University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 220: Computer Systems & Programming

Code Reuse: Subroutines

Want to Reuse Code, Not Rewrite Code

Problem when writing software:
- need to **solve** a task **more than once**,
- **but** want to **write** the code **exactly once**!

LC-3 examples:
- multiplication, division, exponentiation
- reading numbers or strings from the keyboard
- printing decimal or hexadecimal numbers to the display

An Example with Many Opportunities

A more detailed example:
- Human types in a value N followed by integral coefficients of F(x), a degree N polynomial in x.
- Starting near x=0, and going in both directions until F(x) overflows a 16-bit 2's complement representation, find the integral values of x surrounding any roots in the polynomial in the specified region.

Now: how many times did you want to write multiplication?

Letter Frequency Example Reused, but Converged

The letter frequency example reused code to increment bins:
- one block of code for the non-alpha bin (used for three separate regions of ASCII),
- and one block of code for the alpha bins (used for both upper- and lower-case letters).

But **in all cases, control flow converged** to GET_NEXT.

```
NON_ALPHA
LDR R6,R0,#0
ADD R6,R6,#1
STR R6,R0,#0
BRnzp GET_NEXT
```

```
ALPHA
ADD R2,R2,R0
LDR R6,R2,#0
ADD R6,R6,#1
STR R6,R2,#0
BRnzp GET_NEXT
```


How Can We Change PC to Different Values?

What if control flow does not converge?

```
; read degree N from keyboard
; loop from 0 to N
;    read coefficient from keyboard
;    continue with next loop iteration
```

After reading a number, **does PC change to start the loop, or to continue the loop?**

Use the JMP Instruction to Go to the Right Place

Remember the JMP instruction?

JMP BaseR ; PC ← BaseR

Use a register—R7, for example—
- to point to the next instruction
- after executing our common code.

Then,
- at the end of the common code,
- execute JMP R7.

Two Instructions Suffice to Execute the Common Code

Say that the code for reading a number starts at READNUM.

```
; read degree N from keyboard
LEA R7,#1
BRnzp READNUM
; loop from 0 to N
;    read coefficient from keyboard

    ; continue with next loop iteration
```

```
READNUM
; … code to read
;      a number from
;      keyboard
JMP R7
```


Can Use the Same Sequence Many Times

Write the **same two instructions** for the other use of READNUM.

```
; read degree N from keyboard
LEA R7,#1
BRnzp READNUM
; loop from 0 to N
;    read coefficient from keyboard
    LEA R7,#1
    BRnzp READNUM
    ; continue with next loop iteration
```

```
READNUM
; … code to read
;      a number from
;      keyboard
JMP R7
```


Most ISAs Have Special Instructions for Subroutines

The READNUM code in the example is called a **subroutine**.

The notion of subroutines
- also called **procedures**, **functions**, **methods**, and so on
- is so important that
- **most ISAs have special instructions to support subroutines**.

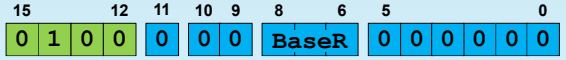
LC-3 also has such instructions.

JSR and JSRR Call Subroutines in LC-3

LC-3 offers two ways to **call a subroutine**: JSR (top form), and JSRR (bottom form).

Notice that either can replace our two-instruction sequence, and both change R7.

R7 ← PC, PC ← PC + SEXT16(PCoffset11)



R7 ← PC, PC ← BaseR

Call Subroutines with JSR(R), Return with RET

Using JSR, we now have…

```
; read degree N from keyboard
JSR READNUM
; loop from 0 to N
;    read coefficient from keyboard
     JSR READNUM
     ; continue with next loop iteration
```

READNUM
; … code to read
; a number from
; keyboard
~~JMP R7~~ RET

Return from subroutine is still JMP R7,
But the **assembler allows pseudo-op** RET.

