
SPECT

ISA v0.2

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Git tag:

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1 Glossary

- $P_{25519} = 2^{255} - 19$
- $P_{256} = 2^{256} - 2^{224} + 2^{192} + 2^{96} - 1$
- $||$ – concatenation

2 Instruction set

SPECT provides 4 types of instructions:

- **R** - Register
- **I** - Immediate
- **M** - Memory
- **J** - Jump

2.1 Operand interpretation

All operands are considered as 256 bits unsigned integers. Arithmetic instructions that work only with 32 bit operands ignores the 244 MSBs of input and clears them in the result. Immediate logic instructions work only with 12 LSBs, ignore the 244 MSBs of input, and pass the 244 MSBs of op2 to the result.

2.2 Instruction Format

31	30	29	28	25	24	22	21	17	16	15	12	11	07	06	00	
p	type	opcode	func	op1	op2	op3										R
p	type	opcode	func	op1	op2	Immediate										I
p	type	opcode	func	op1		Addr										M
p	type	opcode	func			NewPC										J

2.3 Symbols

Following symbols are used in description of instructions:

- **F** – Flags set by the instruction
- **#C** – Number of cycles the instruction takes to execute



2.4 R instructions

Mnemonic	Name	Semantics	F	#C
Arithmetic Instructions (32 bit)				
ADD op1,op2,op3	32 bit addition	$op1 = op2 + op3$	Z	11
SUB op1,op2,op3	32 bit subtraction	$op1 = op2 - op3$	Z	11
CMP op2,op3	32 bit comparison	$op2 - op3$	Z	9
Logic Instructions				
AND op1,op2,op3	Bitwise AND	$op1 = op2 \& op3$	Z	11
OR op1,op2,op3	Bitwise OR	$op1 = op2 \mid op3$	Z	11
XOR op1,op2,op3	Bitwise Exclusive OR	$op1 = op2 \wedge op3$	Z	11
NOT op1,op2	Bitwise NOT	$op1 = \sim op2$	Z	10
SBIT op1,op2,op3	Set bit	$op1 = op2 \vee (0x1 \ll op3[7:0])$		11
CBIT op1,op2,op3	Clear bit	$op1 = op2 \wedge \sim(0x1 \ll op3[7:0])$		11
Shift Instructions				
LSL op1,op2	Logic shift left	$op1 = op2[254:0] \mid \mid 0$	C	10
LSR op1,op2	Logic shift right	$op1 = 0 \mid \mid op2[255:1]$	C	10
ROL op1,op2	Rotating shift left	$op1 = op2[254:0] \mid \mid op2[255]$	C	10
ROR op1,op2	Rotating shift right	$op1 = op2[0] \mid \mid op2[255:1]$	C	10
ROL8 op1,op2	Rotating byte shift left	$op1 = op2[247:0] \mid \mid op2[255:248]$		10
ROR8 op1,op2	Rotating byte shift right	$op1 = op2[7:0] \mid \mid op2[255:8]$		10
ROLIN op1,op2,op3	Rotating byte shift left with shift in from op3	$op1 = op2[247:0] \mid \mid op3[255:248]$		11
RORIN op1,op2,op3	Rotating byte shift right with shift in from op3	$op1 = op3[7:0] \mid \mid op2[255:8]$		11



Mnemonic	Name	Semantics	F	#C
SWE op1,op2	Swap endianness	op1[255:248] = op2[7:0] op1[247:240] = op2[15:8] ... op1[7:0] = op2[255:248]		10
Modular arithmetic instructions				
MUL25519 op1,op2,op3	Multiplication in $GF(P_{25519})$	op1 = (op2 * op3) % P_{25519}		91
MUL256 op1,op2,op3	Multiplication in $GF(P_{256})$	op1 = (op2 * op3) % P_{256}		139
ADDP op1,op2,op3	Generic Modular Addition	op1 = (op2 + op3) % R31		16
SUBP op1,op2,op3	Generic Modular Subtraction	op1 = (op2 - op3) % R31		16
MULP op1,op2,op3	Generic Modular Multiplication	op1 = (op2 * op3) % R31		597
REDP op1,op2,op3	Generic Modular Reduction	op1 = (op2 op3) % R31		528
Load Instructions				
LDR op1,op2	Load register	op1[31:0] = Mem[op2] op1[63:32] = Mem[op2+0x4] ... op1[255:224] = Mem[op2+0x1C]		-
STR op1,op2	Store register	Mem[op2] = op1[31:0] Mem[op2+0x4] = op1[63:32] ... Mem[op2+0x1C] = op1[255:224]		-
Other Instructions				
MOV op1,op2	Move register	op1 = op2		7
CSWAP op1,op2	Conditional swap - C flag	if C == 1 then: op1 = op2 op2 = op1		11
ZSWAP op1,op2	Conditional swap - Z flag	if Z == 1 then: op1 = op2 op2 = op1		11



Mnemonic	Name	Semantics	F	#C
HASH op1,op2	Hash (SHA512)	Updates SHA core with (op2+3 op2+2 op2+1 op2) op1 = SHA state[255:0] op1+1 = SHA state[511:256]		347
TMAC_IT op2	TMAC initialize	Resets TMAC and underlying KECCAK core mask = (op2+3 op2+2 op2+1 op2) Share A = mask[399:0] Share B = mask[799:0] Guard = [803:800]		94
TMAC_UP op2	TMAC update	Updates TMAC with op2[143:0]		44
TMAC_RD op1	TMAC update	op1 = TMAC result		84
GRV op1	Get Random Value	op1 = Random number		–
SCB op1,op2,op3	Blind scalar	B = <i>Blind</i> (op2, op3, R31) op1 = B[255:0] op1+1 = B[511:256]		88

2.5 I instructions

Mnemonic	Name	Semantics	F	#C
Arithmetic Instructions (32 bit)				
ADDI op1,op2,Immediate	32 bit addition	op1 = op2 + Immediate	Z	11
SUBI op1,op2,Immediate	32 bit subtraction	op1 = op2 - Immediate	Z	11
CMPI op2,Immediate	32 bit comparison	op2 - Immediate	Z	9
Logic Instructions (12 bit)				
ANDI op1,op2,Immediate	12 bit bitwise logic AND	op1[11:0] = op2[11:0] & Immediate op1[255:12] = op2[255:12]	Z	11



Mnemonic	Name	Semantics	F	#C
ORI op1,op2,Immediate	12 bit bitwise logic OR	$op1[11:0] = op2[11:0] \mid \text{Immediate}$ $op1[255:12] = op2[255:12]$	Z	11
XORI op1,op2,Immediate	12 bit bitwise exclusive OR	$op1[11:0] = op2[11:0] \wedge \text{Immediate}$ $op1[255:12] = op2[255:12]$	Z	11
KBUS Instructions				
LDK op1,op2,Immediate	Load key	$op1 = \text{KBUS_READ}[\text{type}, \text{slot}, \text{offset}]$ where $\text{type} = \text{Immediate}[11:8]$ $\text{slot} = op2[7:0]$ $\text{offset} = \text{Immediate}[4:0] * 8$	E	–
STK op1,op2,Immediate	Load key	$\text{KBUS_WRITE}[\text{key}, \text{type}, \text{slot}, \text{offset}]$ where $\text{key} = op1$ $\text{type} = \text{Immediate}[11:8]$ $\text{slot} = op2[7:0]$ $\text{offset} = \text{Immediate}[4:0] * 8$	E	–
KBO op2,Immediate	KBUS OP	$\text{KBUS_OP}[\text{type}, \text{slot}, \text{op}]$ where $\text{type} = \text{Immediate}[11:8]$ $\text{slot} = op2[7:0]$ $op = \text{Immediate}[3:0]$	E	–
Other Instructions				
MOVI op1,Immediate	Move immediate	$op1[11:0] = \text{Immediate},$ $op1[255:12] = 0$		6
HASH_IT	Hash init	Reset hash calculation.		9
TMAC_IS op2, Immediate	TMAC initstring	Initialize TMAC with initstring $K = op2, N = \text{Imd}[7:0]$		78

Due to not enough space in the 32 bit instruction format, the immediate operand is just 12 bit. Because of that, the logic instructions works only with the 12 LSBs of op2. E.g. $0xFF12 \ \& \ 0xF0F = 0xFF02$.



2.6 M instructions

Mnemonic	Name	Semantics	F	#C
LD op1,Addr	Load	op1[31:0] = Mem[Addr] op1[63:32] = Mem[Addr+0x4] ... op1[255:224] = Mem[Addr+0x1C]		-
ST op1,Addr	Store	Mem[Addr] = op1[31:0] Mem[Addr+0x4] = op1[63:32] = ... Mem[Addr+0x1C] = op1[255:224]		-



2.7 J instructions

Mnemonic	Name	Semantics	F	#C
CALL NewPC	Subroutine call	push(RAR, PC+0x4), PC = NewPC		5
RET	Return from subroutine	PC = pop(RAR)		5
BRZ NewPC	Branch on Zero	if Z == 1 then: PC = NewPC		5
BRNZ NewPC	Branch on not Zero	if Z == 0 then: PC = NewPC		5
BRC NewPC	Branch on Carry	if C == 1 then: PC = NewPC		5
BRNC NewPC	Branch on not Carry	if C == 0 then: PC = NewPC		5
BRE NewPC	Branch on Error	if E == 1 then: PC = NewPC		5
BRNE NewPC	Branch on not Error	if E == 0 then: PC = NewPC		5
JMP NewPC	Unconditional jump	PC = NewPC		5
END	End of program, stops FW execution and sets STATUS[DONE] .	-		4
NOP	Does nothing.	-		3

3 Flags

3.1 Zero Flag – Z

Zero flag is set to 1, if instruction changing the flag is executed and:

- all 256 bits of op1 are 0
- $op2 - op3 = 0$ in case of CMP and CMPI instructions

and cleared otherwise.

Zero flag keeps its value if instruction that does not modify it is executed.

3.2 Carry Flag – C

Carry flag is set to 1, if instruction changing the flag is executed and:

- $op2[255] = 1$ in case of LSL and ROL instructions
- $op2[0] = 1$ in case of LSR and ROR instructions

and cleared otherwise.

Carry flag keeps its value if instruction that does not modify it is executed.

3.3 Error Flag – E

Error flag is set to 1 in *spect_kbus_error* is set during KBUS request when LDK, STK and KBO instructions are executed.

Error flag keeps its value if instruction that does not modify it is executed.