Procedures

Procedures are very important for writing reusable and maintainable code in assembly and high-level languages. How are they implemented?

- Application Binary Interfaces
- Calling Conventions
- Recursive Calls
- Examples

Reference: PowerPC Embedded ABI

General Concepts

- Caller: The calling procedure
  Callee: The procedure called by the caller

```
…                          int mult(x, y)
prod = mult (a, b)         …
…                          return (x * y)
```

- Caller and callee must agree on:
  - How to pass parameters
  - How to return the return value(s), if any
  - How to maintain relevant information across calls

- PowerPC architecture does not define "agreement". Instead, common policies are defined by convention.

PowerPC Features

The PowerPC ISA provides the following features to support procedure/function calls:

- link register (p. 2-11)

- bl: branch and link (p. 4-41)

- blr: branch to link register (Table F-4)

A Very Simple Calling Convention

- Passing arguments
  - Use GPRs r3 to r10 in order
  - Use stack in main memory if more than 8 arguments

- Passing return value
  - Leave result in r3

Example

```
int func(int a, int b)
{
   return (a + b);
}

main
{
   …
   func(5,6);
   …
}
```

Another Example

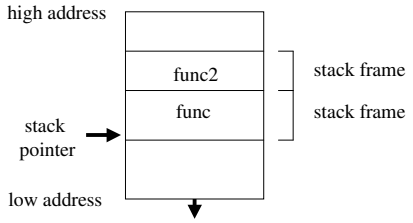
```
int func2(int a, int b)
{
   return func(a , b);
}

main
{
   …
   func2(5,6);
   …
}
```

The Stack

• Information for each function invocation (e.g. link register) is saved on the *call stack* or simply *stack*.

• Each function invocation has its own *stack frame* (a.k.a. *activation record*).



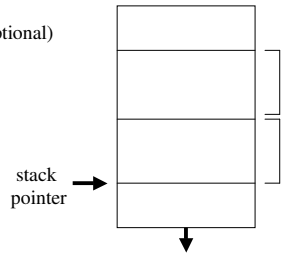
Using the Stack

```
main   …
       …
       bl   func2
       …
func2  …
       …
       bl   func
       …
       ??
       …
func   …
       …
       ??
```

Describe the stack and LR contents
• right before the first bl
• right after the first bl
• right after the second bl
• after each procedure returns

What Goes into Stack Frame?

• link register
• passing parameters (optional)
• return value (optional)
• what else?



Application Binary Interface (ABI)

• Application Binary Interface (ABI): Defines everything needed for a binary object file to run on a system (CPU and operating system), so that it can
  • call system library routines
  • call (and be called by) code generated by other people and other compilers
• The ABI specifies:
  • file format
  • rules for linker operation
  • procedure calling conventions
  • register usage conventions
• PowerPC has different but very similar ABIs for MacOS, AIX, embedded systems (EABI), Unix, Windows.

PowerPC Conventions

• Stack pointer is r1
• Stack pointer is double-word aligned (8 bytes)
• Stack "grows" down, toward address 0
• r1 points to lowest stack address (bottom of current stack frame)
• First item in stack frame (offset 0 from r1) is address of previous stack frame (a.k.a. *frame pointer*)
• Second item (offset 4) is saved link register
• Minimum stack frame is 8 bytes
• Stack frame optional for leaf functions
• Always use update addressing mode to allocate stack frame automatically

Register Usage Convention

Rules about who gets to use/save which registers

• Caller-save: r0, r3-r12, LR, CTR, CR0, CR1, CR5-7

• Callee-save: r14-r31, CR2-4 (non-volatile registers whose values must be preserved across calls and must thus be restored by callee before returning to caller)

Dedicated: r1, r2, r13

EABI Stack Frame