

Chisel3 Cheat Sheet

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Notation In This Document:

For Functions and Constructors:

Arguments given as `kwd:type` (name and type(s))

Arguments in brackets (`[...]`) are optional.

For Operators:

`c`, `x`, `y` are Chisel Data; `n`, `m` are Scala Int

`w(x)`, `w(y)` are the widths of `x`, `y` (respectively)

`minVal(x)`, `maxVal(x)` are the minimum or maximum possible values of `x`

Basic Chisel Constructs

Chisel Wire Operators:

```
// Allocate a as wire of type UInt()
val x = Wire(UInt())
x := y // Connect wire y to wire x
```

When executes blocks conditionally by Bool, and is equivalent to Verilog if

```
when(condition1) {
  // run if condition1 true and skip rest
} .elsewhen(condition2) {
  // run if condition2 true and skip rest
} .otherwise {
  // run if none of the above ran
}
```

Switch executes blocks conditionally by data

```
switch(x) {
  is(value1) {
    // run if x === value1
  }
  is(value2) {
    // run if x === value2
  }
}
```

Enum generates value literals for enumerations

```
val s1::s2::...::sn::Nil
  = Enum(nodeType:UInt, n:Int)
s1, s2, ..., sn will be created as nodeType literals
with distinct values
nodeType  type of s1, s2, ..., sn
n         element count
```

Math Helpers:

```
log2Ceil(in:Int): Int  log2(in) rounded up
log2Floor(in:Int): Int log2(in) rounded down
isPow2(in:Int): Boolean True if in is a power of 2
```

Basic Data Types

Constructors:

```
Bool()           type, boolean value
true.B or false.B literal values
UInt(32.W)       type 32-bit unsigned
UInt()          type, width inferred
77.U or "hdead".U unsigned literals
1.U(16.W)       literal with forced width
SInt() or SInt(64.W) like UInt
-3.S or "h-44".S signed literals
3.S(2.W)       signed 2-bits wide value -1
```

Bits, UInt, SInt Casts: reinterpret cast except for:

UInt → SInt Zero-extend to SInt

State Elements

Registers retain state until updated

```
val my_reg = Reg(UInt(32.W))
```

Flavors

```
RegInit(7.U(32.w))  reg with initial value 7
RegNext(next_val)  update each clock, no init
RegEnable(next, enable) update, with enable gate
```

Updating: assign to latch new value on next clock:

```
my_reg := next_val
```

Read-Write Memory provide addressable memories

```
val my_mem = Mem(n:Int, out:Data)
out memory element type
n memory depth (elements)
```

Using: access elements by indexing:

```
val readVal = my_mem(addr:UInt/Int)
for synchronous read: assign output to Reg
mu_mem(addr:UInt/Int) := y
```

Modules

Defining: subclass Module with elements, code:

```
class Accum(width:Int) extends Module {
  val io = IO(new Bundle {
    val in = Input(UInt(width.W))
    val out = Output(UInt(width.W))
  })
  val sum = Reg(UInt())
  sum := sum + io.in
  io.out := sum
}
```

Usage: access elements using dot notation:

(code inside a Module is always running)

```
val my_module = Module(new Accum(32))
my_module.io.in := some_data
val sum := my_module.io.out
```

Operators:

Chisel	Explanation	Width
!x	Logical NOT	1
x && y	Logical AND	1
x y	Logical OR	1
x(n)	Extract bit, 0 is LSB	1
x(n, m)	Extract bitfield	n - m + 1
x << y	Dynamic left shift	w(x) + maxVal(y)
x >> y	Dynamic right shift	w(x) - minVal(y)
x << n	Static left shift	w(x) + n
x >> n	Static right shift	w(x) - n
Fill(n, x)	Replicate x, n times	n * w(x)
Cat(x, y)	Concatenate bits	w(x) + w(y)
Mux(c, x, y)	If c, then x; else y	max(w(x), w(y))
~x	Bitwise NOT	w(x)
x & y	Bitwise AND	max(w(x), w(y))
x y	Bitwise OR	max(w(x), w(y))
x ^ y	Bitwise XOR	max(w(x), w(y))
x === y	Equality (triple equals)	1
x != y	Inequality	1
x /= y	Inequality	1
x + y	Addition	max(w(x), w(y))
x +% y	Addition	max(w(x), w(y))
x +& y	Addition	max(w(x), w(y))+1
x - y	Subtraction	max(w(x), w(y))
x -% y	Subtraction	max(w(x), w(y))
x -& y	Subtraction	max(w(x), w(y))+1
x * y	Multiplication	w(x)+w(y)
x / y	Division	w(x)
x % y	Modulus	bits(maxVal(y)-1)
x > y	Greater than	1
x >= y	Greater than or equal	1
x < y	Less than	1
x <= y	Less than or equal	1
x >> y	Arithmetic right shift	w(x) - minVal(y)
x >> n	Arithmetic right shift	w(x) - n

UInt bit-reduction methods:

Chisel	Explanation	Width
x.andR	AND-reduce	1
x.orR	OR-reduce	1
x.xorR	XOR-reduce	1

As an example to apply the andR method to an SInt use `x.asUInt.andR`

Hardware Generation

Functions provide block abstractions for code. Scala functions that instantiate or return Chisel types are code generators.

Also: Scala's `if` and `for` can be used to control hardware generation and are equivalent to Verilog `generate if/for`

```
val number = Reg(if(can_be_negative) SInt()
                  else UInt())
```

will create a Register of type `SInt` or `UInt` depending on the value of a Scala variable

Aggregate Types

Bundle contains `Data` types indexed by name

Defining: subclass `Bundle`, define components:

```
class MyBundle extends Bundle {
  val a = Bool()
  val b = UInt(32.W)
}
```

Constructor: instantiate `Bundle` subclass:

```
val my_bundle = new MyBundle()
```

Inline defining: define a `Bundle` type:

```
val my_bundle = new Bundle {
  val a = Bool()
  val b = UInt(32.W)
}
```

Using: access elements through dot notation:

```
val bundleVal = my_bundle.a
my_bundle.a := Bool(true)
```

Vec is an indexable vector of `Data` types

```
val myVec = Vec(elts:Iterable[Data])
  elts initial element Data (vector depth inferred)
val myVec = Vec.fill(n:Int) {gen:Data}
  n vector depth (elements)
  gen initial element Data, called once per element
```

Using: access elements by dynamic or static indexing:

```
readVal := myVec(ind:Data/idx:Int)
myVec(ind:Data/idx:Int) := writeVal
```

Functions: (`T` is the `Vec` element's type)

```
.forall(p:T=>Bool): Bool AND-reduce p on all elts
.exists(p:T=>Bool): Bool OR-reduce p on all elts
.contains(x:T): Bool True if this contains x
.count(p:T=>Bool): UInt count elts where p is True
```

```
.indexWhere(p:T=>Bool): UInt
.lastIndexWhere(p:T=>Bool): UInt
.onlyIndexWhere(p:T=>Bool): UInt
```

Standard Library: Function Blocks

Stateless:

`PopCount(in:Bits/Seq[Bool]): UInt`
Returns number of hot (= 1) bits in `in`

`Reverse(in:UInt): UInt`
Reverses the bit order of `in`

`UIntToOH(in:UInt, [width:Int]): Bits`
Returns the one-hot encoding of `in`
`width` (*optional, else inferred*) output width

`OHToUInt(in:Bits/Seq[Bool]): UInt`
Returns the `UInt` representation of one-hot `in`

`Counter(n:Int): UInt`
.inc() bumps counter returning true when n reached
.value returns current value

`PriorityEncoder(in:Bits/Iterable[Bool]): UInt`
Returns the position the least significant 1 in `in`

`PriorityEncoderOH(in:Bits): UInt`
Returns the position of the hot bit in `in`

`Mux1H(in:Iterable[(Data, Bool]): Data`
`Mux1H(sel:Bits/Iterable[Bool],`
`in:Iterable[Data]): Data`

`PriorityMux(in:Iterable[(Bool, Bits]): Bits`
`PriorityMux(sel:Bits/Iterable[Bool],`
`in:Iterable[Bits]): Bits`

A mux tree with either a one-hot select or multiple selects (where the first inputs are prioritized)
`in` iterable of combined input and select (`Bool, Bits`) tuples or just mux input `Bits`
`sel` select signals or bitvector, one per input

Stateful:

`LFSR16([increment:Bool]): UInt`
16-bit LFSR (to generate pseudorandom numbers)
`increment` (*optional, default True*) shift on next clock

`ShiftRegister(in:Data, n:Int, [en:Bool]): Data`
Shift register, returns n-cycle delayed input `in`
`en` (*optional, default True*) enable

Standard Library: Interfaces

DecoupledIO is a `Bundle` with a ready-valid interface

Constructor:
`Decoupled(gen:Data)`

`gen Chisel Data` to wrap ready-valid protocol around

Interface:

```
(in) .ready ready Bool
(out) .valid valid Bool
(out) .bits data
```

ValidIO is a `Bundle` with a valid interface

Constructor:

`Valid(gen:Data)`

`gen Chisel Data` to wrap valid protocol around

Interface:

```
(out) .valid valid Bool
(out) .bits data
```

Queue is a `Module` providing a hardware queue

Constructor:

```
Queue(enq:DecoupledIO, entries:Int)
  enq DecoupledIO source for the queue
  entries size of queue
```

Interface:

```
.io.enq DecoupledIO source (flipped)
.io.deq DecoupledIO sink
.io.count UInt count of elements in the queue
```

Pipe is a `Module` delaying input data

Constructor:

```
Pipe(enqValid:Bool, enqBits:Data, [latency:Int])
Pipe(enq:ValidIO, [latency:Int])
  enqValid input data, valid component
  enqBits input data, data component
  enq input data as ValidIO
  latency (optional, default 1) cycles to delay data by
```

Interface:

```
.io.enq ValidIO source (flipped)
.io.deq ValidIO sink
```

Arbiters are `Modules` connecting multiple producers to one consumer

`Arbiter` prioritizes lower producers

`RRArbiter` runs in round-robin order

Constructor:

```
Arbiter(gen:Data, n:Int)
  gen data type
  n number of producers
```

Interface:

```
.io.in Vec of DecoupledIO inputs (flipped)
.io.out DecoupledIO output
.io.chosen UInt input index on .io.out,
  does not imply output is valid
```