RISC-V arch test
Module: Privileged spec
Task 2

Test Description:

This test starts in the Machine mode and then configures the memory using pmp, after configuration, test switches to the machine mode and tests the load store and access instrs on memory configured using PMP, after testing it in supervisor mode, there is an ecall instr that helps to switch back to machine mode and then these load, store and access instrs are tested in the machine mode as well.

```
core   0: 0x000000008000001c (0x8002829b) addiw    t0, t0, -2048
core   0: 3 0x000000008000001c (0x8002829b) x5  0x0000000000001800
core   0: 0x0000000080000020 (0x0053e3b3) or      t2, t2, t0
core   0: 3 0x0000000080000020 (0x0053e3b3) x7  0x0000000a00001800
core   0: 0x0000000080000024 (0x30039073) csrw    mstatus, t2
core   0: 3 0x0000000080000024 (0x30039073) c768_mstatus 0x0000000a00001800
```

Start test in Machine mode

```
core   0: 3 0x0000000080000028 (0x07c000ef) x1  0x000000008000002c
core   0: >>>>  configure_pmp
core   0: 0x00000000800000a4 (0x000802b7) lui     t0, 0x80
core   0: 3 0x00000000800000a4 (0x000802b7) x5  0x0000000000080000
core   0: 0x00000000800000a8 (0x0012829b) addiw   t0, t0, 1
core   0: 3 0x00000000800000a8 (0x0012829b) x5  0x0000000000080001
core   0: 0x00000000800000ac (0x00c29293) slli    t0, t0, 12
core   0: 3 0x00000000800000ac (0x00c29293) x5  0x0000000080001000
core   0: 0x00000000800000b0 (0x0022d293) srli    t0, t0, 2
core   0: 3 0x00000000800000b0 (0x0022d293) x5  0x0000000020000400
core   0: 0x00000000800000b4 (0x3b029073) csrw    pmpaddr0, t0
core   0: 3 0x00000000800000b4 (0x3b029073) c944_pmpaddr0 0x0000000020000400
core   0: 0x00000000800000b8 (0x070702b7) lui     t0, 0x7070
core   0: 3 0x00000000800000b8 (0x070702b7) x5  0x0000000007070000
core   0: 0x00000000800000bc (0x70c2829b) addiw   t0, t0, 1804
core   0: 3 0x00000000800000bc (0x70c2829b) x5  0x000000000707070c
core   0: 0x00000000800000c0 (0x3a029073) csrw    pmpcfg0, t0
core   0: 3 0x00000000800000c0 (0x3a029073) c928_pmpcfg0 0x000000000707070c
core   0: 0x00000000800000c4 (0x000802b7) lui     t0, 0x80
core   0: 3 0x00000000800000c4 (0x000802b7) x5  0x0000000000080000
core   0: 0x00000000800000c8 (0x0012829b) addiw   t0, t0, 1
core   0: 3 0x00000000800000c8 (0x0012829b) x5  0x0000000000080001
core   0: 0x00000000800000cc (0x00c29293) slli    t0, t0, 12
core   0: 3 0x00000000800000cc (0x00c29293) x5  0x0000000080001000
core   0: 0x00000000800000d0 (0x0022d293) srli    t0, t0, 2
core   0: 3 0x00000000800000d0 (0x0022d293) x5  0x0000000020000400
core   0: 0x00000000800000d4 (0x1ff2e293) ori     t0, t0, 511
core   0: 3 0x00000000800000d4 (0x1ff2e293) x5  0x00000000200005ff
core   0: 0x00000000800000d8 (0x3b129073) csrw    pmpaddr1, t0
core   0: 3 0x00000000800000d8 (0x3b129073) c945_pmpaddr1 0x00000000200005ff
core   0: 0x00000000800000dc (0x070722b7) lui     t0, 0x7072
core   0: 3 0x00000000800000dc (0x070722b7) x5  0x0000000007072000
core   0: 0x00000000800000e0 (0x90c2829b) addiw   t0, t0, -1780
core   0: 3 0x00000000800000e0 (0x90c2829b) x5  0x000000000707190c
core   0: 0x00000000800000e4 (0x3a029073) csrw    pmpcfg0, t0
core   0: 3 0x00000000800000e4 (0x3a029073) c928_pmpcfg0 0x000000000707190c
core   0: 0x00000000800000e8 (0x000202b7) lui     t0, 0x20
core   0: 3 0x00000000800000e8 (0x000202b7) x5  0x0000000000020000
```

Configure PMP in machine mode

```
18 core   0: 3 0x0000000080000044 (0x0053e3b3) x7  0x0000000a00000800
19 core   0: 0x0000000080000048 (0x30039073) csrw    mstatus, t2
20 core   0: 3 0x0000000080000048 (0x30039073) c768_mstatus 0x0000000a00000800
21 core   0: 0x000000008000004c (0x00000297) auipc   t0, 0x0
22 core   0: 3 0x000000008000004c (0x00000297) x5  0x000000008000004c
23 core   0: 0x0000000080000050 (0x01028293) addi    t0, t0, 16
24 core   0: 3 0x0000000080000050 (0x01028293) x5  0x000000008000005c
25 core   0: 0x0000000080000054 (0x34129073) csrw    mepc, t0
26 core   0: 3 0x0000000080000054 (0x34129073) c833_mepc 0x000000008000005c
27 core   0: 0x0000000080000058 (0x30200073) mret
28 core   0: 3 0x0000000080000058 (0x30200073) c768_mstatus 0x0000000a00000080
29 core   0: >>>>  supervisor_mode
30 core   0: 0x000000008000005c (0x0e4000ef) jal     pc + 0xe4
31 core   0: 1 0x000000008000005c (0x0e4000ef) x1  0x0000000080000060
```

Switch to supervisor mode

```
14 core   0: 0x0000000080000140 (0x00008413) mv      s0, ra
15 core   0: 1 0x0000000080000140 (0x00008413) x8  0x0000000080000060
16 core   0: 0x0000000080000144 (0x0010029b) addiw   t0, zero, 1
17 core   0: 1 0x0000000080000144 (0x0010029b) x5  0x0000000000000001
18 core   0: 0x0000000080000148 (0x01f29293) slli    t0, t0, 31
19 core   0: 1 0x0000000080000148 (0x01f29293) x5  0x0000000080000000
20 core   0: 0x000000008000014c (0x00428293) addi    t0, t0, 4
21 core   0: 1 0x000000008000014c (0x00428293) x5  0x0000000080000004
22 core   0: 0x0000000080000150 (0x0002a303) lw      t1, 0(t0)
23 core   0: exception trap_load_access_fault, epc 0x0000000080000150
24 core   0:           tval 0x0000000080000004
25 core   0: >>>>  trap_handler
```

Load fault in TOR region as it has only execute permissions

```
24 core   0: 0x00000000800001e0 (0x00628863) beq     t0, t1, pc + 16
25 core   0: 3 0x00000000800001e0 (0x00628863)
26 core   0: >>>>  handle_load_fault
27 core   0: 0x00000000800001f0 (0x341022f3) csrr    t0, mepc
28 core   0: 3 0x00000000800001f0 (0x341022f3) x5  0x0000000080000150
29 core   0: 0x00000000800001f4 (0x00428293) addi    t0, t0, 4
30 core   0: 3 0x00000000800001f4 (0x00428293) x5  0x0000000080000154
31 core   0: 0x00000000800001f8 (0x34129073) csrw    mepc, t0
32 core   0: 3 0x00000000800001f8 (0x34129073) c833_mepc 0x0000000080000154
33 core   0: 0x00000000800001fc (0x30200073) mret
34 core   0: 3 0x00000000800001fc (0x30200073) c768_mstatus 0x0000000a00000080
35 core   0: 0x0000000080000154 (0x0010029b) addiw   t0, zero, 1
```

Handle load fault

```
11 core   0: 0x0000000080000154 (0x0010029b) addiw   t0, zero, 1
12 core   0: 1 0x0000000080000154 (0x0010029b) x5  0x0000000000000001
13 core   0: 0x0000000080000158 (0x01f29293) slli    t0, t0, 31
14 core   0: 1 0x0000000080000158 (0x01f29293) x5  0x0000000080000000
15 core   0: 0x000000008000015c (0x00428293) addi    t0, t0, 4
16 core   0: 1 0x000000008000015c (0x00428293) x5  0x0000000080000004
17 core   0: 0x0000000080000160 (0x00400313) li      t1, 4
18 core   0: 1 0x0000000080000160 (0x00400313) x6  0x0000000000000004
19 core   0: 0x0000000080000164 (0x0062a023) sw      t1, 0(t0)
20 core   0: exception trap_store_access_fault, epc 0x0000000080000164
21 core   0:           tval 0x0000000080000004
22 core   0: >>>>  trap_handler
```

Store fault in TOR region

```
core   0: 0x00000000800001e4 (0x00700313) li      t1, 7
core   0: 3 0x00000000800001e4 (0x00700313) x6  0x0000000000000007
core   0: 0x00000000800001e8 (0x00628c63) beq     t0, t1, pc + 24
core   0: 3 0x00000000800001e8 (0x00628c63)
core   0: >>>>  handle_store_fault
core   0: 0x0000000080000200 (0x341022f3) csrr    t0, mepc
core   0: 3 0x0000000080000200 (0x341022f3) x5  0x0000000080000164
core   0: 0x0000000080000204 (0x00428293) addi    t0, t0, 4
core   0: 3 0x0000000080000204 (0x00428293) x5  0x0000000080000168
core   0: 0x0000000080000208 (0x34129073) csrw    mepc, t0
core   0: 3 0x0000000080000208 (0x34129073) c833_mepc 0x0000000080000168
core   0: 0x000000008000020c (0x30200073) mret
```

Handle store Fault

```
core   0: 3 0x000000008000020c (0x30200073) c768_mstatus 0x0000000a00000080
core   0: 0x0000000080000168 (0x000802b7) lui     t0, 0x80
core   0: 1 0x0000000080000168 (0x000802b7) x5  0x0000000000080000
core   0: 0x000000008000016c (0x0012829b) addiw   t0, t0, 1
core   0: 1 0x000000008000016c (0x0012829b) x5  0x0000000000080001
core   0: 0x0000000080000170 (0x00c29293) slli    t0, t0, 12
core   0: 1 0x0000000080000170 (0x00c29293) x5  0x0000000080001000
core   0: 0x0000000080000174 (0x00428293) addi    t0, t0, 4
core   0: 1 0x0000000080000174 (0x00428293) x5  0x0000000080001004
core   0: 0x0000000080000178 (0x0002a303) lw      t1, 0(t0)
core   0: 1 0x0000000080000178 (0x0002a303) x6  0xffffffff87654321 mem 0x0000000080001004
```

No Load Fault in NAPOT region

```
core   0: 0x000000008000017c (0x000802b7) lui     t0, 0x80
core   0: 1 0x000000008000017c (0x000802b7) x5  0x0000000000080000
core   0: 0x0000000080000180 (0x0012829b) addiw   t0, t0, 1
core   0: 1 0x0000000080000180 (0x0012829b) x5  0x0000000000080001
core   0: 0x0000000080000184 (0x00c29293) slli    t0, t0, 12
core   0: 1 0x0000000080000184 (0x00c29293) x5  0x0000000080001000
core   0: 0x0000000080000188 (0x00428293) addi    t0, t0, 4
core   0: 1 0x0000000080000188 (0x00428293) x5  0x0000000080001004
core   0: 0x000000008000018c (0x00400313) li      t1, 4
core   0: 1 0x000000008000018c (0x00400313) x6  0x0000000000000004
core   0: 0x0000000080000190 (0x0062a023) sw      t1, 0(t0)
core   0: exception trap_store_access_fault, epc 0x0000000080000190
core   0:           tval 0x0000000080001004
core   0: >>>>  trap_handler
core   0: 0x00000000800001b0 (0xff010113) addi    sp, sp, -16
core   0: 3 0x00000000800001b0 (0xff010113) x2  0x0000000080002ff0
core   0: 0x00000000800001b4 (0x00512023) sw      t0, 0(sp)
core   0: 3 0x00000000800001b4 (0x00512023) mem 0x0000000080002ff0 0x80001004
```

Store Fault in NAPOT region

```
core   0: 0x000000008000020c (0x30200073) mret
core   0: 3 0x000000008000020c (0x30200073) c768_mstatus 0x0000000a00000080
core   0: 0x0000000080000194 (0x000802b7) lui     t0, 0x80
core   0: 1 0x0000000080000194 (0x000802b7) x5  0x0000000000080000
core   0: 0x0000000080000198 (0x0012829b) addiw   t0, t0, 1
core   0: 1 0x0000000080000198 (0x0012829b) x5  0x0000000000080001
core   0: 0x000000008000019c (0x00c29293) slli    t0, t0, 12
core   0: 1 0x000000008000019c (0x00c29293) x5  0x0000000080001000
core   0: 0x00000000800001a0 (0x00428293) addi    t0, t0, 4
core   0: 1 0x00000000800001a0 (0x00428293) x5  0x0000000080001004
core   0: 0x00000000800001a4 (0x000280e7) jalr    t0
core   0: 1 0x00000000800001a4 (0x000280e7) x1  0x00000000800001a8
core   0: exception trap_instruction_access_fault, epc 0x0000000080001004
core   0:           tval 0x0000000080001004
core   0: >>>>  trap_handler
core   0: 0x00000000800001b0 (0xff010113) addi    sp, sp, -16
core   0: 3 0x00000000800001b0 (0xff010113) x2  0x0000000080002fe0
core   0: 0x00000000800001b4 (0x00512023) sw      t0, 0(sp)
```

Instr access fault in NAPOT region

```
core   0: 3 0x00000000800001c8 (0x342022f3) x5  0x0000000000000001
core   0: 0x00000000800001cc (0x00900313) li      t1, 9
core   0: 3 0x00000000800001cc (0x00900313) x6  0x0000000000000009
core   0: 0x00000000800001d0 (0x04628463) beq     t0, t1, pc + 72
core   0: 3 0x00000000800001d0 (0x04628463)
core   0: 0x00000000800001d4 (0x00100313) li      t1, 1
core   0: 3 0x00000000800001d4 (0x00100313) x6  0x0000000000000001
core   0: 0x00000000800001d8 (0x02628c63) beq     t0, t1, pc + 56
core   0: 3 0x00000000800001d8 (0x02628c63)
core   0: >>>>  handle_instruction_fault
core   0: 0x0000000080000210 (0x34109073) csrw    mepc, ra
core   0: 3 0x0000000080000210 (0x34109073) c833_mepc 0x00000000800001a8
core   0: 0x0000000080000214 (0x30200073) mret
core   0: 3 0x0000000080000214 (0x30200073) c768_mstatus 0x0000000a00000080
core   0: 0x00000000800001a8 (0x00040093) mv      ra, s0
core   0: 1 0x00000000800001a8 (0x00040093) x1  0x0000000080000060
core   0: 0x00000000800001ac (0x00008067) ret
```

Handle instr fault

```
core   0: 1 0x00000000800001a8 (0x00040093) x1  0x0000000080000060
core   0: 0x00000000800001ac (0x00008067) ret
core   0: 1 0x00000000800001ac (0x00008067)
core   0: 0x0000000080000060 (0x00000073) ecall
core   0: exception trap_supervisor_ecall, epc 0x0000000080000060
core   0: >>>>  trap_handler
```

Ecall to switch to machine mode

```
0 core   0: 0x000000008000014c (0x00428293) addi    t0, t0, 4
1 core   0: 3 0x000000008000014c (0x00428293) x5  0x0000000080000004
2 core   0: 0x0000000080000150 (0x0002a303) lw      t1, 0(t0)
3 core   0: exception trap_load_access_fault, epc 0x0000000080000150
4 core   0:           tval 0x0000000080000004
5 core   0: >>>>  trap_handler
6 core   0: 0x00000000800001b0 (0xff010113) addi    sp, sp, -16
```

Load fault in Machine mode in TOR region

```
27 core   0: 3 0x0000000080000154 (0x0010029b) x5  0x0000000000000001
28 core   0: 0x0000000080000158 (0x01f29293) slli    t0, t0, 31
29 core   0: 3 0x0000000080000158 (0x01f29293) x5  0x0000000080000000
30 core   0: 0x000000008000015c (0x00428293) addi    t0, t0, 4
31 core   0: 3 0x000000008000015c (0x00428293) x5  0x0000000080000004
32 core   0: 0x0000000080000160 (0x00400313) li      t1, 4
33 core   0: 3 0x0000000080000160 (0x00400313) x6  0x0000000000000004
34 core   0: 0x0000000080000164 (0x0062a023) sw      t1, 0(t0)
35 core   0: exception trap_store_access_fault, epc 0x0000000080000164
36 core   0:           tval 0x0000000080000004
37 core   0: >>>>  trap_handler
```

Store fault in Machine mode in TOR region

```
25 core   0: 0x0000000080000184 (0x00c29293) slli    t0, t0, 12
26 core   0: 3 0x0000000080000184 (0x00c29293) x5  0x0000000080001000
27 core   0: 0x0000000080000188 (0x00428293) addi    t0, t0, 4
28 core   0: 3 0x0000000080000188 (0x00428293) x5  0x0000000080001004
29 core   0: 0x000000008000018c (0x00400313) li      t1, 4
30 core   0: 3 0x000000008000018c (0x00400313) x6  0x0000000000000004
31 core   0: 0x0000000080000190 (0x0062a023) sw      t1, 0(t0)
32 core   0: exception trap_store_access_fault, epc 0x0000000080000190
33 core   0:           tval 0x0000000080001004
34 core   0: >>>>  trap_handler
35 core   0: 0x00000000800001b0 (0xff010113) addi    sp, sp, -16
36 core   0: 3 0x00000000800001b0 (0xff010113) x2  0x0000000080002fa0
37 core   0: 0x00000000800001b4 (0x00512023) sw      t0, 0(sp)
```

Store fault in Machine mode in NAPOT region

```
25 core   0: 0x0000000080000198 (0x0012829b) addiw   t0, t0, 1
26 core   0: 3 0x0000000080000198 (0x0012829b) x5  0x0000000000080001
27 core   0: 0x000000008000019c (0x00c29293) slli    t0, t0, 12
28 core   0: 3 0x000000008000019c (0x00c29293) x5  0x0000000080001000
29 core   0: 0x00000000800001a0 (0x00428293) addi    t0, t0, 4
30 core   0: 3 0x00000000800001a0 (0x00428293) x5  0x0000000080001004
31 core   0: 0x00000000800001a4 (0x000280e7) jalr    t0
32 core   0: 3 0x00000000800001a4 (0x000280e7) x1  0x00000000800001a8
33 core   0: exception trap_instruction_access_fault, epc 0x0000000080001004
34 core   0:           tval 0x0000000080001004
35 core   0: >>>>  trap_handler
36 core   0: 0x00000000800001b0 (0xff010113) addi    sp, sp, -16
37 core   0: 3 0x00000000800001b0 (0xff010113) x2  0x0000000080002f90
```

Access fault in NAPOT region

```
1 core   0: 3 0x00000000800001a8 (0x00040093) x1  0x0000000080000090
2 core   0: 0x00000000800001ac (0x00008067) ret
3 core   0: 3 0x00000000800001ac (0x00008067)
4 core   0: 0x0000000080000090 (0x00100293) li      t0, 1
5 core   0: 3 0x0000000080000090 (0x00100293) x5  0x0000000000000001
6 core   0: 0x0000000080000094 (0x00002317) auipc   t1, 0x2
7 core   0: 3 0x0000000080000094 (0x00002317) x6  0x0000000080002094
8 core   0: 0x0000000080000098 (0xf6c30313) addi    t1, t1, -148
9 core   0: 3 0x0000000080000098 (0xf6c30313) x6  0x0000000080002000
0 core   0: 0x000000008000009c (0x00532023) sw      t0, 0(t1)
```

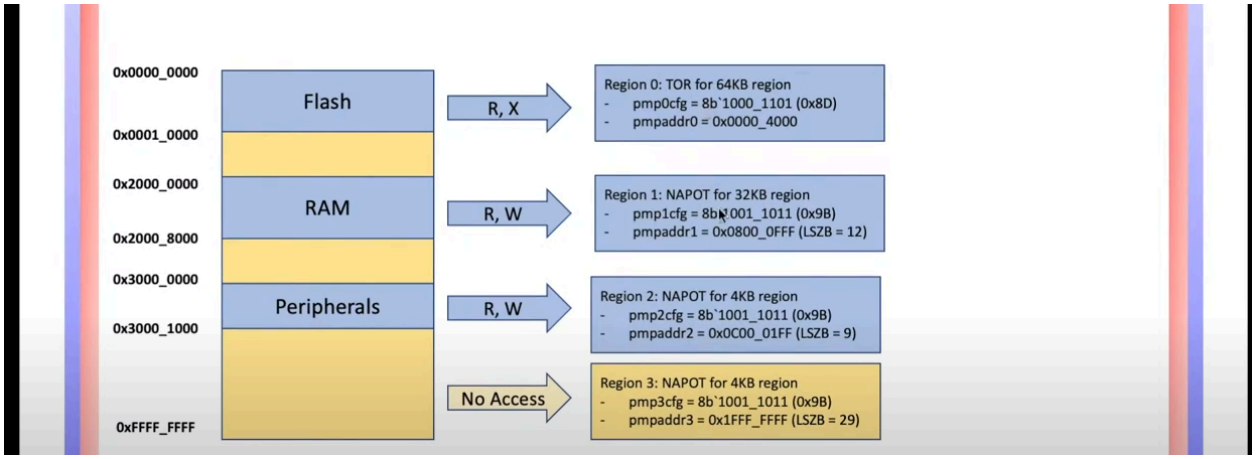
Exit

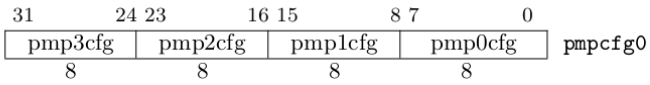
Reference:

Base Address	Region Size	pmpaddrX value
addr[31:0]	8 B	(addr[33:2] | 1`b0)
addr[31:0]	32 B	(addr[33:2] | 3`b011)
addr[31:0]	4 KB	(addr[33:2] | 9`b01_1111_1111)
addr[31:0]	32 KB	(addr[33:2] | 12`b0_1111_1111_1111)
addr[31:0]	64 KB	(addr[33:2] | 14`b01_1111_1111_1111)

Region Size 2 ^(LSZB + 3)

pmpaddr	pmpcfg.A	Match type and size
yyyy…yyyy	NA4	4-byte NAPOT range
yyyy…yyy0	NAPOT	8-byte NAPOT range
yyyy…yy01	NAPOT	16-byte NAPOT range
yyyy…y011	NAPOT	32- byte NAPOT range
…	…	…
yy01…1111	NAPOT	2^XLEN byte NAPOT range
y011…1111	NAPOT	2^XLEN+1 byte NAPOT range
0111…1111	NAPOT	2^XLEN+2 byte NAPOT range
1111…1111	NAPOT	2^XLEN+3 byte NAPOT range





Pmpcfg0 holds the configuration for pmpaddr0 - pmpaddr3

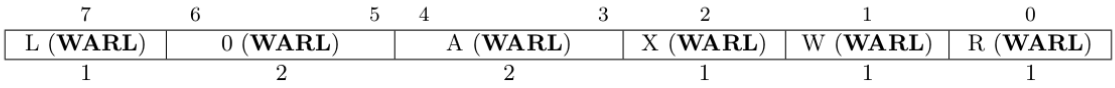


Figure 3.35: PMP configuration register format.