Daniel Leeds, 6.004 R15, April 12, 2006; Quiz #3 Review

Fine print:

Quiz is closed-book, no calculators; covers up to L14 (Stacks and Procedures)/R15 (this recitation)

Practice, practice, practice:

Follow "Previous terms" link from http://6004.csail.mit.edu, pick a semester (the more recent, the better), click on the "Announcements" page for the semester, and find the PDF for Quiz 3 solutions. Don't read the answers until you first figure them out for yourself!

Another perspective on the material – Margaret Chong's Handbook:

Follow "Handouts" link from http://6004.csail.mit.edu, click on handbook link near the bottom of the page.

Handouts

In past years, we have given students the "Summary of Instructions Format" sheet (available from the handouts web page) as a reference during the exam. While studying for the exam, you also might want to look at "Beta Documentation" – this **won't** be available on test day.

Good topics to know:

Models of Computation

Turing Machines (TMs) – more powerful than FSMs

Implementation: FSM attached to infinite tape

Parenthesis checker – requiring arbitrarily many states

Universal TMs capable of performing the computation performed by any TM

Can compute all "computable" functions

Uncomputable functions – for example, will TM **k** ever halt on tape **j**?

(Note "will TM **k** halt on tape **j** in fewer than **m** steps" is computable)

Programmable Machines and *Machine Language*

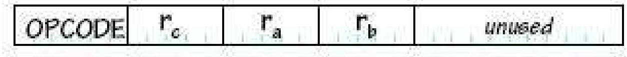
Memory

stores both data and coded instructions in

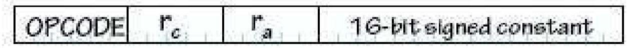
words of W bits (we tend to use 32 bits (= 4 bytes) per word)

Program Counter (PC) specifies address of next instruction to be executed

Binary layout of the two Beta instruction formats:



OPCODE	r_c	r_a	r_b	unused



OPCODE	r_c	r_a	16-bit signed constant

Instructions

move data between memory and registers

operate on register data and store results in registers

change program counter (for loops, procedure calls, conditional statements)

Sample Beta ops:

BEQ(R1, br_addr, R2)   R2 = PC+4   **Machine Language Format**
branch relative to R2 ->   PC = R2 + *4*((br_addr – R2)/4)*, if R1==0
PC = R2, if R1!=0

```
OPCODE Rc=R2 Ra=R1  16-bit literal    Binary Encoding Format
011101 00010 00001  0000000000001010   (PC = PC+4+4*literal, if R1==0)
```

LD(R1,c,R2)   R2 = Mem[R1+c] (load value at address R1+c into R2)

Stacks and Procedures

Special registers: BP Base pointer is a reference point in the most recent activation record in the stack
LP Linkage pointer specifies return address for JMP at end of procedure call
SP Stack pointer points to top of the stack

Operations: PUSH, POP
ALLOCATE, DEALLOCATE (moves SP without read or write to memory)

Typical procedure call:

```
. = 0x00000708
   PUSH(R2)       |
   BR(fact,LP)    | CALL SEQUENCE




. = 0x00000B04    | later in memory
fact:
   PUSH(LP)       |
   PUSH(BP)       |
   MOVE(SP,BP)    | ENTRY SEQUENCE
   PUSH(R1)       |

   LD(BP,-12,R1)  | reads input left by
                  | caller 3 address slots
                  | above BP

   | details of fact omitted

. = 0x00000B44    | at end of fact
   POP(R1)        |
   MOVE(BP,SP)    |
   POP(BP)        | EXIT SEQUENCE
   POP(LP)        |
   JMP(LP)        |
```

```
Stack:

         2  input
       B38  LP
      1058  BP
         2  R1
         1  input
       B38  LP
      1068  BP
BP->     1  R1
SP-> EDED
```

==

Higher points in computability theory (unlikely to be tested, but people asked in class)

Showing something is not computable often employs proof by contradiction - assume the function is computable, use it as part of a more complex Turing machine to construct a Turing machine that does something clearly impossible (recall the TM, T_N, that “halts when it doesn’t halt and doesn’t halt when it halts”). There are various non-computable functions, but you usually see them in theory papers, rather than computer consumer magazines.

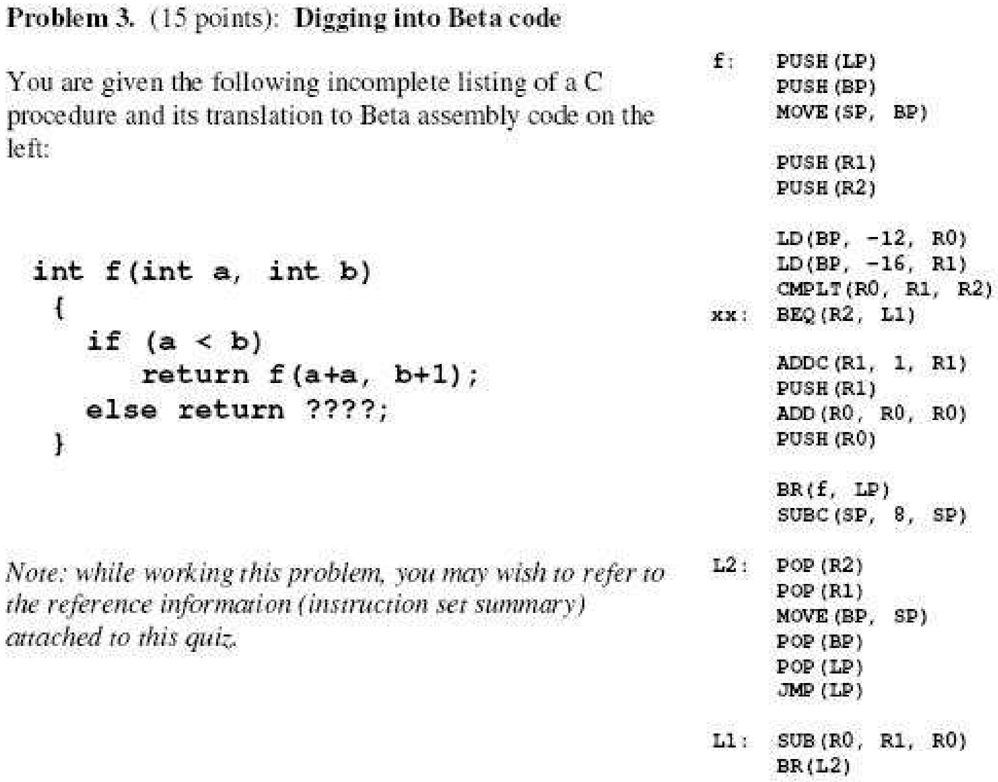
Quiz #3 Spring 2003

Problem 1:
Identify whether the following behavior can be implemented using an FSM, a universal Turing Machine, or none at all. (Circle FSM if it can be implemented via either a Turing Machine or FSM).

A. A device that takes a stream of parentheses and outputs 1 if the input thus far represents a well-formed parenthesis string with **no nesting** (no (…) within (…)). It outputs a zero on mismatched or nested parens. FSM TM uncomputable

D. A machine that takes two binary inputs i and j and halts if and only if executing the ith TM on tape j also halts. FSM TM uncomputable

Quiz #3 Spring 2004



Problem 3. (15 points): **Digging into Beta code**

You are given the following incomplete listing of a C procedure and its translation to Beta assembly code on the left:

```
int f(int a, int b)
 {
   if (a < b)
      return f(a+a, b+1);
   else return ????;
 }
```

Note: while working this problem, you may wish to refer to the reference information (instruction set summary) attached to this quiz.

```
f:    PUSH(LP)
      PUSH(BP)
      MOVE(SP, BP)

      PUSH(R1)
      PUSH(R2)

      LD(BP, -12, R0)
      LD(BP, -16, R1)
      CMPLT(R0, R1, R2)
xx:   BEQ(R2, L1)

      ADDC(R1, 1, R1)
      PUSH(R1)
      ADD(R0, R0, R0)
      PUSH(R0)

      BR(f, LP)
      SUBC(SP, 8, SP)

L2:   POP(R2)
      POP(R1)
      MOVE(BP, SP)
      POP(BP)
      POP(LP)
      JMP(LP)

L1:   SUB(R0, R1, R0)
      BR(L2)
```

Give the HEX value of the instruction labeled ‘xx:’ in the program above.

(C) What is the missing C expression corresponding to the ???? in the above C program?

(D) What would be the effect of removing the instruction MOVE(BP,SP)?

Procedure would work fine

Procedure would compute right value, but not restore registers correctly

Procedure would no longer compute f(a,b) properly

The call f(2, 5) is made via the instruction **`BR(f,LP)`** from an external main program and its execution is interrupted just prior to an execution (not necessarily the first) of the **`BEQ`** instruction labeled **xx:**. The contents of a region of memory are shown to the right.

NB: All addresses and data values are shown in hex. The contents of **BP** are **0x128.**

Address (HEX)	Contents (HEX)	
100	5	
104	2	
108	A8	
10C	0	
110	0	
114	6004	
118	6	
11C	**4**	
120	54	
124	110	
BP ? 128	6	
12C	1	

(E) (2 points) What are the arguments to the ***current*** (most recent) call to f?

Current arguments, a=_____; b=___ __

(F) (1 point) What value is in **SP**?

Contents of **SP** (HEX): 0x______

(G) (2 points) What is the address of the **`BR(f, LP)`** instruction that made the original call to `f(2,5)`?

Address of BR making original call:0x_ __

(H) (2 points) What value was in R2 at the time of the original call?