

# CS/ECE 561: Hardware/Software Design of Embedded Systems

## Fall 2016

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### Homework 5: Software Optimizations

**Assigned:** 15 Nov, 2016

**Due:** 28 Nov, 2016

#### Instructions:

- Please submit your solutions via Canvas. Submissions should include source code files or text/word/pdf files in a single zip file, with separate folders designated for every problem.
  - Some questions might not have a clearly correct or wrong answer. In such cases, grading is based on your arguments and reasoning for arriving at a solution.
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#### Introduction

This assignment makes you apply the software optimization techniques learnt in class on software running on the gem5 architectural simulator, to obtain performance benefits. **It is strongly recommended to use Ubuntu 14.04 for this assignment. There have been some unresolved issues reported with Ubuntu 16.04.**

#### Installing gem5 platform with ARM processor

Follow the steps from the gem5 homework assignment 2 to download a stable version of gem5 and build the simulation environment for ARM processors. The commands are:

```
> hg clone http://repo.gem5.org/gem5-stable
> ls (you should have a gem5 directory if everything went well)
> cd gem5
> scons build/ARM/gem5.opt
```

**Q1 [150 points].** Apply software optimization techniques to improve the performance (reduce the execution cycle count) of the FFT benchmark. Submit a word/pdf document describing the optimizations you made as well as the modified FFT source code file. Add comments to the source code file wherever you make changes. The top 3 submissions with the best FFT performance will receive a bonus of 100, 50, and 25 points, respectively.

To run the FFT benchmark, use the configuration below:

```
build/ARM/gem5.opt configs/example/se.py --cpu-type="detailed" --sys-clock=2GHz --cpu-clock=2GHz --
caches --l1d_size=16kB --l1i_size=16kB --l1d_assoc=2 --l1i_assoc=2 --cmd=splash2-orig/codes/kernels/fft/FFT
-o "-m8 -o"
```

Check stats.txt to obtain the number of execution cycles (numcycles). Your optimizations should reduce the numcycles value obtained after execution. Make sure you check that your output after making all optimizations is consistent with the output without any optimizations. The output of the un-optimized source code should be similar to that shown on the next page.

```
Info: Entering event queue @ 0. Starting simulation...
Info: Increasing stack size by one page.
```

```
FFT with Blocking Transpose
 256 Complex Doubles
 1 Processors
65536 Cache lines
16 Byte line size
4096 Bytes per page
```

```
Original data values:
```

```
0.17 0.75, 0.10 0.87, 0.58 0.79, 0.69 0.37, 0.87 0.75, 0.45 0.35, 0.73 0.26, 0.39 0.78,
0.85 0.58, 0.72 0.08, 0.46 0.11, 0.55 0.39, 0.57 0.96, 0.87 0.16, 0.28 0.26, 0.92 0.44,
0.79 0.13, 0.08 0.94, 0.03 0.15, 0.38 0.15, 0.53 0.88, 0.43 0.26, 0.31 0.77, 0.11 0.77,
0.71 0.22, 0.76 0.41, 0.65 0.93, 0.50 0.69, 0.44 0.61, 0.58 0.63, 0.46 0.63, 0.14 0.96,
0.14 0.45, 0.32 0.95, 0.36 0.40, 0.10 0.96, 0.98 0.58, 0.87 0.15, 0.91 0.65, 0.06 0.95,
0.97 0.79, 0.81 0.57, 0.28 0.96, 0.58 0.44, 0.38 0.92, 0.03 0.77, 0.72 0.59, 0.43 0.64,
0.75 0.07, 0.05 0.77, 0.70 0.12, 0.30 0.07, 0.69 0.36, 0.73 0.19, 0.15 0.16, 0.83 0.55,
0.32 0.53, 0.43 0.21, 0.73 0.00, 0.59 0.48, 0.94 0.76, 0.13 0.01, 0.50 0.84, 0.85 0.09,
0.86 0.79, 0.58 0.10, 0.83 0.75, 0.91 0.51, 0.88 0.96, 0.57 0.47, 0.42 0.65, 0.88 0.59,
0.22 1.00, 0.16 0.70, 0.70 0.99, 0.65 0.65, 0.84 0.68, 0.97 0.33, 0.80 0.16, 0.86 0.60,
0.42 0.98, 0.87 0.46, 0.25 0.84, 0.84 0.74, 0.13 0.48, 0.78 0.50, 0.57 0.44, 0.04 0.33,
0.43 0.58, 0.09 0.67, 0.59 0.24, 0.74 0.96, 0.86 0.07, 0.54 0.38, 0.00 0.72, 0.05 0.02,
0.76 0.63, 0.93 0.55, 0.41 0.39, 0.20 0.31, 0.21 0.61, 0.37 0.16, 0.46 0.80, 0.18 0.72,
0.48 0.14, 0.63 0.24, 0.12 0.87, 0.10 0.75, 0.38 0.56, 0.08 0.38, 0.63 0.79, 0.42 0.82,
0.55 0.73, 0.49 0.26, 0.50 0.49, 0.49 0.85, 0.92 0.36, 0.55 0.60, 0.61 0.44, 0.71 0.22,
0.77 0.31, 0.79 0.09, 0.90 0.93, 0.97 0.62, 0.07 0.11, 0.63 0.07, 0.56 0.23, 0.61 0.93,
0.57 0.57, 0.46 0.12, 0.24 1.00, 0.56 0.86, 0.29 0.73, 0.82 0.49, 0.59 0.11, 0.16 0.70,
0.59 0.88, 0.43 0.21, 0.18 0.69, 0.22 0.26, 0.22 0.49, 0.27 0.45, 0.24 0.30, 0.65 0.75,
0.69 0.42, 0.76 0.40, 0.37 0.64, 0.53 0.90, 0.66 0.93, 0.01 0.17, 0.64 0.77, 0.68 0.77,
0.76 0.90, 0.22 0.64, 0.60 0.62, 0.37 0.07, 0.25 0.36, 0.48 0.50, 0.29 0.24, 0.66 0.90,
0.67 0.04, 0.84 0.57, 0.18 0.03, 0.48 0.56, 0.17 0.61, 0.64 0.31, 0.96 0.77, 0.64 0.07,
0.13 0.76, 0.48 0.71, 0.12 0.64, 0.40 0.71, 0.78 0.71, 0.27 0.78, 0.13 0.28, 0.08 0.21,
0.20 0.62, 0.61 0.55, 0.57 0.13, 0.07 0.88, 0.15 0.57, 0.32 0.33, 0.21 0.68, 0.04 0.04,
0.82 0.06, 0.71 0.41, 0.89 0.94, 0.00 0.35, 0.94 0.99, 0.36 0.98, 0.03 0.34, 0.85 0.44,
0.70 0.57, 0.10 0.18, 0.24 0.68, 0.99 0.51, 0.90 0.47, 0.47 0.41, 0.76 0.12, 0.15 0.70,
0.26 0.53, 0.07 0.15, 0.41 0.08, 0.64 0.02, 0.24 0.58, 0.16 0.26, 0.08 0.15, 0.09 0.14,
0.47 0.72, 0.48 0.56, 0.50 0.08, 0.29 0.30, 0.33 0.08, 0.10 0.20, 0.11 0.17, 0.84 0.83,
0.93 0.54, 0.47 0.70, 0.51 0.77, 0.98 0.46, 0.67 0.89, 0.85 0.75, 0.72 0.09, 0.80 0.37,
0.46 0.36, 0.78 0.60, 0.06 0.12, 0.56 0.66, 0.06 0.52, 0.84 0.16, 0.00 0.90, 0.22 0.19,
0.97 0.82, 0.71 0.59, 0.68 0.77, 0.23 0.22, 0.37 0.82, 0.16 0.61, 0.12 0.44, 0.00 0.52,
0.46 0.69, 0.03 0.41, 0.50 0.28, 1.00 0.36, 0.37 0.95, 0.08 0.61, 0.79 0.36, 0.97 0.18,
0.43 0.79, 0.12 0.53, 0.24 0.62, 0.78 0.18, 0.49 0.93, 0.32 0.36, 0.10 0.37, 0.89 0.89
```

```
No more processors -- this is a uniprocessor version!
Exiting @ tick 1369957000 because target called exit()
```