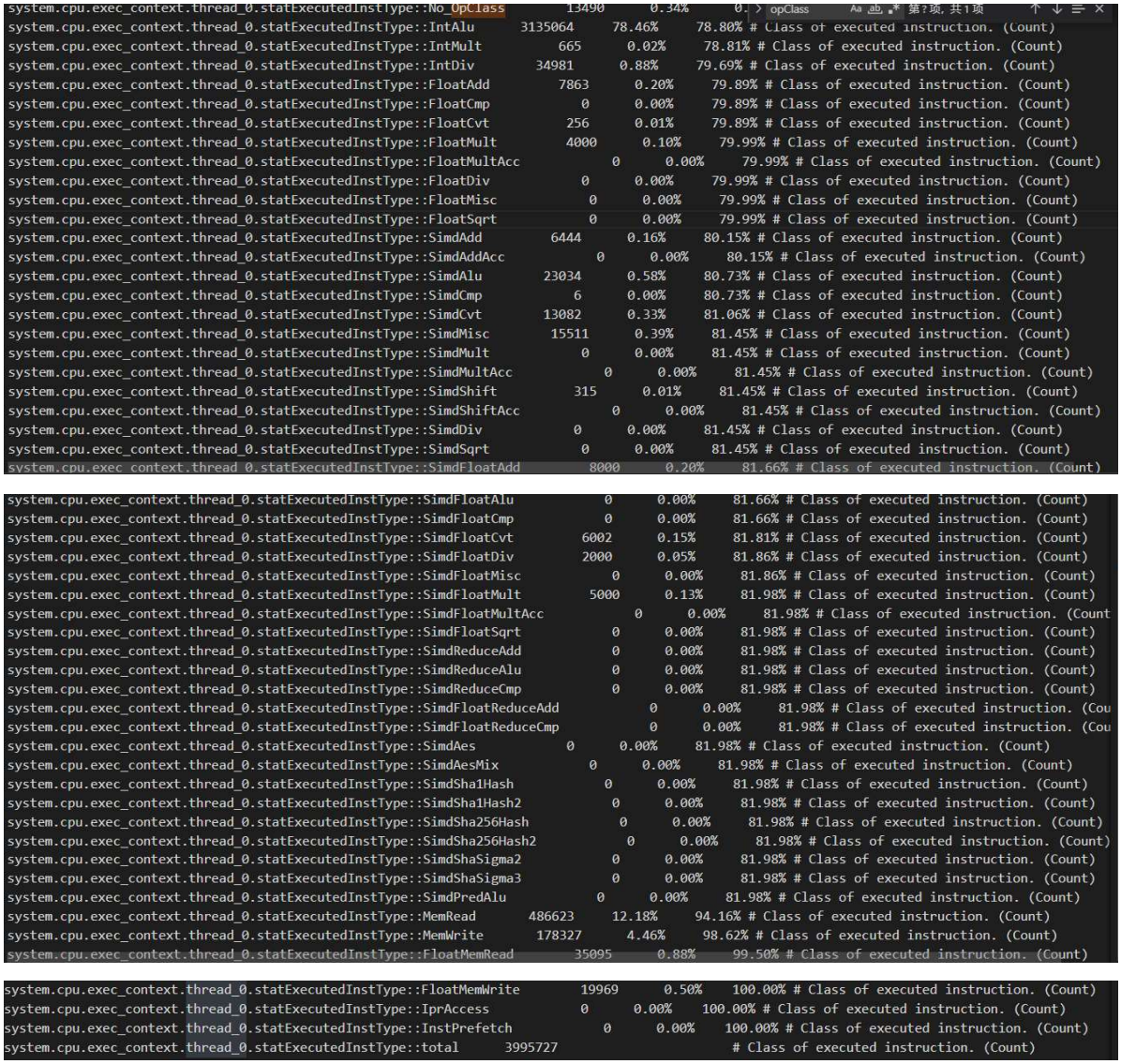
Step 1

Op_class : line 156~209



```
system.cpu.exec_context.thread_0.statExecutedInstType::No_OpClass        13490      0.34%      0.34% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntAlu      3135064     78.46%     78.80% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntMult         665      0.02%     78.81% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntDiv        34981      0.88%     79.69% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatAdd       7863      0.20%     79.89% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCmp          0      0.00%     79.89% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCvt        256      0.01%     79.89% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMult       4000      0.10%     79.99% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMultAcc          0      0.00%     79.99% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatDiv          0      0.00%     79.99% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMisc         0      0.00%     79.99% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatSqrt         0      0.00%     79.99% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAdd       6444      0.16%     80.15% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAddAcc          0      0.00%     80.15% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAlu       23034      0.58%     80.73% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCmp           6      0.00%     80.73% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCvt       13082      0.33%     81.06% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMisc      15511      0.39%     81.45% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMult          0      0.00%     81.45% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMultAcc          0      0.00%     81.45% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShift         315      0.01%     81.45% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShiftAcc          0      0.00%     81.45% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdDiv           0      0.00%     81.45% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdSqrt          0      0.00%     81.45% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatAdd       8000      0.20%     81.66% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatAlu          0      0.00%     81.66% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatCmp          0      0.00%     81.66% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatCvt       6002      0.15%     81.81% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatDiv       2000      0.05%     81.86% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatMisc          0      0.00%     81.86% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatMult       5000      0.13%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatMultAcc          0      0.00%     81.98% # Class of executed instruction. (Count
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatSqrt          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdReduceAdd          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdReduceAlu          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdReduceCmp          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatReduceAdd          0      0.00%     81.98% # Class of executed instruction. (Cou
system.cpu.exec_context.thread_0.statExecutedInstType::SimdFloatReduceCmp          0      0.00%     81.98% # Class of executed instruction. (Cou
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAes          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAesMix          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdSha1Hash          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdSha1Hash2          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdSha256Hash          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdSha256Hash2          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShaSigma2          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShaSigma3          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdPredAlu          0      0.00%     81.98% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::MemRead       486623     12.18%     94.16% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::MemWrite       178327      4.46%     98.62% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMemRead        35095      0.88%     99.50% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMemWrite        19969      0.50%    100.00% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IprAccess          0      0.00%    100.00% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::InstPrefetch          0      0.00%    100.00% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::total      3995727                       # Class of executed instruction. (Count)
```

IntAlu, IntMult, IntDiv对应代码中的整数运算，例如循环变量的加法，同理Float类型的opClass对应了代码中的浮点数运算，例如daxpy循环内的计算，Mem则是在内存上的读写等操作

Step 2

1st part: line 156~209

```
system.cpu.exec_context.thread_0.statExecutedInstType::No_OpClass        13243      0.33%      0.33% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntAlu          3106935     78.56%     78.89% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntMult             652      0.02%     78.91% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntDiv            34863      0.88%     79.79% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatAdd           6792      0.17%     79.96% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCmp              0      0.00%     79.96% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCvt            208      0.01%     79.97% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMult           4000      0.10%     80.07% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMultAcc           0      0.00%     80.07% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatDiv              0      0.00%     80.07% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMisc             0      0.00%     80.07% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatSqrt             0      0.00%     80.07% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAdd            6434      0.16%     80.23% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAddAcc             0      0.00%     80.23% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAlu           23023      0.58%     80.81% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCmp               6      0.00%     80.81% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCvt           13052      0.33%     81.14% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMisc          15419      0.39%     81.53% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMult              0      0.00%     81.53% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMultAcc           0      0.00%     81.53% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShift           345      0.01%     81.54% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShiftAcc           0      0.00%     81.54% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdDiv               0      0.00%     81.54% # Class of executed instruction. (Count)
```

2nd part: line 897~950

```
system.cpu.exec_context.thread_0.statExecutedInstType::No_OpClass            1      0.01%      0.01% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntAlu             8013     57.16%     57.17% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntMult               0      0.00%     57.17% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntDiv                0      0.00%     57.17% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatAdd           1001      7.14%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCmp              0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCvt              0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMult             0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMultAcc          0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatDiv              0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMisc             0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatSqrt             0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAdd               0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAddAcc            0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAlu               0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCmp               0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCvt               0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMisc              0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMult              0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMultAcc           0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShift             0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShiftAcc          0      0.00%     64.31% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdDiv               0      0.00%     64.31% # Class of executed instruction. (Count)
```

3rd part: line 1460~1513

```
system.cpu.exec_context.thread_0.statExecutedInstType::No_OpClass          214      0.83%      0.83% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntAlu            19118     74.19%     75.02% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntMult              13      0.05%     75.07% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::IntDiv              118      0.46%     75.53% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatAdd             51      0.20%     75.73% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCmp              0      0.00%     75.73% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatCvt             48      0.19%     75.91% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMult             0      0.00%     75.91% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMultAcc          0      0.00%     75.91% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatDiv              0      0.00%     75.91% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatMisc             0      0.00%     75.91% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::FloatSqrt             0      0.00%     75.91% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAdd              14      0.05%     75.97% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAddAcc            0      0.00%     75.97% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdAlu              45      0.17%     76.14% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCmp               0      0.00%     76.14% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdCvt              38      0.15%     76.29% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMisc             96      0.37%     76.66% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMult              0      0.00%     76.66% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdMultAcc           0      0.00%     76.66% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShift             5      0.02%     76.68% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdShiftAcc          0      0.00%     76.68% # Class of executed instruction. (Count)
system.cpu.exec_context.thread_0.statExecutedInstType::SimdDiv               0      0.00%     76.68% # Class of executed instruction. (Count)
```

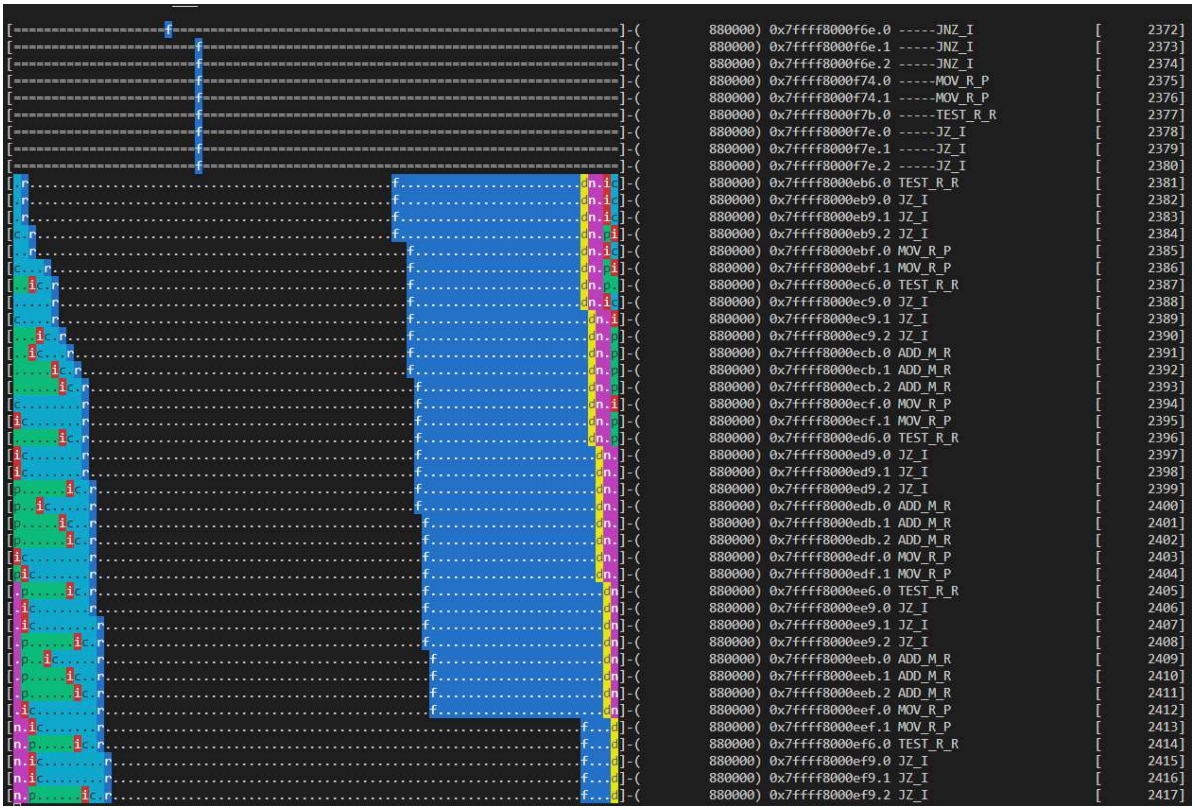
每一部分的大体结构与 Step 1中的一致，当然因为代码划分成3份，每一部分的各类操作占比有所变化，比如第一、二部分涉及浮点运算较多。第一部分IntAlu、IntDiv、IntMult、FloatMult指令尤其多，这可能是因为库函数的调用；第二部分是daxpy循环主体，所以主要是浮点加法、乘法，整数运算来自循环变量、数组访问；第三部分主要是浮点加法和整数运算。详见stats

Step 3

使用的CPU：O3CPU

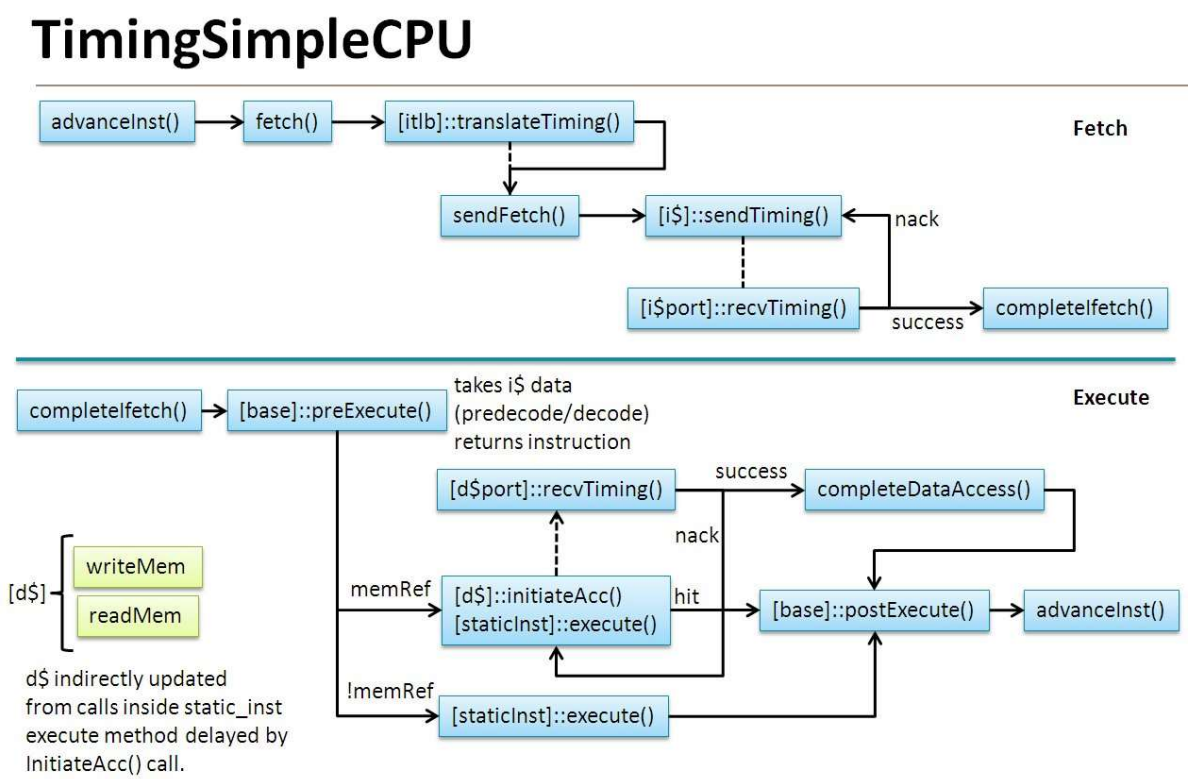
模拟结果详见stats

O3CPU模拟可视化：



What is the difference between an pipeline and a non-pipeline in this assignment：

本次实验中的non-pipeline CPU执行指令过程如下，可以看到非流水线处理器并没有将一条指令划分为多个阶段，一条指令从接收到执行完成是一个整体



流水线处理器则将一条指令划分为五个阶段

Pipeline stages

- Fetch

  Fetches instructions each cycle, selecting which thread to fetch from based on the policy selected. This stage is where the DynInst is first created. Also handles branch prediction.

- Decode

  Decodes instructions each cycle. Also handles early resolution of PC-relative unconditional branches.

- Rename

  Renames instructions using a physical register file with a free list. Will stall if there are not enough registers to rename to, or if back-end resources have filled up. Also handles any serializing instructions at this point by stalling them in rename until the back-end drains.

- Issue/Execute/Writeback

  Our simulator model handles both execute and writeback when the execute() function is called on an instruction, so we have combined these three stages into one stage. This stage (IEW) handles dispatching instructions to the instruction queue, telling the instruction queue to issue instruction, and executing and writing back instructions.

- Commit

  Commits instructions each cycle, handling any faults that the instructions may have caused. Also handles redirecting the front-end in the case of a branch misprediction.

这样可以提高指令并行度，进而提升性能，两次模拟的数据显示，O3CPU比TimingSimpleCPU的模拟速度快了近4倍，可见流水线式处理器较非流水线式处理器可以显著提高执行效率。