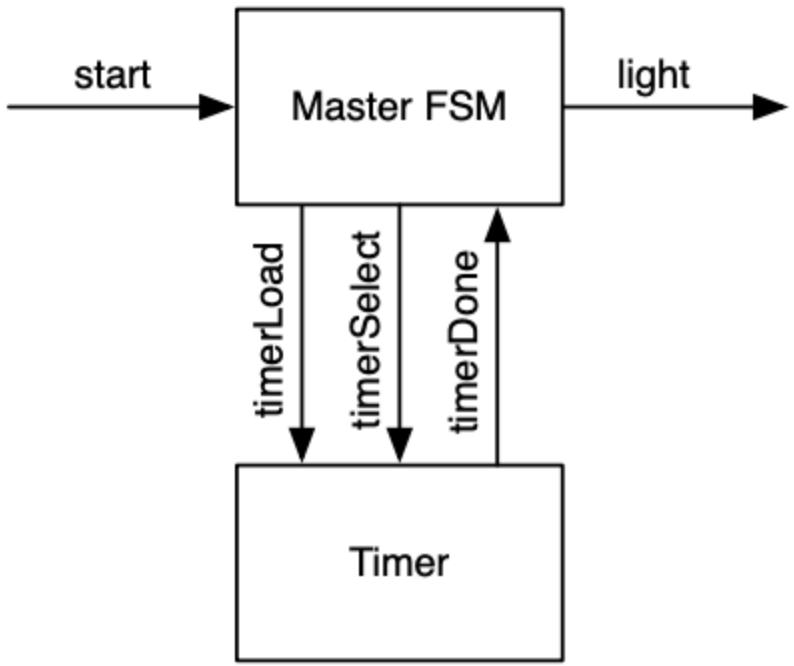
9 Communicating State Machines

9.1 A Light Flasher Example

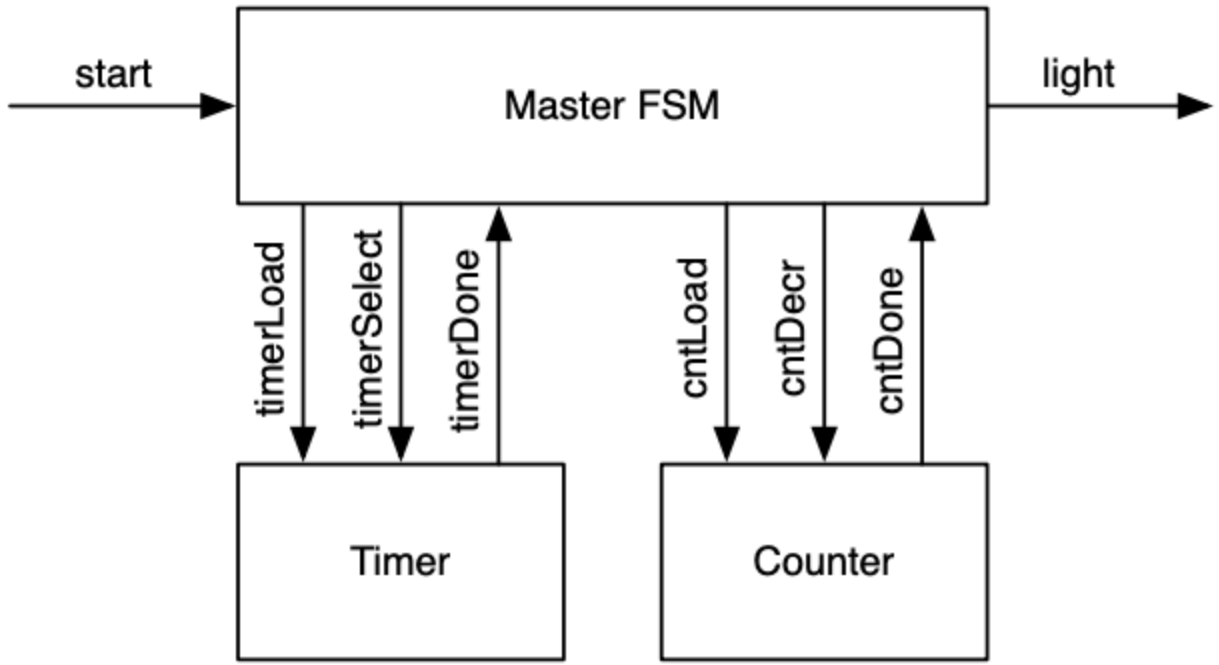
9.2 State Machine with Datapath

9.3 Ready-Valid Interface

9.1 A Light Flasher Example


start
Master FSM
light
timerLoad
timerSelect
timerDone
Timer

```
val timerReg = RegInit(0.U)
timerDone := timerReg === 0.U

// Timer FSM (down counter)
when(!timerDone) {
  timerReg := timerReg - 1.U
}
when (timerLoad) {
  when (timerSelect) {
    timerReg := 5.U
} .otherwise {
  timerReg := 3.U
  }
}

val off :: flash1 :: space1 :: flash2 :: space2 :: flash3 :: Nil = Enum (6)
val stateReg = RegInit(off)

val light = WireDefault(false.B) // FSM output

// Timer connection
val timerLoad = WireDefault(false.B) // start timer with a load
val timerSelect = WireDefault(true.B) // select 6 or 4 cycles
val timerDone = Wire(Bool())

timerLoad := timerDone

// Master FSM
switch(stateReg) {
  is(off) {
    timerLoad := true.B
    timerSelect := true.B
    when (start) { stateReg := flash1 }
  }
  is (flash1) {
    timerSelect := false.B
    light := true.B
    when (timerDone) { stateReg := space1 }
  }
  is (space1) {
    when (timerDone) { stateReg := flash2 }
  }
  is (flash2) {
    timerSelect := false.B
    light := true.B
    when (timerDone) { stateReg := space2 }
  }
  is (space2) {
    when (timerDone) { stateReg := flash3 }
  }
  is (flash3) {
    timerSelect := false.B
    light := true.B
    when (timerDone) { stateReg := off }
  }
}
```

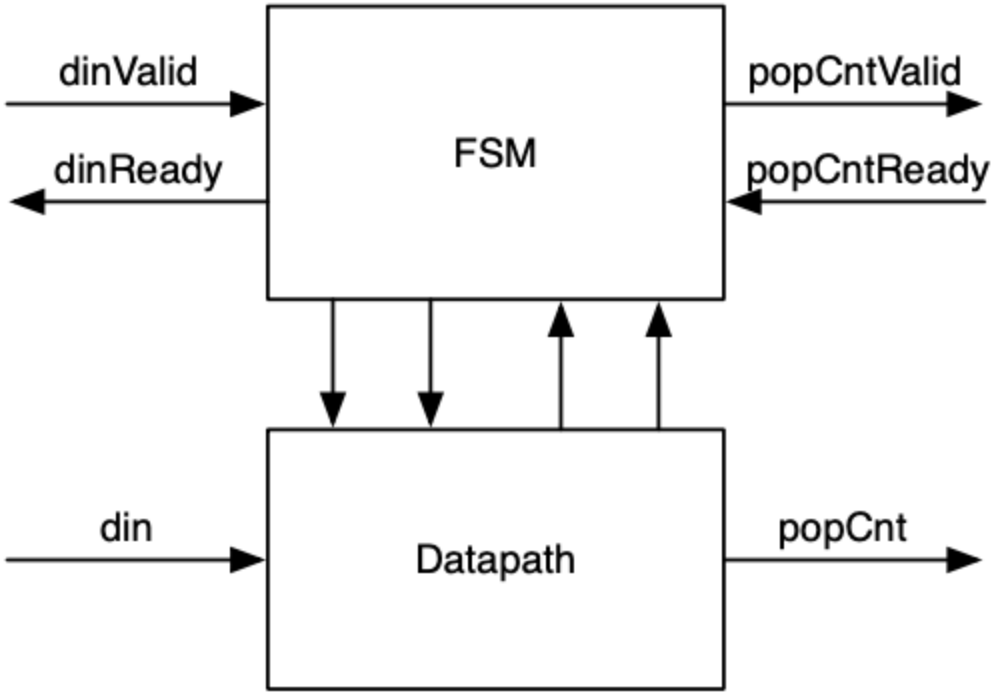

start
Master FSM
light
timerLoad
timerSelect
timerDone
cntLoad
cntDecr
cntDone
Timer
Counter

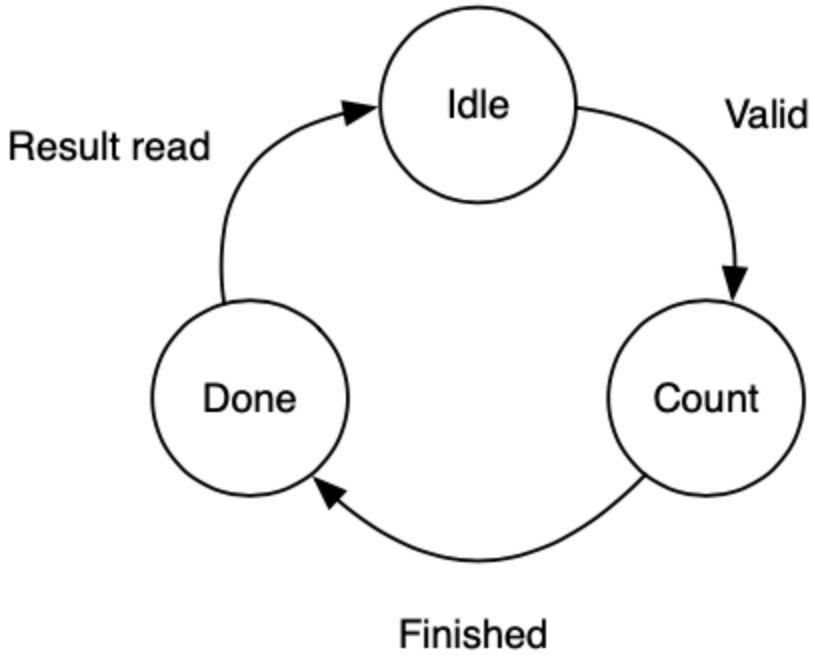
```
val cntReg = RegInit(0.U)
cntDone := cntReg === 0.U

// Down counter FSM
when(cntLoad) { cntReg := 2.U }
when(cntDecr) { cntReg := cntReg - 1.U }
```

```
val off :: flash :: space :: Nil = Enum(3)
val stateReg = RegInit(off)

val light = WireDefault(false.B) // FSM output

// Timer connection
val timerLoad = WireDefault(false.B) // start timer with a load
val timerSelect = WireDefault(true.B) // select 6 or 4 cycles
val timerDone = Wire(Bool())
// Counter connection
val cntLoad = WireDefault(false.B)
val cntDecr = WireDefault(false.B)
val cntDone = Wire(Bool())

timerLoad := timerDone

switch(stateReg) {
  is(off) {
    timerLoad := true.B
    timerSelect := true.B
    cntLoad := true.B
    when (start) { stateReg := flash }
  }
  is (flash) {
    timerSelect := false.B
    light := true.B
    when (timerDone & !cntDone) { stateReg := space }
    when (timerDone & cntDone) { stateReg := off }
  }
  is (space) {
    cntDecr := timerDone
    when (timerDone) { stateReg := flash }
  }
}
```

9.2 State Machine with Datapath

9.2.1 Popcount Example

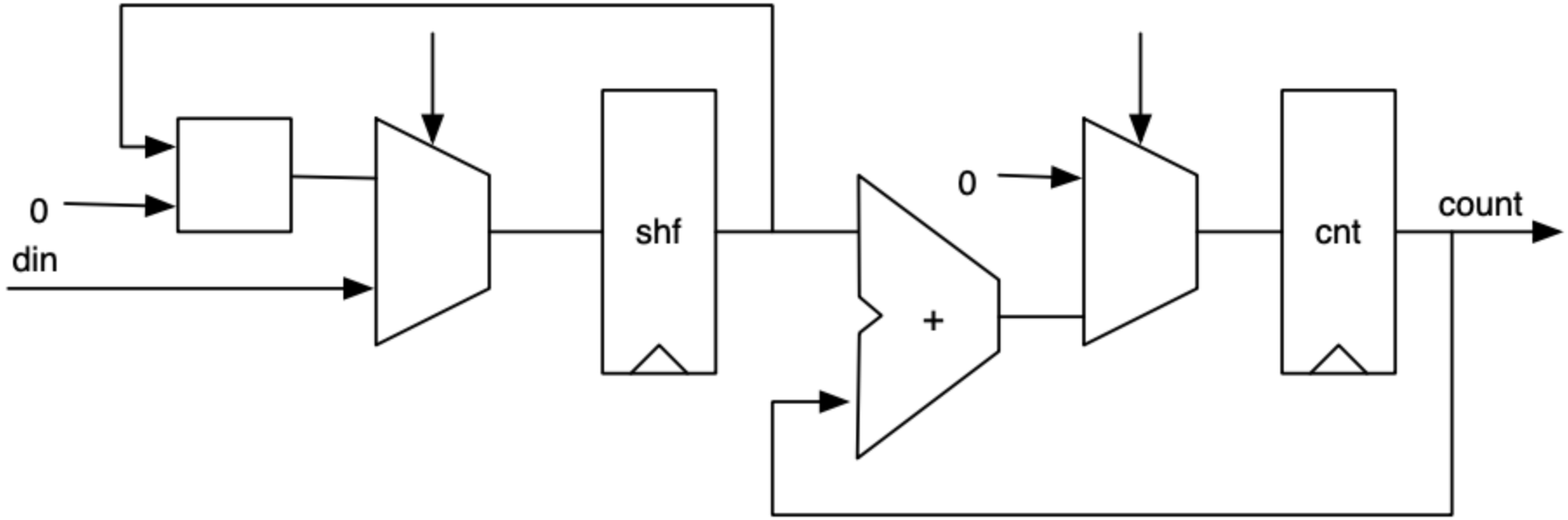



Idle
Valid
Count
Finished
Done
Result read

Pop Count Module

```
class PopCount extends Module {
  val io = IO(new Bundle {
    val dinValid = Input(Bool())
    val dinReady = Output(Bool())
    val din = Input(UInt(8.W))
    val popCntValid = Output(Bool())
    val popCntReady = Input(Bool())
    val popCnt = Output(UInt(4.W))
  })

  val fsm = Module(new PopCountFSM)
  val data = Module(new PopCountDataPath)

  fsm.io.dinValid := io.dinValid
  io.dinReady := fsm.io.dinReady
  io.popCntValid := fsm.io.popCntValid
  fsm.io.popCntReady := io.popCntReady

  data.io.din := io.din
  io.popCnt := data.io.popCnt
  data.io.load := fsm.io.load
```

Datapath

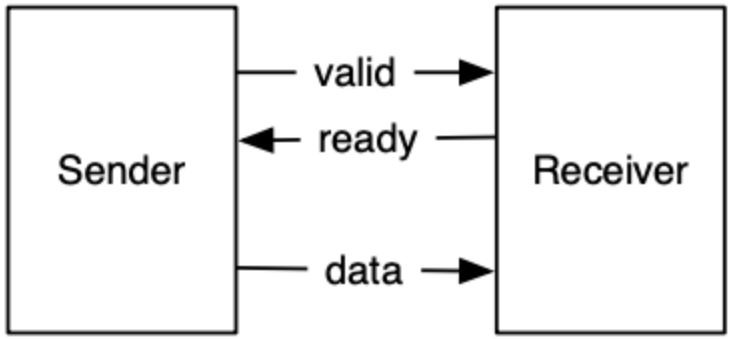


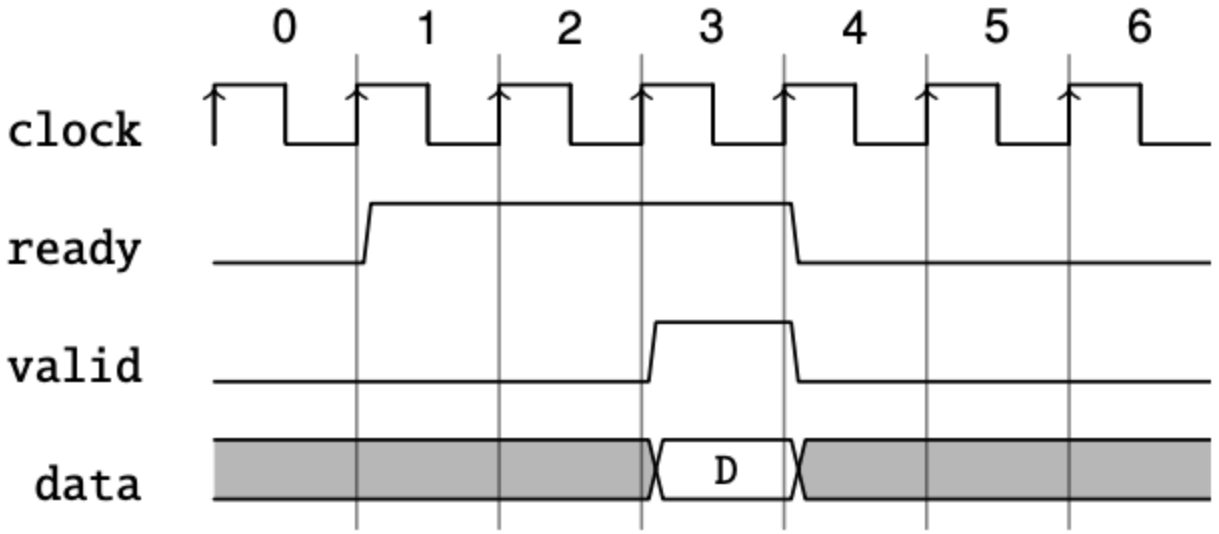
```
class PopCountDataPath extends Module {
  val io = IO(new Bundle {
    val din = Input(UInt(8.W))
    val load = Input(Bool())
    val popCnt = Output(UInt(4.W))
    val done = Output(Bool())
  })

  val dataReg = RegInit(0.U(8.W))
  val popCntReg = RegInit(0.U(8.W))
  val counterReg= RegInit(0.U(4.W))

  dataReg := 0.U ## dataReg(7, 1)
  popCntReg := popCntReg + dataReg(0)

  val done = counterReg === 0.U
  when (!done) {
    counterReg := counterReg - 1.U
  }

  when(io.load) {
    dataReg := io.din
    popCntReg := 0.U
    counterReg := 8.U
  }

  // debug output
  printf("%x %d\n", dataReg, popCntReg)
  io.popCnt := popCntReg
  io.done := done
}
```

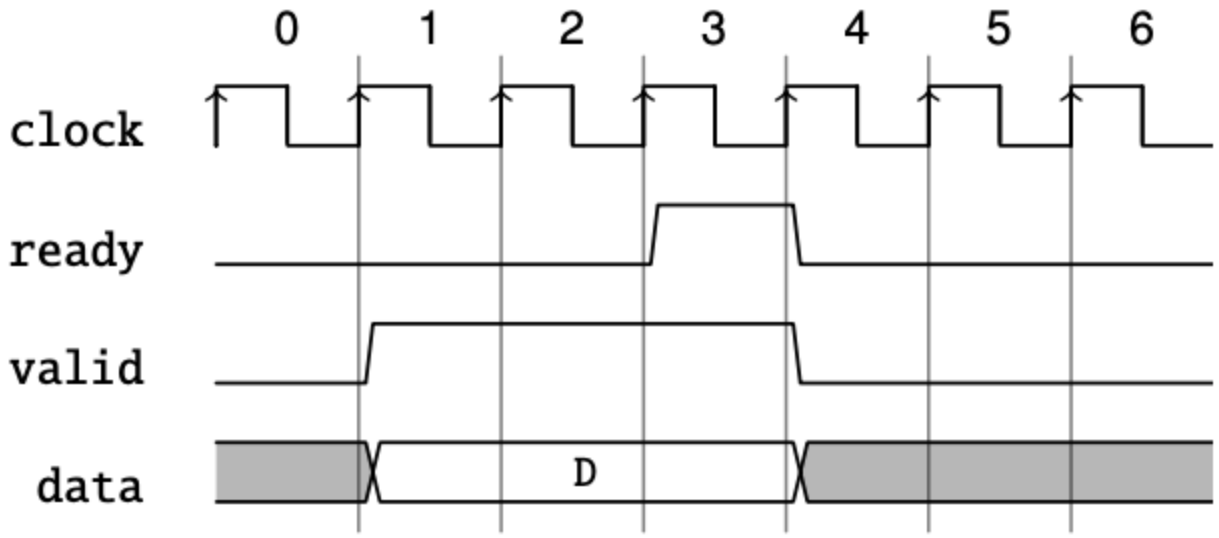
Control

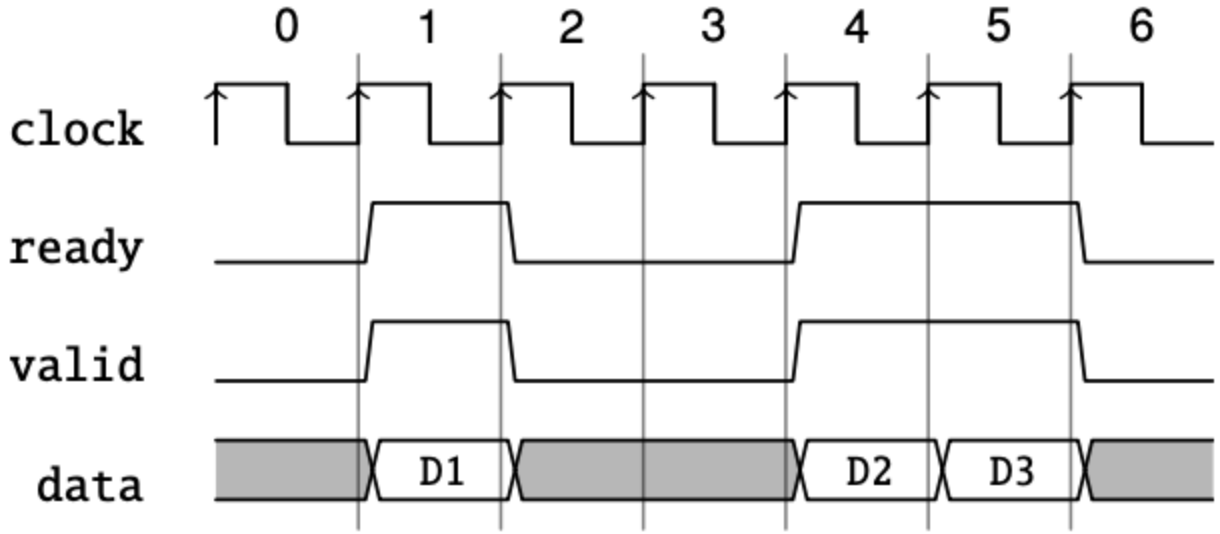
```
class PopCountFSM extends Module {
  val io = IO(new Bundle {
    val dinValid = Input(Bool())
    val dinReady = Output(Bool())
    val popCntValid = Output(Bool())
    val popCntReady = Input(Bool())
    val load = Output(Bool())
    val done = Input(Bool())
  })

  val idle :: count :: done :: Nil = Enum(3)
  val stateReg = RegInit(idle)

  io.load := false.B

  io.dinReady := false.B
  io.popCntValid := false.B

  switch(stateReg) {
    is(idle) {
      io.dinReady := true.B
      when(io.dinValid) {
        io.load := true.B
        stateReg := count
      }
    }
    is(count) {
      when(io.done) {
        stateReg := done
      }
    }
    is(done) {
      io.popCntValid := true.B
      when(io.popCntReady) {
        stateReg := idle
      }
    }
```

9.3 Ready-Valid Interface




0
1
2
3
4
5
6
clock
ready
valid
data
D


0
1
2
3
4
5
6
clock
ready
valid
data
D


0
1
2
3
4
5
6
clock
ready
valid
data
D1
D2
D3

```
class DecoupledIO[T <: Data](gen: T) extends Bundle {
  val ready = Input(Bool())
  val valid = Output(Bool())
  val bits = Output(gen)
}
```