Sony ARW Version 2 “cRAW”

- Raw formats encode *uncooked* sensor data
- **ARW** is Sony's Alpha RaW file format
- ARW used to use packed 12-bit pixel values
- Since 2007, “cRAW” lossy compression in:

**FF E:** NEX-VG900; ILCE-7, 7R, 7S, 7M2, 7RM2, 7SM2
**FF A:** DSLR-A850, A900; SLT-A99
**APS-C E:** NEX-3, 5, 5N, 5R, 6, 7, C3, F3, VG20, VG30;
  ILCE-3000, 3500, 5000, 5100, 6000; QX1
**APS-C A:** DSLR-A450, A500, A550, A560, A580, A700; SLT-A33,
  A35, A37, A55, A57, A58, A65, A77; ILCA-77M2
**Cyber-shot:** DSC-RX100, RX100M2, RX100M3, RX100M4, RX10,
  RX10M2, RX1
Why Would Sony Do That?

- Compressed raws use only 8 bits / pixel
  - Faster camera operation, SD card writes
  - Effectively 1.5X memory capacity
  - Encoding allows random pixel access
- Computationally cheap encode / decode
- Introduced as an option & few complained, so Sony dropped packed 12-bit
Why Did Sony Stop Doing It?

- Lenses with higher microcontrast
- Camera sensor data went from 12→14 bits, so compression ratio increased
- Usable sensor dynamic range increasing
- ISO-less exposure concepts led people to underexpose by up to 6EV & boost in post:
  - EI 2015: our *ISO-less?* paper
  - DPReview: *ISO-Invariance* articles
- Unhappy users, especially for ILCE-A7RM2
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- Unhappy users, especially for ILCE-A7RM2
- Sony didn't stop, but added 16-bit raw
The Problem: Boosting This
Reveals This

IS&T
Rather Than This (16-bit ARW)
Lossy Compression, 1\textsuperscript{st} Step

- Start with 14-bit raw data
- Tone map to approximate log encoding:
  - Add fixed black offset (e.g., 512)
  - Reduce value to 11-bit by 5-segment linear mapping specified by when value step goes from $1 \rightarrow 2$, $2 \rightarrow 4$, $4 \rightarrow 8$, $8 \rightarrow 16$, & $16 \rightarrow 32$
  - Step change thresholds recorded in EXIF

\textit{Really not very different from other cameras...}
Lossy Compression, 2\textsuperscript{nd} Step

- Work on a 32-pixel horizontal strip of pixels
- Break strip into interleaved 16-pixel strips
- For each interleaved 16-pixel strip, record: Max, Min, MaxPos, MinPos, 14 Deltas...
- Delta is scaled to fit 7 bits by dropping least significant bits of actual delta value

*Very different from most other cameras!*
The big problem is the 7-bit Deltas...
Suppose Min..Max is 1000..1518; mapping 518→127 forces 3-bits dropped, to step of 8
Note that Max != Min+8*k for any integer k
Credible Repair With KARWY

- **KARWY**: U. of KY ARW repair raw wrapper
- Tried over 75 different repair algorithms
- Algorithm implemented behind WWW form:
  1. Construct an error model for each pixel
  2. Adobe DNG Converter packages as DNG
  3. Smooth initial pixel value estimates
  4. Texture synthesis to find value in range
  5. Final pixel value adjustment (add noise)
KARWYY Error Model

- Done using decode logic from dcraw
- Compute 11-bit value range:
  - Min, Max give precise 11-bit values
  - Delta<128 reconstructs precise 11-bit
  - Range of others based on delta truncation
- Map 11-bit value into range of 14-bit values
- Extend range slightly to allow for noise
KARWY Bits Valid Map
Why Does KARWY Use Adobe DNG Converter?

- At writing of KARWY, ARW2 only provided a lossy compressed format... so wrap as DNG
- Generating DNG directly gave inconsistent interpretations using various DNG editors
- Adobe DNG Converter used to make wrapper:
  - Builds all the magic fields Adobe wants
  - Does NOT preserve pixel data: both values and image size often wrong!
KARWY Smoothing

- Not really smoothing pixel values… *smoothing initial pixel value estimates*
- Optional % bad, near bad, other
- Removal of “Blondie” (parallel lines) artifacts:
KARWY Texture Synthesis

- Search for similar pixel environment in 1089 same-color positions
- Weighted sum:
  - Bits valid
  - Value range overlap
  - Distance weighting
- Constrained to range
Repaired By KARWY
Rishi Sanyal's DPReview
ILCE-7M2 ISO Invariance Test
ISO Invariance KARWY
ISO Invariance KARWY Smooth
ISO Invariance
Enhanced Repair Difference
Matti Koski's ILCE-7 Star Trail
From RawDigger Article
Star Trail KARWY
Star Trail KARWY Smooth
Star Trail
Enhanced Repair Difference
Repair Quality Evaluation

- It's pretty good, right?
Repair Quality Evaluation

- It's pretty good, right?
- KARWY WWW form allowed voting; >200 users, only 15 voted:
  - 6/15 gave perfect scores
  - 6/15 gave scores below 20%
- Most low scores when no artifacts to repair, one due to Adobe DNG Converter problem
Conclusions

- Adobe DNG Converter changes raw data!
- Credible ARW repair by new algorithm:
  - Construct pixel value range error model
  - Use texture synthesis to refine values
- Artifacts well understood, poorly recognized
- Might be possible to improve dynamic range of any raw using this repair algorithm...