

# Instruction encodings

## 32 bit encodings

### Abbreviations used

<i>cond</i>	: a three bit field specifying execution condition (See table xx at the end)
<i>creg</i>	: a three bit field specifying one of the eight condition registers
<i>cp_sreg/sr</i>	: a five bit field selecting a coprocessor source register
<i>cp_dreg/dr</i>	: a five bit field selecting a coprocessor destination register
<i>dreg</i>	: a five bit field selecting a destination register
<i>dr</i>	: a three bit field selecting a destination register
<i>imm, imm1, imm2</i>	: an immediate constant
<i>imml</i>	: left part of an immediate constant
<i>immr</i>	: right part of an immediate constant
<i>msb</i>	: with lui & lli instructions the most significant bit of a 16 bit immediate.
<i>sregi</i>	: a five bit field selecting a source register (i = ‘ ‘, 1, 2)
<i>sri</i>	: a three bit field selecting a source register(i = ‘ ‘, 1, 2)
<i>cex</i>	: A bit specifying if conditional execution of an instruction is enabled or not. If low the cond and creg fields can be used to represent a longer immediate.
<i>xxx</i>	: A bit field which has no meaning. The assembler can decide what bit patterns to use.

### About notation

The instruction word is presented as adjacent bitfields with symbolic names. The numbers below the name of a bitfield are the range of bit indexes reserved by the field. One can see the exact position and the length of the bitfield from the indexes. The order of significance is from left to right, that is bit index 31 corresponds the msb of the word and index 0 corresponds to lsb of the word. Conditionally executable instructions, which have an immediate as the second operand, have two encodings. The first one is with conditional execution (*cex* = 1) and the second is without conditional execution (*cex* = 0). The latter encoding expands the immediate constant over the *cond* and *creg* fields.

The first field of each instruction is instruction identifier (iid). From iid the processor decodes following: What operation to perform, what kind of operands to use and if there's any constraints on the result or usage of instruction. The iid could also be called opcode even though it strictly speaking isn't plain operation code. Some instructions use the same iid in which case other fields are used to distinguish between them.

If an assembler does not conform to this encoding the results are unpredictable. The reader should refer to the chapter 'Instruction specifications' for information about the description of each instruction.

(cond, creg) **add** dreg, sreg1, sreg2

000001	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **addi** dreg, sreg1, imm

101101	1	creg	cond	imm	sreg1	dreg
31...26	25	24...22	21...19	18...10	9...5	4...0
101101	0	imm			sreg1	dreg
31...26	25	24...10			9...5	4...0

(cond, creg) **addiu** dreg, sreg1, imm

101000	1	creg	cond	imm	sreg1	dreg
31...26	25	24...22	21...19	18...10	9...5	4...0
101000	0	imm			sreg1	dreg
31...26	25	24...10			9...5	4...0

(cond, creg) **addu** dreg, sreg1, sreg2

000000	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **and** dreg, sreg1, sreg2

000010	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **andi** dreg, sreg1, imm

101001	1	creg	cond	imm	sreg1	dreg
31...26	25	24...22	21...19	18...10	9...5	4...0
101001	0	imm			sreg1	dreg
31...26	25	24...10			9...5	4...0

**bc** creg, imm

100000	1	creg	imm
31...26	25	24...22	21...0

**begt** creg, imm

100001	1	creg	imm
31...26	25	24...22	21...0

**belt** creg, imm

100010	1	creg	imm
31...26	25	24...22	21...0

**beq** creg, imm

100011	1	creg	imm
31...26	25	24...22	21...0

**bgt** creg, imm

100100	1	creg	imm
31...26	25	24...22	21...0

**blt** creg, imm

100101	1	creg	imm
31...26	25	24...22	21...0

**bne** creg, imm

100110	1	creg	imm
31...26	25	24...22	21...0

**bnc** creg, imm

100111	1	creg	imm
31...26	25	24...22	21...0

**chrs** imm

110011	0	xxx	imm	xxx
31...26	25	24...12	11...10	9...0

**cmp** creg, sreg1, sreg2

011001	0	creg	xxx	sreg2	sreg1	xxx
31...26	25	24...22	21...15	14...10	9...5	4...0

**cmpi** creg, sreg1, imm

110111	0	creg	immr	sreg1	imml
31...26	25	24...22	21...10	9...5	4...0

(cond, creg) **conb** dreg, sreg1, sreg2

000011	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **conh** dreg, sreg2, sreg1

000100	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

**cop** imm1, imm2

111100	imm1	imm2
31...26	25...24	23...0

**di**

010101	0	xxx
31...26	25	24...0

**ei**

010110	0	xxx
31...26	25	24...0

(cond, creg) **exb** dreg, sreg1, imm

110000	cex	creg	cond	xxx	imm	sreg1	dreg
31...26	25	24...22	21...19	18...12	11...10	9...5	4...0

(cond, creg) **exbf** dreg, sreg1, sreg2

011010	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

**exbfi** dreg, sreg1, imm1, imm2

111101	0	xxx	imm1	imm2	sreg1	dreg
31...26	25	24...21	20...15	14...10	9...5	4...0

(cond, creg) **exh** dreg, sreg1, imm

110001	cex	creg	cond	xxx	imm	sreg1	dreg
31...26	25	24...22	21...19	18...11	10	9...5	4...0

**jal** imm

111001	0	imm					
31...26	25	24...0					

(cond, creg) **jalr** sreg1

110101	cex	creg	cond	xxx	sreg1	11111
31...26	25	24...22	21...19	18...10	9...5	4...0

**jmp** imm

111000	0	imm					
31...26	25	24...0					

(cond, creg) **jmpr** sreg1

011011	cex	creg	cond	xxx	sreg1	xxx
31...26	25	24...22	21...19	18...10	9...5	4...0

(cond, creg) **ld** dreg, sreg1, imm

110010	1	creg	cond	imm	sreg1	dreg	
31...26	25	24...22	21...19	18...10	9...5	4...0	
110010	0	imm				sreg1	dreg
31...26	25	24...10				9...5	4...0

**lli** dreg, imm

111110	0	imm			msb	xxx	dreg
31...26	25	24...10			9	8...5	4...0

**lui dreg, imm**

111111	0	imm			msb	xxx	dreg
31...26	25	24...10			9	8...5	4...0

**(cond, creg) mov dreg, sreg1**

010011	cex	creg	cond	xxx	sreg1	dreg
31...26	25	24...22	21...19	18...10	9...5	4...0

**(cond, creg) movfc imm, dreg, cp\_sreg**

101100	cex	creg	cond	xxx	cp_sreg	imm	xxx	dreg
31...26	25	24...22	21...19	18...17	16...12	11...10	9...5	4...0

**(cond, creg) movtc imm, cp\_dreg, sreg1**

110110	cex	creg	cond	xxx	cp_dreg	imm	sreg1	xxx
31...26	25	24...22	21...19	18...17	16...12	11...10	9...5	4...0

**(cond, creg) mulhi dreg**

011101	cex	creg	cond	xxx			dreg
31...26	25	24...22	21...19	18...5			4...0

**(cond, creg) muli dreg, sreg1, imm**

101110	1	creg	cond	imm	sreg1	dreg
31...26	25	24...22	21...19	18...10	9...5	4...0
101110	0	imm			sreg1	dreg
31...26	25	24...10			9...5	4...0

**(cond, creg) muls dreg, sreg1, sreg2**

000101	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

**(cond, creg) muls\_16 dreg, sreg1, sreg2**

001000	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

**(cond, creg) mulu dreg, sreg1, sreg2**

000110	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **mulu\_16** dreg, sreg1, sreg2

001001	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **mulus** dreg, sreg1, sreg2

000111	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **mulus\_16** dreg, sreg1, sreg2

001010	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

**nop**

111010	0	xxx		111010	xxx	
31...26	25	24...16		15...10	9...0	

(cond, creg) **not** dreg, sreg1

010100	cex	creg	cond	xxx	sreg1	dreg
31...26	25	24...22	21...19	18...10	9...5	4...0

(cond, creg) **or** dreg, sreg1, sreg2

001011	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **ori** dreg, sreg1, imm

101010	1	creg	cond	imm	sreg1	dreg
31...26	25	24...22	21...19	18...10	9...5	4...0
101010	0	imm			sreg1	dreg
31...26	25	24...10			9...5	4...0

**rcon** sreg1

011110	0	xxx			sreg1	xxx
31...26	25	24...10			9...5	4...0

**reti**

010111	0	000	xxx			
31...26	25	24...22	21...0			

**retu**

011111	0	xxx			11111	xxx
31...26	25	24...10			9...5	4...0

(cond, creg) **scall**

111011	cex	creg	cond	xxx	11111	
31...26	25	24...22	21...19	18...5	4...0	

**scon dreg**

011100	0	xxx					dreg
31...26	25	24...5					4...0

**(cond, creg) sext dreg, sreg1, sreg2**

001100	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

**(cond, creg) sexti dreg, sreg1, imm**

101011	1	creg	cond	xxx	imm	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0
101011	0	xxx		imm		sreg1	dreg
31...26	25	24...15		14...10		9...5	4...0

**(cond, creg) sll dreg, sreg1, sreg2**

001101	cex	creg	cond	1	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18	17...15	14...10	9...5	4...0

**(cond, creg) slli dreg, sreg1, imm**

001101	cex	creg	cond	0	xxx	imm	sreg1	dreg
31...26	25	24...22	21...19	18	17...16	15...10	9...5	4...0

**(cond, creg) sra dreg, sreg1, sreg2**

001110	cex	creg	cond	1	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18	17...15	14...10	9...5	4...0

**(cond, creg) srai dreg, sreg1, imm**

001110	cex	creg	cond	0	xxx	imm	sreg1	dreg
31...26	25	24...22	21...19	18	17...16	15...10	9...5	4...0

**(cond, creg) srl dreg, sreg1, sreg2**

001111	cex	creg	cond	1	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18	17...15	14...10	9...5	4...0

**(cond, creg) srli dreg, sreg1, imm**

001111	cex	creg	cond	0	xxx	imm	sreg1	dreg
31...26	25	24...22	21...19	18	17...16	15...10	9...5	4...0

**(cond, creg) st sreg2, sreg1, imm**

110100	1	creg	cond	immr	sreg2	sreg1	imml
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0
110100	0	immr			sreg2	sreg1	imml
31...26	25	24...15			14...10	9...5	4...0

(cond, creg) **sub** dreg, sreg1, sreg2

010000	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

(cond, creg) **subu** dreg, sreg1, sreg2

010001	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0

**swm** imm

101111	0	xxx		imm	xxx	
31...26	25	24...16		15...10	9...0	

(cond, creg) **trap** imm

011000	cex	creg	cond	xxx	imm	xxx	
31...26	25	24...22	21...19	18...15	14...10	9...0	

(cond, creg) **xor** dreg, sreg1, sreg2

010010	cex	creg	cond	xxx	sreg2	sreg1	dreg
31...26	25	24...22	21...19	18...15	14...10	9...5	4...0



## 16 bit encodings

### Notes about 16 bit encoding

Almost all instructions have both a 16 bit and a 32 bit version. Instructions which are valid only in 32 bit mode are: *cop*, *exbfi*, *lli* and *lui*. Conditional execution is not allowed in 16 bit mode, so fields *creg*, *cond* and *cex* are not needed. Also source and destination register fields and immediate fields are shorter. See Chapter ‘Operating modes’ for more information.

#### **add** dr, sr

000001	sr	xxx	dr
15...10	9...7	6...3	2...0

#### **addi** dr, imm

101101	imm	dr
15...10	9...3	2...0

#### **addiu** dr, imm

101000	imm	dr
15...10	9...3	2...0

#### **addu** dr, sr

000000	sr	xxx	dr
15...10	9...7	6...3	2...0

#### **and** dr, sr

000010	sr	xxx	dr
15...10	9...7	6...3	2...0

#### **andi** dr, imm

101001	imm	dr
15...10	9...3	2...0

#### **bc** imm

100000	imm
15...10	9...0

#### **begt**, imm

100001	imm
15...10	9...0

**belt, imm**

100010	imm
15...10	9...0

**beq, imm**

100011	imm
15...10	9...0

**bgt, imm**

100100	imm
15...10	9...0

**blt, imm**

100101	imm
15...10	9...0

**bne, imm**

100110	imm
15...10	9...0

**bnc imm**

100111	imm
15...10	9...0

**chrs imm**

110011	xxx	imm	xxx
15...10	9...5	4...3	2...0

**cmp sr1, sr2**

011001	sr1	xxx	sr2
15...10	9...7	6...3	2...0

**cmpi sr, imm**

110111	sr	imm
15...10	9...7	6...0

**conb dr, sr**

000011	sr	xxx	dr
15...10	9...7	6...3	2...0

**conh dr, sr**

000100	sr	xxx	dr
15...10	9...7	6...3	2...0

**di**

010101	xxx
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15...10	9...0
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**ei**

010110	xxx
15...10	9...0

**exb dr, sr, imm**

110000	sr	xxx	imm	dr
15...10	9...7	6...5	4...3	2...0

**exbf dr, sr**

011010	sr	xxx	dr
15...10	9...7	6...3	2...0

**exh dr, sr, imm**

110001	sr	xxx	imm	dr
15...10	9...7	6...4	3	2...0

**jal imm**

111001	imm
15...10	9...0

**jalr sr**

110101	sr	xxx	111
15...10	9...7	6...3	2...0

**jmp imm**

111000	imm
15...10	9...0

**jmpr sr**

011011	sr	xxx
15...10	9...7	6...0

**ld dr, sr, imm**

110010	sr	imm	dr
15...10	9...7	6...3	2...0

**mov dr, sr**

010011	sr	xxx	dr
15...10	9...7	6...3	2...0

**movfc imm, dr, cp\_sr**

101100	cp_sr	imm	dr
15...10	9...5	4...3	2...0

**movtc** imm, c\_dr, sr

110110	sr	cp_dr	imm
15...10	9...7	6...2	1...0

**mulhi** dr

011101	xxx	xxx	dr
15...10	9...7	6...3	2...0

**muli** dr, imm

101110	imm	dr	
15...10	9...3	2...0	

**muls** dr, sr

000101	sr	xxx	dr
15...10	9...7	6...3	2...0

**muls\_16** dr, sr

001000	sr	xxx	dr
15...10	9...7	6...3	2...0

**mulu** dr, sr

000110	sr	xxx	dr
15...10	9...7	6...3	2...0

**mulu\_16** dr, sr

001001	sr	xxx	dr
15...10	9...7	6...3	2...0

**mulus** dr, sr

000111	sr	xxx	dr
15...10	9...7	6...3	2...0

**mulus\_16** dr, sr

001010	sr	xxx	dr
15...10	9...7	6...3	2...0

**nop**

111010	xxx		
15...10	9...0		

**not dr, sr**

010100	sr	xxx	dr
15...10	9...7	6...3	2...0

**or dr, sr**

001011	sr	xxx	dr
15...10	9...7	6...3	2...0

**ori dr, imm**

101010	imm	dr
15...10	9...3	2...0

**rcon sr**

011110	sr	xxx
15...10	9...7	6...0

**reti**

010111	xxx
15...10	9...0

**retu**

011111	xxx
15...10	9...0

**scall**

111011	xxx	111
15...10	9...3	2...0

**scon dr**

011100	xxx	dr
15...10	9...3	2...0

**sext dr, sr**

001100	sr	xxx	dr
15...10	9...7	6...3	2...0

**sexti dr, imm**

101011	xxx	imm	dr
15...10	9...8	7...3	2...0

**sll dr, sr**

001101	sr	xxx	1	dr
15...10	9...7	6...4	3	2...0

**slli dr, imm**

001101	imm	0	dr
15...10	9...4	3	2...0

**sra dr, sr**

001110	sr	xxx	1	dr
15...10	9...7	6...4	3	2...0

**srai dr, imm**

001110	imm	0	dr
15...10	9...4	3	2...0

**srl dr, sr**

001111	sr	xxx	1	dr
15...10	9...7	6...4	3	2...0

**srli dr, imm**

001111	imm	0	dr
15...10	9...4	3	2...0

**st sr2, sr1, imm**

110100	sr1	imm	sr2
15...10	9...7	6...3	2...0

**sub dr, sr**

010000	sr	xxx	dr
15...10	9...7	6...3	2...0

**subu dr, sr**

010001	sr	xxx	dr
15...10	9...7	6...3	2...0

**swm imm**

101111	x	imm	xxx
15...10	9	8...3	2...0

**trap imm**

011000	xxx	imm	xxx
15...10	9...8	7...3	2...0

**xor dr, sr**

010010	sr	xxx	dr
15...10	9...7	6...3	2...0

<b>mnemonic</b>	<b>condition</b>	<b>explanation</b>	<b>code</b>	<b>flags</b>
c	carry	Carry out of MSB	000	C = 1
eq	=	equal	011	Z = 1
gt	>	greater than	100	Z = 0 & N = 0
lt	<	less than	101	Z = 0 & N = 1
ne	≠	not equal	110	Z = 0
elt	≤	equal or less than	010	Z = 1 or N = 1
egt	≥	equal or greater than	001	Z = 1 or N = 0
nc	!carry	No carry-out	111	C = 0

*Table xx, Condition codes*