Instruction Set

26 Oct. 2020

32-bit instruction format

31:29	28:24	23:16	15:8	7:0
opcode	raddr2 (s3)	raddr1 (s2)	raddr0 (s1)	waddr (dst)

opcode: complex operation code
raddr2: read address 2 of the data memory (5-bit)
raddr1: read address 1 of the data memory (8-bit)
raddr0: read address 0 of the data memory (8-bit)
waddr: write address of the data memory (8-bit)

Opcode:

~~000~~	001	010	011	101	110	111
~~LOAD~~	ADD	SUB	MUL	MAX	MULSUB	MULADD

All of the above are complex operations. (e.g. ADD: (a+jb) + (c+jd))

Examples in RISC-V fashion:

Assembly	Operation	Instructions in Hex
ADD $128, $16, $48	R128 = R16 + R48	32'h20_30_10_80
MUL $129, $17, $49	R129 = R17 + R49	32'h60_31_11_81
MULADD $130, $18, $50, $0	R130 = R18 + R0 * R50	32'hE0_32_12_82
MULSUB $131, $129, $128, $1	R131 = R129 + R1 * R128	32'hC1_80_81_83

Assuming the overlay is comprised of an array of 256 PEs and each PE has 4 DSP blocks. The instruction schedule can be found as follows (if running at 500MHz, 1 cycle = 2ns):

Cycle	Operation	Instruction
256*32	***Load input data[1]***	**Nil**
1*32	*Complex multiplication*	(a+jb)*(c+jd) → a' + jb'
1*80 1*80	*FFT*	a' + jb' + W_N(c'+jd') → a'' + jb'' a' + jb' - W_N(c'+jd') → c'' + jd''
1*16	*Output half values*	Nil
32	*Shift internal data[2]*	Nil
1*32	*Complex multiplication*	(a+jb)*(c+jd) → a' + jb'; c' + jd'
1*80 1*80	*FFT*	a' + jb' + W_N(c'+jd') → a'' + jb'' a' + jb' - W_N(c'+jd') → c'' + jd''
1*16	*Output half values*	Nil
32	*Shift data*	Nil
…	…	…
256*32	***Fetch output data***	**Nil**

[1,2]*Load input data*, *Shift internal data* and *Fetch output data* do not require instructions. They are handled by the SIPO and PISO modules.

Latency = (256*32 + (32+2*80+16) + 255*(32+32+2*80+16) + 256*32) * 2ns = 0.156 ms

Q. How to do a MAX operation among all the outputs of the 256 PEs (after square operation)? Add logic fabrics after the 256 PEs?

Instructions for SCD kernel:

```
# 8 element-wise complex multiplications
MUL $80, $0, $32
MUL $81, $1, $33
MUL $82, $2, $34
MUL $83, $3, $35
MUL $84, $4, $36
MUL $85, $5, $37
MUL $86, $6, $38
MUL $87, $7, $39

# 8-point FFT (bit-reverse order)
# stage 1
MULADD $88, $80, $84, $0
MULSUB $89, $80, $84, $0
MULADD $90, $82, $86, $0
MULSUB $91, $82, $86, $0
MULADD $92, $81, $85, $0
MULSUB $93, $81, $85, $0
MULADD $94, $83, $87, $0
MULSUB $95, $83, $87, $0
# stage 2
MULADD $96, $88, $90, $0
MULSUB $98, $88, $90, $0
MULADD $97, $89, $91, $2
MULSUB $99, $89, $91, $2
MULADD $100, $92, $94, $0
MULSUB $102, $92, $94, $0
MULADD $101, $93, $95, $2
MULSUB $103, $93, $95, $2
# stage 3
MULADD $104, $96, $100, $0
MULSUB $108, $96, $100, $0
MULADD $105, $98, $102, $1
MULSUB $109, $98, $102, $1
MULADD $106, $97, $101, $2
MULSUB $110, $97, $101, $2
MULADD $107, $99, $103, $3
MULSUB $111, $99, $103, $3
```

```
# 32 element-wise complex multiplications
MUL $80, $0, $32
MUL $81, $1, $33
MUL $82, $2, $34
MUL $83, $3, $35
MUL $84, $4, $36
MUL $85, $5, $37
MUL $86, $6, $38
MUL $87, $7, $39
MUL $88, $8, $40
MUL $89, $9, $41
MUL $90, $10, $42
MUL $91, $11, $43
MUL $92, $12, $44
MUL $93, $13, $45
MUL $94, $14, $46
MUL $95, $15, $47
MUL $96, $16, $32
MUL $97, $17, $33
MUL $98, $18, $34
MUL $99, $19, $35
MUL $100, $20, $36
MUL $101, $21, $37
MUL $102, $22, $38
MUL $103, $23, $39
MUL $104, $24, $40
MUL $105, $25, $41
MUL $106, $26, $42
MUL $107, $27, $43
MUL $108, $28, $44
MUL $109, $29, $45
MUL $110, $30, $46
MUL $111, $31, $47

# 32-point FFT (bit-reverse order)
# stage 1
MULADD $112, $80, $96, $0
MULSUB $113, $80, $96, $0
MULADD $114, $88, $104, $0
MULSUB $115, $88, $104, $0
MULADD $116, $84, $100, $0
MULSUB $117, $84, $100, $0
MULADD $118, $92, $108, $0
MULSUB $119, $92, $108, $0
MULADD $120, $82, $98, $0
MULSUB $121, $82, $98, $0
MULADD $122, $90, $106, $0
```

```
MULSUB $123, $90, $106, $0
MULADD $124, $86, $102, $0
MULSUB $125, $86, $102, $0
MULADD $126, $94, $110, $0
MULSUB $127, $94, $110, $0
MULADD $128, $81, $97, $0
MULSUB $129, $81, $97, $0
MULADD $130, $89, $105, $0
MULSUB $131, $89, $105, $0
MULADD $132, $85, $101, $0
MULSUB $133, $85, $101, $0
MULADD $134, $93, $109, $0
MULSUB $135, $93, $109, $0
MULADD $136, $83, $99, $0
MULSUB $137, $83, $99, $0
MULADD $138, $91, $107, $0
MULSUB $139, $91, $107, $0
MULADD $140, $87, $103, $0
MULSUB $141, $87, $103, $0
MULADD $142, $95, $111, $0
MULSUB $143, $95, $111, $0

# stage 2

# stage 3

# stage 4

# stage 5
```