**Test Plan**

**R type Instruction**

**Test case 1: Basic functionality of ADD**

This test case verifies the basic functionality of the ADD instruction in a RISC-V processor by performing an addition operation using immediate and register values. The expected result is that register x7 correctly stores the sum of x5 (0x10) and x6 (0x5), resulting in x7 = 0x15.

ADDI x5, x0, 0x10 # x5 = 0x10

ADDI x6, x0, 0x5 # x6 = 0x5

ADD x7, x6, x5 # x7 = x6 + x5 (0x10 + 0x5)

**Test case 2: Basic functionality of SUB**

This test case verifies the basic functionality of the SUB instruction by performing a subtraction operation between two registers. The expected result is that register x7 correctly stores the result of x5 (0x10) minus x6 (0x5), resulting in x7 = 0xB (0x10 - 0x5 = 0xB).

ADDI x5, x0, 0x10 # x5 = 0x10

ADDI x6, x0, 0x5 # x6 = 0x5

SUB x7, x6, x5 # x7 = x6 - x5 (0x10 – 0x5)

**Test case 3: Basic functionality of SLL**

This test case verifies the functionality of the SLL (Shift Left Logical) instruction by shifting the value in x6 left by the lower 5 bits of x5. The expected result is that register x7 stores the value of x6 (0x5) shifted left by 0x10 & 0x1F (16) positions, resulting in x7 = 0x50000 (0x5 << 16).

ADDI x5, x0, 0x10 # x5 = 0x10

ADDI x6, x0, 0x5 # x6 = 0x5

SLL x7, x6, x5 # x7 = x6 << (x5 & 0x1F) (Logical shift left)

**Test case 4: Differentiate SLTU and SLT**

This test case verifies the difference between signed and unsigned comparisons using the SLT (Set Less Than) and SLTU (Set Less Than Unsigned) instructions. The expected result is that SLT sets x7 to 1 since -1 is less than 1 in signed comparison, while SLTU sets x8 to 0 because 0xFFFFFFFF is greater than 0x00000001 in unsigned comparison.

# Initialize registers with values that show the difference between SLT and SLTU

ADDI x5, x0, -1 # x5 = 0xFFFFFFFF (-1 in signed, large positive in unsigned)

ADDI x6, x0, 1 # x6 = 0x00000001 (1 in both signed and unsigned)

SLT x7, x5, x6 # Signed comparison: (-1 < 1) -> x7 = 1

SLTU x8, x5, x6 # Unsigned comparison: (0xFFFFFFFF < 0x00000001) -> x8 = 0

**Test case 5: Basic functionality of XOR**

This test case verifies the basic functionality of the XOR instruction by performing a bitwise exclusive OR operation between two registers. The expected result is that register x7 stores the result of x6 (0x5) XOR x5 (0x10), resulting in x7 = 0x15 (0x5 ^ 0x10 = 0x15).

ADDI x5, x0, 0x10 # x5 = 0x10

ADDI x6, x0, 0x5 # x6 = 0x5

XOR x7, x6, x5 # x7 = x6 ^ x5 (Bitwise XOR)

**Test case 6: Differentiating between SRA and SRL**

This test case verifies the difference between SRL (Logical Shift Right) and SRA (Arithmetic Shift Right) by shifting a negative value (0xFFFFFFFF). The expected result is that SRL (x7) performs a logical shift, filling with zeros, resulting in 0x0FFFFFFF, while SRA (x8) maintains the sign bit, resulting in 0xFFFFFFFF, demonstrating how arithmetic shift preserves sign extension.

ADDI x5, x0, 0xFFFFFFFF # x5 = 0xFFFFFFFF (-1 in two's complement)

ADDI x6, x0, 4 # x6 = 4 (shift amount)

# Perform Logical Shift Right (SRL)

SRL x7, x5, x6 # x7 = x5 >> x6 (Logical shift, fills with 0s)

# Perform Arithmetic Shift Right (SRA)

SRA x8, x5, x6 # x8 = x5 >> x6 (Arithmetic shift, fills with sign bit)

**Expected Output**

* SRL x7, x5, x6: **Logical Shift Right**
  + 0xFFFFFFFF >> 4 results in 0x0FFFFFFF (fills with 0s).
* SRA x8, x5, x6: **Arithmetic Shift Right**
  + 0xFFFFFFFF >> 4 results in 0xFFFFFFFF (fills with 1s, maintaining the sign bit).

**Test case 7: Basic functionality of OR**

This test case verifies the basic functionality of the OR instruction by performing a bitwise OR operation between two registers. The expected result is that register x7 stores the result of x6 (0x5) OR x5 (0x10), resulting in x7 = 0x15 (0x5 | 0x10 = 0x15).

ADDI x5, x0, 0x10 # x5 = 0x10

ADDI x6, x0, 0x5 # x6 = 0x5

OR x7, x6, x5 # x7 = x6 | x5 (Bitwise OR)

**Test case 8: Basic functionality of AND**

This test case verifies the basic functionality of the AND instruction by performing a bitwise AND operation between two registers. The expected result is that register x7 stores the result of x6 (0x5) AND x5 (0x10), resulting in x7 = 0x0 (0x5 & 0x10 = 0x0) since there are no common set bits.

ADDI x5, x0, 0x10 # x5 = 0x10

ADDI x6, x0, 0x5 # x6 = 0x5

AND x7, x6, x5 # x7 = x6 & x5 (Bitwise AND)

**Test Case 9: Overflow condition for ADD**

This test case verifies integer overflow behaviour when adding the maximum positive 32-bit signed integer (0x7FFFFFFF) with 1. The expected result is that x7 stores 0x80000000, which represents -2147483648 in signed two’s complement. Although this results in an overflow, RISC-V does not raise an exception for signed integer overflow in standard ADD operations.  
ADDI x5, x0, 0x7FFF\_FFFF # x5 = 2147483647 (Max positive value)

ADDI x6, x0, 0x1 # x6 = 1

ADD x7, x5, x6 # x7 = x5 + x6 (Expected: 0x80000000, which is -2147483648 in signed 2's complement)

Expected result : This results in an overflow, but no exception is raised.

**Test Case 10: Overflow condition for SUB**

This test case verifies the behavior of the SUB instruction when subtracting from the minimum signed 32-bit value. The expected result is that x7 stores 0x7FFFFFFF, which is +2147483647 in signed two’s complement, after performing the subtraction of 1 from the minimum signed value (0x80000000). This case checks how the processor handles the wrap-around behavior when performing operations near the limits of signed integers.

ADDI x5, x0, 0x80000000 # x5 = 0x80000000 (-2147483648, Min signed 32-bit value)

ADDI x6, x0, 0x00000001 # x6 = 0x00000001 (1)

SUB x7, x5, x6 # x7 = x5 - x6 (Expected: 0x7FFFFFFF, which is +2147483647 in signed 2's complement)

**Test case 11: attempt to write a value to register 0**

This test case verifies the behavior of attempting to write a value to register x0, which is the zero register in RISC-V and always holds the value 0. The instruction ADD x0, x5, x6 attempts to add the values in x5 (0x10) and x6 (0x5) and store the result in x0. However, since x0 is hardwired to 0, the operation will have no effect, and x0 will remain 0, regardless of the operation. This ensures that writes to register x0 are ignored, as expected.

ADDI x5, x0, 0x10 # x5 = 0x10

ADDI x6, x0, 0x5 # x6 = 0x5

ADD x0, x5, x6