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# Repairability Smackdown II

*iPhone versus iPhone*

By Kyle Wiens and Peter Corcoran

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**F**ollowing our award-winning article last January [1], I thought it might be time to have another repair “smackdown,” courtesy of Kyle Wiens and the iFixit repair gurus. But what could we do that would equal our previous smackdown of tablet computers? Fortunately, Apple announced not one but two new iPhones just in time for iFixit to strip them down and for us to morph this into a new “Repairability Smackdown” article for *IEEE Consumer Electronics Magazine*. In addition to the expert disassembly work illustrated in this article, you will also find world-class punning and several new advanced theories on what the “s” and “c” letters in Apple’s product numbering scheme stand for.

Do remember reader discretion is advised if you are not comfortable viewing the naked electronic innards of mobile devices. If, however, such sights make you dance wildly with glee you are in for a big treat—*Peter Corcoran (PC)*.

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## IPHONE 5S TEARDOWN

A new iPhone release means a trip to the future—the iFixit teardown crew travels 17 h forward in time to get the iPhone 5s a day early. A big thanks for assisting with this magical feat of time travel is due to MacFixit Australia, who provided facilities in Melbourne for the teardown. To cover all our bases and make sure we had the right phone, we confirmed with our best linguists that the 5s “upside down” is still the 5s. (It really is—turn the page upside down if you don’t believe us!)

As we ready ourselves to delve into the delightful innards of the 5s, let us check out some of its tech specs:

- ▼ Apple A7 processor with 64-b architecture
- ▼ M7 motion coprocessor
- ▼ 16, 32, or 64 GB storage
- ▼ a 4-in retina display with 326 ppi
- ▼ an 8-mp iSight camera (with larger 1.5- $\mu$  pixels) and a 1.2-mp FaceTime camera
- ▼ a fingerprint identity sensor built into the home button
- ▼ available in three different colors: space gray, silver, and gold.

Now it’s time to break out the teardown tool kit so we can find out what is inside this baby. Speaking of tool kits, for this

teardown, we will be using iFixit's brand-new Pro Tech Screwdriver Set and a brilliant new antiglue weapon called the iOpener (we really hate glue!). You will recognize the iOpener when you see it because it has "iOpener" written on it.

*[And I guess it does what it says on the tin? Okay, enough product placement Kyle!—PC.]*

### PENTALOBULAR SCREW(ING) TIME

Let us get back to the disassembly. Apple continues the everlasting trend of locking users out with pentalobular screws—the screw that is almost as difficult to remove as it is to pronounce! Luckily, the iFixit team came prepared with their trusty iPhone 5 Liberation Kit, and to our pleasant surprise, it works!

*[What did I say, Kyle!—PC.]*



Unfortunately, we are ill-equipped in the color department, as we only have silver and black replacement Phillips screws. We are currently involved in heavy lobbying to our product designers to create 14k gold replacement screws. They will be US\$50 each and strip the first time you try to unscrew them, so they will be perfect for the iPhone. Stay posted.

Who is going to buy a "gold" phone anyway? We always thought that Apple was about style, not bling.

### SUCTION CUPS AND SPUDGERS

We are done screwing around; it is time to get this baby open! Just like last year, we enlist the help of a suction cup to free the display assembly from the rear casing.



Unlike last year, we make use of some gentle spudgering, just in case... *[Spudgering: inserting a thin plastic tool and gently leveraging the case of an electronic gadget open—PC.]*

Our careful spudgering pays off. At the bottom of the phone, a cable connects the Touch ID sensor in the home button to the lightning port assembly. This adds a small element of danger to disassembly, as pulling too hard

on the suction cup could cause accidental damage to the cable.

We survive this first booby trap and swiftly disconnect the Touch ID cable connector with the help of a spudger. *[That's the thin plastic tool—PC.]*

And so we have our first peek at the internal layout of the 5s. Comparing it to the iPhone 5, we spot very few

differences, the main one being the lack of a battery removal pull tab.

### OF BATTERIES AND WATTHOURS



With our favorite screwdriver set, we next remove a few metal connector covers and embark on the epic battle of battery removal. The missing battery pull tab, though seemingly innocuous, indicates a bigger problem for battery repair: glue.

Perhaps the "s" in 5s stands for "stuck," as in "this battery is stuck in with a lot of glue," or "I hope you didn't want to replace your battery—you're going to be stuck with this one." *[Or maybe it is "secure," as in your battery will never fall out accidentally?—PC.]*

While we did love a tool-less battery removal as we have seen in other phones, we are forced to settle for thermal battery removal via an iOpener. *[And I wonder where I could buy one of those, eh Kyle?—PC.]*



Holy adhesive! It appears Apple ditched the minimal adhesive in the iPhone 5 in favor of those two huge white runways of adhesive holding the 5s(tuck) battery in place. The 5s has a claimed 10 h of talk time on third-generation (3G), but there are rumbles

that iOS 7 is not doing you any favors. Our phone has a 3.8 V–5.92 Wh–1,560 mAh battery. This compares with:

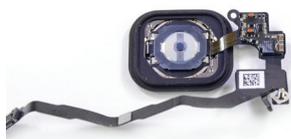
- ▼ **iPhone 5:** 3.8 V–1440 mAh–5.45 Wh. Talk time: Up to 8 h on 3G. Standby time: Up to 225 h.
- ▼ **Samsung Galaxy S4:** 3.8 V–2600 mAh–9.88 Wh. Talk time: up to 7 h. Standby time: Up to 300 h.
- ▼ **Motorola Moto X:** 3.8 V–2200 mAh–8.4 Wh. 24 h of "mixed usage."

### EYEING THE (RETINA) DISPLAY

With the battery safely removed, we turn to the next step in our disassembly journey: removing the (unchanged) 326-ppi retina display assembly. A few flicks of a spudger to disconnect the FaceTime camera, digitizer, and LCD cables, and the display is free.

Looking for some tech specs on the display? Well look no further! In fact, just look backwards...to the iPhone 5. Despite the trend in almost every other recent smartphone release, the iPhone 5s display is no bigger, better, or badder than the iPhone 5.

## FINGERING THE TOUCH ID SENSOR



ing your iPhone the finger will not make it all the way back to Cupertino, California.

We worry about how well the sapphire crystal covering the sensor can protect it from degrading over time like most CMOS fingerprint sensors. If not, it could become a ticking time bomb, just like that super-glued battery.

[There are also questions as to how secure it will prove to be; it seems it was cracked in less than 48 h—PC.]

## IMPROVING ISIGHT



We next uncover the iSight camera. According to our friends at Chipworks, “the DNL markings are consistent with the markings on the camera modules housing the Sony IMX145 we saw in the iPhone 4s and the iPhone 5. The marks on the side of the module are different, but our industry insiders tell us this is Sony’s again.”

Given Apple’s statement that the pixel pitch on this camera is 1.5  $\mu$ , this sensor must be a newer variant of the IMX145. This makes sense given the claims of improved image quality for this new model.

We find another hardware update: the new dual-color flash. White and amber light-emitting diodes sit by the camera to balance the flash-induced ghostly tones of night-life photography. It will be interesting to see if this neat idea works in practice.

## WIRED AND WIRELESS



A great example of Apple’s iterative design, the 5s shows some streamlining and optimization in its internal construction, although so far it is largely similar to the iPhone 5. But those silly antenna

interconnect cables we had to suffer last year are gone, leaving one less thing to break or get accidentally disconnected. Now if only they had decided to move that antenna connector from the bottom of the logic board to the top.

[And they did provide the fingerprint sensor cable booby-trap to make up ... —PC.]

Looks like we found a Murata 339S0205 Wi-Fi module (based on the Broadcom BCM4334, according to Chipworks). Again comparing our 16- and 64-GB iPhone 5s models, it seems that the Murata IC is the same between both iPhone 5 models.



## THE MAIN LOGIC BOARD

Open ses-EMI! [Those iFixit dudes remove the metal EMI shields from the motherboard—PC.]

Behold, the IC treasures identified:

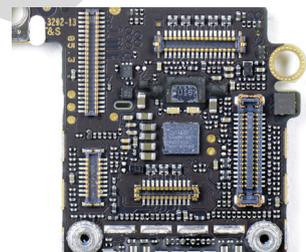
- ▼ **Red:** SK Hynix H2JTD-G8UD3MBR 128 Gb (16 GB) NAND Flash
- ▼ **Orange:** Qualcomm PM8018 RF power management IC
- ▼ **Yellow:** TriQuint TQM6M6224
- ▼ **Green:** Apple 338S1216
- ▼ **Blue:** Broadcom BCM5976 touchscreen controller
- ▼ **Pink:** Texas Instruments 37C64G1
- ▼ **Black:** Skyworks 77810.
- And more ICs!
- ▼ **Red:** Skyworks 77355
- ▼ **Orange:** Avago A790720
- ▼ **Yellow:** Avago A7900
- ▼ **Green:** Apple 338S120L.

A super-awesome thanks to the Chipworks (www.chipworks.com) team for helping us decode and discern these delightful devices.

Turning our attention to the backside of the logic board:

- ▼ **Red:** Apple A7 APL0698 SoC
- ▼ **Orange:** Qualcomm MDM9615M LTE Modem
- ▼ **Yellow:** Qualcomm WTR1605L LTE/HSPA+/CDMA2K/TDSCDMA/EDGE/GPS transceiver
- ▼ **Blue:** M7 motioncoprocessor—it knows where you have been, to the millisecond.

From Chipworks: “The M7 is dedicated to processing and translating the inputs provided to it by the discrete sensors: the



gyroscope, accelerometer, and electromagnetic compass mounted throughout the main printed circuit board.”

### A NEW CPU



It's time to investigate the new kid on the block, the A7 CPU. Along with the fingerprint sensor, the A7 is a major enticement for consumers to pick the iPhone 5s over the 5c. The A7 is

advertised as providing twice the performance of the 5's (and 5c's) A6 processor.

Most of the A7's performance gains do not come from any advantages inherent to a 64-b architecture but rather from the switch to the newly designed ARMv8. In fact, the switch to the A7, with ARMv8 core, marks the first use of a 64-b processor in a smartphone.

The modern ARMv8 instruction set was designed for a 64-b architecture. It does away with the legacy support of the last 20 years, which increases efficiency, improving performance without sacrificing battery life.

### PLUS ÇA CHANGE



The lower peripherals on the 5s look very similar to those in the 5, although the speaker assembly comes out with slightly more ease in this iteration.

With the speaker assembly out, the headphone jack/microphone/lightning connector assembly comes out easily.

As with previous generations, you will have to replace multiple components at once because the design is not modular.

### IPHONE 5C TEARDOWN

The tornado of new Apple devices has taken us over the rainbow, and we have landed in the world of technicolor. We now “c” the light, but what will we “c” inside? Only tools, time, and tenacity (T3) will tell. [The Wizard of Oz meets Terminator 3—Wow! These iFixit guys are sick puppies —PC.]

We know you are as anxious as we are to find out exactly what the “c” means. Here at iFixit, we like to answer the hard questions in life: Why is it called the c? Why can't Apple name devices in a way that makes sense? What will the insides be like? Do penguins really have knees, or is it false information propagated by the Internet? So join us for a colorful taste of the Apple rainbow as we tear down the iPhone 5c.

This is the second teardown of our time-warped tear-a-thon, and though this device may be feeling blue, Teardown Team morale is higher than ever. Nothing can bring us down on such a beautiful moonlit night—if only the same could be said for these guys.

We have said it before, but we really want you, our adoring public, to know how grateful we are for our good friends at MacFixit Australia for letting us use their office in Melbourne for these teardowns. Remember, they stock Mac and iPhone upgrades/accessories. [Kyle, rein it in! —PC.]

### ALMOST ANY COLOR YOU WOULD LIKE?

With an array of colors from which to choose (white, blue, pink, green, and yellow), we decided upon blue. What makes the iPhone 5c different from the iPhone 5s? We're bent on finding out. For starters, the rear case is composed of plastic—is our work here done already?

Technical specs include:

- ▼ Apple A6 system-on-a-chip (SoC)
- ▼ 4-in retina display with 326 ppi
- ▼ 8-mp iSight camera
- ▼ fourth-generation (4G) LTE connectivity
- ▼ 16 or 32 GB storage.

### THE PENTALOBULAR VARIATIONS



So what does the “c” really stand for? We have already identified a major difference in color, but we are not ready to close the book on this mystery, just yet.

As promised, every port, button, and slider has had its metal swapped out for plastic. Cheaper, per chance?

The volume buttons are considerably larger, and the ten-hole microphone grille and 16-hole speaker grille have been replaced with one- and four-hole grilles, respectively. Not only are these parts made of plastic, they also look a lot more...“childish.”

The super-tiny pentalobular screws are slightly different than the ones we found in the iPhone 5 and 5s. A minor variation, but perhaps significant? But back to work.

The front panel assembly is dispatched using a small suction cup. Despite the plastic backing, the display assembly of the 5c fits just as snugly as the 5s and 5. We are beginning to wonder if the “c” might possibly stand for “copy.”



### SMURF (BLACK) AND BLUE

Although it may look like we are performing painful dental procedures on a Smurf, we assure you that removing the 5c screws is as quick and painless as Novocaine. Now removing the battery requires the assistance of our iOpener, a departure from the easy battery replacements of yesteryear. Still, iOpener represents a significant improvement on our past use of a heat gun. Now we can focus the

heat where it should be, and environmentally-friendly microwaves can supply the glue-melting energy—and a bonus for Apple’s carbon footprint.

After a few minutes of heat and some diligent spudgering, we leave our iPhone 5c black and blue in a pile of pieces. [No Smurfs were hurt in the making of this teardown, honest! The display frame is black and the case body is blue—PC.]

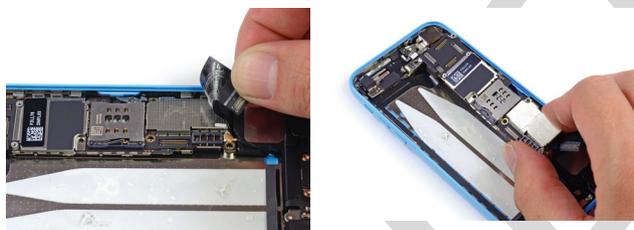
### ASSAULT AND BATTERY



Fear not, despite the new adhesive strips (also seen in the 5s), battery replacement is very much the same process as it was in the 5 and 5s. Although the 5c is essentially a repackaged iPhone 5 (in colored plastic, in case that had

not been made apparent yet), the battery has been beefed up a bit, clocking in at 3.8 V–5.73 Wh–1510 mAh, compared to the 3.8 V–5.45 Wh–1440-mAh battery of the iPhone 5.

Hopefully, this will address some issues with battery life brought about by the iOS7 update. Larger battery...Hmmm, could the “c” stand for battery “capacity?” It’s a theory; it’s probably wrong.



### IN (ANTI-)PRAISE OF ADHESIVE

As we go to remove the antenna connectors with our trusty spudger, we notice something we haven’t seen in any recent iPhone: adhered connectors.

In case our teardown tirades were too subtle, we’ll reiterate: we strongly dislike glue. Actually, that is mild—we hate glue; it is a really unprofessional approach to securing electronics and guaranteeing electrical connectivity.

Annoying adhesive aside, we get to removing the logic board from our little blue iFriend. [Aw, ain’t he cute—PC.]

### COMPARISON TIME: IPHONE 5S VERSUS IPHONE 5C

Since we have both of the new iPhones on the table, it is time to take a little comparison tour. Interestingly enough, the 5s sports a slightly lighter display assembly, despite the addition of a fingerprint sensor and luxurious sapphire home button.

The 5c’s 1,510 mAh battery is just a hair slimmer than the 1,560-mAh battery of the 5s.

### CPUs COMPARED



a 32-b memory architecture.

By contrast, the A7 is on a larger 102-mm<sup>2</sup> die with 28-nm process; while it only runs at the same 1.3 GHz, it has full 64-b instruction set and memory architecture, and you will only find this hot puppy in the iPhone 5s.

### CAMERA MODULES



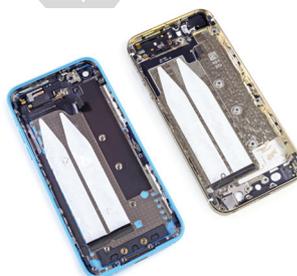
Comparing the cameras on the iPhone 5c (left) and 5s (right), we see little difference between the two. The one difference between the 8-mp rear-facing cameras is the aperture. The 5c boasts an aperture of f/2.4 compared to the f/2.2 of the 5s. Additionally, the vibrator motor assembly in the 5c is actually slightly larger than that of the 5s, despite its similar component design.

### THE BIG QUESTION



Now you have seen the internals, but a new question remains...will it bend? We may not have super strength, but we put this case to the muscle test anyway. The results: this lacquered plastic is as strong and blue as Captain Planet. It is good to know that, although the rear panel is made with plastic presumably to cut costs, Apple did not compromise build quality in the process.

### COMPARING CASE NOTES



Yes, well this is clearly the biggest difference. The iPhone 5c has the A6 CPU manufactured using a 32-nm process on a 96.71-mm<sup>2</sup> die, ARM-7 dual core running at 1.3 GHz. There is also a 266-MHz graphics processing unit (GPU) <AU: Please check whether GPU is spelled out correctly.> and

the 5s sports a slightly lighter display assembly, despite the addition of a fingerprint sensor and luxurious sapphire home button.

All we are left with is a serious case of the blues. Standing next to its sibling, the iPhone 5s, the colorful 5c case looks very similar in structure. The most noticeable difference is (unsurprisingly) the material.

The less visibly noticeable difference is weight: A larger mass of plastic is required to match the

strength and durability of a smaller mass of aluminum. And nestled within the polycarbonate backing is a steel frame that serves as an antenna and structural support. Thus, the 5c rear case is way heavier: 43.8 g versus 25.9 g for the 5s.

## REPAIRABILITY RECKONING



**iPhone 5s Repairability:** 6 out of 10 (with 10 being the easiest to repair).

Just like in the iPhone 5, the display assembly is the first component out of the phone, simplifying screen replacements. The battery is still fairly easy to access,

even though it is not technically “user replaceable.”

But the battery has lost the 5’s convenient pull tab, and gained more resilient adhesive—it now requires heat and prying to remove. This represents a step backwards for iPhone repairability—hand your heads Cupertino people!

The fingerprint sensor cable can be easily ripped out of its socket if a user is not careful while opening the phone.

The iPhone 5s still uses Pentalobe screws on the exterior, making the 5s difficult to open.

The front glass, digitizer, and LCD are all one component, thereby increasing the cost of repair.

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The battery is still fairly easy to access, even though it is not technically “user replaceable.”

Adhesive on the antenna connectors hinders disassembly.

The battery has lost the 5’s convenient pull tab and gained more resilient adhesive—it now requires heat and prying to remove.

The iPhone 5c still uses Pentalobe screws on the exterior, making it difficult to open.

The front glass, digitizer, and LCD are all one component, thereby increasing the cost of repair.

## CONCLUSION

The iPhone 5 was a major step forward in repairability for Apple. The use of adhesive was restrained, and there were many improvements over the earlier iPhone models. Unfortunately, both of these new iPhones share very similar assembly methods that represent lost ground. It is a pity that the market leader in smartphone technology is still shirking its leadership duties in terms of environmental impact and long-term product repairability. We strongly urge the Cupertino crowd to rethink the current manufacturing process and return to the improved practices of the original iPhone 5—and you’ll save a small fortune in glue sticks as well!

## ABOUT THE AUTHORS

**Kyle Wiens** (kyle@ifixit.com) is the cofounder and CEO of iFixit, an online repair community internationally renowned for its open source repair manuals and product teardowns. Launched out of his Cal Poly college dorm room in 2003, iFixit has now empowered millions of people to repair their broken stuff. In 2012, he started Dozuki, a software company that is revolutionizing online technical documentation for manufacturers. He is a board member of the IEEE Consumer Electronics Society. He has testified on electronic exports in front of the International Trade Commission and is actively involved in developing global environmental standards.

**Peter Corcoran** (pcor00@gmail.com) earned his Ph.D. degree from Trinity College Dublin, Ireland, in 1987. He is currently an active researcher with interests in home networking, multimedia and communications technologies, biometrics, embedded systems, and consumer imaging. He is a coinventor on more than 150 granted patents and is an author of over 70 journal publications. He is currently the editor-in-chief of *IEEE Consumer Electronics Magazine* and the vice-dean (engineering) of research and graduate studies at the National University of Ireland Galway. He was elevated to IEEE Fellow in 2010 for his contributions to digital camera technology.

## REFERENCE

[1] K. Wiens and P. Corcoran, “Repairability smackdown: How do the latest tablet models stack up?,” *IEEE Consumer Electron. Mag.*, vol. 2, no. 1, Jan. 2013, pp.42–50.





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