit** numbers:

| Number Representation | Range of Numbers Represented | How many zeroes? | Carry Bit represents Carry-Out from which bit in the Sum Register? | How do you go about finding the representation of the negative of a number? |
|------------------------------|-------------------------------------|-------------------------|---|--|
| Unsigned Numbers | | | | |
| Signed-Magnitude | | | | |
| Ones'-Complement | | | | |
| Two's-Complement | | | | |
| Saturation Arithmetic | | | | |
| Excess-511 | | | | |
| Excess-512 | | | | |

Instructions for the Next Several Problems: Add each of the following pairs of binary numbers five times, following the rules of:

- a. Unsigned Numbers
- b. Signed-Magnitude Numbers
- c. Ones'-Complement Representation
- d. Two's-Complement Representation
- e. Saturation Arithmetic

In each case:

- (i) show the carry in for each bit;
- (ii) show the bit sequence that would appear in the Sum Register;
- (iii) indicate what is the decimal value represented by the bit sequence of the Augend;
- (iv) indicate what is the decimal value represented by the bit sequence of the Addend;
- (v) indicate what is the decimal value represented by the bit sequence that would appear in the Sum Register;
- (vi) indicate whether a *0* or a *1* would appear in the Carry Bit of the Status Register;
- (vii) indicate the value (*0* or *1*) that would appear in the Overflow Bit of the Status Register; and
- (viii) state whether or not the value of the bit sequence appearing in the Sum Register is the correct sum of the values of the numbers represented in the Augend and Addend Registers.

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4.

| UNSIGNED INTEGERS | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| SATURATION ARITHMETIC | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

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| UNSIGNED NUMBERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

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| UNSIGNED NUMBERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| ONES' -COMPLEMENT INTEGERS | | | | | | | | | | | |
|----------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

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| UNSIGNED NUMBERS | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

| SATURATION ARITHMETIC | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: |
| Sum Register: | | | | | | | | | | V bit: |

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| UNSIGNED NUMBERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|--|
| Carry/Borrow Bits: | | | | | | | | | Decimal Values: | Z bit: | |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | N bit: | |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | C bit: | |
| Sum Register: | | | | | | | | | | V bit: | |

Answers to Selected Questions:

Question 1:

(a) 101100111110_2

Unsigned Number: $0 + 2 + 4 + 8 + 16 + 32 + 0 + 0 + 256 + 512 + 0 + 2,048 = 2,878$

Signed-Magnitude: negative sign bit, magnitude $0 + 2 + 4 + 8 + 16 + 32 + 0 + 0 + 256 + 512 + 0$, thus representing -830

Ones' Complement: a negative number, whose complement is 010011000001_2 or 1,217. Thus, the value of the original bit sequence is $-1,217$.

Two's Complement: a negative number, which when first complemented and then incremented comes out to 010011000010_2 or 1,218. Thus, the value of the original bit sequence is $-1,218$.

Saturation Arithmetic: Same value as for Unsigned Numbers: 2,878.

(b) 010010101100_2

Since the MSB is zero, this number represents the same value in all of the representation schemes listed: $0 + 0 + 4 + 8 + 0 + 32 + 0 + 128 + 0 + 0 + 1,024 = 1,196$

(c) 110101110101_2

Unsigned Number: $1 + 0 + 4 + 0 + 16 + 32 + 64 + 0 + 256 + 0 + 1,024 + 2,048 = 3,445$

Signed-Magnitude: negative sign bit, magnitude $1 + 0 + 4 + 0 + 16 + 32 + 64 + 0 + 256 + 0 + 1,024$, thus representing $-1,397$

Ones' Complement: a negative number, whose complement is 001010001010_2 or 740. Thus, the value of the original bit sequence is -650 .

Two's Complement: a negative number which when first complemented and then incremented comes out to 001010001011_2 or 651. Thus, the value of the original bit sequence is -651 .

Saturation Arithmetic: Same value as for Unsigned Numbers: 3,445.

(d) 011100111010_2

Since the MSB is zero, this number represents the same value in all of the representation schemes listed: $0 + 2 + 0 + 8 + 16 + 32 + 0 + 0 + 256 + 512 + 1,024 = 1,850$

(e) 101010101100_2

Unsigned Number: $0 + 0 + 4 + 8 + 0 + 32 + 0 + 128 + 0 + 512 + 0 + 2,048 = 2,732$

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Signed-Magnitude: negative sign bit, magnitude $0 + 0 + 4 + 8 + 0 + 32 + 0 + 128 + 0 + 512 + 0$, thus representing -684 .

Ones' Complement: a negative number, whose complement is 010101010011_2 or 1,363. Thus, the value of the original bit sequence is $-1,363$.

Two's Complement: a negative number which when first complemented and then incremented comes out to 010101010100_2 or . Thus, the value of the original bit sequence is $-1,364$

Saturation Arithmetic: Same value as for Unsigned Numbers: 2,732.

(f) 110000111010_2

Unsigned Number: $0 + 2 + 0 + 8 + 16 + 32 + 0 + 0 + 0 + 0 + 1,024 + 2,048 = 3,130$

Signed-Magnitude: negative sign bit, magnitude $0 + 2 + 0 + 8 + 16 + 32 + 0 + 0 + 0 + 0 + 1,024$, thus representing $-1,082$.

Ones' Complement: a negative number, whose complement is 001111000101_2 or 965. Thus, the value of the original bit sequence is -965 .

Two's Complement: a negative number which when first complemented and then incremented comes out to 001111000110_2 or 966. Thus, the value of the original bit sequence is -966 .

Saturation Arithmetic: Same value as for Unsigned Numbers: 3,130.

(g) 111001111110_2

Unsigned Number: $0 + 2 + 4 + 8 + 16 + 32 + 64 + 0 + 0 + 512 + 1,024 + 2,048 = 3,710$

Signed-Magnitude: negative sign bit, magnitude $0 + 2 + 4 + 8 + 16 + 32 + 64 + 0 + 0 + 512 + 1,024$, thus representing $-1,662$.

Ones' Complement: a negative number, whose complement is 000110000001_2 or 385. Thus, the value of the original bit sequence is -385 .

Two's Complement: a negative number which when first complemented and then incremented comes out to 000110000010_2 or 386. Thus, the value of the original bit sequence is -386 .

Saturation Arithmetic: Same value as for Unsigned Numbers: 3,710.

(h) 100110010101_2

Unsigned Number: $1 + 0 + 4 + 0 + 16 + 0 + 0 + 128 + 256 + 0 + 0 + 2,048 = 2,453$

Signed-Magnitude: negative sign bit, magnitude $1 + 0 + 4 + 0 + 16 + 0 + 0 + 128 + 256 + 0 + 0$, thus representing -405 .

Ones' Complement: a negative number, whose complement is 011001101010_2 or 1,642. Thus, the value of the original bit sequence is $-1,642$.

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Two's Complement: a negative number which when first complemented and then incremented comes out to 011001101011_2 or 1,643. Thus, the value of the original bit sequence is $-1,643$.

Saturation Arithmetic: Same value as for Unsigned Numbers: 2,453.

(i) 001010011010_2

Since the MSB is zero, this number represents the same value in all of the representation schemes listed: $0 + 2 + 0 + 8 + 16 + 0 + 0 + 128 + 0 + 512 = 666$

(j) 100011001100_2

Unsigned Number: $0 + 0 + 4 + 8 + 0 + 0 + 64 + 128 + 0 + 0 + 0 + 2,048 = 2,252$

Signed-Magnitude: negative sign bit, magnitude = $0 + 0 + 4 + 8 + 0 + 0 + 64 + 128 + 0 + 0 + 0$, thus representing -204 .

Ones' Complement: a negative number, whose complement is 011100110011_2 or 1,843.

Thus, the value of the original bit sequence is $-1,843$.

Two's Complement: a negative number which when first complemented and then incremented comes out to 011100110100_2 or 1,844. Thus, the value of the original bit sequence is $-1,844$.

Saturation Arithmetic: Same value as for Unsigned Numbers: 2,252.

Question 2: (i) Are the sign bits identical or different?

(iia) Identical: Replicate the common sign bit in the sum register.

(iia) Add the magnitude bits of the augend and the addend to obtain the magnitude bits of the sum.

(iva) In case of overflow, set the V bit; otherwise, clear it.

(iib) Different: Determine which number has the larger magnitude, and replicate its sign bit in the sum register.

(iiib) Subtract the magnitude of the smaller number from the magnitude of the larger number; the difference goes into the magnitude field of the sum register.

(ivb) Clear the V bit.

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Question 3:

| Number Representation | Range of Numbers Represented | How many zeroes? | Carry Bit represents Carry-Out from which bit in the Sum Register? | How do you go about finding the representation of the negative of a number? |
|-----------------------|------------------------------|------------------|--|---|
| Unsigned Numbers | $0 \rightarrow 1,023$ | 1 | Bit 10 | not applicable |
| Signed-Magnitude | $-511 \rightarrow +511$ | 2 | Bit 9 | Invert the sign bit (bit 10). |
| Ones'-Complement | $-511 \rightarrow +511$ | 2 | Bit 10 | Complement the number (1s'-complement). |
| Two's-Complement | $-512 \rightarrow +511$ | 1 | Bit 10 | Complement the number (1s'-complement), and then increment it. The result is the 2's-complement. Of the number. |
| Saturation Arithmetic | $0 \rightarrow 1,023$ | 1 | not applicable | not applicable |
| Excess-511 | $-511 \rightarrow +512$ | 1 | not applicable | Add 511 to the number, and represent the sum as an "Unsigned" (Non-explicitly-Signed) Number. |
| Excess-512 | $-512 \rightarrow +511$ | 1 | not applicable | Add 512 to the number, and represent the sum as an "Unsigned" (Non-explicitly-Signed) Number. |

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Question 4:

| UNSIGNED INTEGERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +47 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 0 |

Correct sum

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +47 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 0 |

Correct sum

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +47 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 0 |

Correct sum

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +47 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 0 |

Correct sum

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +47 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 0 |

Correct sum

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Question 5:

| UNSIGNED NUMBERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | +111 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | +189 | V bit: | 0 |

Correct sum

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | X | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | +111 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 1 |
| Sum Register: | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | +61 | V bit: | 1 |

Not the correct sum (Overflow)

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | +111 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | -66 | V bit: | 1 |

Not the correct sum (Overflow)

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | +111 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | +61 | V bit: | 1 |

Not the correct sum (Overflow)

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | +111 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | +189 | V bit: | 0 |

Correct sum

Review Questions: Binary Digital Arithmetic

Question 6:

| UNSIGNED NUMBERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +175 | N bit: | 0 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +253 | V bit: | 0 |

Correct sum

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | X | 1 | 1 | 1 | 1 | 1 | 1 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | -47 | N bit: | 1 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | +31 | V bit: | 0 |

Correct sum

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | -80 | N bit: | 1 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | -2 | V bit: | 0 |

Correct sum

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | -81 | N bit: | 1 |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | 0 |
| Sum Register: | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | -3 | V bit: | 0 |

Correct sum

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | X |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +175 | N bit: | X |
| Addend Register: | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +78 | C bit: | X |
| Sum Register: | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +253 | V bit: | X |

Correct sum

Review Questions: Binary Digital Arithmetic

Question 7:

| UNSIGNED NUMBERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +175 | N bit: | 0 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +206 | C bit: | 1 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 1 |

Not the correct sum (Overflow)

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | X | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | -47 | N bit: | 1 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | -78 | C bit: | 0 |
| Sum Register: | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | -125 | V bit: | 0 |

Correct sum

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | -80 | N bit: | 0 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | -49 | C bit: | 1 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 1 |

Not the correct sum (Overflow)

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | -81 | N bit: | 0 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | -50 | C bit: | 1 |
| Sum Register: | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | +125 | V bit: | 1 |

Not the correct sum (Overflow)

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | X |
| Augend Register: | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | +175 | N bit: | X |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +206 | C bit: | X |
| Sum Register: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | +255 | V bit: | X |

Correct sum, in accordance with the rules of Saturation Arithmetic!

Review Questions: Binary Digital Arithmetic

Question 8:

| UNSIGNED NUMBERS | | | | | | | | | | | |
|--------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | +239 | N bit: | 0 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +206 | C bit: | 1 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | +189 | V bit: | 1 |

Not the correct sum

| SIGNED-MAGNITUDE INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | -111 | N bit: | 1 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | -78 | C bit: | 1 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | -61 | V bit: | 1 |

Not the correct sum

| ONES'-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | -16 | N bit: | 1 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | -49 | C bit: | 1 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | -66 | V bit: | 0 |

An additional operation (End-Around Carry) needs to be performed before the value in the sum register becomes equal to the true sum of the numbers (Ones'-Complement arithmetic).

| TWO'S-COMPLEMENT INTEGERS | | | | | | | | | | | |
|---------------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | 0 |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | -17 | N bit: | 1 |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | -50 | C bit: | 1 |
| Sum Register: | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | -67 | V bit: | 0 |

Correct sum

| SATURATION ARITHMETIC | | | | | | | | | | | |
|-----------------------|---|---|---|---|---|---|---|---|-----------------|--------|---|
| Carry/Borrow Bits: | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | Decimal Values: | Z bit: | X |
| Augend Register: | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | +239 | N bit: | X |
| Addend Register: | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | +206 | C bit: | X |
| Sum Register: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | +255 | V bit: | X |

Correct sum, in accordance with the rules of Saturation Arithmetic!