The Sony A7 III and iPhone 8 as “Equivalent Cameras”

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Summary
Equivalent cameras sample the same field of view with the same number of pixels and the same depth of field. The Sony A7 III, with an 18 mm lens at f/9, is very nearly equivalent to the iPhone 8 camera, provided that the Sony images are cropped to the same pixel dimensions as the iPhone’s. Three outdoor scenes were photographed with both cameras on a sunny day. iPhone raw captures (DNG) were made with the ProCamera app. Raw files from both cameras were processed with Adobe Camera Raw and Photoshop. When viewed at a comfortable distance at typical magnifications, pictures produced by both cameras are almost indistinguishable. Well-lit areas of scenes have very similar fine detail rendition. Only at high magnifications (≥ 100% on a standard-resolution display, or ≥ 200% on a high-resolution display) do differences become more apparent. In particular, the iPhone images have greater noise in shadow areas, with some degradation of fine detail, an unsurprising result. However, for many uses, the images from the two cameras are the same.

Key words: Camera equivalence, Sony A7 III, iPhone 8, ProCamera, Zeiss Batis 2.8/18, iPhone Raw

1. Camera Equivalence in Theory
Two cameras with different size sensors are said to be equivalent if:
1. The sensors have the same number of pixels and the same aspect ratio.
2. The lenses on the two cameras provide the same field of view (equivalent focal lengths).
3. The lenses are used at apertures that produce the same depth of field (equivalent apertures).

Put more succinctly, equivalent cameras sample the same field of view with the same number of pixels and the same depth of field. Provided that image quality is not limited by lens performance and that noise levels are the same, images made with equivalent cameras should be indistinguishable. Ideally, lenses should outperform sensors. That is, image resolution should be limited by the number of pixels, not by the resolving power of the lenses. Discernible differences in image detail between equivalent cameras are strong evidence that resolution of one or both cameras is limited by lens performance. There is no requirement that equivalent cameras be used at the same ISO. A reasonable starting point would be to use both at their base ISO. That approach is likely to minimize image noise for both and, perhaps, minimize variation in
image noise between cameras. Again, discernible differences will reveal useful information: in this case about irreducible differences in noise performance of the two cameras.¹

To be concrete, “full frame” sensors have nominal dimensions of 36 × 24 mm; APS-C sensors nominal dimensions of 24 × 16 mm. The aspect ratio is 3:2 in both cases. Equivalent focal lengths and apertures are computed from the ratio of the sensor dimensions, in this case the ratio of lengths of corresponding sides: 36/24 or 24/16, or 1.50. By long-entrenched usage, this ratio is referred to as the “crop factor”, although “equivalence factor” would be a better term. For example, a camera with a 24 MP APS-C format sensor and a 50 mm lens used at f/4 would be equivalent to a camera with a 24 MP full-frame sensor and a 75 mm lens at f/6 (75 mm = 50 mm × 1.5; f/6 = f/4 × 1.5).²

When two sensors have different aspect ratios, it is still possible to have equivalent cameras. Micro 4/3 sensors have, as their name suggests, a 4:3 aspect ratio. The nominal size of micro 4/3 sensors is 17.3 × 13 mm. To compute the crop factor of micro 4/3 relative to full-frame sensors, it is customary to compare the diagonals of the two formats — approximately 21.6 and 43.3 mm, respectively, which gives the commonly used factor of 2.0. A more precise approach would be to “crop” the sensor of one camera so that both had the same aspect ratio. For example, a micro 4/3 sensor “cropped” to 3:2 would have physical dimensions of 17.3 × 11.5 mm. The crop factor vis-a-vis full-frame would be 36/17.3 = 2.08. Or, the full-frame sensor could be “cropped” to 4:3, which would give physical dimensions of 32 × 24 mm, and the crop factor would be 32/17.3 = 1.85. Thus, two (or three) different equivalent cameras are possible when comparing sensors with different aspect ratios. It should be noted that if the more precise approach is taken, the sensors must have different “native” resolutions. A 24 MP full-frame sensor will have only 21.3 effective megapixels when cropped to 4:3 aspect ratio. Thus, it would be equivalent to a micro 4/3 sensor with 21.3 MP, not 24MP.

### 2. The Equivalence Factor for the Sony A7 III and iPhone 8

Full-size images made by the iPhone 8 rear camera are 4,032 × 3,024 pixels (12.2 MP; 4:3 aspect ratio). The camera lens has a focal length of 3.99 mm and a fixed f/1.8 aperture, and base ISO is 20. The sensor dimensions are approximately 4.91 × 3.69 mm. Pixel spacing is approximately 1.22 µm.³ Full-size images from the Sony A7 III are 6,000 × 4,000 pixels (24.0 MP; 3:2 aspect ratio). Base ISO is 100. In order to make the A7 III equivalent to iPhone 8, we begin by cropping the A7 III images to 4,032 × 3,024 pixels. That equalizes total image resolution (megapixels) and aspect ratio for the two cameras. The remaining task is to determine

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¹ The fact that equivalent cameras will have different apertures and often different base ISOs generally means that they will be used at different shutter speeds.

² In reality the closest available aperture to f/6 is likely to be f/6.3. The term “crop factor” presumably originates from the fact that an image made with, say, a 50 mm lens on an APS-C camera would appear to be “cropped” when compared to an image made with a 50 mm lens on a full-frame camera.

³ It is, in fact, difficult or impossible to find any official statement about the dimensions of the imaging area of the iPhone 8 sensor. Several web sources report that the pixel spacing is 1.22 µm. That would make the imaging area 4.91 × 3.69 mm.
the “crop factor”. Given that we have equalized the total number of pixels and the aspect ratios, we can compute the crop factor directly from the pixel spacings: 1.22 µm and 5.91 µm. The resultant crop factor for the iPhone8 relative to the Sony A7 III is 5.91/1.22 = 4.84. Therefore, the “equivalent lens” on the A7 III should have a focal length of 3.99 mm \(\times\) 4.84 = 19.3 mm, and the lens should be used at an “equivalent aperture” of \(f/1.8 \times 4.84 = f/8.7\). The closest that I can come with my equipment is an 18 mm lens (Zeiss Batis 2.8/18) at \(f/9\).

3. Making the Images

I used ProCamera to take pictures with the iPhone. That allowed me to control ISO and shutter speed in order to optimize exposure, and to save raw images in DNG format. Raw format (uncompressed ARW) was also used for the A7 III images. Camera and phone were mounted side-by-side on a rail that was attached to a tripod (Fig. 1). A remote was used to release the Sony shutter, and the built-in timer of ProCamera was used for iPhone shutter release. Images from both cameras were processed through Adobe Camera Raw (10.3.0.933), using the Adobe Standard profile. Exposure and tonality adjustments (color temperature, tint, whites, blacks, highlights, shadows) were used, if necessary, in order to make paired images from the two cameras as similar as possible. However, other adjustments, such as sharpening, noise reduction, clarity, dehaze, etc., were either set to zero or sliders were left at their default midpoints. Corrections for chromatic aberration, lens distortion, and vignetting were not used. Final tonal adjustments and sharpening were done in Photoshop CC (19.1.3).

4. The Images

Image pairs are shown in Figs. 2 – 4. These are “actual-pixel” crops from the full-size processed JPEGs. “Thumbnails” of the entire scenes are provided in Appendix A. The full-size JPEGs may be downloaded using the links in the text and in Appendix B. In order to encourage unbiased assessment of the images, I have intentionally not identified the cameras in the figure captions. A key is provided in Appendix B. Links to the original raw files are provided in Appendix C.

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4 With slightly more work, we can calculate the crop factor by reference to the A7 III sensor area that corresponds to a cropped 4,032 x 3,024 pixel image. Given the sensor pixel spacing of 5.91 µm, the “cropped” sensor dimensions would be 23.8 x 17.8 mm: 23.8/4.91 = 4.85 which, allowing for rounding errors, is the same as 4.84.

5 I used the progressive sharpening method described by Jeff Schewe in The Digital Negative (2nd ed., pp. 228 - 230). It involves sequential application of the Unsharp Mask filter, with different values for amount and radius, in the same smart layer. The intensity of sharpening can be adjusted via the overall opacity of the layer or by adjustment of the opacities of the individual smart filters. This methods seems to work well for images that have detail at different spatial frequencies. The effect is often subtle and delicate, and the method seldom produces obvious artifacts.

6 Please see the note on p. 5 about viewing images.
Fig. 1. Camera and iPhone setup. Note: the pictured Sony is an A7R III, not the A7 III actually used for these comparisons.
4.1. Scene 1 – Fallen tree (Fig. 2)

This scene has a variety of finely detailed surface textures, including rocks, weathered wood, soil, and vegetation. The brightness range encompasses full sun to deep shadow; the sort of scene that places a premium on sensor dynamic range. I find it difficult to find consistent differences in detail rendition between these images when viewed at normal magnification and distance. The shadow areas of the iPhone image are noisier. That is probably to be expected, and it should be borne in mind that no noise reduction was applied in post processing. Also, in order to see the noise differences easily, I need to view the images at 200% magnification (in Photoshop on a 5K iMac). The full-size JPEGs can be downloaded here: A7 III, iPhone 8.

4.2. Scene 2 – Lichen on boulder (Fig. 3)

This scene is mostly in shade, with areas of glancing sunlight on the face of the boulder. There is perceptible movement of the light between images, although the pictures were taken within a minute. The textures, consisting of bare rock and encrusting lichen, are extremely finely detailed. This scene challenges the resolving power of the sensor – lens systems. I see little
Fig. 2. “Actual pixels” central crops (1,308 x 872 px) from the images of a fallen tree. iPhone 8 exposure: ISO 20, f/1.8, 1/1400 sec. Sony A7 III exposure: ISO 100, f/9, 1/250 sec. Key to image identification is in the Appendix.
Fig. 3. “Actual pixels” near-center crops (1,308 x 872 px) of a lichen-encrusted boulder. iPhone 8 exposure: ISO 100, f/1.8, 1/1250 sec. Sony A7 III exposure: ISO 100, f/9, 1/50 sec, -0.7EV exposure compensation. Key to image identification is in the Appendix.
Fig. 4. “Actual pixels” below-center crops (1,308 x 872 px) of a cluster of Gamble oak with leaf litter. iPhone 8 exposure: ISO 25, f/1.8, 1/1250 sec. Sony A7 III exposure: ISO 100, f/9, 1/100 sec. Key to image identification is in the Appendix.
difference between the crops in Fig. 3. Again, with high enough magnification ($\geq 200\%$ on a 218 ppi display) the greater noise in the iPhone image is noticeable. The full-size JPEGs can be downloaded here: A7 III, iPhone 8.

4.3. Scene 3 – Gamble oaks with leaf litter (Fig. 4)

I see differences between the cameras, even just with the crops shown in Fig. 4. For example, there is more detail in the branch leading out of the frame bottom from the lower right; and there is more detail in the shadow areas, such as behind the base of the larger trunk, in the A7 III image. The difference in detail in the branch might be a focussing issue. The difference in shadow detail might have been mitigated by more aggressive shadow recovery with the iPhone image. In any case, these differences are relatively minor: viewed side-by-side at a comfortable distance the two full-size images are essentially the same. At 200% magnification on a 218 ppi display, there is more shadow noise in the iPhone image, although the difference is not as apparent as for the two previous comparisons. The full-size JPEGs can be downloaded here: A7 III, iPhone 8.

5. Discussion

When examined at normal viewing distances and at magnifications that allow the entire frames to be displayed, there are no obvious differences between images from the Sony A7 III and the iPhone when made under these conditions. Differences do exist, but one must resort to “pixel peeping” — close examination at high magnification — to see them. Not surprisingly, shadow areas of the iPhone images have greater noise; something that might be ameliorated with noise reduction in post processing.

Lest anyone think that I am saying the iPhone 8 is as “good” a camera as the Sony A7 III with Zeiss Batis 2.8/18, let me make it clear that I am not. Cropping the Sony images to 12.2 MP, and using the Zeiss lens at f/9 were done to compare images honestly — in an “apples to apples” sense. But, in reality, one of these cameras is an “apple” and the other is an “orange.” There are several reasons why a serious hobbyist or professional photographer would prefer the Sony to the iPhone as a general-purpose camera:

1. The Sony sensor has twice as many pixels as the iPhone. 12 MP is plenty for viewing images on a smart phone, tablet or computer display. It’s not enough for high-quality large prints.
2. The iPhone camera has a fixed, wide-angle equivalent lens — a serious limitation for many subjects.
3. The iPhone camera lens has a fixed, large aperture (f/1.8) that makes it impossible to control depth of field, and isolate subject from background in most situations.
4. The iPhone camera is likely to perform far worse than the Sony in low-light conditions, as attested by higher shadow noise in these images made on a sunny day.
5. Handling and controls: conventional cameras have at least a few buttons and dials which make it possible to quickly adjust important shooting parameters such as aperture, shutter speed, exposure compensation and ISO. More expensive models usually also have a viewfinder for composing and taking the picture. Viewfinders are preferable in
conditions, such as bright sun, that make it difficult to see what is being displayed on a smart phone screen. Also a camera held to the eye is more stable than one held on outstretched arms. Features of phones, such as touching the monitor to indicate the subject to be focused on, are now becoming common in conventional cameras.

I admit to being surprised by how well the iPhone 8 camera rendered fine detail in well-illuminated portions of the scenes: you must pixel-peep to see differences between it and the Sony. And, even then, they are trivial. Given the 1.2 µm spacing of the sensor pixels, that says a lot about the resolving power of the iPhone camera lens. Finally, it should be noted that many of the advantages of larger-format, interchangeable-lens cameras detailed in the list above are being addressed by smart phone makers. For example, the iPhone 8 Plus and the iPhone X have two rear-facing camera modules. The Huawei P20 Pro has three. Multiple modules can, and do, have different focal length lenses. Images from two or more modules can be combined, offering the possibility of noise reduction and depth mapping, which allows for subject isolation by selective de-focus after images have been taken. In sum, multiple imaging modules, of the type currently being used in smart phones, together with sophisticated post-capture processing will continue to close the gap between “phones” and “real cameras”.

Appendix A – Entire scene thumbnails

Scene 1

Scene 2

Scene 3
Appendix B – Key to cameras used for images in Figs. 2 – 4 and links to full-size JPEGs

Fig. 2
Top: Sony A7 III
Bottom: iPhone 8

Fig. 3
Top: iPhone 8
Bottom: Sony A7 III

Fig. 4
Top: iPhone 8
Bottom: Sony A7 III

Appendix C – Links to raw files

Because there will always be skeptics; and skepticism is, in general, a good thing.

https://www.dropbox.com/s/26euv7pi02jaq82/scene1_A7m3.ARW?dl=0

https://www.dropbox.com/s/7f51zhuyazyvghz/scene1_IP8.dng?dl=0

https://www.dropbox.com/s/6wcfzk4hp4klaz/scene2_A7m3.ARW?dl=0

https://www.dropbox.com/s/c8lljg3wv3sjtyo/scene2_IP8.dng?dl=0

https://www.dropbox.com/s/ncviyfrzuklg2hf/scene3_A7m3.ARW?dl=0

https://www.dropbox.com/s/lfbo4agb30jjw1/scene3_IP8.dng?dl=0