



**POLITECNICO**  
MILANO 1863

# Low level optimization of a Convolutional Layer in ResNet-8 on RISC-V

## Screenshots of testing results

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Progetto di Ingegneria Informatica

# Conversion --- Conv0-C Baseline

## HEX → DECIMAL Conversion of the results:

Conv0-C Baseline: 0x04F1DE8 -> 5 185 128 clock cycles

Conv0-ASmv1: 0x052B7C8 -> 5 421 000 clock cycles

Conv0-ASmv2: 0x01CF228 -> 1 897 000 clock cycles

Conv0-Strassen 1liv: 0x035ECB0 -> 3 528 368 clock cycles

Conv0-Strassen 2liv: 0x0D9B5BFD8 -> 3 654 760 280 clock cycles

ResNet-8: 0x0D6346D0 -> 224 508 752 clock cycles

ResNet-8 with Strassen's Algorithm: 0x0DA61460 -> 228 988 000 clock cycles

```
Last login: Tue Aug 19 19:18:49 on ttys000
[(base) lucamedea@MacBook-Pro-di-Luca ~ % cd Desktop
[(base) lucamedea@MacBook-Pro-di-Luca Desktop % cd Ctest
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -o crt0.o crt0.S

crt0.S: Assembler messages:
crt0.S: Warning: end of file in comment; newline inserted
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mmodel=medany \
    -ffreestanding -fno-pic -fno-pie -nostartfiles \
    -c conv0.c -o conv0.o
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mmodel=medany \
    -ffreestanding -fno-pic -fno-pie -nostartfiles \
    -Wl,-T,link.ld,--no-relax \
    -o conv0.elf crt0.o conv0.o
/opt/homebrew/Cellar/riscv-gnu-toolchain/main/lib/gcc/riscv64-unknown-elf/14.2.0/../../../../riscv64-unknown-elf/bin/ld: warning: conv0.elf has a LOAD segment with RWX permissions
(base) lucamedea@MacBook-Pro-di-Luca Ctest % qemu-system-riscv64 -machine virt -cpu rv64 -nographic \
    -bios none -serial mon:stdio -kernel conv0.elf
conv0 cycles: 0x00000000004F1DE8
```



# Conv0-Assembly RISC-V

## Conv0-Assembly RISC-V, First Version

```
Last login: Thu Aug 14 17:08:19 on ttys001
[(base) lucamedea@MacBook-Pro-di-Luca ~ % cd Desktop
[(base) lucamedea@MacBook-Pro-di-Luca Desktop % cd conv0_v1
(base) lucamedea@MacBook-Pro-di-Luca conv0_v1 % riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -o conv0_v1.o conv0_v1.s
riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -o data_v1.o data_v1.s
[(base) lucamedea@MacBook-Pro-di-Luca conv0_v1 % riscv64-unknown-elf-ld -T link.ld -o conv0_v1.elf conv0_v1.o data_v1.o
riscv64-unknown-elf-ld: warning: conv0_v1.elf has a LOAD segment with RWX permissions
(base) lucamedea@MacBook-Pro-di-Luca conv0_v1 % qemu-system-riscv64 \
-machine virt \
-cpu rv64 \
-nographic \
-bios none \
-serial mon:stdio \
-kernel conv0_v1.elf
00000000052B7C8
█
```

## Conv0-Assembly RISC-V, Second Version

```
Last login: Thu Aug 14 18:44:46 on ttys001
[(base) lucamedea@MacBook-Pro-di-Luca ~ % cd Desktop
[(base) lucamedea@MacBook-Pro-di-Luca Desktop % cd conv0_v3
(base) lucamedea@MacBook-Pro-di-Luca conv0_v3 % riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -o conv0_v3.o conv0_v3.s
riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -o data_v3.o data_v3.s
[(base) lucamedea@MacBook-Pro-di-Luca conv0_v3 % riscv64-unknown-elf-ld -T link.ld -o conv0_v3.elf conv0_v3.o data_v3.o

riscv64-unknown-elf-ld: warning: conv0_v3.elf has a LOAD segment with RWX permissions
(base) lucamedea@MacBook-Pro-di-Luca conv0_v3 % qemu-system-riscv64 -machine virt -cpu rv64 -nographic -bios none -serial mon:stdio -kernel conv0_v3.elf
00000000001CF228
█
```



# Conv0-Strassen

## Conv0-C, Strassen applied at only one level of multiplications

```
Last login: Tue Aug 19 19:01:09 on ttys000
[(base) lucamedea@MacBook-Pro-di-Luca ~ % cd Desktop
[(base) lucamedea@MacBook-Pro-di-Luca Desktop % cd test
(base) lucamedea@MacBook-Pro-di-Luca test % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mcmmodel=medany \
  -ffreestanding -fno-pic -fno-pie -mno-relax \
  -c conv0_strassen_1liv.c -o conv0_strassen_1liv.o
[(base) lucamedea@MacBook-Pro-di-Luca test % riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -mno-relax \
  -o crt0.o crt0.S
crt0.S: Assembler messages:
crt0.S: Warning: end of file in comment; newline inserted
(base) lucamedea@MacBook-Pro-di-Luca test % riscv64-unknown-elf-ld --no-relax -T link.ld -o conv0_strassen_1liv.elf \
  crt0.o conv0_strassen_1liv.o
riscv64-unknown-elf-ld: warning: conv0_strassen_1liv.elf has a LOAD segment with RWX permissions
(base) lucamedea@MacBook-Pro-di-Luca test % qemu-system-riscv64 -machine virt -cpu rv64 -nographic \
  -bios none -serial mon:stdio -kernel conv0_strassen_1liv.elf
conv0_strassen cycles: 0x000000000035ECB0
```

## Conv0-C, Strassen applied at two levels of multiplications (Significant Overhead)

```
Last login: Tue Aug 19 19:44:25 on ttys000
[(base) lucamedea@MacBook-Pro-di-Luca ~ % cd Desktop
[(base) lucamedea@MacBook-Pro-di-Luca Desktop % cd Ctest
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mcmmodel=medany \
  -ffreestanding -fno-pic -fno-pie -nostartfiles -mno-relax \
  -c conv0_strassen_2liv.c -o conv0_strassen_2liv.o
[(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -mno-relax \
  -o crt0.o crt0.S
crt0.S: Assembler messages:
crt0.S: Warning: end of file in comment; newline inserted
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mcmmodel=medany \
  -nostartfiles -Wl,-T,link.ld,--no-relax \
  crt0.o conv0_strassen_2liv.o -o conv0_strassen_2liv.elf
/opt/homebrew/Cellar/riscv-gnu-toolchain/main/lib/gcc/riscv64-unknown-elf/14.2.0/../../../../riscv64-unknown-elf/bin/ld: warning: conv0_strassen_2liv.elf has a LOAD segment with RWX permissions
(base) lucamedea@MacBook-Pro-di-Luca Ctest % qemu-system-riscv64 -machine virt -cpu rv64 -nographic \
  -bios none -serial mon:stdio -kernel conv0_strassen_2liv.elf
conv0_strassen_2liv cycles: 0x00000000D9B5BFD8
```



# ResNet-8

## ResNet-8 with baseline Conv0

```
Last login: Tue Aug 19 19:58:22 on ttys000
(base) lucamedea@MacBook-Pro-di-Luca ~ % cd Desktop
(base) lucamedea@MacBook-Pro-di-Luca Desktop % cd Ctest
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mcmmodel=medany \
  -ffreestanding -fno-pic -fno-pie -nostartfiles -mno-relax \
  -c resnet8.c -o resnet8.o
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -mno-relax \
  -o crt0.o crt0.S
crt0.S: Assembler messages:
crt0.S: Warning: end of file in comment; newline inserted
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mcmmodel=medany \
  -nostartfiles -Wl,-T,link.ld,--no-relax \
  crt0.o resnet8.o -o resnet8.elf
/opt/homebrew/Cellar/riscv-gnu-toolchain/main/lib/gcc/riscv64-unknown-elf/14.2.0/../../../../riscv64-unknown-elf/bin/ld: warning: resnet8.elf has a LOAD segment with RWX permissions
(base) lucamedea@MacBook-Pro-di-Luca Ctest % qemu-system-riscv64 -machine virt -cpu rv64 -nographic \
  -bios none -serial mon:stdio -kernel resnet8.elf
resnet8 cycles: 0x00000000D6346D0
```

## ResNet-8 with Strassen's algorithm

```
Last login: Sat Aug 23 11:36:37 on ttys000
(base) lucamedea@MacBook-Pro-di-Luca ~ % cd Desktop
(base) lucamedea@MacBook-Pro-di-Luca Desktop % cd Ctest
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-as -march=rv64im_zicsr -mabi=lp64 -mno-relax \
  crt0.s -o crt0.o
crt0.s: Assembler messages:
crt0.s: Warning: end of file in comment; newline inserted
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mcmmodel=medany \
  -ffreestanding -fno-pic -mno-relax -c \
  resnet8_strassen.c -o resnet8_strassen.o
(base) lucamedea@MacBook-Pro-di-Luca Ctest % riscv64-unknown-elf-gcc -O2 -march=rv64im_zicsr -mabi=lp64 -mcmmodel=medany \
  -nostartfiles -Wl,-T,link.ld -mno-relax \
  crt0.o resnet8_strassen.o -o resnet8_strassen.elf
/opt/homebrew/Cellar/riscv-gnu-toolchain/main/lib/gcc/riscv64-unknown-elf/14.2.0/../../../../riscv64-unknown-elf/bin/ld: warning: resnet8_strassen.elf has a LOAD segment with RWX permissions
(base) lucamedea@MacBook-Pro-di-Luca Ctest % qemu-system-riscv64 -machine virt -cpu rv64 -nographic \
  -bios none -serial mon:stdio -kernel resnet8_strassen.elf
resnet8_strassen cycles: 0x00000000DA61460
```

