LSP Exam - January 15, 2018

> **CVUT FEL (ČVUT) - České vysoké učení technické v Praze | Czech Technical University in Prague**
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> **AI-Generated Solution** - Reference analysis below

Question 4: Signed/Unsigned Bit Value Frequently Tested

Question: What is the decimal value of the 10-bit binary number `10 0000 1111`?

a) **Unsigned**: _____

b) **Two's-complement (signed)**: _____

Detailed Solution

```
Binary: 10 0000 1111
Position:   9  8765 4321 0
```

a) Unsigned calculation:
```
= 1×2^9 + 0×2^8 + 0×2^7 + 0×2^6 + 0×2^5 + 0×2^4 + 1×2^3 + 1×2^2 + 1×2^1 + 1×2^0
= 512 + 0 + 0 + 0 + 0 + 0 + 8 + 4 + 2 + 1
= 527
```

b) Two's-complement (signed) calculation:

Method 1 - Direct calculation:
```
MSB weight is negative: -2^9 + (remaining bits value)
= -512 + (0×2^8 + ... + 1×2^3 + 1×2^2 + 1×2^1 + 1×2^0)
= -512 + 15
= -497
```

Method 2 - Invert and add 1:
```
Original:     10 0000 1111
Inverted:     01 1111 0000
Add 1:        01 1111 0001 = 497
So original = -497
```

Question 5: Equivalent Logic Functions Frequently Tested

Question: Mark all logic functions that are equivalent to other functions:

```vhdl
f1 <= (A xor C) or (A and not C);
f2 <= (B or C) and (not A or B or C);
f3 <= ((C and not B) or (B and A));
f4 <= (A or C) and (not A or not C);
f5 <= (A and not B) xor (A and C);
f6 <= (A and not C) or (C and not A);
```

Solution Method: Karnaugh Map for Each Function

f1 = (A xor C) or (A and not C)

f1	C=0	C=1
A=0	0	1
A=1	1	1

f1 = A + C

f2 = (B or C) and (not A or B or C)

f2	BC=00	BC=01	BC=11	BC=10
A=0	0	1	1	1
A=1	0	1	1	0

f3 = (C and not B) or (B and A)

f3	BC=00	BC=01	BC=11	BC=10
A=0	0	1	0	0
A=1	0	1	1	0

f4 = (A or C) and (not A or not C)

f4	C=0	C=1
A=0	0	1
A=1	1	0

f4 = A C (XOR)

f5 = (A and not B) xor (A and C)

Requires detailed expansion...

f6 = (A and not C) or (C and not A)

f6	C=0	C=1
A=0	0	1

| A=1 | 1 | 0 |

f6 = A C (XOR)

Conclusion
f4 f6 (both equal A XOR C)

Question: RS Latch Circuit Simulation Frequently Tested

Question: Given the circuit, write the Q output value for inputs A, B, C at times t0, t1, t2, t3 as

```
A = ..0..|..1..|..1..|..1..|
B = ..0..|..0..|..0..|..1..|
C = ..1..|..1..|..0..|..0..|

t0   t1   t2   t3
```

Answer
```
Q = ...1...|…0….|…0….|…1.…|
```

Question: Shannon Expansion Frequently Tested

Decompose the function into:
```
Q = (not Q and f0(A,B,C)) or (Q and f1(A,B,C))
```

Solution Method

```
f0 := f(A,B,C,'0') := (A  B) · (B  C)
f1 := f(A,B,C,'1') := (A  B)
```

Karnaugh Map for f0

f0	C=0	C=1
AB=00	0	1
AB=01	0	0
AB=11	1	0
AB=10	0	0

Karnaugh Map for f1

| f1 | C=0 | C=1 |

```
|----|-----|-----|
| AB=00 | 1 | 1 |
| AB=01 | 0 | 0 |
| AB=11 | 1 | 1 |
| AB=10 | 0 | 0 |

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## Quick Reference

### Signed Number Calculation Formula
- n-bit two's complement range: $[-2^{n-1}, 2^{n-1}-1]$
- Negative number calculation: $-2^{n-1} + (remaining\ bits\ value)$

### Equivalent Function Identification Method
1. Draw Karnaugh map for each function
2. Compare if Karnaugh maps are identical
3. Identical functions are equivalent

### Shannon Expansion Formula
$$f(x_1, x_2, ..., x_n, Q) = \bar{Q} \cdot f_0 + Q \cdot f_1$$

Where:
- $f_0 = f(x_1, x_2, ..., x_n, 0)$
- $f_1 = f(x_1, x_2, ..., x_n, 1)$
```