Why Are the PCI Express Ports on My Motherboard Different Sizes? x16, x8, x4, and x1 Explained

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The PCI Express standard is one of the staples of modern computing, with a slot on more or less every desktop computer made in the last decade. But the nature of the connection is somewhat nebulous: on a new PC, you might see a half-dozen ports in three or four different sizes, all labelled “PCIE” or PCI-E.” So why the confusion, and which ones can you actually use?

Understanding the PCI Express Bus

As an upgrade to the original PCI (Peripheral Component Interconnect) system, PCI Express had one huge advantage when it was initially developed in the early 2000s: it used a point-to-point access bus instead of a serial bus. That meant that each individual PCI port and its installed cards could take full advantage of their maximum speed, without multiple cards or expansions being clogged up in a single bus.

PCI Express replaced the older PCI slot standard. This motherboard supports both: PCIE x16 in blue, PCIE x1 in black, and PCI in beige.
In layman’s terms, imagine your desktop PC as a restaurant. The old PCI standard was like a deli, everyone waiting in a single line to get served, with the speed of service limited by a single person at the counter. PCI-E is more like a bar, every patron sitting down in an assigned seat, with multiple bartenders taking everyone’s order at once. (Okay, so it’s never possible to get a bartender to every patron right away, but let’s pretend this is a really great bar.) With dedicated data lanes for each expansion card or peripheral, the entire computer can access components and accessories faster.

Now to extend our deli/bar metaphor, imagine that some of those seats have multiple bartenders reserved just for them. That’s where the idea of multiple lanes comes in.

Life in the Fast Lanes

PCI-E has gone through multiple revisions since its inception; currently new motherboards generally use version 3 of the standard, with the faster version 4 becoming more and more common and version 5 expected to hit in 2019. But the different revisions all use the same physical connections, and those connections can come in four primary sizes: x1, x4, x8, and x16. (x32 ports exist, but are extremely rare and generally not seen on consumer hardware.)

Different sized cards support different maximum PCI-Express lanes.
The different physical sizes allow for different numbers of simultaneous data pin connections to the motherboard: the larger the port, the more maximum connections on the card and the port. These connections are colloquially known as “lanes,” with

each PCI-E lane comprised of two signaling pairs, one for sending data and the other for receiving data. Different revisions of the PCI-E standard allow for different speeds on each lane. But generally speaking, the more lanes there are on a single PCI-E port and its connected card, the faster data can flow between the peripheral and the rest of the computer system.

Going back to our bar metaphor: if you imagine each patron sitting at the bar as a PCI-E device, then an x1 lane would be a single bartender serving a single customer. But a patron sitting in the assigned "x4" seat would have *four* bartenders fetching him drinks and food, and the "x8" seat would have eight bartenders just for her drinks, and the one in the "x16" seat would have a whopping sixteen bartenders just for him. And now we're going to stop talking about bars and bartenders, because our poor metaphorical drinkers are in danger of alcohol poisoning.

What Peripherals Use Which Ports?

For the common revision 3.0 version of PCI Express, the maximum per-lane data rate is eight gigatransfers, a term that means "all the data and electronic overhead at once." In the real world, the speed for PCI-E revision 3 is a little less than one gigabyte per second, per lane.

So a device that uses a PCI-E x1 port, like a low-power sound card or a Wi-Fi antenna, can transfer data to the rest of the computer at approximately 1GBps. A card that bumps up to the physically larger x4 or x8 slot, like a USB 3.0 expansion card, can transfer data four or eight times faster—and it would need to, if more than two of those USB ports were being used at their maximum transfer rate. The PCI-E x16 ports, with a theoretical maximum of around 15GBps on the 3.0 revision, are used for almost all modern graphics cards designed by NVIDIA and AMD.

Most discrete graphics cards use a full PCI-E x16 slot.

There aren't any set guidelines for which expansion cards will use which number of lanes. Graphics cards tend to use x16 just for the sake of maximum data transfer, but obviously you don't need a network card to use an x16 port and sixteen full lanes when its Ethernet port is only capable of transferring data at one gigabit per second (about an eighth of the throughput of one PCI-E lane—remember, eight bits to a byte). There are a small amount of PCI-E mounted solid state drives that prefer an x4 port, but those seem to have been swiftly overtaken by the new M.2 standard, which can also use the PCI-E bus. High-end network cards and enthusiast equipment like adapters and RAID controllers use a mix of x4 and x8 formats.

Remember: PCI-E Port Size and Lanes May Not Be the Same Thing

Here's one of the more confusing parts of the PCI-E setup: a port might be the size of an x16 card, but only have enough data lanes for something much less speedy, like x4. This is because while PCI-E can accommodate basically unlimited amounts of individual connections, there's still a practical limit on the lane throughput of the chipset. Cheaper motherboards with more budget-oriented chipsets might only go up to a single x8 slot, even if that slot can physically accommodate an x16 card. Meanwhile, "gamer" motherboards will include up to four full x16-size and x16-lane PCI-E slots for maximum GPU compatibility. (We've discuss this in more detail here.)

This enthusiast motherboard includes five full-sized PCI-E x16 slots, but only two of them have the full 16 data lanes—the others are x8 and x4.

Obviously, this can cause problems. If your motherboard has two x16-sized slots, but one of them has only x4 lanes, then plugging your fancy new graphics card into the wrong slot could bottleneck its performance by 75%. That's a theoretical result, of course: the architecture of motherboards means you won't see such a dramatic

decline. The point is, the right card needs to go in the right slot.

Luckily, the lane capacity of the specific PCI-slots is generally spelled out in the computer or motherboard manual, with an illustration of which slot has which capacity. If you don't have your manual, the number of lanes is generally written on the PCB of the motherboard next to the port, like so:

The labels on these ports show the available lanes: the x1 port on top has one lane, but the x16 port below has only four, despite its physical size. PCIEX1_2 means it's the second x1 port on the motherboard.
Also, a shorter x1 or x4 card can physically fit into a longer x8 or x16 slot: the initial pin configuration of the electrical contacts makes it compatible. The card may be a bit loose physically, but when screwed into place in the expansion slots of a PC case, it's more than adequately sturdy. Naturally, if a card's contacts are physically larger than the slot, it can't be inserted.

So remember, when buying expansion or upgrade cards for PCI Express slots, you need to be mindful of both the size and the lane rating of your available ports.

Image credit: Newegg, Amazon

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