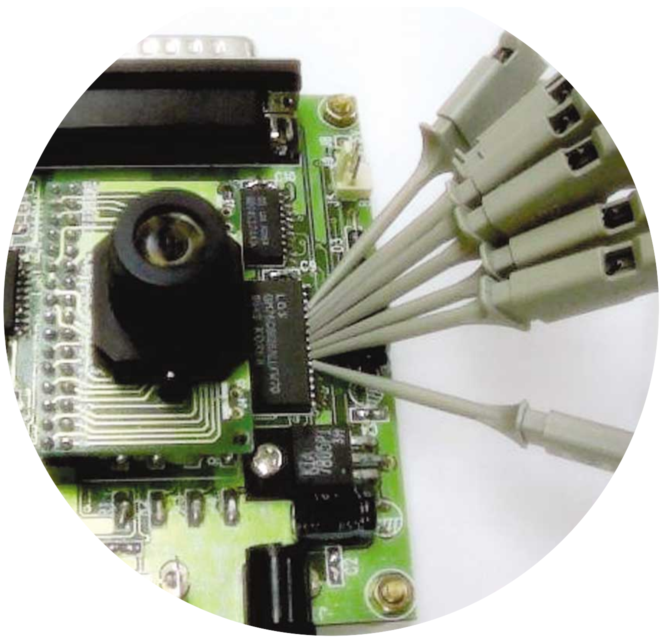
Debugging Digital Cameras: Detecting Redundant Pixels

Application Note



Introduction

Pixel problems and bit problems associated with their hardware and firmware designs can seriously challenge the designers of today's digital cameras. These challenges require new measurement tools and trouble shooting techniques to troubleshoot the problems that arise.

This application note explains how a digital camera works and demonstrates some real-life techniques for debugging pixel problems digital camera design using an Agilent 54622D mixed signal oscilloscope (MSO). Refer to figure 1.

How a Digital Camera Works

A frame of a digital photo consists of a fixed number of pixels. As the number of pixels in a frame increases, so does the photograph's resolution. In a black and white photo, one 8-bit binary number represents each pixel. This number defines the gray scale. For a color photo, three 8-bit binary numbers Y, U, and V represent each pixel. The Y number is the brightness level and the U and V numbers represent the color.

When designing a digital camera, the challenge is to make sure there are no pixel problems within a frame, nor bit problems within a pixel. If there is a pixel problem within a picture, either missing pixels or redundant pixels, the picture will skew. If there is a bit problem (incorrect binary word) within a pixel, the image quality deteriorates. This application note concerns pixel problems.

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To see the various componts and connections made within a digital camera, refer to figure 2. In a digital camera, the data from the charge coupled device (CCD) sensor is stored sequentially into static memory. This activity is governed by the timing relationship of the Horizontal Reference Signal (Href) and the Pixel Clock (Pclk). When Pclk goes high, the pixel data is ready and the static RAM stores the pixel data. The length of the Href signal defines the number of pixels in each horizontal line. A complete picture consists of hundreds of lines.

The analog channels of the mixed signal scope digitize and display Pclk and Href. Refer to figure 2. Logic channels D0 through D7 display the 8-bit Y data (brightness control), while D14 shows CLOCK. This signal is the input to the address control circuitry and is actually Href ANDed with Pclk. Refer to figure 3 for a complete block diagram of the digital camere circuitry.

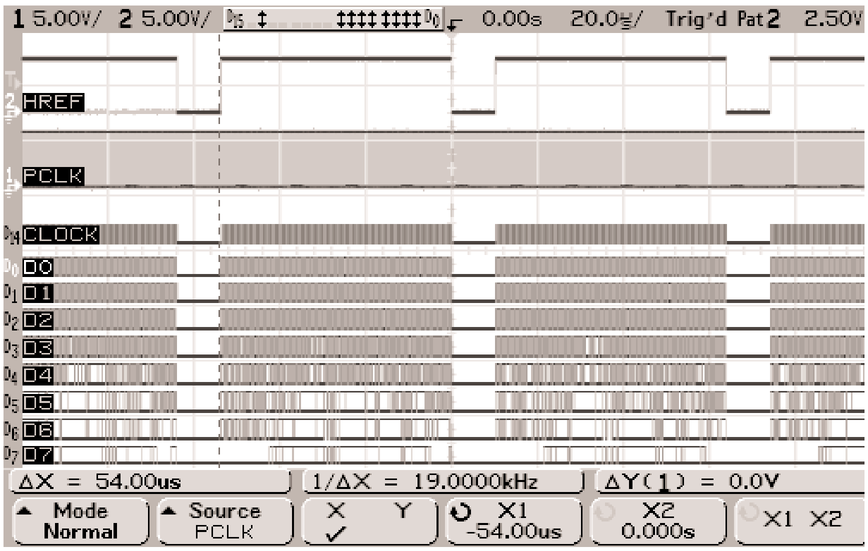

Figure 2. Viewing timing relationship of Href, Pclk, Clock, and Y-data

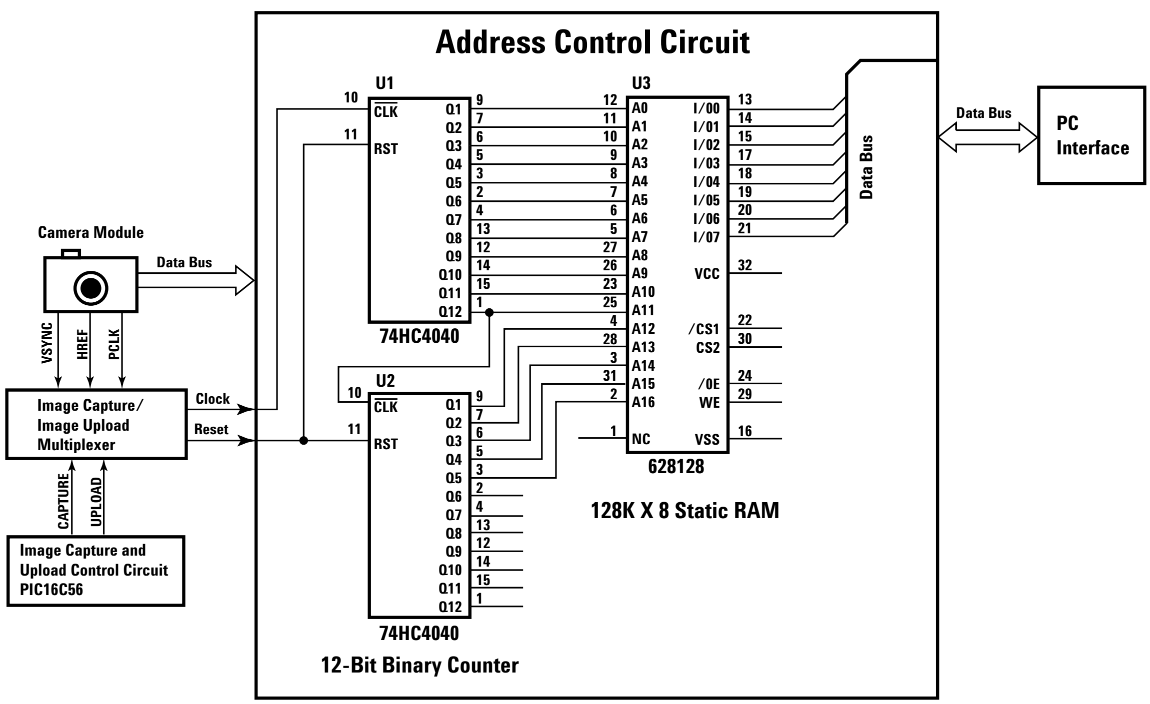

Figure 3. Digital camera block diagram

Figure 4. Digital photo taken with prototype camera A

Figure 5. Enlarged portion of the upper left-hand corner of figure 4, black squares are redundant pixels

Detecting Redundant Pixels

With prototype camera A, we observe a skewed digital photo and there is a black line cutting the picture in two. Refer to figure 4. We suspect that there is one redundant pixel at the end of each horizontal line. Therefore, the second line is offset by one pixel. The third line is offset by two pixels, and so forth. The nth line is offset by n-1 pixels.

When the above problem is observed, the next step is to understand if it is a hardware problem or a firmware problem. To do that, we need to capture the Href and Pclk signals, and then count the number of Pclk pulses while Href is high. If the number is incorrect, then we must have a hardware problem. However, if the number is correct, then we probably have a firmware problem.

In the past, we could not analyze this problem because we didn't have the right tools. For example, in our case there are 640 pixels in each horizontal line. If we require better than 1 percent measurement accuracy within each Pclk period, we need at least 640 ÷ 1 percent or 64 Kbytes of memory. Our old digitizing scope did not have sufficient memory to capture the whole waveform with the required resolution. We tried looking at this problem with an Agilent 54622D mixed signal oscilloscope (MSO). This scope has 2 MB and 4 MB of memory per channel on analog and digital channels respectively. This was the first time we could really "see" the problem.

After we captured the signal, the next challenge was to count the number of pulses. Keep in mind, there can be more than a thousand Pclk pulses during each Href signal. Unless you have a pair of very good eyes and a whole afternoon available, it may be impossible to count the pulses visually. We discovered some helpful tricks to solve this problem.

First, we captured the important signals with the mixed signal oscilloscope, and then imported the waveform data into a Microsoft Excel spreadsheet on our PC. The Agilent IntuiLink software made the data transfer process from the scope to the PC a simple task.

We then sorted the data, grouped all the 1's, and then added them together to get the total. The total should have been 640. However, the number of Pclk pulses we counted was 641. This confirmed that there was one redundant pixel within each horizontal line.

Next, we zoomed in on the falling edge of the Href signal and discovered that the Href was so long that it allowed the 641th Pclk pulse to pass through. Refer to figure 6. During this period of time, Y0-Y7 (brightness control) were all low. This resulted in a black dot being latched into the memory, which gradually formed the black diagonal line. Refer to figure 5.

We concluded that a timing problem existed in prototype A. The next step was to modify the circuit to correct the Href timing. As an alternative solution, we put a subroutine in the camera firmware to eliminate the last pixel from each horizontal line in order to produce a good photo. Refer to figure 7.

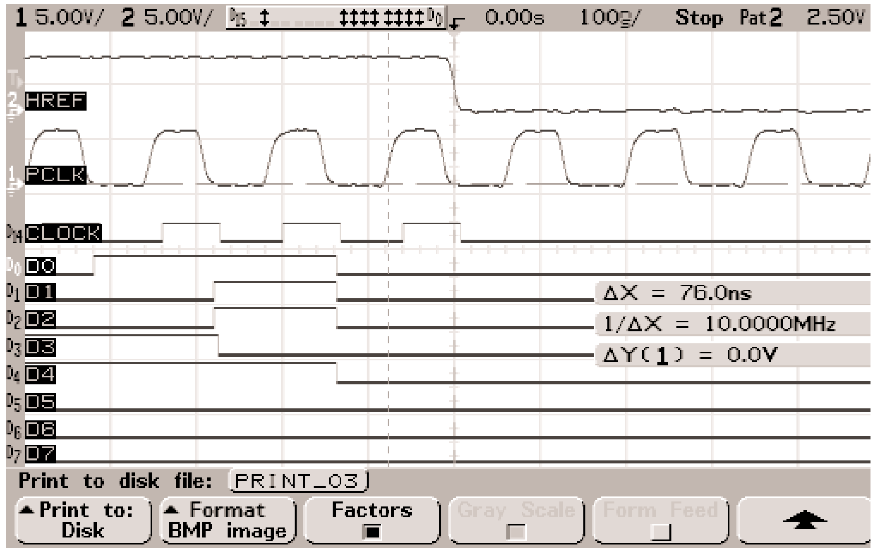

Figure 6. Zooming in to see the unwanted Pclk pulse

Figure 7. Software compensated digital photo taken with prototype camera A

Model Number	Bandwidth	Sample Rate	Channel Count	Memory Depth	Price
54621A	60 MHz	200 MSa/s	2	2 MB/ch	$2,801
54621D	60 MHz	200 MSa/s	2 + 16	2 MB/ch	$4,031
54622A	100 MHz	200 MSa/s	2	2 MB/ch	$3,403
54622D	100 MHz	200 MSa/s	2 + 16	2 MB/ch	$5,352
54624A	100 MHz	200 MSa/s	4	2 MB/ch	$5,207
54641A	350 MHz	2 GSa/s	2	4 MB/ch	$5,716
54641D	350 MHz	2 GSa/s	2 + 16	4 MB/ch	$8,316
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Agilent Reference Documents	Publications Number
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Agilent MSO and CEBus PL Communications Testing	5980-0794EUS
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8 Hints for Debugging Microcontroller-based Designs	5980-0943EN/EUS
54600-Series Product Literature:	
Agilent Technologies 54600-Series Oscilloscopes Data Sheet	5968-8152EUS
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