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<tr>
<td>Author(s)</td>
<td>Corcoran, Peter</td>
</tr>
<tr>
<td>Publication Date</td>
<td>2013</td>
</tr>
<tr>
<td>Publisher</td>
<td>IEEE</td>
</tr>
<tr>
<td>Link to publisher's version</td>
<td><a href="http://dx.doi.org/10.1109/MCE.2012.2223155">http://dx.doi.org/10.1109/MCE.2012.2223155</a></td>
</tr>
<tr>
<td>Item record</td>
<td><a href="http://hdl.handle.net/10379/3298">http://hdl.handle.net/10379/3298</a></td>
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**REPAIRABILITY SMACKDOWN**

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Repairability Smackdown

by

Kyle Wiens & Peter Corcoran

Introduction

Tablets are the latest craze in the Consumer Electronics (CE) world. New models are hitting the shelves every few months, many featuring new screen and speaker technologies and the latest in low-power, high performance mobile CPU with the latest models beginning to feature GPU units and specialized multimedia IP cores.

It is easy to get caught up and lost in this technology jungle and focus on the advanced features of the latest and greatest tablets. But these devices and the advanced technologies they embody require significant quantities of relatively scarce mineral resources, in particular what are known as "rare earths". Given the current scarcity of these materials we should expect that today's tablets will have reasonably long life-spans, and in particular that they can be easily repaired and failed components are easy to access and repair. Highly repairable devices make the best use of today's scarce resources while also providing better value for the consumer and putting less stress on the environment.

Because the repairability of today's devices is seldom discussed we thought it was time to help put a bit more emphasis on it. And a great way of achieving that is to take a look at some of the latest tablet devices available today and compare them from the perspective of repairability.

For this article we have selected two larger tablets, the Galaxy Note 10.1 [3] from Samsung and the iPad3 [4]; and two smaller tablets, the Kindle Fire HD from Amazon [2] and the Nexus 7 [1] from Google.

First Steps - Gaining Entry

Before we can repair any device, the first steps have to be gaining access to the internal circuitry. Many CE devices are intentionally designed to prevent consumers opening the device and specialized tools are often required to simply get the cover off the device. Let's take a look at our four tablets and see how difficult it is to gain access to each of them.

Nexus 7

Plastic opening tools make cracking the Nexus shell like cutting through butter, thanks to its retaining clips around the perimeter of the device.

One single millimeter, that's the difference in thickness between the 9.4 mm glued iPad and the 10.4 mm retaining-clipped Nexus.

That's the difference between being able to open a device and service all of its internals, easily, or with great difficulty.

A small trade-off to allow you to extend the life of your device through repair, as opposed to tossing it in a landfill. Nobody will complain about that one millimeter difference in day-to-

...
day use, but the user-serviceability it brings will make all the difference when the device breaks.

And so the Nexus 7 opens its internals to us. The back cover's dark and light layers remind us of something a Storm-trooper would have in his arsenal, but the key point here is that we've gained access to this "BattleStar" without an epic struggle.

Kindle Fire HD

Again a simple plastic opening tool quickly removes the back case to reveal our first glimpse at the internals.

We just praised the Nexus 7 for being so easy to get into compared to the iPad, and sacrificing only a single millimeter to do so. Amazon has also created an easy-to-open tablet that's another 0.1 mm thinner than the Nexus 7. We've said it before, but we'll say it again: you don't need to sacrifice thinness to make a repairable device.

The Kindle Fire HD is the big kid in town at the moment. Like the Nexus it opens easily and there is good access to all the internal components. The battery is secured by screws and is contained in a metal casing. The layout and design of some of the connectors have been altered from earlier Kindle Fire designs, but none of these compromise the repairability of the device.

Galaxy Note 10.1

The Note 10.1, with a thickness of 8.9 mm, is actually thinner than the third generation iPad, and almost the same thickness as the iPad 2. [As a reminder, a standard pencil measures in at 6.4 mm. So, if you're looking for the ultimate slimness in note taking, paper and pencil is still the way to go.]

The 10.1" screen on the Note 10.1 is also larger than the 9.7" screen on the iPad. [But paper and pencil win again. The Note 10.1 and the iPad fall a few inches short of the 13.9" diagonal length of a standard piece of paper.]
The 10.1" screen on the Note 10.1 is also larger than the 9.7" screen on the iPad. [But paper and pencil win again. The Note 10.1 and the iPad fall a few inches short of the 13.9" diagonal length of a standard piece of paper.]

But enough philosophizing, let's get back to the teardown. Remove a few Phillips screws, a few clips, and we're in!

We liked the combination of screws and clips on the Note. The screws are enough of a hassle to keep out meddling kids, but will by no means deter anyone who needs to fix something inside. Thumbs up to the Note for ease of access.

**iPad3**

The latest and greatest iPad features a 5 MP iSight rear-facing camera, boasting autofocus, face detection, 1080p HD video recording, and video stabilization. This is definitely a great improvement over last year's weak 0.7 MP rear-facing camera.

The 2048×1536 pixel Retina display is another state-of-art feature, but after we turned it off and began the teardown process it becomes a major headache rather than a thing of wonder.

Yes, just like its predecessor, this new iPad is very difficult to disassemble. Adhesive secures the glass to the case, making common repairs and battery replacement extremely difficult. No nice clips or simple screws here - unfortunately we need to break out the heavy duty heat gun to gain entry. This looks like being an epic battle!

Yes, unlike the original iPad we need the help of a handy dandy, high-power, heat gun to remove the front panel. In fact it requires quite a healthy does of heat to loosen all that glue.

Then it is necessary to work on prying up the front panel with a plastic opening tool and carefully inserting a trusty guitar pick, followed by another, and another ...

Yes, you'll need to check out your local guitar store and check they have enough in stock before you try to do this at home. You do not want to run out of these essential items in the middle of this delicate operation!

On a more serious note, Apple is estimated to ship 1 million units on launch day, and the long term environmental impact of this unfortunate design choice will be significant.
Once the display unit is cleanly separated it needs to be lifted. A heavy-duty display like this should only be removed with heavy-duty suction cups, applying an even pressure to avoid cracking the expensive display.

And so the first legitimately-purchased, legitimately-owned iPad 3 also became the first legitimately-opened iPad ... in the world.

Apparently, the new iPad has a face, and it's not happy. Looks a bit like a "bad robot"!

Now much as we hated trying to remove the clips in the original iPad, this quantity of adhesive is even more of a pain. Be ready to crack your front panel if you dare open it! And it's not the only place that Apple has used copious quantities of glue, but more on that later.

We are not quite done yet, because you next have to loosen a few screws around the frame of the LCD screen. Yes, rather than enjoy the 264 pixels per inch on this brand new device, we opt to remove the acclaimed display. Why? Because we're iFixit, and that's how we roll.

As we lift the LCD, we hear the cries of 3,145,728 pixels being dislodged from their homes inside the iPad 3.

Lifting off the LCD finally exposes the iPad 3's battery; While the iPad 2 housed a formidable 25 watt-hour Li-ion battery, the iPad 3 has upped the ante to the tune of 42.5 watt-hours.

So we've finally gained access, but it is pretty clear that Apple did not intend to make things easy for 3rd party repairers. And while you now have access to the main motherboard of the iPad, it will be necessary to remove the battery to get at some of the other sub-components. But more on that later.
The Battery Subsystem

The battery is at the heart of a modern tablet device. Without a day-long battery life the mobility and utility of a tablet is lost. And isn't it this mobility and utility that has made this product category so successful? As suggested in a recent article in [5], tablets allow us to bring the Internet into our living rooms, but without carrying the office with us as well. This is how tablets distinguish themselves from laptops and other more conventional computing devices.

Now as we all know batteries don't last forever and in normal usage the battery is likely the first subsystem whose performance will deteriorate and require replacement. So we can deduce a lot about a manufacturer's commitment to repairability from the ease with which battery replacement is achieved for a device.

Nexus 7

The Nexus 7 has a 4326 mAh, 16 Wh battery that can last 9:49 hours. The Kindle Fire, by comparison, has a 4400 mAh, 16.28 Wh battery -- but only lasts 7:42 hours. Go figure.

For further comparison, this time falls right in between the batteries found in the 2012 iPad models, which have 9:52 hours for HSPA and 9:37 hours for LTE. Except that the iPad 3 units are slightly larger at 42.5 Wh / 11500 mAh.

This battery is glued in, but is still very easy to remove. In our teardown unit there was only a small amount of adhesive around the metal frame and it can be easily prised from the main device frame. We still prefer no glue, but in this case it is not a serious impediment to removing or replacing the batter.

Kindle Fire HD

Ah, this is what we like to see - no glue! The battery is secured by four Phillips #00 screws and one lonely T5 Torx screw. While this single T5 Torx isn't going to keep out our prying fingers, it might be enough to sour the battery removal attempts of someone who is less well-equipped. Lesson learned, kids: don't bring your Phillips to a Torx fight.

Well this is a first. The battery is enclosed within a metal casing. We believe this is for structural reinforcement, as well as for shielding the battery from any possible electrical damage.

The Kindle Fire HD gets its spark from a 3.7 V, 4400 mAh, 16.43 Wh Li-ion battery that— as in most mobile devices— dominates most of the inner real estate. Amazon says this Kindle will operate for 11 hours without having to plug it in. That is a whole four extra episodes of Family Guy than the Nexus 7 will give you. Yipee!
Galaxy Note 10.1

While it may appear as though the battery in the Note 10.1 is strapped down à la Gulliver, the ribbon cables are actually very easy to detach.

In fact, the battery is very easy to remove, even when compared to the Nexus 7.

Just like the iPad, the battery in the Note accounts for a large portion of the device's weight. It weighs in at 136 grams. That's 23 percent of the 594 gram device.

Still, in order to keep this device so slim, we have a feeling the battery capacity had to take a slight hit. This battery is rated at 3.7 volts, 7000 mAh, and 25.90 watt-hours, for an estimated battery life of 8 hours. This is a bit less than other devices we've reviewed here, but it is going to be the easiest battery to replace when your device gets a bit older.

However our focus today is repairability and the Note definitely scores highly here!

iPad3

The iPad battery replacement has a few strong negatives. Apart from the initial difficulty to get the case open, it is also necessary to completely remove the main motherboard before the battery can be "de-glued".

Yes, we are back to the "G" word for the iPad battery - it is stuck into the case with a ton of glue. To get your battery out you first have to flip the case over and heat that shiny aluminum case with your heat gun.

Once it is evenly heated - your can find a detailed guide on http://www.ifixit.com - then you have to carefully separate the batteries from the glue carefully to avoid damage. Its quite likely you'll have to heat the case a few times to get all three batteries out of the case.

The iPad3 uses three massive Li-Ion cells to provide an impressive 10-hours of battery life. While the iPad 2 housed a formidable 25 watt-hour Li-ion battery, the iPad 3 has upped the ante to the tune of 42.5 watt-hours.

Its 3.7 volts and estimated 10 hours of use (9 with cellular data network) are comparable to that of the iPad 2, but we assume the extra 17.5 watt-hours are put to good use powering the extra RAM and greatly improved GPU which is presumably needed to show-off that retina display in all its glory. Apple does make cool stuff - we just can't stand all that glue!

Maybe we should start calling our ifixit techies G-Men?
Heart of a Tablet - The Motherboard
Any CE device these days has a pretty sophisticated core of CPU linked to a number of primary sub-systems, including wireless connectivity, touch-screen controller, and audio and camera modules. For this article our main consideration is to consider how accessible and easy the motherboard, and subsystems are to replace, but as electronic engineers we can’t quite resist taking a more detailed look at such state-of-art electronics. So please forgive if we move a little off-topic in this section.

Nexus 7

The L-shaped motherboard is littered with connectors and screws, but nothing too difficult for the iFixIt Pro Tech Toolkit.

We are guessing that this number is not the date code on expired milk, but rather a part manufacture date. It reads 12 05 04, indicating a May 4, 2012.

There is a seal which you need to break in order to get the motherboard out. Presumably this would invalidate any warranty, but its not a physical impediment to the repairability of the device. There are also some connectors to I/O and camera and microphone subsystems, but nothing difficult.

And finally, here is the front of the motherboard:

• NVIDIA T30L Tegra 3 processor (red)
• Hynix HTC2G83CFR DDR3 RAM (orange)
• Max 77612A inverting switching regulator (yellow)
• AzureWave AW-NH665 wireless module (green-blue)
• Broadcom BCM4751 integrated monolithic GPS receiver (dark blue)
• NXP 65N04 Integrated NFC Chip (purple)
• Invensense MPU-6050 gyro and accelerometer (black)

And the rear side:

• Kingston KE44B-26BN/8GB 8GB flash (red)
• Realtek ALC5642 (orange)
• ELAN eKTF36248WS EKTF3624 series 16-bit touch panel signal processor MCU (yellow)
• ELAN eKTH10368WS EKTH1036 series touch panel controller (green-blue)
• Texas Instruments SN75LVDS83B LVDS LCD display driver (dark blue)
• Hynix HTC2G83CFR DDR3 RAM (black)

Kindle Fire HD

The motherboard in the Kindle is readily accessible, but there is an awkward copper tape covering the main CPU. With some careful work with a razor blade we were able to peel up this tape from the main processor.

The copper tape allows the processor to dissipate heat, but is definitely more problematic to remove than a good ol' fashioned heat sink. And it is important not to damage it if you want to put your Kindle back together again!

Let's see what ICs Amazon threw into the Fire HD to make it burn:

• Samsung KLMAG2GE4A eMMC 16 GB Flash Memory and Flash Memory Controller (red)
• Elpida B8164B3PF-1D-F 8 Gb (1 GB) DDR2 RAM (orange)
• Texas Instruments TWL6032 Fully Integrated Power Management IC (yellow)
• Broadcom BCM2076 Multifunction Monolithic IC with GPS and GLONASS AGPS, Bluetooth 4.0, and FM Receiver/Transmitter (green-blue)
• Wolfson WM8962E Ultra-Low Power Stereo CODEC (dark blue)
• B50 5222 12507A9A10, which Chipworks believes to be the Wi-Fi package (purple)

The backside of the board is mostly blank, save for an InvenSense MPU-6050 gyroscope/accelerometer and one of the two Wi-Fi antennas used for MIMO technology.

Do you notice something strange here? There is no CPU!

With no processor in sight on the Fire HD's board, we figured they had tried to pull one over on us—and we were right! The Texas Instruments OMAP 4460 dual-core processor we uncovered is an upgrade from the standard Fire's 4430 processor and is hidden under the RAM chip!

Amazon states that the Kindle Fire HD has a 1.2 GHz processor, even though TI claims the 4460 operates at up to 1.5 GHz. Rooters, take note.
Once the battery is removed the motherboard in the Note is quite easy to remove. There are a few remaining ribbon cables but once they are gone it is no problem to extract this quite large motherboard.

Now a quick work on EMI shields - an important element of state-of-art motherboard design. These can be scary/tricky to remove, depending on which procedure a manufacturer uses to attach them to the motherboard. In some cases, the shields are soldered directly to the motherboard (the worst scenario), while in others the frames of the shields are soldered, but the top covers are removable.

For the Galaxy Note, the EMI shields happen to be screwed in. We love screws, especially when they hold in components that typically require de-soldering.

This is the first device we've seen with screwable EMI shields. Thumbs up to you, Samsung and a plus for device repairability.

Here is a list of the main components on the system motherboard:

- Samsung Exynos 4 Quad 1.4 GHz processor with integrated 3D graphics (red)
- Wacom W8008 (possibly used for S Pen input) (orange)
- Atmel mXT1664S touchscreen controller (yellow)
- Samsung KLMAG2GE4A NAND flash memory (blue-green)
- Wolfson Audio WM1811AE audio codec (dark blue)
- F0514A 430 1201KP411 (purple)
The iPad motherboard is located beside the rather large battery. Fortunately it is not necessary to remove the battery to release the motherboard - we'll talk about the battery elsewhere.

A few Phillips screws secure the motherboard to the main case. It is well shielded but these can be popped off quite easily to reveal the underlying components.

Chips, Chips, Chips. Here's some of the salsa on the non-A5X side of the logic board:

- Texas Instruments CD3240 driver device (red)
- Broadcom BCM4330 802.11a/b/g/n MAC/baseband/radio with integrated Bluetooth 4.0+HS and FM transceiver (orange)
- 2 x 4Gb Elpida LP DDR2 = 1 GB DRAM in separate packages in a 64-bit configuration (yellow)
- Fairchild FDMC 6683 (blue-green)
- Broadcom BCM5973 I/O controller (dark-blue)
- Broadcom BCM5974 microprocessor (purple)
- Apple 338S0987 (Cirrus Logic audio codec) (black)

Some crafty spudgering reveals the A5X processor in all its glory. Like the A5, the A5X system features a 1 GHz dual-core CPU. The upgrade that earns it an ‘X’ is the new GPU, which Apple claims outperforms even Nvidia’s Tegra 3 processor.

This particular chip was manufactured in the first week of 2012.

If you want to see it in all its naked glory check out the full tear-down at iFixit [4].
And we also have an entirely-new rear side of the logic board:

- Apple A5X processor (red)
- Apple 343S0561 - This IC looks like an updated version of the 343S052 that we found in the iPad 2, and is used for power management (orange)
- The NAND, part number THGVX1G7D2GLA08 is a 16 GB 24 nm MLC Flash from Toshiba (yellow)
- Qualcomm MDM9600 - 3G and 4G wireless modem (blue-green)

A big and hearty thanks to Chipworks for helping us ID these chips!
Additional Repairability Considerations

Here we will talk about additional aspects of each devices that either impressed or disappointed us. From a repairability perspective the speakers, cameras, audio and I/O sub-systems are important elements of a device’s repairability. And let’s not forget the display that is probably the most expensive component of most CE devices.

Now most devices performed well in most of these categories. So, to keep this article to a reasonable length we’ll just focus on the main additional points for each device.

Nexus 7

We liked the Nexus 7 because its I/O sub-systems are easy to disconnect from the motherboard and remove from the case.

Pop! Off comes a connector, and the speaker assembly is free. The Nexus 7’s speakers might not be high quality, but there is already talk of speaker docks to come. And don’t forget that this tablet costs around $200 - you do get what you pay for.

Note that while the official Nexus page says there’s a single speaker in the back, we clearly see a pair of drivers indicating it is stereo compatible.

The L-shaped motherboard is littered with connectors and screws, but nothing too difficult - especially if you follow our teardown [1] and other repair guides for the Nexus 7 on http://www.ifixit.com

Kindle Fire HD

Camera and speaker subsystems are easily accessed in the Kindle Fire. We removed the dual-driver speaker system from the inner framework of the Kindle Fire HD.

According to Amazon, the Kindle Fire HD features "exclusive, custom Dolby audio, dual-driver stereo speakers" which work in conjunction along with the "auto-optimization software" to provide a "clear, crisp, balanced audio" experience. Well, in practice, the speakers sound pretty good, but don’t expect too much from the bass response. For a full sound experience there is a need for at least an external subwoofer.
Once the battery and the motherboard have been removed, the inner framework can easily be lifted up off the LCD assembly.

Good news everyone! The second Wi-Fi antenna is held in place by mild adhesive, so it comes out fairly easily.

In addition to housing the Wi-Fi antenna, the inner framework is home to the ambient light sensor/microphone/front-facing camera ribbon cable and headphone jack ribbon cable.

Finally we get access to the display subsystem. This is manufactured by LG Electronics, and is labeled as LD070WX3-SL01. Bad news this time! The LCD and front glass panel are fused together. This means you have to replace the entire assembly as one unit rather than two separate entities. In turn this implies more expensive repairs, although at least we don't have to play with that hot-air gun.

A negative for the Fire, but in fairness this is the first major repairability blunder that we've come across in this device.

Just like all of the components that we disconnected in the first few steps, the dock connector can be removed by simply detaching a connector and unscrewing a pair of screws. More points for repairability!

As a reminder, the Samsung dock connector is not the same as Apple's dock connector, as shown by this image.

The last part to remove form the Note are the speakers. At this point we note that there have been only five different size screws in the entire disassembly process. This is a nice change from some devices that use nearly as many just to hold the lower case in place.

The speakers were held in place with some light adhesive, which can be spudged right up!

The speakers in the Note 10.1 probably won't shatter any glasses, but they certainly do a good job of playing pleasing bubble noises as you navigate the Note's interface.
Oh boy, where do we start with the iPad. We've already seen that it is quite a challenge to get the battery pack out of the device case. But there are quite a few sub-systems that you can't get access to until you've worked this small miracle!

Here we show the headphone jack and one of the many wireless antennas being extracted as a single unit. That gives access to the two cameras.

Well hello there! Fancy to meet you here iSight camera. You have what specs? Oh, a 5 element lens, an IR filter, and auto exposure. Stop it iSight, you're making us blush ...

Here we can also find the primary camera which is the same image sensor Apple used on the iPhone 4: OmniVision OV5650, 1.75 um pixel pitch, 5 MP back illuminated CMOS Image Sensor.

The secondary image sensor is also an OmniVision, the OV297AA. 0.3 Mp, 3.0 um pixel pitch CMOS Image Sensor

And then there is the board containing the volume control and silent/screen rotation lock button.

On this same little board the AGD8 2103 gyroscope also rears its pretty little head, next door to the LIS331DLH accelerometer, both by STMicroelectronics. And both are components that, should they fail, will impact on significant features of the iPad such as screen rotation.
And the front-facing camera is also trapped by the battery pack. Here we show it inside the iPad and also removed.

Other components that are battery-bound include the speakers and dock connector. Again these are components whose failure could render your iPad unusable.

Oh, and we forgot a bunch of buttons and switches. Yes, What an array of buttons and switches! This truly is a sight to see. Buttons of all kinds. Switches of all types. Any one of which could fail.

Your iPad would remain a thing of beauty, but a non-functional one.
## Final Repairability Scores

### Nexus 7

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<tr>
<th>Nexus 7 Repairability Score: 7 out of 10 (10 is easiest to repair)</th>
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<td><strong>Pros:</strong></td>
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<tr>
<td>• The rear case is very easy to open, and requires minimal prying effort with a plastic opening tool to remove.</td>
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<tr>
<td>• All fasteners inside are Phillips #00 screws — no security or proprietary screws here.</td>
</tr>
<tr>
<td>• Battery replacement can be accomplished without soldering — or even a screwdriver.</td>
</tr>
<tr>
<td>• Many components, including the I/O ports, can be replaced independently of the motherboard.</td>
</tr>
<tr>
<td><strong>Mixed:</strong></td>
</tr>
<tr>
<td>• Copper alloy sheets provide convenient shielding, but they could tear during disassembly.</td>
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<tr>
<td><strong>Cons:</strong></td>
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<tr>
<td>• The LCD does not separate from the display glass, increasing repair costs.</td>
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Samsung Galaxy Note 10.1 Repairability Score: 8 out of 10 (10 is easiest to repair).

Pros:
• Once the rear case is off, most components can be individually replaced without removing any other parts.
• The front glass and LCD can be replaced separately, thereby reducing the cost of fixing your Note should you drop it onto concrete in just the right way.
• All screws are Phillips #0, and there are only five different length screws.
• Components are modular. The absence of complicated ribbon cables makes replacing individual components easy.

Mixed:
• The rear case is held on by a lot of clips and a couple screws. There is no adhesive, but the clips can be tricky to dislodge properly.
• In order to remove the battery, you first have to disconnect four cables and some tape.

Cons:
• The inner frame and some other components are held in with more adhesive than we feel is necessary.

iPad3 Repairability Score: 2 out of 10 (10 is easiest to repair)

Pros:
• The LCD is really easy to remove once the front panel is gone.
• The battery is not soldered to the logic board, making the replacement process a tad less difficult.

Cons:
• Just like the iPad2 the front panel is now glued to the rest of the device, greatly increasing the chances of cracking the glass when trying to remove it.
• Gobs, gobs, and gobs of adhesive hold down everything in place, including the prone-to-start-a-fire-if-punctured battery.
• The LCD has foam sticky tape adhering it
to the front panel, increasing chances of it being shattered during disassembly.
• The battery is very securely stuck down to rear case, and you have to remove the logic board to remove it.
• You can't access the front panel's connector until you remove the LCD.

Concluding Thoughts & Comments
Well here is the final judgment. The consensus is that most of the tablet devices reviewed here have high repairability ratings and their manufacturers should be commended for their social responsibility.

One family of devices, however, is somewhat disappointing. Sorry Apple, but there is just too much about the iPad that indicates it is intended as a disposable device. We can see why that might make sense to encourage users to upgrade to buy the latest model, but it is not a positive, or socially responsible approach for any modern electronics manufacturer. And it is even more disappointing when this is the approach adopted by an acknowledged leader in the CE sector.

In fairness we should add that a recent teardown of the newly released iPhone 5 has achieved a much more acceptable repairability score [6]. We'll take that as a positive sign that Apple has reviewed its product design process and sustainability and repairability of their devices has now become a corporate goal. So to finish on a positive note, we look forward to the next generation iPad which will hopefully follow the recent lead set by the iPhone 5.

References

iFixit is a company, founded in 2003, that specializes in the repair of today's handheld and tabletop consumer electronics devices. And one of the specialism is in disassembling CE devices, analyzing their internals and offering repair advice and free manuals to the public and professional repair community. You can access all these resources from http://www.ifixit.com/Guide and also order spare parts and essential repair tools, all from one Web location.