Function Calls & Stack examples

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November 24, 2020

Computer Organization and Networks
Graz University of Technology

Push and Pop

Push and pop

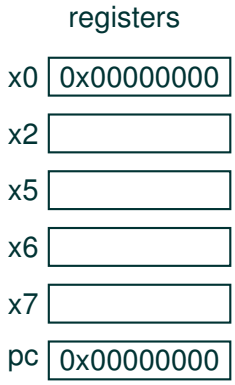
```
ADDI    x2,x0,0x700

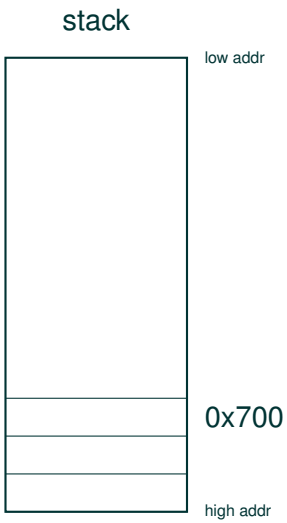
ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```





Push and pop

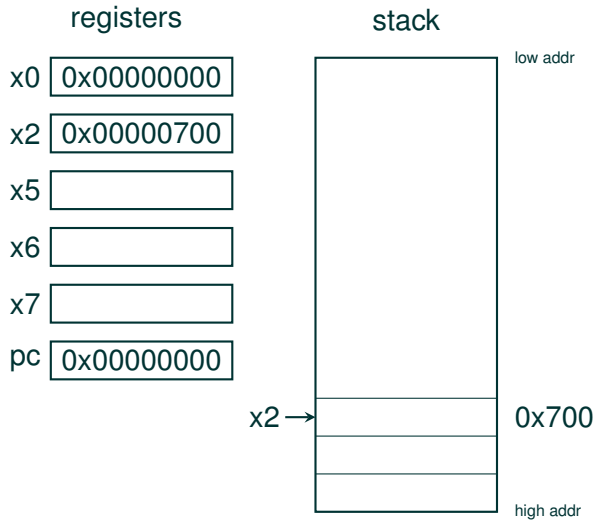
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

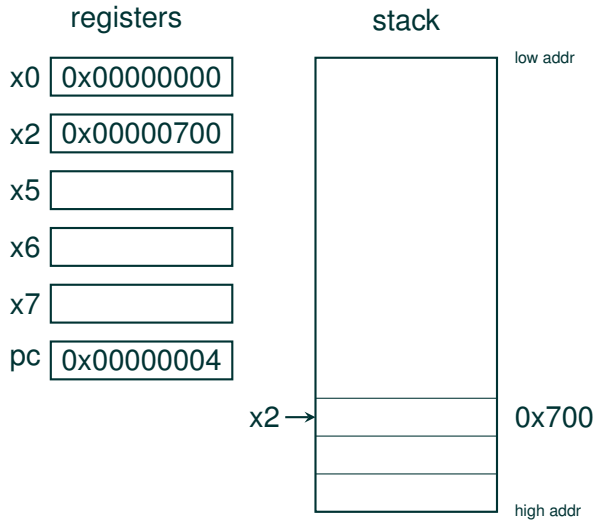
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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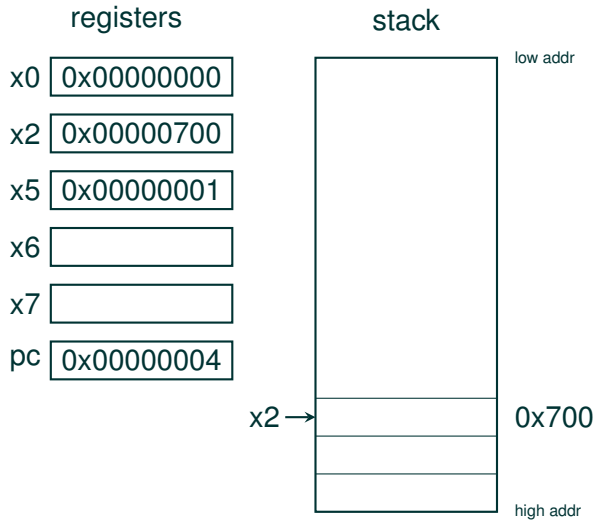
ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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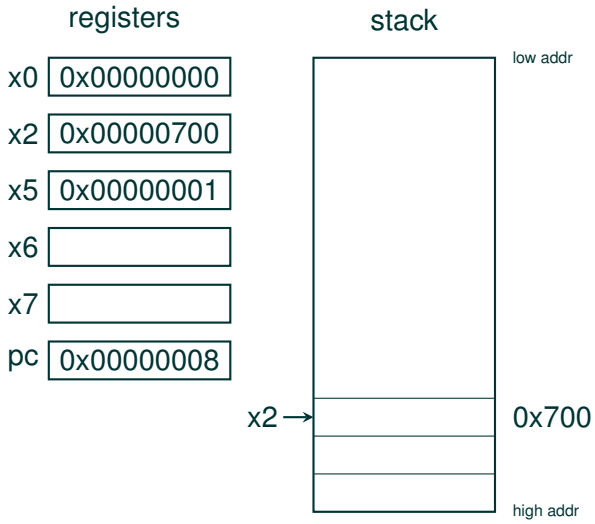
ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
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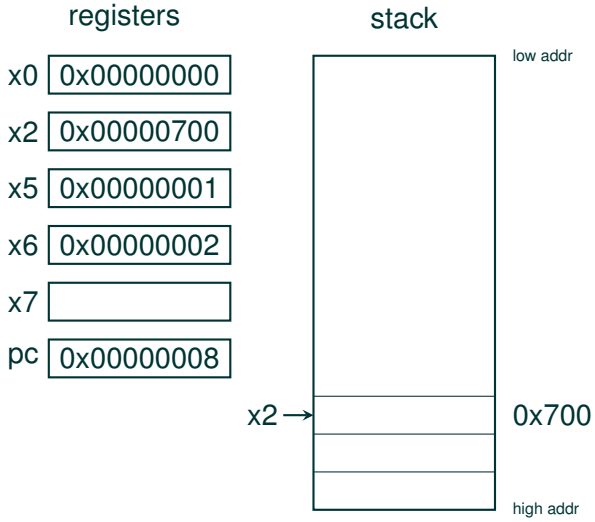
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

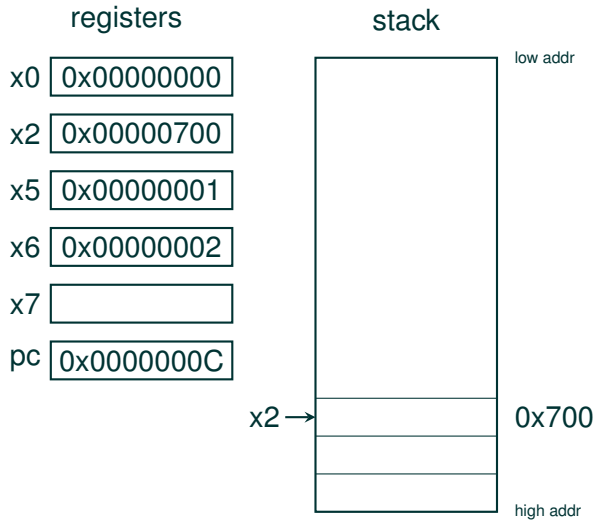
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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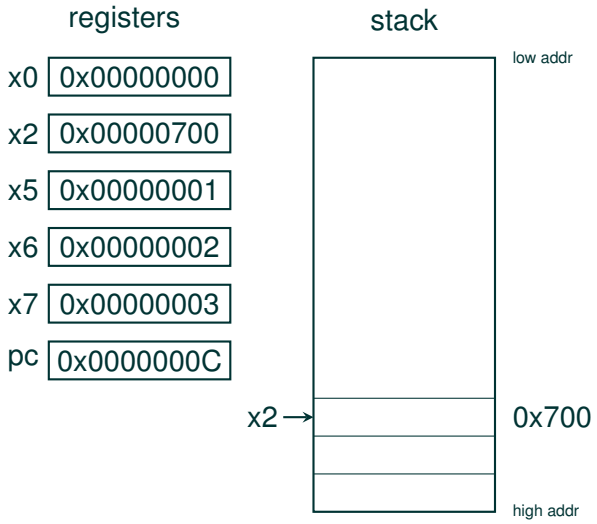
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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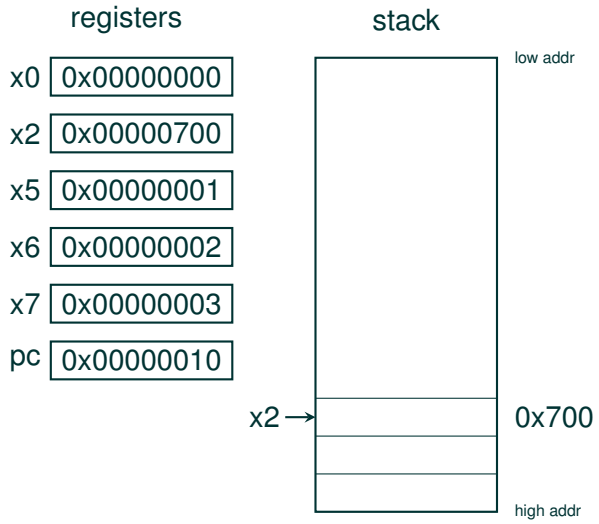
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

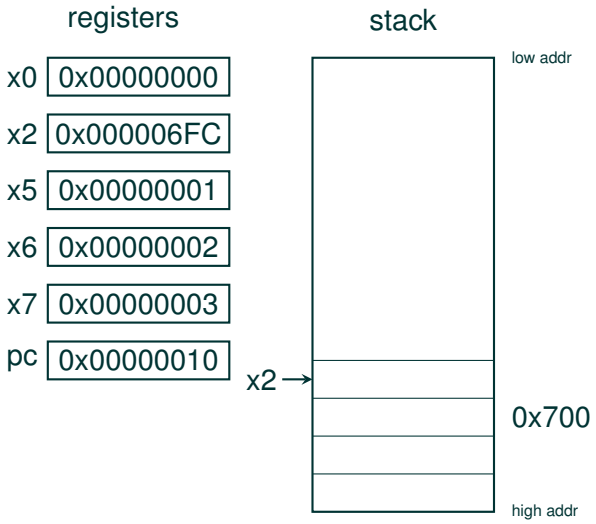
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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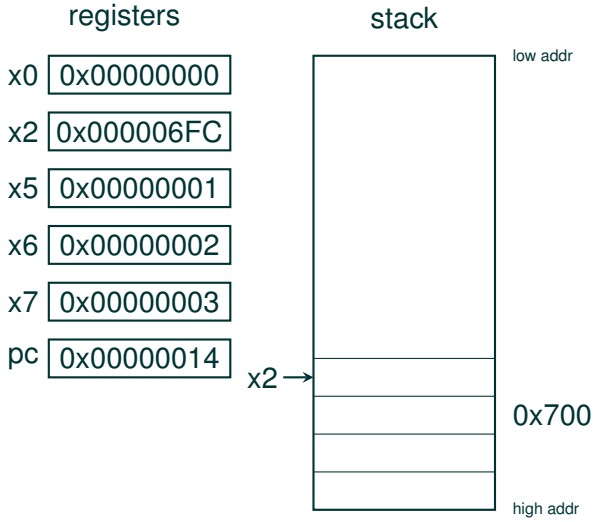
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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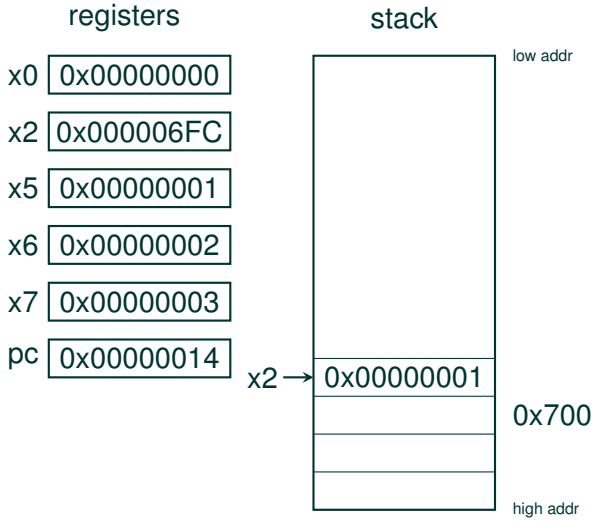
ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
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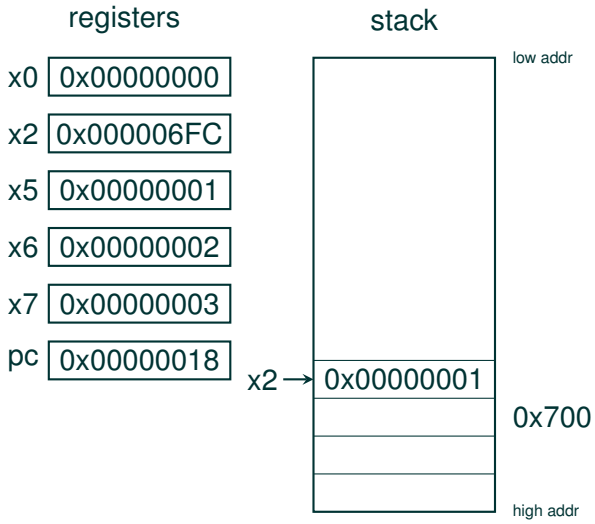
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
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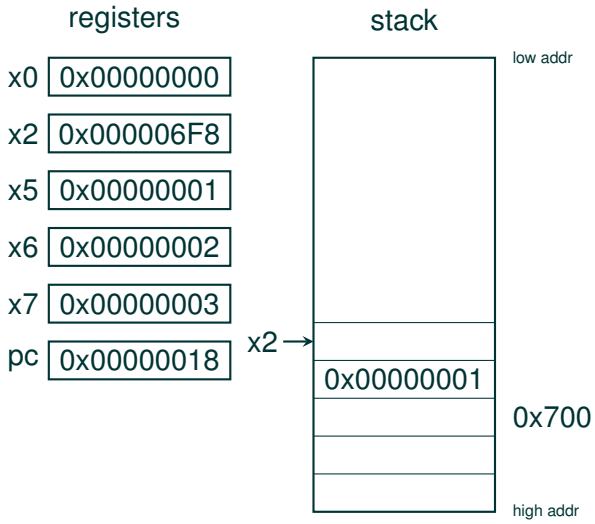
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

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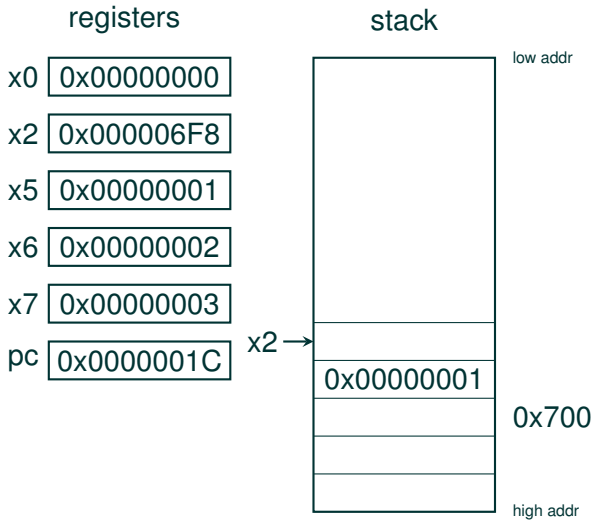
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

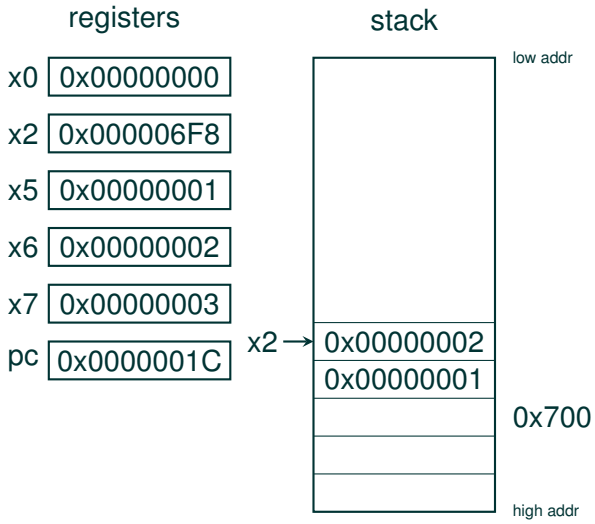
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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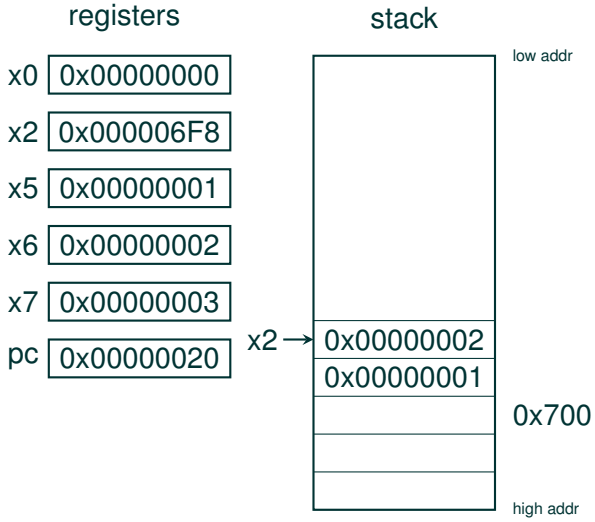
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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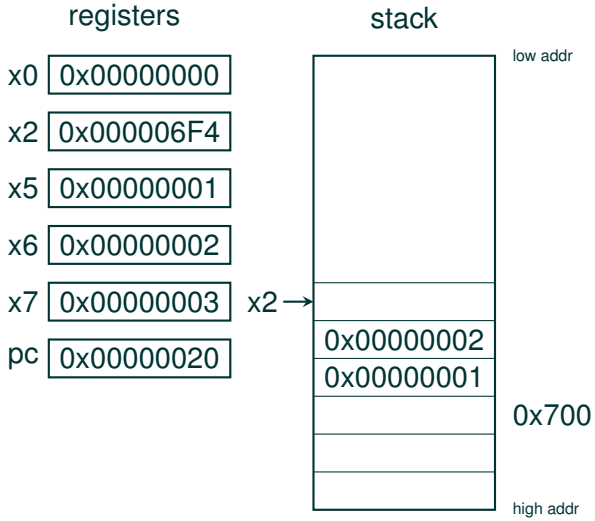
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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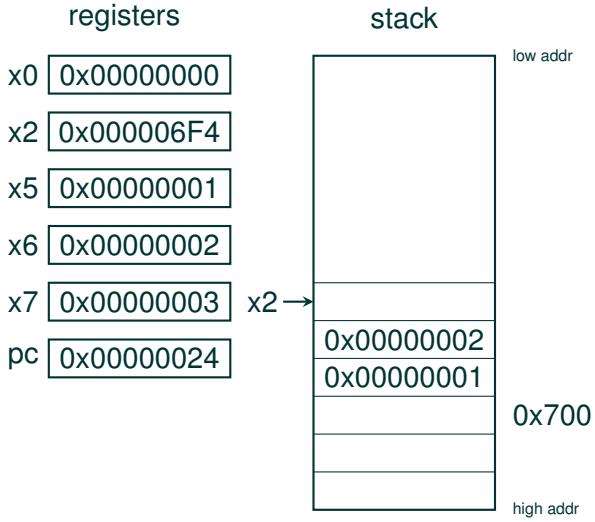
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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ADDI    x6,x0,2
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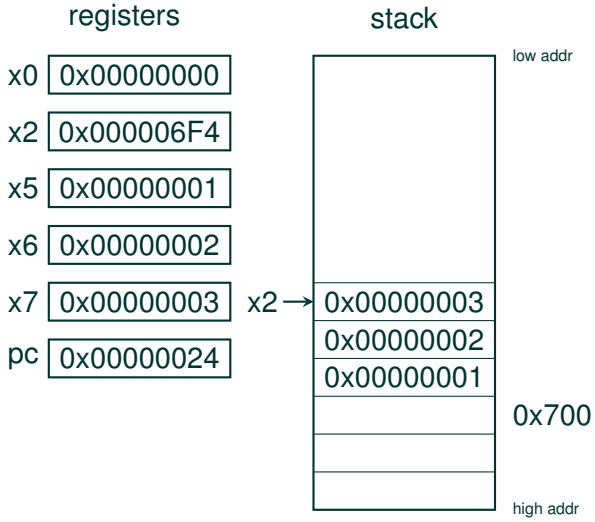
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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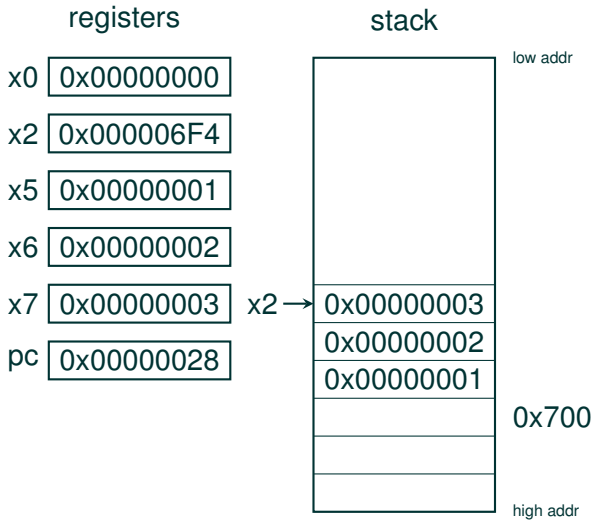
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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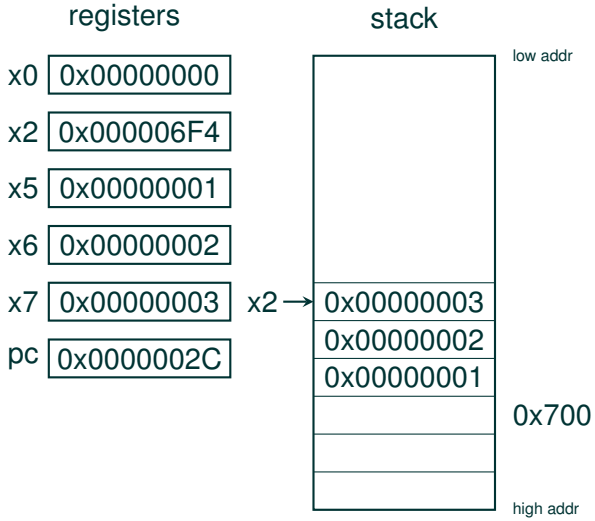
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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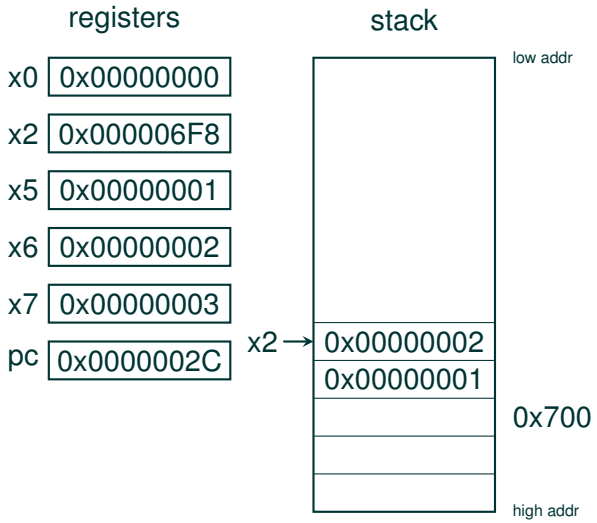
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



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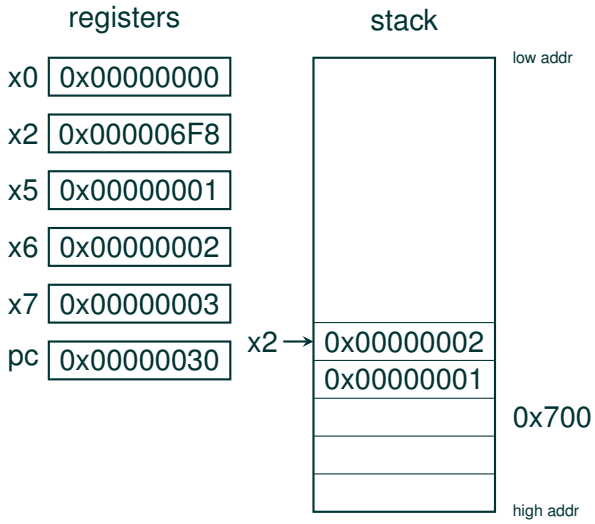
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

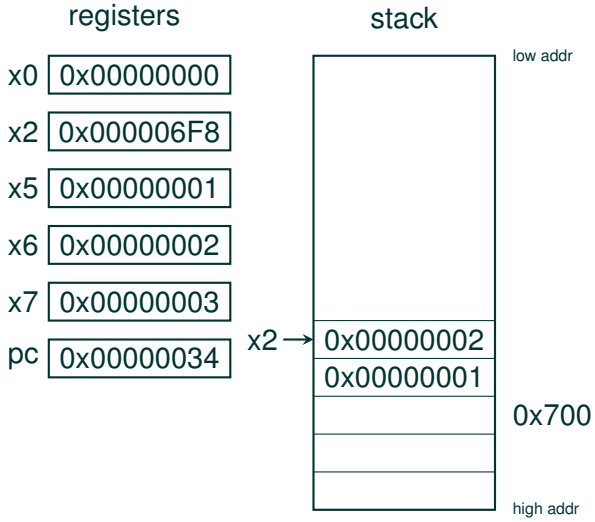
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

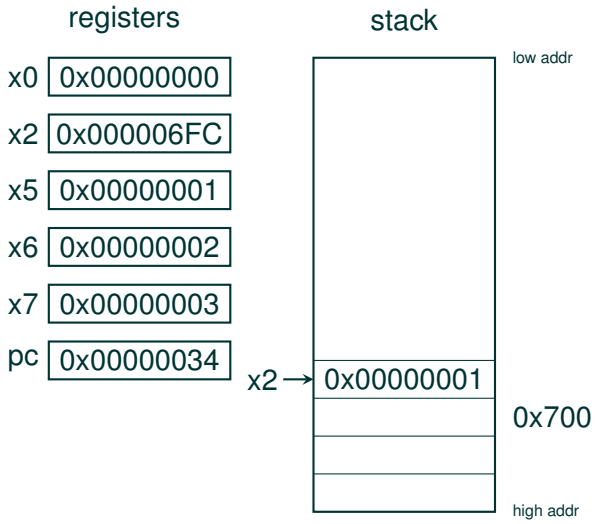
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

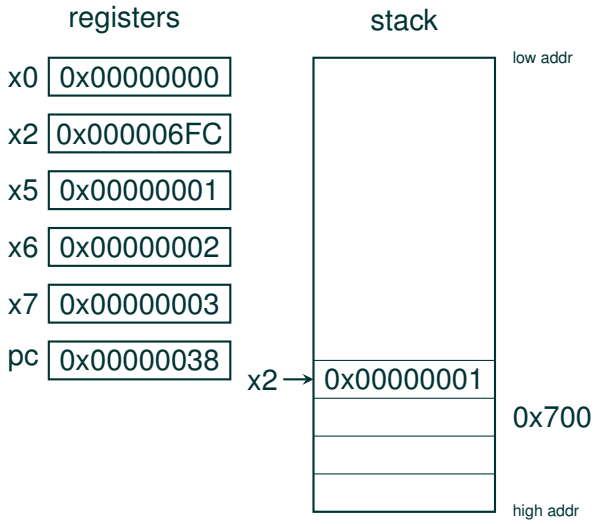
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

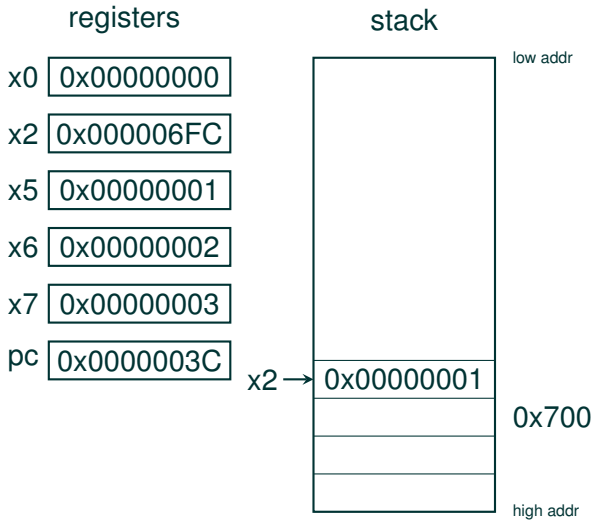
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

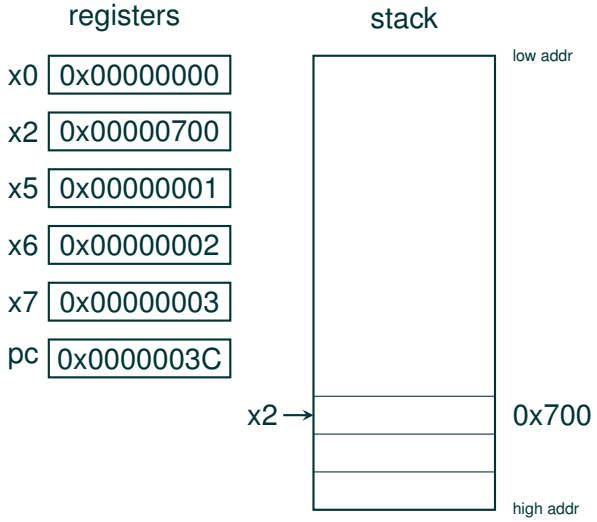
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

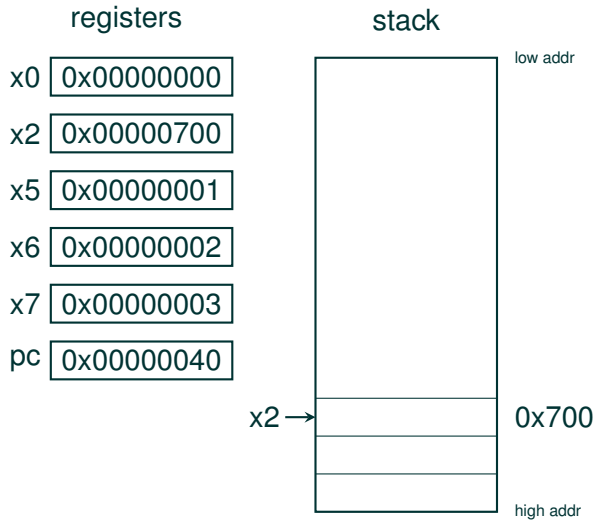
```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```



Push and pop

```
ADDI    x2,x0,0x700

ADDI    x5,x0,1
ADDI    x6,x0,2
ADDI    x7,x0,3

ADDI    x2,x2,-4
SW      x5,0(x2)
ADDI    x2,x2,-4
SW      x6,0(x2)
ADDI    x2,x2,-4
SW      x7,0(x2)

LW      x7,0(x2)
ADDI    x2,x2,4
LW      x6,0(x2)
ADDI    x2,x2,4
LW      x5,0(x2)
ADDI    x2,x2,4

EBREAK
```

Recursive call on a stack

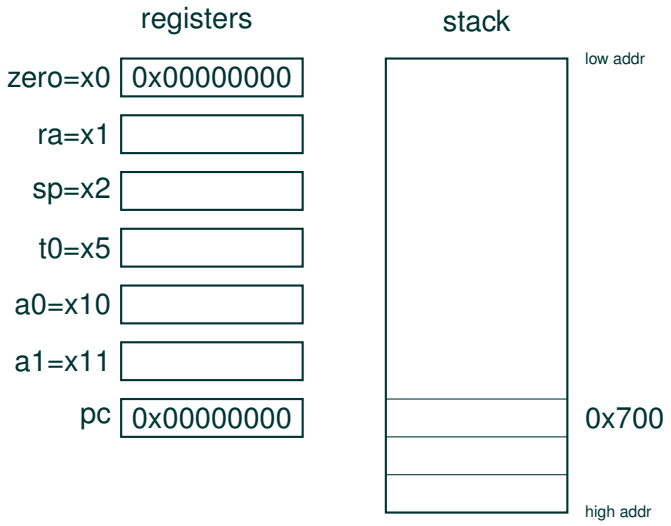
Recursive call on a stack

```c
// Computes the sum of the arithmetic progression defined by
// result = sum init+(n-1), n=[1,count]
int arith_series(int init, int count) {
    if (1 >= count)
        return init;
    return count + arith_series(init, count-1);
}

int main(void) {
    return arith_series(1, 3);
}
```

Recursive call on a stack

```
_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
    ADD a0, a0, a1
arith_series_return:
    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
main:
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
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    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
    ADD a0, a0, a1
arith_series_return:
    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
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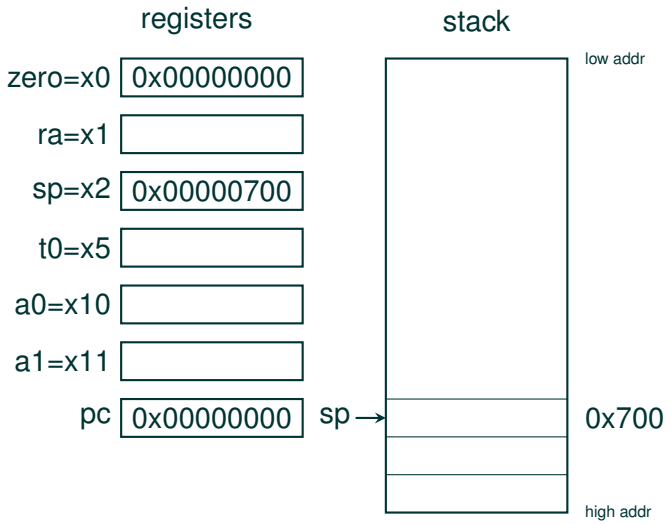
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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    ADDI sp, sp, 8
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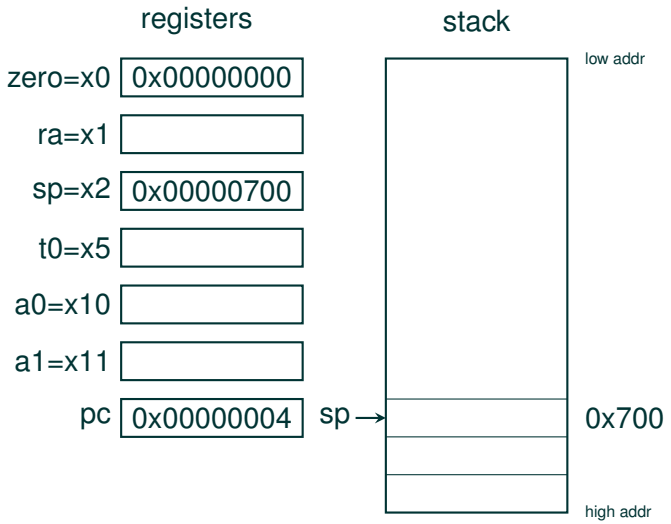
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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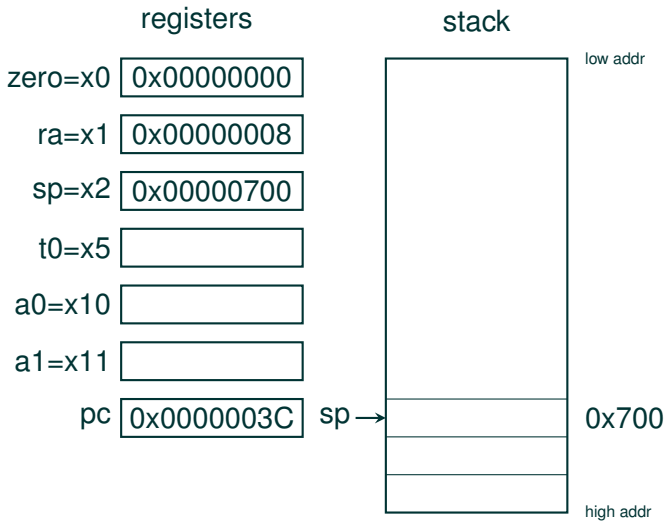
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



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    ADDI sp, sp, 8
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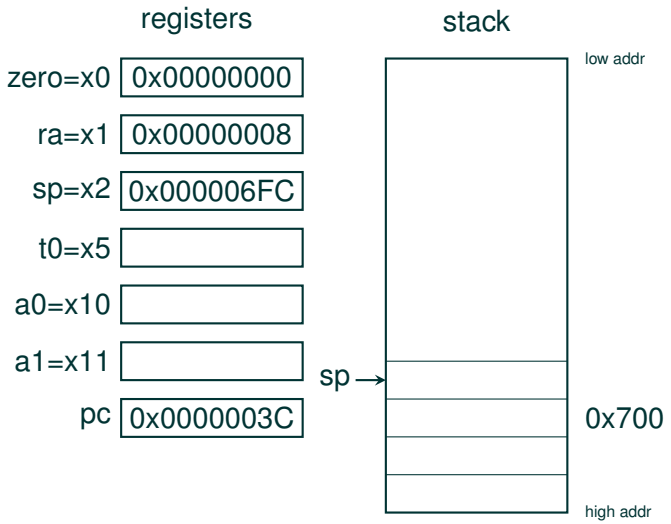
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



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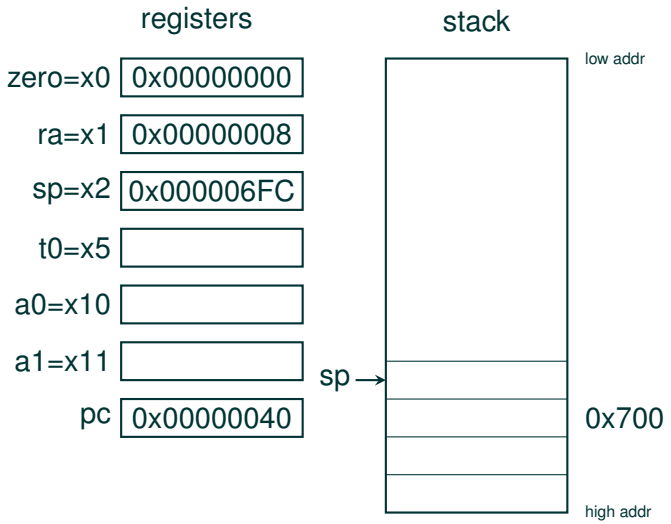
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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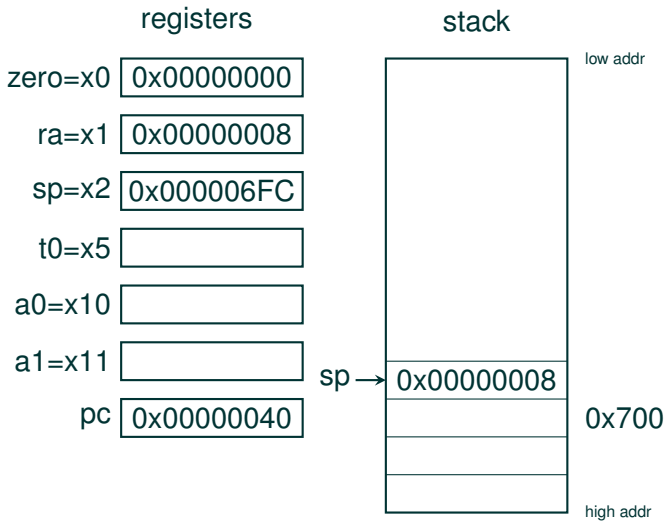
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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    LW ra, 0(sp)
    ADDI sp, sp, 4
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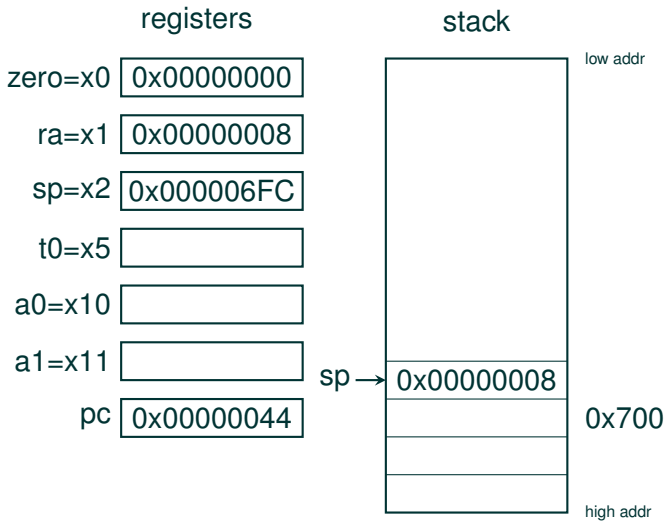

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    LW ra, 0(sp)
    ADDI sp, sp, 4
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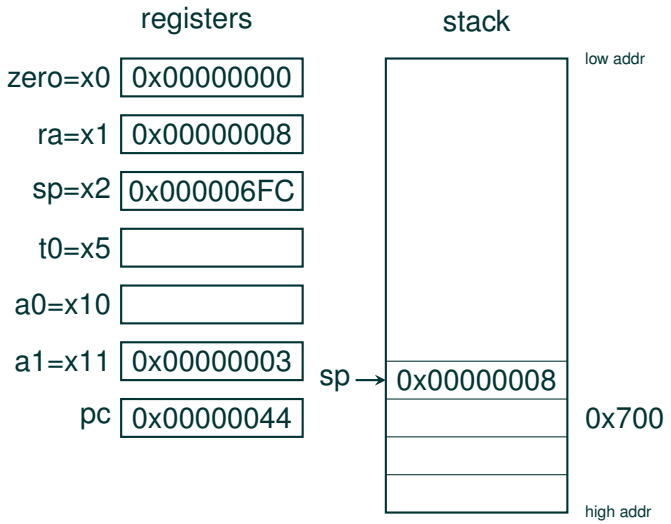
```



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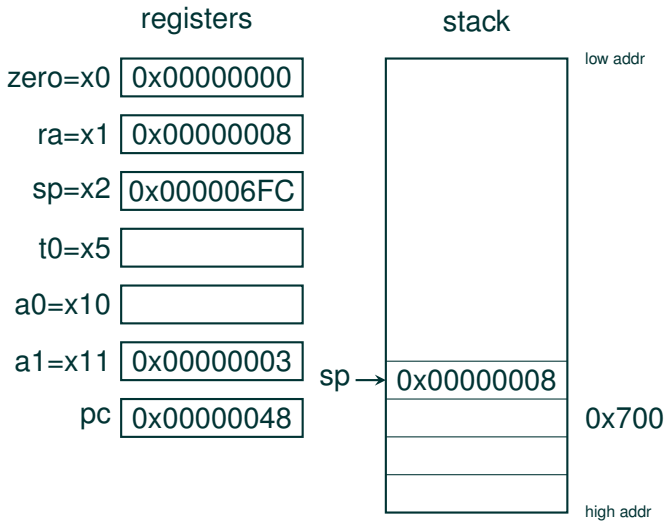

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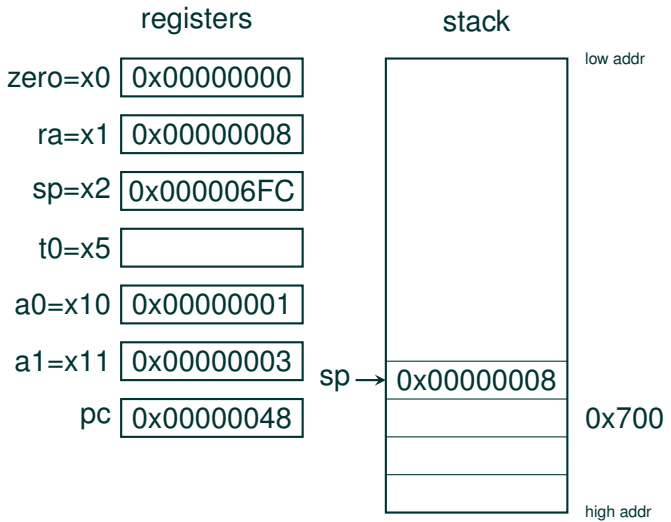
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



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    LW ra, 0(sp)
    ADDI sp, sp, 4
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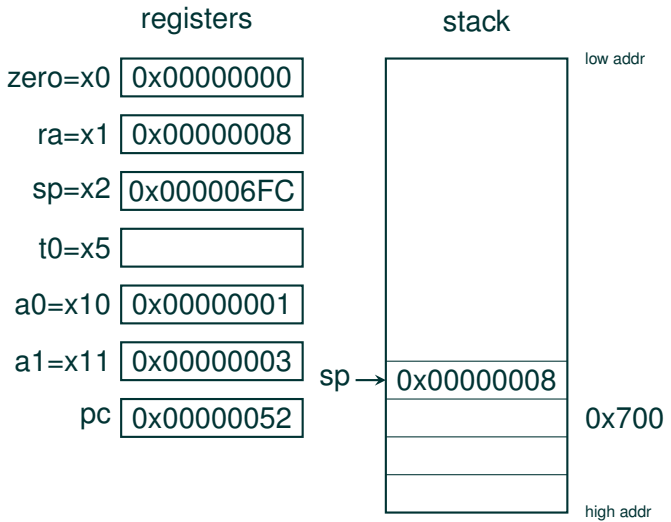
```



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    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
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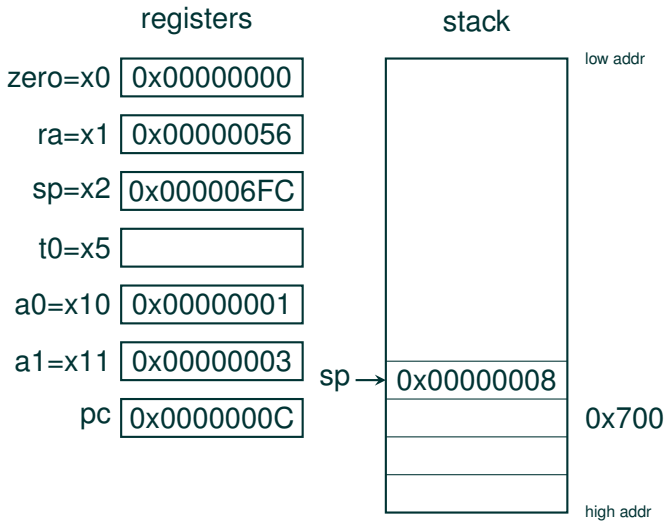
```



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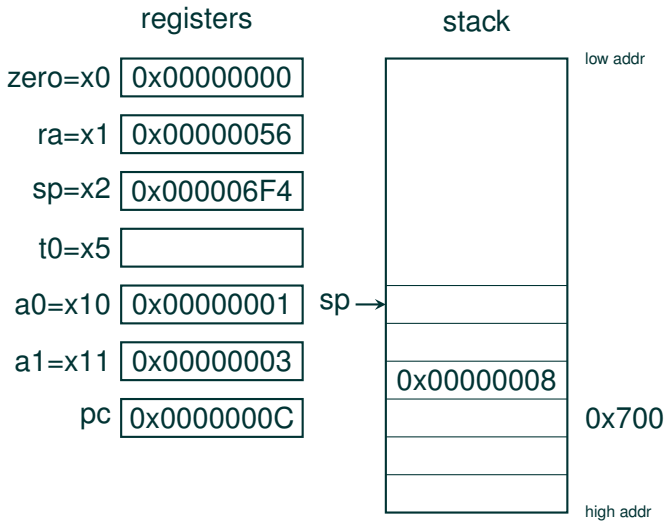
main:
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

```
_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
    ADD a0, a0, a1
arith_series_return:
    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
main:
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
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    JAL ra, arith_series
    LW ra, 0(sp)
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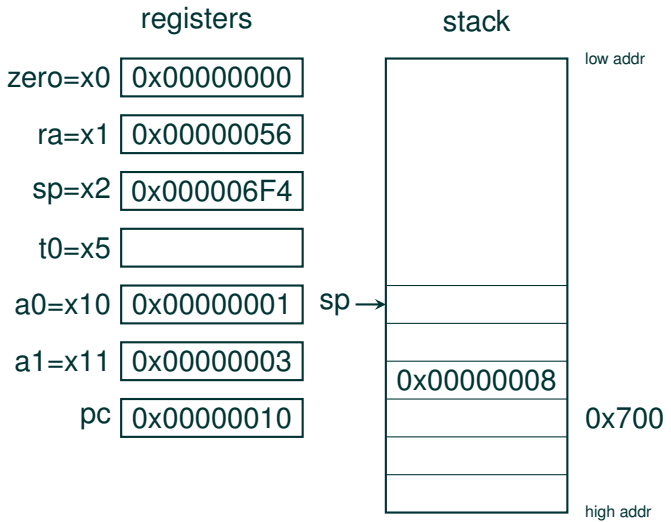

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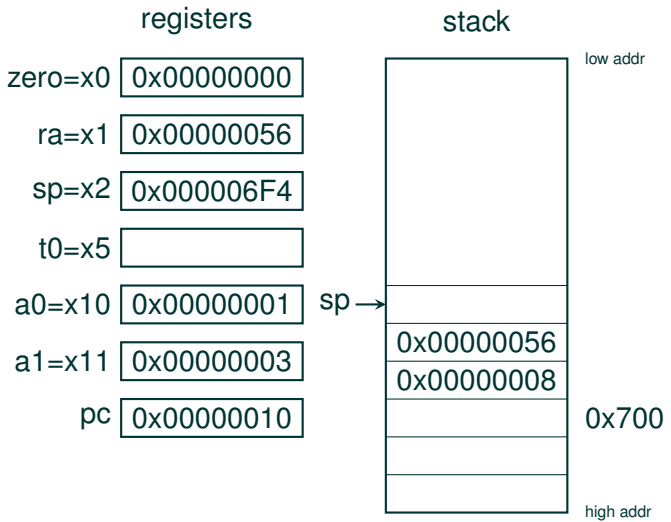

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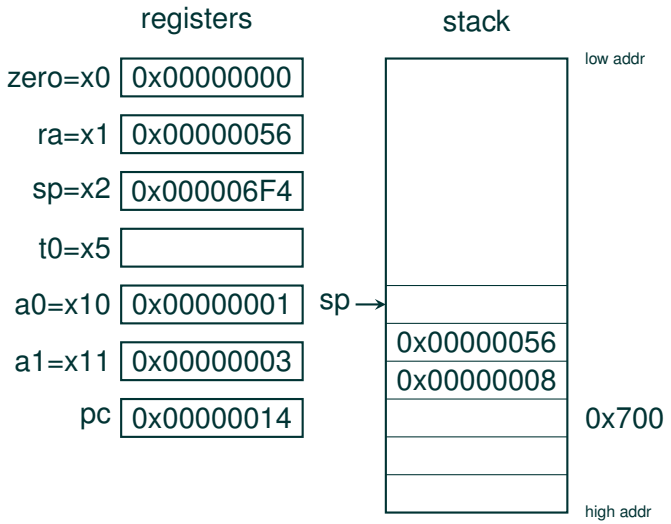

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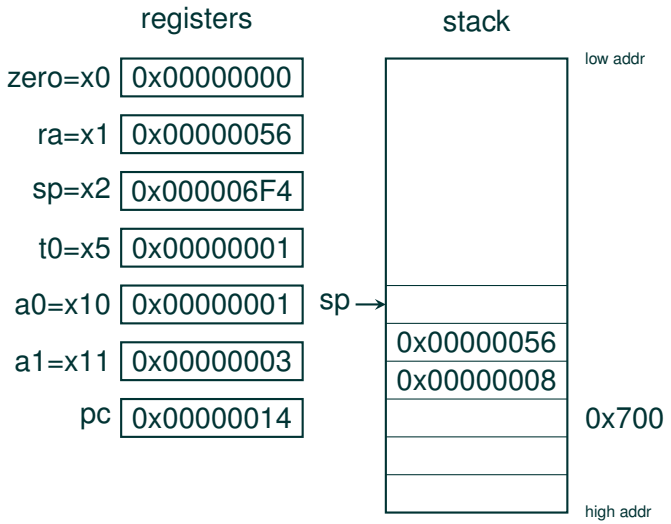

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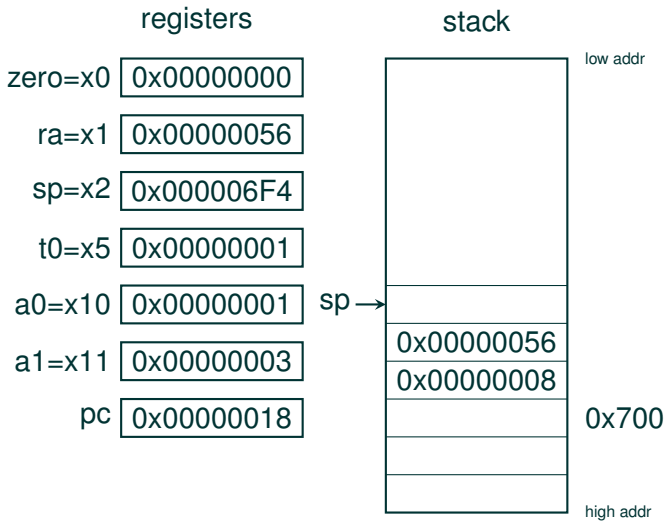

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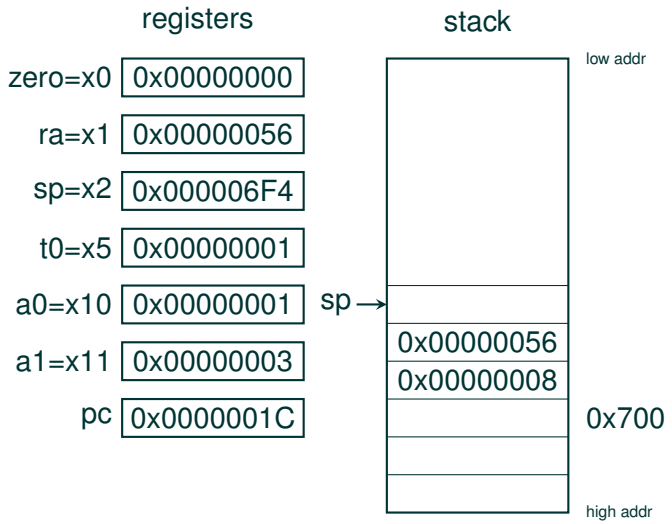

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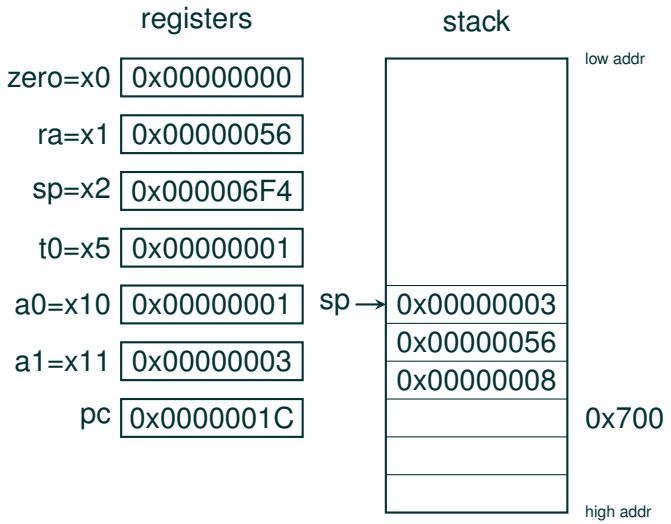

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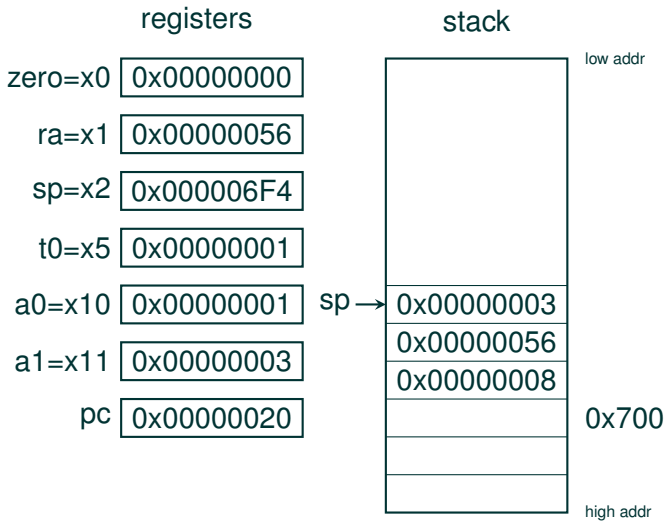

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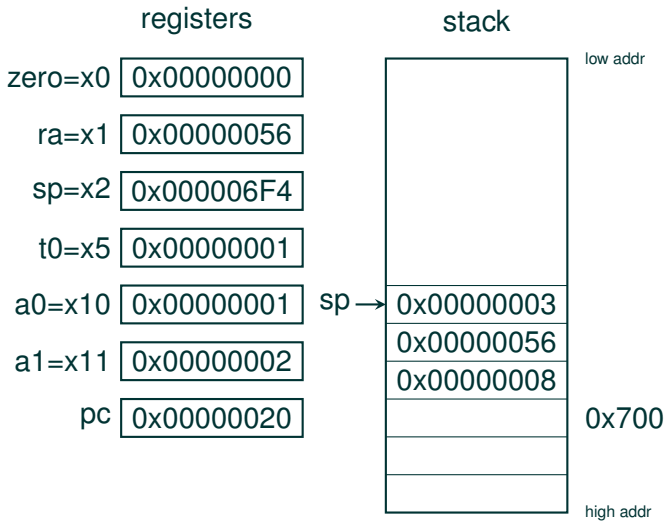

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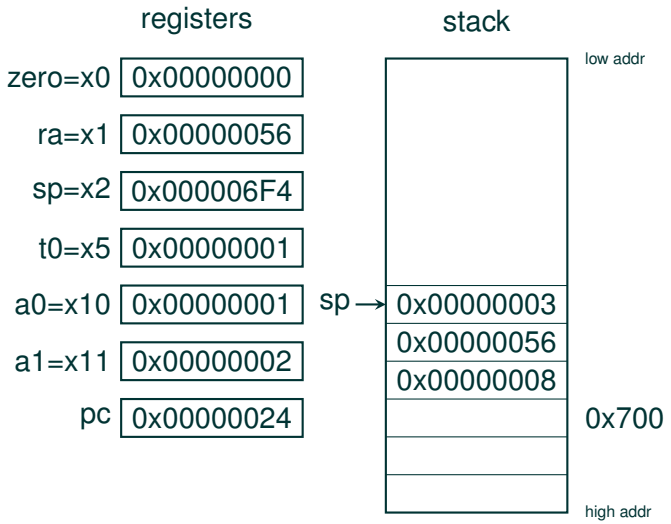

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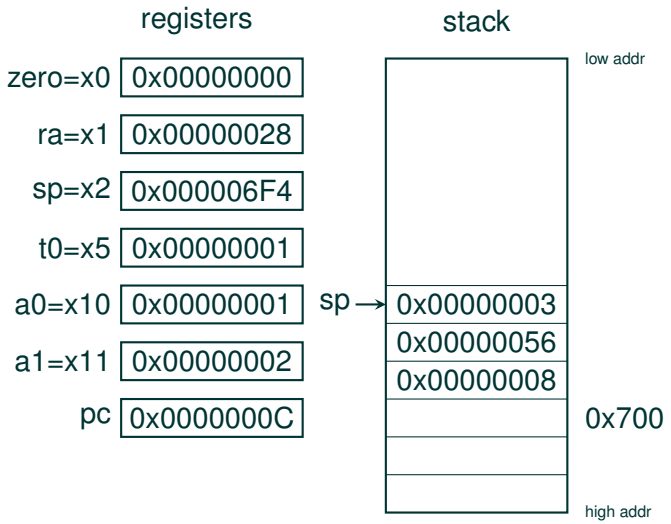

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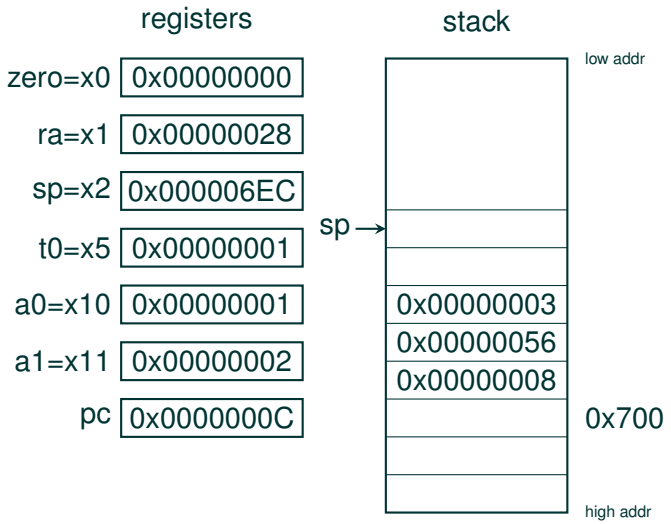

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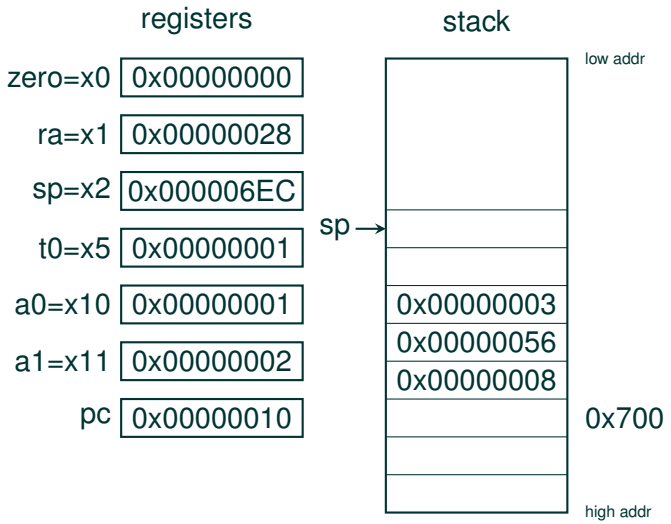

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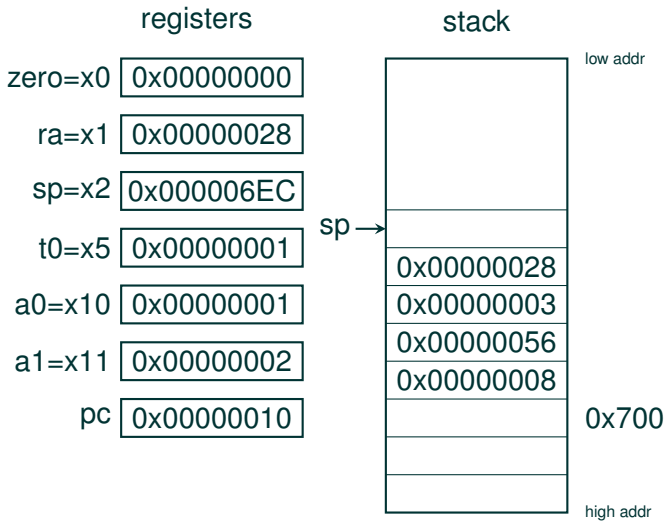

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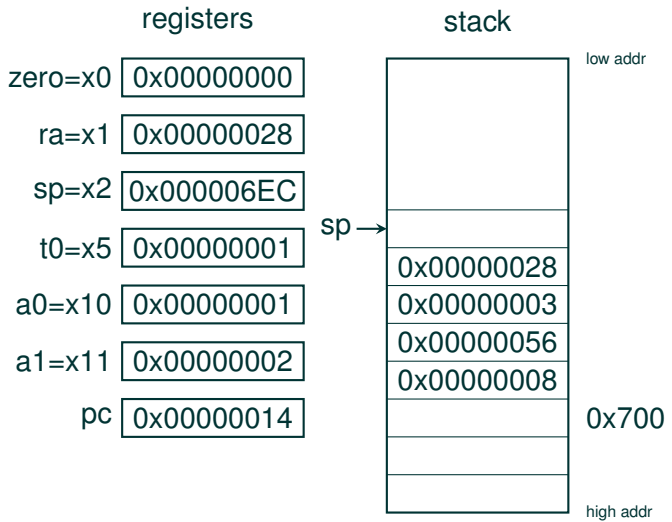

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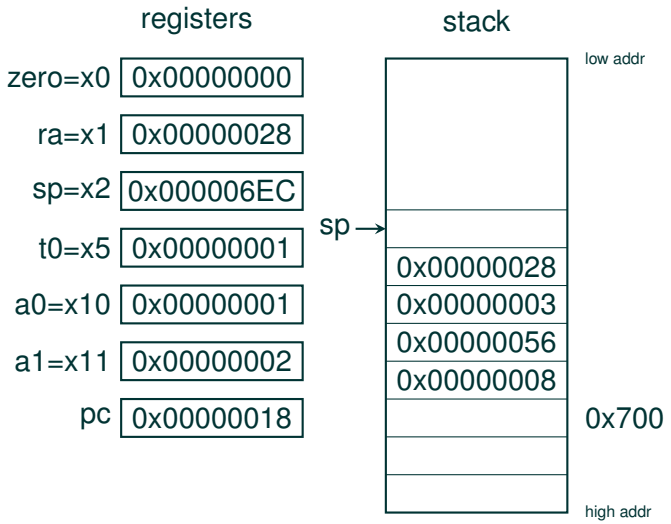

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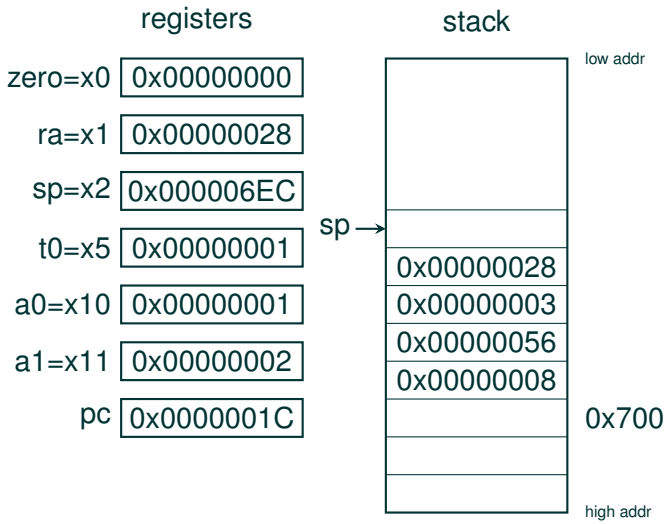

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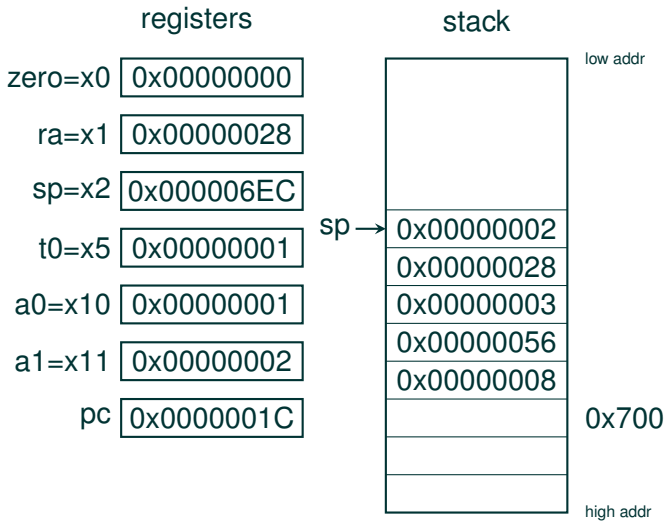

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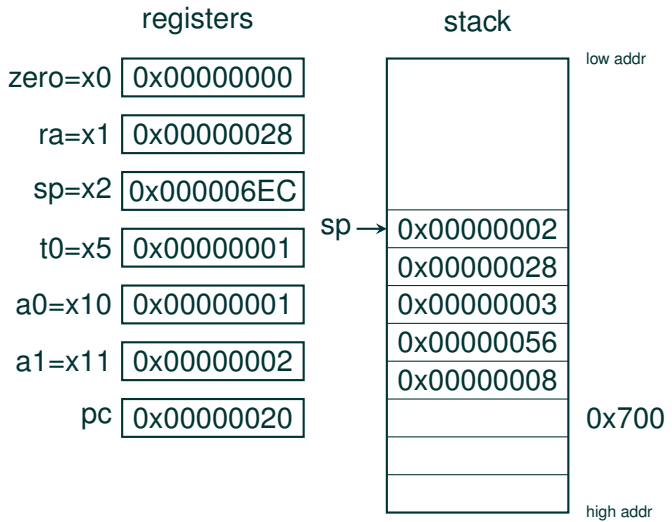
```



Recursive call on a stack

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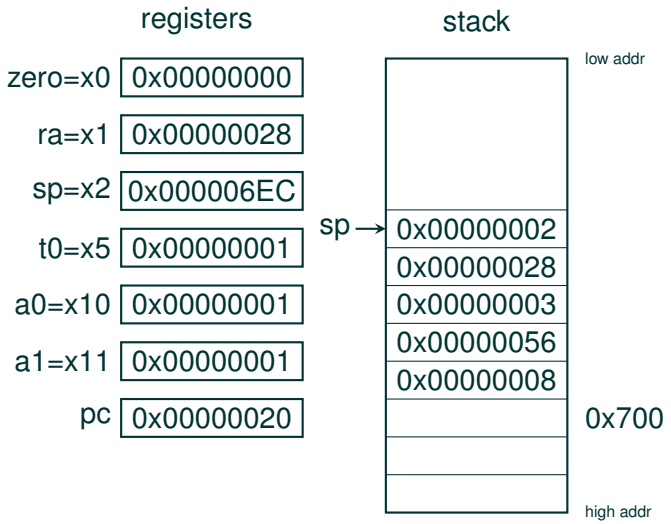
_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
    ADD a0, a0, a1
arith_series_return:
    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
main:
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



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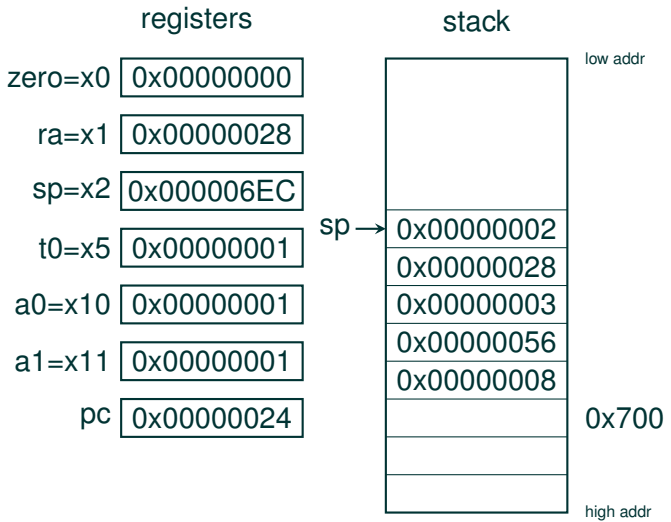

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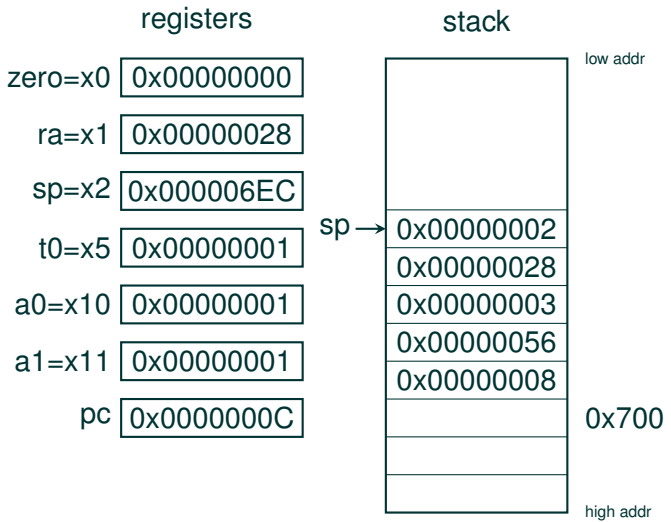

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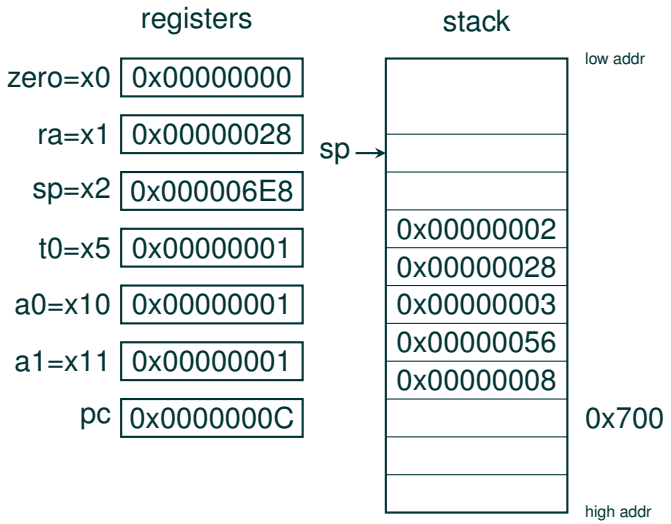

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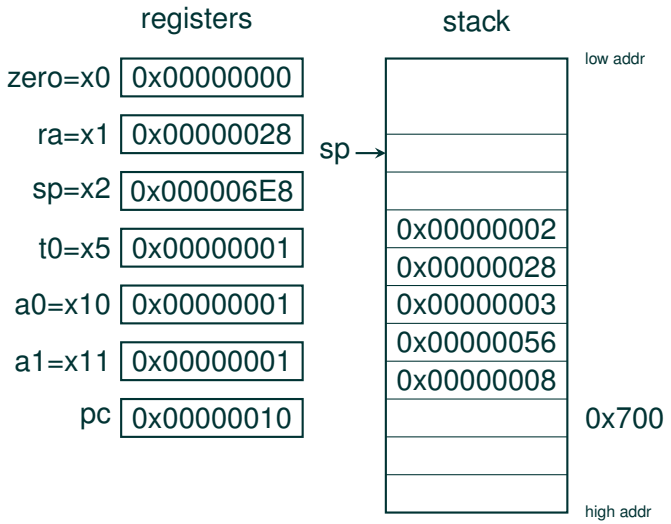

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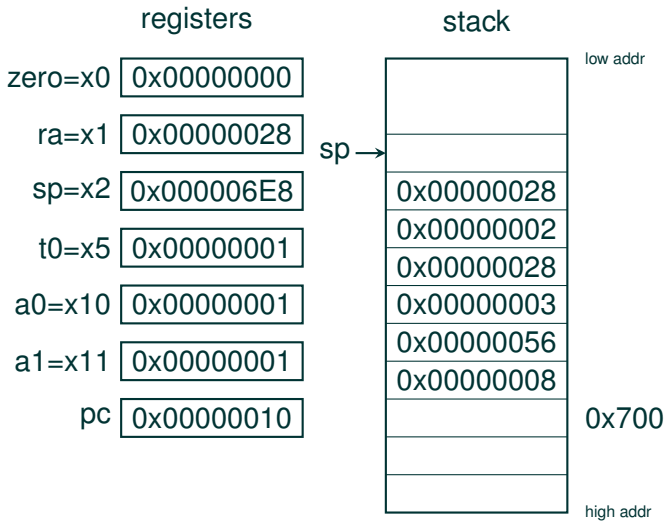

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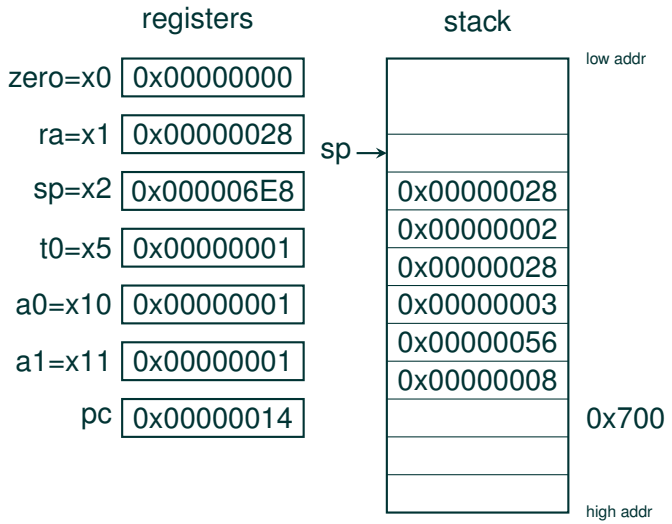

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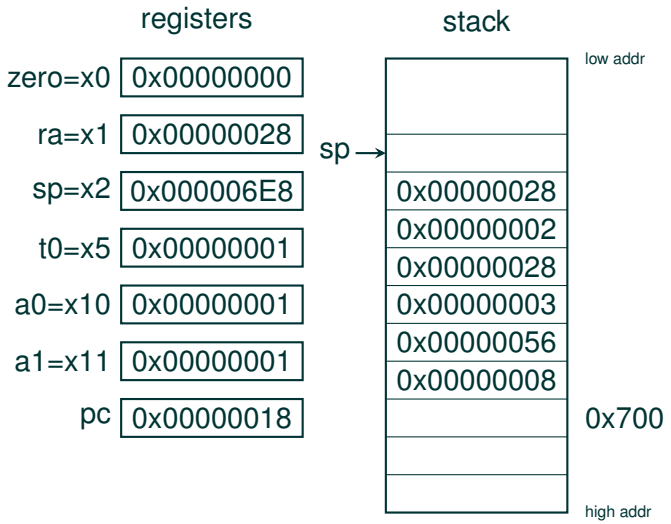

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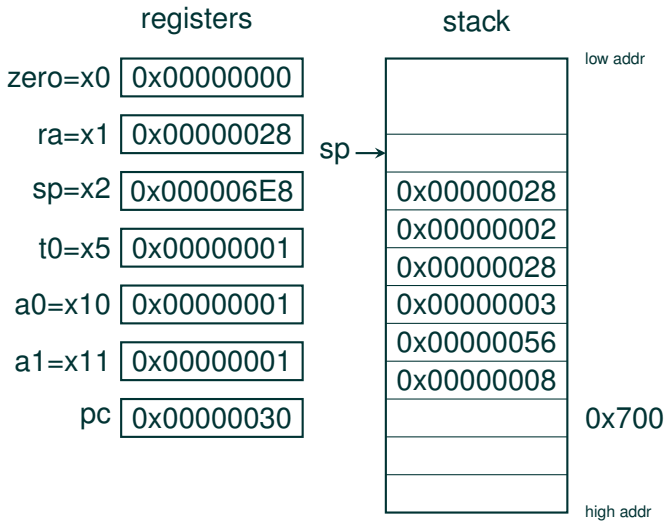

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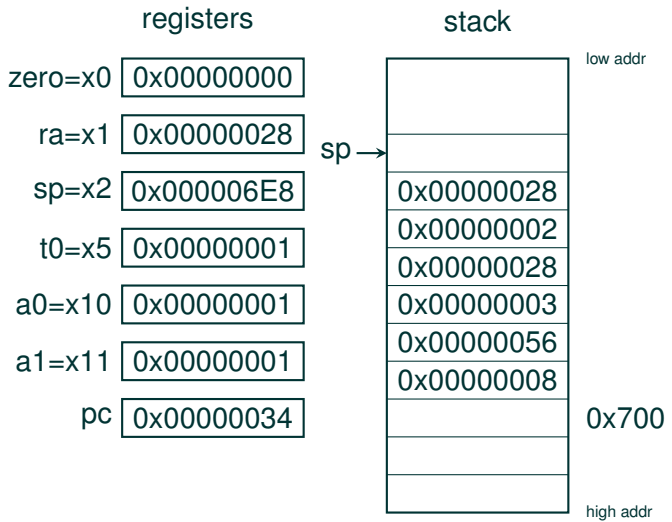

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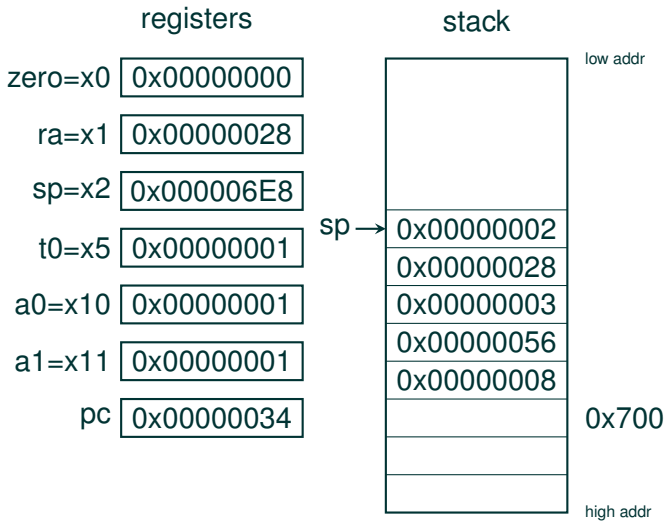

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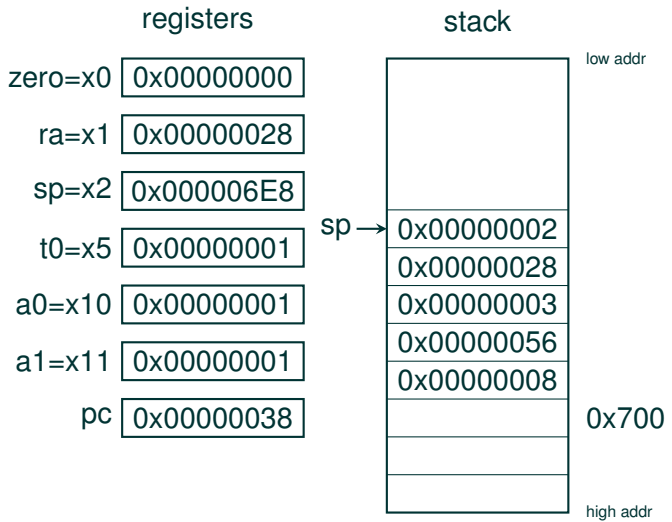

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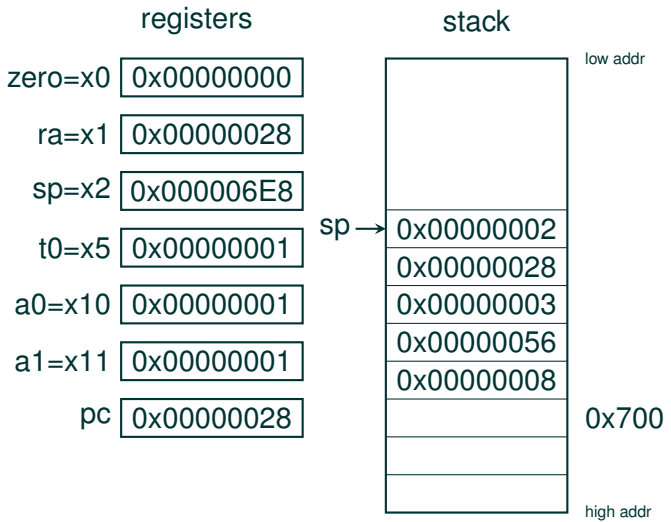

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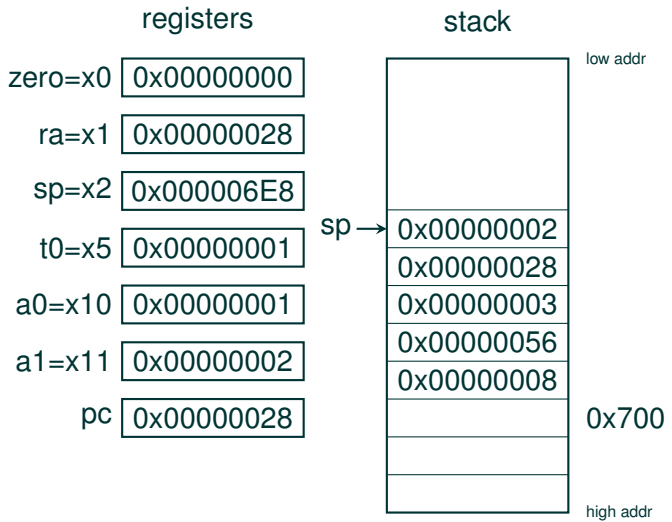

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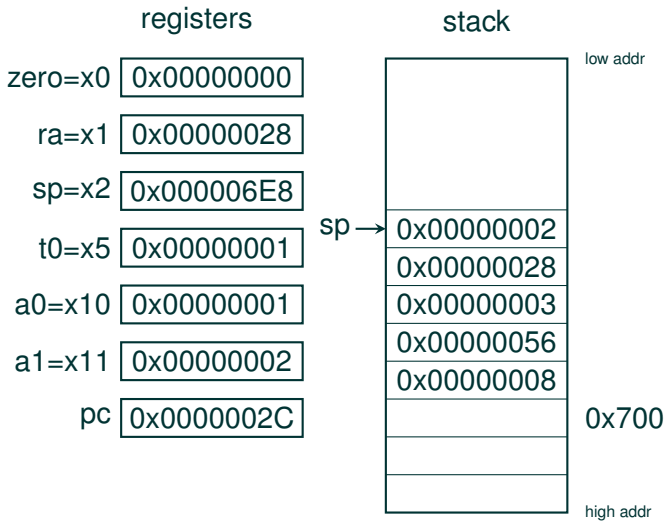

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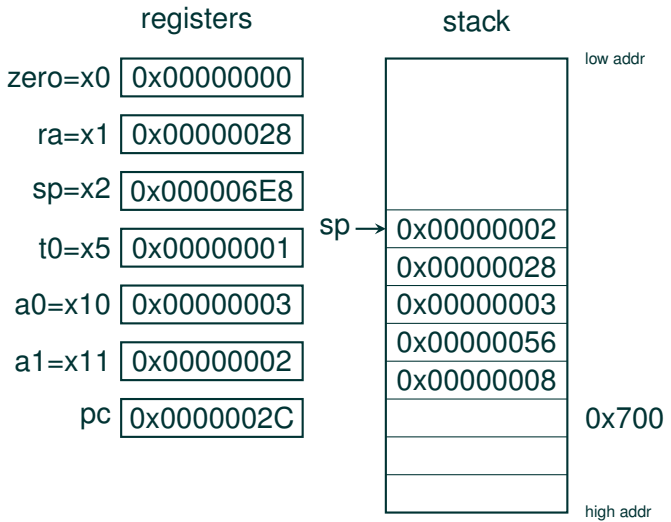

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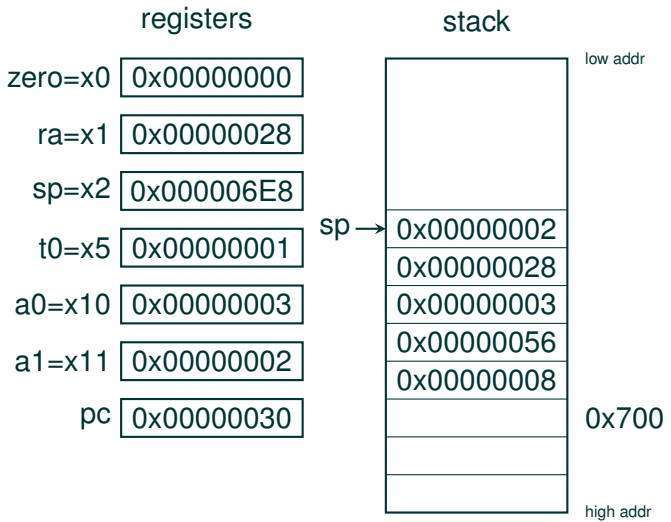

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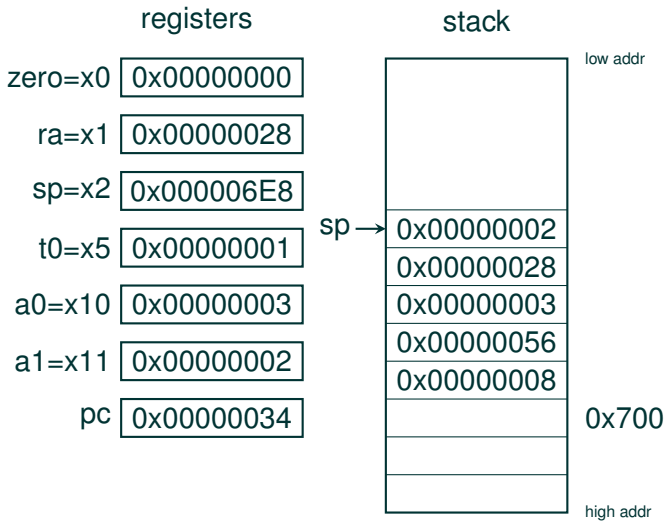

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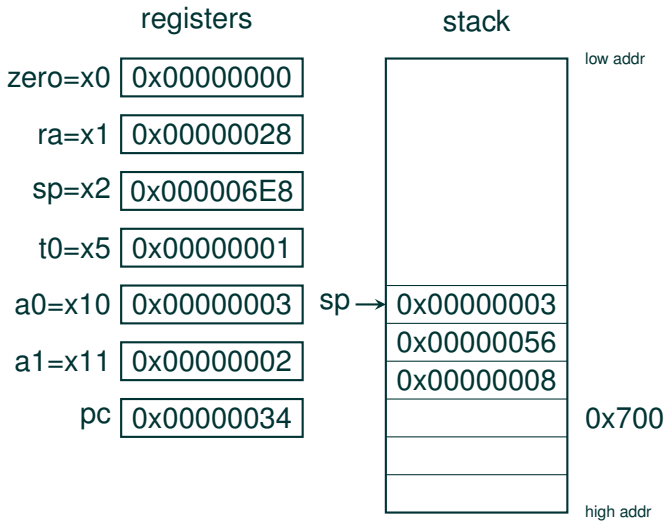

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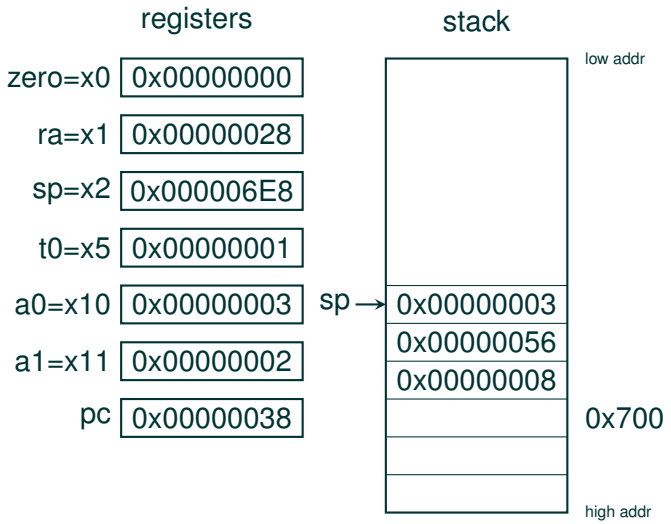
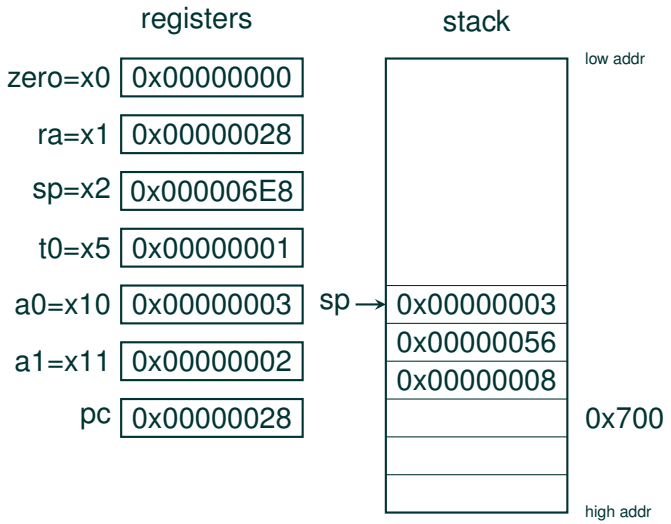
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
    ADD a0, a0, a1
arith_series_return:
    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
main:
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

```
_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
    ADD a0, a0, a1
arith_series_return:
    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
main:
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
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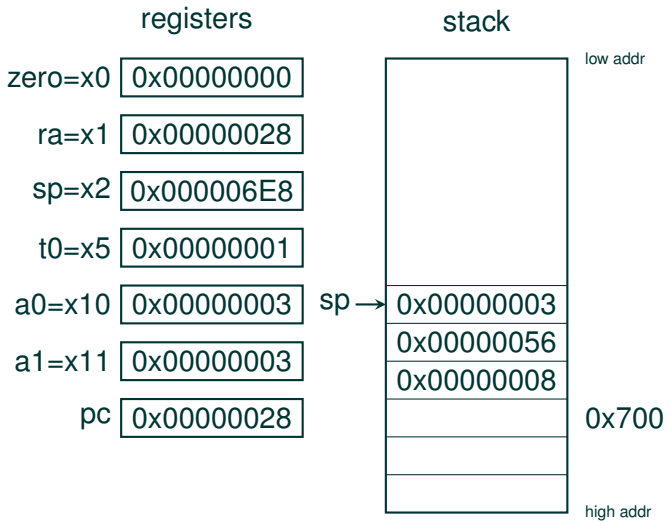
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
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    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
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    SW ra, 0(sp)
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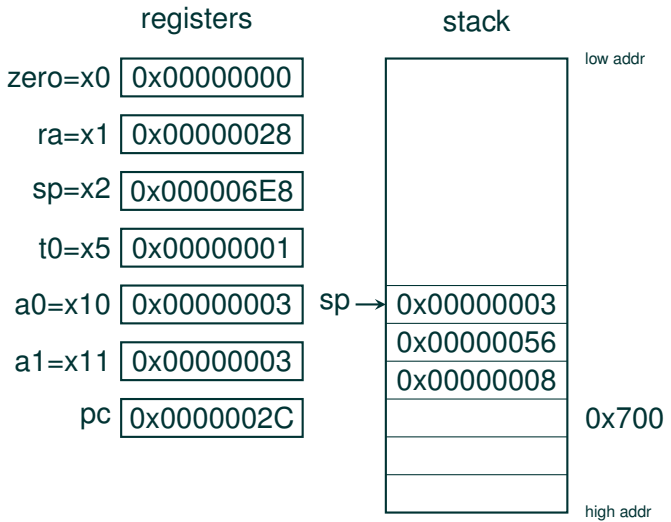
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
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arith_series:
    ADDI sp, sp, -8
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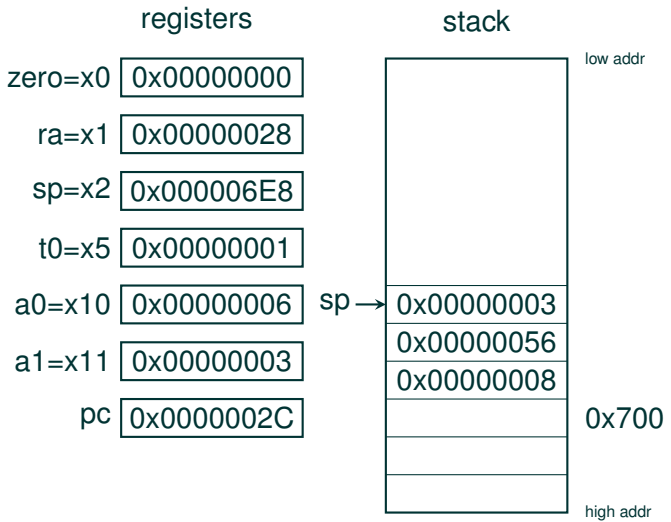
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
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    ADDI a1, zero, 3
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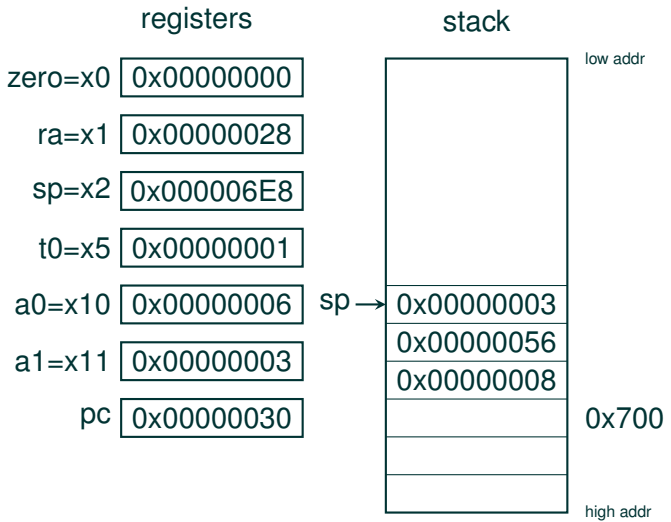
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
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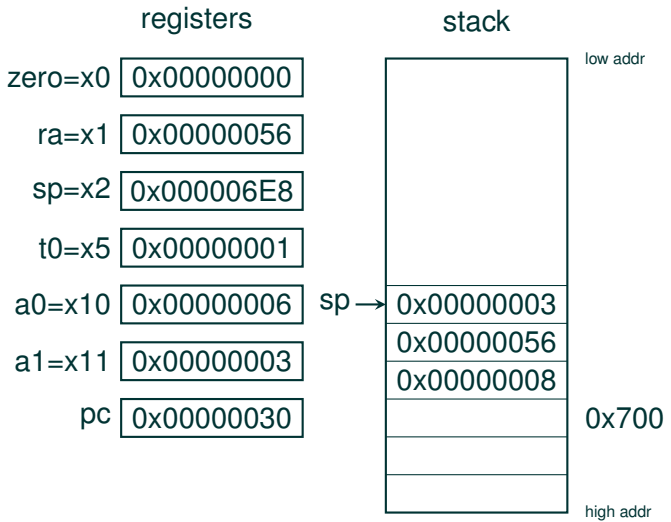
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
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    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
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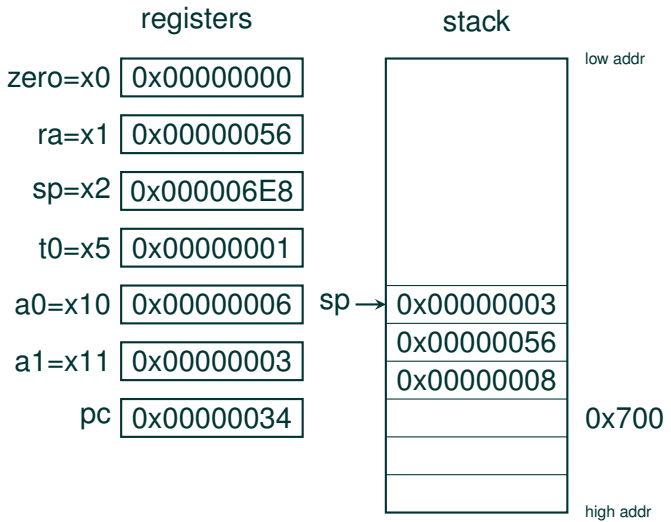
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

```
_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
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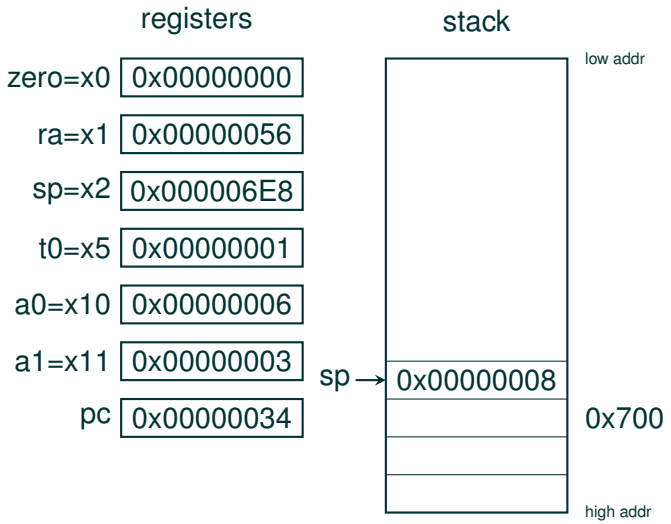
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
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    SW a1, 0(sp)
    ADDI a1, a1, -1
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    ADDI sp, sp, 8
    JALR zero, 0(ra)
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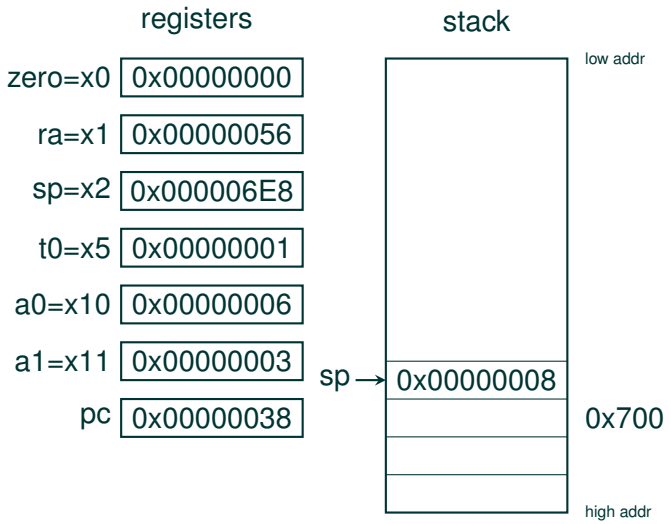
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
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    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
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arith_series_return:
    LW ra, 4(sp)
    ADDI sp, sp, 8
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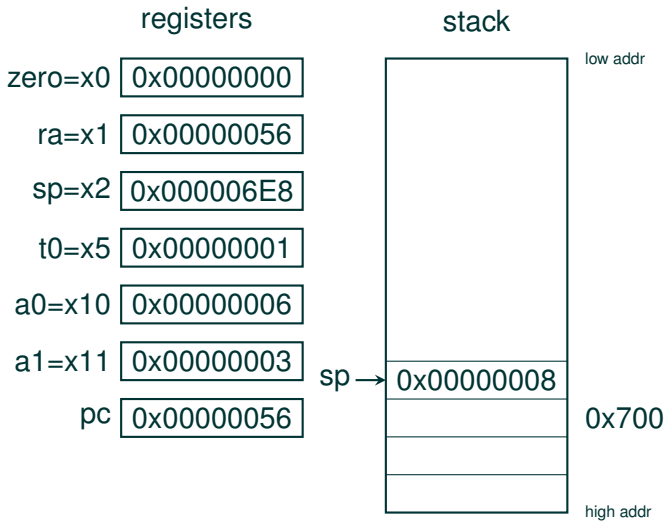
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

```
_start:
    ADDI sp, zero, 0x700
    JAL ra, main
    EBREAK
arith_series:
    ADDI sp, sp, -8
    SW ra, 4(sp)
    ADDI t0, zero, 1
    BGE t0, a1, arith_series_return
    SW a1, 0(sp)
    ADDI a1, a1, -1
    JAL ra, arith_series
    LW a1, 0(sp)
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    LW ra, 4(sp)
    ADDI sp, sp, 8
    JALR zero, 0(ra)
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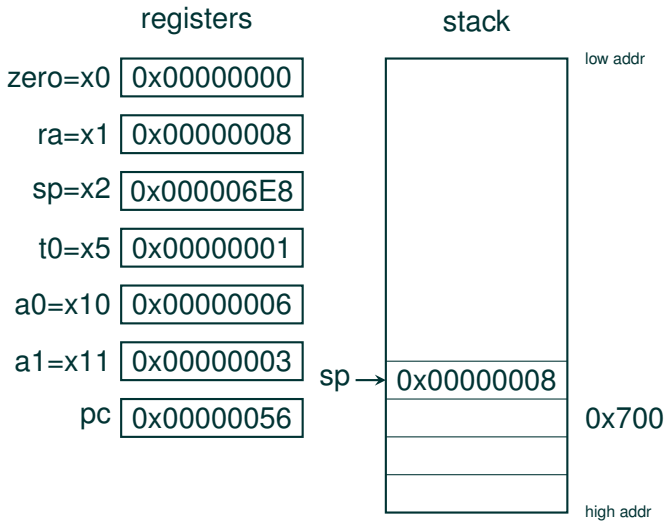
    ADDI sp, sp, -4
    SW ra, 0(sp)
    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
    JALR zero, 0(ra)
```



Recursive call on a stack

```
_start:
    ADDI sp, zero, 0x700
    JAL ra, main
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arith_series:
    ADDI sp, sp, -8
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    ADDI t0, zero, 1
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    SW a1, 0(sp)
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    ADDI sp, sp, 8
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    ADDI sp, sp, -4
    SW ra, 0(sp)
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    LW ra, 0(sp)
    ADDI sp, sp, 4
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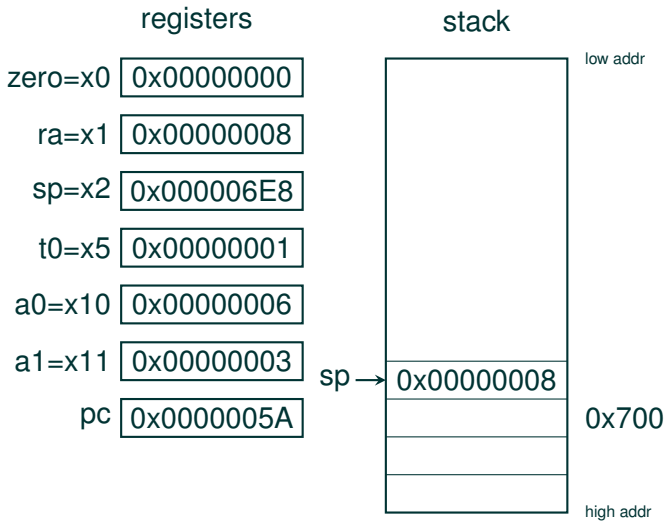
```



Recursive call on a stack

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_start:
    ADDI sp, zero, 0x700
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arith_series:
    ADDI sp, sp, -8
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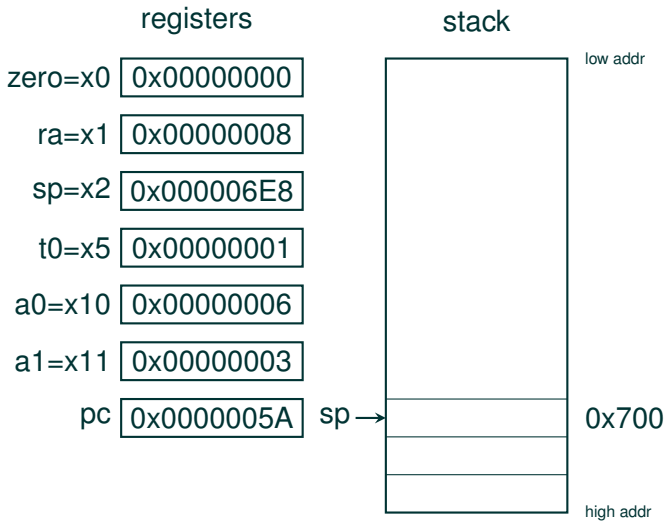
```



Recursive call on a stack

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_start:
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    ADDI sp, sp, 4
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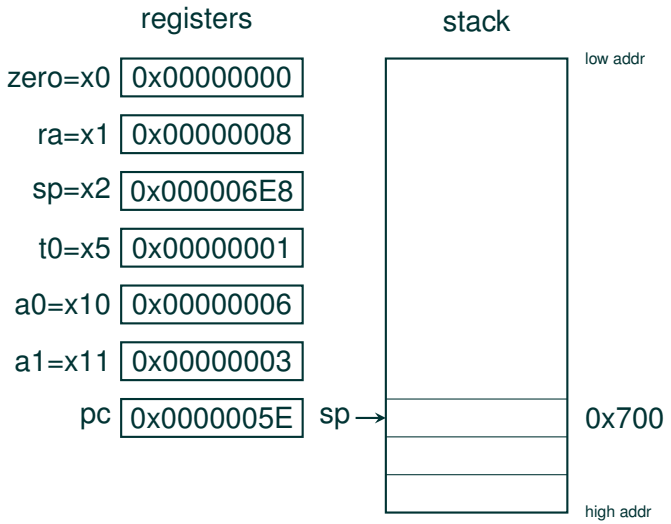
```



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    ADDI sp, zero, 0x700
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    ADDI a1, zero, 3
    ADDI a0, zero, 1
    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
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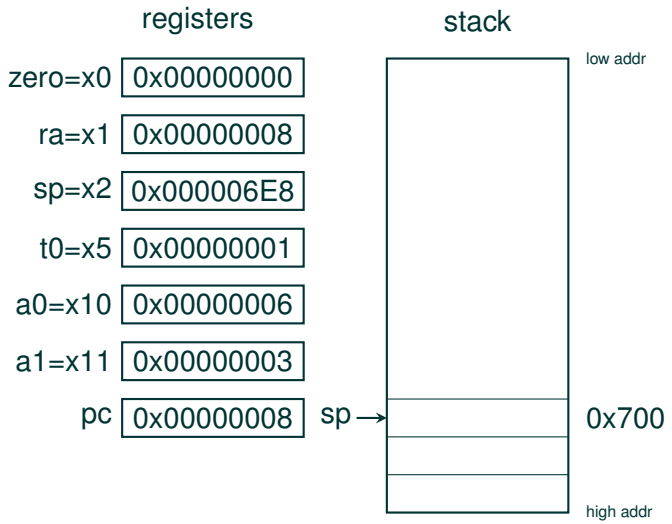
```



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    JAL ra, arith_series
    LW ra, 0(sp)
    ADDI sp, sp, 4
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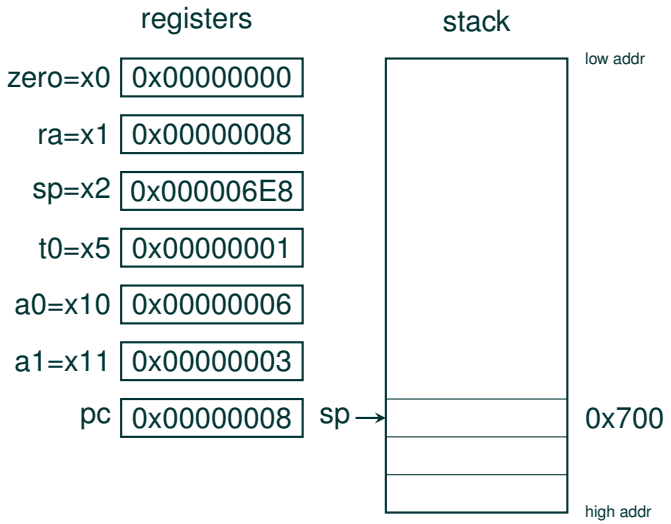
```



Buffer overflow

Buffer overflow

```
_start:
 ADDI sp,zero,0x700
 ADDI fp,zero,0x700
 JAL ra,main
 EBREAK
main:
 ADDI sp,sp,-8
 SW   ra,4(sp)
 SW   fp,0(sp)
 ADDI fp,sp,8
 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
 ADDI sp,sp,8
 JALR zero,0(ra)
```

Buffer overflow

```
_start:
 ADDI sp,zero,0x700
 ADDI fp,zero,0x700
 JAL ra,main
 EBREAK
main:
 ADDI sp,sp,-8
 SW   ra,4(sp)
 SW   fp,0(sp)
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 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
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Buffer overflow

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 ADDI fp,sp,8
 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
 ADDI sp,sp,8
 JALR zero,0(ra)
```

Buffer overflow

```
_start:
 ADDI sp,zero,0x700
 ADDI fp,zero,0x700
 JAL ra,main
 EBREAK
main:
 ADDI sp,sp,-8
 SW   ra,4(sp)
 SW   fp,0(sp)
 ADDI fp,sp,8
 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
 ADDI sp,sp,8
 JALR zero,0(ra)
```

Buffer overflow

```
_start:
 ADDI sp,zero,0x700
 ADDI fp,zero,0x700
 JAL ra,main
 EBREAK
main:
 ADDI sp,sp,-8
 SW   ra,4(sp)
 SW   fp,0(sp)
 ADDI fp,sp,8
 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
 ADDI sp,sp,8
 JALR zero,0(ra)
```

Buffer overflow

```
_start:
 ADDI sp,zero,0x700
 ADDI fp,zero,0x700
 JAL ra,main
 EBREAK
main:
 ADDI sp,sp,-8
 SW   ra,4(sp)
 SW   fp,0(sp)
 ADDI fp,sp,8
 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
 ADDI sp,sp,8
 JALR zero,0(ra)
```

Buffer overflow

```
_start:
 ADDI sp,zero,0x700
 ADDI fp,zero,0x700
 JAL ra,main
 EBREAK
main:
 ADDI sp,sp,-8
 SW   ra,4(sp)
 SW   fp,0(sp)
 ADDI fp,sp,8
 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
 ADDI sp,sp,8
 JALR zero,0(ra)
```

Buffer overflow

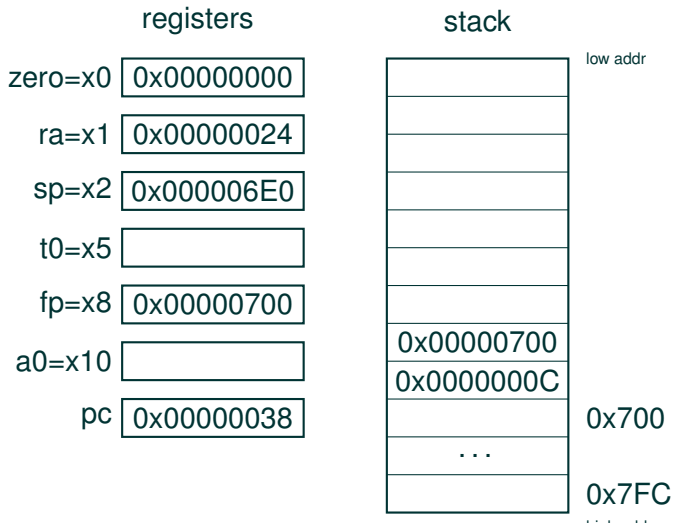
```
_start:
 ADDI sp,zero,0x700
 ADDI fp,zero,0x700
 JAL ra,main
 EBREAK
main:
 ADDI sp,sp,-8
 SW   ra,4(sp)
 SW   fp,0(sp)
 ADDI fp,sp,8
 JAL  ra,vuln
 LW   fp,0(sp)
 LW   ra,4(sp)
 ADDI sp,sp,8
 JALR zero,0(ra)
```

Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```

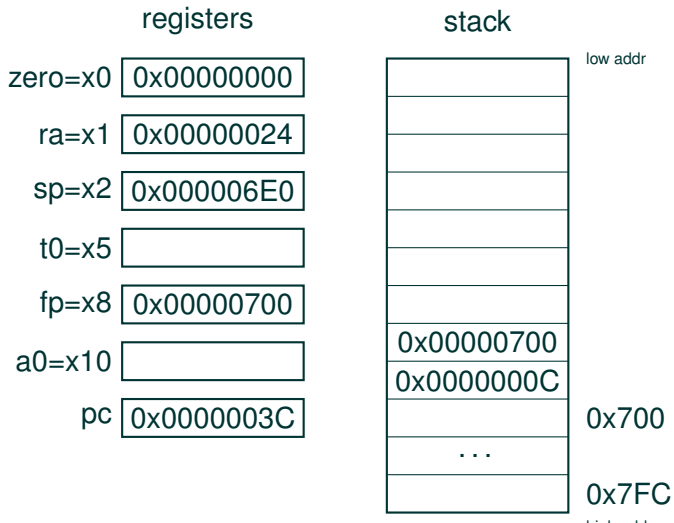
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



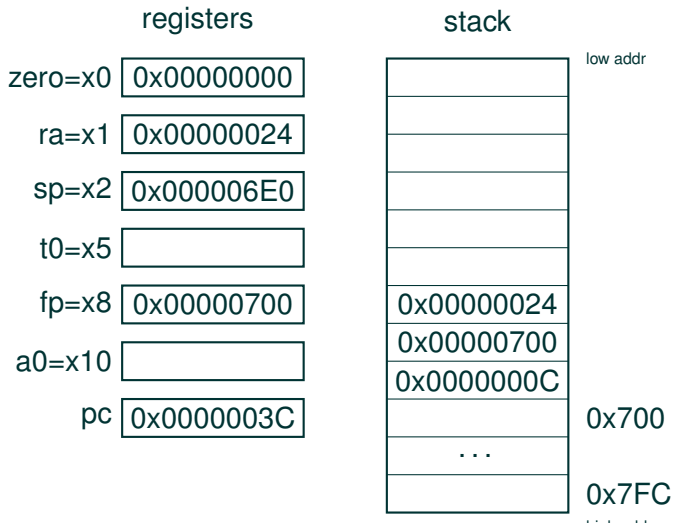
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



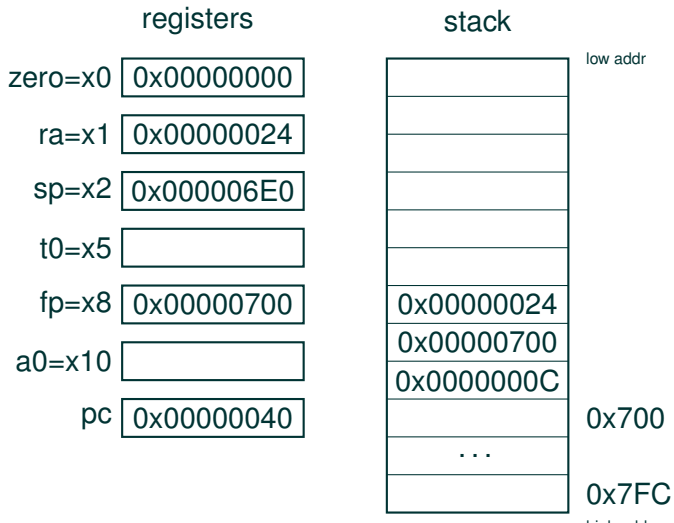
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



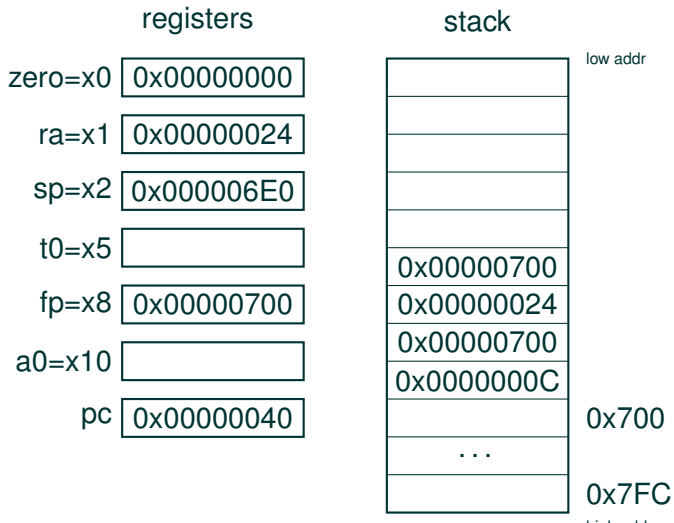
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



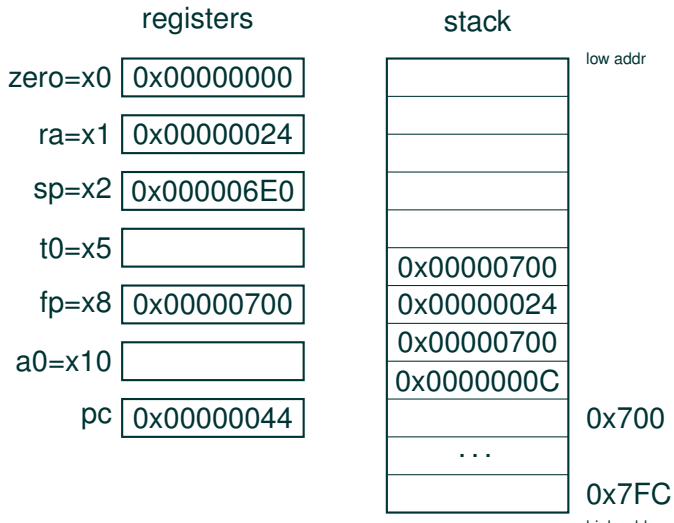
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



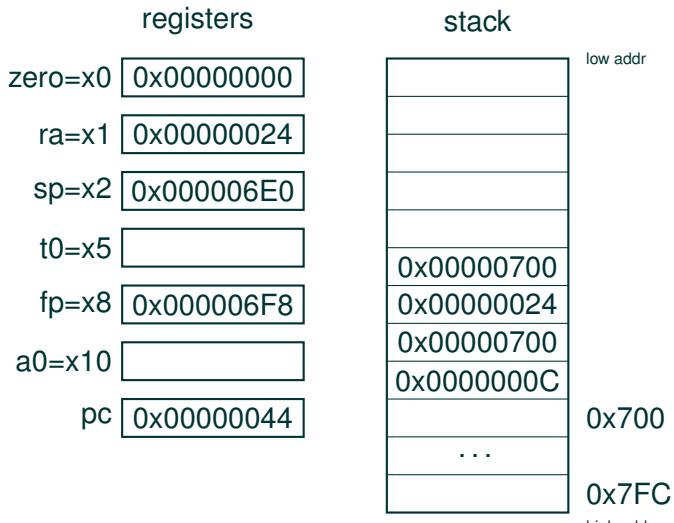
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



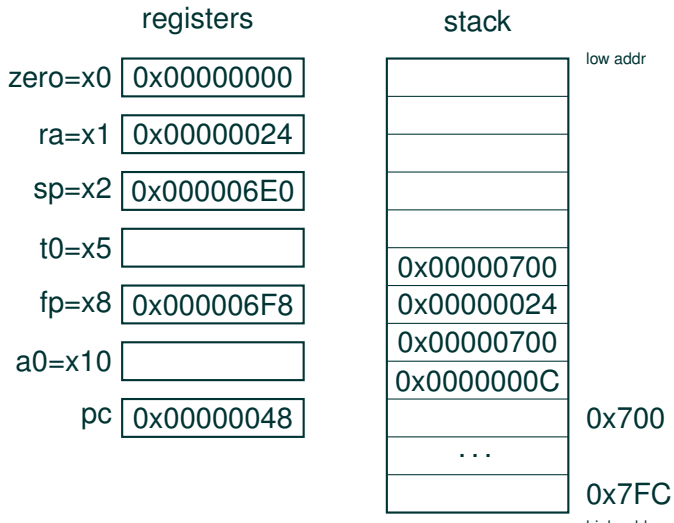
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



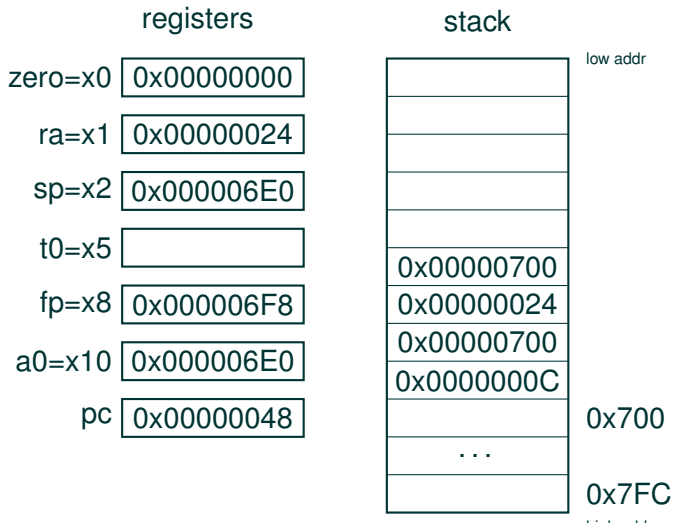
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



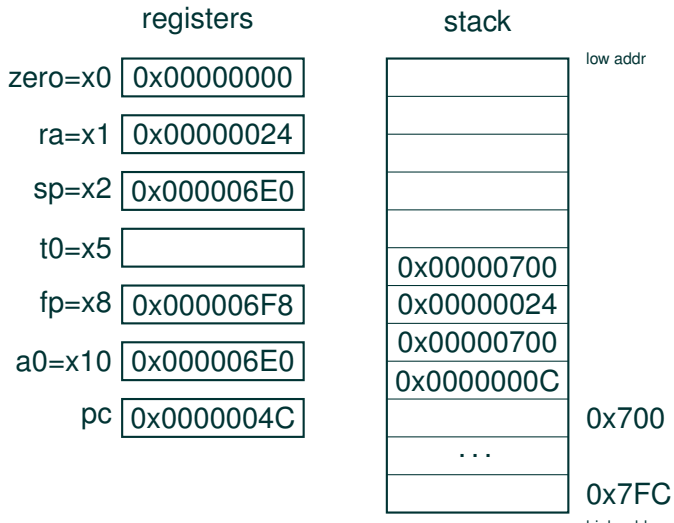
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



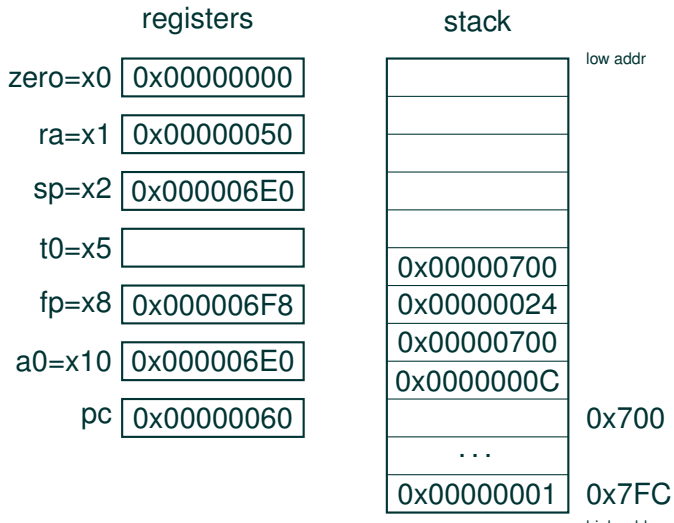
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



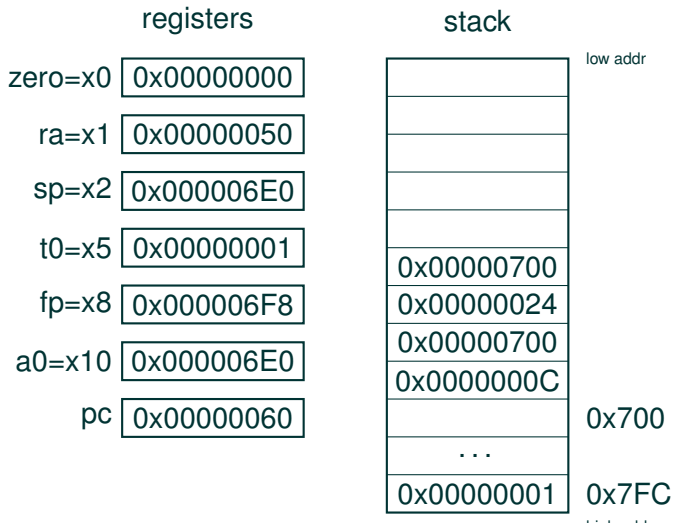
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



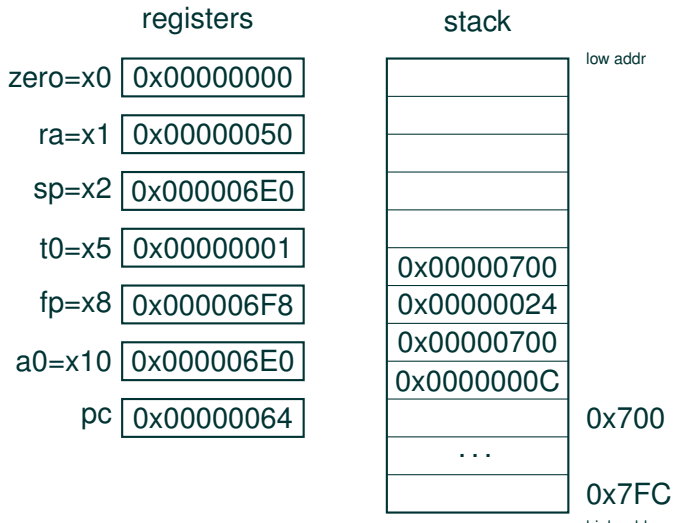
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



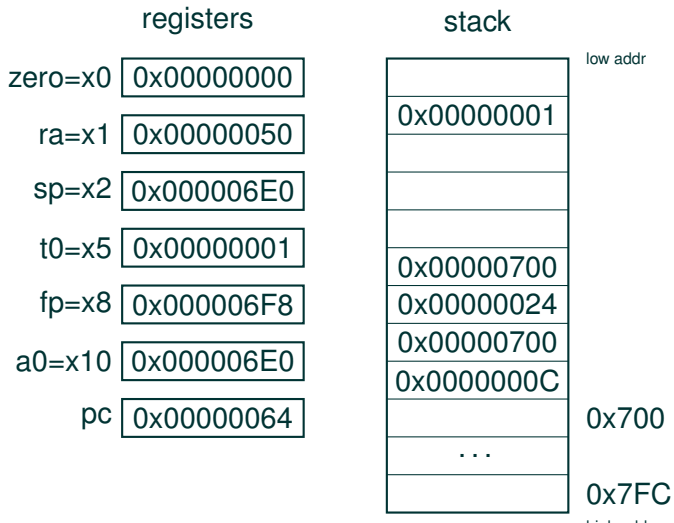
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



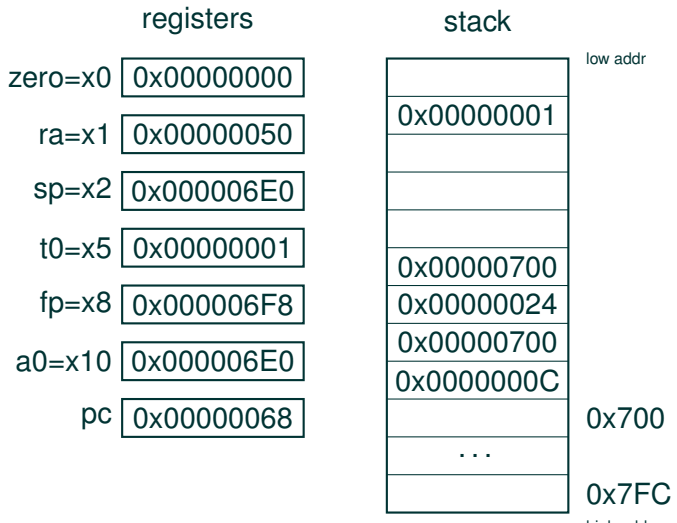
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



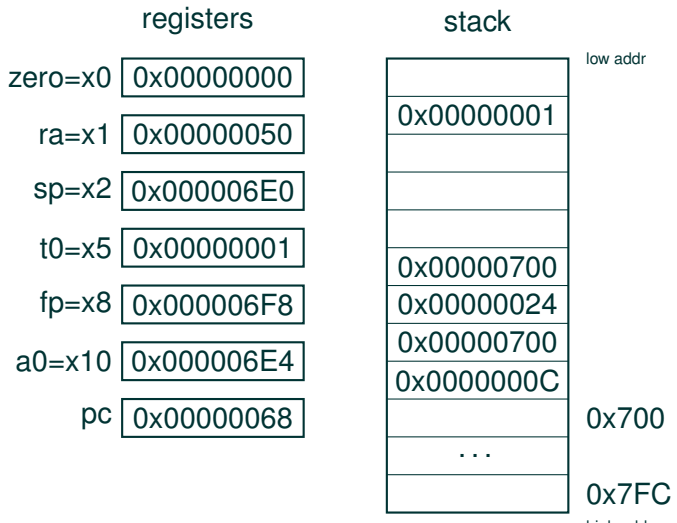
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



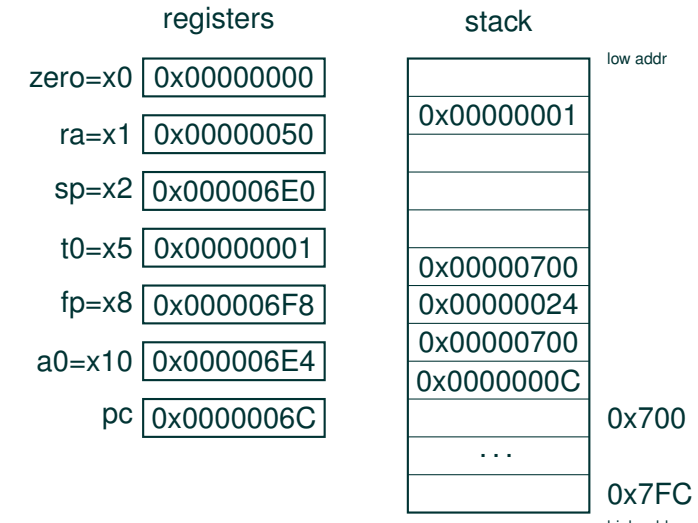
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



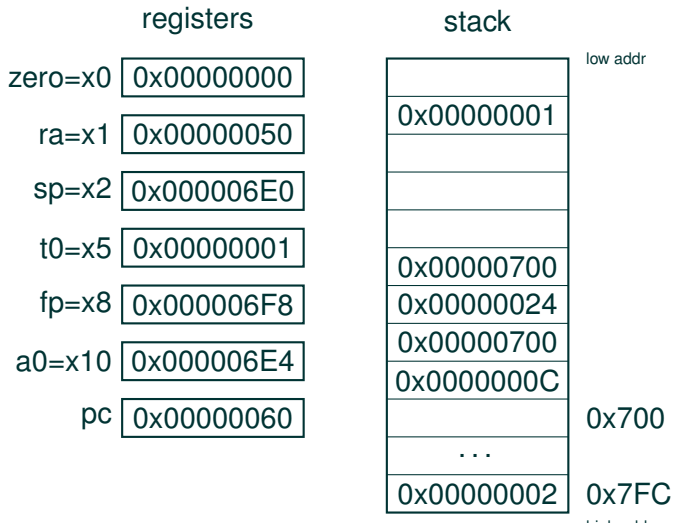
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



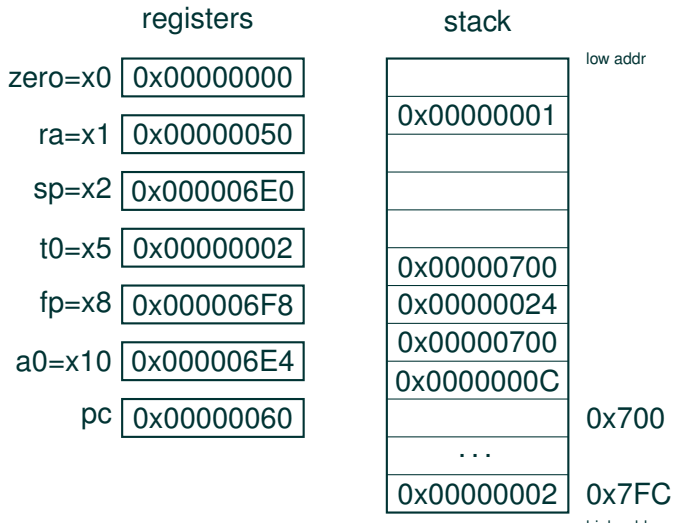
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



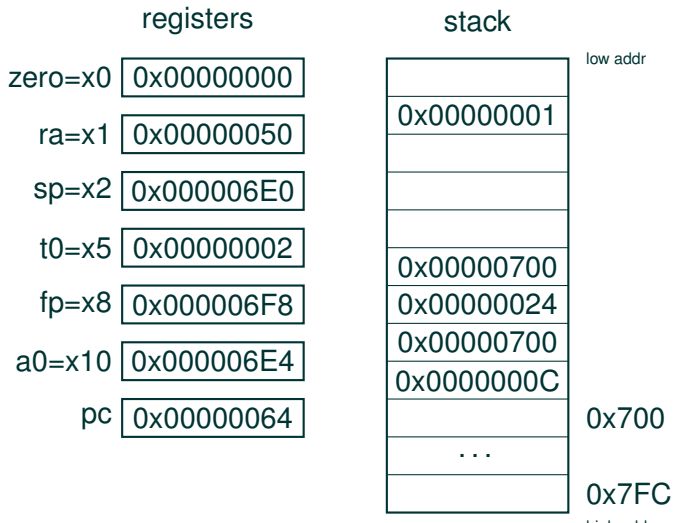
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```

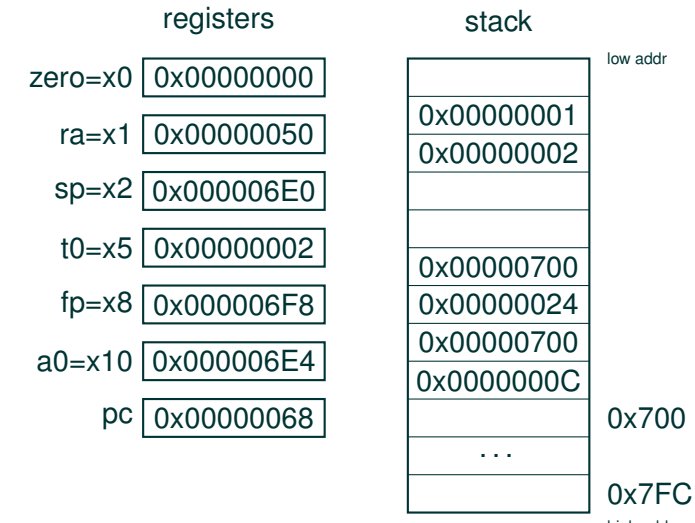


Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```

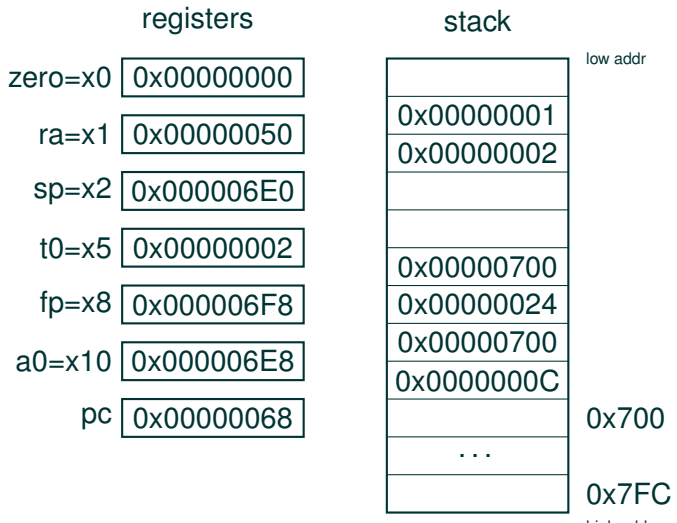
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



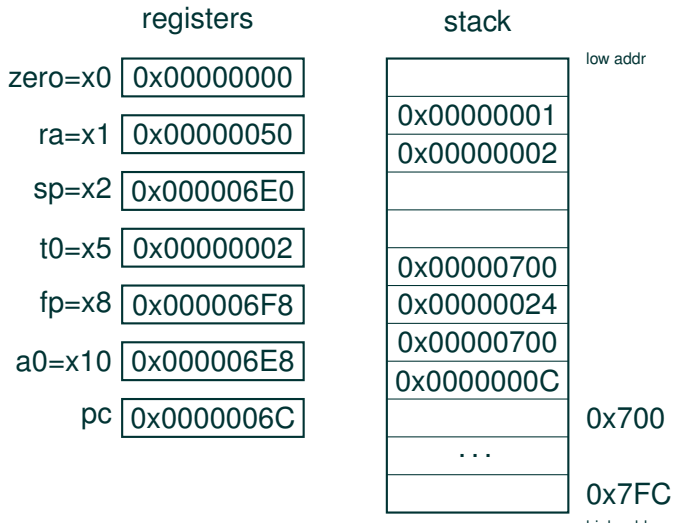
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



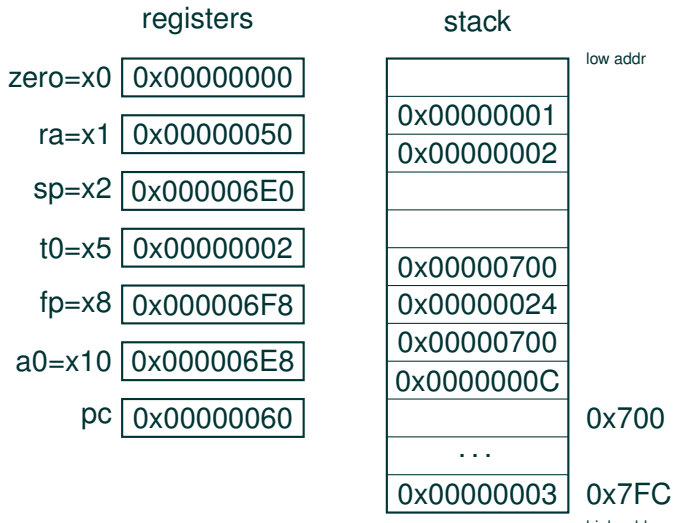
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



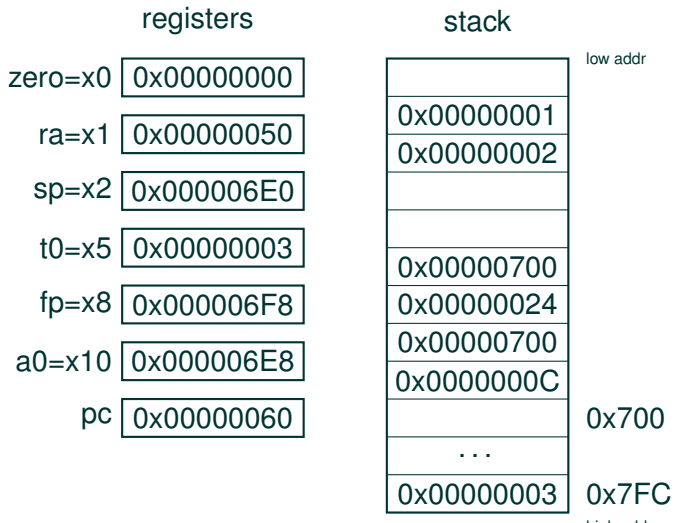
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
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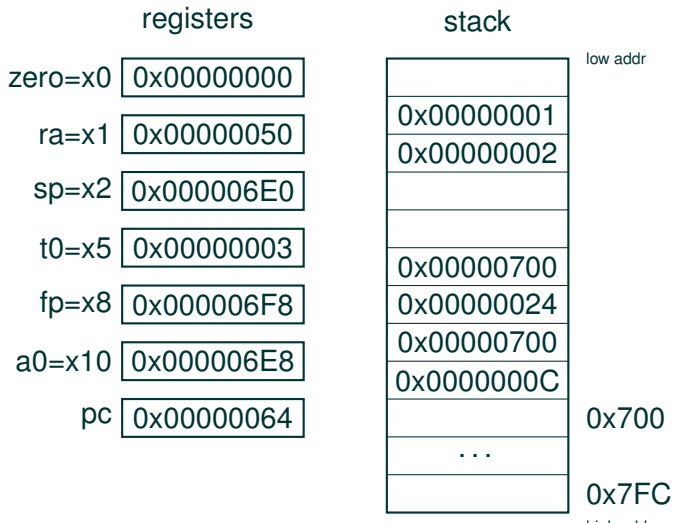
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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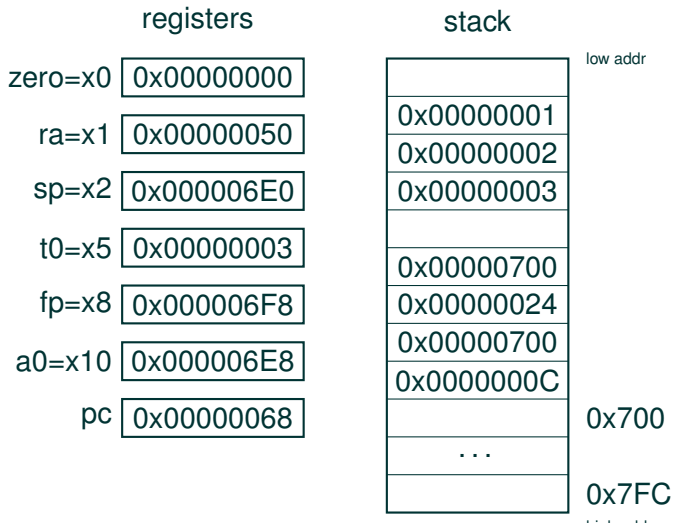
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```

Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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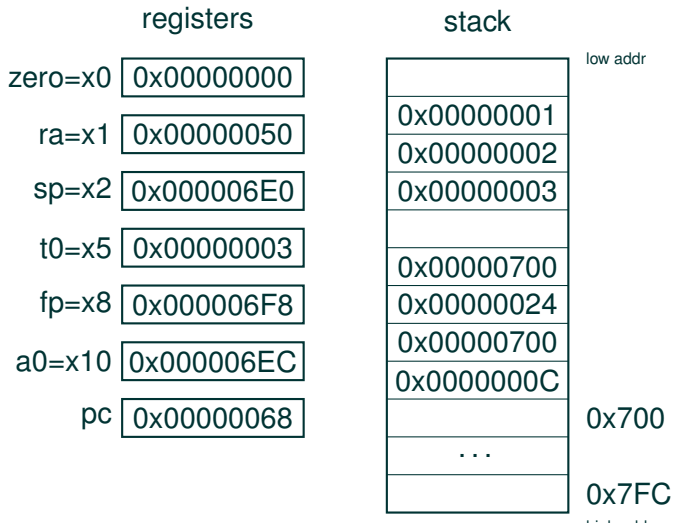
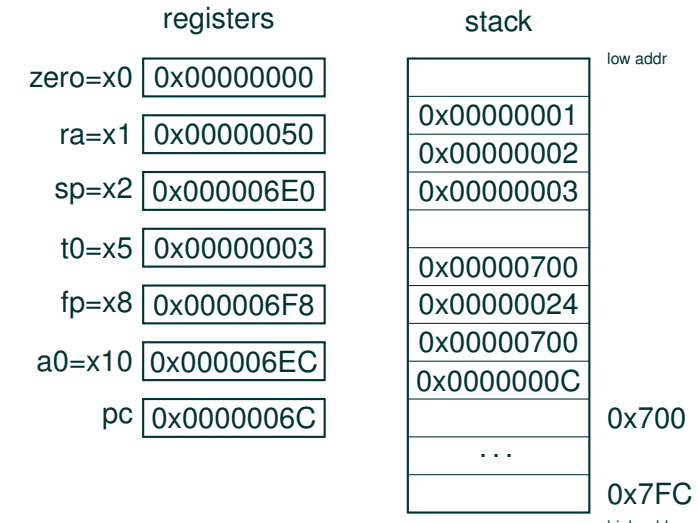
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



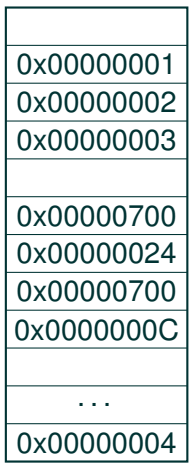
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```

registers

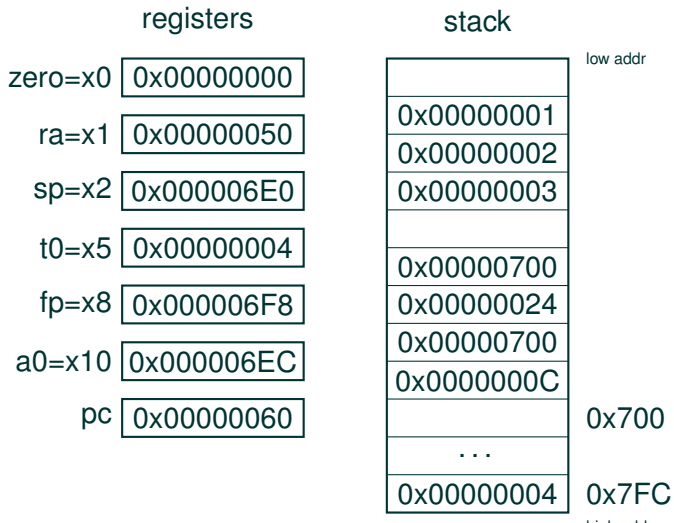
zero=x0	0x00000000
ra=x1	0x00000050
sp=x2	0x000006E0
t0=x5	0x00000003
fp=x8	0x000006F8
a0=x10	0x000006EC
pc	0x00000060

stack



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
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 JALR zero,0(ra)
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 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
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```

Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
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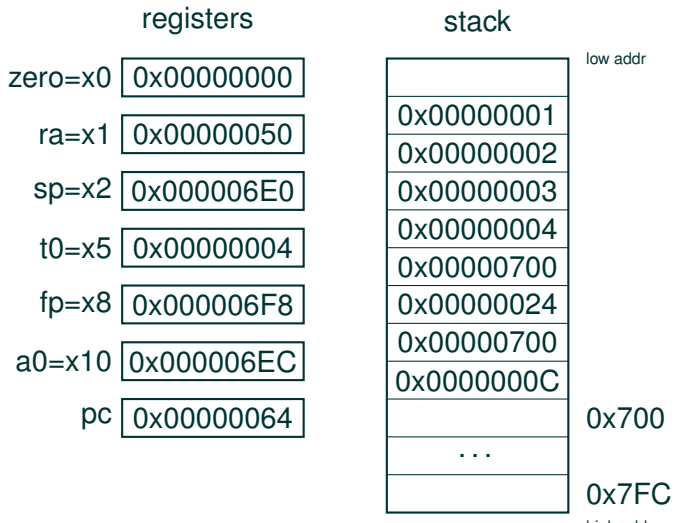
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
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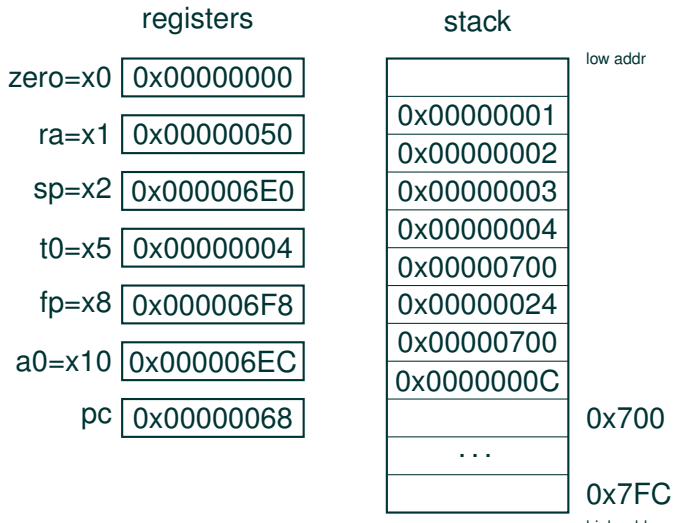
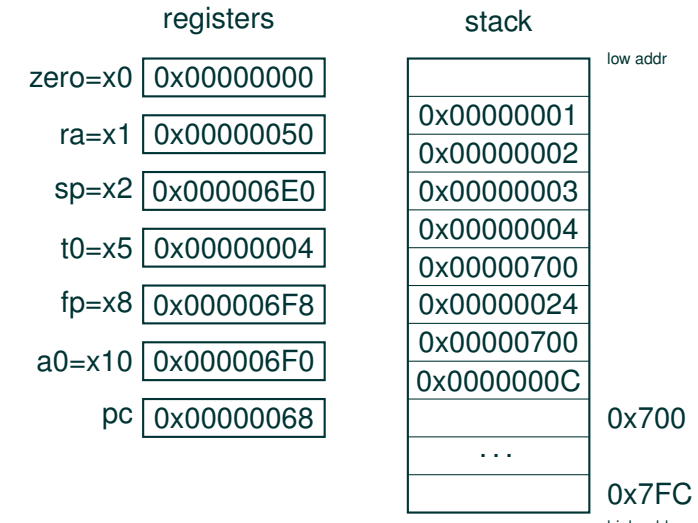
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



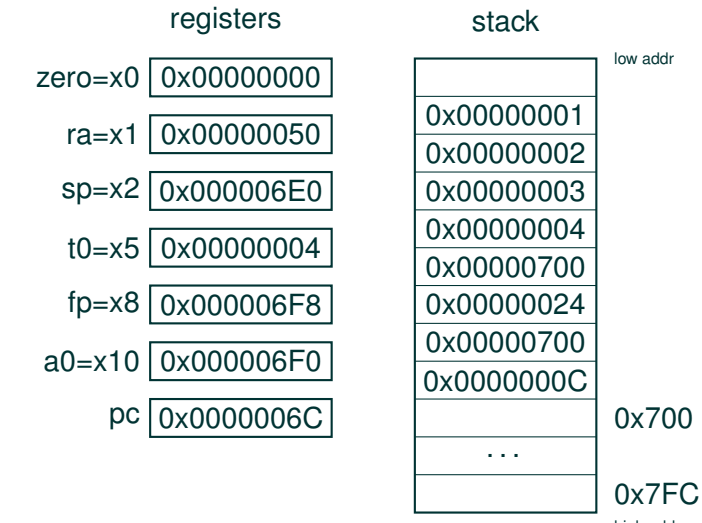
Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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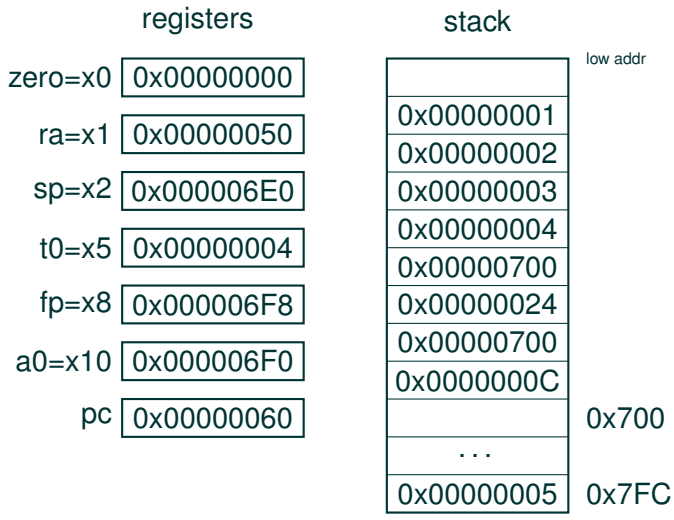
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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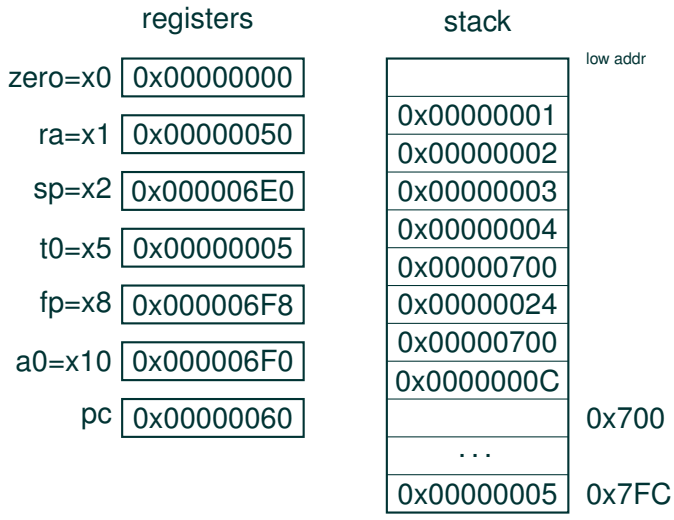
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 ADDI fp,sp,24
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 JAL  ra,gets
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 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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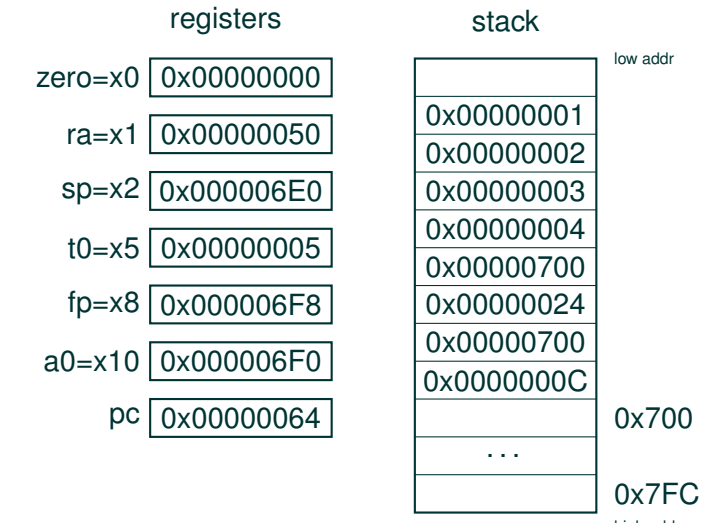
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
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 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
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secret:
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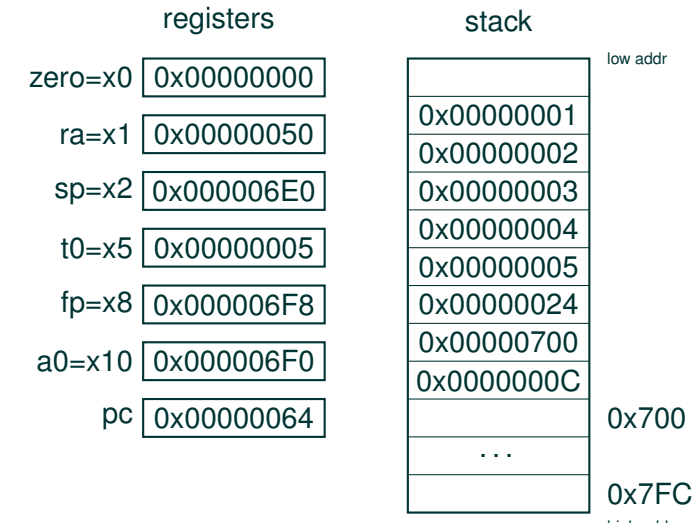

Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 ADDI a0,fp,-24
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 LW   t0,0x7FC(zero)
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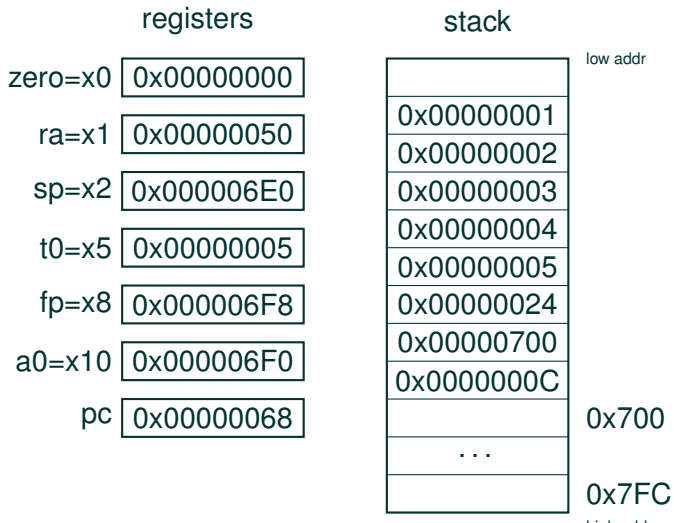
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
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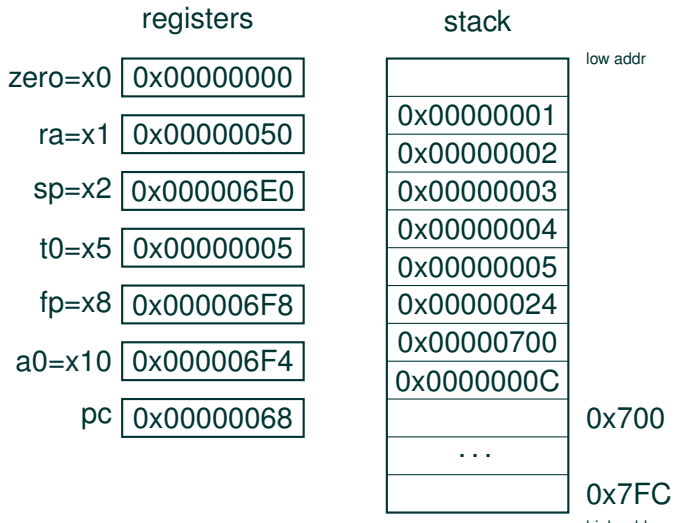
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 ADDI fp,sp,24
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 JAL  ra,gets
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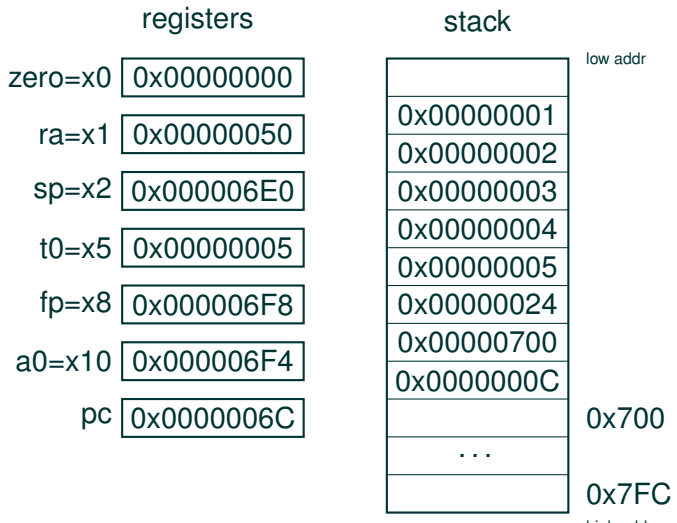
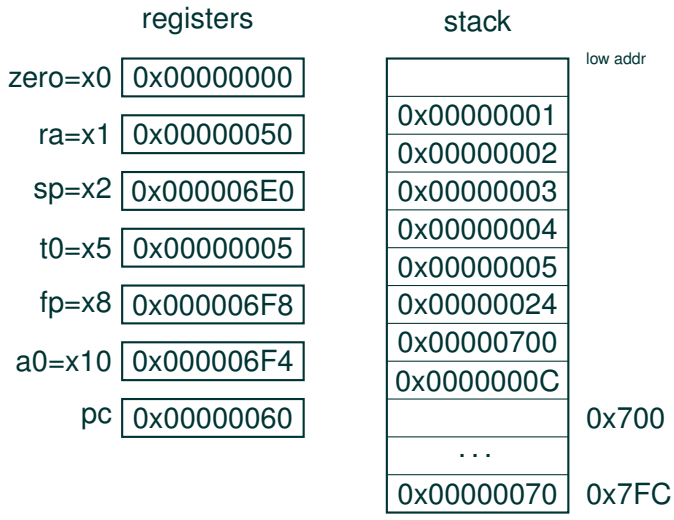
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 LW   fp,16(sp)
 ADDI sp,sp,24
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 SW   t0,0(a0)
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 BNE  t0,zero,gets
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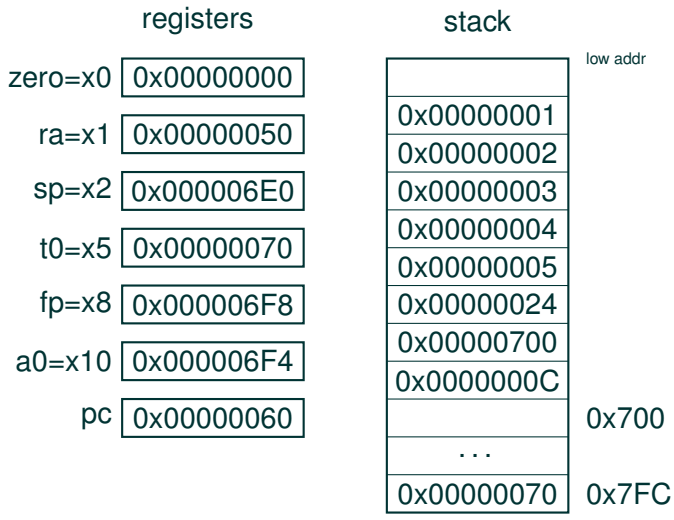
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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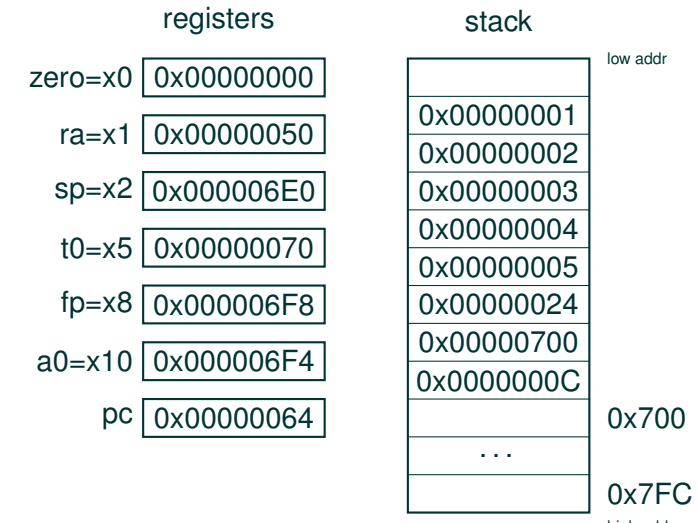

Buffer overflow

```
vuln:
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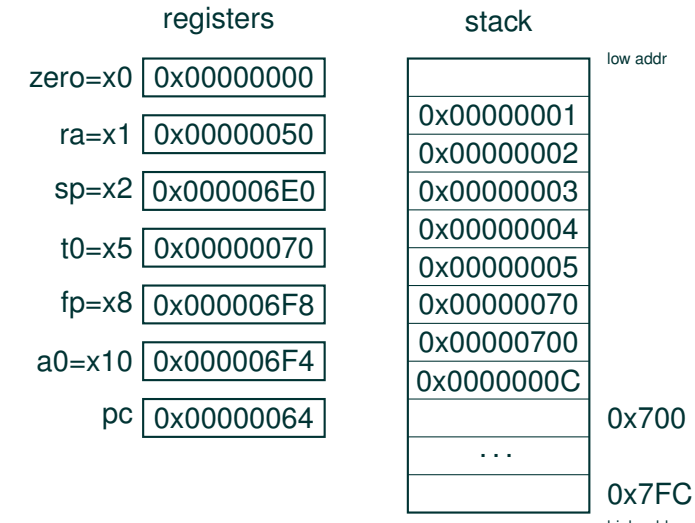
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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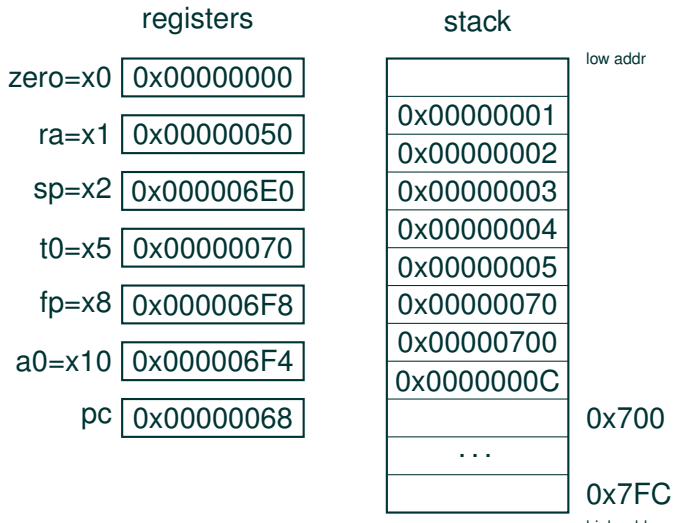
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
 ADDI fp,sp,24
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 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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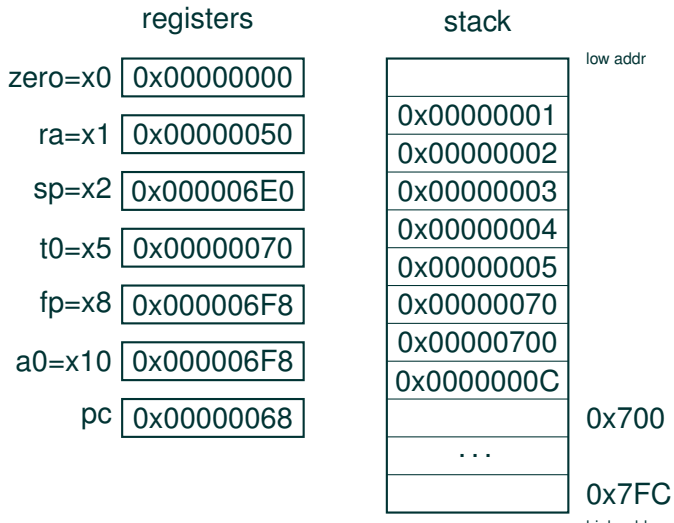
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
 ADDI fp,sp,24
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 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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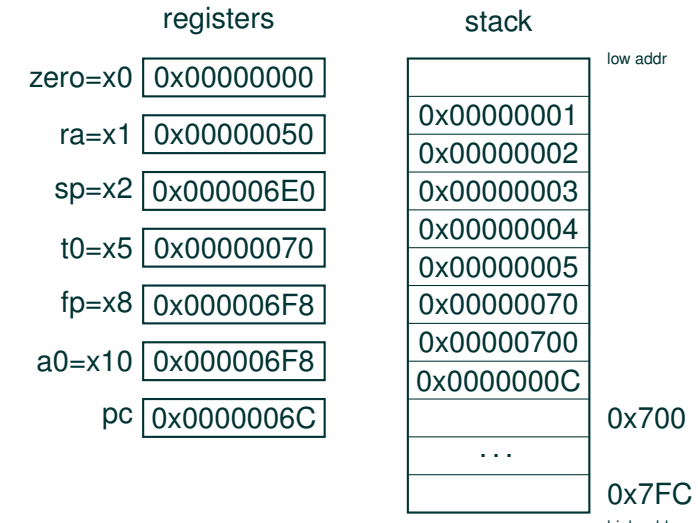
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
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 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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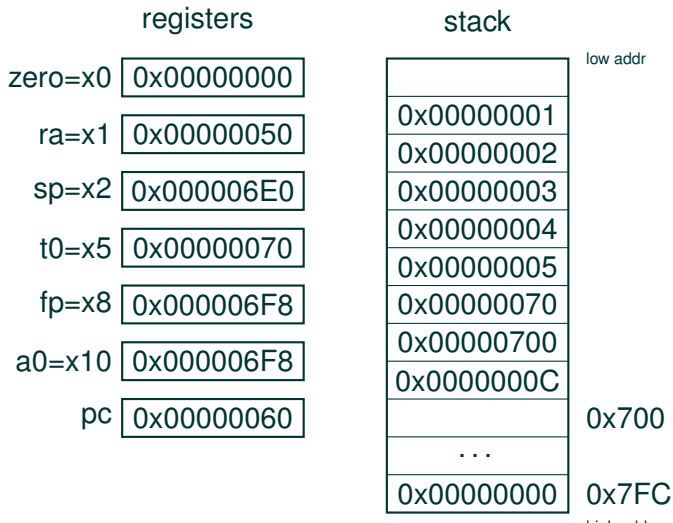
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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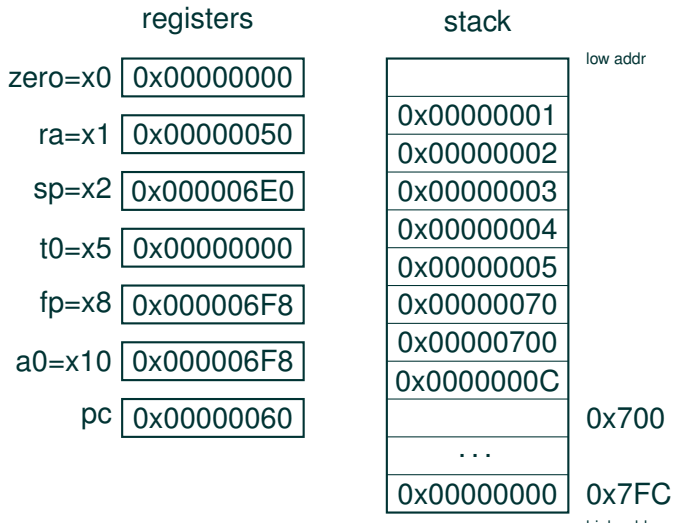
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
 ADDI fp,sp,24
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 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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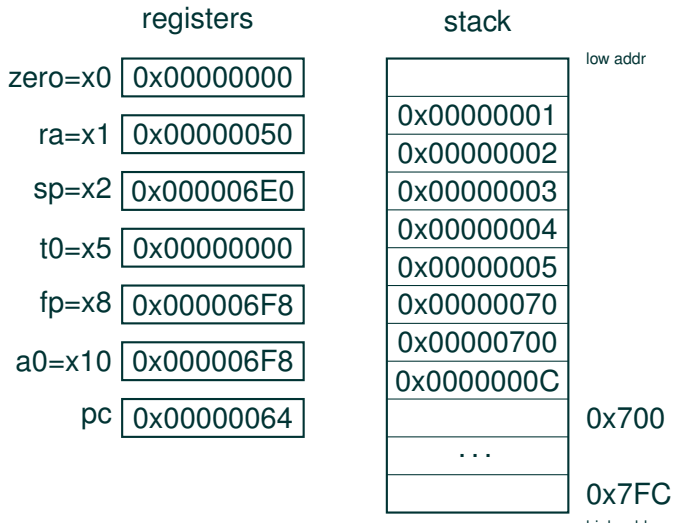
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 SW   fp,16(sp)
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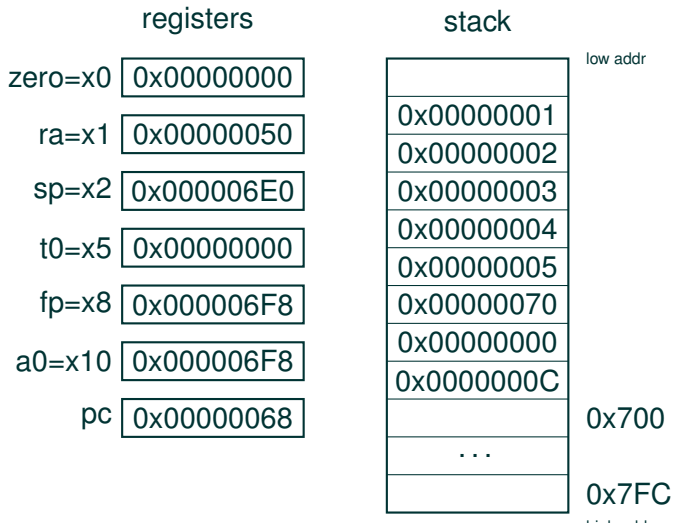
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```

Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
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 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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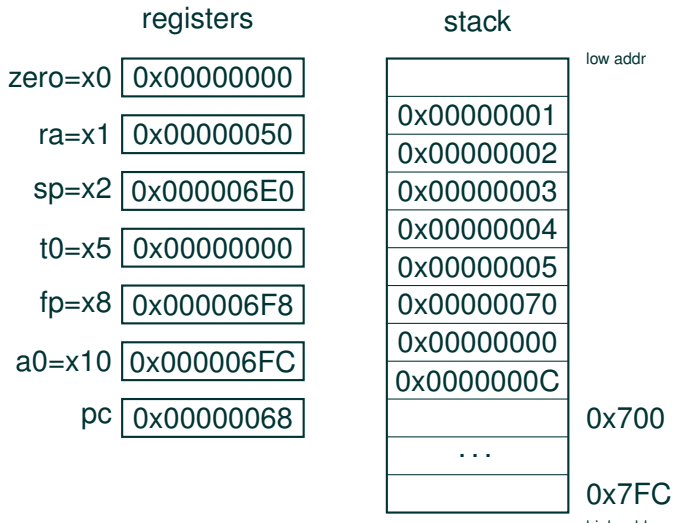
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
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 SW   fp,16(sp)
 ADDI fp,sp,24
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 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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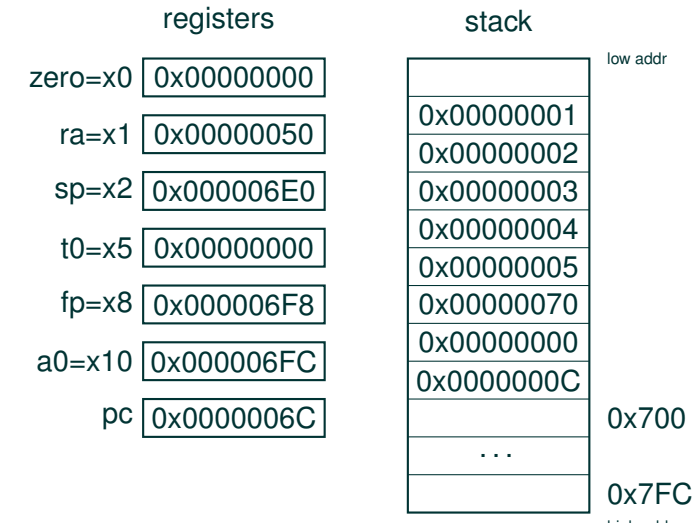
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
 ADDI fp,sp,24
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 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
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gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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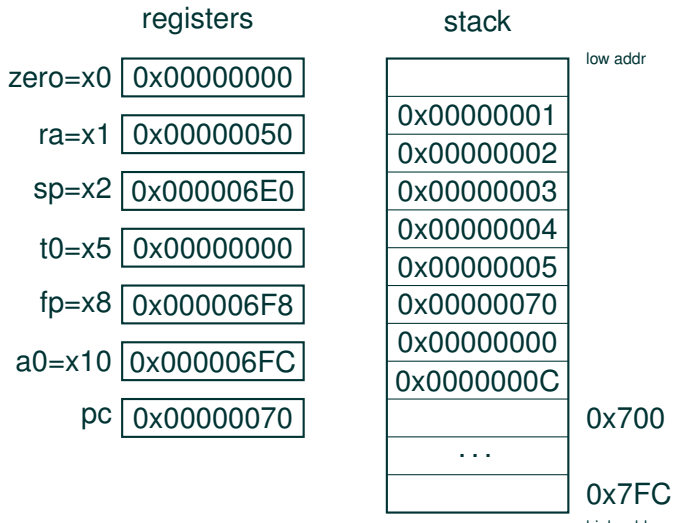
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
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 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
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gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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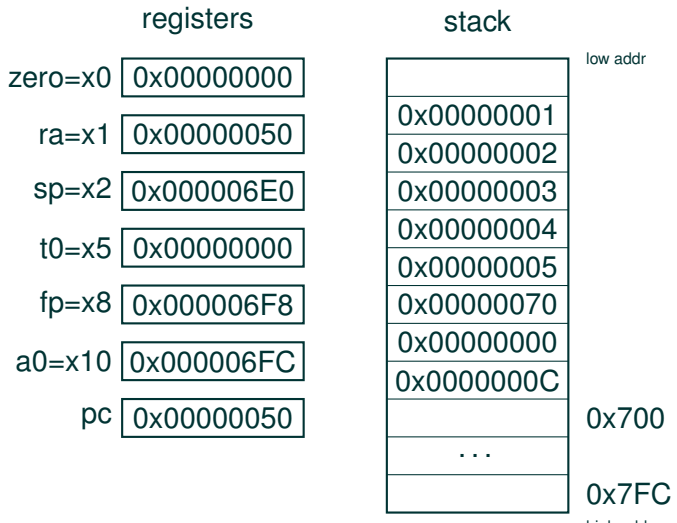
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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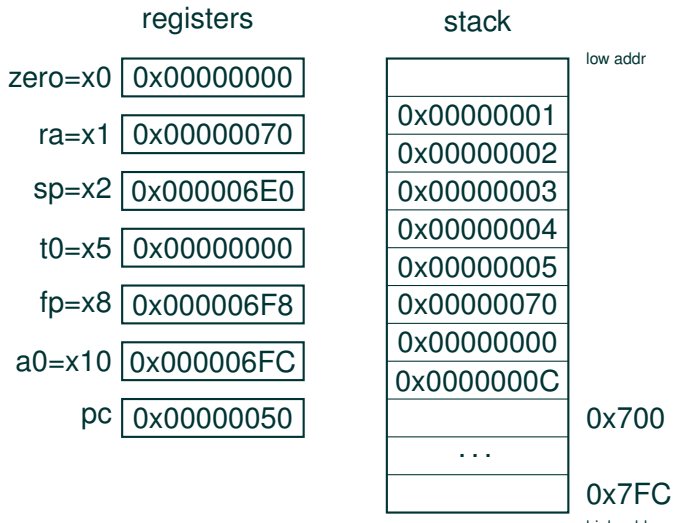
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
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 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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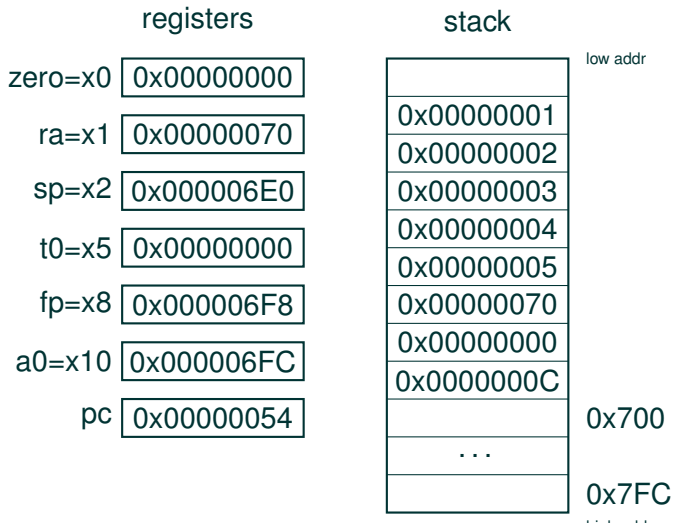
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
 ADDI a0,fp,-24
 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
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gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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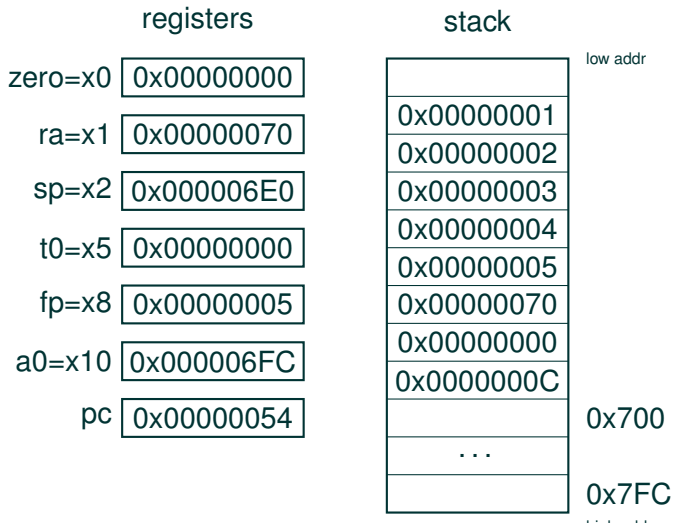
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
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 JAL  ra,gets
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
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gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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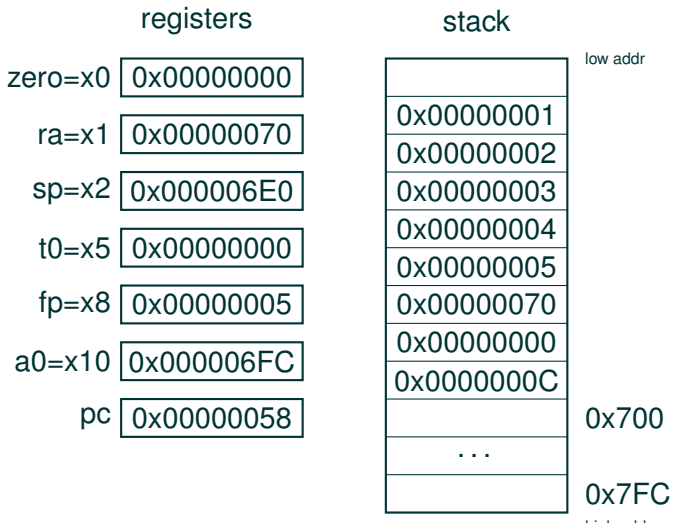
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
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 ADDI fp,sp,24
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 LW   ra,20(sp)
 LW   fp,16(sp)
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gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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secret:
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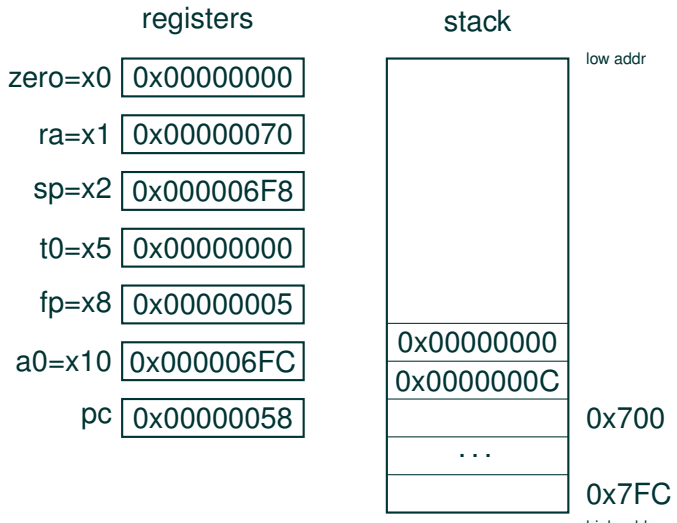

Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
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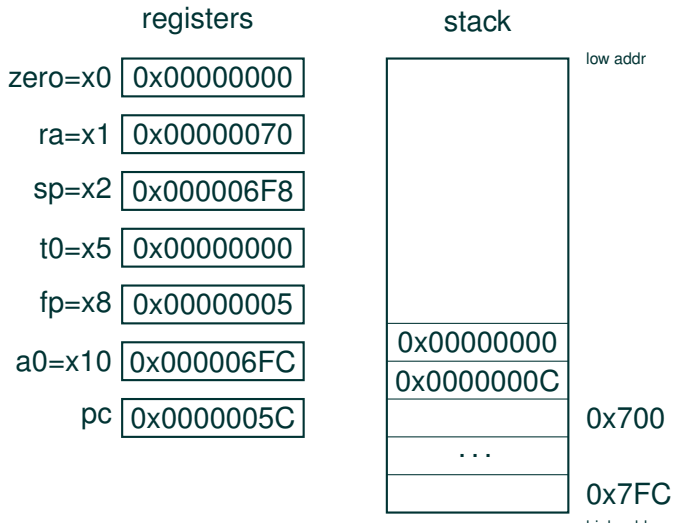
 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
 ADDI a0,a0,4
 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
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 LW   ra,20(sp)
 LW   fp,16(sp)
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gets:
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 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
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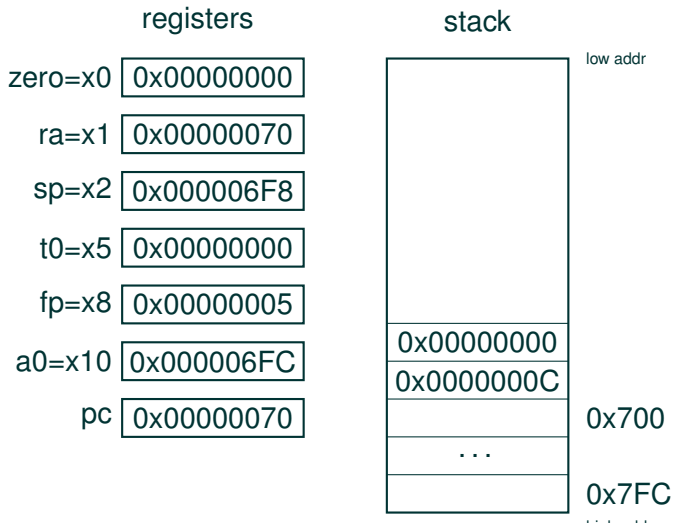

Buffer overflow

```
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 SW   fp,16(sp)
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 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
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gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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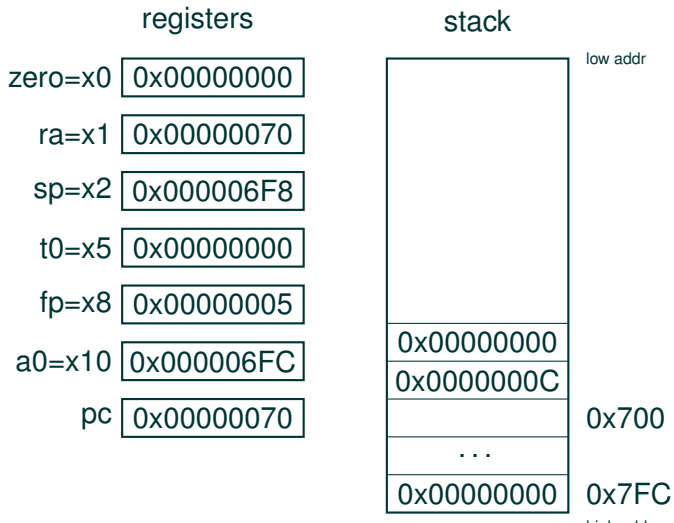
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Buffer overflow

```
vuln:
 ADDI sp,sp,-24
 SW   ra,20(sp)
 SW   fp,16(sp)
 ADDI fp,sp,24
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 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
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 BNE  t0,zero,gets
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
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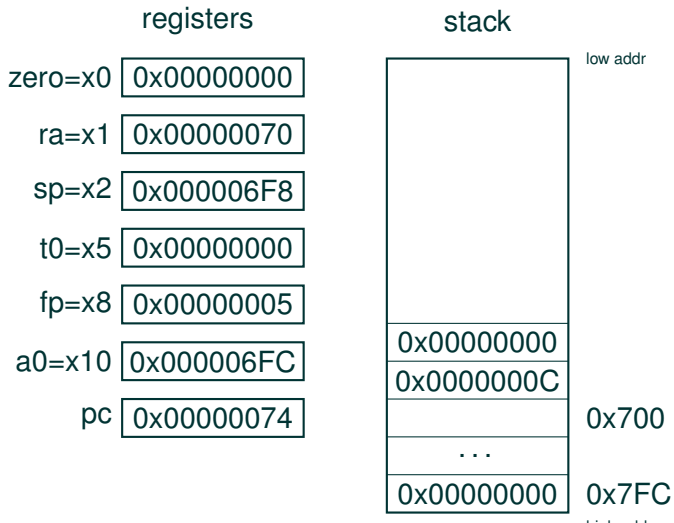

Buffer overflow

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vuln:
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 SW   fp,16(sp)
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 LW   ra,20(sp)
 LW   fp,16(sp)
 ADDI sp,sp,24
 JALR zero,0(ra)
gets:
 LW   t0,0x7FC(zero)
 SW   t0,0(a0)
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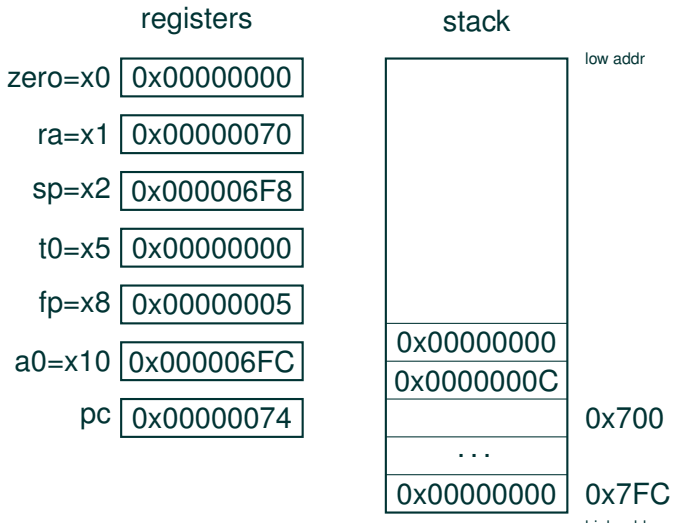
 JALR zero,0(ra)
secret:
 SW   zero,0x7FC(zero)
 EBREAK
```



Function Calls & Stack examples

Stefan Mangard

November 24, 2020

Computer Organization and Networks
Graz University of Technology