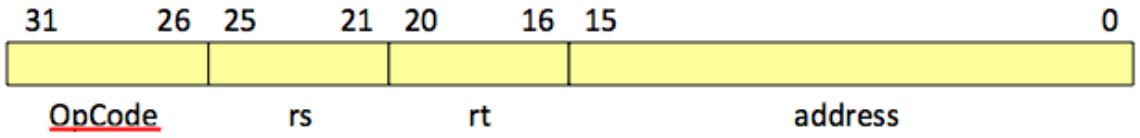
CMPUT 229 - Quiz # 3 - Winter 2012

Name: Solution

Question 1 (100 points): MIPS-LRF is a MIPS instruction-set architecture with a large register file. MIPS-LRF has 128 registers and the instruction formats have to accommodate this change. Consider a branch instruction. Assume that the instruction still has to be 32-bits long and that any changes made to the instruction format only increase/decrease the size of the immediate field. Recall that in the original MIPS architecture, the branch instruction uses the following format:



a. (**20 points**) How many bits are available for the immediate bit field for a branch instruction in MIPS-LRF?

With 128 = 2^7 registers, we need 2 additional bits to specify each register. Therefore there are 16-4=12 bits available for the immediate field.

b. (**20 points**) How does the range of branch in MIPS-LRF compares with the range of a branch in the original MIPS architecture?

With 4 fewer bits for the immediate field, the range is reduced 16 times, or it is reduced by 93.75%, or it is reduced to 6.25% of the original range.

c. **60 points**) Assume that in a program that uses MIPS-LRF the current PC address is `0x 0000 0000`. How many branches (no jump instructions) are necessary to get to address `0x FFFF E000`? Provide the binary representation for the immediate field for the branch(es) instruction(s) required.

The shortest path is through the use of backward branches. The largest negative number that can be stored in a 12-bit immediate field is 0x800. After left shifting by 2 and sign extending to 32 bits it becomes 0xFFFFE000, which brings us close to the final address. Thus we start with the largest possible backward jump:

```
Old PC = 0000 0000 0000 0000 0000 0000 0000 0000
     +   0000 0000 0000 0000 0000 0000 0000 0100 = 4
     +   1111 1111 1111 1111 1110 0000 0000 0000 = SigExtension(immediate)<<2
-------------------------------------------------
         1111 1111 1111 1111 1110 0000 0000 0100 = 0xFFFF E004
```

Therefore the PC after the first branch is 0xFFFF E004

The immediate field of the first branch is: 0x800

We can see now that `PC after first branch + 4 = 0xFFFF E008`

Thus to get to the final destination at 0xFFFF E000, all we have to do is to subtract 8. With the left shift done by the branch, this is equivalent to an immediate field equal -2.

Thus the immediate field of the second branch is -2 = 0xFFE

Verifying:

```
PC after 1st branch = 1111 1111 1111 1111 1110 0000 0000 0100 = 0xFFFFE004
                    +   0000 0000 0000 0000 0000 0000 0000 0100 = 4
                    +   1111 1111 1111 1111 1111 1111 1111 1000 = SigExt(immed)<<2
-------------------------------------------------------------------------------
            Final PC = 1111 1111 1111 1111 1110 0000 0000 0000 = 0xFFFF E000
```