

Features

- Fixed width (8-, 16-, or 32-bit) data transfers (dependent on the width of the data bus)
- Read and write access
- Four-way handshaking
- Arbitrary transaction latency
- Single-synchronous operation for higher performance and lower gate count
- Multi-synchronous operation for multiple clock domains
- Allows multiple slaves with differing bus widths

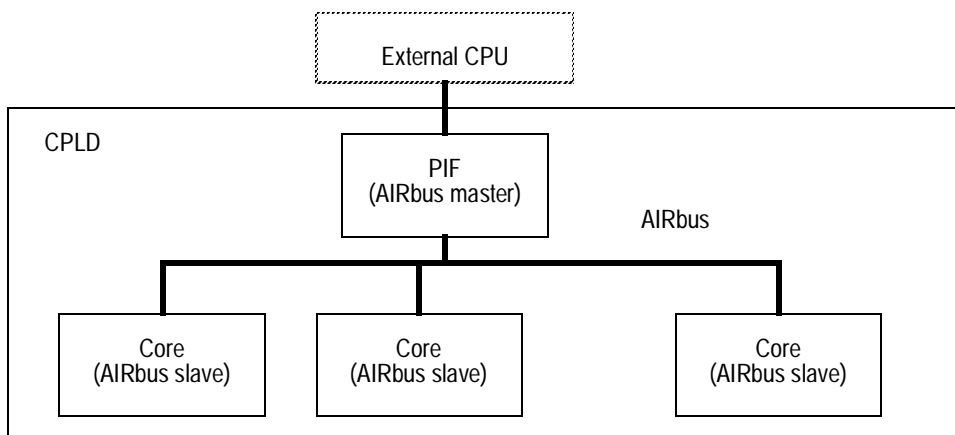
Functional Description

The Access to Internal Registers Interface (AIRbus) is a simple and robust memory-style bus to allow a CPU to read and write registers in various functional cores within a Complex Programmable Logic Device (CPLD). In a typical CPLD, the Processor Interface (PIF) block connects to an external CPU using an industry standard bus such as PCI, PowerPC bus, 68000 bus, 8051 bus. The PIF manages the external bus's protocol and converts the latter's transactions to AIRbus transactions. The PIF is, in general, the master of the AIRbus.

General Arrangement

Figure 1 shows a general arrangement of the AIRbus interface.

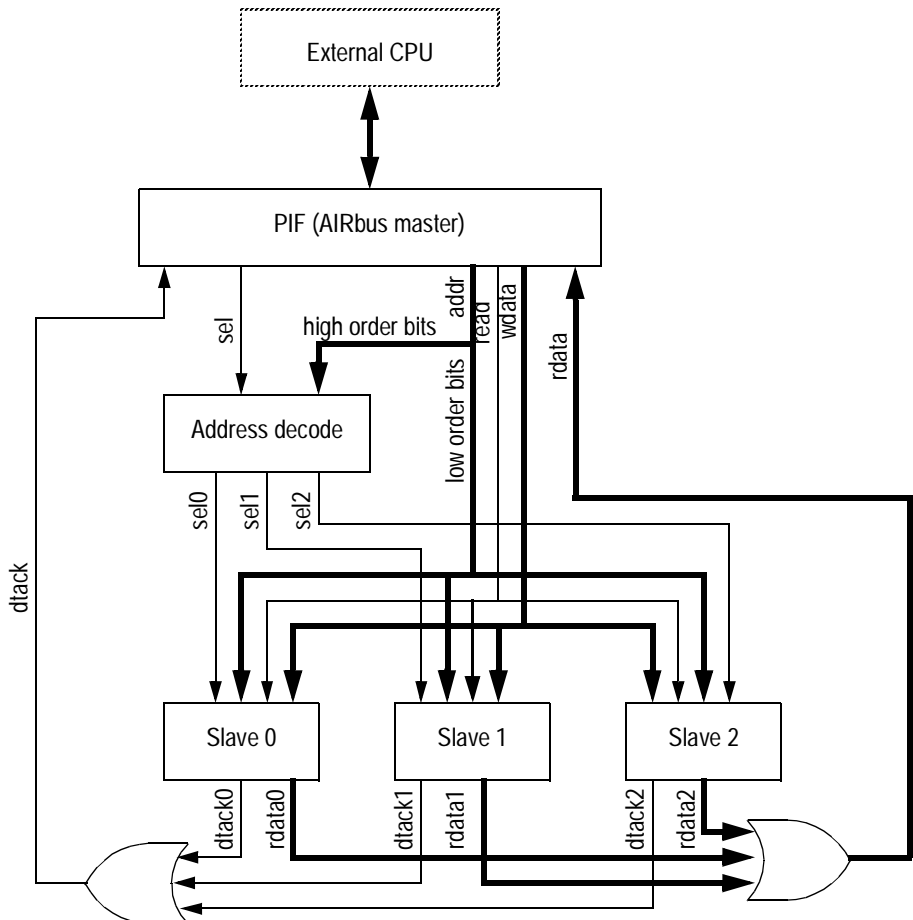
Figure 1. General Arrangements



Topology

The AIRbus uses a broadcast topology for signals driven by the master—typically the PIF. An address decoder, which is separate from the PIF, uses the most significant bits of the address to demultiplex the `sel` signal, producing individual `sel` outputs for each slave. The least significant bits of `addr`, plus `wdata` and `read` are broadcast directly to the slaves. Each slave has its own `rdata` and `dtack` output. The module which instantiates the slaves ORs the `dtacks` together and feeds the result into the master's `dtack` input. Similarly, it bitwise ORs the `rdata` of each slave together. The result is connected to the master's `rdata` input.

Figure 2. Example Implementation



Note:

- (1) This OR-busing requires the slaves to set their `rdata` and `dtack` outputs to 0 when they are not selected. Each slave may have an `irq` output (not shown for clarity). These `irqs` are ORed together to form the master's `irq` input in the same fashion as `dtack`.

Bus Signals

- The clock (*clk*) is input to all blocks on the AIRbus
- In multi-synchronous mode there are multiple clocks
- The data bus is either 8, 16 or 32 bits wide. All lines are used on all cycles. Byte and halfword writes are not possible in the 16- and 32-bit AIRbuses.
- The least significant bit of *addr* is:
 - 0 if *rdata* and *wdata* are 8 bits
 - 1 if they are 16 bits. *addr* [0] is considered to be 0 and is not connected
 - 2 if they are 32 bits. *addr* [1:0] are considered to be 0 and are not connected
- The most significant bit of *addr* depends on the number of bytes of address space required. Thus, 8 registers on the 32-bit AIRbus require 32 bytes of address space. *addr* would then use bits 5:2.

Table 1. Bus Signals

Signal name	Description	Width	Direction (master)	Direction (slave)
<i>clk</i>	Clock	1	Input	Input
<i>sel</i>	Indicates cycle is in progress	1	Output	Input
<i>addr</i>	byte to address of target	application specific	Output	Input
<i>read</i>	set high during read cycles, low during write	1	Output	Input
<i>wdata</i>	write data	32/16/8	Output	Input
<i>rdata</i>	data from read	32/16/8	Input	Output
<i>dtack</i>	data transfer acknowledge	1	Input	Output
<i>irq</i>	interrupt request	1	Input	Output

Bus Protocol

Four-Way Handshake

The bus cycles proceed as follows:

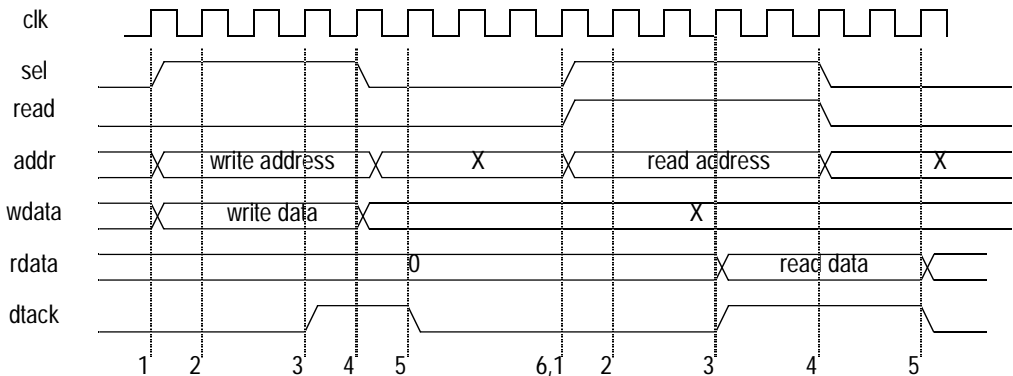
1. Master sets *wdata* (if the cycle is a write), *read*, and *addr* appropriately and asserts *sel*. The address decoder generates the appropriate slave select.
2. Slave observes *sel* asserted and performs its internal read or write operation.
3. Upon completing the read or write, the slave drives *rdata* if the cycle is a read, and asserts its *dtack*.

4. Master observes `dtack` asserted and records `rdata` if the cycle is a read. It then negates (drives low) `sel`. `addr` and `wdata` are now undefined.
5. The slave observes `sel` negated. It sets `rdata` to 0 and negates `dtack`.
6. The master observes `dtack` negated and may now start a new bus cycle.

All signals are sampled, asserted, and negated synchronously to the master's and slaves' clock(s). Note that each step may take multiple clock cycles, e.g. to complete an internal operation or to meet setup time on data or address lines. The time required is implementation-dependant.

Figure 3 illustrates AIRbus read and write cycle. The clock is omitted for clarity.

Figure 3. AIRbus Read & Write Cycle



Single-Synchronous Mode

This has the highest performance (4 clock cycles for a fast slave) but requires the master and all slaves to be on the same clock domain. Figure 3 shows transactions on a single-synchronous bus.

Multi-Synchronous Mode

This mode incurs a penalty of several clock cycles depending on the relative frequencies and phases of the master and slaves clocks but allows the master and the slaves to be on different clock domains. This mode requires a metastability hardening block (two flip-flops clocked by the slave's clock) to transfer the `sel` signal to the slave, and a metastability hardening block (two flip-flops clocked by the master's clock) to transfer the `dtack` and `irq` signals to the master. `sel` is asserted simultaneously with `wdata/read/addr`, and `dtack` is asserted simultaneously with `rdata`. The delay inherent in the metastability hardening process, plus the four-way handshaking, ensures that `addr`, `read`, `wdata`, and `rdata` are stable when they are sampled: no metastability hardening is necessary on these signals. Note that a bus becomes multi-synchronous mode by including metastability hardening blocks. [Figure 4](#) shows the structure of a multi-synchronous bus.

Figure 4. Multi-Synchronous Mode

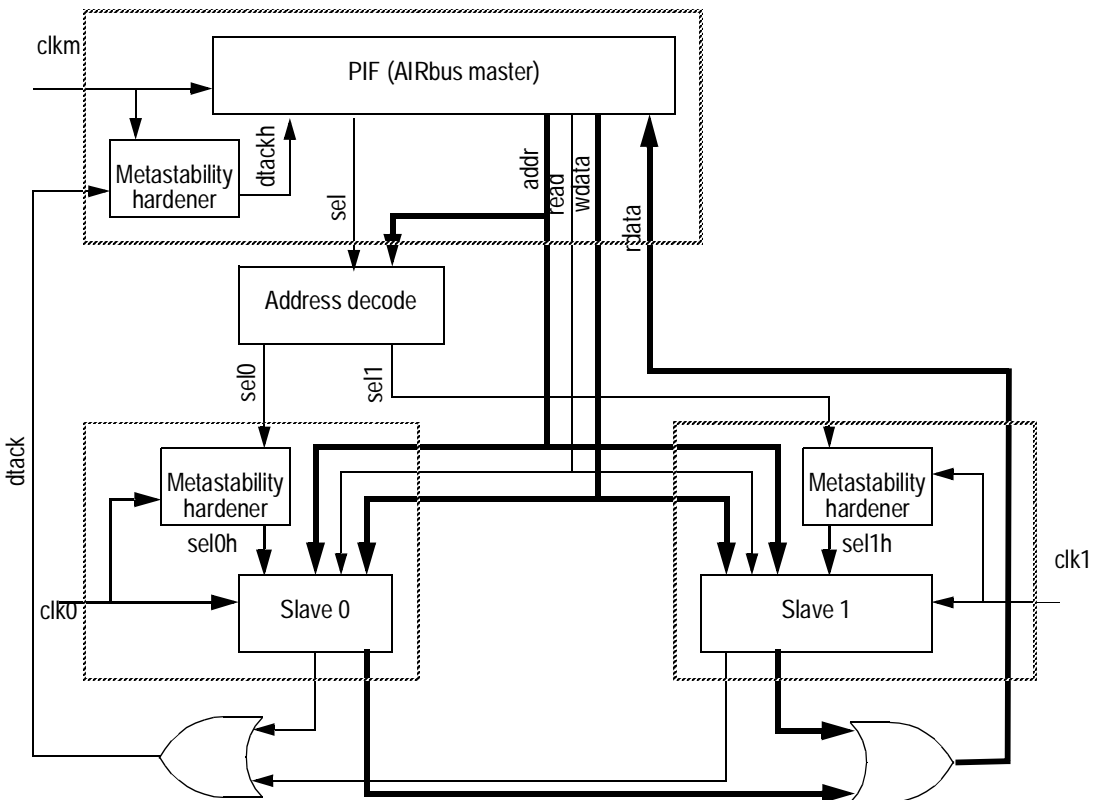
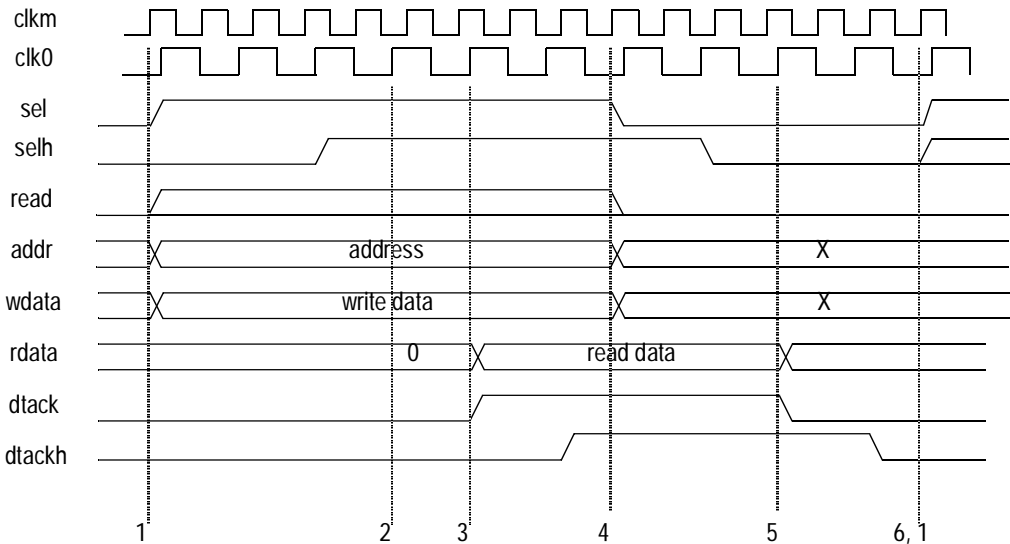


Figure 5 illustrates transactions on a multi-synchronous bus (See “Bus Protocol” on page 3).

Figure 5. Multi-Synchronous Read/Write



Internal Width Conversion

In general, the internal AIRbus is as wide as the widest slave. In this case, all registers are aligned to the natural boundaries of the bus and are padded in the most significant bits with zeros.

- On a 32-bit bus:
 - 8 bit slaves appear as 32-bit slaves with the data carried on bits [7:0]. *rdata* bits [31:8] are set to 0. *wdata* bits [31:8] are ignored. Slave *addr*[0] connects to master *addr*[2].
 - 16 bit slaves appear as 32-bit slaves with the data carried on bits [15:0]. *rdata* bits [31:16] are set to 0. *wdata* bits [31:16] are ignored. Slave *addr*[0] connects to master *addr*[1].
- On a 16-bit bus, 8 bit slaves appear as 16-bit slaves with the data carried on bits [7:0]. *rdata* bits [15:8] are set to 0. *wdata* bits [15:8] are ignored. Slave *addr*[0] connects to master *addr*[1].

Tables 2 and 3 show how the slave address ports map onto the master's address bits.

Table 2. Data Bus Mapping				
		Slave data bus width (bits)		
		8	16	32
		slave wdata/rdata [7:0] connects to:	slave wdata/rdata [15:0] connects to:	slave wdata/rdata [31:0] connects to:
Master bus width (bits)	8	Master wdata/rdata[7:0]	Illegal	Illegal
	16	Master wdata/rdata[7:0]	Master wdata/rdata[15:0]	Illegal
	32	Master wdata/rdata[7:0]	Master wdata/rdata[15:0]	Master wdata/rdata[31:0]

Table 3. Address Bus Mapping				
		Slave data bus width (bits)		
		8	16	32
		slave addr[N-1:0] connects to:	slave addr [N-1:1] connects to:	slave addr [N-1:2] connects to:
Master bus width (bits)	8	Master addr [N-1:0]	Illegal	Illegal
	16	Master addr [N:1]	Master addr [N-1:1]	Illegal
	32	Master addr [N+1:2]	Master addr [N:2]	Master addr [N-1:2]

Unsupported Bus Operations

- Dynamic bus sizing or access to partial words
- Bus width conversion to external bus
- Direct Memory Access (DMA)
- Alternate bus masters
- Burst transactions
- Split transactions
- Read-modify-write cycles



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