Anders Uschold
DIGITALTECHNIK

DIPLOMINFORMATIKER
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Von der Industrie- und Handelskammer für München und Oberbayern öffentlich bestellter und vereidigter Sachverständiger für analoge und digitale Fotografie

Sachverständiger für bilddaten-verarbeitende Technologien

Scientific test report

Subject:

Current capabilities of digital cameras and the comparison of the classical architecture of digital cameras based on 35 mm SLR-systems and a digital optimized architecture

Expert and laboratory:

Anders Uschold
Anders Uschold Digitaltechnik
Munich, Germany

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1. Basics

1.a Abstract

The first goal of this report is the comparison of current digital cameras' features with silver halide film. The second is a quantitative analysis of lenses based on the classical 35 mm SLR architecture and of a full digital designed modern camera model.

1.b General conditions

The intensity and depth of detail of the examination was decided by the laboratory.

1.c Location

Anders Uschold Digitaltechnik, Munich, Germany.

1.d Security

This report was prepared by Anders Uschold Digitaltechnik, Munich Germany, and elaborated for public purposes. Therefore this report is not classified as confidential.

1.e Persons involved

The practical tests have been done by the professional photographers Wolfgang Pulfer, Mathis Beutel and Stefan Obermeier. The technical examination has been done by Anders Uschold. No other persons or experts were involved.

1.f Time period

11 July - 6 September 2002

2. Intentions and background

2.a Intentions of this report

The general intention of this report is to answer three very important questions from the technical point of view. They are as follows:

I. Can actual high-end digital cameras compete with analog models and silver halide film?

I. How do “analog designed” lenses interact with a digital sensor and which restrictions occur compared to “digital designed” lenses?

I. What are the consequences for the semiprofessional and professional photographer?

2.b Analog and digital architecture

Photography today is dominated by one typical design: the single-lens-reflex system SLR. Since the 60’s, this design has offered an excellent flexibility with cameras using interchangeable lenses. One body containing the film can be combined with lenses of various kind: universal types like Megazooms or specialists like Macro, ultrafast telephoto or super wide angle. But for more than 40 years, the “sensor” has always remained the same: silver halide film.

The change from an ”analog sensor”, with chemical image processing, to a digital sensor, with electronic image processing, causes an important difference for the usability of a lens. Silver halide film has a very good stability and sensitivity against lightbeams over a broad range of angle between beam and film plane. According to this property, “analog lenses” offer a high flexibility for optical engineering. Diameter of rear lenses, distance from focal / film plane, angle range of beampencils of light, dimensions of lens mount etc. did not occur in that critical manner.

Unfortunately electronic sensors are very intolerant with slanted beampencils of light and can show relevant to critical loss of quality. Interaction of sensor-microlenses and the lens may cause interference and restrictions at wide apertures. Specific optical defects like chromatic aberration are capable of interfering with the spatial frequency of sensor elements and a possible stepping of image processing functions like sharpening, antialiasing, interpolation. These interferences can produce critical color artefacts and Moiré-effects reducing resolution and image quality. The settings of sharpening, anti-aliasing or corner shading compensation are a permanent tradeoff between unsharpness, artefacts, loss of dynamic ranges and noise.

2.c Cameras and lenses examined

For an overview of advantages and restrictions a typical set of lenses has been tested with three professional state of the art digital cameras. These are the new 6-Megapixel digital cameras with interchangeable lenses. The lens set for each camera consists of three typical professional lenses and one very popular consumer lens.

Canon D 60:

- Canon 16 - 35 mm 1 : 2.8
- Canon 70 - 200 mm 1 : 2.8 IS
- Canon 85 1.8 mm 1 : 2.8
- Sigma 28 - 200 mm 1 : 3.5 - 5.6 AF Compact

Fuji S2 Pro:

- Nikon 17 - 35 mm 1 : 2.8 ED AF-S
- Nikon 80 - 200 mm 1 : 2.8 ED AF-S
- Nikon 85 1.4 mm 1 : 2.8 AF
- Sigma 28 - 200 mm 1 : 3.5 - 5.6 AF Compact

Nikon D 100 with:

- Nikon 17 - 35 mm 1 : 2.8 ED AF-S
- Nikon 80 - 200 mm 1 : 2.8 ED AF-S
- Nikon 85 1.4 mm 1 : 2.8 AF
- Sigma 28 - 200 mm 1 : 3.5 - 5.6 AF Compact

Due to the current lack of high resolution digital cameras with interchangeable lenses, the Olympus E-20 P has been selected to be the representative of a full digital designed architecture. It was felt that the 5-Megapixel CCD-sensor in this model fitted the requirements of this test. The Olympus 9 - 36 mm 1 : 2 - 2.4 lens shows adequate properties. Concerning certain specs like maximum aperture, zoom range, price and quality level, it is regarded to be a fair and preferable counterpart to the professional lenses listed above.

2.d Reliability and test methods

This report is based on non-standardized methods, as no existing standard defines or offers the complexity of test functions and marks, that are necessary to describe the features and answer the questions to the degree required. The methods, based on the scientific testing environment DCTau®, represent one of the most complex sets of testing functions based on state-of-the-art image processing technologies. This environment also includes several advanced control mechanisms to reduce the risk of badly adjusted or defect lenses or cameras. To ensure reliability, additional counterchecks with different samples or multiple iterations of the test proceeding have been done when indicated by the first results.

All lenses and cameras tested have been dedicated test samples provided by the manufacturer.

3. Examination and results, part 1, resolution

3.a Testing environment, settings

The samples have been examined using DCTau®, a scientific testing environment for iconic data processing devices. This testing environment is based on the reverse classification of components to describe the technologies used in digital cameras. For further details, please see the DCTau 3.0 White Paper available on www.uschold.com.

The camera settings for each sample were as follows:

Sharpness:	Standard
Contrast:	Standard
EV correction:	Individual settings for best target exposure
Compression:	JPEG finest degree
Image size:	Maximum, non-interpolated

3.b System resolution coefficient

The system resolution coefficient is well suited to show three important features. The following diagram shows three examples of the function. The first lens shows critical results. The resolution at open aperture is very low and the lens must be closed at least 3 stops to produce a good resolution. The second lens shows very good results. Resolution is very good from open aperture to aperture 8. The third lens does not show critical loss at open aperture, but the overall resolution remains on a low level. The diagrams are made anonymous. For more detailed test results and specific charts, please contact Anders Uschold Digitaltechnik, Germany. See **Chapter 7** for contact.

The numeric value describes the resolution as follows:

< 50 %:	Critical resolution or defect
50 - 60 %:	Low resolution, control of possible defects necessary
60 - 70 %:	Moderate to low resolution
70 - 80 %:	Good resolution
80 - 90 %:	Very good to excellent resolution
90 - 100 %:	Excellent resolution, control of Moiré-effects necessary
> 100 %:	Control of Moiré-effects necessary, artefacts are likely!

The second feature is information about the resolution / aperture - relation. The shape of the graph always starts from the open aperture of the lens to four stops down like 2.8 - 4 - 5.6 - 8 - 11. Further steps as 16 - 22 - 32 are not necessary as diffraction limits resolution in most cases. The shape of the function shows how many stops the aperture of the lens must be closed to eliminate lens and system restrictions present at open lens aperture. On the other hand, the wideness of the function crest represents whether the system offers a larger or smaller range of “preferable aperture settings”. A wide plateau is excellent, a small peak means a negative restriction.

The third aspect is a practical one. Due to the common need for available light, fast aperture marks are necessary to ensure good pictorial results under limited lighting conditions. A lens with a maximum aperture of 1 : 2 will cause heavy restrictions if the preferable aperture range starts from 1 : 5.6. A smaller number of stops to close from open aperture ensures a better practical quality range under restricted lighting conditions.

This is regarded to be very important as brighter lenses are extremely expensive. If those well-paid aperture marks are not suited for use with a digital camera, the cost - benefit - relation of the lens drops dramatically.

Image 1: Lens with critical loss at open aperture and reduced preferable aperture range

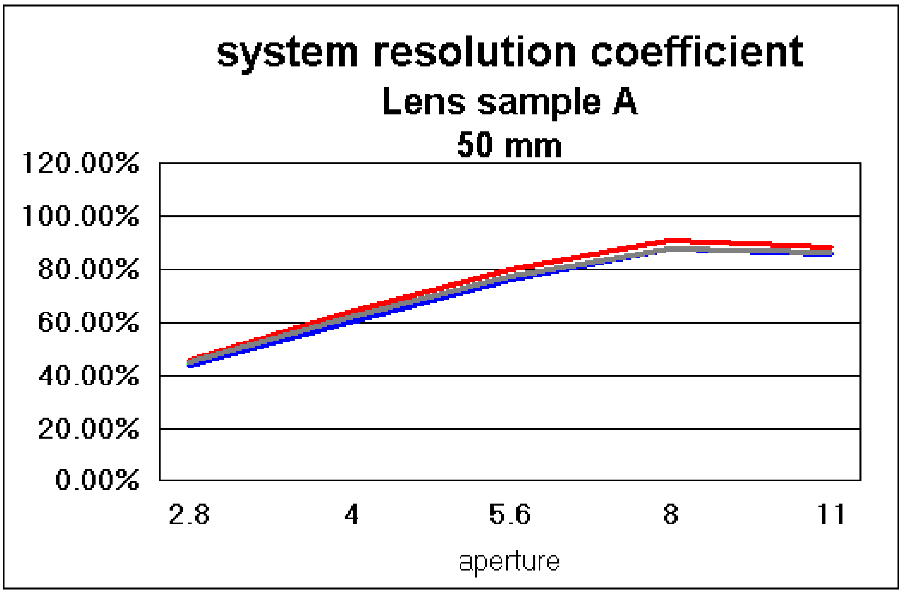

Image 2: Lens with very good resolution and wide preferable aperture range

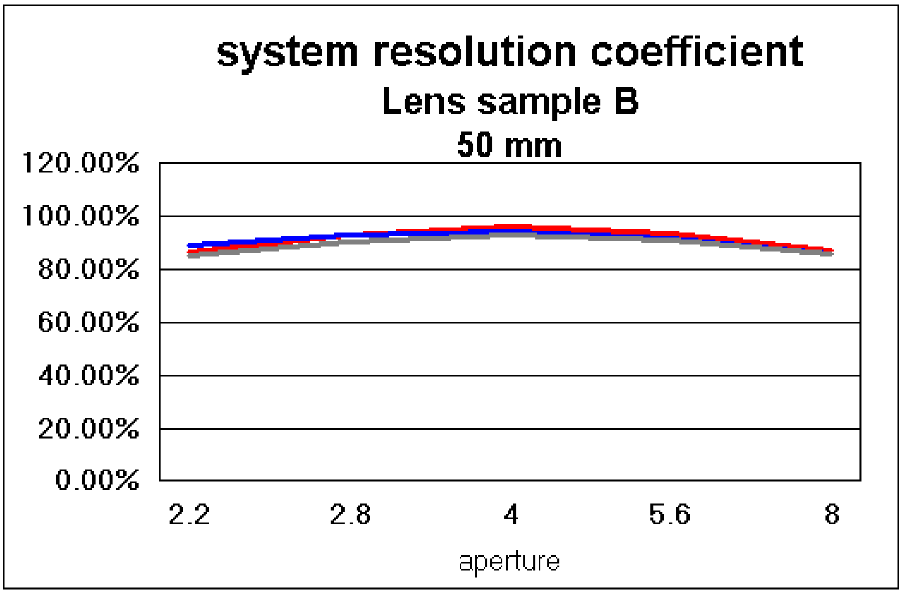

Image 3: Lens with low to moderate resolution

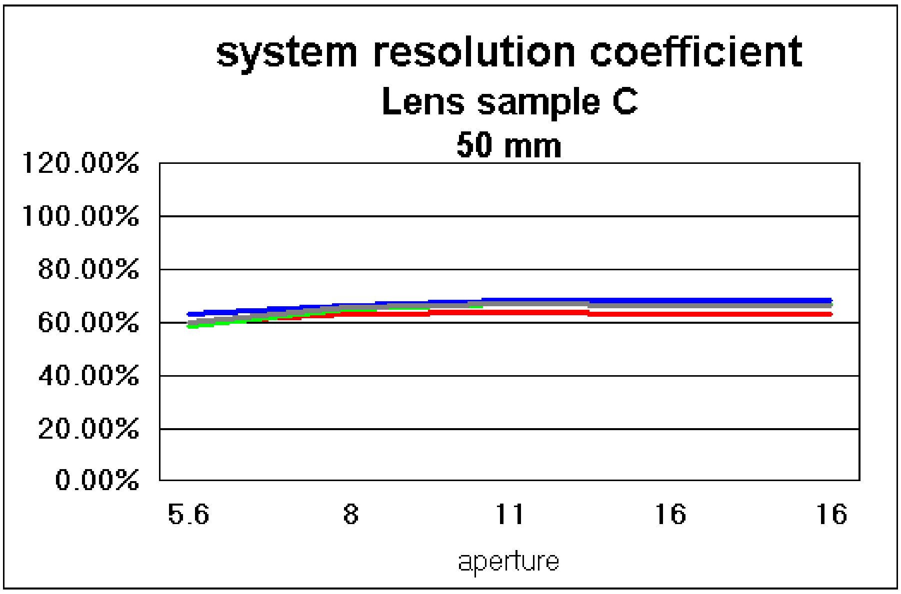

Table 1: Results of resolution and preferable aperture range

Camera & lens	focal length setting	preferable aperture range	number of stops to close	loss of quality at open aperture	Overall quality
Canon D 60, ISO 100					
16 - 35 mm 1 : 2.8	16 mm	4.5 - 16	1.5 stops	obvious	moderate
	24 mm	8 - 16	3 stops	obvious	low
	35 mm	5.6 - 16	2 stops	critical	moderate
28 - 200 mm 1 : 3.5 - 4.5	28 mm	4.5 - 16	1 stop	very good	good
	80 mm	5.6 - 16	0.5 stops	very good	moderate
	200 mm	5.6 - 16	0 stops	very good	low
70 - 200 mm 1 : 2.8	70 mm	5.6 - 16	2 stops	obvious	moderate
	120 mm	4 - 16	1 stop	moderate	good
	200 mm	2.8 - 16	0 stops	very good	low
85 mm 1 : 1.8	85 mm	2.8 - 16	1 stop	very good	very good
Fuji S 2 Pro, ISO 100					
17 - 35 mm 1 : 2.8	17 mm	5.6 - 11	2 stops	obvious	moderate
	24 mm	6.7 - 16	2.5 stops	critical	low
	35 mm	5.6 - 16	2 stops	good	good
28 - 200 mm 1 : 3.5 - 4.5	28 mm	6.7 - 13	2 stop	obvious	moderate
	80 mm	5.6 - 16	0.5 stops	good	good
	200 mm	5.6 - 13	0 stops	very good	low
80 - 200 mm 1 : 2.8	80 mm	2.8 - 11	0 stops	very good	very good
	120 mm	4 - 8	1 stop	good	very good
	200 mm	4 - 8	1 stop	moderate	good
85 mm 1 : 1.4	85 mm	2.8 - 8	2 stops	obvious	good
Nikon D 100, ISO 200					
17 - 35 mm 1 : 2.8	17 mm	4.5 - 11	1.5 stops	obvious	moderate
	24 mm	5.6 - 16	2 stops	obvious	moderate
	35 mm	5.6 - 16	2 stops	good	moderate
28 - 200 mm 1 : 3.5 - 4.5	28 mm	6.7 - 16	2 stops	good	moderate
	80 mm	5.6 - 16	1 stop	good	moderate
	200 mm	5.6 - 11	0 stops	good	low
80 - 200 mm 1 : 2.8	80 mm	2.8 - 11	0 stops	very good	good
	120 mm	2.8 - 11	0 stops	very good	good
	200 mm	4 - 8	1 stop	moderate	moderate
85 mm 1 : 1.4	85 mm	2.8 - 8	2 stops	good	good
Olympus E 20 P, ISO 80					
9 - 36 mm 2 - 2.4	9 mm	2.4 - 6.7	0.5 stops	very good	very good
	18 mm	2.8 - 8	0.5 stops	very good	very good
	36 mm	2.8 - 6.7	0.5 stops	very good	very good

3.c Net image size

The net image size is a special technical unit to give an impression of the practical amount of information and resolution of a digital camera without taking into account the sensor size. This gives the outstanding opportunity of an easy comparison of different camera classes like 4-Megapixel with 5-Megapixel or 6-Megapixel. For further details, please see the DCTau® 3.0 White Paper. The interpretation of the net image size is quite easy. If two cameras, no matter whether they have the same or different sensor size or pixel number, show a significantly different net image size, the camera with the higher mark contains more valuable information and image details. See table 2 for a list of selected marks.

Please note: the net image size is a specification defined for a better comparability. Net image size is not an absolute unit like file size or pixel number. It is not standardized by DIN or ISO and not intended for or applicable to any use but in the context of DCTau®.

3.d Resolution from image center to corner

The loss of resolution from image center to corner is a typical representation of the classical modulation-transfer-function MTF. Limited lens abilities, concerning loss of resolution and interference between slanted beampencils of light and the sensor structure, are the most relevant aspects. For the practical use, the resolution at the image center and image corner do have a low relevance due to the small image areas that are covered by those marks. The highest physiological relevance and image coverage have the resolution marks from 20 to 60 % relative image height. A well-designed lens should show good results in this range. See table 3 for a list of selected marks.

3.e Compensation technologies

The three competitors use different strategies to minimize the problems of analog designed lenses that have been described in **chapter 2.b**.

3.e.i Canon D 60

The Canon D60 shows an extraordinary behavior that has never been regarded by any other model in the market:

Using lenses that have little restrictions by the analog lens / digital sensor - interaction, resolution is **increasing** from image center to corner instead of decreasing. This effect is not based on a non-planarity of the lens' focal plane, as a compensation of the focal deviation by depth of field would result in stepwise increase of every aperture's resolution function. In fact from aperture 2.8 to 11, the center resolution of the best suited sample was not increasing. It is assumed that the CMOS-architecture allows an extremely sophisticated position-dependant signal processing. This means by increasing image height from center to corner, sharpening and edge processing functions try to compensate for the loss of resolution caused by lens architecture.

3.e.ii Fuji S2 Pro

The Fuji gains certain advantages by using the honeycomb - shape of sensor cells that is typical for the Super - CCD design. Less interference between chromatic aberration and sensor structure lead to less color-Moiré-effects than the classical architectures of CCD and CMOS.

3.e.iii Nikon D 100

Nikon is using shifted microlenses on the CCD-elements. The microlens layer looks to be a little contracted compared to the sensor layer below. This leads to less losses and microvignetting with slanted beampencils on areas out of the censor’s center.

3.e.iv Olympus E-20 P

Olympus does not require a special compensation, as the lens is a digital optimized architecture with parallel beampencils of light. The problems of chapter 2.b are not that relevant.

Table 2: Results of net image size

Camera & lens	focal length	at open aperture	2 stops closed	4 stops closed (3 stops with 28-200 at 200 mm position)
Canon D 60, ISO 100 File size 18.00 MByte				
16 - 35 mm 1 : 2.8	16 mm	5.05 MByte	9.70 MByte	10.58 MByte
	24 mm	4.88 MByte	6.57 MByte	8.86 MByte
	35 mm	3.19 MByte	10.23 MByte	12.55 MByte
28 - 200 mm 1 : 3.5 - 4.5	28 mm	8.88 MByte	11.92 MByte	10.39 MByte
	80 mm	8.88 MByte	11.27 MByte	9.64 MByte
	200 mm	6.61 MByte	8.00 MByte	7.92 MByte
70 - 200 mm 1 : 2.8	70 mm	5.83 MByte	9.82 MByte	11.89 MByte
	120 mm	7.74 MByte	12.55 MByte	12.47 MByte
	200 mm	7.81 MByte	8.59 MByte	10.13 MByte
85 mm 1 : 1.8	85 mm	10.43 MByte	13.40 MByte	14.67 MByte
Fuji S 2 Pro, ISO 100 File size 17.44 MByte				
17 - 35 mm 1 : 2.8	17 mm	6.18 MByte	13.04 MByte	12.06 MByte
	24 mm	3.47 MByte	10.63 MByte	13.24 MByte
	35 mm	8.51 MByte	10.62 MByte	12.96 MByte
28 - 200 mm 1 : 3.5 - 4.5	28 mm	5.37 MByte	11.24 MByte	8.40 MByte
	80 mm	9.70 MByte	12.01 MByte	12.82 MByte
	200 mm	10.79 MByte	7.97 MByte	7.43 MByte
80 - 200 mm 1 : 2.8	80 mm	11.33 MByte	12.57 MByte	8.45 MByte
	120 mm	10.30 MByte	13.39 MByte	6.57 MByte
	200 mm	6.16 MByte	8.69 MByte	3.51 MByte
85 mm 1 : 1.4	85 mm	7.11 MByte	11.25 MByte	13.32 MByte
Nikon D 100, ISO 200 File size 17.21 MByte				
17 - 35 mm 1 : 2.8	17 mm	4.88 MByte	8.94 MByte	8.17 MByte
	24 mm	4.74 MByte	9.15 MByte	9.32 MByte
	35 mm	6.07 MByte	7.57 MByte	8.85 MByte
28 - 200 mm 1 : 3.5 - 4.5	28 mm	7.75 MByte	9.17 MByte	7.75 MByte
	80 mm	6.20 MByte	9.04 MByte	8.47 MByte
	200 mm	8.43 MByte	7.45 MByte	5.00 MByte
80 - 200 mm 1 : 2.8	80 mm	8.20 MByte	9.35 MByte	7.46 MByte
	120 mm	8.34 MByte	9.52 MByte	8.44 MByte
	200 mm	5.72 MByte	8.41 MByte	4.98 MByte
85 mm 1 : 1.4	85 mm	5.95 MByte	8.61 MByte	9.55 MByte
Olympus E 20 P, ISO 80 File size 14.06 MByte				
9 - 36 mm 2 - 2.4	9 mm	9.65 MByte	11.93 MByte	8.30 MByte
	18 mm	10.61 MByte	12.57 MByte	10.46 MByte
	36 mm	9.99 MByte	11.91 MByte	10.27 MByte

Table 3: Results of resolution from center to corner

Camera & lens	focal length	loss at open aperture	loss at 2 stops closed
Canon D 60, ISO 100			
16 - 35 mm 1 : 2.8	16 mm	obvious	very good
	24 mm	moderate	moderate
	35 mm	moderate	good
28 - 200 mm 1 : 3.5 - 4.5	28 mm	moderate	very good
	80 mm	very good	very good
	200 mm	good	good
70 - 200 mm 1 : 2.8	70 mm	moderate	very good
	120 mm	obvious	good
	200 mm	good	good
85 mm 1 : 1.8	85 mm	good	very good
Fuji S 2 Pro, ISO 100			
17 - 35 mm 1 : 2.8	17 mm	obvious	very good
	24 mm	obvious	moderate
	35 mm	moderate	good
28 - 200 mm 1 : 3.5 - 4.5	28 mm	moderate	good
	80 mm	very good	very good
	200 mm	very good	good
80 - 200 mm 1 : 2.8	80 mm	very good	very good
	120 mm	good	very good
	200 mm	good	very good
85 mm 1 : 1.4	85 mm	critical	good
Nikon D 100, ISO 200			
17 - 35 mm 1 : 2.8	17 mm	obvious	very good
	24 mm	obvious	very good
	35 mm	good	good
28 - 200 mm 1 : 3.5 - 4.5	28 mm	very good	very good
	80 mm	good	very good
	200 mm	very good	very good
80 - 200 mm 1 : 2.8	80 mm	very good	very good
	120 mm	very good	very good
	200 mm	very good	very good
85 mm 1 : 1.4	85 mm	moderate	very good
Olympus E 20 P, ISO 80			
9 - 36 mm 2 - 2.4	9 mm	moderate	very good
	18 mm	moderate	very good
	36 mm	very good	very good

4. Examination and results, part 2, OECF

Beside the omnipresent and frequently discussed resolution, a certain set of quality aspects is essential for every photographer. The cameras have been tested by three professional photographers under real life conditions in their daily work. The topics have been fashion, studio work, portrait, concert, nightscene, still-life, architecture. The metrical aspects are examined by scientific tests.

The resulting images have been discussed between the photographers and the lab tester.

4.a Input signal range

Dynamic range, capable object contrast, tone reproduction are important features of all imagecapturing devices, whether analog or digital. Silver halide film is usually capable of reproducing an object contrast from 7 to 9 stops.

The cameras tested have the following input dynamic ranges / capable object contrast:

Table 4: Comparison of input dynamic ranges

Camera	input dynamic range	Equivalence to film
Canon D 60, ISO 100	8.5 stops	good
Fuji S 2 Pro, ISO 100	8.9 stops	very good
Nikon D 100, ISO 200	8.4 stops	good
Olympus E 20 P, ISO 80	8.6 stops	good

4.b Color reproduction and graininess

Color reproduction and graininess are very difficult features. Nevertheless lab results of the color space of cameras are published in different magazines, the practical relevance of these tests is regarded to be low. The requirements for color management, illumination or filtering do not meet by far the real conditions of outdoor or press photography. So the visual and subjective comparison of digital images and silver halide based images by experts has been used for our classification.

4.b.i ISO 100 - 200 daylight or flash lighting

Color reproduction and graininess of the digital images are more or less on a comparable level to silver halide film. The results of all tested models are regarded to meet the professional requirements.

4.b.ii ISO 400 - 1600 daylight or flash lighting

The quality of digital images is considered equivalent or even better than silver halide film. The results of most of the tested models are regarded to produce equivalent to better results.

4.b.iii ISO 400 - 1600 tungsten lighting

The quality of digital images is on a better degree or offers features that are not available using silver halide film. The combination of tungsten light and ISO 1600 is unbeatable. The results offer possibilities with topics like concerts or nightscene, that have not been available before.

4.b.iv All ISO settings with fluorescent lighting or mixed lighting

The possibilities and various color settings of the tested digital cameras give new features, that are not available by using silver halide film under practical and economical aspects. Especially the control feature by using the camera monitor after every shot offers outstanding possibilities.

4.c OECF

The OECF is equivalent to the density function of silver halide film. A straight and continuous shape without distortion or nonlinearities is important for an accurate tone reproduction.

Table 5: Comparison of tone reproduction

Camera	non-linearities	equivalence to film
Canon D 60, ISO 100	very good	very good
Fuji S 2 Pro, ISO 100	good, little soft shadow parts	very good
Nikon D 100, ISO 200	excellent	excellent
Olympus E 20 P, ISO 80	moderate, little soft shadow parts	good

All tested cameras show a good to excellent OECF. The optical density function of film is nearly equivalent to the OECF of an digital sensor.

4.d Sharpening and edge analysis

Edge sharpening is not a typical digital function. Developer dilution and exhaustion effects during the developing process of silver halide film cause chemical sharpening too. Not the presence but the degree of sharpening is important for a natural image reproduction. Too much will produce an artificial look, images get the character of a TV-screen. High spatial frequency sharpening may cause artefacts like Moiré.

The amount of sharpening is a tradeoff between a defensive strategy and an aggressive strategy. The first creates a soft look but ensures excellent post-processing abilities with a dtp-software like Adobe Photoshop. The latter creates a sharp brilliant look with good printing abilities but disadvantages with post-processing.

Table 6: Comparison of edge enhancement strategies

Camera	character at default setting	equivalence to film
Canon D 60, ISO 100	moderate to slightly aggressive	good
Fuji S 2 Pro, ISO 100	moderate	very good
Nikon D 100, ISO 200	soft	good
Olympus E 20 P, ISO 80	moderate to slightly aggressive	good

All models offer a sophisticated sharpening technology. Using a very complex local frequency analysis, they provide low spatial frequency edge enhancement **and** avoid high spatial frequency artefacts.

4.e Corner shading

Corner shading with digital cameras is much more complex to interpret than it is with silver halide film. CCD-sensors are very sensitive towards slanted beampencils of light. Usually the degree of loss of light is higher with a sensor even using the same lens and aperture. To compensate this effect, the sensor sensitivity increases from images center to corner. This results in an increase of noise and loss of dynamic range. In this test only the pictorial effect of visual shading will be discussed.

The distribution of light from the image center to the four corners is an excellent indicator for defects of the optical centering of the whole system.

Table 7: Comparison of corner shading

Camera	loss of light in stops at different zoom position at maximum aperture / minus two stops	comment	maximum deviation centering test
Canon D 60, ISO 100		good	
16 - 35 mm 1 : 2.8	0.8/0.8 - 0.9/0.5 - 0.9/0.3	moderate to good	< 0.3 stops
28 - 200 mm 1 : 3.5 - 4.5	0.8/0.5 - 0.3/0.3 - 0.5/0.2	good	< 0.25 stops
70 - 200 mm 1 : 2.8	0.4/0.1 - 0.2/0.2 - 1.0/0.2	good	< 0.35 stops
85 mm 1 : 1.8	1.2/0.1	very good	< 0.2 stops
Fuji S 2 Pro, ISO 100		very good	
17 - 35 mm 1 : 2.8	0.6/0.6 - 0.5/0.5 - 1.2/0.4	moderate to good	< 0.25 stops
28 - 200 mm 1 : 3.5 - 4.5	1.0/0.7 - 0.3/0.3 - 0.7/0.2	moderate to good	< 0.3 stops
80 - 200 mm 1 : 2.8	0.2/0.2 - 0.1/0.1 - 0.9/0.0	very good	< 0.1 stops
85 mm 1 : 1.4	0.9/0.1	very good	< 0.1 stops
Nikon D 100, ISO 200			
17 - 35 mm 1 : 2.8	0.5/0.5 - 0.7/0.4 - 1.2/0.3	moderate to good	< 0.4 stops
28 - 200 mm 1 : 3.5 - 4.5	1.0/0.5 - 0.3/0.3 - 0.6/0.2	moderate to good	< 0.2 stops
80 - 200 mm 1 : 2.8	0.1/0.1 - 0.2/0.2 - 0.9/0.0	very good	< 0.25 stops
85 mm 1 : 1.4	1.1/0.2	very good	< 0.1 stops
Olympus E 20 P, ISO 80	0.8/0.2 - 0.6/0.2 - 0.4/0.2	very good	< 0.2 stops

The results of all tested cameras show a degree comparable to analog photography. The low marks of deviation prove a good adjustment of lens mount and sensor plane.

5. Final results

To give the required answers, we repeat the three essential questions put forward in **Chapter 2.a.** They describe the central intention of this examination:

I. Can actual high-end digital cameras compete with analog models and silver halide film?

II. How do “analog designed lenses” interact with a digital sensor and which restrictions occur compared to digital designed lenses?

III. What are the consequences for the semi-professional and professional photographer?

5.a Ad I: Comparison between analog and digital

The Comparison of silver halide film-based photography and digital photography show the following results. These results are applicable for 35 mm film only:

i. Regarding the very sophisticated part of photography, producing high-end large format prints using appropriate lenses and low to midrange ISO speed films, silver halide photography is still able to produce better and more detailed results than digital photography can do.

ii. For small to mid-range format prints using midrange ISO speed films, all of the tested digital cameras can produce results that are equivalent to those of silver halide film.

iii. In a lighting situation requiring a high ISO speed or in a tungsten, fluorescent or mixed lighting situation, digital photography shows remarkable advantages or offers even new possibilities that have not been available with silver halide film.

iv. Under most practical conditions digital photography now offers results and quality aspects that can compete with silver halide film. For use at concerts, low light and by the press, digital cameras can already beat their analog competitors.

5.b Ad II: Analog and digital lenses

The question for the right lens guides to a decision for the system that fits best each individual demands. Therefore the properties and the compatibility of analog designed lenses were examined at the most sophisticated level to ensure results on a reliable degree. The results of this examination lead to the following statements:

i. A significant change in technology happens. The actual generation of 6-Megapixelsensors reach a limitation of 35 mm - SLR - lenses. The resolution bottlenecks, formerly caused by the sensor, are now defined by the lens' abilities.

ii. As the lens is now regarded to be the significant resolution factor, the practical need for the next, higher resolving camera generation loses importance. People must not fear a huge investment that seems to have lost its value within half a year facing the next improved model.

iii. Beside some highly sophisticated topics like studio reproduction or large format printing, the actual digital cameras have the capability to substitute analog competitors.

iv. To gain good results the photographer needs to pay more attention to the choice of suited lenses. Therefore there is a public need for more sophisticated compatibility tests to avoid ”bad combinations” of lenses and cameras. This helps to preserve an acceptable cost-benefit-relation especially with fast lenses of high aperture.

v. To improve resolution it is necessary to say goodbye to an old tradition. The analog architecture 35 mm - SLR - lenses underlies serious restrictions when used with high resolution digital sensors. New lenses, optimized for the sensors' needs, are necessary. Regarding the features of state-of-the-art sensors it seems to be hardly recommended to develop new completely digital optimized systems. The expected advantages are smaller dimensions, higher resolution, faster lenses and less limitations with the reduced angle of view. This effect lead to the so-called “extended focal length” that occurs with 35 mm - lenses on the current cameras.

5.c Ad III: Guidelines for the photographer

The situation for the photographer is not very complicated. The most important step is to define the personal needs:

i. Those who waited for digital cameras that can compete with silver halide film based models can buy now. Regarding resolution, speed, film properties, digital cameras can compete. Under extreme lighting conditions, actual digital photography exceeds analog capabilities.

ii. For those photographers who have spent much money on their existing set of AF-lenses and wish to keep them and who want to use both, analog and digital with the same system, they will find a good solution with the new 6-Megapixel-generation.

iii. But it is highly recommended to read the latest tests and reports about compatibility and bad-suited combinations. Especially to avoid bad investment with new lenses, publications and articles in magazines are a preferable information source as well as specific internet newsgroups.

iv. From the technical point of view a new architecture of digital cameras is the best way to gain most advantages from the new technologies without critical tradeoffs. Some of these advantages are a broader range of focal length, faster lenses, better resolution marks, compactness, wide preferable aperture ranges. From the professional and sophisticated semi-professional point of view, an optimized system ensures significant advantages for an efficient work and the professional competition.

v. A very specific but important aspect is efficient data handling. The results prove, that a large number of pixel produces big files but it isn’t a guarantee for sharp and high resolving images. The consumer must focus on memory card capacity, data storage, file transfer on networks etc. All of them require an effective and economic data management with high quality image files. The more pictures a photographer takes, stores and distributes the more advantages he gains with cameras of good efficiency marks or an economic file-size / net-file-size ratio.

6. General declaration

This examination has been done under unbiased conditions, respecting information and technical specifications provided by the manufacturer.

The test methods applied for this examination are not based on given standards like DIN or ISO standards. The results are not intended for general statements out of the context of this report.

Munich, 6 September 2002 Anders Uschold

7. Information about the expert

Anders Uschold studied computer science at the Technical University of Munich, with scientific photography and digital image analysis as major subjects. He is assistant professor for digital imaging and digital photography at the Institute of Computer Science, Department of Digital Image Analysis at the Technical University of Munich, Germany.

As an expert on image-processing technologies his test institute offers various services. Anders Uschold is an expert witness at court for analog and digital photography certified by the chambers of industry and commerce. He is a member of the DIN / ISO - committee phoki 2.2 / TC 42 WG18 , "Photography".

Since 1995 he has been working as a journalist for several German magazines.

For further information, please contact us.

Anders Uschold
Anders Uschold Digitaltechnik
Gleichmannstrasse 9 / III
D - 81241 Germany

Telephone:	++49 - 89 - 54643077
Telefax:	++49 - 89 - 54643078
Cell phone:	++49 - 172 - 8240541
e-mail:	info@uschold.com
URL:	http://www.uschold.com

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