Chapter

1

Upgrading and Repairing: Build a PC with Scott Mueller

Welcome to *Upgrading and Repairing: Build a PC with Scott Mueller*. In this video, and in the included booklet, I cover all aspects of building a PC from scratch, including everything from the initial component selection, to actually building the system and getting it running. The booklet you are reading now is designed to enhance the video, adding important details and reference information to aid in the process.

Video Segment 1: Goals When Building a PC

One of the best features of PCs is their nearly infinite variability. There are so many different components to choose from, and they can be both configured and assembled in any number of ways. As with many things, you must consider a number of trade-offs when building a PC from scratch. For example, if performance is the ultimate goal and cost is no consideration, the type of PC you could build is entirely different from one where a more limited budget is in effect. Although no single set of choices results in one perfect PC for everybody, it is certainly possible to come up with a reasonable set of goals to achieve.

I've built hundreds of PCs over the more than 25 years I've been in the business, and with the exception of systems for specialized purposes such as servers, database processors, or even pure

gaming systems, my usual goals in building a universally useful PC are the same. I want the resulting system to be

- Fast
- Inexpensive
- Upgradeable
- Practical and reliable

Note

Note that the specific choices in components that I show and use in this system are not important, because those will change over time. As new or different components are introduced, my choices will change based on what components are available, what they cost, and who or what the specific system is being designed for. With that in mind, I try to focus more on general principles rather than specific components.

Fast

For the system to be fast, I recommend the system include the following components/considerations:

- **Dual- or quad-core processor**—The days of multicore computing are here, and because of the relative low cost and yet high performance of multicore processors, I don't recommend single-core processors for all but the most economical or low-power designs.
- **Dual-channel RAM**—There are relatively few differences in performance between different types of memory such as DDR2 or DDR3, or with different speeds within a type such as 667MHz or 800MHz DDR2. But one feature that makes a larger difference is running memory in dual channel (also called *interleaved*) mode versus single-channel or noninterleaved mode. By installing memory modules in matched pairs, with one of each module in a different channel, modern motherboards will run them in dual-channel mode, resulting in twice the memory bandwidth. Although this will not have nearly as large an effect on overall system performance, it is the easiest and most economical way to optimize memory performance.
- **Gigabit Ethernet**—Many people or families today have a growing collection of digital data to deal with, including videos, photos, music files, documents, and more. With sharing or even backing up these files over a network becoming commonplace, as well as the larger number and sizes of the files accumulating on systems, using Gigabit Ethernet can increase network performance up to 10 times that of the slower 100Mb speed. With Gigabit Ethernet adapters available for $10 or less (and some even built in to the motherboard) and the availability of low-cost gigabit switches (used to interconnect the devices on the network), there is little excuse for not running your network at gigabit speeds. When building a PC, choose a motherboard that incorporates Gigabit Ethernet built in; or if the built-in port only runs 100Mb, add a Gigabit Ethernet card (you might need to disable the onboard network adapter through the BIOS; check your motherboard manual for details).

- **eSATA external drive backup**—USB and FireWire are adequate for connecting external backup drives, but by choosing a motherboard with eSATA (external Serial ATA) support built in, you can effectively double the speed of your backups.
- **Optional: RAID 0 (striped) boot partition**—With hard drives becoming cheaper all the time, and modern motherboards available with integrated chipset-based RAID controllers offering performance not previously available with card-based RAID implementations, I recommend considering the use of a RAID 0 boot volume. Because RAID 0 more than doubles the chance for failure, data should still be stored on either a standalone data drive or RAID 1 (mirrored) volume. However, for booting the OS, maximizing the OS page-file performance, and loading drivers and applications, RAID 0 offers at least double the performance of a standalone drive. There is some risk because if any drive in a RAID 0 volume fails, all files on the volume will be lost; but because the OS, drivers, and applications can easily be backed up and reloaded, the risk may be warranted given the performance gains. Although running a RAID 0 boot volume might not be for everybody, it can dramatically increase the performance of the system as a whole.

Inexpensive

PCs have always offered excellent value, especially when compared to less-popular alternative types of personal computers, but you can build a PC to fit in many different price ranges. For most uses, you can easily keep the total cost of a system to $1,000 or less, and a relatively high-performance full-featured system can easily be built in the $2,000 or less range.

Starter System with Upgrade Potential

For a general-use PC, I like to keep the cost as low as possible, while still allowing for performance and future upgrades. For me this means building a system with as many integrated components as possible, while also containing the necessary slots or ports where future upgrades can be added. I recommend purchasing a motherboard that includes at least the following integrated components:

- Gigabit Ethernet
- HD (high-definition) audio
- USB/FireWire/eSATA

Other integrated components that might be considered include the following:

- Video
- RAID (chipset based)

Of those, integrated video is perhaps the most controversial, because there seems to be a relatively large gap in performance between integrated video and the video you find on available add-in cards. If you are building a system where gaming is important, you will almost definitely want an add-in video card. In that case, you might want to choose a motherboard without inte-

grated video, because you will be installing a video card anyway, which will automatically disable the integrated video.

But even so, I usually find that having the integrated video option adds no cost to the motherboard, and motherboards with integrated video still normally have an expansion slot allowing a video card to be installed initially or as an upgrade later. This means that if you have a video card installed you essentially have a backup video adapter in the system for free. I find the integrated video especially useful when troubleshooting or initially configuring a system. And especially I find that when a system is a few years old, I usually like to rebuild it as a server or media player, and having the ability to revert back to the integrated video is a great feature.

If you are considering the use of RAID, having chipset-based RAID integrated into your motherboard is something you should consider. Except for high-availability servers where RAID 6 is desired, chipset-based RAID will normally outperform that of any card-based RAID solutions.

One or Two Internal Hard Disk Drives

For the lowest cost, you should build your system with a single internal hard drive. If desired, it can be partitioned into multiple partitions, say one for boot (OS/drivers/applications) and one for data; but in most cases, I recommend leaving the drive as a single partition and organizing your data into a folder rather than a separate partition.

Another option is to use two drives, one for booting the system and the other for data. With two drives and an integrated RAID controller, you have the option of even higher performance or reliability, or both. You can run both drives in a RAID 0 (striped) configuration for double the performance (and unfortunately half the reliability), or in a RAID 1 configuration for the same performance as a single drive (or slightly better in the case of Intel's chipset-based RAID, which does load balancing) and double the reliability.

Intel's so-called Matrix RAID also offers a third choice—running both RAID 0 and RAID 1 volumes on the same two drives. Note that I am not recommending this setup for everybody, but it does allow the best of both RAID 0 and RAID 1 on two drives. If you are willing to spend more on four drives, I recommend a RAID 10 setup, which combines striping and mirroring in an array with the best of both features.

Upgradeable

One of the best features of self-built PCs is their inherent upgradeability. But with a careful selection of components, you can improve on the future upgradeability of a system over what it might be otherwise. For example, choosing a motherboard with one chipset over another might allow a wider range of future processors/memory to be installed.

- **Intel-based systems**—If you are building an Intel processor–based system, I recommend choosing a motherboard based on the Intel 3x series chipsets over the older 9xx series chipsets. The 3x series supports the newer Penryn-based Wolfdale (dual-core) and Yorkfield (quad-core) processors built on 45nm (nanometer) technology. This means that even if you install a current 65nm Conroe (dual-core) or Kentsfield (quad-core) Core2 processor, you

can later upgrade to the newer 45nm processors without having to change the motherboard/memory in the process. In addition, the 3x series chipsets also have the following capabilities:

- Up to 1333MHz Front Side Bus (FSB)
- Up to 8GB RAM
- PCIe 2.0 (X38)
- Crossfire (X38)
- Optional DDR3 memory (X38, P35, G33, G35)

Those chipsets that support DDR3 also support DDR2, but not on the same motherboard. That means that the motherboard you choose will be designed to support either DDR2 or DDR3, but not both.

- **AMD-based systems**—If you are building an AMD processor–based system, for maximum upgradeability make sure you choose a chipset that supports the newer AMD Phenom X2 and X4 processors. Motherboards with these chipsets also support either Socket AM2+ and DDR2 memory or Socket AM3 and DDR3 memory.

Industry-Standard Form Factors

An important consideration for future upgradeability is the choice of motherboard, chassis, and power-supply form factors. For maximum future upgradeability, you can choose an ATX chassis, which will support both ATX and microATX motherboards (and ATX power supplies). You can also go with a smaller microATX chassis, but in that case I generally recommend those that still use standard ATX power supplies, too. You can get small form factor (SFF) chassis that support microATX motherboards, but those often use smaller, less-powerful, and less-available power-supply form factors.

PCIe x16 Slot for Video

If you are choosing a motherboard with integrated video, make sure it still has a PCIe x16 slot allowing you to add a video card later. For example, you might want to add a video card later if you start gaming and find that the performance of the integrated video just doesn't cut it. If you want to enable the ultimate gaming experience now or in the future, choose a board with dual PCIe x16 slots supporting either Crossfire (ATI) or SLI (NVIDIA) dual graphics card solutions.

Chassis Bays for Additional Drives

Another factor in the choice of your chassis is the number of different drive bays that are available. Modern chassis will generally have three types of drive bays:

- **5.25" external**—The 5.25" external bays are primarily designed for optical (CD/DVD) drives, but they can also hold 3.5" hard disk drives using simple adapter brackets. Another option for those bays are external port adapters, fan controllers, or even storage drawers.

- **3.5" external**—The 3.5" external bays are primarily designed for floppy drives, but they can also hold front-panel port adapters or fan controllers. In some cases, it is possible to also mount a hard drive in these bays, but that might require minor modifications in some chassis.
- **3.5" internal**—Finally, the internal 3.5" bays are designed for hard disk drives. In general, you want to ensure that there are enough of these bays to hold all the internal hard disks you want to install. If the chassis supports more than two drives, I highly recommend ensuring that provisions are available to install a fan to cool the drives. In most cases, you will find a position for one or more optional front-mounted fans that are designed to blow air directly on the installed internal 3.5" drives.

RAID Ready

By choosing a motherboard that has built-in chipset-based RAID, and by enabling the RAID controller before the initial OS installation (even if you are only installing a single drive in a non-RAID configuration), you will make the system what we call *RAID ready*. Being RAID ready means that the system can easily be upgraded from non-RAID to a RAID configuration at any time in the future, without having to reinstall the OS or restore any files. You could, for example, add one or more additional drives in the future, and then perform what is called a *RAID migration*, which moves the volume and all of its contents from the single drive to the multiple-drive RAID volume, without reinstalling anything. Even more amazing is that the system can even be used normally while the migration is taking place.

Future CPU Overclock/Upgrade Possible

By carefully choosing your motherboard, processor, and RAM, you can build a system that will be overclockable. For example, because the different speed-grade processors in a given family are built on the same die, in general the slower the rated speed grade of the processor you purchase, the more you will be able to overclock it in the future. As a specific example, the Intel Core2 Quad Q6600 is rated at the relatively slow speed of 2.4GHz, yet many people have success in overclocking it to 3GHz and beyond. That is a 25% or greater increase in speed, for little or no cost.

The most important issue with overclocking is the choice of motherboard. Most motherboards installed in store-bought systems don't allow overclocking for obvious warranty and support reasons, nor do most of the Intel desktop motherboards. On the other hand, the Intel "extreme series" motherboards do allow overclocking, as do most non-Intel boards such as those from Abit, Asus, Gigabyte, MSI, and so on.

In addition to the motherboard, overclocking is obviously influenced by the capabilities of your processor, and also involves the memory. There are some risks with overclocking, but if that is something you want to try, choose your motherboard, processor, and even your memory with overclocking in mind.

Caution

When building a system for a friend, relative, customer, or client where you will be the one providing support, you might want to avoid overclocking because of the potential for additional instability or problems.

Practical and Reliable

Few people will tolerate a system that locks up all the time, or one that is extremely loud. The overall size and shape of the system might be important, too. For example, you probably don't want a full-size ATX tower system as a media center PC in your living room. Try to consider what the final use of the system will be, where it will be installed, and what you will be using it for.

Standard MicroATX Form Factor Motherboard and Chassis

Although full-size ATX motherboads and chassis offer the ultimate in expandability and upgradeability, I often don't need or want a system that large. With most important features integrated into the motherboard already, additional card slots often go unused. The same goes for additional drive bays. Having four external 5.25" drive bays makes little sense if you are only going to install a single optical drive. I find that for most normal uses, a smaller form factor microATX chassis and motherboard is more appropriate than the full-size alternatives.

Processor and Chipset from the Same Manufacturer

In general, I have found greater reliability and system integrity when mating processors and chipsets from the same manufacturer. What this means in essence is that if I am building a system with an Intel processor, I generally like to use a motherboard with an Intel chipset, and when building a motherboard with an AMD processor, I like to use a motherboard with an AMD chipset.

RAID 1 (Mirrored) Data Partition

If stability and integrity is valued over performance, you might consider installing two drives and just running them in a straight RAID 1 (mirrored) setup. This will provide redundancy, in that if one drive fails you will not lose any data and the system will remain running. You can then replace the drive and rebuild the array while still using the system.

Caution

If any drive in a RAID 0 array fails, the entire array will be unavailable and all data will be lost. If you use a RAID 0 setup, performing regular backups to a separate external drive is not only a good idea, it's *crucial*.

External eSATA/USB Backup Drive

Backup is an important part of system reliability and integrity, and unfortunately many people fail to consider backup when building a PC. If the PC is part of a home or small office network, you can use a server or network-attached storage device for backup, but the simplest and fastest form of backup is to use an external drive directly attached to the system. Interface choices for external drives are normally USB, FireWire, and more recently eSATA. Of those, eSATA offers relatively double the performance of the others, which can cut backup times in half.

Quiet Fans

Noise (or the lack thereof) is an important consideration for system practicality. A user of a full-

bore gaming system might be willing to tolerate the additional noise of dual fan-cooled video cards and exotic gamer cases with numerous fans, but many people prefer a quieter system. It is possible to cut the noise in a system by choosing quieter fans, hard drives, and other components. If a quiet system is the goal, look for lower-speed fans and those with fluid bearings (and hard drives with fluid bearings). Also note that larger fans spin more slowly and generate less heat and noise while moving more air through your system.

Video Segment 2: Selecting Components

In this segment, I show all the components necessary to build a system and provide additional detail on all of them.

Motherboard

If the CPU is the brain of the system, the chipset is the central nervous system, connecting the brain to all the other components and peripherals. Because of the relative importance of the chipset to everything else, when choosing the components for a system, I usually start with the chipset, and often spend more time deciding on what chipset I will use than I do on any other component in the system. The chipset will govern the type/range of processors that will be supported, and the types of buses, memory sockets, integrated components such as video, audio, and RAID, and so on. Because so many other things depend on the chipset, I recommend making that selection carefully.

For the purposes of this video, originally I intended to build an Intel system using a Core2 Quad processor, with either older 9xx or newer 3x chipsets. However, for maximum future upgradeability, I ultimately chose to go with a 3x chipset motherboard. The current 3x series chipsets include the following:

- X38 for high-performance systems
  - 1333/1066/800MHz FSB
  - No built-in video
  - Two PCI x16 slots (Crossfire support)
  - 8GB max. DDR2 or DDR3 up to 1333MHz
  - 6 SATA
  - Most likely full ATX
- P35 for medium to high performance
  - 1333/1066/800MHz FSB
  - No built-in video
  - One PCI x16 slot
  - 8GB max. DDR2 or DDR3 up to 1066MHz
  - 4-6 SATA
  - Most likely full ATX