# 19. The Stack
# Chapter 10

November 5, 2018

- Data Structures
  - Linked Lists
  - Queues
- Hardware stack — LIFO
  - Software implementation
  - PUSH and POP
- Arithmetic using a stack

QUEUE: FIFO
FIRST IN FIRST OUT

# Stack: An Abstract Data Type

**An important abstraction that you will encounter in many applications**

**We will describe three uses:**

## Interrupt-Driven I/O

- The rest of the story…

## Evaluating arithmetic expressions

- Store intermediate results on stack instead of in registers

## Data type conversion

- 2's comp binary to ASCII strings

SUBROUTINE CALLS — RECURSION

# Stacks

A LIFO (last-in first-out) storage structure.

- The first thing you put in is the last thing you take out.
- The last thing you put in is the first thing you take out.

This means of access is what defines a stack,
not the specific implementation.

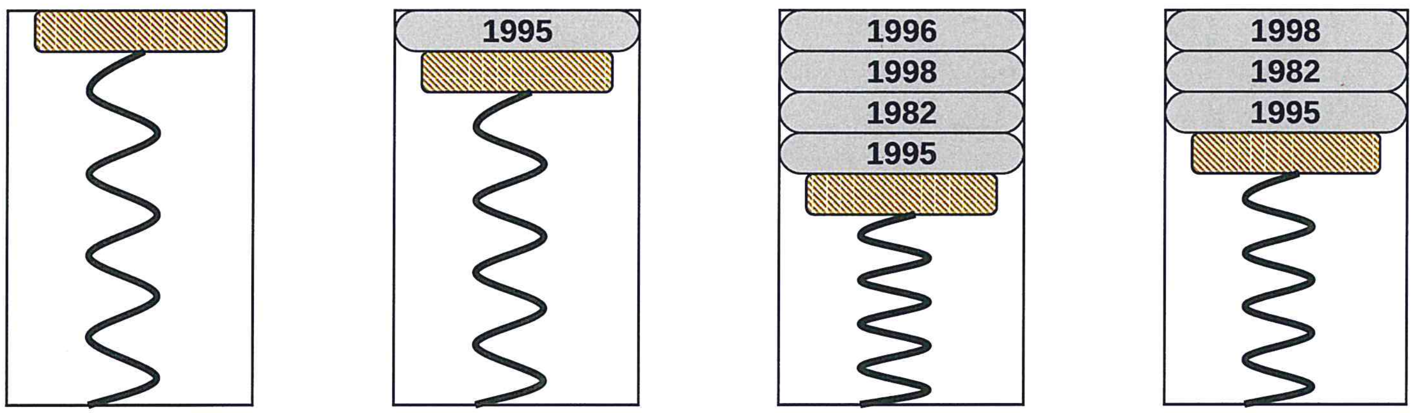
Two main operations:

PUSH: add an item to the stack

POP: remove an item from the stack

# A Physical Stack (HARDWARE)

## Coin rest in the arm of an automobile

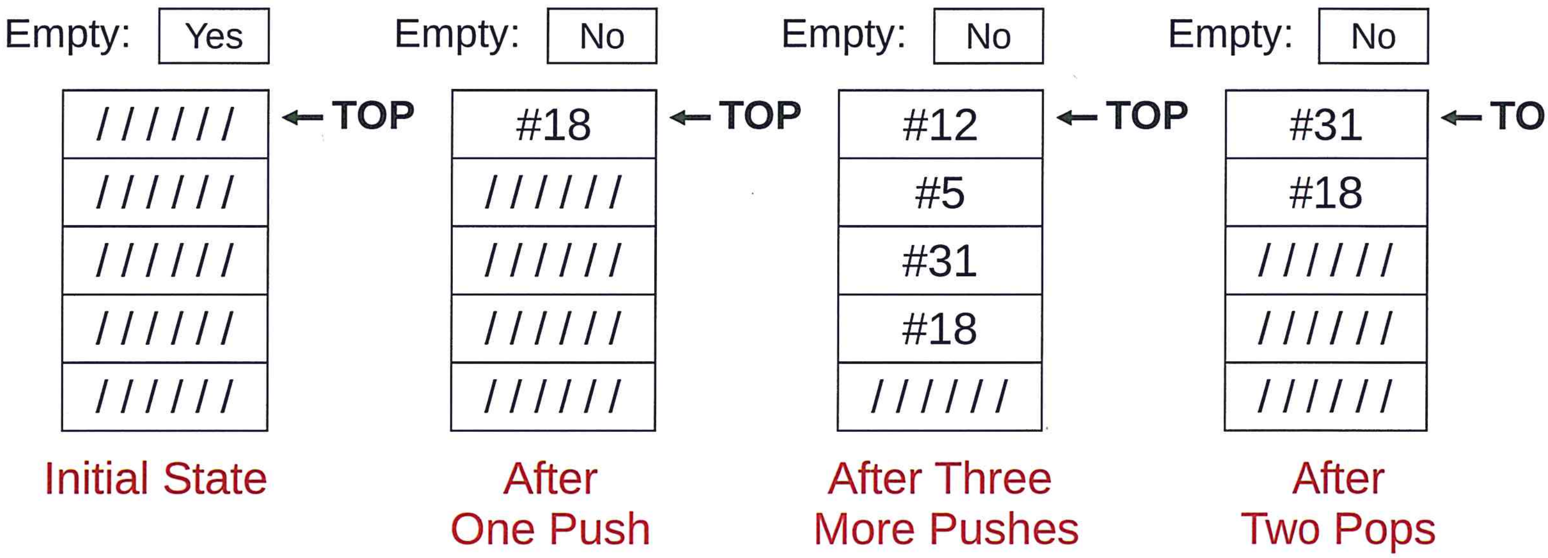



Initial State | After One Push | After Three More Pushes | After One Pop

## First quarter out is the last quarter in.

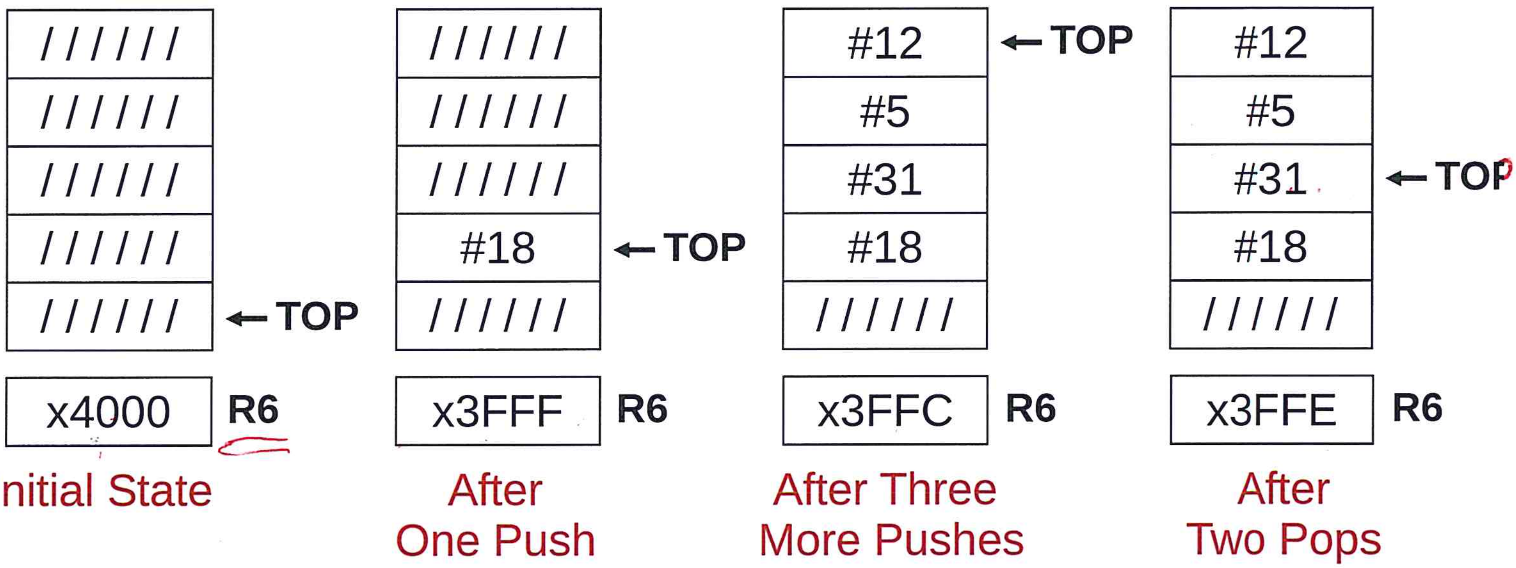
# A Hardware Implementation

## Data items move between registers



## A Software Implementation

**Data items don't move in memory,**
**just our idea about there the TOP of the stack is.**




**By convention, R6 holds the Top of Stack (TOS) pointer.**

# Basic Push and Pop Code

For our implementation, stack grows downward (when item added, TOS moves closer to 0) DATA IN R0

## Push

```
ADD  R6, R6, #-1 ; decrement stack ptr
STR  R0, R6, #0  ; store data (R0)
```

## Pop

```
LDR  R0, R6, #0  ; load data from TOS
ADD  R6, R6, #1  ; ~~decrement~~ stack ptr
                   increment
```

# Pop with Underflow Detection

**If we try to pop too many items off the stack, an underflow condition occurs.**

- Check for underflow by checking TOS before removing data.
- Return status code in R5 (0 for success, 1 for underflow)

```
POP    LD   R1, EMPTY   ; EMPTY = -x4000
       ADD R2, R6, R1 ; Compare stack pointer
       BRz FAIL        ; with x3FFF
       LDR R0, R6, #0
       ADD R6, R6, #1
       AND R5, R5, #0 ; SUCCESS: R5 = 0
       RET
FAIL   AND R5, R5, #0 ; FAIL: R5 = 1
       ADD R5, R5, #1
       RET
EMPTY .FILL xC000
```

## Push with Overflow Detection

**If we try to push too many items onto the stack, an overflow condition occurs.**

- Check for underflow by checking TOS before adding data.
- Return status code in R5 (0 for success, 1 for overflow)

```
PUSH  LD  R1, MAX     ; MAX = -x3FFB
      ADD R2, R6, R1  ; Compare stack pointer
      BRz FAIL        ; with x3FFF
      ADD R6, R6, #-1
      STR R0, R6, #0
      AND R5, R5, #0  ; SUCCESS: R5 = 0
      RET
FAIL  AND R5, R5, #0  ; FAIL: R5 = 1
      ADD R5, R5, #1
      RET
MAX   .FILL xC005
```

# Saving Registers when using Stack

## Using R1, R2 and R5

## Save R1 and R2 in PUSH and POP routines then restore before return

- Calling program does not have to know that these registers are being used
- “Callee-save”

## R5 is needed to report success or failure

- Calling program needs to save R5 before the JSR routine is executed
- “Caller-save”

# Arithmetic Using a Stack

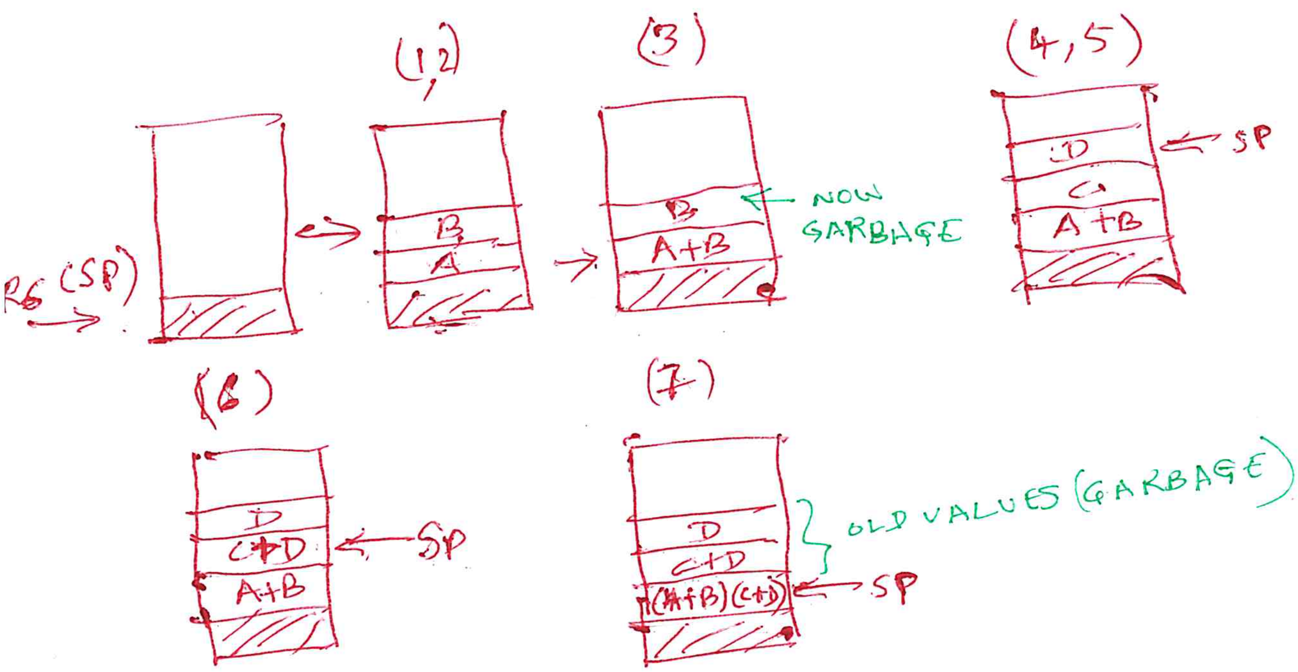
**Instead of registers, some ISAs use a stack for source and destination operations: a zero-address machin**

- **Example:**
  **ADD instruction pops two numbers from the stack, adds them, and pushes the result to the stack.**

## Evaluating (A+B)·(C+D) using a stack:

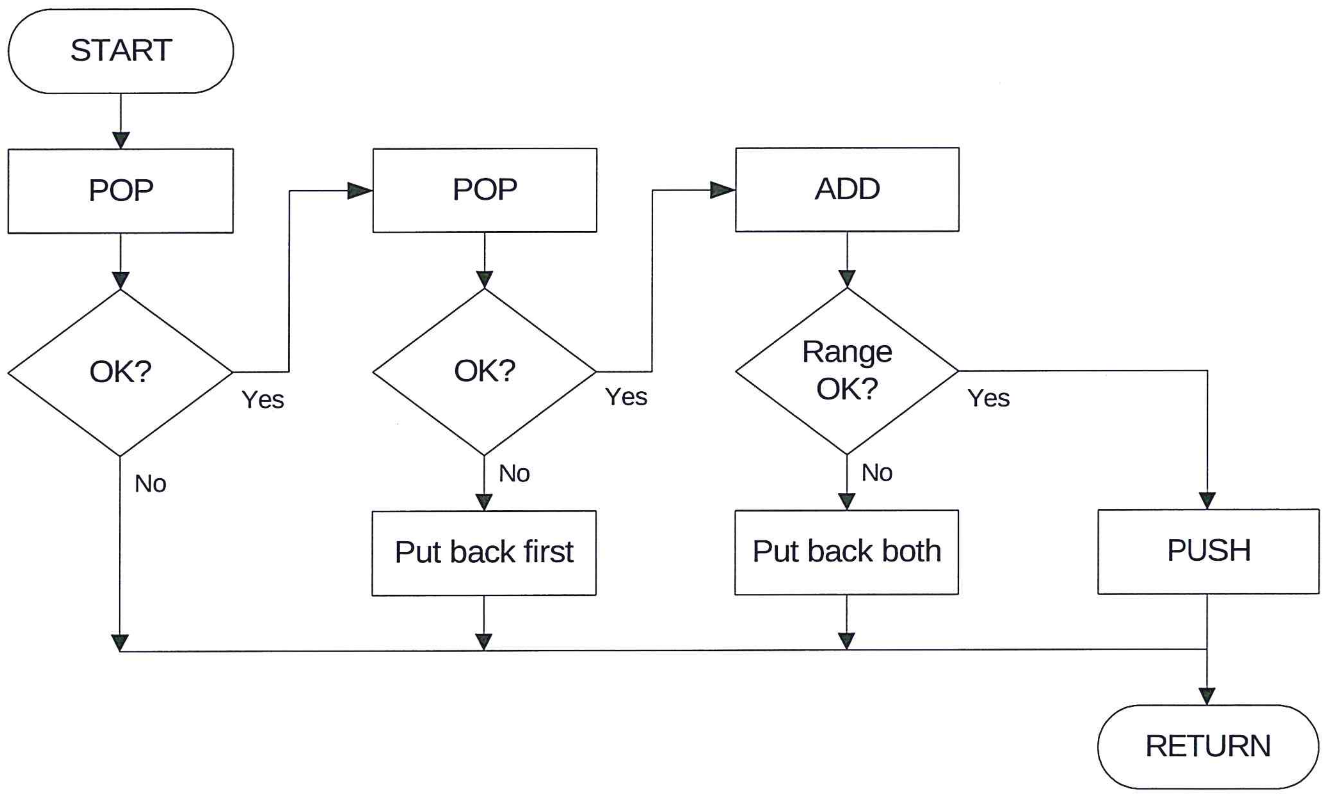
**(1) push A**
**(2) push B**
**(3) ADD**
**(4) push C**
**(5) push D**
**(6) ADD**
**(7) MULTIPLY**
**(8) pop result**

**Why use a stack?**
- Limited registers.
- Convenient calling convention for subroutines.
- Algorithm naturally expressed using FIFO data structure.



# Example: OpAdd

## POP two values, ADD, then PUSH result.



## Example: OpAdd

```
OpAdd      JSR POP            ; Get first operand.
           ADD R5,R5,#0       ; Check for POP success.
           BRp Exit           ; If error, bail.
           ADD R1,R0,#0       ; Make room for second.
           JSR POP            ; Get second operand.
           ADD R5,R5,#0       ; Check for POP success.
           BRp Restore1       ; If err, restore & bail.
           ADD R0,R0,R1       ; Compute sum.
           JSR RangeCheck     ; Check size.
           BRp Restore2       ; If err, restore & bail.
           JSR PUSH           ; Push sum onto stack.
           RET
Restore2   ADD R6,R6,#-1      ; Decrement stack pointer
                              ; (undo POP)
Restore1   ADD R6,R6,#-1      ; Decrement stack pointer
Exit       RET
```

ISSUE WITH R7 (SUBROUTINE CALLING ANOTHER SUBROUTINE)

SAVE R7 IN MEMORY OR PUSH/POP ON/FROM STACK