

Program Counter

Purpose:

The Program Counter (**PC**) is a central register in any CPU. It holds the address of the next instruction to fetch from memory. On each clock cycle, it normally increments by 4 (to point to the next 32-bit instruction), or, on a branch/jump instruction, it loads a new target address.

Inputs:

- **clk**: The clock signal. All sequential logic in the CPU operates in sync with this.
- **rst**: The reset signal (active high). When active, puts the PC back to a known state (here, 0).
- **pc_next**: The next value that the PC is supposed to take. It's calculated by other modules (PC+4 for sequential instructions, or a branch target if branching).

Output:

- **pc**: The current value of the Program Counter, exposed as an output so it can be used by the instruction memory (to fetch the corresponding instruction).

Behavior:

- This is a sequential always block (**always_ff**), so its statements happen only on the **positive edge of the clock** or when **rst** goes high.
- If **rst** is 1 (reset asserted): Sets **pc** to 0. This ensures the CPU starts executing from the base address (conventionally, the "reset vector").
- Otherwise (normal operation): At every positive clock edge, take the value on **pc_next** and store it in **pc**.
 - For most instructions, **pc_next** will be **pc + 4**.
 - For branches or jumps, **pc_next** will be calculated as the destination address.

Why This is Important

- **Sequential Control**: The PC is the instruction pointer for the CPU, updated every clock cycle.
- **Branch Support**: By not always incrementing by 4 inside this module, but taking in **pc_next** from outside, the CPU can support branches and jumps easily.
- **Reset Support**: Allows CPU to start safely or restart program execution.

- **Pipeline Role:** In a pipeline, the PC provides the instruction address for the IF stage and is latched in pipeline registers for later stages as needed.

In the Pipeline

- **IF Stage:** This module is referenced to decide which instruction to fetch next.
- **Branch Support:** External logic sets `pc_next` based on branch decisions made in the EXE stage, ensuring correct program flow.