

## Introduction

This section introduces the Nios® II instruction word format and provides a detailed reference of the Nios II instruction set. This chapter contains the following sections:

- “Word Formats” on page 8–1
- “Instruction Opcodes” on page 8–2
- “Assembler Pseudo-Instructions” on page 8–3
- “Assembler Macros” on page 8–4
- “Instruction Set Reference” on page 8–4

## Word Formats

There are three types of Nios II instruction word format: I-type, R-type, and J-type.

### I-Type

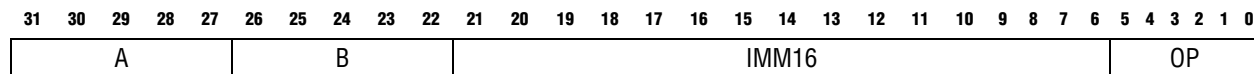
The defining characteristic of the I-type instruction word format is that it contains an immediate value embedded within the instruction word. I-type instructions words contain:

- A 6-bit opcode field OP
- Two 5-bit register fields A and B
- A 16-bit immediate data field IMM16

In most cases, fields A and IMM16 specify the source operands, and field B specifies the destination register. IMM16 is considered signed except for logical operations and unsigned comparisons.

I-type instructions include arithmetic and logical operations such as `addi` and `andi`; branch operations; load and store operations; and cache management operations.

The I-type instruction format is:



### R-Type

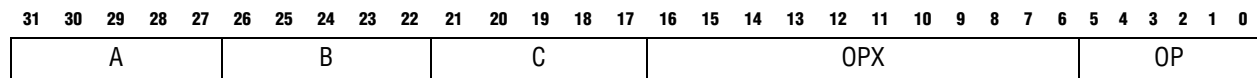
The defining characteristic of the R-type instruction word format is that all arguments and results are specified as registers. R-type instructions contain:

- A 6-bit opcode field OP
- Three 5-bit register fields A, B, and C
- An 11-bit opcode-extension field OPX

In most cases, fields A and B specify the source operands, and field C specifies the destination register. Some R-Type instructions embed a small immediate value in the low-order bits of OPX.

R-type instructions include arithmetic and logical operations such as `add` and `nor`; comparison operations such as `cmpeq` and `cmplt`; the custom instruction; and other operations that need only register operands.

The R-type instruction format is:



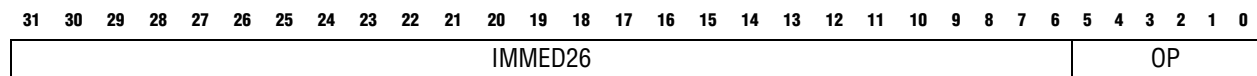
## J-Type

J-type instructions contain:

- A 6-bit opcode field
- A 26-bit immediate data field

J-type instructions, such as `call` and `jmpi`, transfer execution anywhere within a 256 MByte range.

The J-type instruction format is:



## Instruction Opcodes

The OP field in the Nios II instruction word specifies the major class of an opcode as shown in [Table 8-1](#) and [Table 8-2](#). Most values of OP are encodings for I-type instructions. One encoding, OP = 0x00, is the J-type instruction `call`. Another encoding, OP = 0x3a, is used for all R-type instructions, in which case, the OPX field differentiates the instructions. All undefined encodings of OP and OPX are reserved.

**Table 8-1.** OP Encodings (Part 1 of 2)

OP	Instruction	OP	Instruction	OP	Instruction	OP	Instruction
0x00	<code>call</code>	0x10	<code>cmplti</code>	0x20	<code>cmpeqi</code>	0x30	<code>cmpltui</code>
0x01	<code>jmp<i>i</i></code>	0x11		0x21		0x31	
0x02		0x12		0x22		0x32	<code>custom</code>
0x03	<code>ldbu</code>	0x13	<code>initda</code>	0x23	<code>ldbuio</code>	0x33	<code>initd</code>
0x04	<code>addi</code>	0x14	<code>ori</code>	0x24	<code>muli</code>	0x34	<code>orhi</code>
0x05	<code>stb</code>	0x15	<code>stw</code>	0x25	<code>stbio</code>	0x35	<code>stwio</code>
0x06	<code>br</code>	0x16	<code>blt</code>	0x26	<code>beq</code>	0x36	<code>bltu</code>
0x07	<code>ldb</code>	0x17	<code>ldw</code>	0x27	<code>ldbio</code>	0x37	<code>ldwio</code>
0x08	<code>cmpgei</code>	0x18	<code>cmpnei</code>	0x28	<code>cmpgeui</code>	0x38	<code>rdprs</code>
0x09		0x19		0x29		0x39	
0x0A		0x1A		0x2A		0x3A	R-type

**Table 8-1.** OP Encodings (Part 2 of 2)

OP	Instruction	OP	Instruction	OP	Instruction	OP	Instruction
0x0B	ldhu	0x1B	flushda	0x2B	ldhuio	0x3B	flushd
0x0C	andi	0x1C	xori	0x2C	andhi	0x3C	xorhi
0x0D	sth	0x1D		0x2D	sthio	0x3D	
0x0E	bge	0x1E	bne	0x2E	bgeu	0x3E	
0x0F	ldh	0x1F		0x2F	ldhio	0x3F	

**Table 8-2.** OPX Encodings for R-Type Instructions

OPX	Instruction	OPX	Instruction	OPX	Instruction	OPX	Instruction
0x00		0x10	cmplt	0x20	cmpeq	0x30	cmpltu
0x01	eret	0x11		0x21		0x31	add
0x02	roli	0x12	slli	0x22		0x32	
0x03	rol	0x13	sll	0x23		0x33	
0x04	flushp	0x14	wrprs	0x24	divu	0x34	break
0x05	ret	0x15		0x25	div	0x35	
0x06	nor	0x16	or	0x26	rdctl	0x36	sync
0x07	mulxuu	0x17	mulxsu	0x27	mul	0x37	
0x08	cmpge	0x18	cmpne	0x28	cmpgeu	0x38	
0x09	bret	0x19		0x29	initi	0x39	sub
0x0A		0x1A	srl	0x2A		0x3A	srai
0x0B	ror	0x1B	srl	0x2B		0x3B	sra
0x0C	flushi	0x1C	nextpc	0x2C		0x3C	
0x0D	jmp	0x1D	callr	0x2D	trap	0x3D	
0x0E	and	0x1E	xor	0x2E	wrctl	0x3E	
0x0F		0x1F	mulxss	0x2F		0x3F	

## Assembler Pseudo-Instructions

Table 8-3 lists pseudo-instructions available in Nios II assembly language. Pseudo-instructions are used in assembly source code like regular assembly instructions. Each pseudo-instruction is implemented at the machine level using an equivalent instruction. The `movia` pseudo-instruction is the only exception, being implemented with two instructions. Most pseudo-instructions do not appear in disassembly views of machine code.

**Table 8-3.** Assembler Pseudo-Instructions (Part 1 of 2)

Pseudo-Instruction	Equivalent Instruction
<code>bgt rA, rB, label</code>	<code>blt rB, rA, label</code>
<code>bgtu rA, rB, label</code>	<code>bltu rB, rA, label</code>
<code>ble rA, rB, label</code>	<code>bge rB, rA, label</code>
<code>bleu rA, rB, label</code>	<code>bgeu rB, rA, label</code>
<code>cmpgt rC, rA, rB</code>	<code>cmplt rC, rB, rA</code>

**Table 8-3.** Assembler Pseudo-Instructions (Part 2 of 2)

Pseudo-Instruction	Equivalent Instruction
cmpgti rB, rA, IMMED	cmpgei rB, rA, (IMMED+1)
cmpgtu rC, rA, rB	cmpltu rC, rB, rA
cmpgtui rB, rA, IMMED	cmpgeui rB, rA, (IMMED+1)
cmple rC, rA, rB	cmpge rC, rB, rA
cmplei rB, rA, IMMED	cmplti rB, rA, (IMMED+1)
cmpleu rC, rA, rB	cmpgeu rC, rB, rA
cmpleui rB, rA, IMMED	cmpltui rB, rA, (IMMED+1)
mov rC, rA	add rC, rA, r0
movhi rB, IMMED	orhi rB, r0, IMMED
movi rB, IMMED	addi, rB, r0, IMMED
movia rB, label	orhi rB, r0, %hiadj(label) addi, rB, r0, %lo(label)
movui rB, IMMED	ori rB, r0, IMMED
nop	add r0, r0, r0
subi rB, rA, IMMED	addi rB, rA, (-IMMED)

## Assembler Macros

The Nios II assembler provides macros to extract halfwords from labels and from 32-bit immediate values. [Table 8-4](#) lists the available macros. These macros return 16-bit signed values or 16-bit unsigned values depending on where they are used. When used with an instruction that requires a 16-bit signed immediate value, these macros return a value ranging from -32768 to 32767. When used with an instruction that requires a 16-bit unsigned immediate value, these macros return a value ranging from 0 to 65535.

**Table 8-4.** Assembler Macros

Macro	Description	Operation
%lo(immed32)	Extract bits [15..0] of immed32	immed32 & 0xffff
%hi(immed32)	Extract bits [31..16] of immed32	(immed32 >> 16) & 0xffff
%hiadj(immed32)	Extract bits [31..16] and adds bit 15 of immed32	((immed32 >> 16) & 0xffff) + ((immed32 >> 15) & 0x1)
%gprel(immed32)	Replace the immed32 address with an offset from the global pointer <a href="#">(1)</a>	immed32 -_gp

**Note to Table 8-4:**

(1) Refer to the [Application Binary Interface](#) chapter of the *Nios II Processor Reference Handbook* for more information about global pointers.

## Instruction Set Reference

The following pages list all Nios II instruction mnemonics in alphabetical order. [Table 8-5](#) shows the notation conventions used to describe instruction operation.

**Table 8-5.** Notation Conventions

Notation	Meaning
$X \leftarrow Y$	X is written with Y
$PC \leftarrow X$	The program counter (PC) is written with address X; the instruction at X is the next instruction to execute
PC	The address of the assembly instruction in question
rA, rB, rC	One of the 32-bit general-purpose registers
prs.rA	General-purpose register rA in the previous register set
IMM $n$	An $n$ -bit immediate value, embedded in the instruction word
IMMED	An immediate value
$X_n$	The $n^{\text{th}}$ bit of X, where $n = 0$ is the LSB
$X_{n..m}$	Consecutive bits $n$ through $m$ of X
0xNNMM	Hexadecimal notation
$X : Y$	Bitwise concatenation For example, $(0x12 : 0x34) = 0x1234$
$\sigma(X)$	The value of X after being sign-extended to a full register-sized signed integer
$X \gg n$	The value X after being right-shifted $n$ bit positions
$X \ll n$	The value X after being left-shifted $n$ bit positions
$X \& Y$	Bitwise logical AND
$X   Y$	Bitwise logical OR
$X \wedge Y$	Bitwise logical XOR
$\sim X$	Bitwise logical NOT (one's complement)
Mem8[X]	The byte located in data memory at byte address X
Mem16[X]	The halfword located in data memory at byte address X
Mem32[X]	The word located in data memory at byte address X
label	An address label specified in the assembly file
(signed) rX	The value of rX treated as a signed number
(unsigned) rX	The value of rX treated as an unsigned number

**Note to Table 8-5:**

(1) All register operations apply to the current register set, except as noted.

The following exceptions are not listed for each instruction because they can occur on any instruction fetch:

- Supervisor-only instruction address
- Fast TLB miss (instruction)
- Double TLB miss (instruction)
- TLB permission violation (execute)
- MPU region violation (instruction)



For details on these and all Nios II exceptions, refer to the *Programming Model* chapter of the *Nios II Processor Reference Handbook*.

**add****add****Operation:**  $rC \leftarrow rA + rB$ **Assembler Syntax:** `add rC, rA, rB`**Example:** `add r6, r7, r8`**Description:** Calculates the sum of rA and rB. Stores the result in rC. Used for both signed and unsigned addition.**Usage: Carry Detection (unsigned operands):**

Following an `add` operation, a carry out of the MSB can be detected by checking whether the unsigned sum is less than one of the unsigned operands. The carry bit can be written to a register, or a conditional branch can be taken based on the carry condition. Both cases are shown below.

```
add rC, rA, rB           ; The original add operation
cmpltu rD, rC, rA       ; rD is written with the carry bit
```

```
add rC, rA, rB           ; The original add operation
bltu rC, rA, label      ; Branch if carry generated
```

**Usage: Overflow Detection (signed operands):**

An overflow is detected when two positives are added and the sum is negative, or when two negatives are added and the sum is positive. The overflow condition can control a conditional branch, as shown below.

```
add rC, rA, rB           ; The original add operation
xor rD, rC, rA          ; Compare signs of sum and rA
xor rE, rC, rB          ; Compare signs of sum and rB
and rD, rD, rE          ; Combine comparisons
blt rD, r0, label       ; Branch if overflow occurred
```

**Exceptions:** None**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA  
B = Register index of operand rB  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A					B					C					0x31					0					0x3a						

## addi

## add immediate

**Operation:**  $rB \leftarrow rA + \sigma(\text{IMM16})$

**Assembler Syntax:** `addi rB, rA, IMM16`

**Example:** `addi r6, r7, -100`

**Description:** Sign-extends the 16-bit immediate value and adds it to the value of rA. Stores the sum in rB.

**Usage:** **Carry Detection (unsigned operands):**

Following an `addi` operation, a carry out of the MSB can be detected by checking whether the unsigned sum is less than one of the unsigned operands. The carry bit can be written to a register, or a conditional branch can be taken based on the carry condition. Both cases are shown below.

```
addi rB, rA, IMM16      ; The original add operation
cmltu rD, rB, rA       ; rD is written with the carry bit

addi rB, rA, IMM16      ; The original add operation
bltu rB, rA, label     ; Branch if carry generated
```

**Overflow Detection (signed operands):**

An overflow is detected when two positives are added and the sum is negative, or when two negatives are added and the sum is positive. The overflow condition can control a conditional branch, as shown below.

```
addi rB, rA, IMM16      ; The original add operation
xor rC, rB, rA         ; Compare signs of sum and rA
xorhi rD, rB, IMM16    ; Compare signs of sum and IMM16
and rC, rC, rD         ; Combine comparisons
blt rC, r0, label     ; Branch if overflow occurred
```

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A								B								IMM16								0x04							

**and****bitwise logical and**

**Operation:**  $rC \leftarrow rA \& rB$

**Assembler Syntax:** `and rC, rA, rB`

**Example:** `and r6, r7, r8`

**Description:** Calculates the bitwise logical AND of rA and rB and stores the result in rC.

**Exceptions:** None

**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA  
B = Register index of operand rB  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A								B								C				0x0e				0				0x3a			

## andhi bitwise logical and immediate into high halfword

**Operation:**  $rB \leftarrow rA \& (IMM16 : 0x0000)$

**Assembler Syntax:** `andhi rB, rA, IMM16`

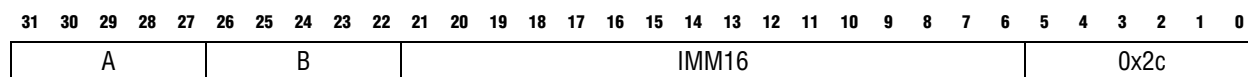
**Example:** `andhi r6, r7, 100`

**Description:** Calculates the bitwise logical AND of rA and (IMM16 : 0x0000) and stores the result in rB.

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit unsigned immediate value



**andi****bitwise logical and immediate**

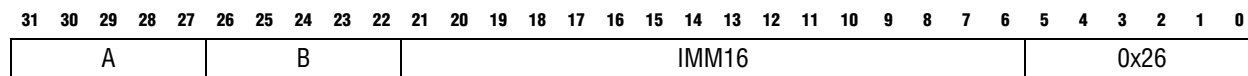
<b>Operation:</b>	$rB \leftarrow rA \& (0x0000 : IMM16)$
<b>Assembler Syntax:</b>	<code>andi rB, rA, IMM16</code>
<b>Example:</b>	<code>andi r6, r7, 100</code>
<b>Description:</b>	Calculates the bitwise logical AND of rA and (0x0000 : IMM16) and stores the result in rB.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB IMM16 = 16-bit unsigned immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A					B					IMM16												0x0c									

## beq

## branch if equal

- Operation:** if (rA == rB)  
 then PC ← PC + 4 + σ (IMM16)  
 else PC ← PC + 4
- Assembler Syntax:** beq rA, rB, label
- Example:** beq r6, r7, label
- Description:** If rA == rB, then `beq` transfers program control to the instruction at label. In the instruction encoding, the offset given by IMM16 is treated as a signed number of bytes relative to the instruction immediately following `beq`. The two least-significant bits of IMM16 are always zero, because instruction addresses must be word-aligned.
- Exceptions:** Misaligned destination address
- Instruction Type:** I
- Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**bge****branch if greater than or equal signed**

<b>Operation:</b>	if ((signed) rA >= (signed) rB) then PC ← PC + 4 + σ (IMM16) else PC ← PC + 4
<b>Assembler Syntax:</b>	bge rA, rB, label
<b>Example:</b>	bge r6, r7, top_of_loop
<b>Description:</b>	If (signed) rA >= (signed) rB, then <code>bge</code> transfers program control to the instruction at label. In the instruction encoding, the offset given by IMM16 is treated as a signed number of bytes relative to the instruction immediately following <code>bge</code> . The two least-significant bits of IMM16 are always zero, because instruction addresses must be word-aligned.
<b>Exceptions:</b>	Misaligned destination address
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB IMM16 = 16-bit signed immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				IMM16										0x0e													

## bgeu

## branch if greater than or equal unsigned

**Operation:** if ((unsigned) rA >= (unsigned) rB)  
 then PC ← PC + 4 + σ (IMM16)  
 else PC ← PC + 4

**Assembler Syntax:** bgeu rA, rB, label

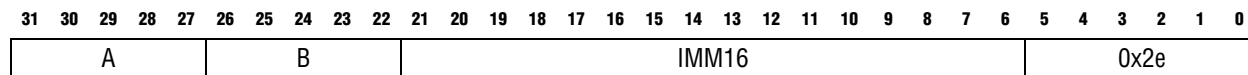
**Example:** bgeu r6, r7, top\_of\_loop

**Description:** If (unsigned) rA >= (unsigned) rB, then bgeu transfers program control to the instruction at label. In the instruction encoding, the offset given by IMM16 is treated as a signed number of bytes relative to the instruction immediately following bgeu. The two least-significant bits of IMM16 are always zero, because instruction addresses must be word-aligned.

**Exceptions:** Misaligned destination address

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**bgt****branch if greater than signed**

<b>Operation:</b>	if ((signed) rA > (signed) rB) then PC ← label else PC ← PC + 4
<b>Assembler Syntax:</b>	bgt rA, rB, label
<b>Example:</b>	bgt r6, r7, top_of_loop
<b>Description:</b>	If (signed) rA > (signed) rB, then <code>bgt</code> transfers program control to the instruction at label.
<b>Pseudo-instruction:</b>	<code>bgt</code> is implemented with the <code>blt</code> instruction by swapping the register operands.

## **bgtu**

## **branch if greater than unsigned**

<b>Operation:</b>	if ((unsigned) rA > (unsigned) rB) then PC ← label else PC ← PC + 4
<b>Assembler Syntax:</b>	bgtu rA, rB, label
<b>Example:</b>	bgtu r6, r7, top_of_loop
<b>Description:</b>	If (unsigned) rA > (unsigned) rB, then <code>bgtu</code> transfers program control to the instruction at label.
<b>Pseudo-instruction:</b>	<code>bgtu</code> is implemented with the <code>b1tu</code> instruction by swapping the register operands.

**ble****branch if less than or equal signed**

<b>Operation:</b>	if ((signed) rA <= (signed) rB) then PC ← label else PC ← PC + 4
<b>Assembler Syntax:</b>	ble rA, rB, label
<b>Example:</b>	ble r6, r7, top_of_loop
<b>Description:</b>	If (signed) rA <= (signed) rB, then ble transfers program control to the instruction at label.
<b>Pseudo-instruction:</b>	ble is implemented with the bge instruction by swapping the register operands.

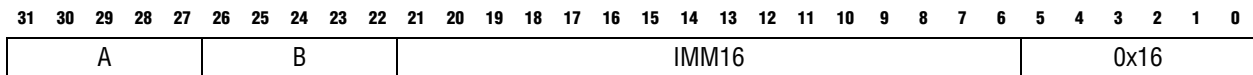
## bleu

## branch if less than or equal to unsigned

<b>Operation:</b>	if ((unsigned) rA <= (unsigned) rB) then PC ← label else PC ← PC + 4
<b>Assembler Syntax:</b>	bleu rA, rB, label
<b>Example:</b>	bleu r6, r7, top_of_loop
<b>Description:</b>	If (unsigned) rA <= (unsigned) rB, then bleu transfers program counter to the instruction at label.
<b>Pseudo-instruction:</b>	bleu is implemented with the bgeu instruction by swapping the register operands.

**blt****branch if less than signed**

<b>Operation:</b>	if ((signed) rA < (signed) rB) then PC ← PC + 4 + σ (IMM16) else PC ← PC + 4
<b>Assembler Syntax:</b>	blt rA, rB, label
<b>Example:</b>	blt r6, r7, top_of_loop
<b>Description:</b>	If (signed) rA < (signed) rB, then <code>blt</code> transfers program control to the instruction at label. In the instruction encoding, the offset given by IMM16 is treated as a signed number of bytes relative to the instruction immediately following <code>blt</code> . The two least-significant bits of IMM16 are always zero, because instruction addresses must be word-aligned.
<b>Exceptions:</b>	Misaligned destination address
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB IMM16 = 16-bit signed immediate value



## bltu

## branch if less than unsigned

**Operation:** if ((unsigned) rA < (unsigned) rB)  
 then PC ← PC + 4 + σ (IMM16)  
 else PC ← PC + 4

**Assembler Syntax:** bltu rA, rB, label

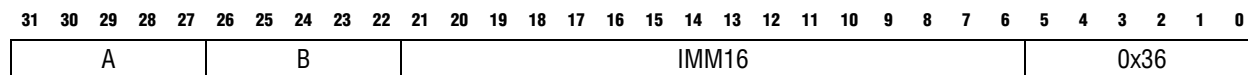
**Example:** bltu r6, r7, top\_of\_loop

**Description:** If (unsigned) rA < (unsigned) rB, then bltu transfers program control to the instruction at label. In the instruction encoding, the offset given by IMM16 is treated as a signed number of bytes relative to the instruction immediately following bltu. The two least-significant bits of IMM16 are always zero, because instruction addresses must be word-aligned.

**Exceptions:** Misaligned destination address

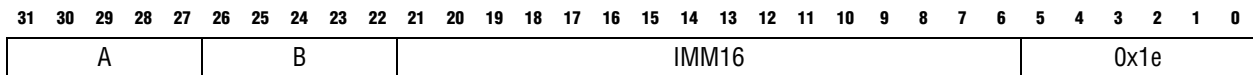
**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**bne****branch if not equal**

<b>Operation:</b>	if ( $rA \neq rB$ ) then $PC \leftarrow PC + 4 + \sigma(\text{IMM16})$ else $PC \leftarrow PC + 4$
<b>Assembler Syntax:</b>	<code>bne rA, rB, label</code>
<b>Example:</b>	<code>bne r6, r7, top_of_loop</code>
<b>Description:</b>	If $rA \neq rB$ , then <code>bne</code> transfers program control to the instruction at <code>label</code> . In the instruction encoding, the offset given by <code>IMM16</code> is treated as a signed number of bytes relative to the instruction immediately following <code>bne</code> . The two least-significant bits of <code>IMM16</code> are always zero, because instruction addresses must be word-aligned.
<b>Exceptions:</b>	Misaligned destination address
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB IMM16 = 16-bit signed immediate value



**br**

**unconditional branch**

**Operation:**  $PC \leftarrow PC + 4 + \sigma(\text{IMM16})$

**Assembler Syntax:** `br label`

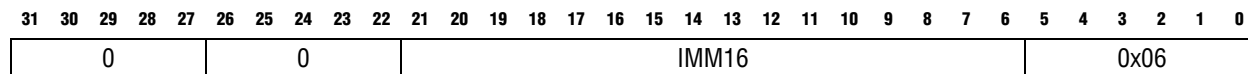
**Example:** `br top_of_loop`

**Description:** Transfers program control to the instruction at label. In the instruction encoding, the offset given by IMM16 is treated as a signed number of bytes relative to the instruction immediately following `br`. The two least-significant bits of IMM16 are always zero, because instruction addresses must be word-aligned.

**Exceptions:** Misaligned destination address

**Instruction Type:** I

**Instruction Fields:** IMM16 = 16-bit signed immediate value



**break****debugging breakpoint**

**Operation:**  $bstatus \leftarrow status$   
 $PIE \leftarrow 0$   
 $U \leftarrow 0$   
 $ba \leftarrow PC + 4$   
 $PC \leftarrow \text{break handler address}$

**Assembler Syntax:** `break`  
`break imm5`

**Example:** `break`

**Description:** Breaks program execution and transfers control to the debugger break-processing routine. Saves the address of the next instruction in register `ba` and saves the contents of the `status` register in `bstatus`. Disables interrupts, then transfers execution to the break handler.

The 5-bit immediate field `imm5` is ignored by the processor, but it can be used by the debugger.

`break` with no argument is the same as `break 0`.

**Usage:** `break` is used by debuggers exclusively. Only debuggers should place `break` in a user program, operating system, or exception handler. The address of the break handler is specified at system generation time.

Some debuggers support `break` and `break 0` instructions in source code. These debuggers treat the `break` instruction as a normal breakpoint.

**Exceptions:** Break

**Instruction Type:** R

**Instruction Fields:** IMM5 = Type of breakpoint

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0					0					0x1e					0x34					IMM5					0x3a						

## bret

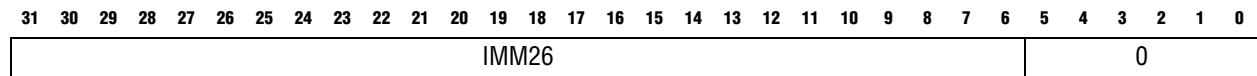
## breakpoint return

<b>Operation:</b>	$status \leftarrow bstatus$ $PC \leftarrow ba$
<b>Assembler Syntax:</b>	bret
<b>Example:</b>	bret
<b>Description:</b>	Copies the value of <code>bstatus</code> to the <code>status</code> register, then transfers execution to the address in <code>ba</code> .
<b>Usage:</b>	<code>bret</code> is used by debuggers exclusively and should not appear in user programs, operating systems, or exception handlers.
<b>Exceptions:</b>	Misaligned destination address Supervisor-only instruction
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	None

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x1e				0				0				0x09				0				0x3a											

**call****call subroutine**

<b>Operation:</b>	$ra \leftarrow PC + 4$ $PC \leftarrow (PC_{31..28} : IMM26 \times 4)$
<b>Assembler Syntax:</b>	<code>call label</code>
<b>Example:</b>	<code>call write_char</code>
<b>Description:</b>	Saves the address of the next instruction in register <code>ra</code> , and transfers execution to the instruction at address $(PC_{31..28} : IMM26 \times 4)$ .
<b>Usage:</b>	<code>call</code> can transfer execution anywhere within the 256 MByte range determined by $PC_{31..28}$ . The Nios II GNU linker does not automatically handle cases in which the address is out of this range.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	J
<b>Instruction Fields:</b>	IMM26 = 26-bit unsigned immediate value



## callr

## call subroutine in register

**Operation:**  $ra \leftarrow PC + 4$   
 $PC \leftarrow rA$

**Assembler Syntax:** `callr rA`

**Example:** `callr r6`

**Description:** Saves the address of the next instruction in the return address register, and transfers execution to the address contained in register rA.

**Usage:** `callr` is used to dereference C-language function pointers.

**Exceptions:** Misaligned destination address

**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				0				0x1f				0x1d				0				0x3a											

**cmpeq****compare equal**

<b>Operation:</b>	if (rA == rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpeq rC, rA, rB
<b>Example:</b>	cmpeq r6, r7, r8
<b>Description:</b>	If rA == rB, then stores 1 to rC; otherwise, stores 0 to rC.
<b>Usage:</b>	cmpeq performs the == operation of the C programming language. Also, cmpeq can be used to implement the C logical negation operator "!".  cmpeq rC, rA, r0 ; Implements rC = !rA
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x20				0				0x3a											

## cmpeqi

## compare equal immediate

**Operation:** if ( $rA \sigma$  (IMM16))  
 then  $rB \leftarrow 1$   
 else  $rB \leftarrow 0$

**Assembler Syntax:** `cmpeqi rB, rA, IMM16`

**Example:** `cmpeqi r6, r7, 100`

**Description:** Sign-extends the 16-bit immediate value IMM16 to 32 bits and compares it to the value of rA. If  $rA == \sigma$  (IMM16), `cmpeqi` stores 1 to rB; otherwise stores 0 to rB.

**Usage:** `cmpeqi` performs the `==` operation of the C programming language.

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				IMM16												0x20											

**cmpge****compare greater than or equal signed**

<b>Operation:</b>	if ((signed) rA >= (signed) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpge rC, rA, rB
<b>Example:</b>	cmpge r6, r7, r8
<b>Description:</b>	If rA >= rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmpge performs the signed >= operation of the C programming language.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x08				0				0x3a											

## cmpgei compare greater than or equal signed immediate

**Operation:** if ((signed) rA >= (signed)  $\sigma$  (IMM16))  
 then rB  $\leftarrow$  1  
 else rB  $\leftarrow$  0

**Assembler Syntax:** `cmpgei rB, rA, IMM16`

**Example:** `cmpgei r6, r7, 100`

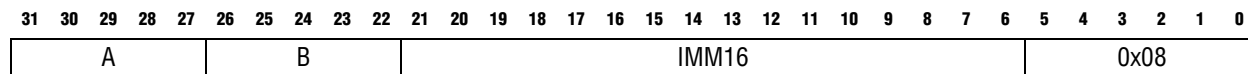
**Description:** Sign-extends the 16-bit immediate value IMM16 to 32 bits and compares it to the value of rA. If rA >=  $\sigma$ (IMM16), then `cmpgei` stores 1 to rB; otherwise stores 0 to rB.

**Usage:** `cmpgei` performs the signed >= operation of the C programming language.

**Exceptions:** None

**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**cmpgeu****compare greater than or equal unsigned**

<b>Operation:</b>	if ((unsigned) rA >= (unsigned) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpgeu rC, rA, rB
<b>Example:</b>	cmpgeu r6, r7, r8
<b>Description:</b>	If rA >= rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmpgeu performs the unsigned >= operation of the C programming language.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x28				0				0x3a											

## cmpgeui compare greater than or equal unsigned immediate

**Operation:** if ((unsigned) rA >= (unsigned) (0x0000 : IMM16))  
 then rB ← 1  
 else rB ← 0

**Assembler Syntax:** `cmpgeui rB, rA, IMM16`

**Example:** `cmpgeui r6, r7, 100`

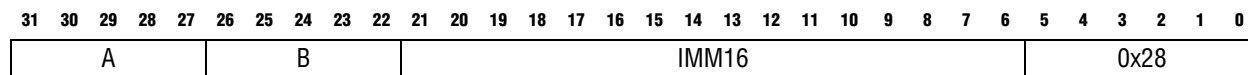
**Description:** Zero-extends the 16-bit immediate value IMM16 to 32 bits and compares it to the value of rA. If rA >= (0x0000 : IMM16), then `cmpgeui` stores 1 to rB; otherwise stores 0 to rB.

**Usage:** `cmpgeui` performs the unsigned >= operation of the C programming language.

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit unsigned immediate value



**cmpgt****compare greater than signed**

<b>Operation:</b>	if ((signed) rA > (signed) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpgt rC, rA, rB
<b>Example:</b>	cmpgt r6, r7, r8
<b>Description:</b>	If rA > rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmpgt performs the signed > operation of the C programming language.
<b>Pseudo-instruction:</b>	cmpgt is implemented with the <code>cmplt</code> instruction by swapping its rA and rB operands.

## cmpgti

## compare greater than signed immediate

<b>Operation:</b>	if ((signed) rA > (signed) IMMED) then rB ← 1 else rB ← 0
<b>Assembler Syntax:</b>	cmpgti rB, rA, IMMED
<b>Example:</b>	cmpgti r6, r7, 100
<b>Description:</b>	Sign-extends the immediate value IMMED to 32 bits and compares it to the value of rA. If rA > $\sigma(\text{IMMED})$ , then <code>cmpgti</code> stores 1 to rB; otherwise stores 0 to rB.
<b>Usage:</b>	<code>cmpgti</code> performs the signed > operation of the C programming language. The maximum allowed value of IMMED is 32766. The minimum allowed value is -32769.
<b>Pseudo-instruction:</b>	<code>cmpgti</code> is implemented using a <code>cmpgei</code> instruction with an IMM16 immediate value of IMMED + 1.

**cmpgtu****compare greater than unsigned**

<b>Operation:</b>	if ((unsigned) rA > (unsigned) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpgtu rC, rA, rB
<b>Example:</b>	cmpgtu r6, r7, r8
<b>Description:</b>	If rA > rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmpgtu performs the unsigned > operation of the C programming language.
<b>Pseudo-instruction:</b>	cmpgtu is implemented with the <code>cmpltu</code> instruction by swapping its rA and rB operands.

## cmpgtui

## compare greater than unsigned immediate

<b>Operation:</b>	if ((unsigned) rA > (unsigned) IMMED) then rB ← 1 else rB ← 0
<b>Assembler Syntax:</b>	cmpgtui rB, rA, IMMED
<b>Example:</b>	cmpgtui r6, r7, 100
<b>Description:</b>	Zero-extends the immediate value IMMED to 32 bits and compares it to the value of rA. If rA > IMMED, then <code>cmpgtui</code> stores 1 to rB; otherwise stores 0 to rB.
<b>Usage:</b>	<code>cmpgtui</code> performs the unsigned > operation of the C programming language. The maximum allowed value of IMMED is 65534. The minimum allowed value is 0.
<b>Pseudo-instruction:</b>	<code>cmpgtui</code> is implemented using a <code>cmpgeui</code> instruction with an IMM16 immediate value of IMMED + 1.

**cmple****compare less than or equal signed**

<b>Operation:</b>	if ((signed) rA <= (signed) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmple rC, rA, rB
<b>Example:</b>	cmple r6, r7, r8
<b>Description:</b>	If rA <= rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmple performs the signed <= operation of the C programming language.
<b>Pseudo-instruction:</b>	cmple is implemented with the cmpge instruction by swapping its rA and rB operands.

## **cmplei**

## **compare less than or equal signed immediate**

<b>Operation:</b>	if ((signed) rA < (signed) IMMED) then rB ← 1 else rB ← 0
<b>Assembler Syntax:</b>	<code>cmplei rB, rA, IMMED</code>
<b>Example:</b>	<code>cmplei r6, r7, 100</code>
<b>Description:</b>	Sign-extends the immediate value IMMED to 32 bits and compares it to the value of rA. If $rA \leq \sigma(\text{IMMED})$ , then <code>cmplei</code> stores 1 to rB; otherwise stores 0 to rB.
<b>Usage:</b>	<code>cmplei</code> performs the signed $\leq$ operation of the C programming language. The maximum allowed value of IMMED is 32766. The minimum allowed value is -32769.
<b>Pseudo-instruction:</b>	<code>cmplei</code> is implemented using a <code>cmplti</code> instruction with an IMM16 immediate value of IMMED + 1.

**cmpleu****compare less than or equal unsigned**

<b>Operation:</b>	if ((unsigned) rA < (unsigned) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpleu rC, rA, rB
<b>Example:</b>	cmpleu r6, r7, r8
<b>Description:</b>	If rA <= rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmpleu performs the unsigned <= operation of the C programming language.
<b>Pseudo-instruction:</b>	cmpleu is implemented with the cmpgeu instruction by swapping its rA and rB operands.

## **cmpleui**

## **compare less than or equal unsigned immediate**

<b>Operation:</b>	if ((unsigned) rA <= (unsigned) IMMED) then rB ← 1 else rB ← 0
<b>Assembler Syntax:</b>	<code>cmpleui rB, rA, IMMED</code>
<b>Example:</b>	<code>cmpleui r6, r7, 100</code>
<b>Description:</b>	Zero-extends the immediate value IMMED to 32 bits and compares it to the value of rA. If rA <= IMMED, then <code>cmpleui</code> stores 1 to rB; otherwise stores 0 to rB.
<b>Usage:</b>	<code>cmpleui</code> performs the unsigned <= operation of the C programming language. The maximum allowed value of IMMED is 65534. The minimum allowed value is 0.
<b>Pseudo-instruction:</b>	<code>cmpleui</code> is implemented using a <code>cmpltui</code> instruction with an IMM16 immediate value of IMMED + 1.

**cmplt****compare less than signed**

<b>Operation:</b>	if ((signed) rA < (signed) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmplt rC, rA, rB
<b>Example:</b>	cmplt r6, r7, r8
<b>Description:</b>	If rA < rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmplt performs the signed < operation of the C programming language.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x10				0				0x3a											

## cmplti

## compare less than signed immediate

**Operation:** if ((signed) rA < (signed)  $\sigma$  (IMM16))  
 then rB  $\leftarrow$  1  
 else rB  $\leftarrow$  0

**Assembler Syntax:** `cmplti rB, rA, IMM16`

**Example:** `cmplti r6, r7, 100`

**Description:** Sign-extends the 16-bit immediate value IMM16 to 32 bits and compares it to the value of rA. If rA <  $\sigma$  (IMM16), then `cmplti` stores 1 to rB; otherwise stores 0 to rB.

**Usage:** `cmplti` performs the signed < operation of the C programming language.

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A								B								IMM16								0x10							

**cmpltu****compare less than unsigned**

<b>Operation:</b>	if ((unsigned) rA < (unsigned) rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpltu rC, rA, rB
<b>Example:</b>	cmpltu r6, r7, r8
<b>Description:</b>	If rA < rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmpltu performs the unsigned < operation of the C programming language.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x30				0				0x3a											

## cmpltui

## compare less than unsigned immediate

**Operation:** if ((unsigned) rA < (unsigned) (0x0000 : IMM16))  
 then rB ← 1  
 else rB ← 0

**Assembler Syntax:** cmpltui rB, rA, IMM16

**Example:** cmpltui r6, r7, 100

**Description:** Zero-extends the 16-bit immediate value IMM16 to 32 bits and compares it to the value of rA. If rA < (0x0000 : IMM16), then cmpltui stores 1 to rB; otherwise stores 0 to rB.

**Usage:** cmpltui performs the unsigned < operation of the C programming language.

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit unsigned immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A								B								IMM16								0x30							

**cmpne****compare not equal**

<b>Operation:</b>	if (rA != rB) then rC ← 1 else rC ← 0
<b>Assembler Syntax:</b>	cmpne rC, rA, rB
<b>Example:</b>	cmpne r6, r7, r8
<b>Description:</b>	If rA != rB, then stores 1 to rC; otherwise stores 0 to rC.
<b>Usage:</b>	cmpne performs the != operation of the C programming language.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x18				0		0x3a													

## cmpnei

## compare not equal immediate

**Operation:** if ( $rA \neq \sigma(\text{IMM16})$ )  
 then  $rB \leftarrow 1$   
 else  $rB \leftarrow 0$

**Assembler Syntax:** `cmpnei rB, rA, IMM16`

**Example:** `cmpnei r6, r7, 100`

**Description:** Sign-extends the 16-bit immediate value IMM16 to 32 bits and compares it to the value of rA. If  $rA \neq \sigma(\text{IMM16})$ , then `cmpnei` stores 1 to rB; otherwise stores 0 to rB.

**Usage:** `cmpnei` performs the `!=` operation of the C programming language.

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				IMM16												0x18											

**custom****custom instruction**

<b>Operation:</b>	if $c == 1$ then $rC \leftarrow f_N(rA, rB, A, B, C)$ else $\emptyset \leftarrow f_N(rA, rB, A, B, C)$
<b>Assembler Syntax:</b>	<code>custom N, xC, xA, xB</code> Where xA means either general purpose register rA, or custom register cA.
<b>Example:</b>	<code>custom 0, c6, r7, r8</code>
<b>Description:</b>	The <code>custom</code> opcode provides access to up to 256 custom instructions allowed by the Nios II architecture. The function implemented by a custom instruction is user-defined and is specified at system generation time. The 8-bit immediate N field specifies which custom instruction to use. Custom instructions can use up to two parameters, xA and xB, and can optionally write the result to a register xC.
<b>Usage:</b>	To access a custom register inside the custom instruction logic, clear the bit <code>readra</code> , <code>readrb</code> , or <code>writerc</code> that corresponds to the register field. In assembler syntax, the notation <code>cN</code> refers to register N in the custom register file and causes the assembler to clear the <code>c</code> bit of the opcode. For example, <code>custom 0, c3, r5, r0</code> performs custom instruction 0, operating on general-purpose registers r5 and r0, and stores the result in custom register 3.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand A B = Register index of operand B C = Register index of operand C <code>readra</code> = 1 if instruction uses rA, 0 otherwise <code>readrb</code> = 1 if instruction uses rB, 0 otherwise <code>writerc</code> = 1 if instruction provides result for rC, 0 otherwise N = 8-bit number that selects instruction

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				ra	rb	rc	N				0x32												

## div

## divide

**Operation:**  $rC \leftarrow rA \div rB$

**Assembler Syntax:** `div rC, rA, rB`

**Example:** `div r6, r7, r8`

**Description:** Treating rA and rB as signed integers, this instruction divides rA by rB and then stores the integer portion of the resulting quotient to rC. After attempted division by zero, the value of rC is undefined. There is no divide-by-zero exception. After dividing -2147483648 by -1, the value of rC is undefined (the number +2147483648 is not representable in 32 bits). There is no overflow exception.

Nios II processors that do not implement the `div` instruction cause an unimplemented instruction exception.

**Usage:** Remainder of Division:

If the result of the division is defined, then the remainder can be computed in rD using the following instruction sequence:

```
div rC, rA, rB      ; The original div operation
mul rD, rC, rB
sub rD, rA, rD      ; rD = remainder
```

**Exceptions:** Division error  
 Unimplemented instruction

**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x25				0				0x3a											

**divu****divide unsigned****Operation:**  $rC \leftarrow rA \div rB$ **Assembler Syntax:** `divu rC, rA, rB`**Example:** `divu r6, r7, r8`**Description:** Treating rA and rB as unsigned integers, this instruction divides rA by rB and then stores the integer portion of the resulting quotient to rC. After attempted division by zero, the value of rC is undefined. There is no divide-by-zero exception.Nios II processors that do not implement the `divu` instruction cause an unimplemented instruction exception.**Usage:** Remainder of Division:

If the result of the division is defined, then the remainder can be computed in rD using the following instruction sequence:

```
divu rC, rA, rB ; The original divu operation
mul rD, rC, rB
sub rD, rA, rD ; rD = remainder
```

**Exceptions:** Division error  
Unimplemented instruction**Instruction Type:** R**Instruction Fields:** A = Register index of operand rA  
B = Register index of operand rB  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
A								B								C								0x24				0				0x3a			

## eret

## exception return

**Operation:**  $status \leftarrow estatus$   
 $PC \leftarrow ea$

**Assembler Syntax:** `eret`

**Example:** `eret`

**Description:** Copies the value of `estatus` into the `status` register, and transfers execution to the address in `ea`.

**Usage:** Use `eret` to return from traps, external interrupts, and other exception handling routines. Note that before returning from hardware interrupt exceptions, the exception handler must adjust the `ea` register.

**Exceptions:** Misaligned destination address  
 Supervisor-only instruction

**Instruction Type:** R

**Instruction Fields:** None

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x1d				0x1e				0				0x01				0				0x3a											

**flushd****flush data cache line**

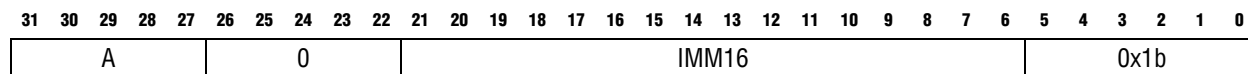
<b>Operation:</b>	Flushes the data cache line associated with address $rA + \sigma$ (IMM16).
<b>Assembler Syntax:</b>	<code>flushd IMM16 (rA)</code>
<b>Example:</b>	<code>flushd -100 (r6)</code>
<b>Description:</b>	<p>If the Nios II processor implements a direct mapped data cache, <code>flushd</code> writes the data cache line that is mapped to the specified address back to memory if the line is dirty, and then clears the data cache line. Unlike <code>flushda</code>, <code>flushd</code> writes the dirty data back to memory even when the addressed data is not currently in the cache. This process comprises the following steps:</p> <ul style="list-style-type: none"> <li>■ Compute the effective address specified by the sum of <code>rA</code> and the signed 16-bit immediate value.</li> <li>■ Identify the data cache line associated with the computed effective address. Each data cache effective address comprises a <code>tag</code> field and a <code>line</code> field. When identifying the data cache line, <code>flushd</code> ignores the <code>tag</code> field and only uses the <code>line</code> field to select the data cache line to clear.</li> <li>■ Skip comparing the cache line tag with the effective address to determine if the addressed data is currently cached. Because <code>flushd</code> ignores the cache line tag, <code>flushd</code> flushes the cache line regardless of whether the specified data location is currently cached.</li> <li>■ If the data cache line is dirty, write the line back to memory. A cache line is dirty when one or more words of the cache line have been modified by the processor, but are not yet written to memory.</li> <li>■ Clear the valid bit for the line.</li> </ul> <p>If the Nios II processor core does not have a data cache, the <code>flushd</code> instruction performs no operation.</p>
<b>Usage:</b>	<p>Use <code>flushd</code> to write dirty lines back to memory even if the addressed memory location is not in the cache, and then flush the cache line. By contrast, refer to “<a href="#">flushda flush data cache address</a>” on page 8-51, “<a href="#">initd initialize data cache line</a>” on page 8-54, and “<a href="#">initda initialize data cache address</a>” on page 8-55 for other cache-clearing options.</p> <p>For more information on data cache, refer to the <i>Cache and Tightly Coupled Memory</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	<p>A = Register index of operand <code>rA</code></p> <p>IMM16 = 16-bit signed immediate value</p>

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A					0	IMM16												0x3b													

## flushda

## flush data cache address

<b>Operation:</b>	Flushes the data cache line currently caching address $rA + \sigma$ (IMM16)
<b>Assembler Syntax:</b>	<code>flushda IMM16 (rA)</code>
<b>Example:</b>	<code>flushda -100 (r6)</code>
<b>Description:</b>	<p>If the Nios II processor implements a direct mapped data cache, <code>flushda</code> writes the data cache line that is mapped to the specified address back to memory if the line is dirty, and then clears the data cache line. Unlike <code>flushd</code>, <code>flushda</code> writes the dirty data back to memory only when the addressed data is currently in the cache. This process comprises the following steps:</p> <ul style="list-style-type: none"> <li>■ Compute the effective address specified by the sum of <code>rA</code> and the signed 16-bit immediate value.</li> <li>■ Identify the data cache line associated with the computed effective address. Each data cache effective address comprises a <code>tag</code> field and a <code>line</code> field. When identifying the line, <code>flushda</code> uses both the <code>tag</code> field and the <code>line</code> field.</li> <li>■ Compare the cache line tag with the effective address to determine if the addressed data is currently cached. If the <code>tag</code> fields do not match, the effective address is not currently cached, so the instruction does nothing.</li> <li>■ If the data cache line is dirty and the <code>tag</code> fields match, write the dirty cache line back to memory. A cache line is dirty when one or more words of the cache line have been modified by the processor, but are not yet written to memory.</li> <li>■ Clear the valid bit for the line.</li> </ul> <p>If the Nios II processor core does not have a data cache, the <code>flushda</code> instruction performs no operation.</p>
<b>Usage:</b>	<p>Use <code>flushda</code> to write dirty lines back to memory only if the addressed memory location is currently in the cache, and then flush the cache line. By contrast, refer to “<a href="#">flushd flush data cache line</a>” on page 8-50, “<a href="#">initd initialize data cache line</a>” on page 8-54, and “<a href="#">initda initialize data cache address</a>” on page 8-55 for other cache-clearing options.</p> <p>For more information on the Nios II data cache, refer to the <i>Cache and Tightly Coupled Memory</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
<b>Exceptions:</b>	<p>Supervisor-only data address</p> <p>Fast TLB miss (data)</p> <p>Double TLB miss (data)</p> <p>MPU region violation (data)</p>
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	<p>A = Register index of operand <code>rA</code></p> <p>IMM16 = 16-bit signed immediate value</p>



**flushi****flush instruction cache line**

<b>Operation:</b>	Flushes the instruction cache line associated with address rA.
<b>Assembler Syntax:</b>	<code>flushi rA</code>
<b>Example:</b>	<code>flushi r6</code>
<b>Description:</b>	<p>Ignoring the tag, <code>flushi</code> identifies the instruction cache line associated with the byte address in rA, and invalidates that line.</p> <p>If the Nios II processor core does not have an instruction cache, the <code>flushi</code> instruction performs no operation.</p> <p>For more information about the data cache, refer to the <i>Cache and Tightly Coupled Memory</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				0				0				0x0c				0				0x3a											

## flushp

## flush pipeline

- Operation:** Flushes the processor pipeline of any prefetched instructions.
- Assembler Syntax:** `flushp`
- Example:** `flushp`
- Description:** Ensures that any instructions prefetched after the `flushp` instruction are removed from the pipeline.
- Usage:** Use `flushp` before transferring control to newly updated instruction memory.
- Exceptions:** None
- Instruction Type:** R
- Instruction Fields:** None

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				0				0				0x04				0				0x3a											

**initd****initialize data cache line**

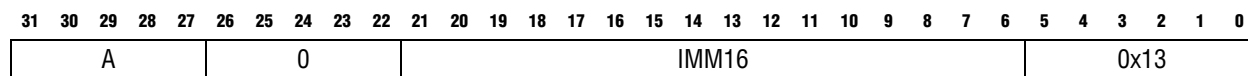
<b>Operation:</b>	Initializes the data cache line associated with address $rA + \sigma$ (IMM16).
<b>Assembler Syntax:</b>	<code>initd IMM16(rA)</code>
<b>Example:</b>	<code>initd 0(r6)</code>
<b>Description:</b>	<p>If the Nios II processor implements a direct mapped data cache, <code>initd</code> clears the data cache line without checking for (or writing) a dirty data cache line that is mapped to the specified address back to memory. Unlike <code>initda</code>, <code>initd</code> clears the cache line regardless of whether the addressed data is currently cached. This process comprises the following steps:</p> <ul style="list-style-type: none"> <li>■ Compute the effective address specified by the sum of <code>rA</code> and the signed 16-bit immediate value.</li> <li>■ Identify the data cache line associated with the computed effective address. Each data cache effective address comprises a <code>tag</code> field and a <code>line</code> field. When identifying the line, <code>initd</code> ignores the <code>tag</code> field and only uses the <code>line</code> field to select the data cache line to clear.</li> <li>■ Skip comparing the cache line tag with the effective address to determine if the addressed data is currently cached. Because <code>initd</code> ignores the cache line tag, <code>initd</code> flushes the cache line regardless of whether the specified data location is currently cached.</li> <li>■ Skip checking if the data cache line is dirty. Because <code>initd</code> skips the dirty cache line check, data that has been modified by the processor, but not yet written to memory is lost.</li> <li>■ Clear the valid bit for the line.</li> </ul> <p>If the Nios II processor core does not have a data cache, the <code>initd</code> instruction performs no operation.</p>
<b>Usage:</b>	<p>Use <code>initd</code> after processor reset and before accessing data memory to initialize the processor's data cache. Use <code>initd</code> with caution because it does not write back dirty data. By contrast, refer to “<a href="#">flushd flush data cache line</a>” on page 8-50, “<a href="#">flushda flush data cache address</a>” on page 8-51, and “<a href="#">initda initialize data cache address</a>” on page 8-55 for other cache-clearing options. Altera recommends using <code>initd</code> only when the processor comes out of reset.</p> <p>For more information on data cache, refer to the <a href="#">Cache and Tightly Coupled Memory</a> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
<b>Exceptions:</b>	Supervisor-only instruction
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	<p>A = Register index of operand <code>rA</code></p> <p>IMM16 = 16-bit signed immediate value</p>

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				0				IMM16										0x33													

## initda

## initialize data cache address

<b>Operation:</b>	Initializes the data cache line currently caching address $rA + \sigma$ (IMM16)
<b>Assembler Syntax:</b>	<code>initda IMM16 (rA)</code>
<b>Example:</b>	<code>initda -100 (r6)</code>
<b>Description:</b>	<p>If the Nios II processor implements a direct mapped data cache, <code>initda</code> clears the data cache line without checking for (or writing) a dirty data cache line that is mapped to the specified address back to memory. Unlike <code>initd</code>, <code>initda</code> clears the cache line only when the addressed data is currently cached. This process comprises the following steps:</p> <ul style="list-style-type: none"> <li>■ Compute the effective address specified by the sum of <code>rA</code> and the signed 16-bit immediate value.</li> <li>■ Identify the data cache line associated with the computed effective address. Each data cache effective address comprises a <code>tag</code> field and a <code>line</code> field. When identifying the line, <code>initda</code> uses both the <code>tag</code> field and the <code>line</code> field.</li> <li>■ Compare the cache line tag with the effective address to determine if the addressed data is currently cached. If the <code>tag</code> fields do not match, the effective address is not currently cached, so the instruction does nothing.</li> <li>■ Skip checking if the data cache line is dirty. Because <code>initd</code> skips the dirty cache line check, data that has been modified by the processor, but not yet written to memory is lost.</li> <li>■ Clear the valid bit for the line.</li> </ul> <p>If the Nios II processor core does not have a data cache, the <code>initda</code> instruction performs no operation.</p>
<b>Usage:</b>	<p>Use <code>initda</code> to skip writing dirty lines back to memory and to flush the cache line only if the addressed memory location is currently in the cache. By contrast, refer to “<a href="#">flushd flush data cache line</a>” on page 8-50, “<a href="#">flushda flush data cache address</a>” on page 8-51, and “<a href="#">initd initialize data cache line</a>” on page 8-54 for other cache-clearing options. Use <code>initda</code> with caution because it does not write back dirty data.</p> <p>For more information on the Nios II data cache, refer to the <i>Cache and Tightly Coupled Memory</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
<b>Exceptions:</b>	<p>Supervisor-only data address Fast TLB miss (data) Double TLB miss (data) MPU region violation (data) Unimplemented instruction</p>
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	<p>A = Register index of operand <code>rA</code> IMM16 = 16-bit signed immediate value</p>



**init****initialize instruction cache line**

<b>Operation:</b>	Initializes the instruction cache line associated with address rA.
<b>Assembler Syntax:</b>	<code>init rA</code>
<b>Example:</b>	<code>init r6</code>
<b>Description:</b>	<p>Ignoring the tag, <code>init</code> identifies the instruction cache line associated with the byte address in rA, and <code>init</code> invalidates that line.</p> <p>If the Nios II processor core does not have an instruction cache, the <code>init</code> instruction performs no operation.</p>
<b>Usage:</b>	<p>This instruction is used to initialize the processor's instruction cache. Immediately after processor reset, use <code>init</code> to invalidate each line of the instruction cache.</p> <p>For more information on instruction cache, refer to the <i>Cache and Tightly Coupled Memory</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
<b>Exceptions:</b>	Supervisor-only instruction
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				0				0				0x29				0				0x3a											

## jmp

## computed jump

**Operation:**  $PC \leftarrow rA$

**Assembler Syntax:** `jmp rA`

**Example:** `jmp r12`

**Description:** Transfers execution to the address contained in register rA.

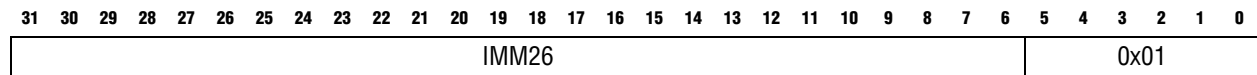
**Usage:** It is illegal to jump to the address contained in register r31. To return from subroutines called by `call` or `callr`, use `ret` instead of `jmp`.

**Exceptions:** Misaligned destination address

**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
A			0			0			0x0d			0			0x3a																	

**jmp****jump immediate****Operation:**  $PC \leftarrow (PC_{31..28} : IMM26 \times 4)$ **Assembler Syntax:** `jmp label`**Example:** `jmp write_char`**Description:** Transfers execution to the instruction at address  $(PC_{31..28} : IMM26 \times 4)$ .**Usage:** `jmp` is a low-overhead local jump. `jmp` can transfer execution anywhere within the 256 MByte range determined by  $PC_{31..28}$ . The Nios II GNU linker does not automatically handle cases in which the address is out of this range.**Exceptions:** None**Instruction Type:** J**Instruction Fields:** IMM26 = 26-bit unsigned immediate value

## ldb / ldbio

## load byte from memory or I/O peripheral

**Operation:**  $rB \leftarrow \sigma(\text{Mem8}[rA + \sigma(\text{IMM16})])$

**Assembler Syntax:** `ldb rB, byte_offset(rA)`  
`ldbio rB, byte_offset(rA)`

**Example:** `ldb r6, 100(r5)`

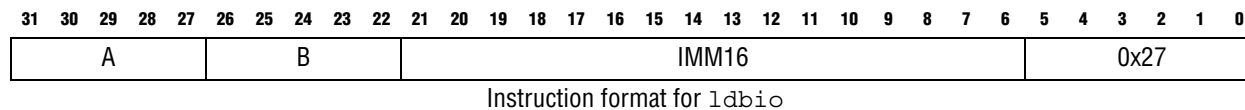
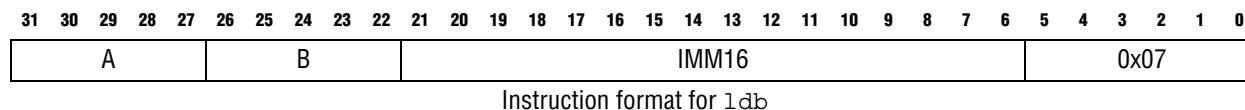
**Description:** Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Loads register rB with the desired memory byte, sign extending the 8-bit value to 32 bits. In Nios II processor cores with a data cache, this instruction may retrieve the desired data from the cache instead of from memory.

**Usage:** Use the `ldbio` instruction for peripheral I/O. In processors with a data cache, `ldbio` bypasses the cache and is guaranteed to generate an Avalon-MM data transfer. In processors without a data cache, `ldbio` acts like `ldb`.  
 For more information on data cache, refer to the *Cache and Tightly Coupled Memory* chapter of the *Nios II Software Developer's Handbook*.

**Exceptions:** Supervisor-only data address  
 Misaligned data address  
 TLB permission violation (read)  
 Fast TLB miss (data)  
 Double TLB miss (data)  
 MPU region violation (data)

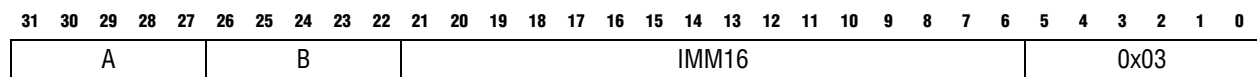
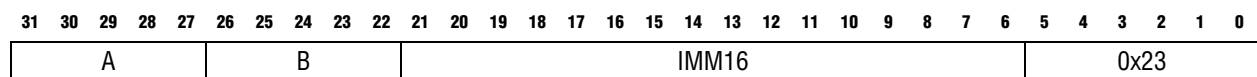
**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**ldbu / ldbuio****load unsigned byte from memory or I/O peripheral****Operation:**  $rB \leftarrow 0x000000 : \text{Mem8}[rA + \sigma(\text{IMM16})]$ **Assembler Syntax:**  
`ldbu rB, byte_offset(rA)`  
`ldbuio rB, byte_offset(rA)`**Example:** `ldbu r6, 100(r5)`**Description:** Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Loads register rB with the desired memory byte, zero extending the 8-bit value to 32 bits.**Usage:** In processors with a data cache, this instruction may retrieve the desired data from the cache instead of from memory. Use the `ldbuio` instruction for peripheral I/O. In processors with a data cache, `ldbuio` bypasses the cache and is guaranteed to generate an Avalon-MM data transfer. In processors without a data cache, `ldbuio` acts like `ldbu`.For more information on data cache, refer to the [Cache and Tightly Coupled Memory](#) chapter of the *Nios II Software Developer's Handbook*.**Exceptions:**

- Supervisor-only data address
- Misaligned data address
- TLB permission violation (read)
- Fast TLB miss (data)
- Double TLB miss (data)
- MPU region violation (data)

**Instruction Type:** I**Instruction Fields:**  
A = Register index of operand rA  
B = Register index of operand rB  
IMM16 = 16-bit signed immediate valueInstruction format for `ldbu`Instruction format for `ldbuio`

## ldh / ldhio

## load halfword from memory or I/O peripheral

**Operation:**  $rB \leftarrow \sigma(\text{Mem16}[rA + \sigma(\text{IMM16})])$

**Assembler Syntax:**  
`ldh rB, byte_offset(rA)`  
`ldhio rB, byte_offset(rA)`

**Example:** `ldh r6, 100(r5)`

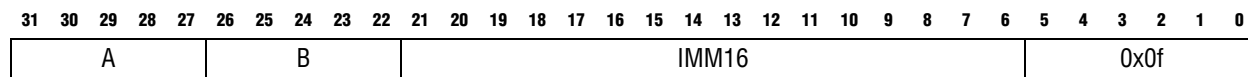
**Description:** Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Loads register rB with the memory halfword located at the effective byte address, sign extending the 16-bit value to 32 bits. The effective byte address must be halfword aligned. If the byte address is not a multiple of 2, the operation is undefined.

**Usage:** In processors with a data cache, this instruction may retrieve the desired data from the cache instead of from memory. Use the `ldhio` instruction for peripheral I/O. In processors with a data cache, `ldhio` bypasses the cache and is guaranteed to generate an Avalon-MM data transfer. In processors without a data cache, `ldhio` acts like `ldh`.  
 For more information on data cache, refer to the *Cache and Tightly Coupled Memory* chapter of the *Nios II Software Developer's Handbook*.

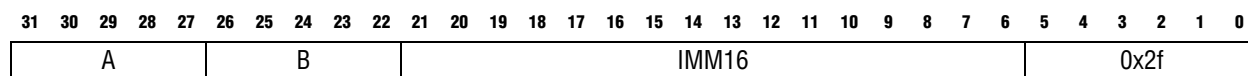
- Exceptions:**
- Supervisor-only data address
  - Misaligned data address
  - TLB permission violation (read)
  - Fast TLB miss (data)
  - Double TLB miss (data)
  - MPU region violation (data)

**Instruction Type:** I

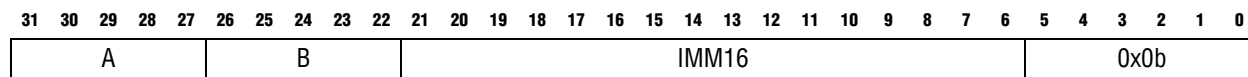
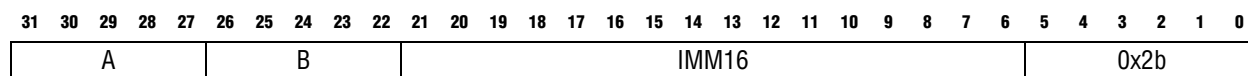
**Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



Instruction format for `ldh`



Instruction format for `ldhio`

**ldhu / ldhuio** **load unsigned halfword from memory or I/O peripheral****Operation:**  $rB \leftarrow 0x0000 : \text{Mem16}[rA + \sigma(\text{IMM16})]$ **Assembler Syntax:**  
`ldhu rB, byte_offset(rA)`  
`ldhuio rB, byte_offset(rA)`**Example:** `ldhu r6, 100(r5)`**Description:** Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Loads register rB with the memory halfword located at the effective byte address, zero extending the 16-bit value to 32 bits. The effective byte address must be halfword aligned. If the byte address is not a multiple of 2, the operation is undefined.**Usage:** In processors with a data cache, this instruction may retrieve the desired data from the cache instead of from memory. Use the `ldhuio` instruction for peripheral I/O. In processors with a data cache, `ldhuio` bypasses the cache and is guaranteed to generate an Avalon-MM data transfer. In processors without a data cache, `ldhuio` acts like `ldhu`.For more information on data cache, refer to the [Cache and Tightly Coupled Memory](#) chapter of the *Nios II Software Developer's Handbook*.**Exceptions:**  
Supervisor-only data address  
Misaligned data address  
TLB permission violation (read)  
Fast TLB miss (data)  
Double TLB miss (data)  
MPU region violation (data)**Instruction Type:** I**Instruction Fields:**  
A = Register index of operand rA  
B = Register index of operand rB  
IMM16 = 16-bit signed immediate valueInstruction format for `ldhu`Instruction format for `ldhuio`

## ldw / ldwio

## load 32-bit word from memory or I/O peripheral

**Operation:**  $rB \leftarrow \text{Mem32}[rA + \sigma(\text{IMM16})]$

**Assembler Syntax:**  
`ldw rB, byte_offset(rA)`  
`ldwio rB, byte_offset(rA)`

**Example:**  
`ldw r6, 100(r5)`

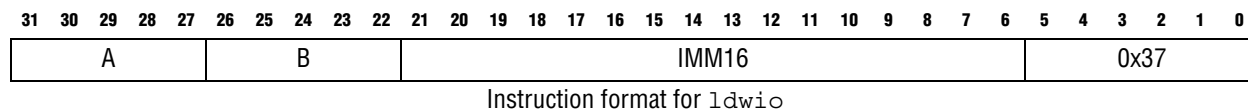
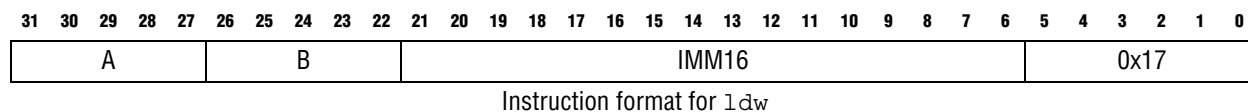
**Description:** Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Loads register rB with the memory word located at the effective byte address. The effective byte address must be word aligned. If the byte address is not a multiple of 4, the operation is undefined.

**Usage:** In processors with a data cache, this instruction may retrieve the desired data from the cache instead of from memory. Use the `ldwio` instruction for peripheral I/O. In processors with a data cache, `ldwio` bypasses the cache and memory. Use the `ldwio` instruction for peripheral I/O. In processors with a data cache, `ldwio` bypasses the cache and is guaranteed to generate an Avalon-MM data transfer. In processors without a data cache, `ldwio` acts like `ldw`.  
 For more information on data cache, refer to the *Cache and Tightly Coupled Memory* chapter of the *Nios II Software Developer's Handbook*.

**Exceptions:** Supervisor-only data address  
 Misaligned data address  
 TLB permission violation (read)  
 Fast TLB miss (data)  
 Double TLB miss (data)  
 MPU region violation (data)

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**mov****move register to register**

<b>Operation:</b>	$rC \leftarrow rA$
<b>Assembler Syntax:</b>	<code>mov rC, rA</code>
<b>Example:</b>	<code>mov r6, r7</code>
<b>Description:</b>	Moves the contents of rA to rC.
<b>Pseudo-instruction:</b>	<code>mov</code> is implemented as <code>add rC, rA, r0</code> .

## movhi

## move immediate into high halfword

**Operation:**  $rB \leftarrow (\text{IMMED} : 0x0000)$

**Assembler Syntax:** `movhi rB, IMMED`

**Example:** `movhi r6, 0x8000`

**Description:** Writes the immediate value IMMED into the high halfword of rB, and clears the lower halfword of rB to 0x0000.

**Usage:** The maximum allowed value of IMMED is 65535. The minimum allowed value is 0. To load a 32-bit constant into a register, first load the upper 16 bits using a `movhi` pseudo-instruction. The `%hi()` macro can be used to extract the upper 16 bits of a constant or a label. Then, load the lower 16 bits with an `ori` instruction. The `%lo()` macro can be used to extract the lower 16 bits of a constant or label as shown below.

```
movhi rB, %hi(value)
ori rB, rB, %lo(value)
```

An alternative method to load a 32-bit constant into a register uses the `%hiadj()` macro and the `addi` instruction as shown below.

```
movhi rB, %hiadj(value)
addi rB, rB, %lo(value)
```

**Pseudo-instruction:** `movhi` is implemented as `orhi rB, r0, IMMED`.

**movi****move signed immediate into word**

<b>Operation:</b>	$rB \leftarrow \sigma(\text{IMMED})$
<b>Assembler Syntax:</b>	<code>movi rB, IMMED</code>
<b>Example:</b>	<code>movi r6, -30</code>
<b>Description:</b>	Sign-extends the immediate value IMMED to 32 bits and writes it to rB.
<b>Usage:</b>	The maximum allowed value of IMMED is 32767. The minimum allowed value is -32768. To load a 32-bit constant into a register, refer to the <code>movhi</code> instruction.
<b>Pseudo-instruction:</b>	<code>movi</code> is implemented as <code>addi rB, r0, IMMED</code> .

## movia

## move immediate address into word

<b>Operation:</b>	$rB \leftarrow \text{label}$
<b>Assembler Syntax:</b>	<code>movia rB, label</code>
<b>Example:</b>	<code>movia r6, function_address</code>
<b>Description:</b>	Writes the address of label to rB.
<b>Pseudo-instruction:</b>	movia is implemented as: <code>orhi rB, r0, %hiadj(label)</code> <code>addi rB, rB, %lo(label)</code>

**movui****move unsigned immediate into word**

<b>Operation:</b>	$rB \leftarrow (0x0000 : IMMED)$
<b>Assembler Syntax:</b>	<code>movui rB, IMMED</code>
<b>Example:</b>	<code>movui r6, 100</code>
<b>Description:</b>	Zero-extends the immediate value IMMED to 32 bits and writes it to rB.
<b>Usage:</b>	The maximum allowed value of IMMED is 65535. The minimum allowed value is 0. To load a 32-bit constant into a register, refer to the <code>movhi</code> instruction.
<b>Pseudo-instruction:</b>	<code>movui</code> is implemented as <code>ori rB, r0, IMMED</code> .

## mul

## multiply

**Operation:**  $rC \leftarrow (rA \times rB)_{31..0}$

**Assembler Syntax:** `mul rC, rA, rB`

**Example:** `mul r6, r7, r8`

**Description:** Multiplies rA times rB and stores the 32 low-order bits of the product to rC. The result is the same whether the operands are treated as signed or unsigned integers.  
Nios II processors that do not implement the `mul` instruction cause an unimplemented instruction exception.

### Usage:

#### Carry Detection (unsigned operands):

Before or after the multiply operation, the carry out of the MSB of rC can be detected using the following instruction sequence:

```
mul rC, rA, rB          ; The mul operation (optional)
mulxuu rD, rA, rB      ; rD is nonzero if carry occurred
cmpne rD, rD, r0       ; rD is 1 if carry occurred, 0 if not
```

The `mulxuu` instruction writes a nonzero value into rD if the multiplication of unsigned numbers generates a carry (unsigned overflow). If a 0/1 result is desired, follow the `mulxuu` with the `cmpne` instruction.

#### Overflow Detection (signed operands):

After the multiply operation, overflow can be detected using the following instruction sequence:

```
mul rC, rA, rB          ; The original mul operation
cmlt rD, rC, r0
mulxss rE, rA, rB
add rD, rD, rE          ; rD is nonzero if overflow
cmpne rD, rD, r0       ; rD is 1 if overflow, 0 if not
```

The `cmlt-mulxss-add` instruction sequence writes a nonzero value into rD if the product in rC cannot be represented in 32 bits (signed overflow). If a 0/1 result is desired, follow the instruction sequence with the `cmpne` instruction.

**Exceptions:** Unimplemented instruction

**Instruction Type:** R

**Instruction Fields:**  
A = Register index of operand rA  
B = Register index of operand rB  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x27				0				0x3a											

**mul****multiply immediate**

**Operation:**  $rB \leftarrow (rA \times \sigma(\text{IMM16}))_{31:0}$

**Assembler Syntax:** `mul rB, rA, IMM16`

**Example:** `mul r6, r7, -100`

**Description:** Sign-extends the 16-bit immediate value IMM16 to 32 bits and multiplies it by the value of rA. Stores the 32 low-order bits of the product to rB. The result is independent of whether rA is treated as a signed or unsigned number.

Nios II processors that do not implement the `mul` instruction cause an unimplemented instruction exception.

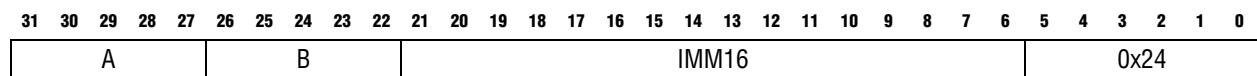
**Carry Detection and Overflow Detection:**

For a discussion of carry and overflow detection, refer to the `mul` instruction.

**Exceptions:** Unimplemented instruction

**Instruction Type:** I

**Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



## mulxss

## multiply extended signed/signed

**Operation:**  $rC \leftarrow ((\text{signed } rA) \times (\text{signed } rB))_{63..32}$

**Assembler Syntax:** `mulxss rC, rA, rB`

**Example:** `mulxss r6, r7, r8`

**Description:** Treating *rA* and *rB* as signed integers, `mulxss` multiplies *rA* times *rB*, and stores the 32 high-order bits of the product to *rC*.

Nios II processors that do not implement the `mulxss` instruction cause an unimplemented instruction exception.

**Usage:** Use `mulxss` and `mul` to compute the full 64-bit product of two 32-bit signed integers. Furthermore, `mulxss` can be used as part of the calculation of a 128-bit product of two 64-bit signed integers. Given two 64-bit integers, each contained in a pair of 32-bit registers, (*S1* : *U1*) and (*S2* : *U2*), their 128-bit product is  $(U1 \times U2) + ((S1 \times U2) \ll 32) + ((U1 \times S2) \ll 32) + ((S1 \times S2) \ll 64)$ . The `mulxss` and `mul` instructions are used to calculate the 64-bit product  $S1 \times S2$ .

**Exceptions:** Unimplemented instruction

**Instruction Type:** R

**Instruction Fields:**  
 A = Register index of operand *rA*  
 B = Register index of operand *rB*  
 C = Register index of operand *rC*

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x1f				0				0x3a											

**mulxsu****multiply extended signed/unsigned**

**Operation:**  $rC \leftarrow ((\text{signed})\ rA) \times ((\text{unsigned})\ rB)_{63..32}$

**Assembler Syntax:** `mulxsu rC, rA, rB`

**Example:** `mulxsu r6, r7, r8`

**Description:** Treating `rA` as a signed integer and `rB` as an unsigned integer, `mulxsu` multiplies `rA` times `rB`, and stores the 32 high-order bits of the product to `rC`.

Nios II processors that do not implement the `mulxsu` instruction cause an unimplemented instruction exception.

**Usage:** `mulxsu` can be used as part of the calculation of a 128-bit product of two 64-bit signed integers. Given two 64-bit integers, each contained in a pair of 32-bit registers, (`S1 : U1`) and (`S2 : U2`), their 128-bit product is:  $(U1 \times U2) + ((S1 \times U2) \ll 32) + ((U1 \times S2) \ll 32) + ((S1 \times S2) \ll 64)$ . The `mulxsu` and `mul` instructions are used to calculate the two 64-bit products  $S1 \times U2$  and  $U1 \times S2$ .

**Exceptions:** Unimplemented instruction

**Instruction Type:** R

**Instruction Fields:**  
 A = Register index of operand `rA`  
 B = Register index of operand `rB`  
 C = Register index of operand `rC`

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
A								B								C								0x17				0				0x3a			

## mulxuu

## multiply extended unsigned/unsigned

**Operation:**  $rC \leftarrow ((\text{unsigned}) rA) \times ((\text{unsigned}) rB)_{63..32}$

**Assembler Syntax:** `mulxuu rC, rA, rB`

**Example:** `mulxuu r6, r7, r8`

**Description:** Treating rA and rB as unsigned integers, `mulxuu` multiplies rA times rB and stores the 32 high-order bits of the product to rC.

Nios II processors that do not implement the `mulxuu` instruction cause an unimplemented instruction exception.

**Usage:** Use `mulxuu` and `mul` to compute the 64-bit product of two 32-bit unsigned integers. Furthermore, `mulxuu` can be used as part of the calculation of a 128-bit product of two 64-bit signed integers. Given two 64-bit signed integers, each contained in a pair of 32-bit registers, (S1 : U1) and (S2 : U2), their 128-bit product is  $(U1 \times U2) + ((S1 \times U2) \ll 32) + ((U1 \times S2) \ll 32) + ((S1 \times S2) \ll 64)$ . The `mulxuu` and `mul` instructions are used to calculate the 64-bit product  $U1 \times U2$ .

`mulxuu` also can be used as part of the calculation of a 128-bit product of two 64-bit unsigned integers. Given two 64-bit unsigned integers, each contained in a pair of 32-bit registers, (T1 : U1) and (T2 : U2), their 128-bit product is  $(U1 \times U2) + ((U1 \times T2) \ll 32) + ((T1 \times U2) \ll 32) + ((T1 \times T2) \ll 64)$ . The `mulxuu` and `mul` instructions are used to calculate the four 64-bit products  $U1 \times U2$ ,  $U1 \times T2$ ,  $T1 \times U2$ , and  $T1 \times T2$ .

**Exceptions:** Unimplemented instruction

**Instruction Type:** R

**Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
A								B								C								0x07				0				0x3a			

**nextpc****get address of following instruction****Operation:**  $rC \leftarrow PC + 4$ **Assembler Syntax:** `nextpc rC`**Example:** `nextpc r6`**Description:** Stores the address of the next instruction to register rC.**Usage:** A relocatable code fragment can use `nextpc` to calculate the address of its data segment. `nextpc` is the only way to access the PC directly.**Exceptions:** None**Instruction Type:** R**Instruction Fields:** C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				0				C				0x1c				0				0x3a											

## **nop**

## **no operation**

<b>Operation:</b>	None
<b>Assembler Syntax:</b>	<code>nop</code>
<b>Example:</b>	<code>nop</code>
<b>Description:</b>	<code>nop</code> does nothing.
<b>Pseudo-instruction:</b>	<code>nop</code> is implemented as <code>add r0, r0, r0</code> .

**nor****bitwise logical nor**

<b>Operation:</b>	$rC \leftarrow \sim(rA \mid rB)$
<b>Assembler Syntax:</b>	<code>nor rC, rA, rB</code>
<b>Example:</b>	<code>nor r6, r7, r8</code>
<b>Description:</b>	Calculates the bitwise logical NOR of rA and rB and stores the result in rC.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x06				0				0x3a											

**or**

**bitwise logical or**

**Operation:**  $rC \leftarrow rA \mid rB$

**Assembler Syntax:** `or rC, rA, rB`

**Example:** `or r6, r7, r8`

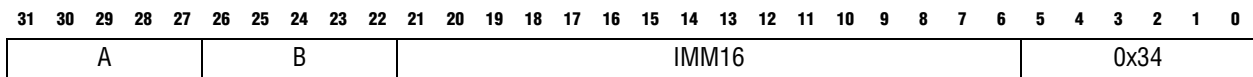
**Description:** Calculates the bitwise logical OR of rA and rB and stores the result in rC.

**Exceptions:** None

**Instruction Type:** R

**Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 C = Register index of operand rC

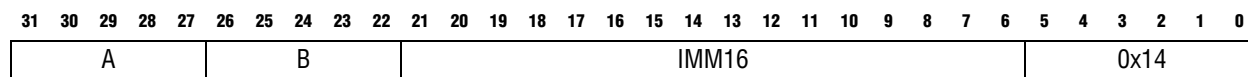
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A					B					C					0x16					0					0x3a						

**orhi****bitwise logical or immediate into high halfword****Operation:**  $rB \leftarrow rA \mid (\text{IMM16} : 0x0000)$ **Assembler Syntax:** `orhi rB, rA, IMM16`**Example:** `orhi r6, r7, 100`**Description:** Calculates the bitwise logical OR of rA and (IMM16 : 0x0000) and stores the result in rB.**Exceptions:** None**Instruction Type:** I**Instruction Fields:**  
A = Register index of operand rA  
B = Register index of operand rB  
IMM16 = 16-bit signed immediate value

## ori

## bitwise logical or immediate

- Operation:**  $rB \leftarrow rA \mid (0x0000 : IMM16)$
- Assembler Syntax:** `ori rB, rA, IMM16`
- Example:** `ori r6, r7, 100`
- Description:** Calculates the bitwise logical OR of rA and (0x0000 : IMM16) and stores the result in rB.
- Exceptions:** None
- Instruction Type:** I
- Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit unsigned immediate value



**rdctl****read from control register**

**Operation:**  $rC \leftarrow ctIN$

**Assembler Syntax:** `rdctl rC, ctIN`

**Example:** `rdctl r3, ct131`

**Description:** Reads the value contained in control register ctIN and writes it to register rC.

**Exceptions:** Supervisor-only instruction

**Instruction Type:** R

**Instruction Fields:** C = Register index of operand rC  
N = Control register index of operand ctIN

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				0				C				0x26				N				0x3a											

## rdprs

## read from previous register set

**Operation:**  $rB \leftarrow prs.rA + \sigma(IMM16)$

**Assembler Syntax:** `rdprs rB, rA, IMM16`

**Example:** `rdprs r6, r7, 0`

**Description:** Sign-extends the 16-bit immediate value IMM16 to 32 bits, and adds it to the value of rA from the previous register set. Places the result in rB in the current register set.

**Usage:** The previous register set is specified by `status.PRS`. By default, `status.PRS` indicates the register set in use before an exception, such as an external interrupt, caused a register set change.

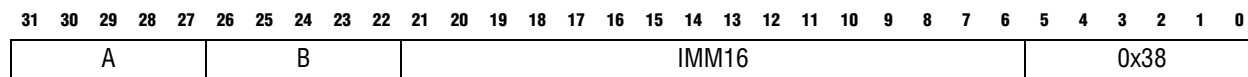
To read from an arbitrary register set, software can insert the desired register set number in `status.PRS` prior to executing `rdprs`.

If shadow register sets are not implemented on the Nios II core, `rdprs` is an illegal instruction.

**Exceptions:** Supervisor-only instruction  
 Illegal instruction

**Instruction Type:** I

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**ret****return from subroutine**

**Operation:**  $PC \leftarrow ra$

**Assembler Syntax:** `ret`

**Example:** `ret`

**Description:** Transfers execution to the address in `ra`.

**Usage:** Any subroutine called by `call` or `callr` must use `ret` to return.

**Exceptions:** Misaligned destination address

**Instruction Type:** R

**Instruction Fields:** None

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x1f				0				0				0x05				0				0x3a											

## rol

## rotate left

**Operation:**  $rC \leftarrow rA$  rotated left  $rB_{4..0}$  bit positions

**Assembler Syntax:** `rol rC, rA, rB`

**Example:** `rol r6, r7, r8`

**Description:** Rotates  $rA$  left by the number of bits specified in  $rB_{4..0}$  and stores the result in  $rC$ . The bits that shift out of the register rotate into the least-significant bit positions. Bits 31–5 of  $rB$  are ignored.

**Exceptions:** None

**Instruction Type:** R

**Instruction Fields:**  
 A = Register index of operand  $rA$   
 B = Register index of operand  $rB$   
 C = Register index of operand  $rC$

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
A						B						C						0x03						0						0x3a					

**rol****rotate left immediate****Operation:**  $rC \leftarrow rA$  rotated left IMM5 bit positions**Assembler Syntax:** `rol rC, rA, IMM5`**Example:** `rol r6, r7, 3`**Description:** Rotates rA left by the number of bits specified in IMM5 and stores the result in rC. The bits that shift out of the register rotate into the least-significant bit positions.**Usage:** In addition to the rotate-left operation, `rol` can be used to implement a rotate-right operation. Rotating left by  $(32 - IMM5)$  bits is the equivalent of rotating right by IMM5 bits.**Exceptions:** None**Instruction Type:** R**Instruction Fields:**  
A = Register index of operand rA  
C = Register index of operand rC  
IMM5 = 5-bit unsigned immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A					0					C					0x02					IMM5					0x3a						

**ror**

**rotate right**

**Operation:**  $rC \leftarrow rA$  rotated right  $rB_{4..0}$  bit positions

**Assembler Syntax:** `ror rC, rA, rB`

**Example:** `ror r6, r7, r8`

**Description:** Rotates rA right by the number of bits specified in  $rB_{4..0}$  and stores the result in rC. The bits that shift out of the register rotate into the most-significant bit positions. Bits 31–5 of rB are ignored.

**Exceptions:** None

**Instruction Type:** R

**Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A					B					C					0x0b					0			0x3a								

**sll****shift left logical****Operation:**  $rC \leftarrow rA \ll (rB_{4..0})$ **Assembler Syntax:** `sll rC, rA, rB`**Example:** `sll r6, r7, r8`**Description:** Shifts rA left by the number of bits specified in rB<sub>4..0</sub> (inserting zeroes), and then stores the result in rC. `sll` performs the `<<` operation of the C programming language.**Exceptions:** None**Instruction Type:** R**Instruction Fields:**  
A = Register index of operand rA  
B = Register index of operand rB  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x13				0				0x3a											

## slli

## shift left logical immediate

- Operation:**  $rC \leftarrow rA \ll IMM5$
- Assembler Syntax:** `slli rC, rA, IMM5`
- Example:** `slli r6, r7, 3`
- Description:** Shifts rA left by the number of bits specified in IMM5 (inserting zeroes), and then stores the result in rC.
- Usage:** `slli` performs the `<<` operation of the C programming language.
- Exceptions:** None
- Instruction Type:** R
- Instruction Fields:**  
 A = Register index of operand rA  
 C = Register index of operand rC  
 IMM5 = 5-bit unsigned immediate value

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				0				C				0x12				IMM5				0x3a											

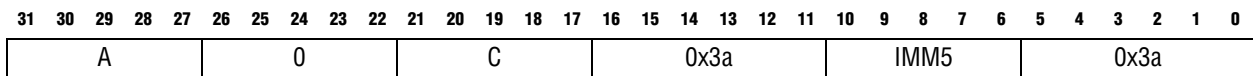
**sra****shift right arithmetic****Operation:**  $rC \leftarrow (\text{signed}) rA \gg ((\text{unsigned}) rB_{4..0})$ **Assembler Syntax:** `sra rC, rA, rB`**Example:** `sra r6, r7, r8`**Description:** Shifts rA right by the number of bits specified in rB<sub>4..0</sub> (duplicating the sign bit), and then stores the result in rC. Bits 31–5 are ignored.**Usage:** `sra` performs the signed `>>` operation of the C programming language.**Exceptions:** None**Instruction Type:** R**Instruction Fields:**  
A = Register index of operand rA  
B = Register index of operand rB  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x3b				0				0x3a											

## srai

## shift right arithmetic immediate

- Operation:**  $rC \leftarrow (\text{signed}) rA \gg ((\text{unsigned}) IMM5)$
- Assembler Syntax:** `srai rC, rA, IMM5`
- Example:** `srai r6, r7, 3`
- Description:** Shifts rA right by the number of bits specified in IMM5 (duplicating the sign bit), and then stores the result in rC.
- Usage:** `srai` performs the signed `>>` operation of the C programming language.
- Exceptions:** None
- Instruction Type:** R
- Instruction Fields:**  
 A = Register index of operand rA  
 C = Register index of operand rC  
 IMM5 = 5-bit unsigned immediate value



**srl****shift right logical**

**Operation:**  $rC \leftarrow (\text{unsigned}) rA \gg ((\text{unsigned}) rB_{4:0})$

**Assembler Syntax:** `srl rC, rA, rB`

**Example:** `srl r6, r7, r8`

**Description:** Shifts rA right by the number of bits specified in rB<sub>4:0</sub> (inserting zeroes), and then stores the result in rC. Bits 31–5 are ignored.

**Usage:** `srl` performs the unsigned `>>` operation of the C programming language.

**Exceptions:** None

**Instruction Type:** R

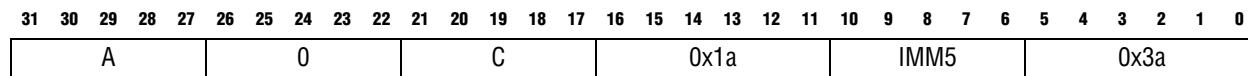
**Instruction Fields:** A = Register index of operand rA  
B = Register index of operand rB  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				B				C				0x1b				0				0x3a											

## srli

## shift right logical immediate

- Operation:**  $rC \leftarrow (\text{unsigned}) rA \gg ((\text{unsigned}) IMM5)$
- Assembler Syntax:** `srli rC, rA, IMM5`
- Example:** `srli r6, r7, 3`
- Description:** Shifts rA right by the number of bits specified in IMM5 (inserting zeroes), and then stores the result in rC.
- Usage:** `srli` performs the unsigned `>>` operation of the C programming language.
- Exceptions:** None
- Instruction Type:** R
- Instruction Fields:** A = Register index of operand rA  
 C = Register index of operand rC  
 IMM5 = 5-bit unsigned immediate value



**stb / stbio****store byte to memory or I/O peripheral**

**Operation:**  $\text{Mem8}[\text{rA} + \sigma(\text{IMM16})] \leftarrow \text{rB}_{7:0}$

**Assembler Syntax:** `stb rB, byte_offset(rA)`  
`stbio rB, byte_offset(rA)`

**Example:** `stb r6, 100(r5)`

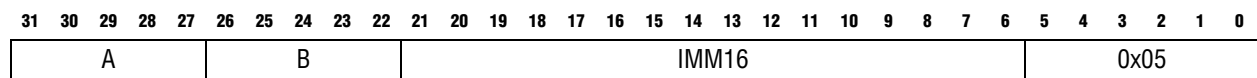
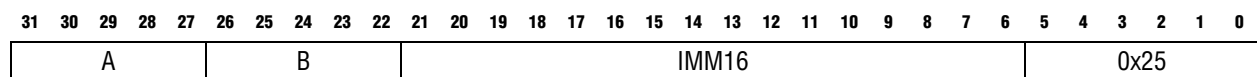
**Description:** Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Stores the low byte of rB to the memory byte specified by the effective address.

**Usage:** In processors with a data cache, this instruction may not generate an Avalon-MM bus cycle to noncache data memory immediately. Use the `stbio` instruction for peripheral I/O. In processors with a data cache, `stbio` bypasses the cache and is guaranteed to generate an Avalon-MM data transfer. In processors without a data cache, `stbio` acts like `stb`.

**Exceptions:** Supervisor-only data address  
Misaligned data address  
TLB permission violation (write)  
Fast TLB miss (data)  
Double TLB miss (data)  
MPU region violation (data)

**Instruction Type:** I

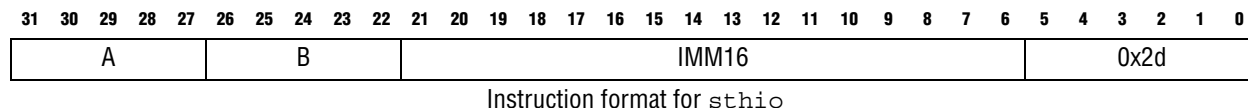
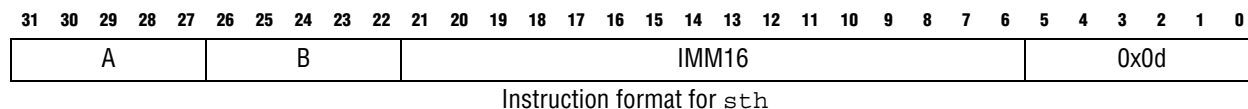
**Instruction Fields:** A = Register index of operand rA  
B = Register index of operand rB  
IMM16 = 16-bit signed immediate value

Instruction format for `stb`Instruction format for `stbio`

## sth / sthio

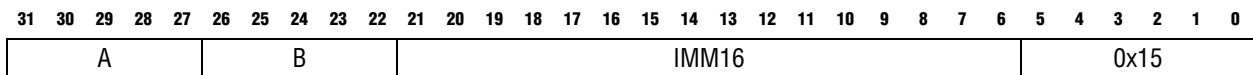
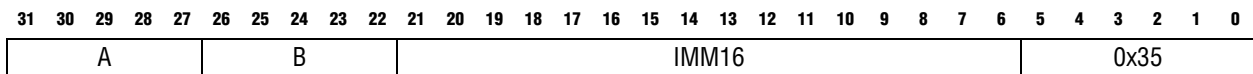
## store halfword to memory or I/O peripheral

- Operation:**  $\text{Mem16}[\text{rA} + \sigma(\text{IMM16})] \leftarrow \text{rB}_{15:0}$
- Assembler Syntax:**  
`sth rB, byte_offset(rA)`  
`sthio rB, byte_offset(rA)`
- Example:**  
`sth r6, 100(r5)`
- Description:** Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Stores the low halfword of rB to the memory location specified by the effective byte address. The effective byte address must be halfword aligned. If the byte address is not a multiple of 2, the operation is undefined.
- Usage:** In processors with a data cache, this instruction may not generate an Avalon-MM data transfer immediately. Use the sthio instruction for peripheral I/O. In processors with a data cache, sthio bypasses the cache and is guaranteed to generate an Avalon-MM data transfer. In processors without a data cache, sthio acts like sth.
- Exceptions:**  
 Supervisor-only data address  
 Misaligned data address  
 TLB permission violation (write)  
 Fast TLB miss (data)  
 Double TLB miss (data)  
 MPU region violation (data)
- Instruction Type:** I
- Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit signed immediate value



**stw / stwio****store word to memory or I/O peripheral**

<b>Operation:</b>	$\text{Mem32}[\text{rA} + \sigma(\text{IMM16})] \leftarrow \text{rB}$
<b>Assembler Syntax:</b>	<code>stw rB, byte_offset(rA)</code> <code>stwio rB, byte_offset(rA)</code>
<b>Example:</b>	<code>stw r6, 100(r5)</code>
<b>Description:</b>	Computes the effective byte address specified by the sum of rA and the instruction's signed 16-bit immediate value. Stores rB to the memory location specified by the effective byte address. The effective byte address must be word aligned. If the byte address is not a multiple of 4, the operation is undefined.
<b>Usage:</b>	In processors with a data cache, this instruction may not generate an Avalon-MM data transfer immediately. Use the <code>stwio</code> instruction for peripheral I/O. In processors with a data cache, <code>stwio</code> bypasses the cache and is guaranteed to generate an Avalon-MM bus cycle. In processors without a data cache, <code>stwio</code> acts like <code>stw</code> .
<b>Exceptions:</b>	Supervisor-only data address Misaligned data address TLB permission violation (write) Fast TLB miss (data) Double TLB miss (data) MPU region violation (data)
<b>Instruction Type:</b>	I
<b>Instruction Fields:</b>	A = Register index of operand rA B = Register index of operand rB IMM16 = 16-bit signed immediate value

Instruction format for `stw`Instruction format for `stwio`

## sub

## subtract

**Operation:**  $rC \leftarrow rA - rB$

**Assembler Syntax:** `sub rC, rA, rB`

**Example:** `sub r6, r7, r8`

**Description:** Subtract rB from rA and store the result in rC.

**Usage:** **Carry Detection (unsigned operands):**

The carry bit indicates an unsigned overflow. Before or after a `sub` operation, a carry out of the MSB can be detected by checking whether the first operand is less than the second operand. The carry bit can be written to a register, or a conditional branch can be taken based on the carry condition. Both cases are shown below.

```
sub rC, rA, rB      ; The original sub operation (optional)
cmpltu rD, rA, rB  ; rD is written with the carry bit
sub rC, rA, rB      ; The original sub operation (optional)
bltu rA, rB, label ; Branch if carry generated
```

**Overflow Detection (signed operands):**

Detect overflow of signed subtraction by comparing the sign of the difference that is written to rC with the signs of the operands. If rA and rB have different signs, and the sign of rC is different than the sign of rA, an overflow occurred. The overflow condition can control a conditional branch, as shown below.

```
sub rC, rA, rB      ; The original sub operation
xor rD, rA, rB      ; Compare signs of rA and rB
xor rE, rA, rC      ; Compare signs of rA and rC
and rD, rD, rE      ; Combine comparisons
blt rD, r0, label   ; Branch if overflow occurred
```

**Exceptions:** None

**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA  
 B = Register index of operand rB  
 C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
A								B								C								0x39				0				0x3a			

**subi****subtract immediate**

<b>Operation:</b>	$rB \leftarrow rA - \sigma(\text{IMMED})$
<b>Assembler Syntax:</b>	<code>subi rB, rA, IMMED</code>
<b>Example:</b>	<code>subi r8, r8, 4</code>
<b>Description:</b>	Sign-extends the immediate value IMMED to 32 bits, subtracts it from the value of rA and then stores the result in rB.
<b>Usage:</b>	The maximum allowed value of IMMED is 32768. The minimum allowed value is -32767.
<b>Pseudo-instruction:</b>	<code>subi</code> is implemented as <code>addi rB, rA, -IMMED</code>

## sync

## memory synchronization

<b>Operation:</b>	None
<b>Assembler Syntax:</b>	<code>sync</code>
<b>Example:</b>	<code>sync</code>
<b>Description:</b>	Forces all pending memory accesses to complete before allowing execution of subsequent instructions. In processor cores that support in-order memory accesses only, this instruction performs no operation.
<b>Exceptions:</b>	None
<b>Instruction Type:</b>	R
<b>Instruction Fields:</b>	None

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				0				0				0x36				0				0x3a											

**trap****trap**

**Operation:**  $estatus \leftarrow status$   
 $PIE \leftarrow 0$   
 $U \leftarrow 0$   
 $ea \leftarrow PC + 4$   
 $PC \leftarrow \text{exception handler address}$

**Assembler Syntax:** `trap`  
`trap imm5`

**Example:** `trap`

**Description:** Saves the address of the next instruction in register `ea`, saves the contents of the `status` register in `estatus`, disables interrupts, and transfers execution to the exception handler. The address of the exception handler is specified at system generation time.

The 5-bit immediate field `imm5` is ignored by the processor, but it can be used by the debugger.

`trap` with no argument is the same as `trap 0`.

**Usage:** To return from the exception handler, execute an `eret` instruction.

**Exceptions:** Trap

**Instruction Type:** R

**Instruction Fields:** IMM5 = Type of breakpoint

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				0				0x1d				0x2d				IMM5				0x3a											

## wrctl

## write to control register

**Operation:**  $ctlN \leftarrow rA$

**Assembler Syntax:** `wrctl ctlN, rA`

**Example:** `wrctl ctl6, r3`

**Description:** Writes the value contained in register rA to the control register ctIN.

**Exceptions:** Supervisor-only instruction

**Instruction Type:** R

**Instruction Fields:** A = Register index of operand rA  
 N = Control register index of operand ctIN

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				0				0				0x2e				N				0x3a											

**wrprs****write to previous register set****Operation:**  $\text{prs.rC} \leftarrow \text{rA}$ **Assembler Syntax:** `wrprs rC, rA`**Example:** `wrprs r6, r7`**Description:** Copies the value of rA in the current register set to rC in the previous register set. This instruction can set r0 to 0 in a shadow register set.**Usage:** The previous register set is specified by `status.PRS`. By default, `status.PRS` indicates the register set in use before an exception, such as an external interrupt, caused a register set change.To write to an arbitrary register set, software can insert the desired register set number in `status.PRS` prior to executing `wrprs`.System software must use `wrprs` to initialize r0 to 0 in each shadow register set before using that register set.If shadow register sets are not implemented on the Nios II core, `wrprs` is an illegal instruction.**Exceptions:** Supervisor-only instruction  
Illegal instruction**Instruction Type:** R**Instruction Fields:** A = Register index of operand rA  
C = Register index of operand rC

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A				0x0				C				0x14				0				0x3a											

**XOR**

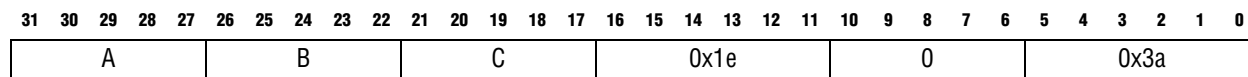
**bitwise logical exclusive or**

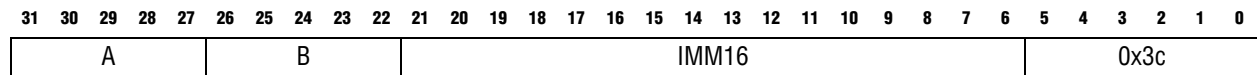
**Operation:**  $rC \leftarrow rA \wedge rB$   
**Assembler Syntax:** `xor rC, rA, rB`  
**Example:** `xor r6, r7, r8`  
**Description:** Calculates the bitwise logical exclusive-or of rA and rB and stores the result in rC.

**Exceptions:** None

**Instruction Type:** R

**Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 C = Register index of operand rC



**xorhi** **bitwise logical exclusive or immediate into high halfword****Operation:**  $rB \leftarrow rA \wedge (\text{IMM16} : 0x0000)$ **Assembler Syntax:** `xorhi rB, rA, IMM16`**Example:** `xorhi r6, r7, 100`**Description:** Calculates the bitwise logical exclusive XOR of rA and (IMM16 : 0x0000) and stores the result in rB.**Exceptions:** None**Instruction Type:** I**Instruction Fields:**  
A = Register index of operand rA  
B = Register index of operand rB  
IMM16 = 16-bit unsigned immediate value

## xori

## bitwise logical exclusive or immediate

**Operation:**  $rB \leftarrow rA \wedge (0x0000 : IMM16)$

**Assembler Syntax:** `xori rB, rA, IMM16`

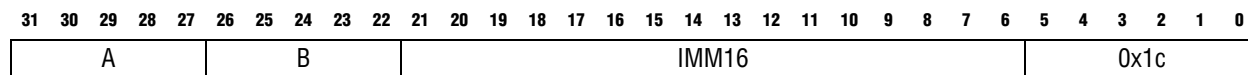
**Example:** `xori r6, r7, 100`

**Description:** Calculates the bitwise logical exclusive OR of rA and (0x0000 : IMM16) and stores the result in rB.

**Exceptions:** None

**Instruction Type:** I

**Instruction Fields:**  
 A = Register index of operand rA  
 B = Register index of operand rB  
 IMM16 = 16-bit unsigned immediate value



## Referenced Documents

This chapter references the following documents:

- *Programming Model* chapter of the *Nios II Processor Reference Handbook*
- *Application Binary Interface* chapter of the *Nios II Processor Reference Handbook*
- *Cache and Tightly Coupled Memory* chapter of the *Nios II Software Developer's Handbook*

## Document Revision History

Table 8-6 shows the revision history for this document.

**Table 8-6.** Document Revision History (Part 1 of 2)

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	rdprs and wrprs instructions.	Added shadow register sets and external interrupt controller support
March 2009 v9.0.0	Backwards-compatible change to the eret instruction B field encoding.	—
November 2008 v8.1.0	Maintenance release.	—
May 2008 v8.0.0	Added an Exceptions section to all instructions.	Added MMU.
October 2007 v7.2.0	Added jmp_i instruction.	—
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Added table of contents to Introduction section.</li> <li>■ Added Referenced Documents section.</li> </ul>	—
March 2007 v7.0.0	Maintenance release.	—
November 2006 v6.1.0	Maintenance release.	—
May 2006 v6.0.0	Maintenance release.	—
October 2005 v5.1.0	<ul style="list-style-type: none"> <li>■ Correction to the blt instruction.</li> <li>■ Added U bit operation for break and trap instructions.</li> </ul>	—
July 2005 v5.0.1	<ul style="list-style-type: none"> <li>■ Added new flushda instruction.</li> <li>■ Updated flushd instruction.</li> <li>■ Instruction Opcode table updated with flushda instruction.</li> </ul>	—
May 2005 v5.0.0	Maintenance release.	—
December 2004 v1.2	<ul style="list-style-type: none"> <li>■ break instruction update.</li> <li>■ srl_i instruction correction.</li> </ul>	—

**Table 8-6.** Document Revision History (Part 2 of 2)

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
September 2004 v1.1	Updates for Nios II 1.01 release.	—
May 2004 v1.0	Initial release.	—

