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The MacBook Pro Review (13 & 15-inch): 2011 Brings Sandy Bridge

by **Anand Lal Shimpi, Brian Klug, Vivek Gowri** on 3/10/2011 4:17:00 PM
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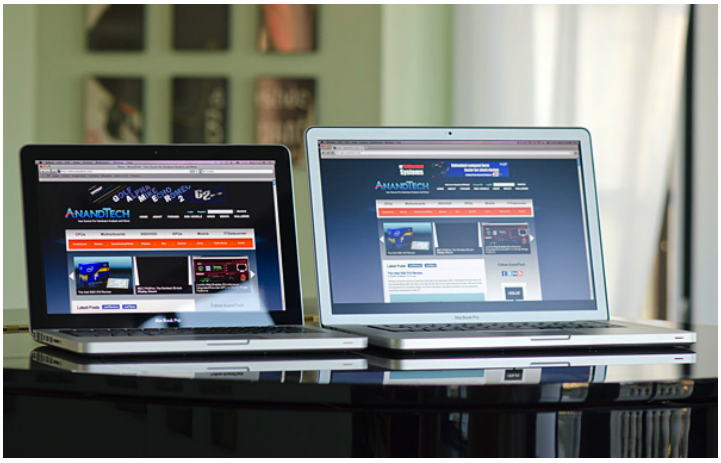
AAPL Revenue Sources—Q1 2011

	iPad	iPhone	iPod	Mac	iTunes Store	Software/Services	Peripherals
Percentage	17.2%	39.1%	12.8%	20.3%	5.4%	2.9%	2.2%

Just looking at iPad and iPhone, that's 56% of Apple's sales. All Macs put together? Only 20%. Granted 20% of $26.7 billion in sales is still $5.3 billion, but the iOS crew gets most of the attention these days.

It shouldn't come as a surprise that when Apple launched its 2011 MacBook Pro lineup last week that it did so with little fanfare. There was no special press event and no video of an unusually charismatic man on a white background describing the latest features of the systems. All we got two weeks ago were a few pages describing the high level features of the lineup, a short outage on the Mac Store and five new configurations available for sale.



We've been working non-stop since the launch on our review of the new 13-inch and 15-inch MacBook Pros. Despite the lack of fanfare, this is a pretty serious upgrade. Read on for our in-depth analysis!

Page 1

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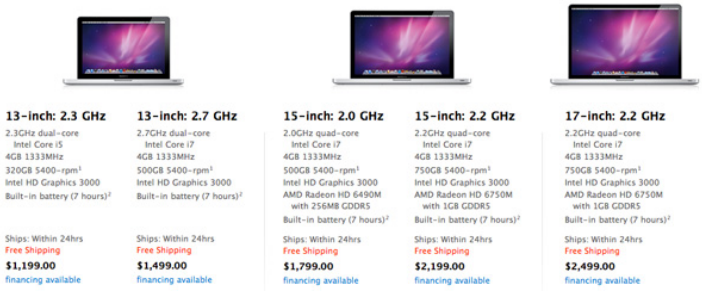
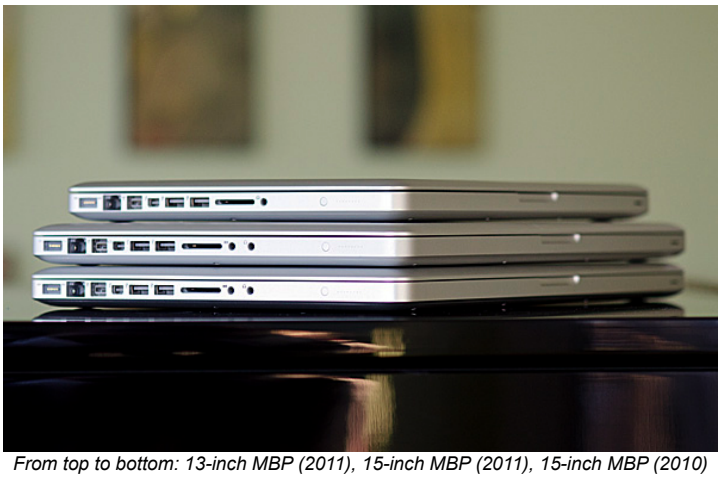


Apple tends to not mix architecture updates and chassis changes. The 2011 MacBook Pro lineup is no different. These models fundamentally implement the same updated unibody shell that was introduced in 2009. The term unibody comes from the fact that the base of the chassis is machined out of a

single block of aluminum. There's no way to gain access to the MacBook Pro's internals from above, you have to go in from below. As a result there's absolutely no chassis flex or squeaking while you pound on the keyboard, use the trackpad or just interact with the part of the machine that you're most likely to be touching. Apple has been shipping unibody MacBook Pros since 2008 and from my experience the design has held up pretty well.



From top to bottom: 13-inch MBP (2011), 15-inch MBP (2011), 15-inch MBP (2010)

The biggest letdown in the design has been the hinge connecting the display to the rest of the chassis. I haven't had it fail completely but I've had it become frustratingly loose. Even brand new, out of the box, the 15-inch MacBook Pro will have its display move by a not insignificant amount if you tilt the machine 90 degrees so that the display is parallel to the ground. A number of readers have written me over the years asking if Apple has improved the locking ability of the hinge in each new version of the MacBook Pro. It doesn't seem to be any better with the 2011 model—sorry guys.

Other than screen size, ports and internals, there's nothing that separates the 13-, 15- and 17-inch MacBook Pros from one another. They all feature the same excellent backlit keyboard (keyboard size is constant across all models) and a variant of the same high quality display. All of them have the same front facing 720p camera and the same large glass-covered trackpad.

Battery capacity hasn't changed compared to last year, although power consumption on some models has gone up (more on this later).

2011 MacBook Pro Lineup

	13-inch (low end)	13-inch (high end)	15-inch (low end)	15-inch (high end)	17-inch
Dimensions	0.95 H x 12.78 W x 8.94 D		0.95 H x 14.35 W x 9.82 D		0.98 H x 15.47 W x 10.51 D
Weight	4.5 lbs (2.04 kg)		5.6 lbs (2.54 kg)		6.6 lbs (2.99 kg)
CPU	2.3 GHz dual-core Core i5	2.7 GHz dual-core Core i7	2.0 GHz quad-core Core i7	2.2 GHz quad-core Core i7	2.2 GHz quad-core Core i7
GPU	Intel HD 3000 Graphics		Intel HD 3000 + AMD Radeon HD 6490M (256MB)	Intel HD 3000 + AMD Radeon HD 6750M (1GB)	Intel HD 3000 + AMD Radeon HD 6750M (1GB)
RAM	4GB 1333MHz DDR3 (8GB max)				
HDD	320GB 5400 RPM	500GB 5400 RPM	500GB 5400 RPM	750GB 5400 RPM	750GB 5400 RPM
Display Resolution	1280x800		1440x900 (1680x1050 optional)		1920x1200

Ports	Gigabit LAN, Firewire 800, Thunderbolt, 2x USB 2.0, SDHC slot, combined audio in/out jack		Gigabit LAN, Firewire 800, Thunderbolt, 2x USB 2.0, SDHC slot, separate audio in/out jacks		Gigabit LAN, Firewire 800, Thunderbolt, 3x USB 2.0, separate audio in/out jacks, ExpressCard 34 slot
Battery Capacity	63.5Wh		77.5Wh		95Wh
Price	$1,199	$1,499	$1,799	$2,199	$2,499

The new MacBook Pros are still equipped with DVD drives and thus Apple still distributes OS X and the application preload on a pair of DVDs. I was hoping Apple would go to an all-USB distribution starting with the MBA but it looks like we'll have to wait for another generation of Pro systems before we see that.

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Turbo and the 15-inch MacBook Pro

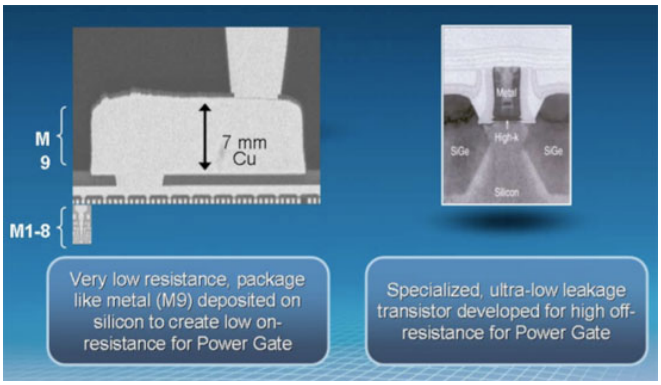
The 15 and 13 are different enough that I'll address the two separately. Both are huge steps forward compared to their predecessors, but for completely different reasons. Let's start with the 15.

Starting with Sandy Bridge, all 15 and 17-inch MacBook Pros now feature quad-core CPUs. This is a huge deal. Unlike other notebook OEMs, Apple tends to be a one-size-fits-all sort of company. Sure you get choice of screen size, but the options dwindle significantly once you've decided how big of a notebook you want. For the 15 and 17-inch MBPs, all you get are quad-core CPUs. Don't need four cores? Doesn't matter, you're getting them anyway

Evolution of the 15-inch MacBook Pro	Early 2011	Mid 2010	Late 2009
CPU	Intel Core i7 2.0GHz (QC)	Intel Core i5 2.40GHz (DC)	Intel Core 2 Duo 2.53GHz (DC)
Memory	4GB DDR3-1333	4GB DDR3-1066	4GB DDR3-1066
HDD	500GB 5400RPM	320GB 5400RPM	250GB 5400RPM
Video	Intel HD 3000 + AMD Radeon HD 6490M (256MB)	Intel HD Graphics + NVIDIA GeForce GT 330M (256MB)	NVIDIA GeForce 9400M (integrated)
Optical Drive	8X Slot Load DL DVD +/-R	8X Slot Load DL DVD +/-R	8X Slot Load DL DVD +/-R
Screen Resolution	1440 x 900	1440 x 900	1440 x 900
USB	2	2	2
SD Card Reader	Yes	Yes	Yes
FireWire 800	1	1	1
ExpressCard/34	No	No	No
Battery	77.5Wh	77.5Wh	73Wh
Dimensions (W x D x H)	14.35" x 9.82" x 0.95"	14.35" x 9.82" x 0.95"	14.35" x 9.82" x 0.95"
Weight	5.6 lbs	5.6 lbs	5.5 lbs
Price	$1799	$1799	$1699

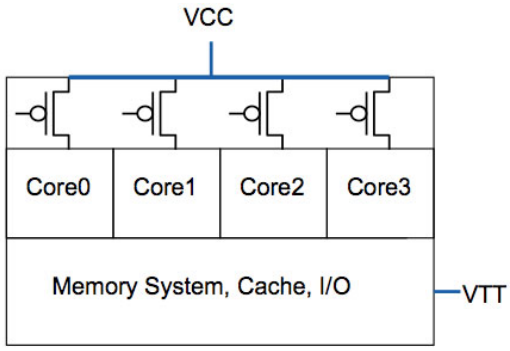
Apple was able to rationalize this decision because of one feature: Intel Turbo Boost.

In the ramp to 90nm Intel realized that it was expending a great deal of power in the form of leakage current. You may have heard transistors referred to as digital switches. Turn them on and current flows, turn them off and current stops flowing. The reality is that even when transistors are off, some current may still flow. This is known as leakage current and it becomes a bigger problem the smaller your transistors become.



With Nehalem Intel introduced a new type of transistor into its architecture: the power gate transistor. Put one of these babies in front of the source voltage to a large group of transistors and at the flip of a, err, switch you can completely shut off power to those transistors. No current going to the transistors means effectively no leakage current.

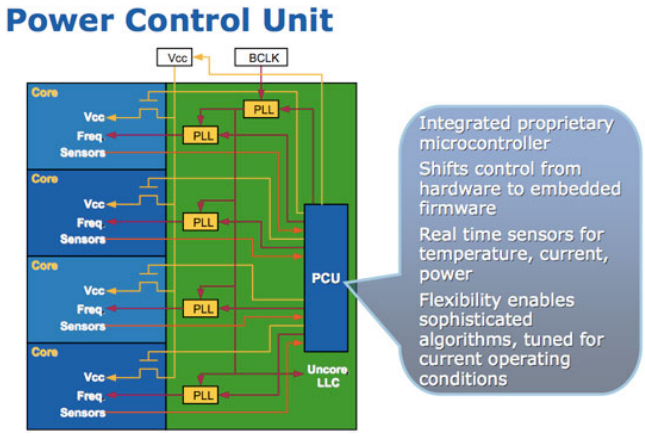
Prior to Intel's use of power gating, we had the next best thing: clock gating. Instead of cutting power to a group of transistors, you'd cut the clock signal. With no clock signal, any clocked transistors would effectively be idle. Any blocks that are clock gated consume no active power, however it doesn't address the issue of leakage power. So while clock gating got you some thermal headroom, it became less efficient as we moved to smaller and smaller transistors.



All four cores in this case have the same source voltage, but can be turned off individually thanks to the power gate above the core

Power gating gave Intel one very important feature: the ability to truly shut off a core when not in use. Prior to power gating Intel, like any other microprocessor company, had to make tradeoffs in choosing core count vs. clock speed. The maximum power consumption/thermal output is effectively a fixed value, physics has something to do with that. If you want four cores in the same thermal envelope as two cores, you have to clock them lower. In the pre-Nehalem days you had to choose between two faster cores or four slower cores, there was no option for people who needed both.

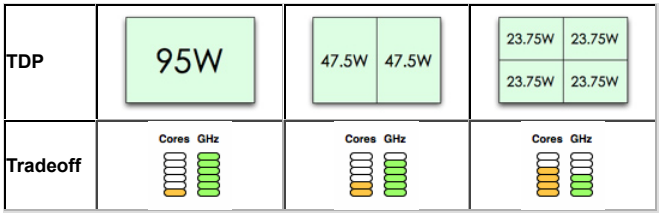
Now, with the ability to mostly turn off idle cores, you can get around that problem. A fully loaded four core CPU will still run at a lower clock than a dual core version, however with power gating if you are only using two cores then you have the thermal headroom to ramp up the clock speed of the two active cores (since the idle ones are effectively off).



Get a little more clever and you can do this power gate and clock up dance for more configurations. Only using one core? Power gate three and run the single active core at a really really high speed. All of this is done by a very complex piece of circuitry on the microprocessor die. Intel introduced it in Nehalem and called it the Power Control Unit (this is why engineers aren't good marketers but great truth tellers). The PCU in Nehalem was about a million transistors, around the complexity of the old Intel 486, and all it did was look at processor load, temperature, power consumption, active cores and clock speed. Based on all of these inputs it would determine what to turn off and what clock speed to run the entire chip at.

Another interesting side effect of the PCU is that if you're using all cores but they're not using the most power hungry parts of their circuitry (e.g. not running a bunch of floating point workloads) the PCU could keep all four active but run them at a slightly higher frequency.

	Single Core	Dual Core	Quad Core



The PCU actually works very quickly. Let's say you're running an application that only for a very brief period is only using a single core. That's more than enough time for the PMU to turn off all unused cores, turbo up the single core and complete the task quicker.

Intel calls this dynamic frequency scaling Turbo Boost (ah this is where the marketing folks took over). The reason I went through this lengthy explanation of Turbo is because it allowed Apple to equip the 15-inch Macbook Pro with only quad-core options and not worry about it being slower than the dual-core 13-inch offering, despite having a lower base clock speed (2.0GHz for the 15 vs. 2.3GHz for the 13).

13-inch MacBook Pro (left), 15-inch MacBook Pro with optional high res/anti-glare display (right)

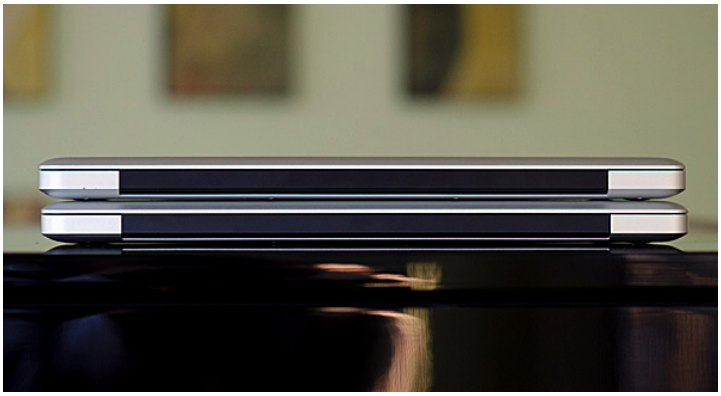
Apple offers three CPU options in the 15-inch MacBook Pro: a 2.0GHz, 2.2GHz or 2.3GHz quad-core Core i7. These actually correspond to the Core i7-2635QM, 2720QM and 2820QM. The main differences are in the table below:

Apple 15-inch 2011 MacBook Pro CPU Comparison

	2.0GHz quad-core	2.2GHz quad-core	2.3GHz quad-core
Intel Model	Core i7-2635QM	Intel Core i7-2720QM	Intel Core i7-2820QM
Base Clock Speed	2.0GHz	2.2GHz	2.3GHz
Max SC Turbo	2.9GHz	3.3GHz	3.4GHz
Max DC Turbo	2.8GHz	3.2GHz	3.3GHz
Max QC Turbo	2.6GHz	3.0GHz	3.1GHz
L3 Cache	6MB	6MB	8MB
AES-NI	No	Yes	Yes
VT-x	Yes	Yes	Yes
VT-d	No	Yes	Yes
TDP	45W	45W	45W

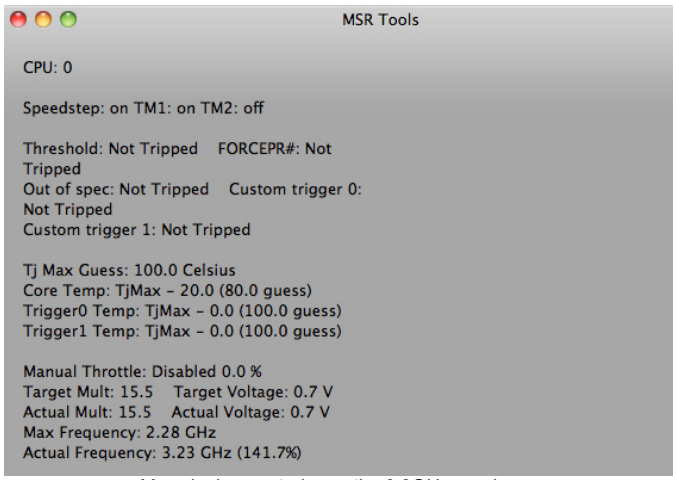
The most annoying part of all of this is that the base 2635 doesn't support Intel's AES-NI. Apple still doesn't use AES-NI anywhere in its OS it seems so until Lion rolls around I guess this won't be an issue. Shame on Apple for not supporting AES-NI and shame on Intel for using it as a differentiating feature between parts. The AES instructions, introduced in Westmere, are particularly useful in accelerating full disk encryption as we've seen under Windows 7.

Note that all of these chips carry a 45W TDP, that's up from 35W in the 13-inch and last year's 15-inch model. We're talking about nearly a billion transistors fabbed on Intel's 32nm process—that's almost double the transistor count of the Arrandale chips found in last year's MacBook Pro. These things are going to consume more power.



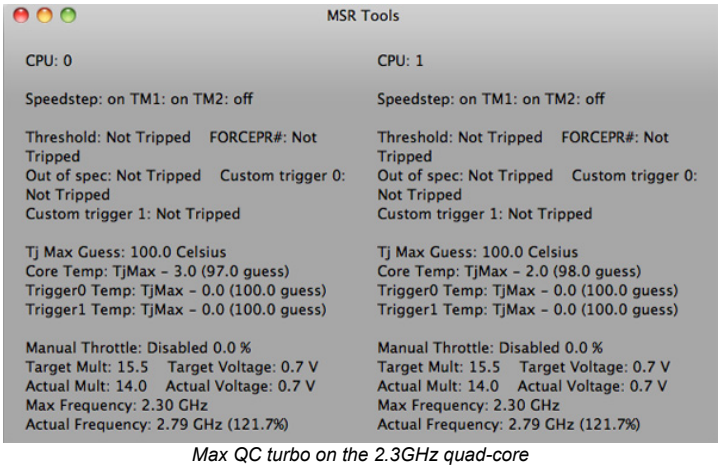
Despite the fairly low base clock speeds, these CPUs can turbo up to pretty high values depending on how many cores are active. The base 2.0GHz quad-core is only good for up to 2.9GHz on paper, while the 2720QM and 2820QM can hit 3.3GHz and 3.4GHz, respectively.

Given Apple's history of throttling CPUs and not telling anyone I was extra paranoid in finding out if any funny business was going on with the new MacBook Pros. Unfortunately there are very few ways of measuring turbo frequency under OS X. Ryan Smith pointed me in the direction of MSR Tools which, although not perfect, does give you an indication of what clock speed your CPU is running at.



Max single core turbo on the 2.3GHz quad-core

With only a single thread active the 2.3GHz quad-core seemed to peak at ~3.1—3.3GHz. This is slightly lower than what I saw under Windows (3.3—3.4GHz pretty consistently running Cinebench R10 1CPU test). Apple does do power management differently under OS X, however I'm not entirely sure that the MSR Tools application is reporting frequency as quickly as Intel's utilities under Windows 7.



Max QC turbo on the 2.3GHz quad-core

With all cores active (once again, Cinebench R10 XCPU) the max I saw on the 2.3 was 2.8GHz. Under Windows running the same test I saw similar results at 2.9GHz.

Max QC turbo on the 2.3GHz quad-core under Windows 7

I'm pretty confident that Apple isn't doing anything dramatic with clock speeds on these new MacBook Pros. Mac OS X may be more aggressive with power management than Windows, but max clock speed remains untouched.

Mac OS X 10.6.6 vs. Windows 7 Performance

15-inch 2011 MBP, 2.0GHz quad-core	Single-Threaded	Multi-Threaded
Mac OS X 10.6.6	4060	15249
Windows 7 x64	4530	16931

Note that even though the operating frequencies are similar under OS X and Windows 7, Cinebench performance is still higher under Windows 7. It looks like there's still some software optimization that needs to be done under OS X.

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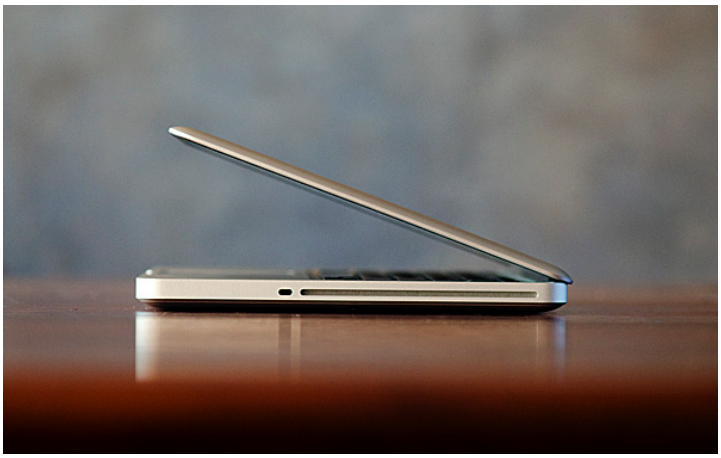
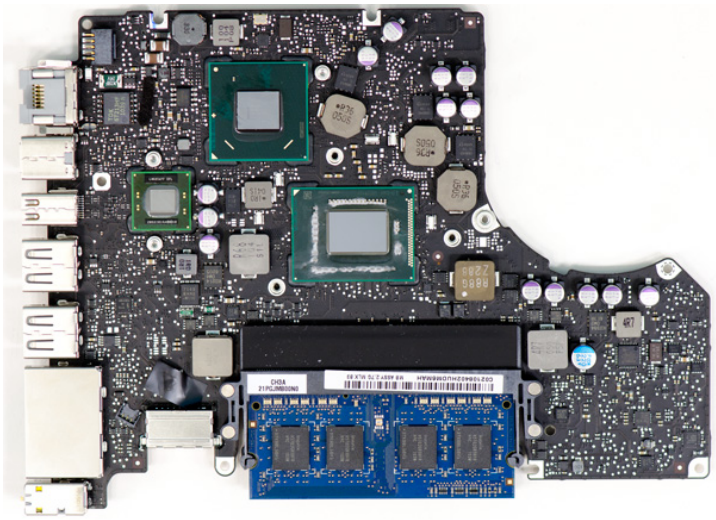
What About The 13?

Apple's new 13-inch MacBook Pro received the biggest upgrade of the lot. Last year Apple opted against moving the 13-inch model to Arrandale and instead gave it a beefy GPU and a mildly evolved Core 2 Duo CPU. The presumed public reasoning was Apple didn't like Arrandale's GPU performance and needed a two chip solution to maintain the platform's size hence the NVIDIA GT 330M + Intel Core 2 Duo setup. Internally I'm wondering if there was a small amount of corporate politics being played there. Apple used to get a discount on Intel CPUs in exchange for exclusivity, that agreement expired with Nehalem. When Nehalem hit, Apple had to pay the same price as everyone else for CPUs. Now does the 2010 Core 2 based 13-inch MacBook Pro make more sense? Keeping Intel's flagship CPU out of Apple's highest volume MacBook Pro had to hurt. I wonder if Apple got discounted pricing on Sandy Bridge as a result...



Evolution of the 13-inch MacBook Pro	Early 2011	Mid 2010	Late 2009
CPU	Intel Core i5 2.3GHz (DC)	Intel Core 2 Duo 2.40GHz (DC)	Intel Core 2 Duo 2.26GHz (DC)
Memory	4GB DDR3-1333	4GB DDR3-1066	2GB DDR3-1066
HDD	320GB 5400RPM	250GB 5400RPM	160GB 5400RPM
Video	Intel HD 3000 (integrated)	NVIDIA GeForce 320M (integrated)	NVIDIA GeForce 9400M (integrated)
Optical Drive	8X Slot Load DL DVD +/-R	8X Slot Load DL DVD +/-R	8X Slot Load DL DVD +/-R
Screen Resolution	1280 x 800	1280 x 800	1280 x 800
USB	2	2	2
SD Card Reader	Yes	Yes	Yes
FireWire 800	1	1	1
ExpressCard/34	No	No	No
Battery	63.5Wh	63.5Wh	60Wh
Dimensions (W x D x H)	12.78" x 8.94" x 0.95"	12.78" x 8.94" x 0.95"	12.78" x 8.94" x 0.95"
Weight	4.5 lbs	4.5 lbs	4.5 lbs
Price	$1199	$1199	$1199

While the 15-inch MacBook Pro is quad-core only, the new 13 is strictly dual-core. You get two options: a 2.3GHz or 2.7GHz dual-core Core i5 or Core i7. In Intel speak it's the Core i5-2410M or the Core i7-2620M (it's no wonder Apple doesn't list model numbers for these things).

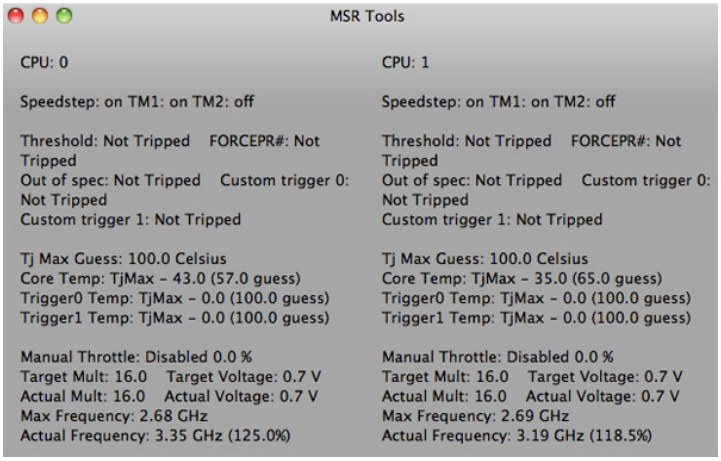


The 2011 13-inch MacBook Pro Motherboard

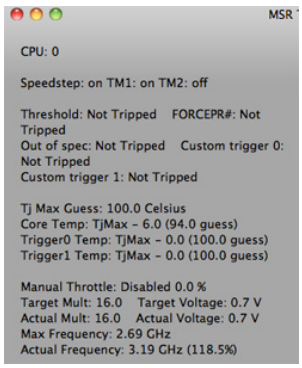
Apple 13-inch 2011 MacBook Pro CPU Comparison

	2.3GHz dual-core	2.7GHz dual-core
Intel Model	Core i5-2410M	Core i7-2620M
Base Clock Speed	2.3GHz	2.7GHz
Max SC Turbo	2.9GHz	3.4GHz
Max DC Turbo	2.6GHz	3.2GHz
GPU Base Clock Speed	650MHz	650MHz
GPU Max Turbo	1.2GHz	1.3GHz
L3 Cache	3MB	4MB
AES-NI	No	Yes
VT-x	Yes	Yes
VT-d	No	Yes
TDP	35W	35W

The primary differences between these two parts are clock speed, L3 cache size and AES-NI support once again. The 2.3GHz Core i5 lacks AES-NI, has a 3MB L3 cache and can only turbo up to 2.9GHz. The 2.7GHz Core i5 has AES-NI, a 4MB L3 cache and can turbo up as high as 3.4GHz.



I verified turbo frequencies on the 2.7GHz 13-inch. The highest I saw single core turbo hit was 3.4GHz, and dual core turbo was good for 3.2GHz. There's absolutely no funny business going on here, the dual-core 2.7 is allowed to hit its maximum frequencies.



You'll notice that the 2.7GHz DC chip has the same max single core turbo as the 2.3GHz QC chip from the upgraded 15-inch MacBook Pro. In practice

this means that for light workloads the upgraded 15 won't feel any faster than the 13 (or that the 13 will feel as fast as the 15 depending on how you look at it). I'm talking about things like web page load times and application launch/install times. There may even be a slight performance advantage for the 13-inch setup as it's able to turbo up to higher frequencies easier than the quad-core 15. Crank up the threads and you've got a different story entirely of course. There's no replacement for more cores on highly threaded workloads.

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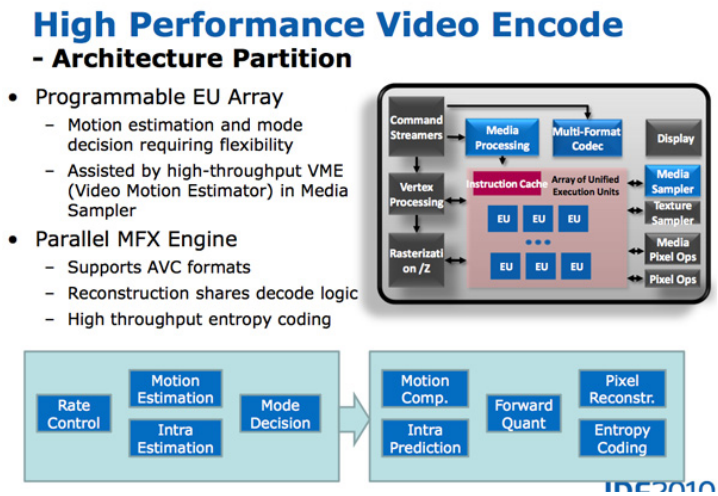
Mostly No QuickSync

One of the most significant features of Intel's Sandy Bridge CPU is Quick Sync, the hardware assisted video transcode engine. In our review we found it to be better than any of the currently available GPU based transcoding methods and far better than just running the transcode operation on your CPU. While Quick Sync's performance/quality in the pro space is unproven, there's simply no better way of taking your existing video content and transcoding it for use on mobile devices like an iPhone or an iPad.

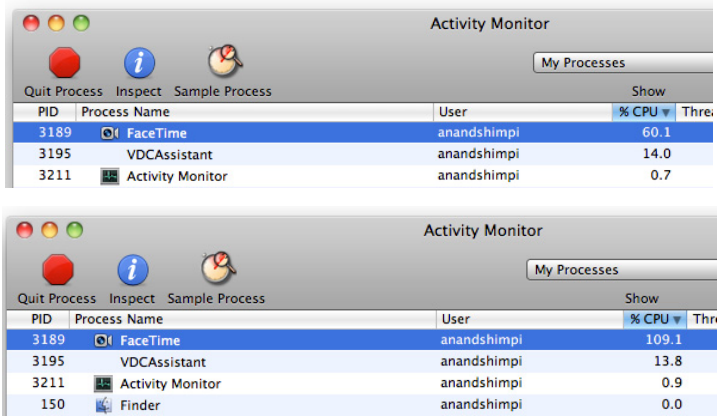


Given how well Quick Sync is suited for moving content between i-devices it's surprising that Apple doesn't tout it as a feature of the new 2011 MacBook Pros. Not only is Quick Sync not featured by Apple, it's not supported by any Apple application other than FaceTime.

That means iMovie and QuickTime rely on CPU based video encoding and not Quick Sync.

Apple has traditionally been very conservative with adopting new hardware features in software (ahem, TRIM). I'm worried that we may not see Quick Sync in iMovie until the 2012 version, however once the rest of the Mac lineup moves to Sandy Bridge maybe the incentive to introduce it sooner will be there.

Apple does claim support for Quick Sync in FaceTime however CPU utilization is still very high when using FaceTime HD:



Depending on available upstream bandwidth I saw between 50 and 100% CPU utilization of a single core while running FaceTime. According to Apple, FaceTime HD wasn't possible on a dual-core machine without the SNB video encoder. As to why we're seeing such high CPU utilization even with hardware accelerated encode and decode, your guess is as good as mine.

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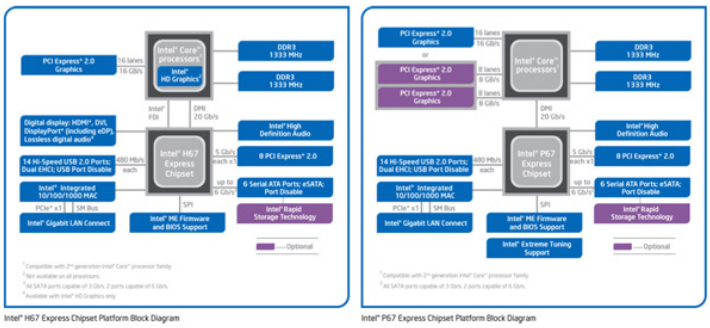
6Gbps SATA

Twenty eight days after Intel launched its Sandy Bridge microprocessors, it announced the stop-shipment of all 6-series Sandy Bridge chipsets. The first shipping version of these chipsets (B2 stepping) was affected by an unfortunate "oversight" that could cause failure in the four 3Gbps SATA ports that branch off the chipset. The remaining two 6Gbps SATA ports were unaffected by the bug.

Intel® 6 Series Chipset Block Diagrams

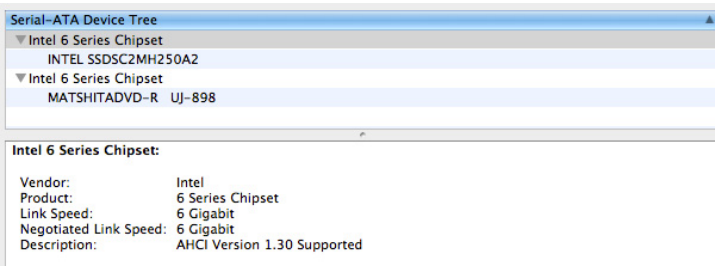


Most notebooks only use two of the six SATA ports supported by most members of Intel's 6-series chipset family. If a notebook design used the 6Gbps ports exclusively, the notebook would be fine to ship using the flawed B2 stepping parts. With the 3Gbps ports not in use the bug would never show up. Notebooks that used more than just two ports or used at least one of the 3Gbps ports would be affected and would have to be remanufactured with a fixed version of the 6-series chipset. Intel promised to begin shipping fixed (B3 stepping) 6-series chipsets by the end of February.

Apple announced and started selling the 2011 MacBook Pro lineup on February 24, four days before the end of the month. Surely that would be too soon for Apple's manufacturing partners to have received B3 stepping chipsets, built boards around them, integrated them into MacBook Pro designs and shipped them half way across the world to Apple stores all around the US.

Naturally Apple wouldn't comment on what chipset revision was in the 2011 MacBook Pro, so the first thing we did was check to see what SATA ports were in use on our systems.

Here we have the high end 15-inch MacBook Pro. I installed an Intel SSD 510 in the lone 2.5" drive bay and it is connected via a 6Gbps port internally:

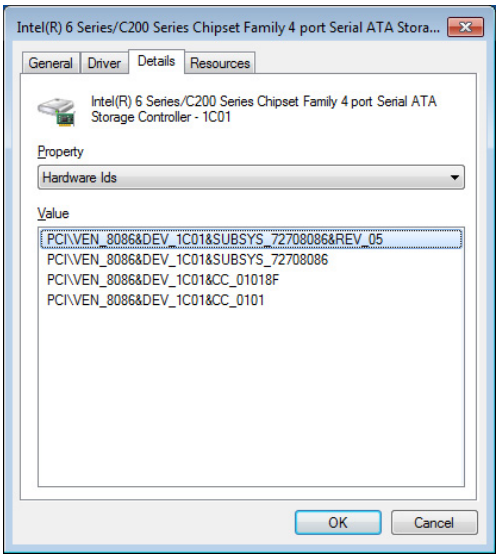


So far, so good. The only other bay in the new MacBook Pro is used for the optical drive. And it's connected to a:

...3Gbps SATA port. Uh-oh.

Apple doesn't directly report chipset IDs under OS X. I installed Windows 7 via Boot Camp and headed over to device manager to pull the device ID of the SATA controller: 1C01.

Cross referencing with Intel's datasheets I found that there are two revisions of the SATA controller: 04 and 05. The latter is used in the "fixed" B3 stepping chipsets. And what do we have here at the end of the hardware ID string for the SATA controller?



REV_05.

This is a B3 stepping chipset. In fact, Apple's manufacturing partners seem to have received B3 chipsets before anyone else given that boards were produced, tested and shipped in time for a February 24th launch. It would appear that Apple was among the first if not the first company to receive B3 stepping 6-series chipsets. Although I had concern for the health of the Apple/Intel relationship over the past couple of years, it looks like the two are back to being bedfellows.

Internally there are no visible changes to the MacBook Pro's primary SATA cable. It's still a flex cable but apparently capable of delivering twice the bandwidth of last year's model. Apple doesn't ship the new MacBook Pros with any 6Gbps drives and I would be surprised if it selected anything other than Samsung or Toshiba for SSDs, which means even the SSD options are 3Gbps. Luckily I happen to have a small cache of SSDs, including a bunch of new 6Gbps offerings.

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Apple's SSD Strategy

Despite the rumors, the 2011 MacBook Pro lineup does nothing to change the storage setup of the machine. All of the models have a single 2.5" 5400RPM hard drive and an integrated slot-load DVD drive.

I personally don't mind the lack of hard drive options. While 5400RPM is pretty slow, any additional money you spend on storage should go towards an SSD and not a faster mechanical drive. If you need the additional capacity there's always the optibay route, which replaces the optical drive with another 2.5" HDD bay. Other than installing Mac OS X, I pretty much never use the optical drive so the optibay approach in my opinion is a good combination of the performance of an SSD with the mass storage of a mechanical disk.

Apple offers an array of BTO (Build to Order) SSD options, however the drives are likely of average performance. Pricing actually isn't bad for the upgraded 13-inch and especially the upgraded 15-inch models. At $100 for a 128GB drive you really can't beat the upgrade price there. We're probably only one more generation away from seeing a standard SSD on some of these models.

Apple SSD Upgrade Pricing		
128GB	256GB	512GB

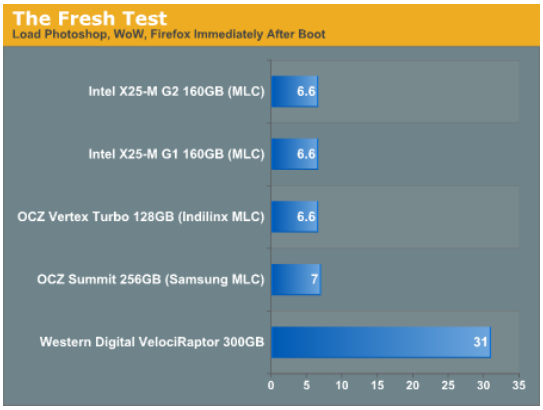
13-inch 2011 MacBook Pro	$250	$650	$1250
13-inch 2011 MacBook Pro (high end)	$200	$600	$1200
15-inch 2011 MacBook Pro	$200	$600	$1200
15-inch 2011 MacBook Pro (high end)	$100	$500	$1100
17-inch 2011 MacBook Pro	$100	$500	$1100

In the MacBook Air Apple standardized on a Toshiba controller, delivering performance nearly identical to Kingston's SSDNow V+100. I wouldn't be surprised if Apple used the same controller in the new MacBook Pros. The SSDs are still 3Gbps and will be a huge improvement over the standard hard drive, but just know that you aren't getting the best performance possible. In exchange for the price premium, what you do get is a drive that Apple will support completely (and also official TRIM support, no 3rd party drives have TRIM support under OS X). In the past Apple has had serious compatibility issues with 3rd party SSDs, so there is some merit to the BTO SSD option.

This isn't Mac specific advice, but if you've got a modern Mac notebook I'd highly recommend upgrading to an SSD before you even consider the new MacBook Pro. I've said this countless times in the past but an SSD is the single best upgrade you can do to your computer.

To be honest the new MacBook Pros feel slow to me right out of the box. The issue is that once you have a few applications installed and start multitasking with a notebook that only has a 5400RPM hard drive application response time stops being consistent.

It seems like the more you have installed, the greater the chances are of there being small file random reads/writes going on in the background while you're trying to do other things on your computer. These aren't huge IO operations, but since we're dealing with mechanical storage they significantly reduce the throughput of other IO requests. For example, opening an image in Photoshop will take longer if the sequential read operation is constantly interrupted by several other reads spread out over the platters. The same is true for launching an application. Application launch speed is one area where an SSD really shines. The process of launching an application involves a lot of sequential and seemingly random reads (they aren't totally random but they aren't totally sequential either). On a hard drive the seemingly random operations aren't fast to begin with, but interrupt them with any other IO requests that may be happening in the background (saving files, backing up a disk, launching another application, etc...) and the application you're trying to launch will take significantly longer. In my older SSD articles I called this the "fresh test". When you first get a new computer everything responds quickly and applications just fly open. After a few weeks/months/years the performance stops being so fresh and instead everything seems to take forever. The graph below is one I've used in the past, it simply shoes the performance benefit realized from switching to an SSD when trying to launch a few applications in parallel:



The improvement is staggering. Generally speaking application launch time isn't really impacted by which SSD you get. In my experience pretty much all of the current crop of SSDs on the market will launch single (or even multiple) applications in about the same time. What really separates one SSD from the next are three things:

1) Reliability
2) Performance in periods of unusually heavy IO activity
3) Performance over time

The first one is really difficult to quantify. Reliability is the one area where going with a larger manufacturer typically helps. Intel, Samsung, Toshiba, all of these controller makers sell in large quantities to OEM systems and have significant experience in testing and validation. Reliability is also an area where I would say the Apple SSDs are probably going to be a good bet. They may not be the fastest, but Apple has likely tested them and is comfortable that they will at least work problem-free for a while. Apple also apparently does some firmware tuning of its own to make its SSDs play a bit nicer with OS X.

The second vector of differentiation is worst case (or best case depending on how you look at it) performance under load. This isn't just launching a single application, or even loading multiple, but it's how the drive performs when you're doing a lot at once. Perhaps you're running a backup, installing an application, opening a document, loading a web page, downloading a movie, downloading emails and trying to open another application all at once. In these sorts of situations you will notice a difference between SSD performance.

Performance over time is another important factor to consider. Building a good SSD controller really boils down to knowing how to manage data written to the drive's NAND. To measure performance over time we're really looking at quantifying write amplification and measuring how effective TRIM is at restoring performance.

I try to tackle as much of these items in our SSD reviews as possible, and we're constantly evolving so expect to see even more depth here going forward.

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6Gbps Performance

I installed the Intel SSD 510 in a 15-inch 2011 MacBook Pro as well as a 15-inch 2010 MacBook Pro to put together a 3Gbps vs. 6Gbps performance comparison. I turned to Xbench for some quick and dirty performance data:

	SATA Performance—XBench 1.3		
Intel SSD 510 250GB	**3Gbps (2010 15-inch MBP)**	**6Gbps (2011 15-inch MBP)**	**6Gbps Advantage**
4KB Sequential Write	157.8 MB/s	192.2 MB/s	**+21.8%**
256KB Sequential Write	182.0 MB/s	257.1 MB/s	**+41.3%**
4KB Sequential Read	32.5 MB/s	32.7 MB/s	0.0%
256KB Sequential Read	197.3 MB/s	315.6 MB/s	**+60.0%**
4KB Random Write	47.8 MB/s	49.0 MB/s	+2.5%
256KB Random Write	186.4 MB/s	260.9 MB/s	**+40.0%**
4KB Random Read	14.5 MB/s	13.4 MB/s	-7.6%
256KB Random Read	149.7 MB/s	207.3 MB/s	**+38.5%**

As you'd expect, there's no real benefit to the new 6Gbps interface for random operations (particularly at low queue depths). Sequential speeds are much improved however. Xbench shows up to a 60% increase in performance in sequential operations.

You'll note that the absolute numbers are pretty low to begin with. A 128KB sequential read of the Intel SSD 510 on our desktop Sandy Bridge SSD testbed pulls nearly 400MB/s. On the new MacBook Pro we can't get more than 320MB/s.

Our sequential Iometer tests are run at a queue depth of 1 so there's no advantage there. The only explanation I can come up with (assuming Xbench's test is accurate) is that Apple may be aggressively implementing SATA controller power management under OS X. Capping the link's performance or aggressively putting it to sleep could reduce performance at the benefit of increasing battery life.

The other thing I noticed was that performance on the 13-inch MBP using Xbench was a bit lower than the 15-inch MBP. Take a look at these numbers:

	SATA Performance—XBench 1.3	
Intel SSD 510 250GB	**13-inch 2011 MBP**	**15-inch 2011 MBP**
4KB Sequential Write	155.3 MB/s	192.2 MB/s
256KB Sequential Write	184.8 MB/s	257.1 MB/s
4KB Sequential Read	30.4 MB/s	32.7 MB/s
256KB Sequential Read	201.8 MB/s	315.6 MB/s
4KB Random Write	49.6 MB/s	49.0 MB/s
256KB Random Write	183.9 MB/s	260.9 MB/s
4KB Random Read	13.9 MB/s	13.4 MB/s
256KB Random Read	144.9 MB/s	207.3 MB/s

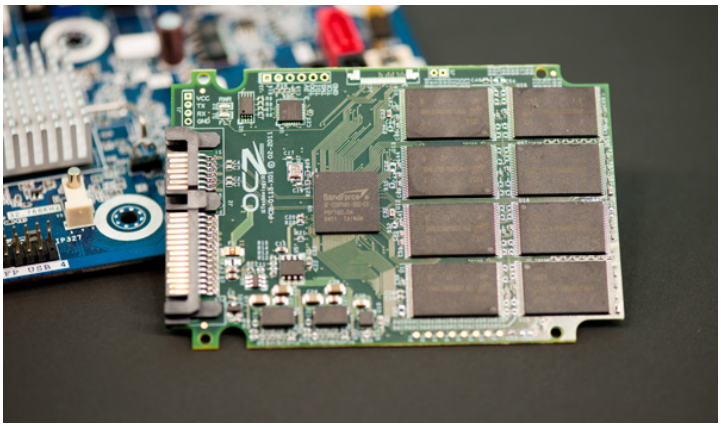
I only noticed this with the Intel SSD 510, the Crucial RealSSD C300 and Vertex 3 both performed identically between the 13 and 15-inch MBPs. I'm not sure what's going on here at all, although I suspect that it's somehow related to the issues users have been having with some of these drives (more on this below).

SSD Recommendations

Where does all of this discussion about SSDs leave us? Unfortunately recommending an SSD for the new MacBook Pro today is pretty difficult but I'll try my best.

If you're the conservative type and just wants something that for sure works with little to no concern about absolute performance, the Apple SSDs are probably the safest bet. You'll get a drive that's much faster than a hard drive, fully supported by Apple and with TRIM support. Yes, that's right, OS X finally has TRIM support but Apple only enables it on it's own branded SSDs. To Apple's credit, given the number of problems I've seen with SSDs over the past couple of years it makes sense to lock down and only support drives you've validated. On the flip side however, Apple should be validating and working with controller makers to ensure all drives work under OS X. Making as much money as Apple does, I don't buy the "we didn't have the time/resources" argument.

If you are going down the Apple SSD path, at least the 128GB drive isn't super ridiculously priced, although I'm less comfortable recommending the 256GB version unless you can get it at $500.



Now if you want to get a faster SSD or actually take advantage of the 6Gbps interface, things get more complicated. I've heard reports of users having issues with the Intel SSD 510 and Crucial RealSSD C300. I've tested both drives as well as the OCZ Vertex 3 in three different MacBook Pros, and in all cases the drives worked perfectly. They were all detected as 6Gbps drives and all performed well. I should note that while I couldn't get the Vertex 3 Pro to work in the 2010 MacBook Pro, the Vertex 3 worked just fine in the 2011 MacBook Pro.

	SATA Performance—XBench 1.3		
13-inch 2011 MBP	**Crucial C300 256GB**	**Intel SSD 510 250GB**	**OCZ Vertex 3 240GB**
4KB Sequential Write	239.0 MB/s	155.3 MB/s	**319.9 MB/s**
256KB Sequential Write	217.2 MB/s	184.8 MB/s	**257.8 MB/s**
4KB Sequential Read	**35.1 MB/s**	30.4 MB/s	33.3 MB/s
256KB Sequential Read	248.3 MB/s	201.8 MB/s	**311.8 MB/s**
4KB Random Write	175.0 MB/s	49.6 MB/s	**247.8 MB/s**
256KB Random Write	226.6 MB/s	183.9 MB/s	**290.0 MB/s**
4KB Random Read	19.1 MB/s	13.9 MB/s	**21.1 MB/s**
256KB Random Read	239.0 MB/s	144.9 MB/s	**304.0 MB/s**

	SATA Performance—XBench 1.3		
15-inch 2011 MBP	**Crucial C300 256GB**	**Intel SSD 510 250GB**	**OCZ Vertex 3 240GB**
4KB Sequential Write	239.3 MB/s	192.2 MB/s	**316.5 MB/s**
256KB Sequential Write	218.8 MB/s	257.1 MB/s	**282.0 MB/s**
4KB Sequential Read	34.8 MB/s	32.7 MB/s	34.2 MB/s
256KB Sequential Read	245.1 MB/s	315.6 MB/s	**306.7 MB/s**
4KB Random Write	160.5 MB/s	49.0 MB/s	**240.5 MB/s**
256KB Random Write	227.5 MB/s	260.9 MB/s	**311.3 MB/s**
4KB Random Read	18.7 MB/s	13.4 MB/s	**20.9 MB/s**
256KB Random Read	238.2 MB/s	207.3 MB/s	**303 MB/s**

The Vertex 3 is the fastest drive out of the aforementioned three, but its availability and firmware maturity are both unknowns at this point. If you have to buy today and are ok with the chance that the drive may not work (given other experiences online, although I haven't seen problems), Intel's SSD 510 is likely a good runner up (at least for the 15-inch, the C300 seems to perform better on the 13).

As far as the reports of incompatibilities with these drives are concerned, I'm not really sure what's going on. I've been hammering on all of the drives, putting the system to sleep/waking it up, and haven't encountered any failures or high latency IO operations (stuttering) yet. That's not to say that these problems won't appear over time (I'm currently doing long term testing to figure that out now), but just that I haven't seen them yet.

If you are having issues with the Intel SSD 510, Crucial RealSSD C300 or anything else please email me (link at the top of the page) the following information:

1) What are the full specs of your MBP? Any upgrades?

2) Tell me about your SSD. Is it new out of box? Have you done anything to the drive? What model, firmware revision, etc...

3) Describe the symptoms of the issue—beachballs, data corruption, etc...? What do you have to do create the issue?

4) Is the drive detected as a 6Gbps drive or a 3Gbps drive?

5) Take me through your drive installation procedure, did you just pop it in, partition and install OS X?

6) Any visible damage to the SATA flex cable when you installed the drive?

7) Have you tried exchanging the SSD or MBP? Any difference in behavior?

We haven't seen any issues on three different 2011 models that we've been testing here extensively with the Intel SSD 510, Crucial RealSSD C300, OCZ Vertex 3 and OCZ Vertex 2. I realize a number of you are having issues so the more details I can get the better.

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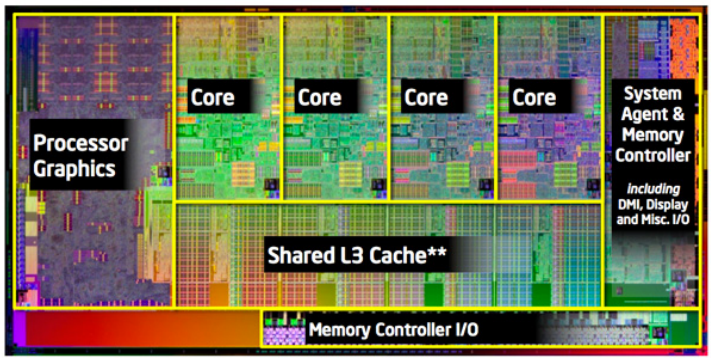
The GPU Comparison

If you had asked me last year I would've told you that Apple clearly values GPU performance more than CPU performance—and I wouldn't be far off the mark. Apple went to great lengths to use the best of the entry level GPUs and paid no mind to the fact that the 13-inch MacBook Pro, Mac mini and

MacBook Air all used much older Core 2 Duo CPUs while the competition was busy shipping Core i3/5/7s.

This year is the year of the CPU however. The entire MacBook Pro lineup gets Sandy Bridge CPUs and as a result they all get Intel's new HD Graphics 3000. Here's a die shot of Sandy Bridge:



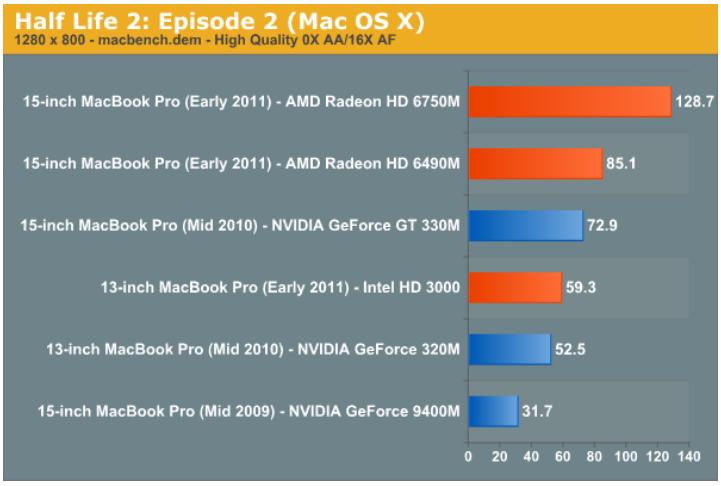
Note that the GPU core is integrated on-die. There are actually two versions of Intel's HD Graphics available on Sandy Bridge, but all current mobile versions of SNB come with the 3000 model. What does the 3000 offer you? Twelve scalar execution units (EUs) running at a base clock speed of 650MHz. The GPU can also turbo up depending on available TDP. The max frequency is somewhere between 1.2—1.3GHz depending on the processor SKU.

Being basically desktop replacements, the 15-inch and 17-inch MacBook Pros also include a discrete GPU. This round they both use AMD hardware and the options are below:

	Discrete GPU Options	
	AMD Radeon HD 6490M	**AMD Radeon HD 6750M**
Manufacturing Process	40nm	40nm
SPs	160	480
Texture Units	8	24
ROPs	4	8
Core Clock	800MHz	600MHz
Memory Bus Width	64-bit	128-bit
Memory Clock	800MHz	900MHz
Frame Buffer	256MB GDDR5	1024MB GDDR5

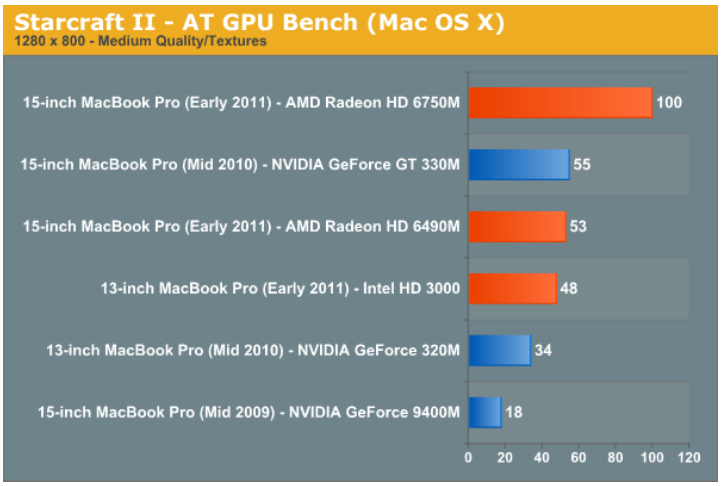
The entry level 15 uses a Radeon HD 6490M while the upgraded 15 and the 17 both use a Radeon HD 6750M. The difference between the two GPUs amounts to compute horsepower, memory bandwidth and available frame buffer. With only a 256MB frame buffer the 6490M is insufficient for high performance at larger resolutions (courtesy of an external display). The 6750M is paired with 1GB of GDDR5 and thus has no problems smoothly driving a 27-inch 2560 x 1440 panel. The new GPUs now only use a x8 connection to the SNB CPU compared to the x16 from last year's models. Remember Sandy Bridge has a x16 PCIe controller on-die. The controller can be split into two x8s or 1 x8 and 2 x4. In this case one of the x4 ports is used for Thunderbolt, leaving 4 unused lanes and a x8 for the GPU. I don't expect this move will have a noticeable impact on GPU performance.

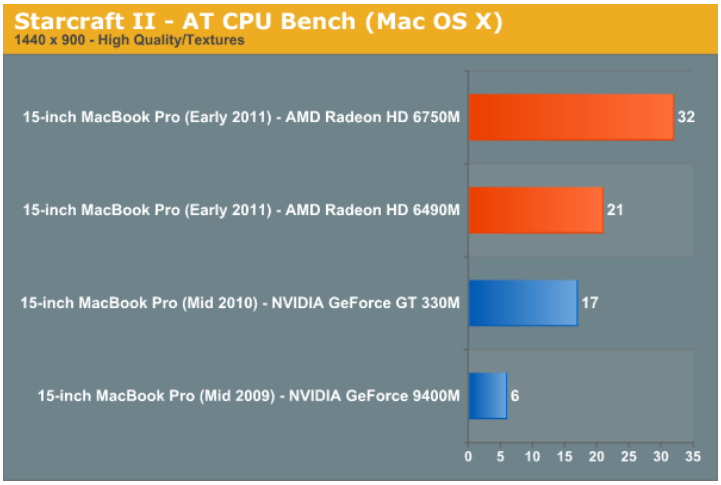
The 13-inch MacBook Pro has absolutely no GPU options, all you get is the on-die Intel HD Graphics 3000. Based on what we saw in our original mobile Sandy Bridge review this should mean that GPU performance between the two stays the same. Intel's HD Graphics 3000 is about the performance of a GeForce 320M, the latter is what was used in last year's 13-inch MBP.



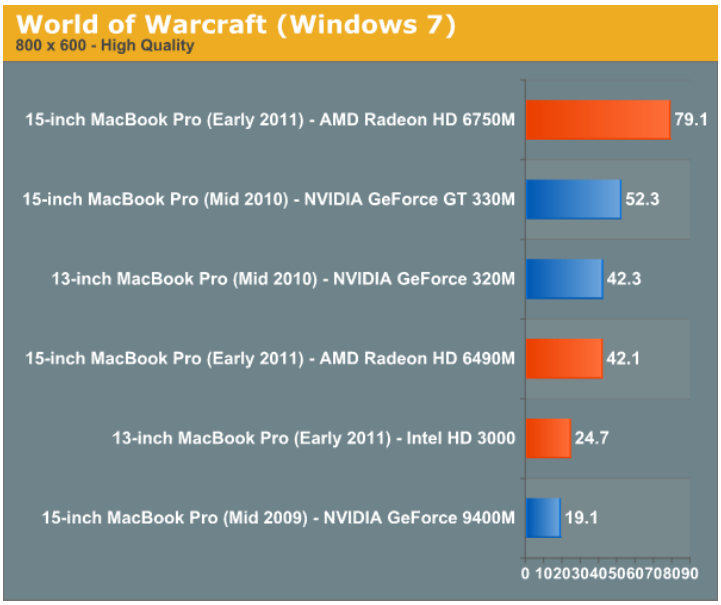
For Starcraft II performance we brought over our two benchmarks from our PC CPU and GPU reviews. We don't have FRAPS availalble under OS X so we resort to measuring lowest instantaneous frame rate at a couple of points.

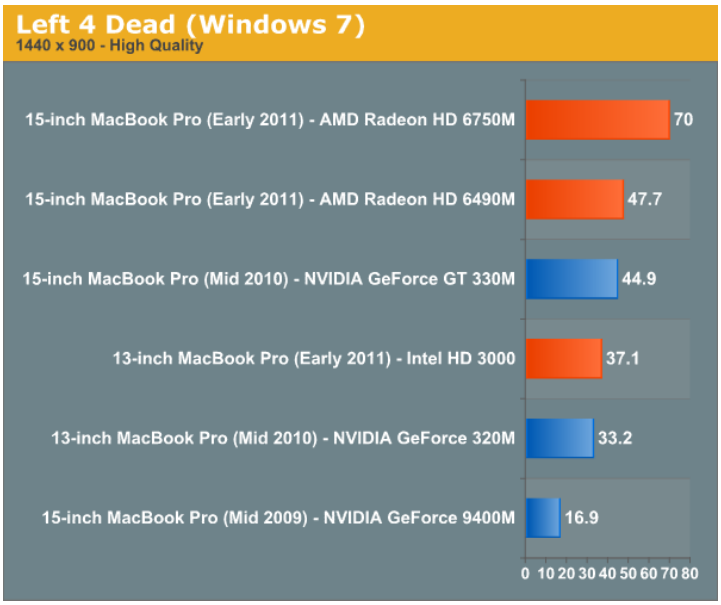
The two tests focus on different aspects of SC2 gameplay. The GPU test looks at general unit management performance, which tends to be less CPU bound and more GPU bound. The CPU test looks at performance during a very large battle which, as you might guess, is largely influenced by CPU performance.



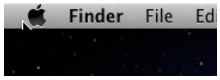


Under OS X, the new HD Graphics 3000 GPU is actually about the same performance or even faster than the 2010 13-inch's GeForce 320M. Remember that Apple does a lot of its own driver writing under OS X and the SNB GPU received some TLC from Apple in the form of very well optimized drivers.





Under Windows running WoW the situation is quite different and I'm not entirely sure why. Either Apple is very aggressive with driver optimizations under OS X or there's some other funniness happening under Windows (more on this later).

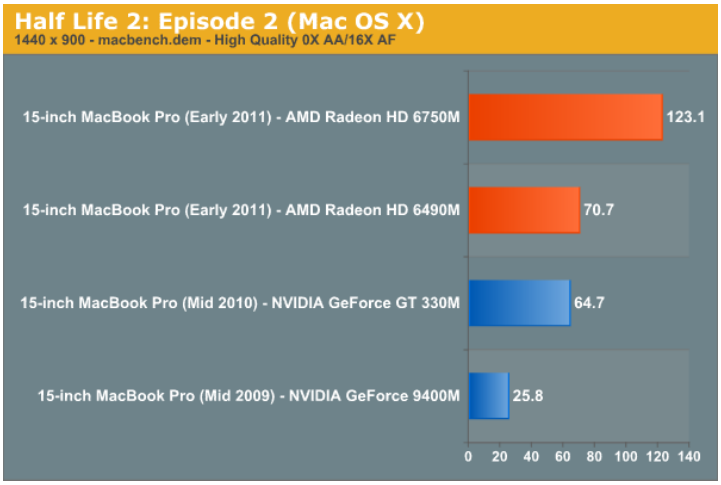


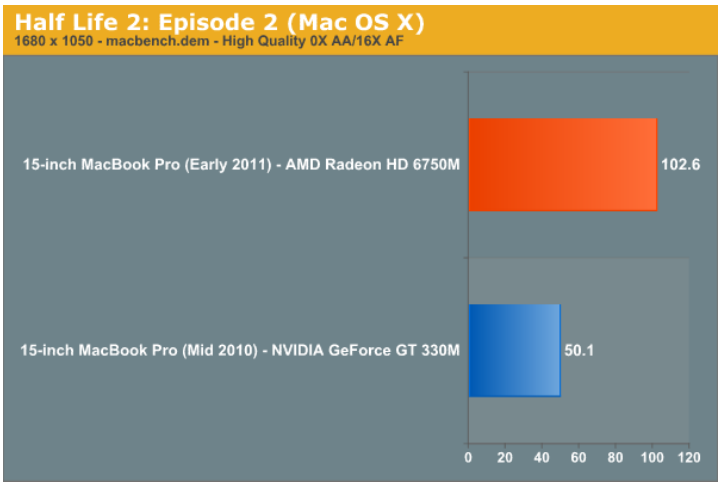
I did notice some bouts of instability with the 13-inch MacBook Pro as well as minor graphical corruption on the screen. Early on whenever I'd boot the system up I'd get a copy of the mouse cursor in the upper left of the screen.

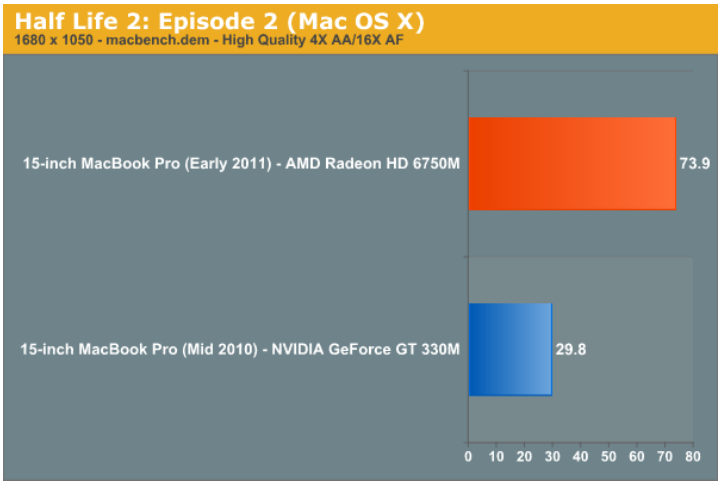
15-inch MacBook Pro GPU Performance

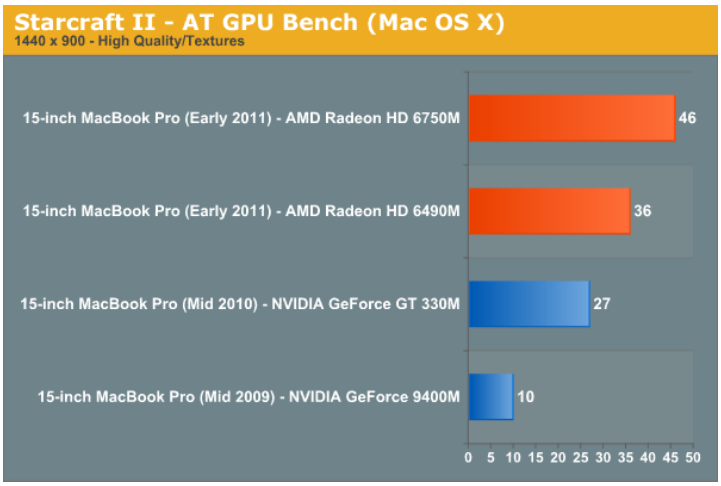
Next up is the 15-inch MBP gaming performance comparison.

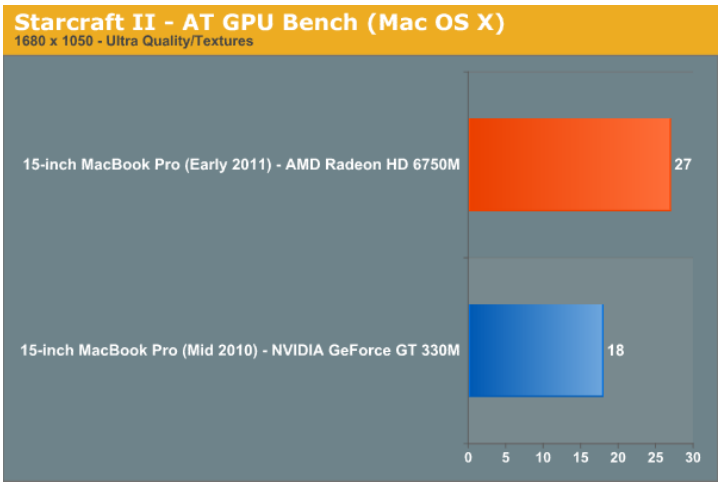
For 15-inch users the Radeon HD 6490M is pretty much the same speed as last year's GeForce GT 330M (if not marginally faster). The Radeon HD 6750M however is a lot faster. In fact, the performance improvement and increase in frame buffer you get with the 6750M is well worth the upgrade. If you're buying a 15-inch MacBook Pro and plan on gaming or using a high-res external display, get the 6750M.

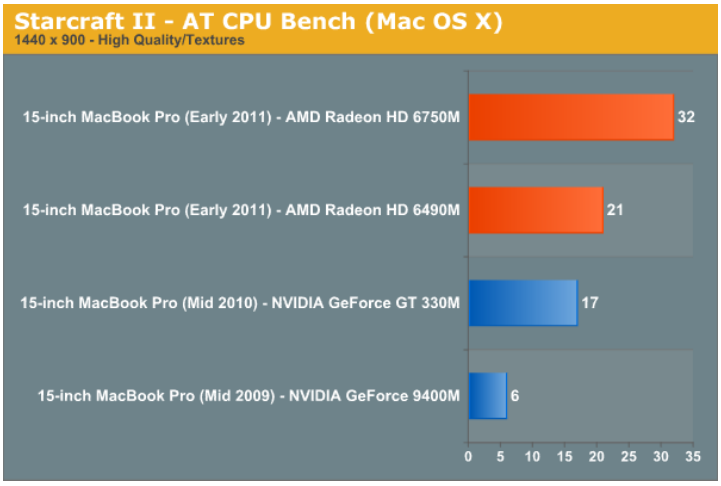


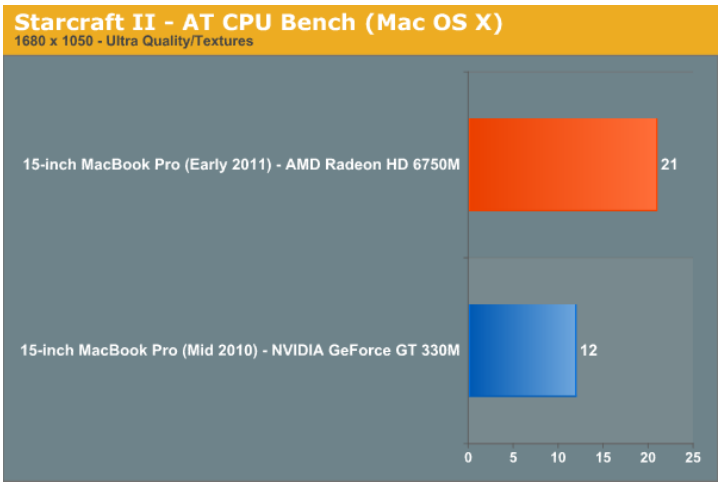

Half Life 2: Episode 2 (Mac OS X)
1680 x 1050 - macbench.dem - High Quality 0X AA/16X AF
15-inch MacBook Pro (Early 2011) - AMD Radeon HD 6750M
102.6
15-inch MacBook Pro (Mid 2010) - NVIDIA GeForce GT 330M
50.1
0 20 40 60 80 100 120


Half Life 2: Episode 2 (Mac OS X)
1680 x 1050 - macbench.dem - High Quality 4X AA/16X AF
15-inch MacBook Pro (Early 2011) - AMD Radeon HD 6750M
73.9
15-inch MacBook Pro (Mid 2010) - NVIDIA GeForce GT 330M
29.8
0 10 20 30 40 50 60 70 80


Starcraft II - AT GPU Bench (Mac OS X)
1440 x 900 - High Quality/Textures
15-inch MacBook Pro (Early 2011) - AMD Radeon HD 6750M
46
15-inch MacBook Pro (Early 2011) - AMD Radeon HD 6490M
36
15-inch MacBook Pro (Mid 2010) - NVIDIA GeForce GT 330M
27
15-inch MacBook Pro (Mid 2009) - NVIDIA GeForce 9400M
10
0 5 10 15 20 25 30 35 40 45 50







Page 9

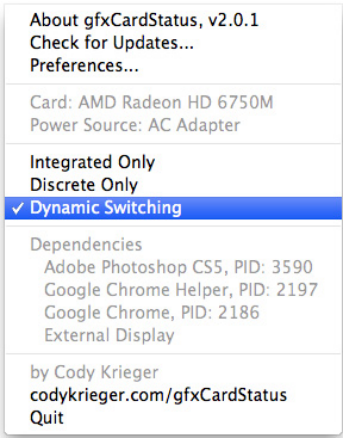
The dGPU: Killing Battery Life

The 15 and 17-inch MacBook Pros have a discrete GPU that only turns on if you fire up an application that really needs it—at least that's how it is supposed to work. In practice, the discrete GPU takes over control if your application uses any one of a number of frameworks—and some of the time, the dGPU simply isn't necessary.

Case in point, launching Chrome won't trigger a dGPU switch but the moment it encounters Flash the discrete GPU will take over. The bad news is that even if you close all Chrome windows, the dGPU won't power down until you quit chrome entirely. The same is true for Photoshop. Launch the application and you're still on the iGPU. Actually open up an image and the dGPU takes over. Even if you close all open images and just leave the Photoshop application open, the dGPU won't relinquish control. FaceTime and anything using the integrated camera also require the dGPU, despite it being totally unnecessary.

If you connect any external display to the 15 or 17-inch MacBook Pro that also forces the dGPU on, at which point both the integrated panel and external display are driven by the dGPU. There is no funny frame buffer copying going on, both the integrated and discrete GPUs have their own connection to the

display.



Apple also fails to provide a way of turning off the dGPU by default—the best you can do is shut off the iGPU and just use the dGPU entirely. Thankfully Cody Krieger's gfxCardStatus tool gives us exactly what OS X does not. Version 2.0.1 adds support for the 2011 MacBook Pros.

I'm going on and on about the dGPU because it's state can seriously impact battery life. The numbers below should help put that in perspective for you:

Impact of Discrete GPU on Battery Life		
15-inch 2011 MacBook Pro	**Light Web Browsing**	**Flash Web Browsing**
Integrated GPU (Intel HD 3000)	8.85 hours	7.03 hours
Discrete GPU (AMD Radeon HD 6750M)	5.67 hours	2.97 hours

Even just browsing the web, the dGPU being on drops battery life by 35—60%. Under full CPU load I suspect the percentage difference would be smaller, but still significant. The worst part of this all is that without gfxCardStatus you can negatively impact battery life by doing something completely innocent like accidentally leaving an application open. Given how much OS X is tailored to simply closing windows when you're done with them and not quitting applications, an overly aggressive dGPU can really be an issue.

Thankfully we do have gfxCardStatus but there's honestly no reason Apple shouldn't include this functionality with OS X from the start.

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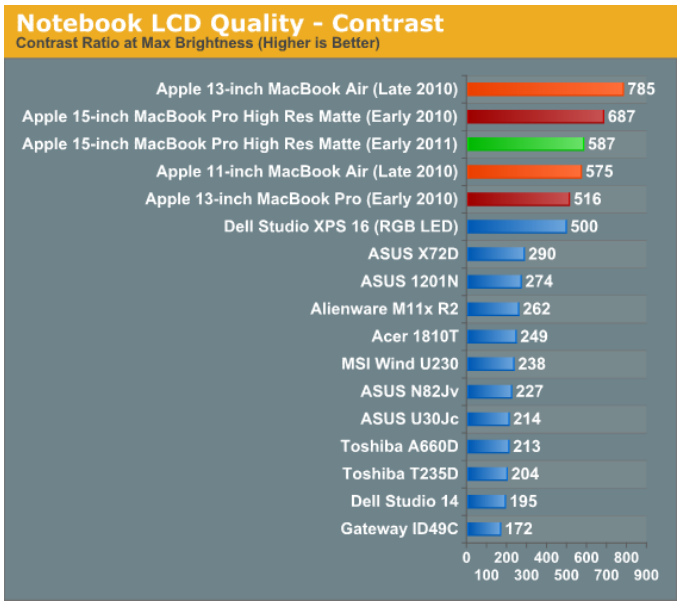
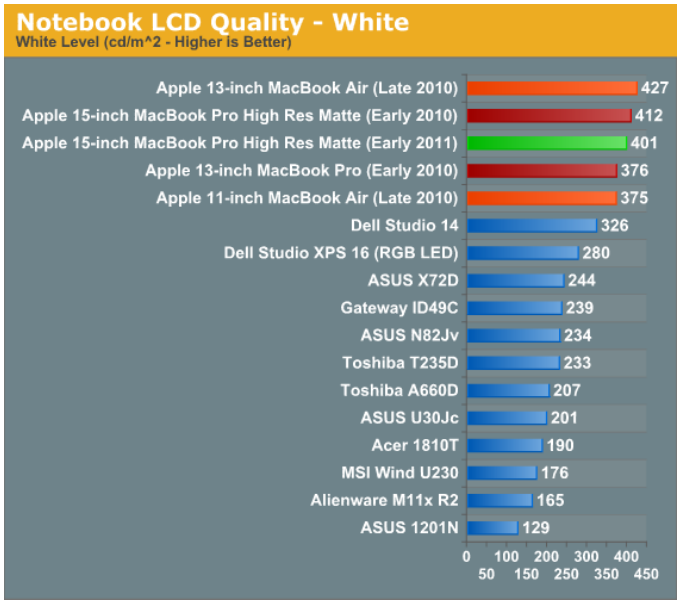
Display Quality

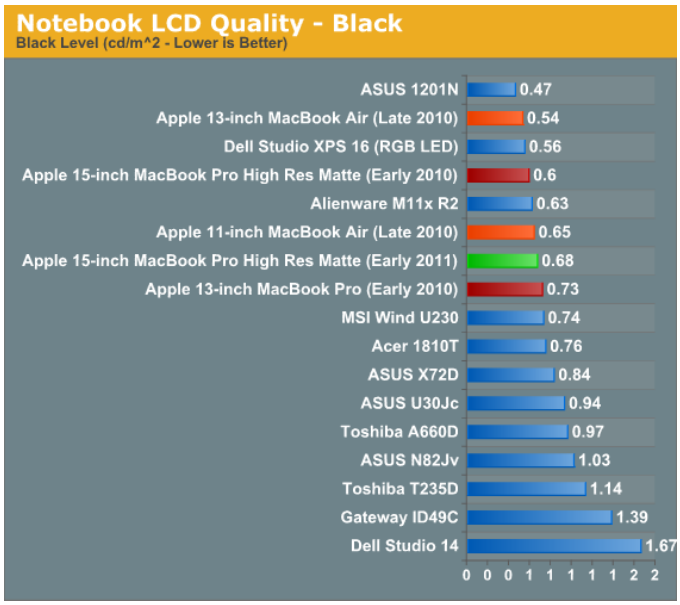
We analyzed the 15" antiglare display on the new MacBook Pro since in all likelihood if you care about display quality you'll opt for the high res or high res antiglare option. Before even starting to analyze display quality, I pulled the panel model out of EDID and wasn't surprised to see the same LTN154MT07 Samsung panel in the new 15" MBP as we did in the previous generation. It's literally the exact same. It's not surprising in the least that Apple is using the same panel; there wasn't anything wrong with the old one.

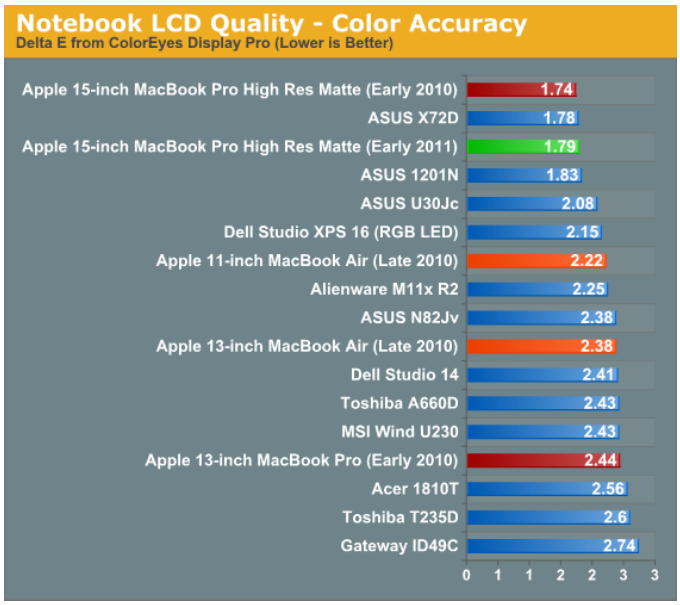
13-inch Glossy MBP (back) vs. 15-inch MBP with optional anti-glare screen (front)

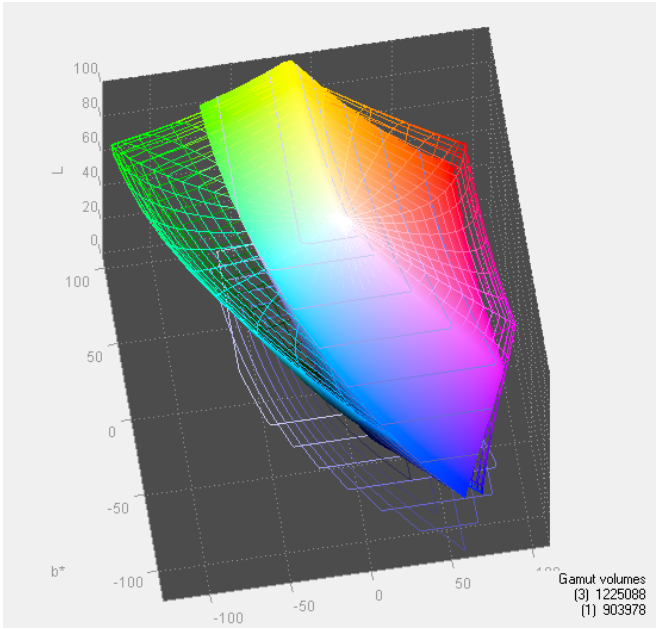
We calibrated using the i1D2 and ColorEyes Display Pro same as we did before, then check with the GMB color checker card colors and get Delta E. There's shockingly little to say about it that we haven't said before. It's the same as the previous one, and unsurprisingly the data backs that conclusion up very well. Apple also seems to ship an ICC profile for each specific panel type with LUT curves already, which actually put the display close to where it should be. It's a TN and likewise still has the same mediocre vertical viewing angles as virtually every TN.

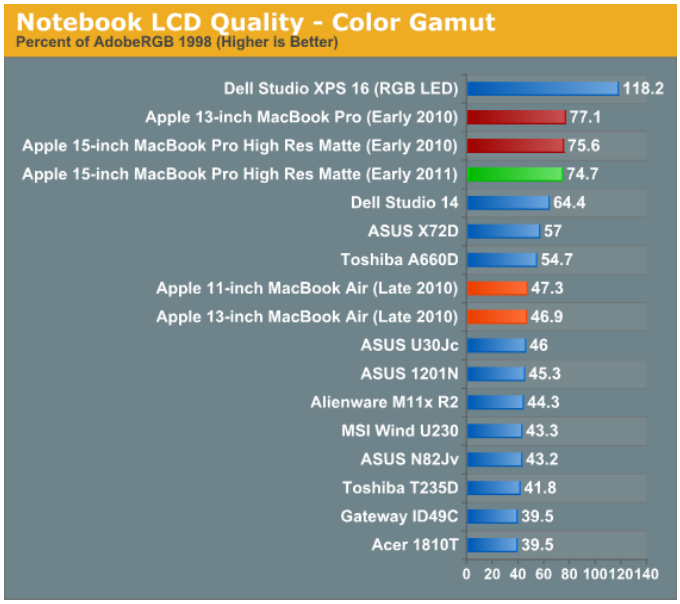

Notebook LCD Quality - Contrast
Contrast Ratio at Max Brightness (Higher is Better)
Apple 13-inch MacBook Air (Late 2010) 785
Apple 15-inch MacBook Pro High Res Matte (Early 2010) 687
Apple 15-inch MacBook Pro High Res Matte (Early 2011) 587
Apple 11-inch MacBook Air (Late 2010) 575
Apple 13-inch MacBook Pro (Early 2010) 516
Dell Studio XPS 16 (RGB LED) 500
ASUS X72D 290
ASUS 1201N 274
Alienware M11x R2 262
Acer 1810T 249
MSI Wind U230 238
ASUS N82Jv 227
ASUS U30Jc 214
Toshiba A660D 213
Toshiba T235D 204
Dell Studio 14 195
Gateway ID49C 172
0 100 200 300 400 500 600 700 800 900


Notebook LCD Quality - White
White Level (cd/m^2 - Higher is Better)
Apple 13-inch MacBook Air (Late 2010) 427
Apple 15-inch MacBook Pro High Res Matte (Early 2010) 412
Apple 15-inch MacBook Pro High Res Matte (Early 2011) 401
Apple 13-inch MacBook Pro (Early 2010) 376
Apple 11-inch MacBook Air (Late 2010) 375
Dell Studio 14 326
Dell Studio XPS 16 (RGB LED) 280
ASUS X72D 244
Gateway ID49C 239
ASUS N82Jv 234
Toshiba T235D 233
Toshiba A660D 207
ASUS U30Jc 201
Acer 1810T 190
MSI Wind U230 176
Alienware M11x R2 165
ASUS 1201N 129
0 50 100 150 200 250 300 350 400 450


Notebook LCD Quality - Black
Black Level (cd/m^2 - Lower is Better)
ASUS 1201N 0.47
Apple 13-inch MacBook Air (Late 2010) 0.54
Dell Studio XPS 16 (RGB LED) 0.56
Apple 15-inch MacBook Pro High Res Matte (Early 2010) 0.6
Alienware M11x R2 0.63
Apple 11-inch MacBook Air (Late 2010) 0.65
Apple 15-inch MacBook Pro High Res Matte (Early 2011) 0.68
Apple 13-inch MacBook Pro (Early 2010) 0.73
MSI Wind U230 0.74
Acer 1810T 0.76
ASUS X72D 0.84
ASUS U30Jc 0.94
Toshiba A660D 0.97
ASUS N82Jv 1.03
Toshiba T235D 1.14
Gateway ID49C 1.39
Dell Studio 14 1.67
0 0 0 1 1 1 1 1 2 2







It's a bit disappointing that Apple didn't take the opportunity to dramatically improve displays on the MBPs this time around. While everyone was

speculating about what display the iPad 2 would get, there was very little discussion about how the Mac side of things needs higher resolution to even get close to being able to display 1:1. Hopefully higher resolution notebook displays are somewhere on the horizon.

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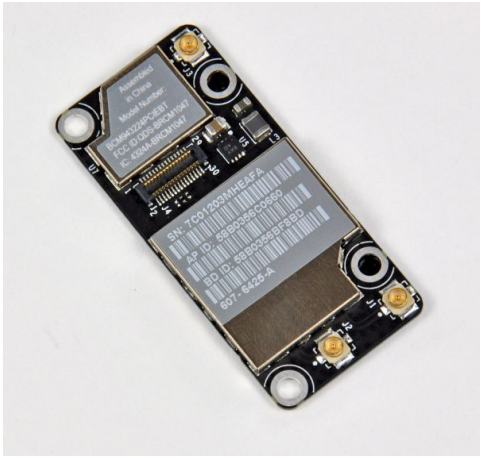
Improved WiFi Performance

One of the more notable changes in the 2011 MacBook Pro lineup is a completely different WiFi chipset and subsequent RF design. The previous 2010 MacBook Pro included 802.11a/b/g/n support using a BCM4322 which included full 2x2 MIMO support, meaning two spatial streams were supported. Bluetooth 3.0 was provided by a BCM2070, and the whole solution was simply a BCM954224HMB reference design.



2011 MacBook Pro WiFi+BT Module—Courtesy iFixit

Back when the new Airport Extreme (Simultaneous Dual-Band II) launched, it included one little-hyped feature. One of the most notable improvements over the previous design was inclusion of a full 3x3 radio—again 3 spatial stream support. At the time, there were no Apple products that could actually use 3 spatial streams, and as a result many assumed the feature was completely locked down.

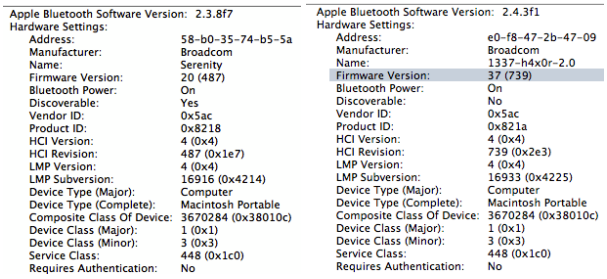
My wall-mounted Airport Extreme (Simultaneous Dual-Band II)

The Airport Extreme has had this feature for a long time to little fanfare. The Airport Extreme oddly still only allows 20 MHz channels on 2.4 GHz spectrum, a carryover from when 802.11n was in its infancy, and everyone was worried about being a good neighbor. Since those days, virtually everyone has allowed 40 MHz channels on 2.4 GHz but Apple. It's an artificially imposed limitation that exists purely to prevent you from being, well, less than courteous and eating up over 80% of spectrum on the already crowded 2.4 GHz ISM band with one AP. Thankfully, 40 MHz support exists (as it should) on 5 GHz.

2011 MacBook Pro WiFi+BT Module—Courtesy iFixit

The 2011 MacBook Pro refresh is the first line of Apple products to bring 3x3 radios that can finally enable faster transfer rates and better performance at the edge of WiFi range. 3x3 MIMO support is starting to become relatively common in the PC notebook space, but this is the first for Apple. Inside the 2011 MacBook Pro is a BCM4331 and three clearly U.FL antenna connectors (on the left) for WiFi, as opposed to two in the previous design.

The fourth on the right is for Bluetooth, which remains 3.0 and provided by the same BCM2070 as previous models. Interestingly enough, though the Bluetooth controller is the same, the 2011 MacBook Pro includes newer firmware (37 vs 20), and software (2.4.3f1 vs 2.3.8f7). Hopefully at some point the older design will see a firmware update and bring whatever changes and improvements were made. Though the software versions are different, we couldn't detect any notable differences between the two in practice.

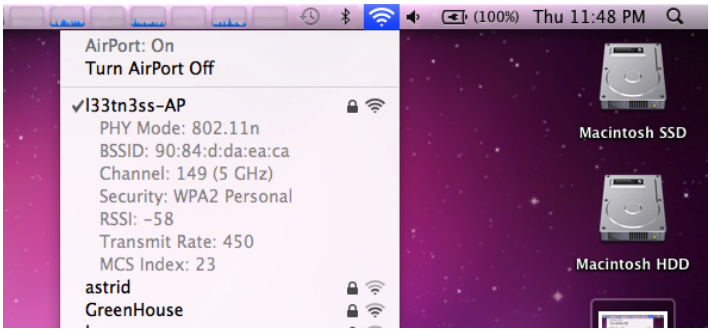


Apple Bluetooth Software Version:	2.3.8f7
Hardware Settings:	
Address:	58-b0-35-74-b5-5a
Manufacturer:	Broadcom
Name:	Serenity
Firmware Version:	20 (487)
Bluetooth Power:	On
Discoverable:	Yes
Vendor ID:	0x5ac
Product ID:	0x8218
HCI Version:	4 (0x4)
HCI Revision:	487 (0x1e7)
LMP Version:	4 (0x4)
LMP Subversion:	16916 (0x4214)
Device Type (Major):	Computer
Device Type (Complete):	Macintosh Portable
Composite Class Of Device:	3670284 (0x38010c)
Device Class (Major):	1 (0x1)
Device Class (Minor):	3 (0x3)
Service Class:	448 (0x1c0)
Requires Authentication:	No

Apple Bluetooth Software Version:	2.4.3f1
Hardware Settings:	
Address:	e0-f8-47-2b-47-09
Manufacturer:	Broadcom
Name:	1337-h4x0r-2.0
Firmware Version:	37 (739)
Bluetooth Power:	On
Discoverable:	No
Vendor ID:	0x5ac
Product ID:	0x821a
HCI Version:	4 (0x4)
HCI Revision:	739 (0x2e3)
LMP Version:	4 (0x4)
LMP Subversion:	16933 (0x4225)
Device Type (Major):	Computer
Device Type (Complete):	Macintosh Portable
Composite Class Of Device:	3670284 (0x38010c)
Device Class (Major):	1 (0x1)
Device Class (Minor):	3 (0x3)
Service Class:	448 (0x1c0)
Requires Authentication:	No

Left: 2010 MBP Bluetooth Hardware, Right: 2011 MBP Bluetooth

However, there's a dramatic improvement in both WiFi range and performance between the 2010 and 2011 refresh. With 400 ns guard intervals 40 MHz channels, 64-QAM modulation, each spatial stream adds n*150 Mbps. With 20 MHz channels, it's 72.2*n Mbps. For example, 1 spatial stream has a data rate of 150 Mbps, 2 has 300 Mbps, 3 has 450 Mbps, and so forth all the way up to 4 spatial streams and 600 Mbps as defined in the 802.11n specification. The reality of the matter is that what physical layer rate you'll see depends on the modulation and coding scheme and how many streams are going. You can look those up at any time by holding option and clicking the WiFi indicator, and looking them up in a table.



We tested a 15" 2011 MacBook Pro alongside a 15" 2010 MacBook pro connected to an Airport Extreme (Simultaneous Dual-Band II) running latest firmware. I originally suspected that 3 spatial stream support wasn't enabled, and that Apple would push a firmware update out right after their first 3 spatial stream products started shipping. Interestingly enough, it's always been there, enabled, this is just the first client I've gotten my hands on that does it. I'm not a huge fan of the Airport Extreme (I use a WRT54G-TM with Tomato and a WRT-600N with DD-WRT), but it's the only thing on hand with 3x3 MIMO. I tested in four different locations in my house—in my office, living room, kitchen, and outdoor patio. The base station is in my office mounted on the wall close to the ceiling, and those locations are subjectively ordered from best to worst.

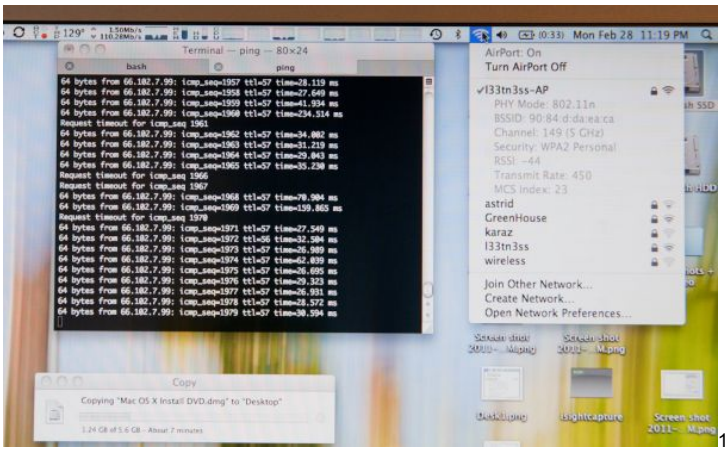
To test, I initiated a large transfer over SMB (from a Windows Server 2008 R2 install with a 5 TB RAID5 array connected over gigabit ethernet) on each client, continually pinged AT, and at each location checked the reported transmit rate and RSSI. What we're reporting here is again the physical layer link. I'll show in a second that real-world transfers also improved, this just gives some perspective for what raw link rates are being negotiated at each location.

WiFi Transfer Rate Differences—802.11n

	2011 MacBook Pro		**2010 MacBook Pro**	
	RSSI	Transfer Rate (Mbps)	RSSI	Transfer Rate (Mbps)
Location 1—Office	-44	450	-42	300
Location 2—Living Room	-61	130	-64	117
Location 3—Kitchen	-69	117	-68	78
Location 4—Outdoor Patio	-85	20	-84	13

In most cases, RSSI is within the margin of error. RSSI is generally not something you can compare, but since both wireless chipsets are Broadcom and the numbers are so close, it seems they're reported the same way and probably just dBm. Just know that generally it doesn't work that way unless you're lucky. What's important, however is that the negotiated link speed is noticeably better in essentially all locations on the new 2011 MBP. Even when the extra antenna isn't being used for a spatial stream of its own, it's actively improving link quality and helping the new MBP negotiate higher physical layer speeds.

So how much of a difference does 450 Mbps 3x3 make over 300 Mbps 2x2? With both in the exact same spot in my office, I saw throughput of 98.1 Mbps on the 2010 MBP compared to 113 Mbps on the 2011 MBP. The modest 15% improvement over the previous generation's wireless chipset isn't dramatic, instead the dramatically improved range is.



110.28 Megabits/s over WiFi. I later saw sustained 113 Megabits/s.

Subjectively, I found many more APs visible with the new MBP. I was able to cling onto my AP all the way out to the curb (just like smartphones) when connected on 2.4 GHz, something the old generation just couldn't do.

The only complaint I have about the new wireless chipset is that it seems to hunt around for what rate it wants negotiated. I saw a number of different MCS (modulation coding scheme) values with the 2011 MBP in the exact same place. Link rates from just below 300 Mbps all the way up to the expected 450. It seems to settle out at the expected 450 Mbps in the same room as the AP, it just takes a while, whereas other 2x2 stacks I've seen always lock onto 300 Mbps and stay there in the same room and position.

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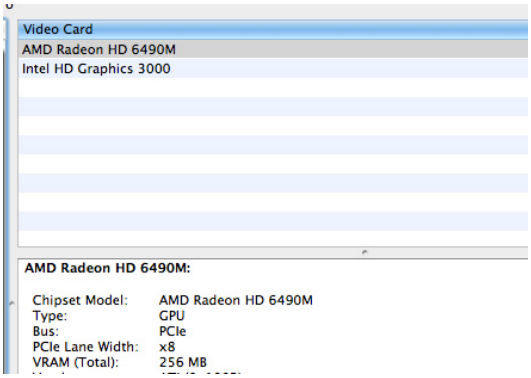
Thunderbolt

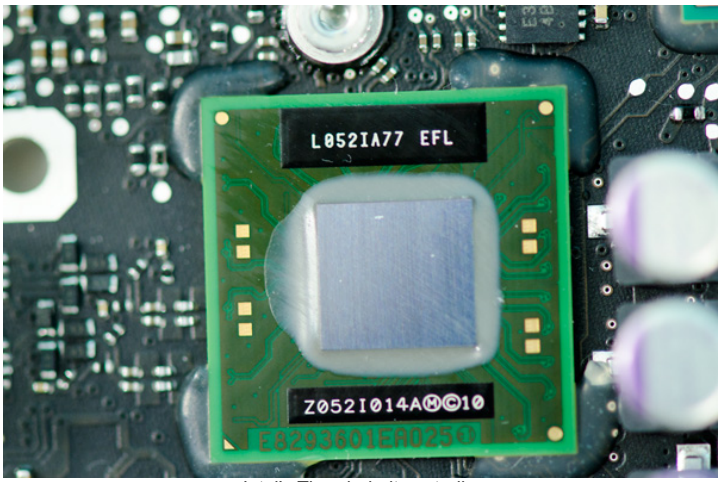
We wrote about Thunderbolt when the new MBPs launched, and about the differences between when it existed as Intel's codename Light Peak like we used to know it and saw at IDF. Thunderbolt differs technically and in practice in a number of ways. The short version of the story is that Thunderbolt is Light Peak sans light in this initial form (electrical right now), uses the mini DisplayPort connector on the MBP, and is capable of two channels of full duplex 10 Gbps traffic, for a theoretical 20 Gbps up and down. Thunderbolt requires a controller on the host and peripheral, uses 4 PCIe lanes, and connects to Display Port internally on the MBP's discrete GPU. One of the interesting things is where those 4 lanes come from on the 2011 MacBook Pro.

Thunderbolt can supply 10 watts of power and support up to 7 devices, up to two of which can be DisplayPort 1.1a devices. Just PCIe and DisplayPort are tunneled over Thunderbolt links. However, you can connect a standard DisplayPort monitor to the jack on the MBP and use it natively as well.

Sandy Bridge brings 16 lanes of PCIe really purposed for running a GPU. Interestingly enough, the discrete GPU on the 2011 MBPs uses just 8 PCIe lanes:



So where do the remaining 8 lanes get used for? They're split into 2 x 4x ports, one of which is for Thunderbolt. It's surprising, but this configuration is totally supported. Originally I speculated that the other 4x lane was being used for another PCIe interface device in the MBP (the SDXC card reader and BCM7765 are both 1xPCIe devices), but it appears they're unused.



Intel's Thunderbolt controller

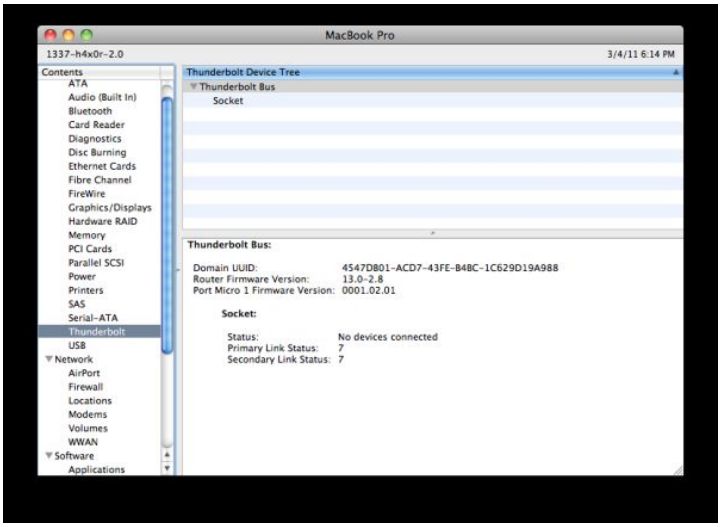
Thunderbolt launches with Apple, but isn't Apple exclusive. Intel reports that we just likely won't see adoption in the PC space until 2012. In addition, there's no per-port licensing fee or royalty for peripheral manufactuers wanting to use the port or controller, which are entirely Intel's. The controller is actually of appreciable size on the 2011 MBP:

Initially, Thunderbolt is electrical only, though the optical version of Thunderbolt is coming later this year. Optical cabling will be compatible with this electrical version through the use of electro-optical transceivers on the cable ends.

Bottom: 2011 MBP with Thunderbolt port, Top: 2010 MBP

We can't test and see whether Thunderbolt works or does anything right now, because there aren't any devices on the market with support. That said, Western Digital, LaCie, Promise, and other external storage manufacturers have stated that drives will arrive shortly, which we will surely take a look at. There are also rumors of various high end DSLRs shipping with Thunderbolt in the near future, though that's anyone's guess.

There's a field for Thunderbolt in system profiler, but even with a DisplayPort monitor attached, it shows nothing connected:



Interestingly enough, in Windows there's no trace of Thunderbolt at all. There aren't any unknown devices in the device manager, no device ID either. Hopefully Boot Camp drivers come along for Thunderbolt in Windows before devices start rolling out.

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FaceTime HD Cameras

One of the more subtle changes between the 2010 and 2011 MBPs (and other MacBooks) is the departure from strictly VGA "iSight" cameras. The new FaceTime HD cameras are 1280x720, though Photo Booth oddly still only captures at just VGA.

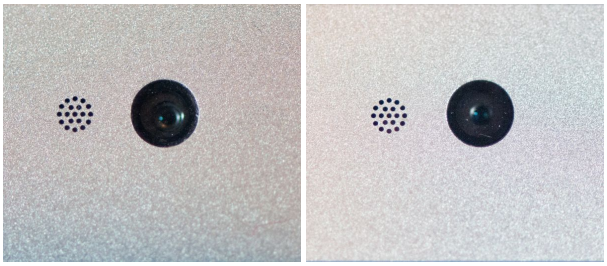
A quick run to the command line and use of isightcapture enables true native resolution capture at 1280x720 until Photo Booth gets updated (if ever). I propped a 2011, 2010, and 2006 MBP up inside my lightbox and setup the scene I usually use for smartphones, and tossed in a GMB color checker card. I

took photos from the command line at full resolution with no compression with both tons of light from a huge CCFL, and again with very little light. You can immediately see how things have changed if you check out the gallery with those uncompressed photos at native resolution.

{gallery 967}

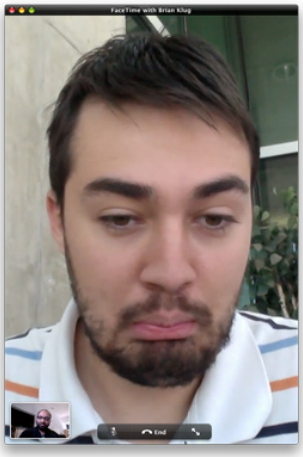
The 2011 MBP's optical system achieves almost the exact same magnification (eg the height of the test objects remains the same if you scale vertical resolution) as the 2010 model. You just get a wider image at higher resolution. It isn't perfect, and even with gobs of light there's noise visible, but the quality is dramatically better. White balance is changed, with the old 2010 model having a slightly reddish cast. The difference is easily discernible in the color checker card. The old model also had less than perfect exposure (the light part at the right of the cup is completely saturated) compared to the new. Dark performance is also slightly better, again with a different color cast.

Visually, I was hard pressed to notice anything different between the two cameras on the outside. The older 2010 MBP seems to have a larger aperture, subjectively, which seems the opposite of how I'd expect things to go.

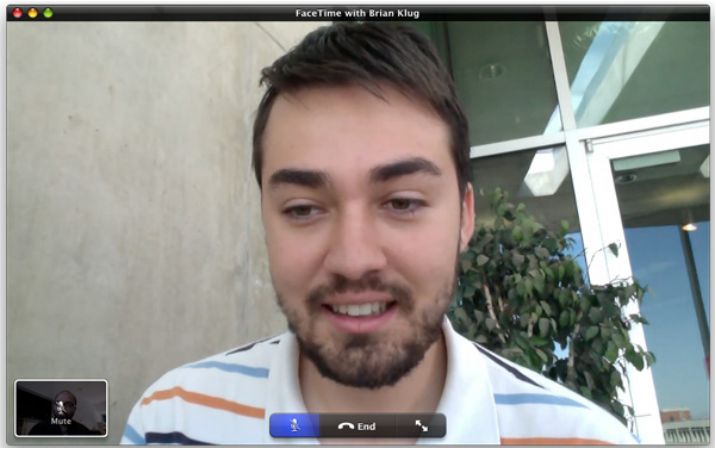


Left: 2010 MBP, Right: 2011 MBP

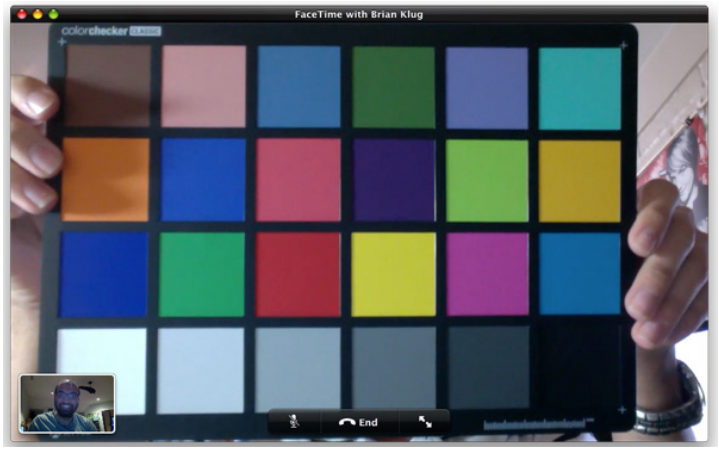
The other part of the story is of course FaceTime HD itself, which ups the quality of FaceTime sent from the 2011 MBP from 320x240 to 720P. While the new MacBook Pros ship with FaceTime preinstalled, older Macs need to purchase it from the App Store for $0.99. FaceTime HD leverages Sandy Bridge's Quick Sync for encoding 720P, although as we pointed out earlier—CPU utilization is still quite high. While only 2011 MBPs can send HD FaceTime, there are also restrictions on what Macs have enough processing power to decode it.



FaceTime HD works pretty well. The application starts in a small portrait window but is both scalable and viewable in landscape as well.



There's no support for text communication during a FaceTime HD chat, just video. The video quality scales dynamically with available bandwidth. FaceTime HD worked over a 512Kbps upstream connection but had reduced quality compared to transmitting over a 2Mbps connection.



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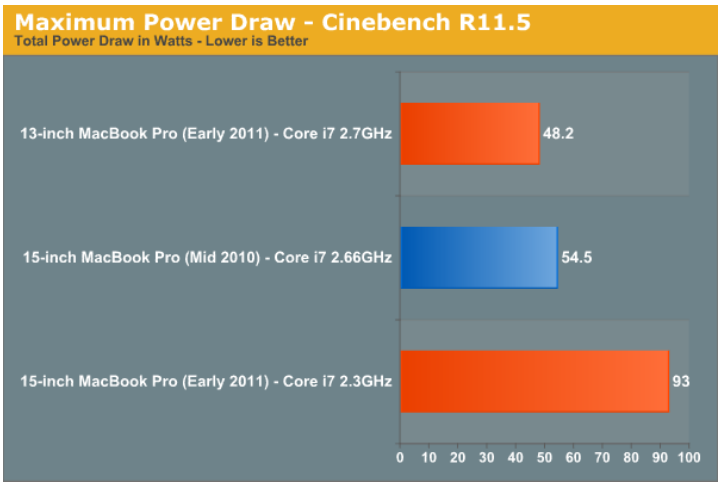
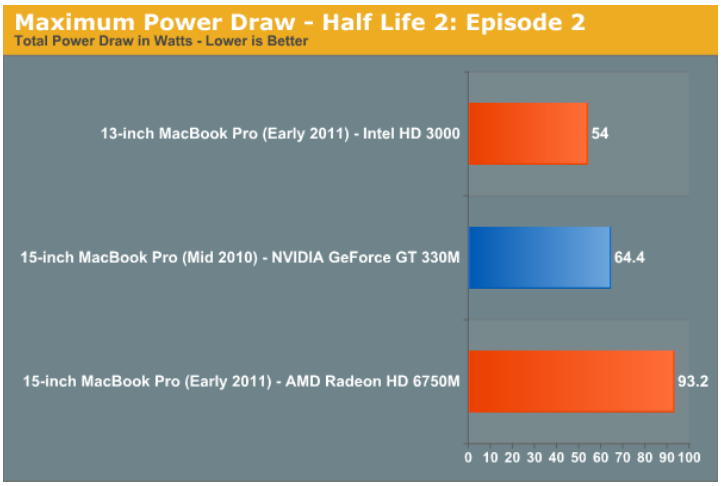
Thermals and Power Consumption

The new MacBook Pros have the potential to draw more power than the previous generation. Despite being built on a 32nm process, the new 15 has twice the cores of last year's model—there's no question that it can draw more power under a full load.

I measured maximum power consumption at the wall using the same power brick and a fully charged battery. I chose two high-load scenarios: Cinebench 11.5 and Half Life 2. The former will fully load all CPU cores while the latter ramps up CPU and GPU usage.



Under Cinebench the new quad-core 15-inch MacBook Pro draws 70% more power at the wall than last year's dual-core model. This shouldn't be surprising as Cinebench scales nearly perfectly with core count—twice the cores should result in nearly twice the power draw. The scaling isn't perfect since we are dealing with different architectures and a number of factors such as display remain static. The new 13-inch MacBook Pro isn't as worrisome, it has 88% of the power usage of the high end 2010 15-inch MBP and 81% of the battery capacity.

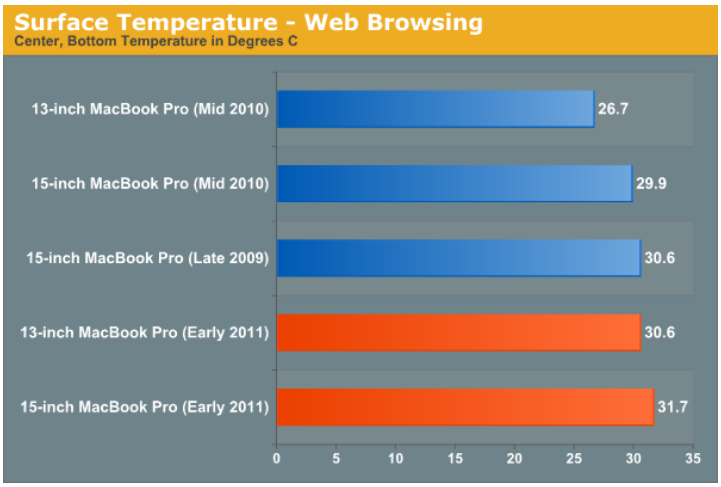


The Half Life 2 comparison is not quite as bad, although the new 15-inch MBP still uses 45% more power under full load compared to the previous generation. These numbers tell you one thing: although the new MBP is significantly faster than its predecessor, it can also draw significantly more power.

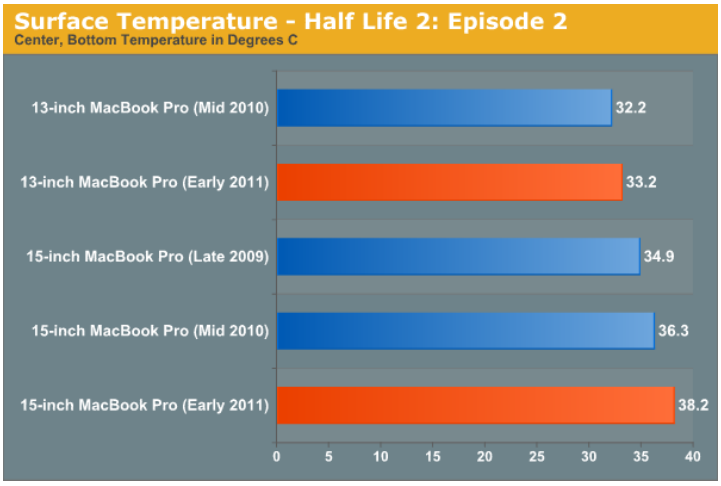
Running the same workload the new MBP shouldn't have any problems lasting as long as the old MBP on battery, but running a more aggressive workload will result in shorter battery life as a result of the higher max power consumption. In other words if you use the higher performance to do more, you can expect your battery to last proportionally less than the 2010 MBP.

The 15-inch MBP uses an 85W power adapter (left) and the 13-inch MBP uses a 60W adapter (right)

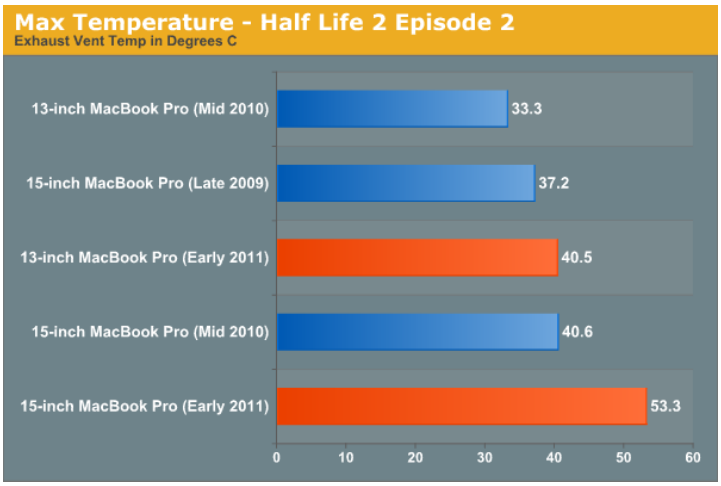
Drawing more power also has another unfortunate side effect: the bottom of the chassis gets even hotter than before. I took some crude temperature measurements when I did the 2010 MacBook Pro reviews last year. I pointed an IR thermometer at the center of the bottom of the notebook, right where you'd have your lap, and measured surface temperature in a couple of scenarios.



While browsing the web with tons of windows/tabs open I noticed a small but tangible increase in surface temperature of the 2011 15-inch MBP compared to the 2010 model. Even the new 13 is warmer than last year's 15. Under light workloads none of these temperatures are high enough to really be a problem.

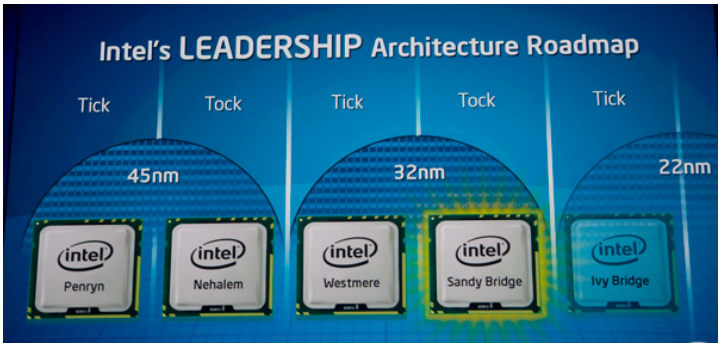


Load up the system however and you start getting into the uncomfortable zone. The new 15 breaks 38C, while the new 13 is actually only marginally warmer than the old 13 thanks to the use of Intel's HD Graphics 3000.



The biggest difference I noticed was the max temperature near the exhaust fan(s) on the notebooks. The new 15 is a whole 13C warmer than last year's model.

There's no way to get around it—if you're going to be using these systems to anywhere near their potential, they are going to get significantly warmer than last year's. Also, as a result, the new systems are noisier. Fans are more likely to spin up and given how small they are, they are quite audible. If this is a deal breaker for you, the best advice I can give you is to wait for Ivy Bridge.



Ivy Bridge will bring mild updates to the Sandy Bridge architecture, an increase in performance but more importantly it'll bring Intel's 22nm process. At 22nm I'd expect somewhat lower power usage than what we're seeing here today. Ivy Bridge is expected to ship in the first half of 2012, with updated MacBook Pros arriving ~2 months post introduction.

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Battery Life

With the potential for higher power draw, battery life on these new systems has the chance to be really, really bad. In reality it breaks down like this: light usage cases are equal if not better than last year's model. Apple makes up for the higher core count of the 15-inch MBP by capping turbo speeds and being very good about allowing the CPU to go into deep sleep states under OS X. On top of that, Sandy Bridge is a very efficient microarchitecture that manages to get work done quicker than Arrandale and get to sleep faster.

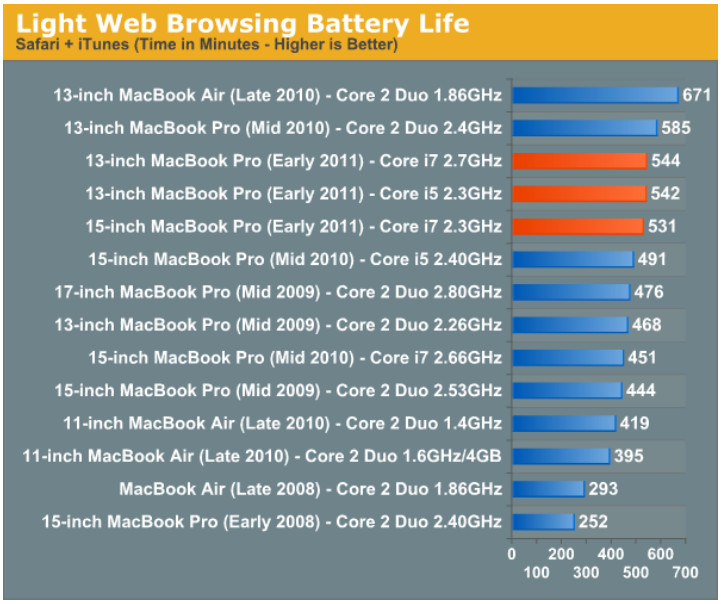
Heavy usage cases however can easily be worse than last year's model, specifically with the 15 and 17-inch systems. The new 13 is a mixed bag. Core 2 was a pretty low power architecture, beating its battery life will be difficult. The only scenario our battery life tests don't duplicate is one where workload scales with performance. Right now all of our tests are fixed workloads: web pages may render quicker, but you'll still be idle for the same amount of time regardless of system. Video frames may decode quicker, but they'll still play back at the same 24 fps. If you use the additional performance of these

systems to do more then you'll likely see even worse battery life (see the power numbers on the previous page).

Light Web Browsing

Here we're simply listing to MP3s in iTunes on repeat while browsing through a series of webpages with no flash on them. Each page forwards on to the next in the series after 20 seconds.

The display is kept at 50% brightness, all screen savers are disabled, but the hard drive is allowed to go to sleep if there's no disk activity. The wireless connection is enabled and connected to a local access point less than 20 feet away. This test represents the longest battery life you can achieve on the platform while doing minimal work. The results here are comparable to what you'd see typing a document in TextEdit or reading documents.

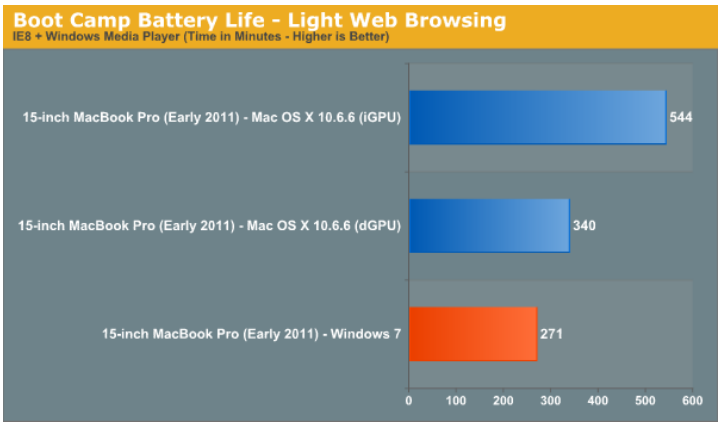


For the 15-inch model battery life has doubled since 2008. Even compared to last year's model Apple has actually improved idle/light usage battery life by 8%. With 9 hours of battery life I can confirm that if you're just using the 15-inch MBP as a glorified typewriter this is what you'll see. It's a great combination of a system that has performance on tap but the battery life to last you if you just need to do some writing.

The 13-inch MacBook Pro actually takes a step back compared to last year's model but it's still the Mac with the 3rd longest battery life.

Boot Camp Battery Life

Under Windows 7 there's no option to use the iGPU, the 15 and 17-inch MacBook Pros default to their dGPU. As we already showed, simply enabling the dGPU hurts battery life. What about the move to Windows 7 on top of that? To find out I ran our light web browsing battery life test under Windows 7. I subbed in IE8 and Windows Media Player for Safari and iTunes and otherwise ran with similar settings as our Mac test:

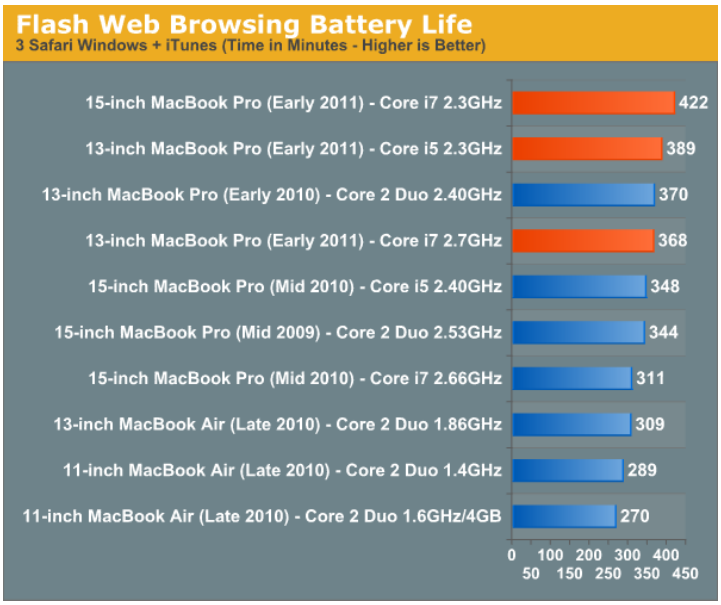


Compared to OS X with the dGPU enabled, Windows 7 delivers 20% lower battery life. The bigger penalty however is the forced dGPU usage under Windows. If you're planning on using the new 15-inch MBP as a Windows notebook, don't expect to get anywhere near the battery life that is promised under OS X.

Flash Web Browsing

The test here has three Safari windows open, each browsing a set of web pages with between 1—4 animated flash ads per page, at the same time. Each page forwards onto the next after about 20 seconds.

As always, the display is set to 50% brightness, audio at two bars, screensaver disabled and the hard drive is allowed to go to sleep if idle. The wireless connection is enabled and connected to a local access point less than 20 feet away.

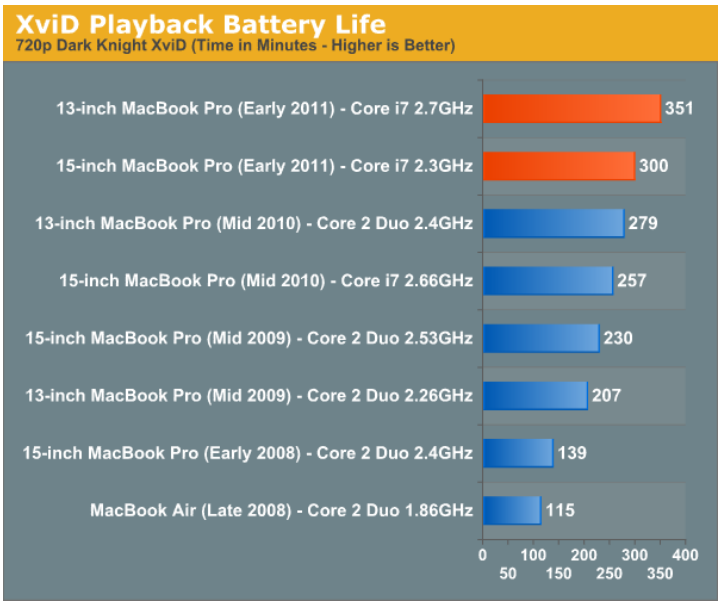


Turn Flash on and up the intensity of the workload and the numbers get a lot more reasonable. The new 15-inch MacBook Pro leads the pack with 7 hours of battery life. You'll note that this is exactly what Apple promises on its website. At 7 hours this is also a 20% improvement over last year's model. Other than OS/optimization differences the only explanation I have here is that Sandy Bridge provides a sufficient enough increase in CPU performance to render a page and flash ads get to sleep quicker compared to Arrandale. Another contributing factor is the new 32nm iGPU which is active full-time under Safari. The GPU alone is probably a bit more efficient at rendering flash than last year's GeForce GT 330M.

The 13-inch model actually equals its predecessor. I suspect the Core 2 Duo is still a lower power CPU under a moderate load.

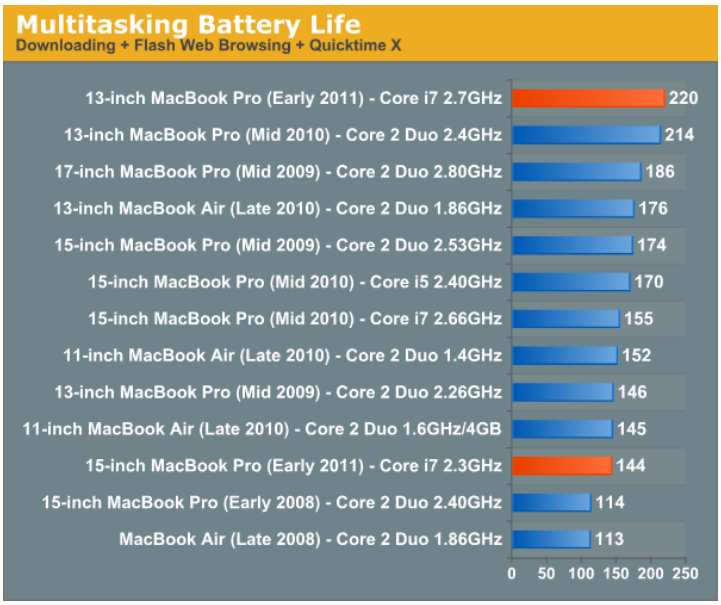
XviD Video Playback

I ripped The Dark Knight to XviD and played it back continuously in QuickTime X with Perian installed. For this test the display was set to full brightess and audio was set at two bars below maximum. Once more the hard drive was allowed to go to sleep if it was idle. The AirPort (wireless LAN) was enabled and connected to a local access point less than 20 feet away.



Multitasking Battery Life

Our final battery life test is the worst case scenario. In this test we have three open Safari windows, each browsing a set of web pages with between 1—4 flash ads per page, at the same time. We're also playing an XviD video in a window all while downloading files from a server at approximately 500KB/s.



I mentioned earlier that the new 15-inch MBP has the potential to have much worse battery life given that it has twice the cores of its predecessor. Our multitasking battery life test gives you a little indication of that. At 144 minutes the new 15 lasts just under 2.5 hours here. It's only a slight reduction compared to last year's model but that's only because the workload isn't scaled up at all. OS X is likely scheduling work here across all four cores rather than just two in last year's model, driving up power consumption and decreasing battery life ever so slightly.

The new 13-inch on the other hand is pretty sweet. At 3.66 hours it's the new king of our multitasking battery life test, and it's even a slight improvement compared to the 2010 version.

Just playing back movies on the new SNB notebooks is an improvement on both models. The new 15 manages 5 hours while the new 13 is good for almost 6 hours of battery life.

Overall I'd say the battery life story of the new MacBook Pros is a mixed bag. Under light to moderate workloads the 15-inch will likely do better than the 2010 15-inch MBP, while the 13-inch is roughly the same as its predecessor. It's only under heavy use that the new 15-inch will actually do worse than last year's model. You will have to keep an eye on what you're doing with the machine because the new 15-inch MBP has the ability to use a lot more power than last year's model. The bigger issue actually has to do with the dGPU. If you use Chrome or any of the other applications that will trigger the dGPU to turn on, kiss your battery life goodbye. Even light usage suffers if your discrete GPU is active.

The new 13 is a bit less finicky. It's either going to offer you similar or better battery life than last year's model.

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Performance

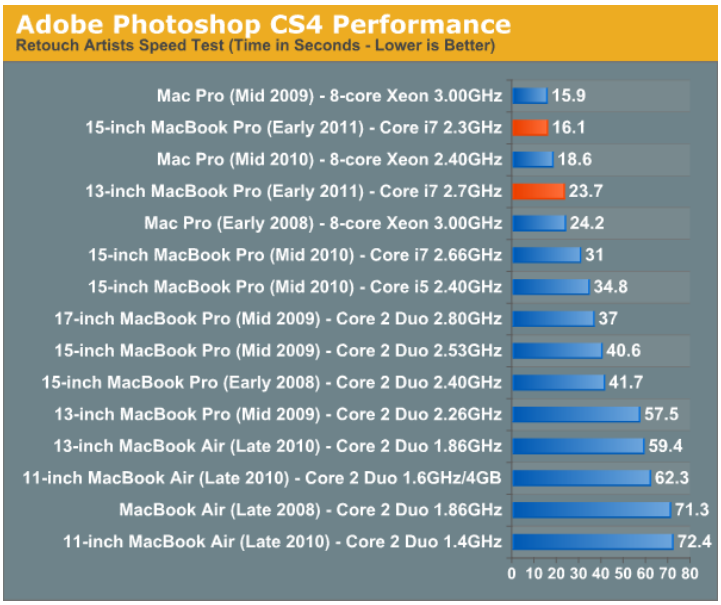
For our performance comparison I actually dusted off some of our 2008 8-core Mac Pro data just to show you exactly how close to a high end desktop the new quad-core MacBook Pro has come. Note that we only have comparative data for a few benchmarks so you may see the Mac Pro disappear from a few charts.

Keep in mind that the Mac Pro numbers are taken with a 3.5" hard drive (vs. the 2.5" HDD in the MBP). The big difference however is microprocessor architecture. In 2008 the Mac Pro was still running Core 2 based CPUs, while Sandy Bridge is two tocks away. What the new MBPs lack in TDP headroom and core count, they can make up for in clock speed. The result is that for the first time since I've been reviewing Apple hardware we have portable Macs that can truly hang with their desktop brethren (with some caveats of course). In order to truly bridge the mobile/desktop gap you definitely need an SSD; a 2.5" hard drive just isn't going to cut it. The Mac Pro still has a pure core count advantage. The reason I feel like the mobile/desktop gap has narrowed is because while I feel that there is a general performance benefit when going from 2 to 4 cores, it's far more difficult to find applications or usage models that take advantage of 8 or more cores.

The gap will grow once more as the iMac and Mac Pro get updated with Sandy Bridge hardware later this year, but I suspect that for even desktop users a 15-inch MacBook Pro paired with an external display may be near perfect. I believe this is a big reason for pushing Thunderbolt in this generation. While the standard may not really take off until next year, the new 15-inch MBP is definitely built for desktop replacement usage models and for that to work without sacrifice you need high speed external storage.

Adobe Photoshop CS4 Performance

The Retouch Artists Speed Test we use for our CPU testing under Windows also works under OS X. We're running the exact same benchmark here, basically performing a bunch of image manipulations and filters and timing the entire process.



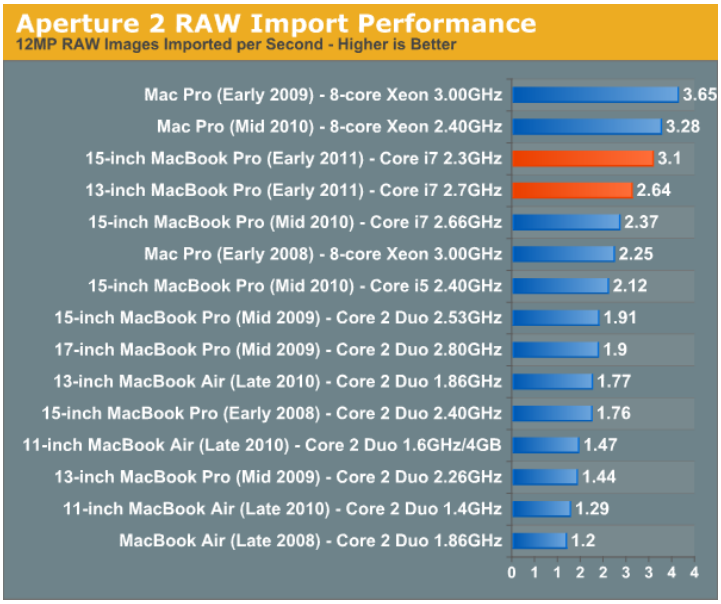
Photoshop performance is just amazing on the new systems. The high end 15-inch MacBook Pro is actually faster than last year's 8-core Mac Pro. Of course this is because Photoshop doesn't scale perfectly with core count but it just shows you just how powerful these new quad-core CPUs are.

Owners of last year's 13-inch MBP will notice that the new high end 13-inch can run through our CS4 test in roughly half the time. The performance improvement is of course exaggerated because Apple kept the 13 on Core 2 for longer than it should have, but what's important is that the new 13 is really fast.

If you do a lot of Photoshop work, the Sandy Bridge upgrade will be worth it.

Aperture 2 RAW Import

For my Aperture test I simply timed how long it took to import 203 12MP RAW images into the library.

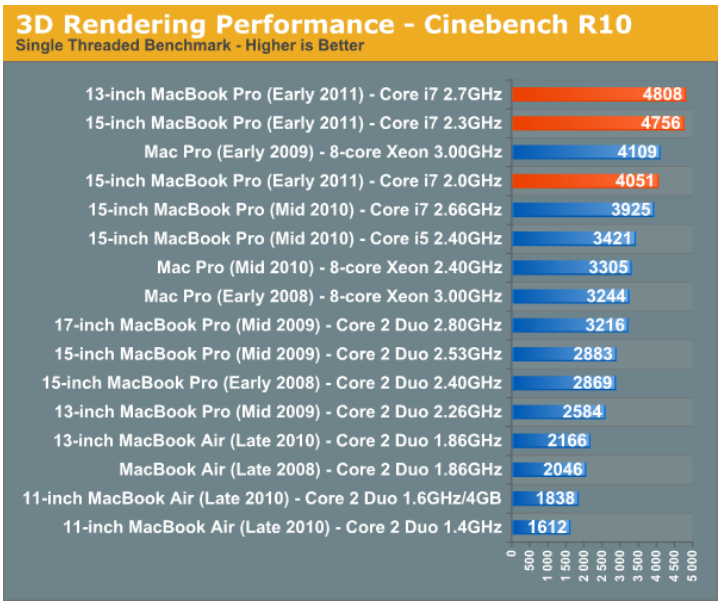


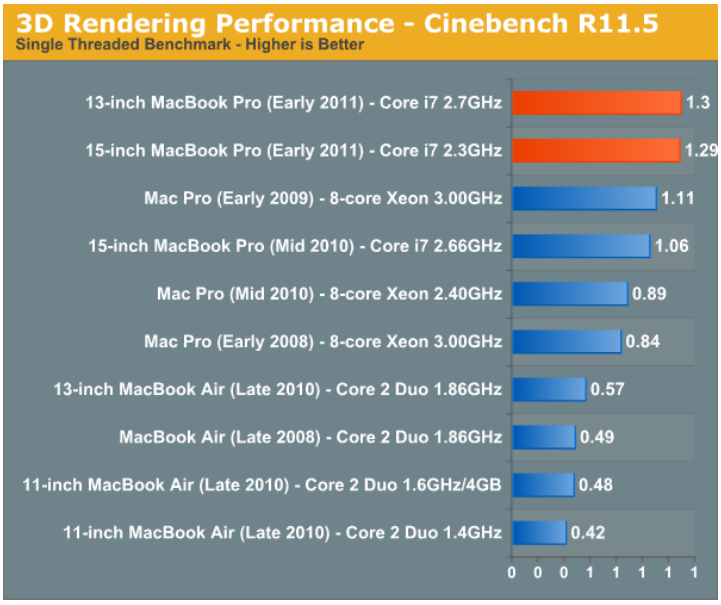
Aperture performance is similarly class leading. Here the 2010 Mac Pro actually outperforms the high end 15 by around 6% but the fact that we can even mention the two in the same sentence is huge.

The new 13 is still really quick, itself faster than a Mac Pro from as recently as 2008 in this test.

Cinebench R10 & 11.5

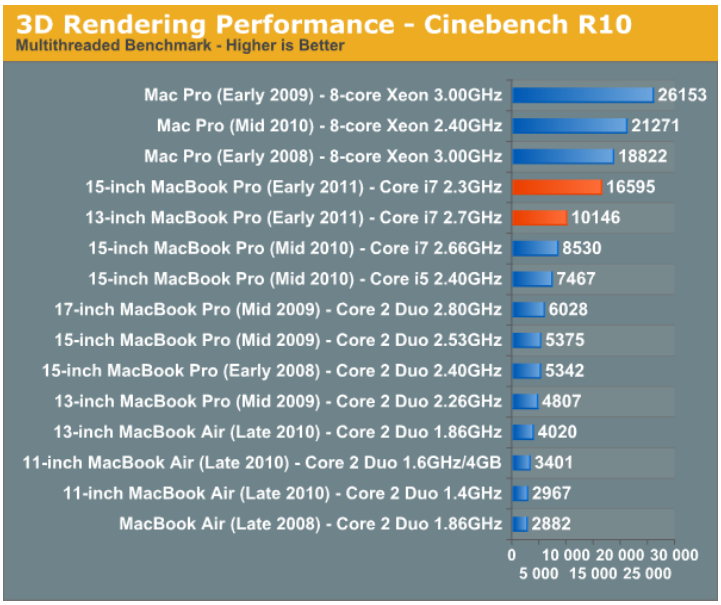
I'm a fan of the Cinebench tests because they lets me show off both single and multithreaded performance in the same workload. First, the single threaded performance:





Single threaded performance is really where these systems shine and it's what makes them feel so fast in normal usage. Even the base 15-inch MacBook Pro has better single threaded performance than last year's high end model.

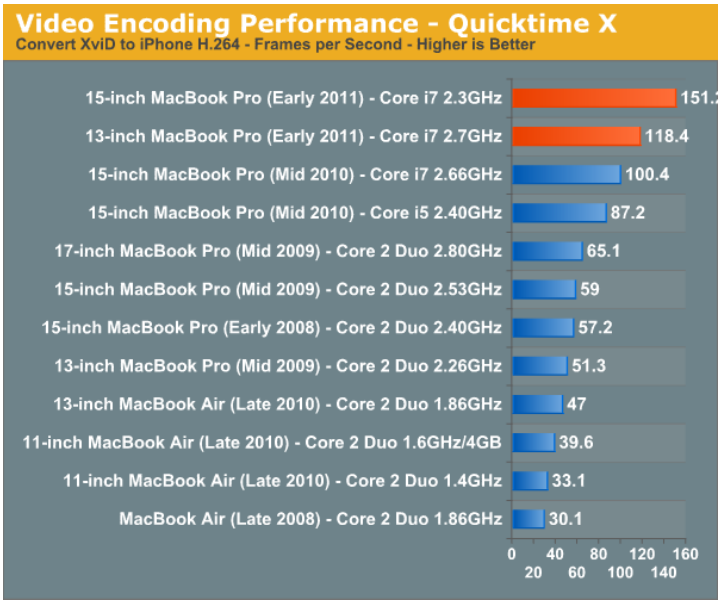
You'll notice that the 13-inch 2.7GHz MBP has a bit of an edge compared to the 15-inch 2.3GHz system here. Although both chips can technically turbo up to 3.4GHz with only one core active, Apple seems to limit the 13-inch dual-core less. As a result it will sometimes have higher single threaded performance than the 15. I noticed this in actual usage as well. The advantage is very subtle and really only visible if you do a side to side comparison however.



Multithreaded performance is obviously a huge boon on the 15-inch MacBook Pro. With four cores and eight threads the new 15-inch MBP behaves a lot more like a desktop than a notebook. Multithreaded performance is also one area where the high end Mac Pros do a lot better as they have twice the cores of even the 15-inch MBP.

Quicktime H.264 Video Encoding

Our final benchmark is more consumer focused. Here I'm taking an XviD and converting it to an iPhone-supported H.264 format.



Despite missing Quick Sync support, the 2011 MacBook Pros do very well in our video transcoding tests. If Apple does get around to enabling Quick Sync you can expect the performance advantage to grow even more.

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Application Performance in Windows

by Vivek Gowri

In keeping with recent tradition, I'm in charge of evaluating the new MBP under our Windows notebook benchmark suite. Mostly, the MBP works very well as a PC, something I looked at last year with the old 13-inch MacBook Pro. I have the new base 13 in the labs, and I must say, the overall experience is pretty similar...unless you're gaming. But I'll get to that in a minute.

Unlike on the Air I was testing last time around, the Windows install went pretty smoothly thanks to the built-in optical drive. Unfortunately, that's probably going to be the last time I ever use it. And also unlike the Air, there's no problems with storage space here—with the 320GB drive included in the base 13, you have more than enough space for two moderately-sized OS install partitions.

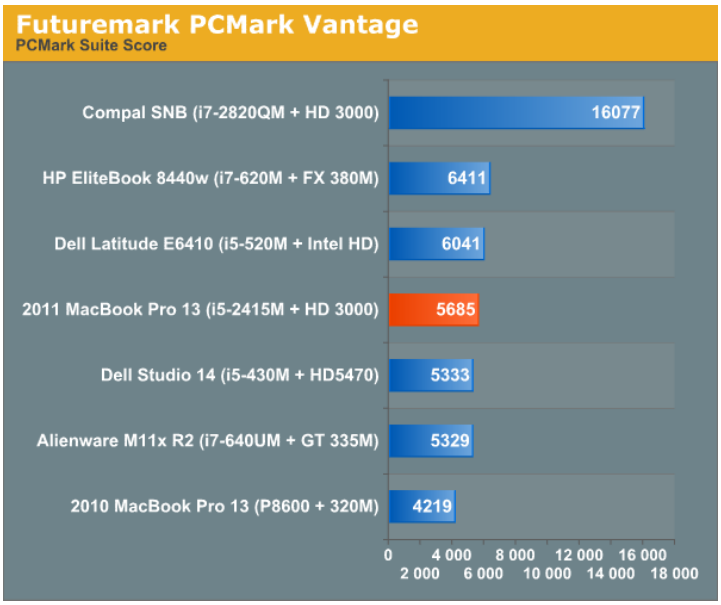
With Windows and Boot Camp drivers out of the way, I fired up our notebook benchmark suite. The new MBP is the first dual core Sandy Bridge notebook we've had in our labs, so I was pretty interested in seeing the performance relative to Arrandale, as well as the old Core 2 Duo-based MBP13. According to CPU-Z, the base spec 13 that I have has the i5-2415M inside, a dual core processor with HyperThreading and clocked at 2.3GHz with max turbo

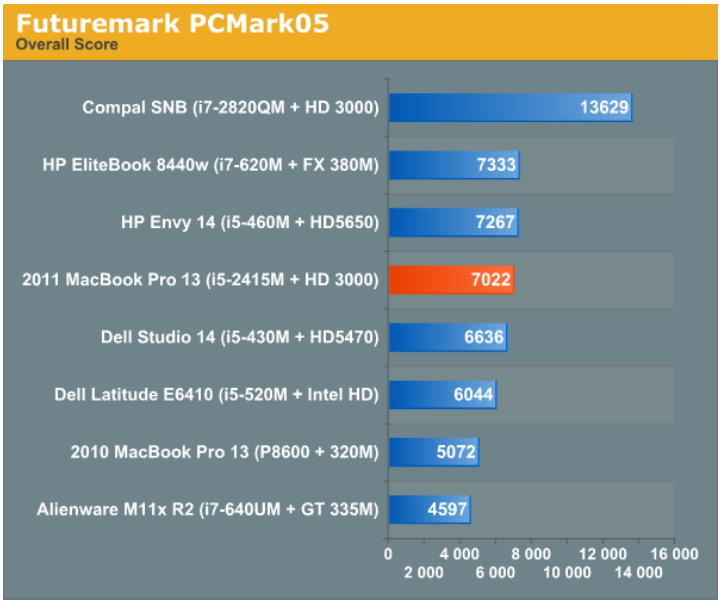
frequency of 2.9GHz. The 2415M is an interesting chip, closely related to the i5-2410M. It's so interesting that Intel doesn't even have a product page for it, which made me curious as to what the difference between the two is. Turns out, the 2415M is the same chip as the 2410M, just in a smaller package. The normal mobile Core i5/i7 processors have a 37.5 x 37.5mm PPGA (plastic pin grid array) package, meant for Socket G2 (also known as rPGA 988B).

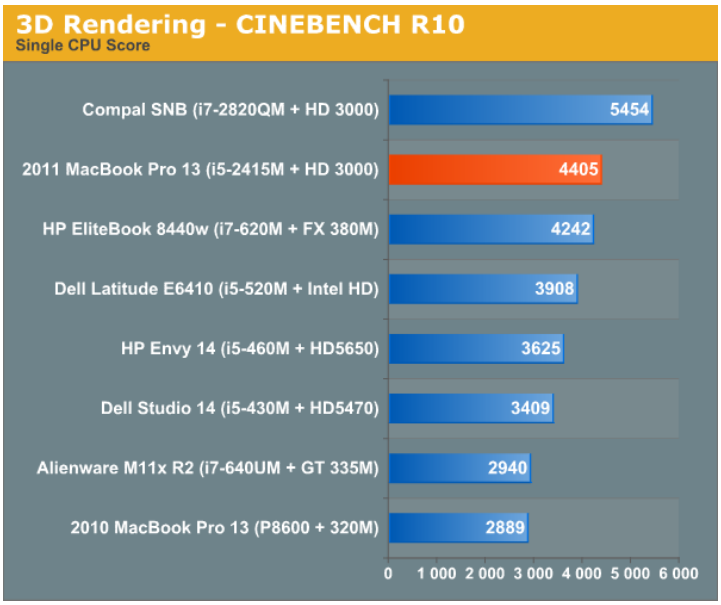
The 2415M, on the other hand, has a package size of 31 x 24mm with a micro-FCBGA mounting method. It's the same package size and mounting as the low voltage and ultra-low voltage Sandy Bridge processors, using the same BGA 1023 socket. Apple probably chose the 2415M to make packaging around the processor easier. Smaller is always better in the Apple world.

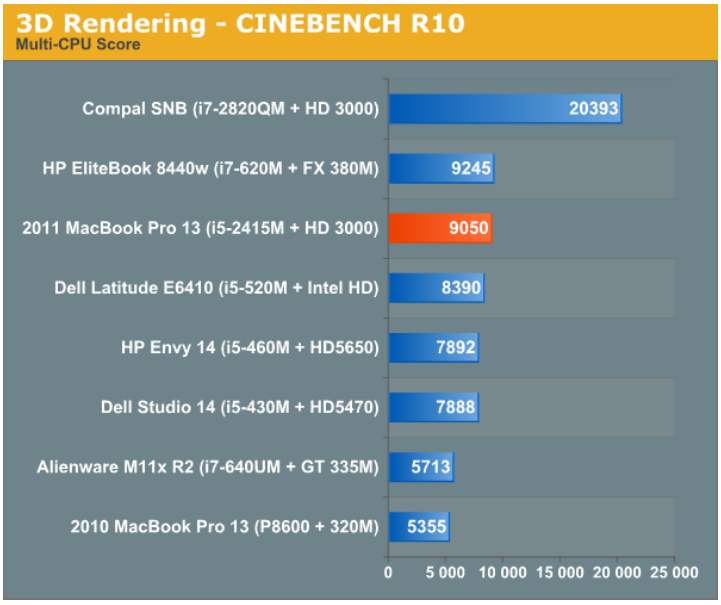
The other interesting wrinkle here is that Apple has forgone a separate graphics chip for the first time in a very long while. This is the first Apple with Intel graphics since the MacBook's January 2009 refresh brought Nvidia 9400M graphics, and the first MacBook Pro with Intel graphics. Ever.

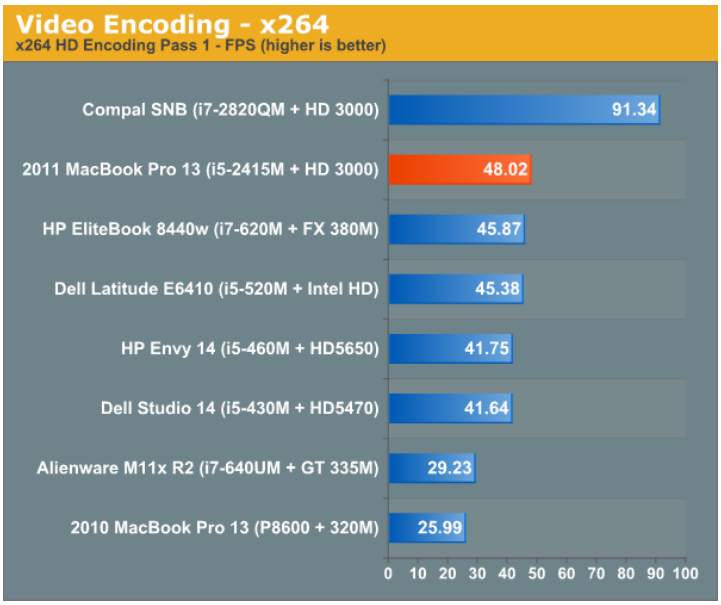
What does all of this mean for performance? Let's take a look. If you're comparing to the old Core 2 Duo based MBP13, CPU-based performance is almost two times faster across the board. Given the huge jump in power between Core 2 and the further two generations of Core processors, this makes a lot of sense. It was seriously about time that Apple moved on from Core 2 in its smaller notebooks, and this huge performance jump is a direct result. We'll see what happens with the regular MacBook and MacBook Air, but I'd expect a similarly large increase in performance in those models when they're next updated as well.

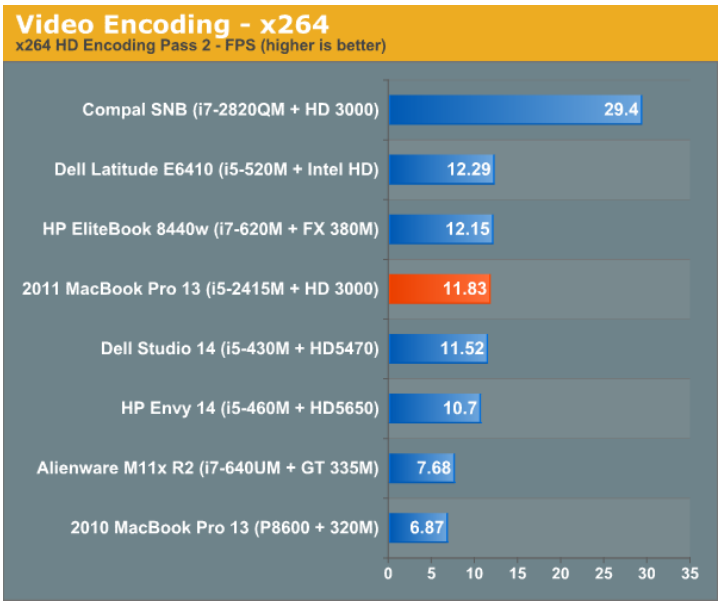





3D Rendering - CINEBENCH R10
Single CPU Score
Compal SNB (i7-2820QM + HD 3000)
5454
2011 MacBook Pro 13 (i5-2415M + HD 3000)
4405
HP EliteBook 8440w (i7-620M + FX 380M)
4242
Dell Latitude E6410 (i5-520M + Intel HD)
3908
HP Envy 14 (i5-460M + HD5650)
3625
Dell Studio 14 (i5-430M + HD5470)
3409
Alienware M11x R2 (i7-640UM + GT 335M)
2940
2010 MacBook Pro 13 (P8600 + 320M)
2889
0 1 000 2 000 3 000 4 000 5 000 6 000


3D Rendering - CINEBENCH R10
Multi-CPU Score
Compal SNB (i7-2820QM + HD 3000)
20393
HP EliteBook 8440w (i7-620M + FX 380M)
9245
2011 MacBook Pro 13 (i5-2415M + HD 3000)
9050
Dell Latitude E6410 (i5-520M + Intel HD)
8390
HP Envy 14 (i5-460M + HD5650)
7892
Dell Studio 14 (i5-430M + HD5470)
7888
Alienware M11x R2 (i7-640UM + GT 335M)
5713
2010 MacBook Pro 13 (P8600 + 320M)
5355
0 5 000 10 000 15 000 20 000 25 000


Video Encoding - x264
x264 HD Encoding Pass 1 - FPS (higher is better)
Compal SNB (i7-2820QM + HD 3000)
91.34
2011 MacBook Pro 13 (i5-2415M + HD 3000)
48.02
HP EliteBook 8440w (i7-620M + FX 380M)
45.87
Dell Latitude E6410 (i5-520M + Intel HD)
45.38
HP Envy 14 (i5-460M + HD5650)
41.75
Dell Studio 14 (i5-430M + HD5470)
41.64
Alienware M11x R2 (i7-640UM + GT 335M)
29.23
2010 MacBook Pro 13 (P8600 + 320M)
25.99
0 10 20 30 40 50 60 70 80 90 100



Looking at the Arrandale-based Core i5-430M, which at 2.26GHz is a logical point of comparison to the i5-2415, we see that performance has improved 15-20%.

This doesn't look as impressive as the gains in performance we saw with our first look at the mobile SNB quad-cores, but Sandy Bridge quads are clocked a lot higher than the preceding Clarksfield chips. Our quad-core SNB mobile testbed had an i7-2820QM, with a 2.3GHz core clock and max turbo frequency of 3.4GHz. The 2820QM replaces the 1.86GHz i7-840QM, so the clock speed is 24% higher. Factor that in, and the increase is more in line with what we saw from the dual-cores.

The big deal here is that now, the lowest end SNB i5 performs roughly on par with the top end Arrandale i7 dual cores. Like Anand said in his Sandy Bridge review, you get yesterday's top of the line performance for a much lower price.

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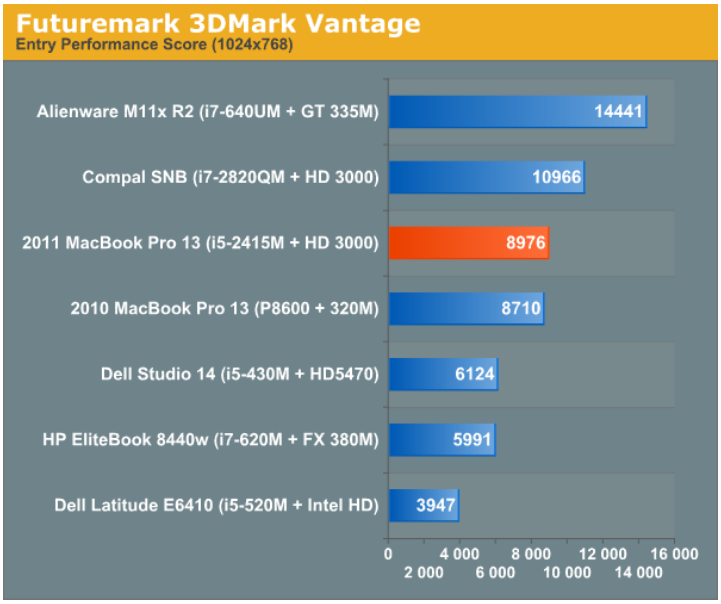
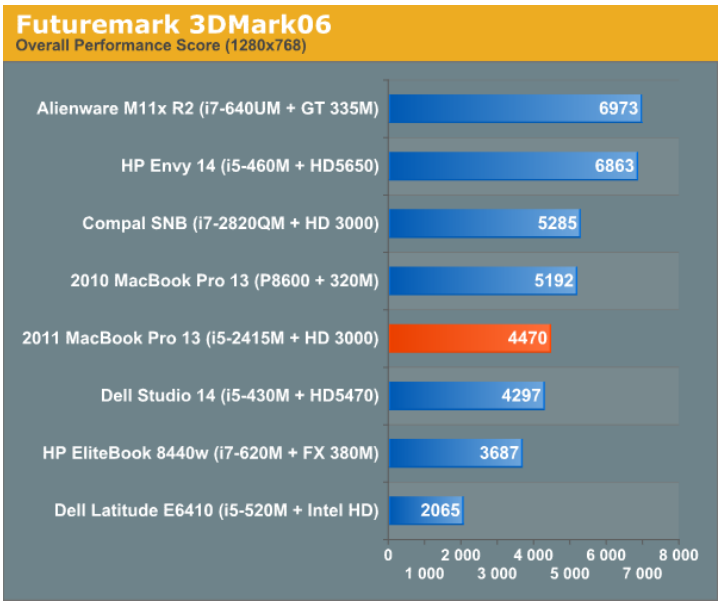
13-inch Gaming Performance under Windows

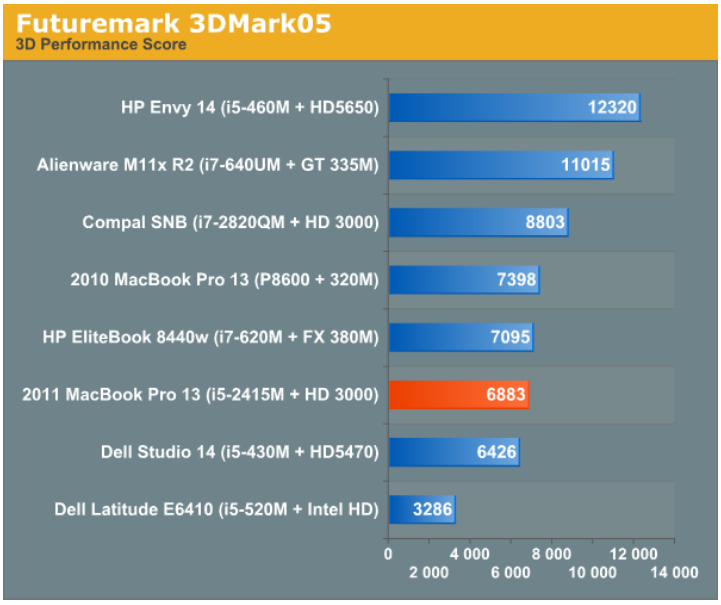
Like I said earlier, this is the first Apple portable with Intel graphics in over two years. What does this mean for graphics performance?

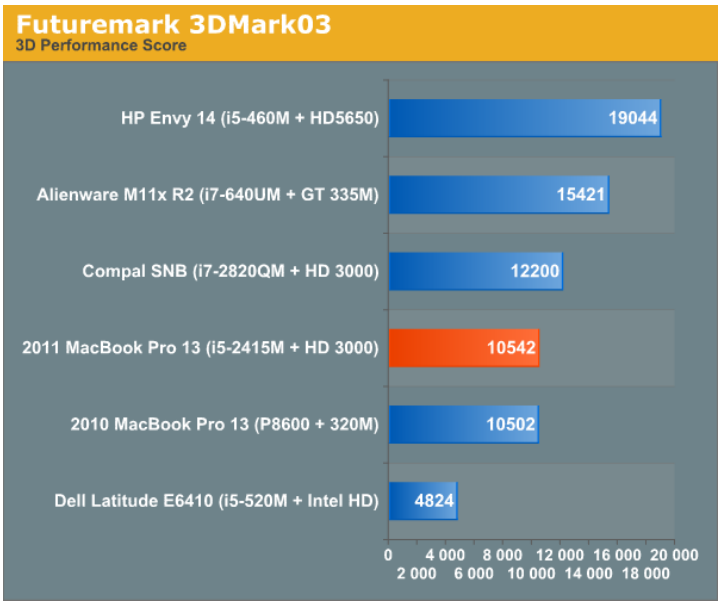
Bad things. See, when Jarred looked at HD 3000 in our SNB mobile testbed, he found that it was a bit faster than the 320M at low settings, and a little bit slower at medium settings. The i5-2415M has the same specs as our testbed, with 12 execution units with a max clock speed of 1300MHz. Given the gaming performance from our Sandy Bridge review, I was actually pretty optimistic that the new 13" MacBook Pro's graphics weren't actually worse than the outgoing models.

Oh how I wish I wasn't wrong. 3DMark scores go down about 20% relative to the SNB testbed and stay within 10% of the old MBP. So far, so mediocre.



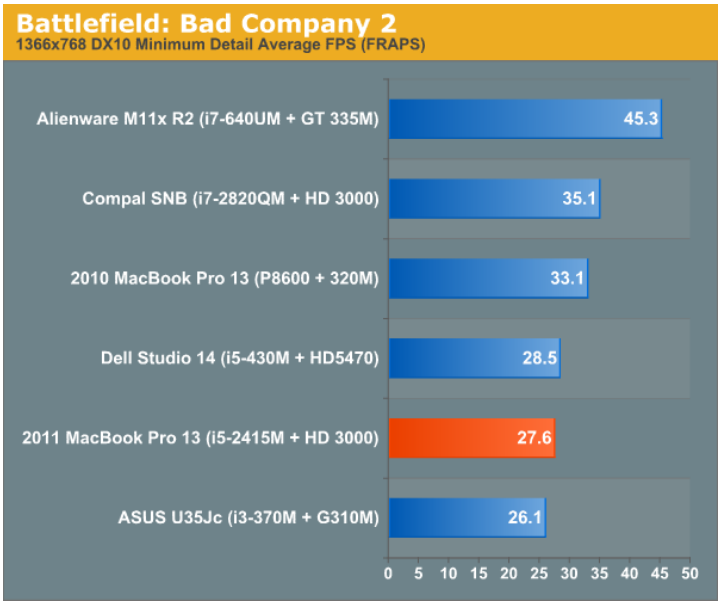


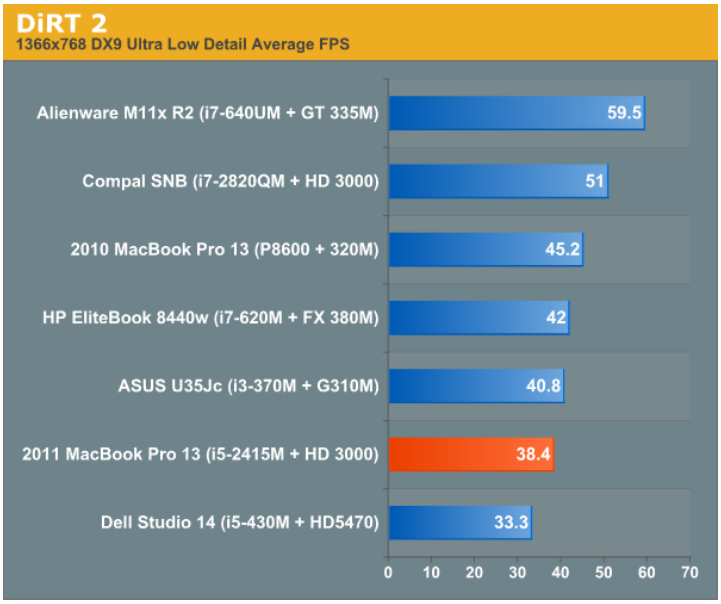


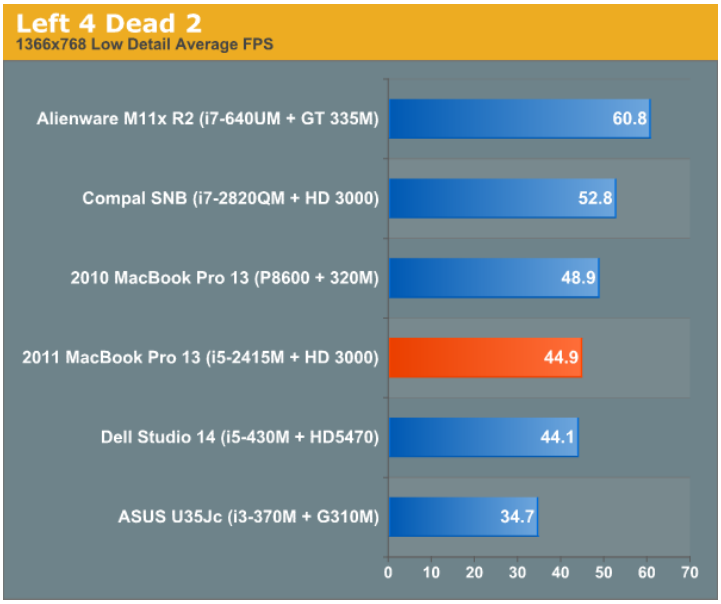


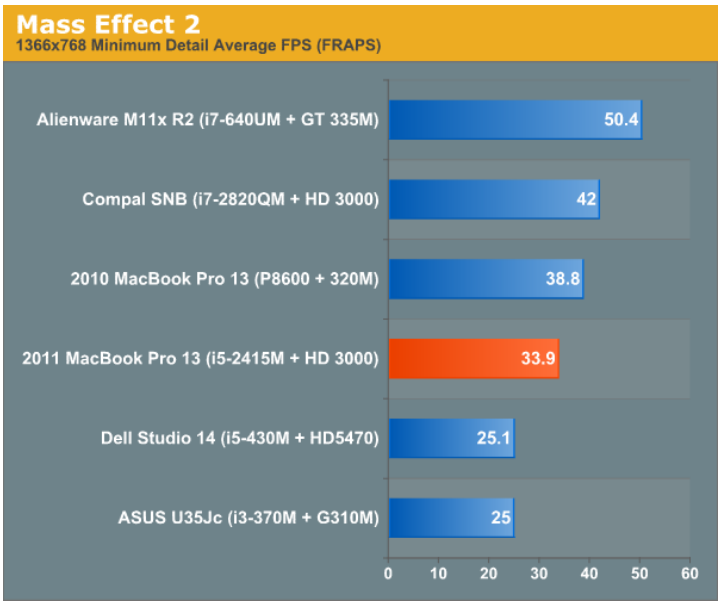
The good news in the gaming numbers is that everything is playable, at low settings at least. Unfortunately, performance is, for the most part, a lot slower than the outgoing 13" MBP. 30% slower in STALKER, 20% slower in Mass Effect 2, DiRT 2, and Battlefield: Bad Company 2, 10% slower in L4D2, and a

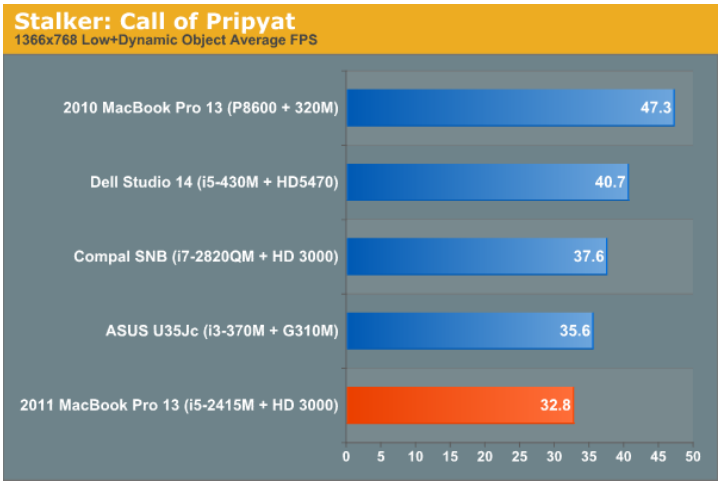
hair faster in StarCraft 2. StarCraft isn't actually that surprising, since it's by far the most CPU-centric game in our benchmark suite.

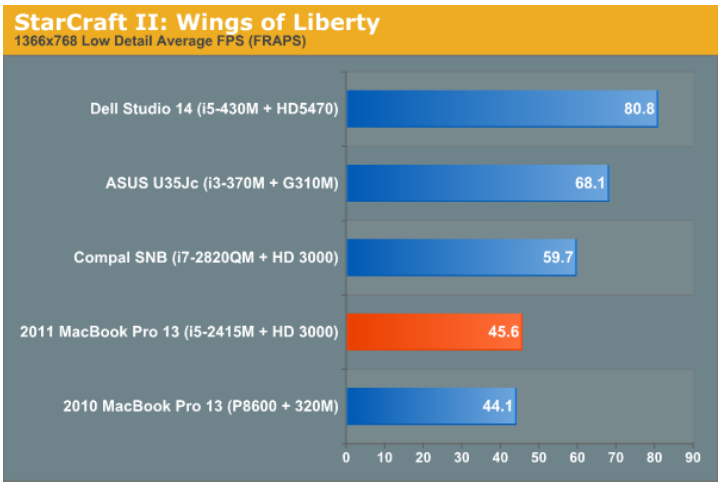












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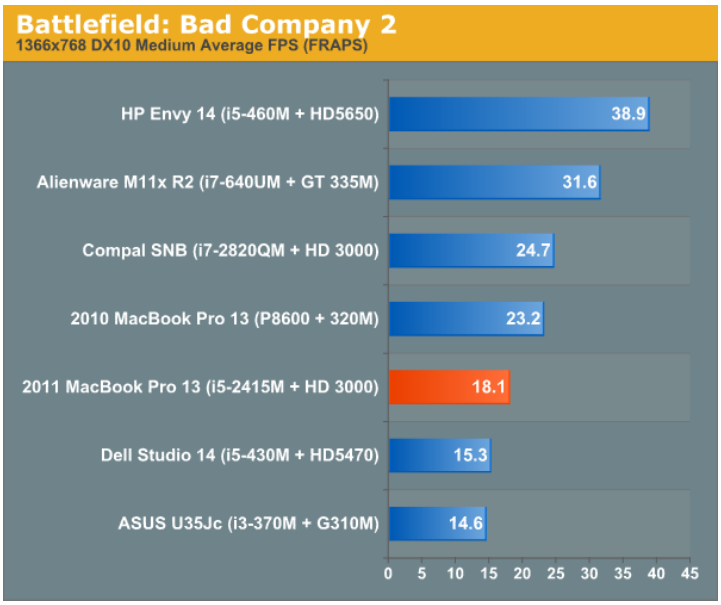
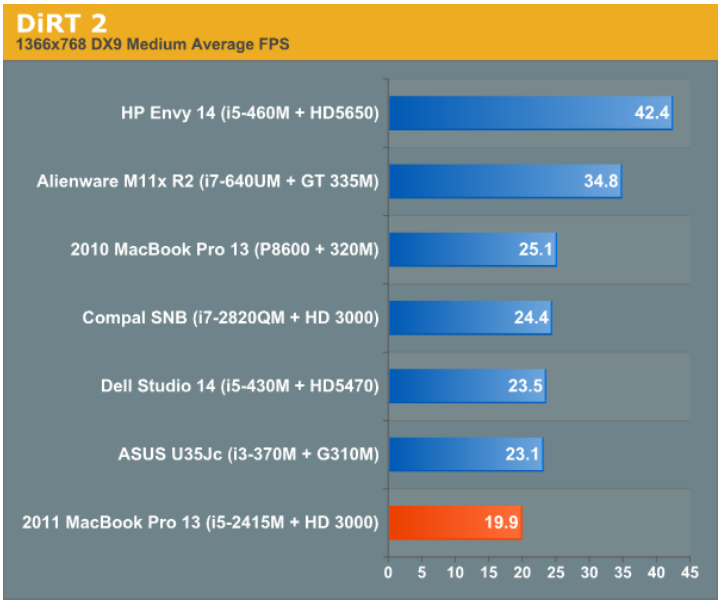
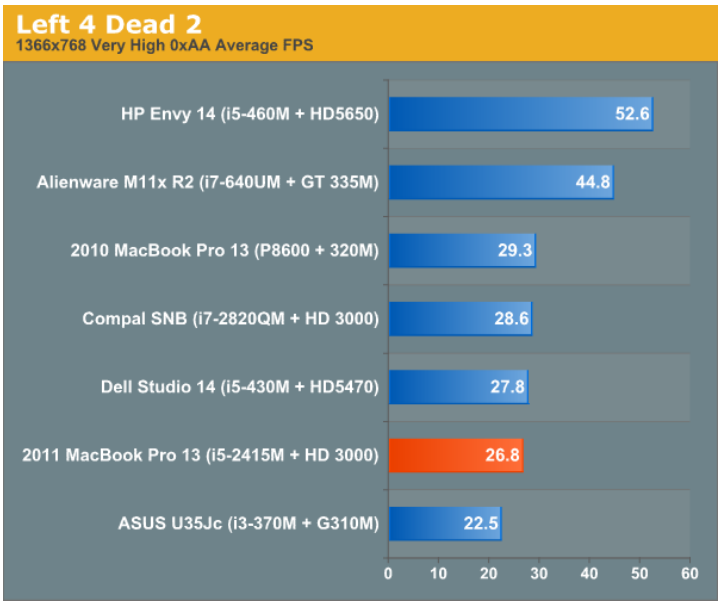
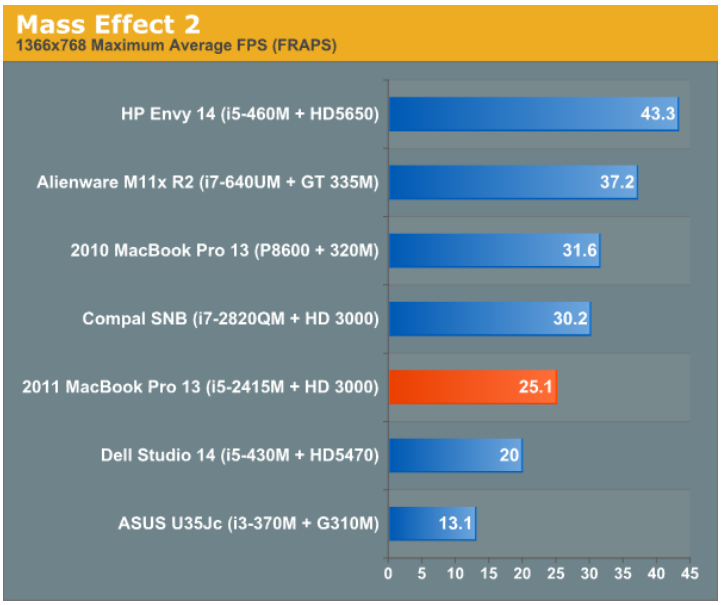
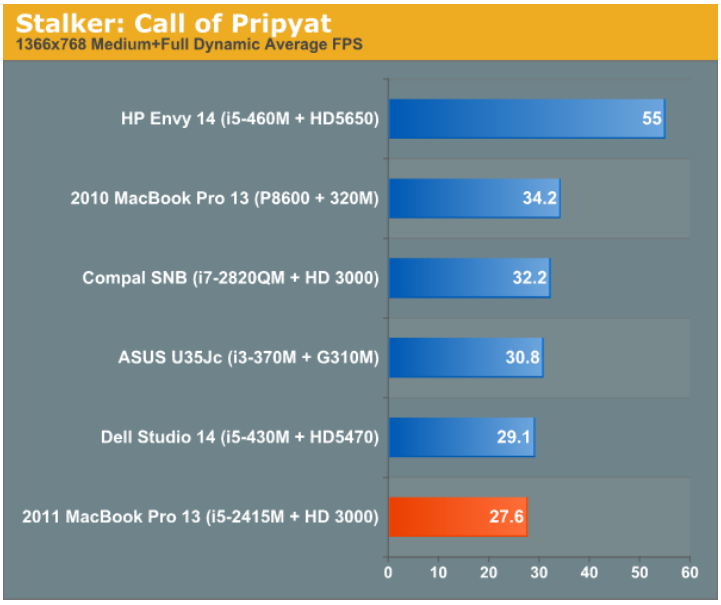
At medium settings, it's a bit worse, but L4D2, Mass Effect, STALKER, and SC2 remain almost playable. Battlefield and DiRT, not so much. Overall, we see performance goes down from the 320M by just under 20% on average (not counting StarCraft, which is again marginally faster due to the reliance on CPU performance).

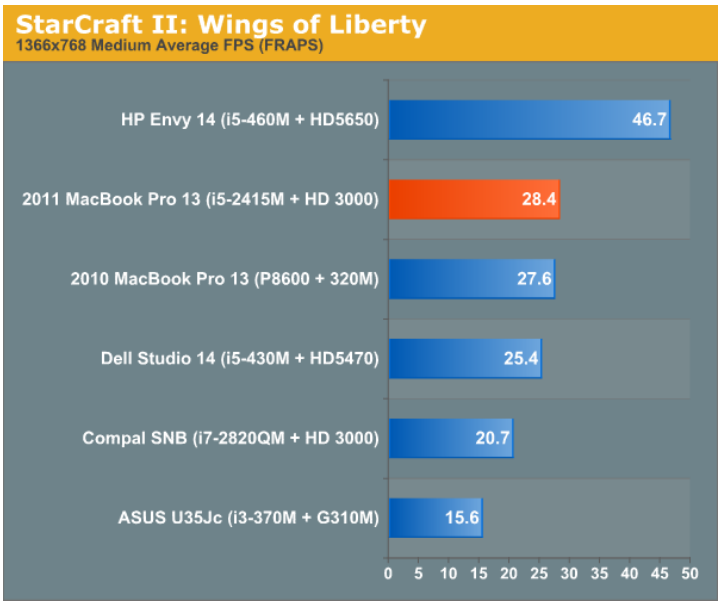

Battlefield: Bad Company 2
1366x768 DX10 Medium Average FPS (FRAPS)
HP Envy 14 (i5-460M + HD5650)
38.9
Alienware M11x R2 (i7-640UM + GT 335M)
31.6
Compal SNB (i7-2820QM + HD 3000)
24.7
2010 MacBook Pro 13 (P8600 + 320M)
23.2
2011 MacBook Pro 13 (i5-2415M + HD 3000)
18.1
Dell Studio 14 (i5-430M + HD5470)
15.3
ASUS U35Jc (i3-370M + G310M)
14.6
0 5 10 15 20 25 30 35 40 45


DiRT 2
1366x768 DX9 Medium Average FPS
HP Envy 14 (i5-460M + HD5650)
42.4
Alienware M11x R2 (i7-640UM + GT 335M)
34.8
2010 MacBook Pro 13 (P8600 + 320M)
25.1
Compal SNB (i7-2820QM + HD 3000)
24.4
Dell Studio 14 (i5-430M + HD5470)
23.5
ASUS U35Jc (i3-370M + G310M)
23.1
2011 MacBook Pro 13 (i5-2415M + HD 3000)
19.9
0 5 10 15 20 25 30 35 40 45

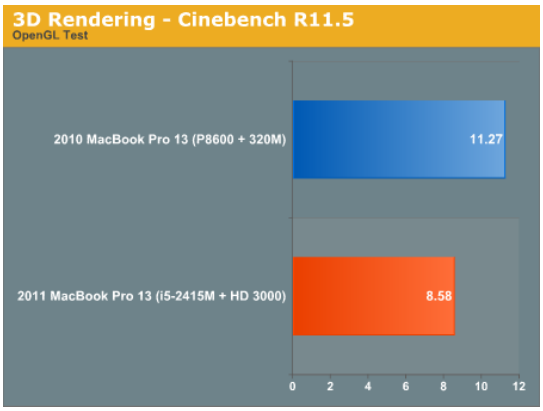

Left 4 Dead 2
1366x768 Very High 0xAA Average FPS
HP Envy 14 (i5-460M + HD5650)
52.6
Alienware M11x R2 (i7-640UM + GT 335M)
44.8
2010 MacBook Pro 13 (P8600 + 320M)
29.3
Compal SNB (i7-2820QM + HD 3000)
28.6
Dell Studio 14 (i5-430M + HD5470)
27.8
2011 MacBook Pro 13 (i5-2415M + HD 3000)
26.8
ASUS U35Jc (i3-370M + G310M)
22.5
0 10 20 30 40 50 60







We see a similar result in the Cinebench 11.5 OpenGL test—a 24% decrease in performance relative to the old MBP.



Given the huge leap in CPU performance, I'd have been okay if the graphics stayed on par with the previous MBP 13, but I was a little disappointed to see it that much slower. This is a weird one, since the same GPU gave us significantly better performance in the SNB test system. The only explanation we have has to do with turbo. The max turbo supported by the HD 3000 in the Core i5 2415M is 1.2GHz, down from 1.3GHz in the 2820QM. Now max clock speed isn't enough to explain this performance difference, but perhaps under Windows the 2415M's GPU doesn't turbo up quite as aggressively as the 2820QM's.

Anand consistently saw 10-15% faster results during the first run of a benchmark than the next four or five runs of the same test. This is probably due to thermal limitations—heat soak and overheating are pretty time-honored MBP traditions. However, my system shouldn't have been affected by thermal stress over time—I let it sit for some time between each benchmark run to let it cool, just to eliminate residual heat as a factor.

Based on CPU-Z, Apple isn't underclocking the GPU—it's running at the same 1.2GHz that's on the Intel spec sheets. The difference in performance is a little odd. The MacBook Pro, especially in 13-inch form, does have the potential to be thermally limited due to the size of the enclosure, but I'm not sure why a supposedly low-power graphics solution would be so thermally limited, even when testing to avoid the effects of heat build up as much as possible.

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The Big Picture

For years Intel has been telling me that the world is becoming more mobile. Yet I could never bring myself to replace my desktop with a notebook, despite the convenience. I was always a two-machine-man. I had my desktop at home and my notebook that I carried around with me to tradeshows and meetings. I eventually added more mobile devices to my collection: an ultraportable for when I need to write but don't need to edit/publish, a smartphone and a tablet. Admittedly the tablet gets the least amount of use of my computing devices, I mostly just have it because I sort of have to. Although my collection of computing devices has become more mobile, none of these devices has supplanted the need for a desktop in my life.

Last year when the Arrandale based MacBook Pros came out I decided to give the notebook as a desktop thing a try. The benefits were obvious. I would always have everything with me whenever I carried around my notebook. I wouldn't have to worry about keeping documents in sync between two machines. And I'd see a significant reduction in power consumption and heat output. I setup an external storage array for my photos, music and movies, and then moved my main drive image over to the 2010 15-inch MacBook Pro. I even made sure I had the fastest 2.66GHz Core i7 available at my disposal. Sure it wasn't an 8-core Nehalem setup, but maybe it wouldn't be that noticeable?

I lasted less than a day.

It wasn't so much that I needed an 8-core Xeon setup. I spend less than 10% of my time running applications that require all 8 cores/16 threads. No, the issue was that Arrandale's two cores just weren't enough.

Most of my workload isn't heavily threaded, but the issue with only having two cores is that if you are running one processor intensive task you're limited in what else you can do with your system. Run a heavily threaded application and you've got no CPU time left for anything else. Run a lightly threaded application that's CPU intensive and you still only have one remaining core to deal with everything else. I don't need 8 cores all of the time, but I need more than two.

I suspect I'm not the only user around who may not constantly run heavily threaded apps, but can definitely feel the difference between two and four cores.

I'll also go out on a limb and say the number of users who can tell the difference between 2 and 4 cores is larger than the number of users who can tell the difference between 4 and 8. What I'm getting at is this: Apple outfitting the new 15-inch MacBook Pro with a quad-core processor is a deliberate attempt by Cupertino to bring mobility to more of its desktop users.

Apple doesn't offer a good desktop Mac. You can get the Mac Pro but it's quite expensive and is often times overkill if you don't have a heavy content creation workload. Then there's the iMac, which can hit the sweet spot of the performance curve but there's no way to get it without a massive integrated display. Truth be told, Apple's 27-inch iMac is actually a bargain (for a Mac) considering you get a quad-core Lynnfield with a pretty good $999 display all for $1999. However not everyone is sold on the all-in-one form factor.

The new 15-inch MacBook Pro, when paired with an SSD, gives desktop users another alternative. Bring your external display to the party but drive it off of a notebook. You'll sacrifice GPU performance of course, but if you aren't a heavy gamer then you're not giving up all that much. In fact, for normal workloads you'd be hard pressed to tell the difference between one of these new MBPs and an iMac or Mac Pro.

Ultimately I believe this is why Apple chose to make the move to quad-core alongside Thunderbolt enablement. The main reason to stick four cores in a 15-inch chassis is for desktop replacement workloads. The last remaining limitation for desktop users adoption a notebook? Expansion.

The Mac Pro has four 3.5" drive bays. The 15-inch MacBook Pro, on a good day, has two 2.5" drive bays and that's only if you ditch the optical drive and buy an optibay. Then there's the whole fact that you can't add anything that's not a USB or FireWire device. Where are the PCIe slots? What about GPU upgrades? Currently you can't do any of that on a 15-inch MacBook Pro.

Thunderbolt could enable external expansion boxes. Not just for storage but other PCIe add-in cards. The bandwidth offered by a single Thunderbolt channel isn't really enough for high end GPUs, but a faster link could change the way switchable graphics works in the future.

My Concerns

Ever since the new MacBook Pros have arrived I've powered down the Mac Pro and have been using the 15-inch 2.3GHz quad-core as my desktop replacement. When at my desk it's connected directly to my monitor, keyboard, mouse, speakers and other peripherals. It's my desktop. But when I leave my desk, I unplug the five cables I've got going to the MBP (power, DisplayPort, 2xUSB, 1/8" audio and Ethernet) and carry my "desktop" with me.

The convenience is nice, I will admit. Before the mobile-as-a-desktop switch I always had to prepare my notebook with the data I needed for whatever trip I was taking. That usually included the latest copy of my Bench databases, snippets of articles I was writing and other pertinent documents. I don't rely on any cloud syncing for my most sensitive information, I did it all manually. With my laptop being my desktop (and vice versa), I lose the need to manually sync content across those two devices. All of my windows are in the same place all the time and life is good.

The performance difference in my day to day work isn't noticeable. Everything seems just as fast. If Quick Sync were enabled I'm pretty sure I'd be happy with the overall level of performance from this machine vs. a beefier Mac Pro setup. The number of times I need more than 4 cores for something other than video transcoding are pretty limited. I'm not saying that's the case for everyone, it's just the case for me personally.

There are downsides however.

Security. In the past, if I lost my notebook I only lost a minimal amount of data. I typically only put whatever I needed for my trip on my notebook, everything else was at home on my desktop. Now if I lose my notebook, tons of data goes with it—including lots of NDA data. FileVault (OS X's built in home folder encryption) is an obvious solution, but it doesn't come without issues. With FileVault enabled Time Machine backups can only happen when you're logged out and seem to take forever.

I believe OS X 10.7 is better equipped to handle security for a mobile desktop usage model. You get full drive encryption (FileVault only does your home folder) and perhaps even a Find my Mac feature.

Noise. In a desktop, when you've got a high workload on one or more cores your fans may spin a little faster but it's hardly noticeable. The heatsink you have cooling your CPU has a lot of surface area and the fan attached to it is large and spins slowly. With a notebook you don't have the luxury of quickly dissipating heat. As a result, when I have too many browser windows open with Flash running or if the dGPU is doing anything in 3D, the CPU/GPU fans in the 15-inch MBP spin up and are loud. Under these circumstances the setup is louder than my desktop which is annoying.

Cables. Ideally I'd want no cables connecting my notebook to all of the peripherals I need to connect it to. I want to sit it down and have everything just work wirelessly. I'd also want wireless power and a bunch of things that aren't realistic today. So I'm willing to deal with some cabling inconvenience. My preference would be two cables: one for power and one for peripherals/display. Today, it's five.

I believe this is another potential use for Thunderbolt down the road. Apple could build a Cinema Display with Ethernet, more USB ports, FireWire and audio out integrated into the display itself. A single Thunderbolt cable would carry all of those interfaces, reducing my current cable clutter to just two cables.

All of these are solvable problems, but they are definite issues today. Personally I don't believe they are enough to make me switch back to a desktop for work, although the security thing still bothers me. I may end up segmenting my data into stuff I keep on locally attached storage vs. on my notebook's internal drive in order to minimize what I carry around with me when I'm traveling. As for FileVault, I may look into alternative encryption options as Apple's solution right now just isn't practical if you use Time Machine.

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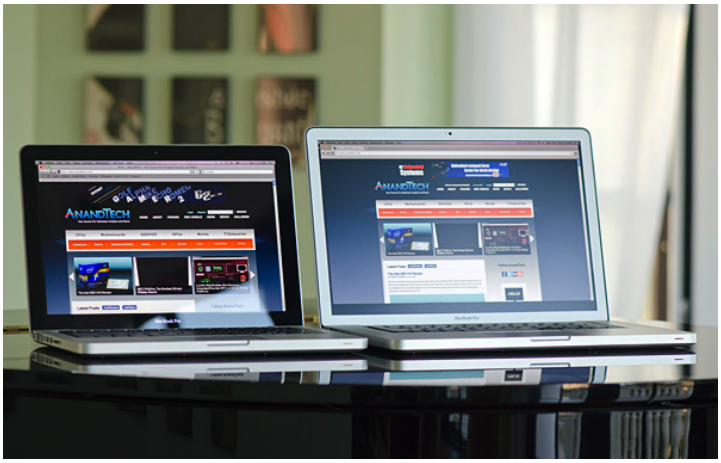
Final Words

For as little attention as the 2011 MacBook Pro launch was given by Apple, there sure is a lot to talk about.

The advantages are numerous. With the 13-inch MacBook Pro, under OS X at least, there simply aren't any downsides. You get much better CPU performance over the previous generation. In fact, the new 13 can outperform last year's 15 thanks to Sandy Bridge. The new 13 is quite possibly the best balance of portability and performance. It's the single largest upgrade you'll find in the lineup. If you own a previous generation 13-inch MBP, the upgrade is 100% worth it. Graphics performance is solid under OS X however questionable under Windows. For some reason we actually saw a step back in GPU performance vs. last year's 13-inch MBP when running games in Windows 7.

The 15-inch MacBook Pro is a beast. Although it comes in the same chassis as last year's model, it delivers much more performance. The move to quad-core Sandy Bridge makes the 15-inch MacBook Pro's performance formidable. Whereas I couldn't use the 2010 15 as my primary work machine, with an SSD the 2011 15-inch MBP does just fine.



Displays haven't really changed, which is both good and bad. On the one hand, Apple's MacBook Pros have always used good quality panels. On the other hand I'd like to see a higher res option for the 13-inch display—1280 x 800 is a big turnoff for me with the 13-inch model.

Thunderbolt is a nice addition however I expect that it'll be grossly underused for a while. We'll see some nice Thunderbolt enabled external storage solutions this Spring (helping perpetuate the mobile desktop usage model), but it'll be a while before we get the single-cable carrying USB, Ethernet, FireWire and DisplayPort to a display.

The WiFi improvements are welcome, although surprisingly absent from Apple's marketing collateral. The front facing 720p camera is also a nice touch.

It's not all rosy however. Apple fails to really take advantage of one of Sandy Bridge's biggest features: Quick Sync. The hardware encoder is used in FaceTime HD but you still get some very high CPU usage (at least of a single core). There's no support in QuickTime or iMovie 2011 for Quick Sync as of now, which is a major disappointment.

I mentioned that the 15-inch MacBook Pro is easily a desktop replacement, however you do have to deal with a loud fan under heavier CPU loads. Something a well designed desktop won't bother you with.

SSD support is still problematic. There are far too many reports of drives that don't work properly in the 2011 MacBook Pro, and Apple refuses to validate/ship anything but fairly mainstream SSD solutions. To make matters worse, although TRIM is finally enabled under OS X—it only works on Apple branded SSDs. I can understand Apple's desire to want to avoid dealing with the pitfalls of early SSDs with questionable firmware maturity, but I also believe it's Apple's duty to support as much hardware that's out there in the market today. If Apple offered something with SandForce SF-2200 class performance I'd have less of a bone to pick, but presently it doesn't.

Then there are the concerns about battery life. Under light usage there's a clear improvement over last year's models. The new 15-inch MacBook Pro is good for anywhere between 7—9 hours of light usage. That is assuming you don't have the dGPU running of course, at which point you should start talking about numbers below 5 hours. Even without the discrete GPU enabled, in the hands of a multitasker the new 15-inch MacBook Pro can easily burn through its 77Whr battery quicker than last year's model. While our worst case numbers don't look much lower than the 2010 model, the chances of you

getting less than 2.5 hours out of the new 15 are much higher than they were last year.

The new 13-inch model is less of a concern when it comes to battery life. It's still got a 35W TDP dual-core CPU and no discrete GPU to sap power. It's the move to four cores and the additional GPU that really hurt the 15-inch MacBook Pro under heavy usage.

Overall the new lineup is a significant step forward. As I mentioned earlier, if you're in the market for a 13-inch system the 2011 Sandy Bridge MacBook Pro is likely the one to get. The 15 is just as easy to recommend, provided you're ok with the downsides (higher temperatures, louder fans, shorter battery life under load). If you aren't ok with the downsides, just wait another year and get the Ivy Bridge based successor.