

KEY TERMS

**BUFFER** = temporary holding area for data

- **Row Buffer** = build into memory chips, holds on row's worth of data for fast repeated access
- **DMA Buffer** = region of system meory set aside for transfers between devices
- **FIFO Buffer** = Hardware queue for data moving between components

**BUS** = a set of electrical wires that carry signals between components.

- **Width** = how many bits can travel in parallel (like highway lanes)
- Examples:
  - **DDR4 bus** = wires connecting CPU to memory chips (64 bits wide)
  - **PCIe bus** = wires connecting CPU to FPGA (512 bits wide for us)
  - **AXI bus** = wires inside the FPGA connecting modules

**BUS MASTER** = a device that can initiate transfers on a bus

- typically CPU is the master and everything else responds
- FPGA can also be a bus master via DMA (can request data from CPU)

**PACKET** = a chunk of encoded information.

- like an envelope: has destination address, sender info, and actual message inside
- Examples:
  - **PCIe TLP** (Transaction Layer Packet) = data moving over PCIe includes address, length, type. The FPGA communicates directly to system memory via PCIe (this is called **Direct Memory Access / DMA**)
  - **Memory Write TLP** =
    - **Memory Read Request TLP** = FPGA requesting data from host; includes address within host
    - **Completion TLP** = host sends data to FPGA in response to FPGA sending a read request
  - **Network Packet** = data over ethernet/WiFi
- Not all communication uses packets: CPU talking to memory uses raw electrical signals, not packets

**TX+, TX-, RX+ RX-** = transmit and receive, each using a differential pair

**Differential signaling** = Instead of sending voltage on a single wire, we send the signal as the difference between two wires

- Advantage: Noise affects both wires equally, so the difference remains clean
- This is why PCIe can run at very high speeds reliably

**MMIO (Memory Mapped Input/Output)** = make hardware devices look like addresses

- "input/output" (I/O) means communication with devices (keyboard, disk, FPGA, etc.)
- "Memory-Mapped" means we use memory addresses to talk to these devices

**AXI4 slave** =

