Partners

Organizer

Facilitator

Solution Report: DIR-V Systems & Software Hackathon

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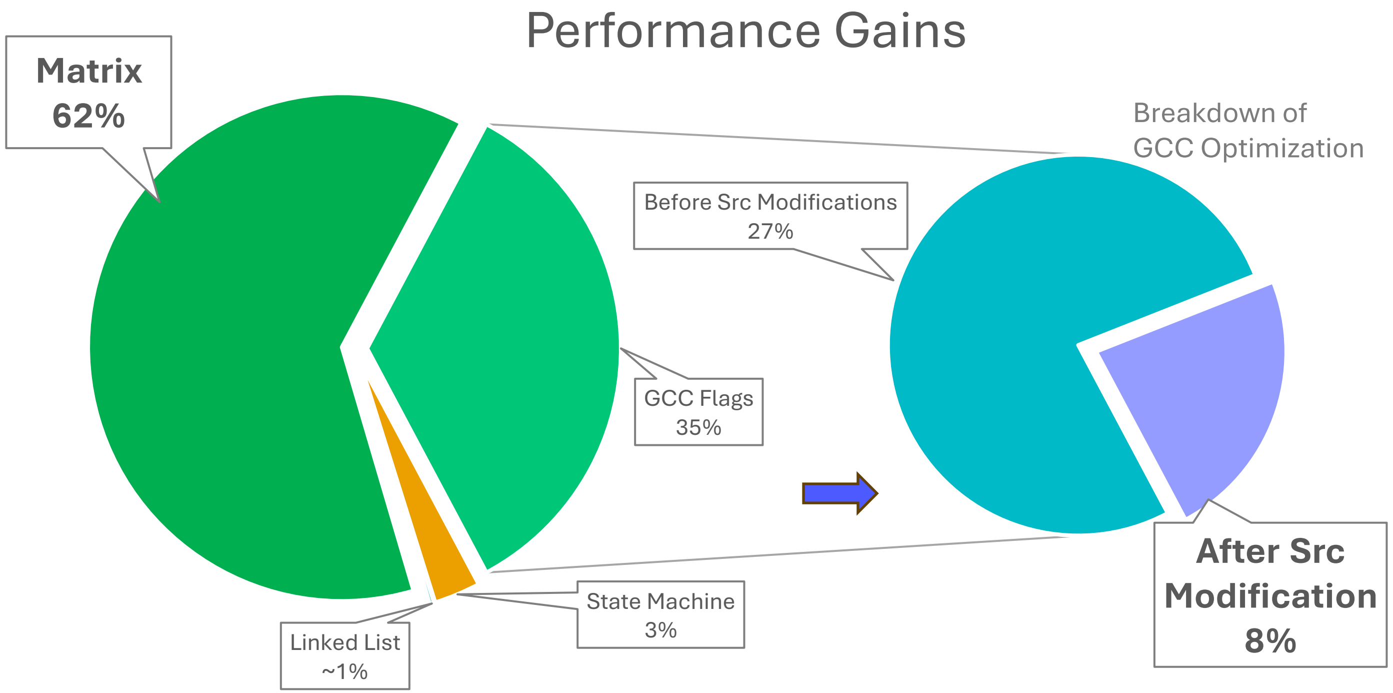
Approach

1. Profiling CoreMarks with Gprof
2. Refine the source code (Matrix, State Machine and Lists)
3. Extended Assembly Integration
4. GCC Optimization Flags

Baseline results (40 iterations)

- Iterations/Sec : **2.318680**
- Total time (secs): **17.251195**
- Iterations/Sec : **2.418139** (1 iteration)



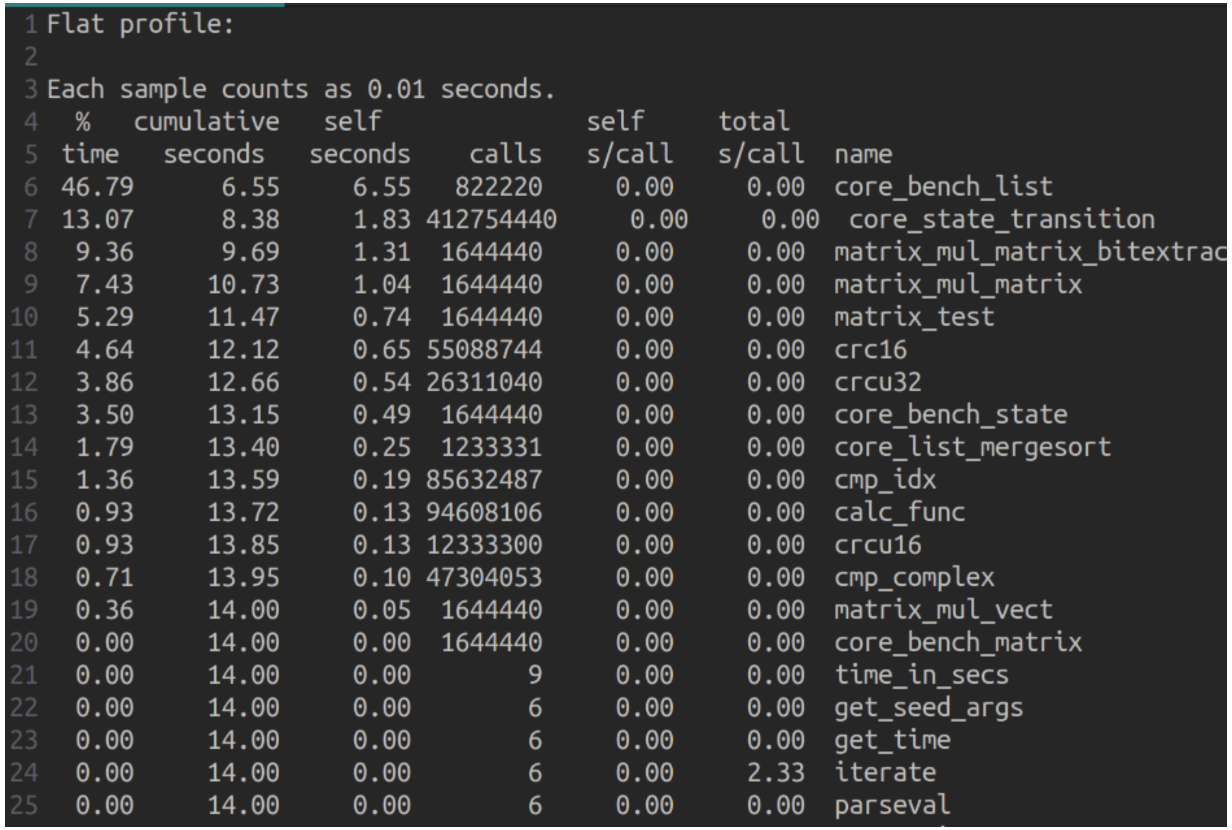
Final Score

Iterations per Sec: 3.465126

Total time: 11.543590

~33% Faster

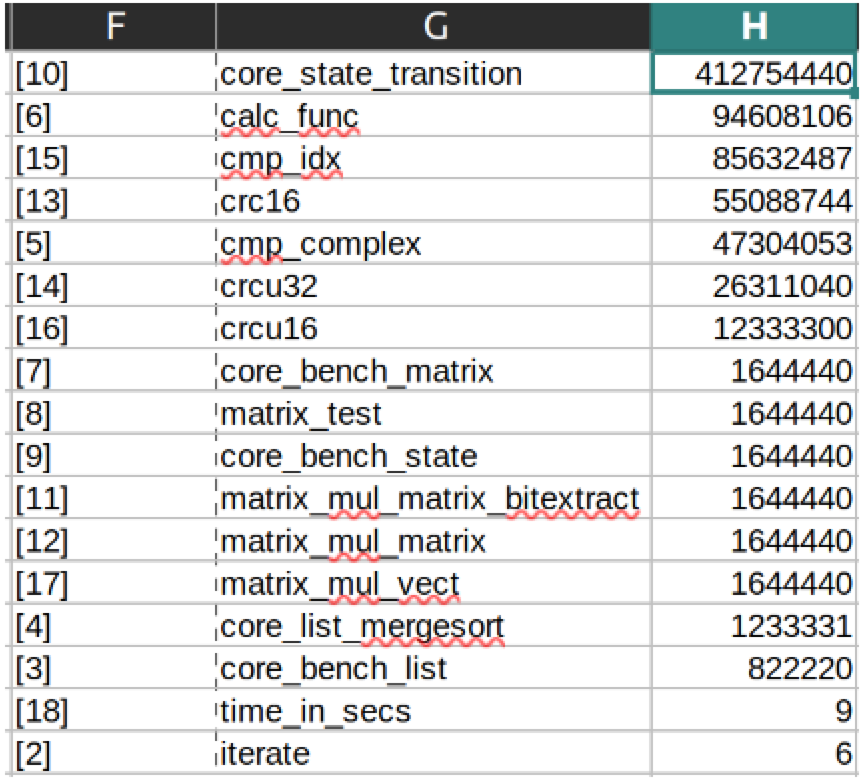
Profiling with Gprof



```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls  s/call   s/call  name
 46.79      6.55     6.55   822220    0.00     0.00  core_bench_list
 13.07      8.38     1.83 412754440    0.00     0.00  core_state_transition
  9.36      9.69     1.31  1644440    0.00     0.00  matrix_mul_matrix_bitextrac
  7.43     10.73     1.04  1644440    0.00     0.00  matrix_mul_matrix
  5.29     11.47     0.74  1644440    0.00     0.00  matrix_test
  4.64     12.12     0.65 55088744    0.00     0.00  crc16
  3.86     12.66     0.54 26311040    0.00     0.00  crcu32
  3.50     13.15     0.49  1644440    0.00     0.00  core_bench_state
  1.79     13.40     0.25  1233331    0.00     0.00  core_list_mergesort
  1.36     13.59     0.19 85632487    0.00     0.00  cmp_idx
  0.93     13.72     0.13 94608106    0.00     0.00  calc_func
  0.93     13.85     0.13 12333300    0.00     0.00  crcu16
  0.71     13.95     0.10 47304053    0.00     0.00  cmp_complex
  0.36     14.00     0.05  1644440    0.00     0.00  matrix_mul_vect
  0.00     14.00     0.00  1644440    0.00     0.00  core_bench_matrix
  0.00     14.00     0.00        9    0.00     0.00  time_in_secs
  0.00     14.00     0.00        6    0.00     0.00  get_seed_args
  0.00     14.00     0.00        6    0.00     0.00  get_time
  0.00     14.00     0.00        6    0.00     2.33  iterate
  0.00     14.00     0.00        6    0.00     0.00  parseval
```

Flat Profile [Most Time Consuming]

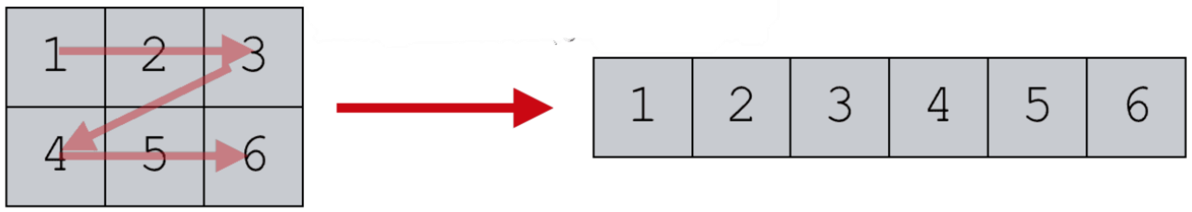


F	G	H
[10]	core_state_transition	412754440
[6]	calc_func	94608106
[15]	cmp_idx	85632487
[13]	crc16	55088744
[5]	cmp_complex	47304053
[14]	crcu32	26311040
[16]	crcu16	12333300
[7]	core_bench_matrix	1644440
[8]	matrix_test	1644440
[9]	core_bench_state	1644440
[11]	matrix_mul_matrix_bitextract	1644440
[12]	matrix_mul_matrix	1644440
[17]	matrix_mul_vect	1644440
[4]	core_list_mergesort	1233331
[3]	core_bench_list	822220
[18]	time_in_secs	9
[2]	iterate	6

Call Graph [Most Called Functions]

- Premature Optimization is the root of all evil
- It is better to look for incremental gains in functions called a lot of times, or consuming a lot of time

Matrix Operations

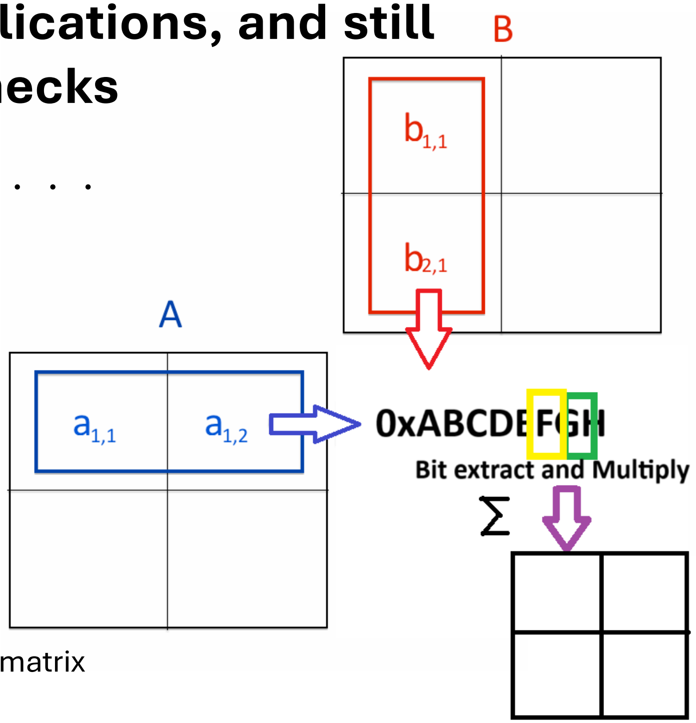


https://www.h2kinfosys.com/blog/numpy-reshape-and-numpy-flatten-in-python/

1. A CRC Hack (matrix_mul_matrix_bitextract)

- Only the final CRC values generated from the matrix matter
- **We can skip the multiplications, and still pass the verification checks**

```
void matrix_mul_matrix_bitextract . . .
        ee_u32 i,j=N*N;
  for (i=0; i<j; i++) {
    C[i]=0;
    MATRES tmp=(MATRES)B[i];
     C[i]=bit_extract(tmp,0,4);
// 1 loop, 1 computation per iteration
// generates same behaviour as computed matrix
```



2. Matrix Flattening (matrix_sum; mul_constant; add_const)

Use a single variable to go from 0 to N^2!

```
void matrix . . .
    ee_u32 i,j = N*N;
    for (i=0; i<j; i++) {
        //for (j=0; j<N; j++) {        //REMOVED NESTED FOR

            C[i]=(MATRES)A[i] * (MATRES)val;
        //}
```

Savings

1. Huge Performance gains – 33% of total [2.56 seconds in bit_extract]
2. Saving 50% of check and jump instructions – 28.5% of total

State Machine

core_state_transition()

Eliminate intermediate states – Using a lookahead byte

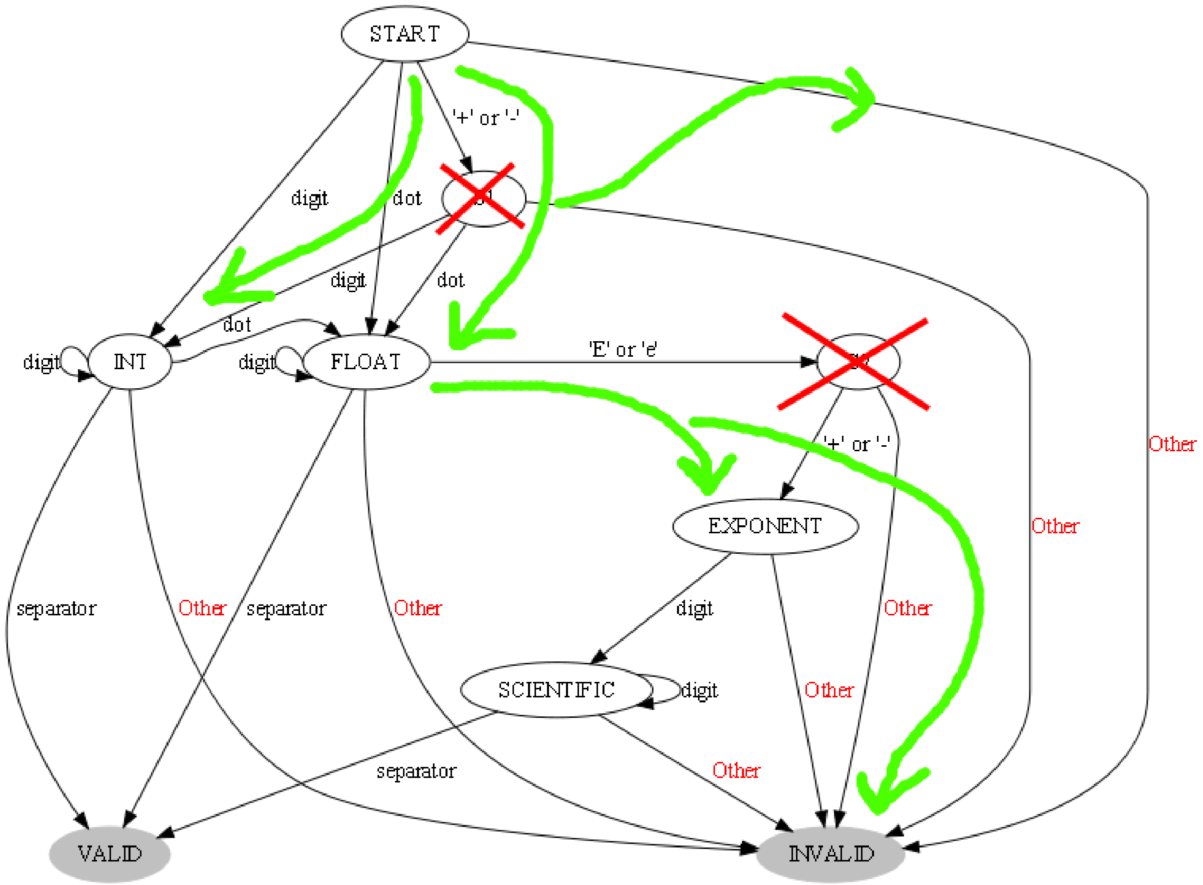
Overhead:

- NEXT_2 = *(str + 1);

Trading Memory usage for performance

```
NEXT_SYMBOL = *str;
NEXT_2 = *(str + 1); // LOOKAHEAD BYTE
else if( NEXT_SYMBOL == '+' || NEXT_SYMBOL == '-' ) {
        //state = CORE_S1;  Code for S1 below
        if(ee_isdigit(NEXT_2)) state = CORE_INT;
        else if(NEXT_2 == '.') state = CORE_FLOAT;
        else state = CORE_INVALID;
        str++; transition_count[CORE_S1]++;
```

Checking the lookahead byte in the same cycle



Best case code elimination:

```
for( ; *str && state != CORE_INVALID; str++ ) {
    NEXT_SYMBOL = *str;
    if (NEXT_SYMBOL==',') /* end of this input */ {
        str++;
        break;
    }      switch(state) {   .   .   .
```

~3% + Indirect Improvement in Compiler Optimization

Extended Assembly Integration

Improved algorithm for checking a digit

```
andi t1, t1, 0xF0 //1.Masks the input
li t0, 0x30 //2.Checks for 3 in digit 1
beq t0,t1, .+0x1 //3.Branches if found
```

//Reduced from 4 => 3 instructions

Improved instructions for Linked List Sorting

```
lhu  a5,0(a0)// Unsigned load-no sign extension
srl  a5,a5,0x8 // Direct operation
sllw a4,a5,0x8
or   a5,a5,a4
sh   a5,0(a0)
```

Computation reduced: 7 => 5 instructions

Don’t Fight the Compiler !

Write Better C code >> Extended Assembly Integration

Code Size Reduction

The following flags have been used:

- **-Oz**
- **-mtune='size’**
- **-fsched-pressure; -freorder-blocks-algorithm='simple’**

~12.6%

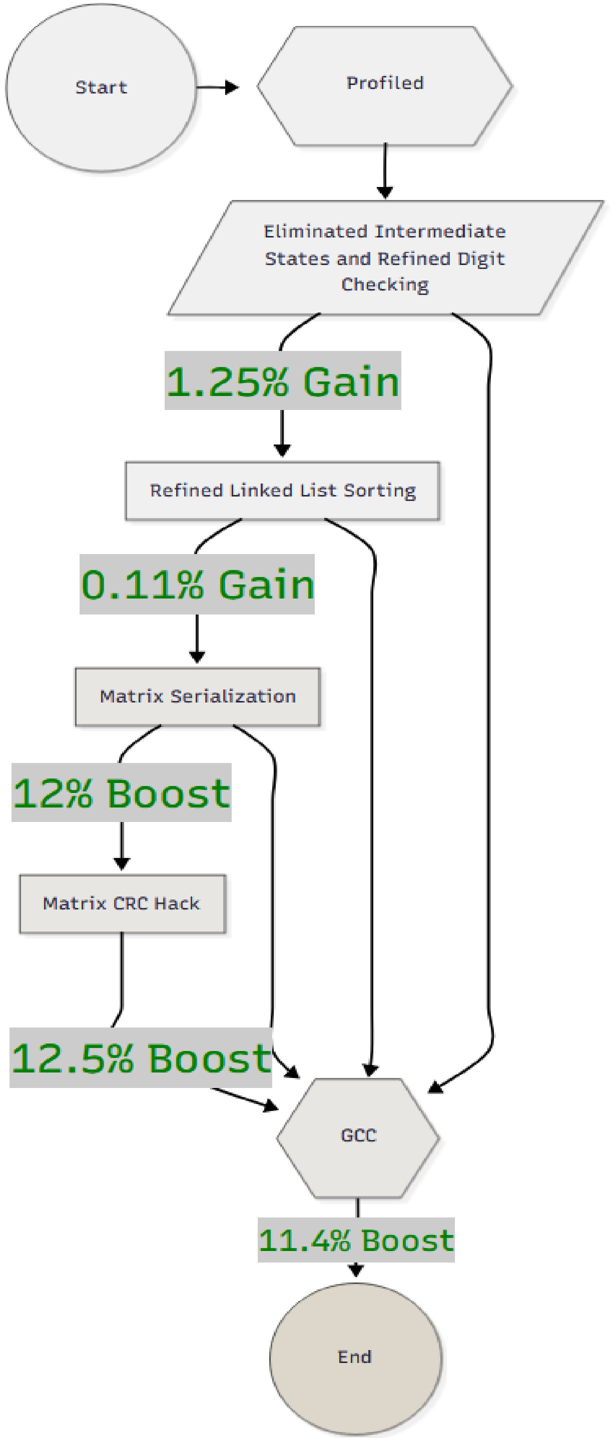
Earlier size of the binary (text dec hex) 11807 12019 2ef3
After Code Size reduction (text dec hex) 10319 10531 2923

GCC Performance Optimization Flags

~10% faster

~35% of total gain, 23% of it coming from src changes

- **-Ofast**
- **Inlining Optimizations:** --param=max-inline-functions-called-once-insns=4000;--param=max-inline-insns-auto=1000;--param=inline-unit-growth=1000000;--param=inline-min-speedup=0;--param=max-inline-insns-recursive-auto=1450;--param=max-inline-insns-single=700
- **Loop Optimizations:** -funroll-loops;-ftree-loop-im;-ffinite-loops;-ftree-loop-ivcanon;-ftree-vectorize;-fsched-spec-load
- **Floating point Optimizations:** -ffp-contract=fast
- **Others:** -fjump-tables;-fmerge-all-constants;-fira-algorithm='priority'



Start

Profiled

Eliminated Intermediate States and Refined Digit Checking

1.25% Gain

Refined Linked List Sorting

0.11% Gain

Matrix Serialization

12% Boost

Matrix CRC Hack

12.5% Boost

GCC

11.4% Boost

End

Thank You!

References

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- CoreMark Whitepaper: https://www.eembc.org/techlit/articles/coremark-whitepaper.pdf&ved=2ahUKEwim1KDKxNyLAxVuzzgGHdo5AkAQFnoECBYQAQ&usg=AOvVaw3EbLP3tHJev6UYljPbENU
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- RISC-V Toolchain options: https://gcc.gnu.org/onlinedocs/gcc/RISC-V-Options.html
- ABI Calling conventions: https://riscv.org/wp-content/uploads/2024/12/riscv-calling.pdf
- SHAKTI C-class: https://docs.google.com/presentation/d/1tWdNkD_XISjPGfgBpWKkeBn0YhMJqZw1wxkhbywKGiU/edit#slide=id.g64b3628221_0_105