UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HTC CORPORATION and HTC AMERICA, INC.
Petitioners

v.

E-WATCH, INC. and E-WATCH CORPORATION
Patent Owner

CASE: To Be Assigned
Patent No. 7,643,168 B2

DECLARATION OF KENNETH PARULSKI IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 7,643,168 B2

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I. INTRODUCTION

1. My name is Kenneth Parulski. I was the former Chief Scientist in the Digital Camera and Devices Division of Eastman Kodak Company and I am currently Chief Scientist and Managing Member of aKAP Innovation, LLC, which I founded in June 2012. aKAP Innovation, LLC provides innovation and digital photography related consulting services, and participates in the development of ISO ("International Organization for Standardization") standards for digital photography.

2. I have been engaged by HTC Corporation and HTC America, Inc. ("HTC") to investigate and opine on certain issues relating to U.S. Patent No. 7,643,168 B2 entitled "APPARATUS FOR CAPTURING, CONVERTING AND TRANSMITTING A VISUAL IMAGE SIGNAL VIA A DIGITAL TRANSMISSION SYSTEM" ("168 Patent") in HTC's Petition for Inter Partes Review of the 168 Patent ("HTC IPR Petition") which requests the Patent Trial and Appeal Board ("PTAB") to review and cancel Claims 1-6, 8, 10-11, 13-18, 21-29 and 31 of the 168 Patent, which, based on my understanding, are all the claims that are currently being asserted in a patent litigation against HTC.

3. I understand that, according to USPTO assignment records of the 168 Patent, the 168 Patent is owned by E-Watch, Inc. It is also my understanding that E-Watch Corporation claims to be the exclusive licensee of the 168 Patent. E-Watch, Inc. and E-Watch Corporation are asserting the 168 Patent in litigation against HTC and others and are therefore referred to as the "Patent Owner" in this Declaration.

4. In this declaration, I will discuss the technology related to the 168 Patent, including an overview of that technology as it was known prior to, and up to the January 12, 1998 filing date to which the parent of the 168 Patent claims priority. This overview of the relevant technology provides some of the bases for my opinions with respect to the 168 Patent.

5. This declaration is based on the information currently available to me. To the extent that additional information becomes available, I reserve the right to continue my investigation and study, which may include a review of documents and information that may be produced, as well as testimony from depositions that may not yet be taken.

6. In forming my opinions, I have relied on information and evidence identified in this declaration, including the 168 Patent, the prosecution history of the 168 Patent, and prior art references listed as Exhibits to the Petition for *Inter Partes* Review of the 168 Patent. I have also relied on my own experience

and expertise in the relevant technologies and systems that were already in use prior to, and within the timeframe of the earliest priority date of the claimed subject matter in the 168 Patent— January 12, 1998.

II. SUMMARY OF OPINIONS

7. The claims of the 168 Patent are directed to technical issues or needs that were recognized and well understood, and technical solutions that were well developed to address the technical issues or needs, at the time of filing the 168 Patent – January 12, 1998.

8. For purpose of my analysis in this declaration only and based on the disclosure and file history of the 168 Patent, I provide my proposed construction of certain terms in Claims 1-6, 8, 10-11, 13-18, 21-29 and 31 in detail in a later part of this declaration.

9. In simple terms, Claims 1-6, 8, 10-11, 13-18, 21-29 and 31 of the 168 Patent attempt to claim the combination of a handheld wireless telephone and a digital camera having components and features which were well-known at the time. It is my opinion that there is nothing novel in the claims of the 168 Patent and Claims 1-6, 8, 10-11, 13-18, 21-29 and 31 of the 168 Patent merely recite routine and common features that were well known and were published before the filing of the 168 Patent and are rendered obvious by the prior art cited in the HTC IPR Petition.

10. The subsequent sections of this declaration will first provide my qualifications and experience and then describe details of my analysis and observations of Claims 1-6, 8, 10-11, 13-18, 21-29 and 31 of the 168 Patent.

III. QUALIFICATIONS AND EXPERIENCE

A. Education and Work Experience

11. I received a Master of Science degree and a Bachelor of Science degree in Electrical Engineering from the Massachusetts Institute of Technology in 1980. I completed my master's thesis research while working at Motorola Corporate Research Labs from 1978 through 1980, where I developed a system for transmitting a series of digital images from a moving vehicle over an FM radio communications link to a base station. The laboratory where I worked was managed by Dr. Martin Cooper, who led the Motorola team that built and demonstrated the world's first handheld cellular telephone.

12. I joined Kodak Research Labs in 1980, and began developing and implementing image processing algorithms. Beginning in 1984, I led a project to develop the world's first color megapixel digital camera system prototype. Prints made using this system were exhibited at the Photokina trade show in 1986, in Kodak's first public demonstration of its digital photography technology. Photokina is the world's largest trade show for the imaging industry. I also lead teams which developed an image processing

VLSI chipset for digital video cameras, and designed high performance video cameras for industrial and government applications.

13. From approximately 1986 through 1992, I served as Kodak's technical representative to the Advanced Television Research Program at MIT, which developed "source adaptive" video compression technologies now used in most HDTV transmission systems. As part of this project, I became a named inventor on a television decoding patent which was licensed by MIT to many HDTV manufacturers.

14. Beginning in 1992, I served as architect of Kodak's first generation of consumer-oriented digital still cameras, which included the Kodak DC40 camera as well as the Apple QuickTake 100 camera, the first digital camera marketed by Apple. In my role as digital camera architect at Kodak and through my participation in various projects I acquired experience in all aspects of digital camera design, including the selection of hardware and software components, user interfaces, and image formats.

15. I am a named inventor on more than 200 issued United States patents. Most of these inventions related to digital cameras and digital photography systems, and have been broadly licensed by Kodak to more than 40 companies for use in digital cameras, smartphones, and photo sharing services. Licensing these

patents provided Kodak with earnings of more than $2 Billion dollars from 2005 to 2010.

16. I have authored more than 50 presentations and papers, including invited talks on digital cameras in the US, Europe and Asia. I authored the "Digital Photography" chapter in the Consumer Digital Electronics Handbook by McGraw-Hill 1997, and co-authored the "Color Image Processing for Digital Cameras" chapter in the Digital Color Imaging Handbook; CRC Press 2003. I have also developed and taught Kodak internal courses on video technology and digital cameras.

17. I have served as Chair of the IT10 standards committee for digital photography since 1994. This group provides the officially recognized United States input for many international standards used by digital cameras, including smart phone digital cameras. In addition, from March 2007 through February 2013, I was chair of ISO technical committee 42 (ISO/TC42), which is responsible for all international photography standards. In May 2013, I was elected chair of the US technical advisory group to ISO/TC42. From June 3-7, 2013, I served as head of the US delegation to the 23rd plenary meeting of ISO/TC42, held at the National Museum in Copenhagen, Denmark.

18. I currently serve as an expert in ISO Technical Committee 42 (Photography), and am co-project leader (with Mr. Toru Nagata of Canon) for both ISO

12234-1:2012 *Electronic still-picture imaging -- Removable memory -- Part 1: Basic removable-memory model*, which standardizes image formats, including the Exif image format, used in digital cameras and ISO/WD 12234-3, which is intended to standardize the use of XMP metadata in digital photography.

19. I am a Fellow of the Society of Motion Picture and Television Engineers. In 2001, Kodak received a Technical Emmy Award for contributions I made to the development of the 24P HDTV production standard, which is used by Hollywood studios to produce movies and TV programs. In 2002, I received the Photo-imaging Manufacturing & Distributors Association Technical Achievement Award for "pioneering work in the development of digital imaging technology," becoming the first digital photography expert to be honored by this photographic association. In 2008, I received the International Imaging Industries Association (I3A) Achievement Award, for "significant contributions to the advancement and growth of the imaging industry."

20. A copy of my resume is provided as **Attachment A** at the end of this Declaration.

B. Compensation

21. I am being compensated at the rate of $525 per hour for the services I am providing in this case. The compensation is not contingent upon my performance, the outcome of this *inter partes* review or any other proceeding, or any issues involved in or related to this *inter partes* review.

C. Documents and Other Materials Relied Upon

22. The documents on which I rely for the opinions expressed in this declaration are documents and materials identified in this declaration, including the 168 Patent, related patents and applications in the same family as the 168 Patent, the prosecution histories for the 168 Patent and related family members of the 168 Patent, the prior art references and information discussed in this declaration, and any other references specifically identified in this declaration, in their entirety, even if only portions of these documents are discussed here in an exemplary fashion.

IV. STATEMENT OF LEGAL PRINCIPLES

A. Claim Construction

23. I understand that, when construing claim terms, a claim subject to *inter partes* review receives the "broadest reasonable construction in light of the specification of the patent in which it appears." I further understand that the broadest reasonable construction is the broadest reasonable interpretation

(BRI) of the claim language, and that any term that lacks a definition in the specification is also given a broad interpretation.

B. Anticipation

24. I understand that in order for a patent claim to be valid, the claimed invention must be novel. I further understand that if each and every element of a claim is disclosed in a single prior art reference, then the claimed invention is anticipated, and the invention is not patentable according to pre-AIA 35 U.S.C. § 102 effective before March 16, 2013. In order for the invention to be anticipated, each element of the claimed invention must be described or embodied, either expressly or inherently, in the single prior art reference. In order for a reference to inherently disclose a claim limitation, that claim limitation must necessarily be present in the reference. I also understand that a prior art reference must be enabling in order to anticipate a patent claim.

C. Obviousness

25. I understand that obviousness under pre-AIA 35 U.S.C. § 103 effective before March 16, 2013 is a basis for invalidity. Specifically, I understand that where a prior art reference discloses less than all of the limitations of a given patent claim, that patent claim is invalid if the differences between the claimed subject matter and the prior art reference are such that the claimed subject matter as a whole would have been obvious at the time the invention was

made to a person having ordinary skill in the relevant art. Obviousness can be based on a single prior art reference or a combination of references that either expressly or inherently disclose all limitations of the claimed invention.

V. LEVEL OF ORDINARY SKILL IN THE ART

26. I understand that the claims and specification of a patent must be read and construed through the eyes of a person of ordinary skill in the art at the time of the priority date of the claims. I also understand that to determine the appropriate level of a person having ordinary skill in the art, the following factors may be considered: (a) the types of problems encountered by those working in the field and prior art solutions thereto; (b) the sophistication of the technology in question, and the rapidity with which innovations occur in the field; (c) the educational level of active workers in the field; and (d) the educational level of the inventor.

27. The relevant technologies to the 168 Patent are those used in digital cameras and other digital imaging devices which capture, compress, store, and wirelessly transmit images, and also provide wireless telephony. The 168 Patent describes embodiments which capture a video image using a digital camera, analog camera, or a camcorder, convert the image to a digital format, and transmit the image to a remote location using, for example, the Group-III fax protocol. (See Col. 2, lines 37-45).

28. Based on the above considerations and factors, it is my opinion that a person having ordinary skill in the art would have at least a bachelor's degree in electrical engineering, computer science, or a related field, and 3-5 years of experience in designing digital imaging devices. This description is approximate and additional educational experience in digital imaging could make up for less work experience and vice versa.

VI. TECHNOLOGY BACKGROUND OF CLAIMED SUBJECT MATTER OF THE 168 PATENT

A. Evolution of Digital Cameras

29. The first known working prototype digital camera was designed by Mr. Steven Sasson of Kodak between 1974 and 1976. This work lead to U.S. Patent No. 4,131,919, titled "Electronic still camera," and issued to Lloyd and Sasson. Sasson's prototype digital camera was publicly revealed for the first time many decades later, in the digital camera history portion of an invited paper entitled "The Continuing Evolution of Digital Cameras and Digital Photography Systems," which I personally presented in Geneva, Switzerland at the IEEE International Symposium on Circuits and Systems in May 2000.

30. The Sasson prototype digital camera used the lens and optical viewfinder from a Kodak XL55 Super 8mm film movie camera. The image sensor was a Fairchild type 201 CCD array having 100 x 100 pixels. The sensor's analog

output signal was digitized using a 4-bit A/D converter. The prototype camera captured and stored black and white still images using a standard Phillips digital cassette tape. The tape recorded 2275 bits/sec, moving at 5-1/4 inches/sec. It took 23 seconds to capture and store each image, and each tape could store up to 30 images.

31. Despite this primitive technology, Mr. Sasson recognized that images from electronic cameras could be sent over conventional communication channels with little or no modification, and mentioned this possibility in the 1977 Kodak technical report he authored which described the camera and playback system he had just developed. (See "Driving desired futures – turning design thinking into real innovation", Shamiyeh, Birkhauser Verlag GmbH, Basel, 2014, pp. 238-247)

32. On Aug 24, 1981, Sony chairman Akio Morita demonstrated the Sony MAVICA electronic still camera and described the Sony MAVICA system, which included a printer and a telephone transmission unit for transmitting images captured by the MAVICA camera. I personally attended the IEEE Conference on Consumer Electronics in June 1982, where Sony presented their first technical papers describing their MAVICA camera and transmission system. The MAVICA camera stored up to 50 images on an approximately 2" MAVIPAK floppy disk (See Kihara, et al, "The electronic still camera – a

new concept in photography," IEEE Trans Consumer Electronics, Vol. CE-28, No. 3, Aug 1982). A slightly modified version of the "MAVIPAK" was later standardized as the "still video floppy" (SVF).

33. Canon was the first company to sell electronic still cameras in the US, when they introduced the Canon RC-701 electronic camera in 1986. The Canon RC-701 system components included the camera, a player/recorder, a printer, and a unit for phone transmission of images captured by the camera. Early prototypes of the camera and phone transmission unit were designed for the 1984 Los Angeles Olympic Games so that images of Olympic events could be captured with the camera and wirelessly transmitted using the Canon electronic transmitter connected to an automobile telephone to a Japanese newspaper, Yomiuri Shimbun. (See http://www.canon.com/camera-museum/history/canon_story/1976_1986/1976_1986.html)

34. By 1989, many other companies, including Fuji, Konica, Minolta, Nikon, Olympus, Sony and Panasonic were selling electronic still cameras using the SVF format. (See Kriss, et al. "Critical technologies for electronic still imaging systems," SPIE vol. 1082, pp. 157-184 at p. 159) Systems assembled from products available at the time included the ability to send images anywhere in the world, using image transceivers connected to telephone communication systems. (ibid at p.158)

35. All digital cameras envisioned, designed or produced prior to the 1998 priority date of the 168 Patent include essentially the same fundamental components: an optics section that receives the light from an object, a semiconductor image sensor, such as a CCD array, that receives the light and produces corresponding electrical signals, an analog-to-digital converter that converts the analog signals into digital image data, at least one processing component, such as a microprocessor or specialized circuitry which controls image capture operations and performs subsequent digital image processing, and a memory which stores the digital images. The very same fundamental components that were known as early as the 1970s appear as claim elements in the 168 Patent.

B. Image Processing in Digital Cameras

36. By the early 1990s, it was widely known that digital camera images could be processed using custom hardware circuitry or using programmable processors which execute software algorithms. For example, the first publication describing an experimental digital camera was made by NHK in 1983 (See "Fully Digitalized Electronic Still Camera", Ohnishi, et. al., J. Inst. TV Engnrs of Japan, Vol. 37, No. 10 (1983) pp. 863-868). In this camera, images were captured by a color image sensor and stored using a detachable static RAM memory. An Intel 8086 microprocessor, located in a playback device, was

used to perform image processing, including color separation, white balance, and gamma correction.

37. Custom digital processing integrated circuits were then developed for use in digital still and video cameras. (See "A Basic Approach to a Digital Color Camera System", O'Keefe, et al., IEEE Trans on Consumer Electronics, Vol. CE-30, No. 3, Aug. 1984, pp 409-415 and "A High-Performance Digital Color Video Camera", Parulski et al., SPIE Vol. 1448 Camera and Input Scanner Systems, 1991, pp 45-58). These hardwired integrated circuits performed specific digital image processing functions, in order to rapidly produce full-color images from a single-chip color image sensor. A microprocessor could be used to set some of the image processing parameters, in order to perform functions such as white balancing and flare correction, and adjust the processing to match the user's preferences.

38. Digital cameras developed as early as the 1980s included a software programmable processor which controlled the camera hardware in order to capture, store, and retrieve images. For example, the world's first D-SLR camera, which was called the "Electro-optic" camera and was designed and constructed by Eastman Kodak Company under a U.S. Government contract between 1987 and 1988, used software commands executed by an Intel 80C196 16 bit microcontroller to control the camera. (See

http://eocamera.jemcgarvey.com/). The software commands were written in the PL/M language, and included, for example, commands which opened the camera shutter and exposed the image sensor to light, controlled a SCSI magnetic hard disk drive in order to write and read image data, and controlled the camera status display module. (See http://eocamera.jemcgarvey.com/pdf/firmware.pdf).

C. Proliferation of Commercially Available Digital Cameras

39. The Fuji DS-1P digital camera, announced in September 1988, was the first digital still camera to be publicly demonstrated. The camera stored digital images using a removable card having RAM semiconductor memory ICs. Rechargeable batteries on the removable card were used to power the RAM, in order to retain the images. In 1990, Dycam introduced their "Model 1" portable digital still camera, the first digital camera with a list price of under $1,000. The Dycam Model 1 stored up to 32 monochrome, QVGA resolution (376 x 240 pixel) images in internal RAM memory, which was continuously powered by batteries in order to retain the images. (See "Point and shoot digital electronic camera introduced", Electronic Photography News, Sept 1990, p. 7)

40. In 1991, Kodak introduced the Kodak Professional Digital Camera System, later known as the DCS-100, which consisted of a camera back fitted to a

Nikon F3 camera and a separate digital storage unit (DSU) connected to the camera back using a digital interconnect cable. The DSU included a magnetic hard drive which stored the captured images and an LCD display which displayed a user interface and the images captured by the digital camera. The DSU also included a set of 12 keys which enabled the camera operator to select images and perform operations such as image transmission. The DSU also included a keyboard connector, which enabled the user to enter text, such as image titles, captions, and keywords, using a separate keyboard. A Telebit T2500 modem was used to transmit user-selected image files from the digital storage unit over a telephone line to a remote Macintosh computer. Captured images were selected for transmission using the display and keys on the DSU. (See "User's Manual, Kodak Professional Digital Camera System", 1991-1992)

41. The Apple QuickTake 100 was introduced in February 1994. I was the architect of the Apple QuickTake 100 and 150 cameras, which were designed by Kodak and marketed by Apple. The QuickTake 100 stored a maximum of 8 VGA (640 x 480 pixels) "high resolution" images or 32 QVGA (320 x 240 pixels) "standard resolution" images in a 1 MB internal Flash EPROM memory. The digital images were compressed prior to storage in the camera using a Kodak developed ADPCM (Adaptive Differential Pulse Code

Modulation) software compression algorithm contained in the camera's firmware memory. In 1994, I co-authored a paper at the Imaging Science and Technology (IS&T) Conference that detailed the architecture and components of this camera. The presentation was subsequently published as "Digital, Still-Optimized Architecture for Electronic Photography", IS&T's 47th Annual Conference/ICPS 1994, pp. 665-667, which is reproduced in **Attachment B** at the end of this Declaration. The digital image compression algorithm in this camera was executed by a Texas Instruments (TI) digital signal processor (DSP), controlled by Kodak developed software instructions. The TI DSP read the image data from a RAM buffer memory, performed image compression, and stored the compressed image data in the camera's Flash EPROM memory.

42. I was also the architect of the Kodak DC40 camera, which was introduced in April 1995. The DC40 used 4 Mbytes of internal Flash EPROM memory to store 48 images at 400K pixel resolution, or 99 lower resolution images. It took approximately 6 seconds in order to capture, compress, and store each digital image. The camera used an improved Kodak designed RADC (Rate Adaptive Different Compression) image compression algorithm, which was executed by a TI DSP within the camera. (See "The digital camera using new compression and interpolation algorithm", Shimizu et. al., SPSTJ 70th

Anniversary Symposia on Fine Imaging, pp 69-72, Oct 1995, Tokyo, Japan, in Japanese)

43. The Olympus VC-1100 camera, introduced in 1994, included image transmission capabilities. The user could connect an accessory modem to the VC-1100 and transmit digital photos over cellular and analog phone lines to a second camera or to a personal computer. The VC-1100 camera included a zoom lens as well as an LCD viewfinder which was used to compose images prior to capture. The captured images were stored on removable PCMCIA cards.

44. The Casio QV-10 digital camera, released in 1995 in Japan included an LCD panel for composing and reviewing digital still images, rather than an LCD or CRT electronic viewfinder, or an optical viewfinder. (see http://world.casio.com/news/2012/0913_qv10/) The Casio QV-10 used 2 MB of internal Flash memory in order to store a maximum of 96 JPEG compressed color images with 320 x 240 pixels. A 32-bit RISC microcontroller was used to perform JPEG compression by executing the compression algorithm instructions which were stored in a ROM memory. (See "LCD Digital Camera QV-10", Hiroyuki Suetaka, SPSTJ 70th Anniversary Symposia on Fine Imaging, pp 63-64, Oct 1995, Tokyo, Japan, in Japanese). An English description of the QV-10 Camera and its architecture

is provided in Parulski, “Chapter 21 Digital Photography” in Jurgen, “Digital Consumer Electronics Handbook”, 1997, McGraw-Hill, pp. 21.5, which is reproduced in **Attachment C** at the end of this Declaration.

45. In August 1995, Toshiba announced the PDR-100 digital camera, which featured an integrated modem and communications software, allowing users to transmit digital still images over a cellular phone (See https://www.toshiba.co.jp/about/press/1995_08/pr0701.htm). The camera included a built-in microphone to record audio as well as images, and a PC Memory card slot to store the compressed images and audio files.

46. Electronic viewfinders were used in almost all video camcorders, including the Kodak Kodavision 8mm camcorder which was introduced in January 1984. Some early digital cameras used electronic viewfinders, while others used optical viewfinders. For example, the first publicly disclosed experimental digital camera used an electronic viewfinder to preview images before capture and to also review captured images. (See Fig. 3 in “Fully Digitalized Electronic Still Camera”, Ohnishi, et. al., J. Inst. TV Engnrs of Japan, Vol. 37, No. 10 (1983) pp. 863-868.) The main difference between an electronic viewfinder and an optical viewfinder is that the images in the former are produced when the light from a scene to be captured is collected by the camera optics and is incident on an image sensor (such as a CCD image

sensor). The image sensor outputs electrical signals that are converted from analog to digital values and provided to an electronic display such as an LCD for viewing. An optical viewfinder, on the other hand, does not manipulate electronic signals. Instead the light from the scene to be captured is collected by the camera optics and relayed to the user through optical components such as lenses, mirrors, etc. for viewing through a viewfinder window. In 1992, Sharp introduced their VL-HL 1 LCD ViewCam, the first consumer camcorder to include a large color LCD display panel rather than a small electronic viewfinder. (See http://sharp-world.com/corporate/info/his/h_company/1993/).

47. The Casio QV-10 digital camera, released in 1995, included a color LCD digital camera to preview images before capture, and to review the captured images. (See "LCD Digital Camera QV-10", Hiroyuki Suetaka, SPSTJ 70th Anniversary Symposia on Fine Imaging, pp 63-64, Oct 1995, Tokyo, Japan, and Parulski, "Chapter 21 Digital Photography" in Jurgen, "Digital Consumer Electronics Handbook", 1997, McGraw-Hill, pp. 21.5, which is reproduced in **Attachment C** at the end of this Declaration). From 1996 to 1997, Kodak introduced three digital cameras, the model DC25, DC120, and DC210 cameras, which included a color LCD to display both captured images as well as a graphic user interface. Switches and other user controls enabled the

captured images to be selectively viewed, manipulated, deleted, or transferred to a removable memory card. These cameras included an optical viewfinder in addition to the color LCD display, since the optical viewfinder provided a sharper and more responsive viewfinder image.

48. By the mid-1990s, commercially available digital cameras had matured from their earlier predecessors, and many included common features such as an image display and user interface switches, dials, menus or other items that allowed a user to selectively view, manipulate, delete, store or transmit the digital images captured by the camera. These cameras often incorporated software or firmware based capabilities that could be updated or changed. Further, with advancements in image compression technology, software- or hardware-based image compression algorithms were implemented in the cameras, which allowed more images to be captured and stored in the digital camera, while also facilitating the transmission of the images via phone connections. The use of compression technologies in digital cameras is further discussed below.

49. The above features, which were well developed and implemented in consumer digital cameras of by the mid-1990s, are also listed as claim elements in the 168 Patent.

D. Integrated versus Modular Implementations

50. Prior to the 1998 priority date of the 168 Patent, it was widely known that rather than being designed as a single, integral unit, digital cameras and camcorders can be designed using a modular approach. For example, Kodak's first generation 8mm camcorders, known as "Kodavision", integrated the camera and recorder into a single, self-contained, portable housing. But Kodak's next generation camcorders used a modular approach, known as the Kodak MVS Modular Video System. I personally used the Kodak MVS Modular Video System soon after it was introduced in 1986. When capturing video, including images and audio, the camera and recorder were normally linked together both mechanically and electrically, and used like any other one-piece camcorder. But at home, the recorder and camera could be separated, so that the recorder could be connected to a tuner/timer module. This allowed it to not only play back video images and audio captured with the camera, but also perform all the functions of a normal home VCR, such as recording television and cable programs. The modular approach allowed customers to choose between two different camera options, and two different recorder options, so they could purchase a camcorder having the camera and recorder features that they preferred. The modular system also allowed the camera to be connected to the recorder by a cable, since some customers preferred a two-piece camcorder arrangement. (See

http://www.nytimes.com/1986/02/09/arts/home-video-this-versatile-unit-does-double-duty.html).

51. I have personally applied this type of modular design to digital cameras, as described in U.S. Patent 5,040,068 "Electronic imaging apparatus with interchangeable pickup units" to Parulski, et. al. This patent describes a digital camera which is partitioned into separate modular units, including a pickup unit and a recorder unit. Different pickup units can be used to capture different types of images, such as color vs. monochrome and still vs. motion.

52. Using a modular approach is advantageous in allowing the use of the same module (e.g. the same lens, camera, display, removable memory card, or transmission module) in multiple systems. It also allows the use of multiple modules with different capabilities (e.g. removable lenses having different focal lengths, or different capacity removable memory cards) in a single system, such as a D-SLR camera. However, it is usually just as easy (if not easier) to develop a single integrated unit with fixed (e.g. hardwired and permanently attached) components. The prior art landscape before the 1998 priority date of the 168 Patent is filled with examples of camera systems having fixed components inside a single integrated housing, as well as camera systems which were assembled from modular components, which makes any

differentiation of the 168 claim elements based on integration of components (or lack thereof) obvious and non-patentable.

E. Image Compression Technologies

53. Most digital cameras prior to the 1998 priority date of the 168 Patent used image compression, in order to reduce the amount of data that represents each image. This reduced the amount of memory used to store an image, and the amount of time it took to transmit an image. The JPEG standard, ISO/IEC 10918-1, specifies a baseline compression algorithm using the adaptive discrete cosine transform (ADCT). The JPEG standard was developed in the late 1980's and published as an approved international standard in 1994 (See ISO/IEC 10918-1:1994, Information technology - Digital compression and coding of continuous-tone still images: Requirements and guidelines, available online at http://www.iso.ch.). Almost all digital cameras sold after 1995 have incorporated JPEG image compression, which was also the subject of many publications before the commercial availability of these products. JPEG image compression was implemented using custom hardware (See D'Luna, et. al., "An 8×8 discrete cosine transform chip with pixel rate clocks" Third Annual IEEE ASIC Seminar and Exhibit, Proceedings, P7/5.1 - P7/5.4 , 1990.) or using software executed by DSP or RISC processor (See Yamamoto, et. al, "A Full Frame Still Camera using Software JPEG", SPSTJ

70th Anniversary Symposia on Fine Imaging, pp 65-66, Oct 1995, Tokyo, Japan.).

54. Software implementation of compression algorithms is also described in U.S. Patent 5,477,264 filed in 1994 and issued in 1995 (in which I am a named inventor). This patent describes storing compression software, such as JPEG, in a memory of the digital camera that is accessed by a digital signal processor of the digital camera to compress the images.

55. The Exif format used in digital cameras to store digital images is referenced in a mandatory part of the International Standard ISO 12234-1:2012 "Electronic still-picture imaging — Removable memory — Part 1: Basic removable-memory model," and is specified in "Exchangeable image file format for digital still cameras: Exif Version 2.3." (This specification is available at http://www.cipa.jp/english/hyoujunka/kikaku/pdf/DC-008-2012_E.pdf.) The Exif image format uses baseline JPEG compression to store a compressed still image, and uses TIFF tags in an APP1 application segment to store attribute information. The first edition, Exif 1.0, was published in October 1995 and established basic tag definitions. Additional capabilities and tag definitions were added in later revisions of the Exif standard, starting with Exif version 1.1 in May 1997.

56. As I discussed earlier, the use of image compression was a routine aspect of digital cameras many years before the 1998 priority date of the 168 Patent. Such image compression capabilities were implemented by executing software algorithms or via custom hardware circuits. In my opinion, the implementation of a compression algorithm in software or in hardware is a design choice that would depend on the cost of the digital camera, the speed of the processor used in the camera, the maturity and complexity of the compression algorithm, and the resolution of the image sensor in the digital camera, which dictates the amount of image data that needs to be processed.

F. Evolution of Mobile Telephony and Image Transmission

57. The first public mobile telephone service was introduced in 1946. In each city, a high-power transmitter located in a single, tall tower used analog frequency modulation (FM) radios to transmit and receive half-duplex telephone calls initiated by mobile phones in the subscriber's automobiles. (See Rappaport, "Wireless Communications, Principles & Practise, Prentice-Hall, Inc. 1996, at p. 4) While these mobile phones used analog voice transmission, FM modulation has been used since at least the mid 1960s to wirelessly transmit digital data (See Salz, "Performance of Multilevel Narrow-Band FM Digital Communication Systems", IEEE Transactions on

Communication Technology, Vol.13 , No. 4, Dec. 1965, pp. 420 – 424, available on-line from http://ieeexplore.ieee.org/)

58. In the late 1960s, AT&T proposed the concept of a cellular mobile phone system to the Federal Communications Commission (FCC). In 1983, the FCC allocated 40 MHz of radio frequency spectrum in the 800 MHz band for use by the AMPS (Advance Mobile Phone Service) cellular phone system. AMPS employs a seven-cell frequency re-use pattern, and each duplex channel used 60 KHz of bandwidth. (See Rappaport, ibid, pp. 483-491). During the 1970s, the communications technology needed for cellular phones and cellular base stations was developed by a number of companies, including AT&T and Motorola, in order to demonstrate the viability of cellular telephony. Dr. Marty Cooper of Motorola recognized that it in addition to car phones, it was possible to build a hand-held cellular phone. His team built the Motorola DynaTAC, the world's first hand-held cell phone, which he demonstrated in April 1973 in New York City. (See http://www.cbsnews.com/news/cell-phone-turns-40-martin-coopers-first-call-on-the-dynatac/).

59. In 1991, the first digital cellular system, USDC (United States Digital Cellular) was installed, in order to support the growing demand for cellular phone service in large cities. USDC uses Electronic Industry Association

(EIA) Interim Standard IS-54, which employs speech compression, digital modulation, and time division multiple access (TDMA) in order to reduce the RF bandwidth needed to support each user.

60. Qualcomm then developed a digital cellular system using code division multiple access (CDMA), which was standardized by the Telecommunications Industry Association (TIA) as Interim Standard IS-95. (See TIA/EIA Interim Standard-95 "Mobile Station – Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System", July 1993.) Because CDMA can operate under relatively larger interference levels, the same set of frequencies can be reused in each cell. An improved audio compression algorithm reduced the average bit-rate, which significantly increased the number of mobile phones that could be supported by each cell.

61. Global System for Mobile (GSM) was introduced in Europe in 1991, in order to provide a unified cellular telephony standard and a wide range of network services. GSM provides telephone services including facsimile, data services, and supplementary services such as SMS messages. GSM handsets must include a Subscriber Identity Module (SIM), which stores the subscribers ID number, privacy keys, and other user-specific information. (See Rappaport, ibid, pp. 500-519.)

62. Systems for transmitting still images have been used commercially since the 1860s. The pantelegraph, developed by Giovanni Caselli, could transmit handwriting or drawings over normal telegraph lines. An image was drawn on a tin plate using insulating ink. The transmitted image was reproduced at the receiver using a stylus synchronized by a pendulum. Modulating the electric current from the stylus selectively darkened the paper, which had been treated with potassium ferricyanide. In the early 1900s, Dr. Arthur Korn developed a photoelectric scanning system and established a commercial picture transmission system which linked Berlin, London and Paris. In 1935, the Associated Press introduced the AP wire photo service, in order to distribute photographs to newspapers. (See http://www.ap.org/company/history/ap-history)

63. Radiofax, also known as weatherfax, is a system for wirelessly broadcasting graphic weather maps and other graphic images. Maps and other images are received, for example by ships or people in remote areas, using a dedicated radiofax receiver or a shortwave receiver connected to an external facsimile recorder or PC equipped with appropriate hardware interface and application software. Radiofax was first demonstrated in the 1920s, and has been used to transmit everything from newspapers to wanted posters. (See http://www.nws.noaa.gov/os/marine/radiofax.htm)

64. In the late 1960s, Dacom introduced the first digital fax machines. The Dacom Rapixfax used digital image compression to reduce the amount of data to be transmitted. (See Hochman, et. al., "Dacom Facsimile Data Compression Technique"s, IEEE ICC70 Proceedings of the International Conference on Communications, San Francisco, June 1970, pp. 20.14-20.21, and Weber, U.S. Patent 4,135,214 "Method and apparatus for compressing facsimile transmission data").

65. The T.4 (Group III) digital facsimile standard was approved by the CCITT in 1980. Images were compressed by encoding the run lengths of black or white pixels using a modified Huffman code. This allowed page-sized black and white images scanned at normal resolution to be transmitted in about one minute over a standard telephone phone line. (See Hunter, "International digital facsimile coding standards", Proceedings of the IEEE, Vol. 68, No. 7, July 1980, pp. 854 – 867)

66. During the 1980s, several companies developed products to transmit digital still color images around the world. For example, in 1987 Kodak introduced the SV9600 Still Video Transceiver, which stored, compressed, transmitted, and received digital still video images over a standard telephone line. A high level description of the SV9600 transceiver is provided in "Kodak SV9600 still video transceiver", Hadley, SPIE Vol. 1071, Optical sensors and

electronic photography, 1989, pp. 238-245, which is reproduced in **Attachment D** at the end of this Declaration. (See also, Kodak SV9600 still video transceiver user's manual", Eastman Kodak Company, Electronic Photography Division, 1987.) I personally used the SV9600 Transceiver soon after it was developed. The SV9600 unit included a frame store, a modem, and a microprocessor which controlled the transceiver. The SV9600 user interface controls included "capture image", "transmit image", and "live / stored display" buttons. The SV9600 unit was used to capture a video frame from a video source, such as a video camera, which was connected to the NTSC video input connector on the SV9600 unit. A color TV monitor, such as the Kodak SV1300 monitor, was connected to the NTSC video output connector on the SV9600 unit. The TV monitor was used to display the live video images framed by the TV camera.

67. When the operator pressed the "capture image" button on the SV9600 unit, a still video frame image was stored in the frame store, and this captured image was displayed on the TV monitor. The captured image was then compressed by the microprocessor and a companion digital signal processor (DSP). If the user did not want to transmit the captured image, the "live / stored display" button could be used to gain select the live display mode, in order to capture a new image. In order to transmit images, a telephone handset connected to the

SV9600 was used to dial the phone number for the receiving device, and place a phone call. The user of the SV9600 unit which was to receive the images would answer the phone call, and normally conduct a short audio conversation with the caller, to discuss the purpose of the images to be transmitted. Then the caller would press the "transmit image" button, to initiate the transmission of the first compressed image.

68. In addition to industrial applications using wired telephone lines, the SV9600 product targeted applications such as news gathering, where a TV new crew captures an image off a video tape and sends it via cellular phone to the studio. The SV9600 Still Video Transceiver used a Kodak-developed compression algorithm, based on the discrete cosine transform (DCT) and a human visual system (HVS) sensitivity model, to reduce the amount of image data used to represent the image, thus shortening the transmission time. (See "An optimized image data compression technique utilized in the Kodak SV9600 still video transceiver", Rabbani et al., SPIE Vol. 1071 Optical sensors and electronic photography, 1989, pp. 246-256)

69. In 1991, Kodak integrated the image selection, compression, and transmission functions provided by the SV9600 unit into the DSU of the Kodak Professional Digital Camera System, as described earlier. Starting in 1992, companies began filing patent applications describing integrated, hand-held

products which combined a digital camera and a cellular telephone. These included, for example, "Electronic still camera with portable telephone function" to Morita of Kyocera Corp, filed in Japan as Application No. H04-302935 on Oct 15, 1992, "Information transmission device" to Kawatsu et. al of Konica Corp, filed in Japan as Application No. Hei 5[1993]-57016 on March 17, 1993, and "Electronic camera system with programmable transmission capability" to Parulski et. al of Kodak, filed in the US as Application No. 426,993 on April 24, 1995.

70. These and other publications in early 1990s demonstrate a trend in integration of different functionalities and services in a single handheld device. The prior art references that are used in this inter partes review petition and further described below, illustrate four references, among numerous other references, that describe how each and every limitation in the claims of the 168 Patent were known and obvious several years before the 1998 priority date.

VII. OVERVIEW OF THE 168 PATENT

71. The 168 Patent describes a system which provides image capture, conversion, compression, storage, and transmission (See abstract). The system includes a camera and a communications interface, which uses a standard transmission interface such as a hard line telephonic transmission, cellular transmission, radio signal, or satellite transmission (See 6:47-52). In

some embodiments, a cellular telephone is used as an audio telephone as well as to transmit captured images and receive incoming images (See 10:31-36).

VIII. IDENTIFICATION OF THE PRIOR ART AND SUMMARY OF OPINIONS

72. I understand that the earliest potential priority date for the claims of the 168 Patent is January 12, 1998, since the application for the 168 Patent was filed on May 17, 2007, as a Continuation of Application No. 10/336,470 (now U.S. Patent no. 7,365,871), which was filed Jan. 3, 2003 as a Divisional of Application No. 09/006,073 (filed Jan. 12, 1998, now abandoned). As explained below, it is my opinion that the following prior art references, which are listed as Exhibits to the Petition for Inter Partes Review of the 168 Patent, disclose all technical features in Claims 1-6, 8, 10-11, 13-18, 21-29 and 31 of the '781 Patent, thus rendering them unpatentable.

73. Based on my review of the above cited prior art references, Claims 1-6, 8, 10-11, 13-15, 21-29 and 31 are rendered obvious and unpatentable by Morita in view of Sarbadhikari, Claims 16-18 are rendered obvious and unpatentable by Morita in view of Sarbadhikari combined with Longginou, Claims 1-6, 8, 10-11, 16-18, 21-22, 24, 26-27 and 29 are rendered obvious and unpatentable by Wilska in view of Yamagishi-992, and Claims 13-15, 23, 25, 28 and 31 are

rendered obvious and unpatentable by Wilska in view of Yamagishi-992 combined with McNelley.

IX. CLAIM CONSTRUCTION

74. In conducting my analysis of the asserted claims of the 168 Patent, I have applied the legal understandings I set out below regarding claim constructions consistent with the "broadest reasonable construction" standard described above, and offer them only for this *Inter Partes* Review. The claim constructions do not necessary reflect the appropriate claim constructions to be used in litigation proceedings, such as litigation in a district court, where a different standard applies.

75. I understand that, under the BRI claim construction, a claim in an unexpired patent shall be given its broadest reasonable construction in light of the specification of the patent. Claim terms are given their ordinary and customary meaning as would be understood by one of ordinary skill in the art in the context of the entire disclosure. An inventor may rebut that presumption by providing a definition of the term in the specification with reasonable clarity, deliberateness, and precision. In the absence of such a definition, limitations are not to be read from the specification into the claims.

A. "Media being suitable to embody … algorithm" in Claims 1-31

76. The proposed BRI claim construction for the term is "media that can embody an algorithm, in hardware form, software form or a combination of hardware and software forms."

77. This term appears in three different variations: (1) media being suitable to embody at least one compression algorithm in claims 1-28; (2) compression algorithm embodied at least in part in suitable programmed media in claims 29-31; and (3) transmission protocol algorithm embodied in suitable media in claims 16-18.

78. The 168 Patent does not explicitly describe these terms, which were added during the prosecution of the 168 Patent. Some recitations of "media" (i.e., "news media" and "print media" (1:40-50)) are unrelated to the claims. Other references to "media" pertain to storage of captured image data on a "writable optical media" (7:24-31) as one type of a memory device, or storage of compressed image data on a "limited capacity portable media … such as floppy disks or a portable PCMCIA card" (7:58-62). Other sections of the specification relate to general storage of software in memory that can be used by a processor or a DSP: "…the processor 86 may be any processor or such as a microprocessor or DSP …The circuitry supporting the processor comprises the processor chip 86 and the control store memory (ROM, Flash RAM,

PROM, EPROM or the like) 92 for storing the software program executed by the processor." (9:15-29). The specification also describes: "The processor 86 can also perform image compression and output the image …the processor 86 executes a code for performing a bi-level compression of the data and the signal representing the frame data is output" (11:3-10). At the same time, the specification uses the term "circuit" or "circuitry" more than 30 times to refer to various components that implement and perform the disclosed functionalities (e.g., 6:16-25; 8:42-43; 9:57-59; 12:5-10).

79. In my opinion, one of ordinary skill in the art at the time of the 168 Patent would have understood that the broadest reasonable interpretation of "media being suitable to embody a compression or transmission protocol algorithm" includes a media that can embody the algorithm in one or both of (1) a software form or (2) a hardware form.

X. UNPATENTABILITY OF THE 168 PATENT CLAIMS

A. GROUND 1: CLAIMS 1-6, 8, 10-11, 13-15, 21-29 AND 31 ARE UNPATENTABLE UNDER 35 U.S.C. § 103(A) AS OBVIOUS OVER MORITA IN VIEW OF SARBADHIKARI

80. In my opinion, claims 1-6, 8, 10-11, 13-15, 21-29 and 31 are unpatentable as obvious over Morita in view of Sarbadhikari. Morita was published on May 13, 1994 and is therefore prior art to the 168 Patent under 35 U.S.C. § 102(b). Sarbadhikari issued on Dec. 19, 1995 and is therefore also prior art to the 168

Patent under 35 U.S.C. § 102(b). Neither Morita nor Sarbadhikari was cited by either the Patent Owner or the Examiner during the prosecution of the 168 Patent.

81. Morita describes a camera phone which functions as a wireless telephone and which also captures, stores, displays, transmits, and receives digital images. The camera phone is contained in a wireless portable housing shown in Fig. 2, which includes a lens and an image sensor that serves as an image collection device. The camera phone also includes a display, which displays images that were captured by the image sensor, converted to digital images by an A/D converter, and processed by an image processing circuit. The processed digital images are compressed and stored in an internal memory or in a removable memory card. The camera phone housing supports a number of input devices, including a dial control unit and a shutter release button. When the shutter release button is pressed halfway in, images from the sensor are processed and displayed on the display, so that the user can compose the image to be captured. When the shutter release button is fully pressed, the digital image is compressed using a compression algorithm embodied in an encoding circuit, and the compressed image is stored in memory. Compressed images can be transmitted using the mobile phone using a single image transmission mode or a batch mode.

82. Sarbadhikari describes a digital camera which captures digital images using a CCD sensor and an A/D converter and temporarily stores the images in a buffer memory. A programmable digital signal processor receives the images from the buffer memory, compresses each still image using a compression algorithm such as JPEG, and stores the compressed images on a removable memory card. The compression algorithm is stored as operating code in an algorithm memory in the digital camera. The memory card can also be used to store "enhancement files", which can be used to modify the camera image processing, including the compression algorithm.

83. A person of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to combine the teachings of Sarbadhikari into the device of Morita. Morita is a combination digital camera and cellular phone, which uses an encoding circuit to perform compression on captured digital images prior to storage in a memory, such as an internal memory or a removable memory card. Sarbadhikari is a digital camera that uses a programmable processor to compress digital images prior to storage in a memory card. A person of ordinary skill in the art at the time of the 168 Patent in possession of the teachings of Morita and Sarbadhikari would understand that image compression can be provided using custom circuitry or using a programmable processor, and would have found it obvious and

straightforward to use the teachings of Sarbadhikari in the camera phone of Morita in order to compress digital images using a programmable digital signal processor which executes a compression algorithm stored in an algorithm memory.

84. **Table 1** below provides a detailed mapping of exemplary sections of the Morita and Sarbadhikari Prior Art references to Claims 1-6, 8, 10-11, 13-15, 21-29 and 31 of the 168 Patent. Further, in the below paragraphs, I have provided explanations regarding some of the claim limitations and the associated description to be used as a companion to **Table 1**. For convenience, claim limitations are given labels in this declaration. For example, the claim limitation of "an input device supported by the portable housing, the input device being operable by the user" in claim 22 is assigned a label "Element [D22]."

85. It is my opinion that the cited sections in **Table 1**, which are also included in the IPR petition, establish that Morita and Sarbadhikari teach or suggest all of the limitations in Claims 1-6, 8, 10-11, 13-15, 21-29 and 31 and render those claims obvious and unpatentable.

86. Regarding independent claims 1, 22, 24, 26, 27 and 29, these claims include many overlapping limitations that are described by Morita and Sarbadhikari. In particular, Morita describes a camera phone apparatus which is contained in

a wireless portable housing, as shown for example in Fig. 2(a). The camera phone functions as a wireless telephone and also captures, stores, displays, transmits, and receives digital images.

87. The camera phone described by Morita includes a lens (2), an image sensor (3), and an A/D (4) as shown in Fig. 1, which serves as an image collection device. This image collection device provides visual image data which is displayed on the display (8).

88. Morita teaches that the display (8) is supported by the camera phone housing, as shown for example in Fig. 2(a). The display provides a visual image which is viewed by the user in order to determine the composition of the image. (*See* 8:9-18).

89. Morita teaches that camera phone housing contains an internal memory (26) and a memory card insertion section (10a) which receives a memory card (10), as shown for example in Fig. 1. Compressed digital images obtained using the image sensor can be stored in either the internal memory or the external memory card, as shown in Fig. 3.

90. Morita teaches that the camera phone housing also supports a number of input devices, including a dial control unit (14) and a shutter release button (12) shown in Fig. 2(a).

91. Morita teaches that when the shutter release button input device is pressed halfway in, images from the sensor are processed and displayed on the display, so that the user can compose the image to be captured. When the shutter release button is fully pressed, the digital image is compressed and stored in memory. (*See* 8:9-18).

92. Morita teaches that the camera phone includes encoding circuit (5) which compresses the image data. This encoding circuit must be supported by the camera phone housing, and must embody a compression algorithm, in order to perform image compression on the image data. The encoding circuit is a hardware processing platform, which executes a compression algorithm that is embodied either in hardware circuitry or operating code.

93. Sarbadhikari describes a digital camera which stores the operating code for a compression algorithm, such as the well-known JPEG compression algorithm, in a processing algorithm memory 28. The processing algorithm memory 28 is contained within the portable digital camera shown in Fig. 2, and therefore must be supported by the camera housing.

94. Sarbadhikari also teaches a processing platform, which includes digital signal processor 22. The digital signal processor 22 executes the operating code stored in the algorithm memory 28. The digital signal processor 22 applies the compression algorithm stored in the algorithm memory 22 to the digital

image signals, and sends the compressed signals to a removable memory card. (*See* 6:31-40). The digital signal processor 22 is contained within the portable digital camera shown in Fig. 2, and therefore must be supported by the camera housing.

95. A person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to incorporate software-based image compression, using for example the algorithm memory 22 and the digital signal processor 22 taught by Sarbadhikari, into the camera phone described by Morita, since such a capability could reduce costs, allow for a more complex compression algorithm to be used, or reduce the development time needed to design and debug a new image compression algorithm.

96. As noted in paragraphs 87-88, Morita's device includes a display for viewing images. Morita's display can be used to also view previously captured images (11:7-8). In this regard, Sarbadhikari also describes that captured and stored images can be viewed on a viewfinder or on a separate display (7:29-30; 10:55-58).

97. A person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to use the display in Morita or in Sarbadhikari to view images before, after, or both before and after storage in memory since such an action would have enabled the user to view the images that are about

to be taken, or to review the stored images. The use of a display to view images is a basic function of a digital camera that was well known at the time of the 168 Patent.

98. Morita teaches that the camera phone includes a mobile phone supported by the portable housing, as shown for example in portion B of Fig. 1. The compressed digital images are transmitted using the mobile phone, using a single image transmission mode or a batch mode, as shown in Fig. 3.

99. Since the components of the image collection device and the display are all contained in the same portable housing, shown for example in Fig. 2 of Morita, movement of the camera phone housing by the user will commonly move both the image collection device and the display.

100. As to dependent claims 2-6, 8, 10, 11, 13-15, 21, 23, 25, 28 and 31, these claims merely recite well known features that were described in Morita and Sarbadhikari (as well as many other prior art systems that were described earlier in this Declaration), and are therefore obvious and non-patentable.

101. Regarding dependent claim 2, Sarbadhikari teaches a processing platform, which includes digital signal processor 22.

102. Regarding dependent claim 3, Morita teaches that the camera phone housing includes a handset, as shown for example in Fig. 2(a).

103. Regarding dependent claim 4, Morita teaches that the camera phone includes a microphone 15 and a speaker 13, as shown for example in Fig. 1 and Fig 2(a)

104. Regarding dependent claim 5, Morita teaches that the camera phone can function as a conventional mobile phone to send and receive telephone conversations. (*See* 2:7-8).

105. Regarding dependent claim 6, Morita teaches that the camera phone can receive incoming wireless transmissions which includes image data (*See* 11:6-7) and can also receive telephone conversations (i.e., wireless voice transmissions) (*See* 2:7-8). One of ordinary skill in the art at the time of the 168 Patent would also understand the received image data could be received from a second camera phone of the type described by Morita, and the image data would therefore be compressed image data that would be decompressed in a decoder prior to display. In fact, Fig. 10 of Morita shows a decoding unit 6 that receives such images and provides the uncompressed data to the display (11:6-7). Such a person would also understand that image compression was widely used in digital image transmission systems in order to reduce the amount of data that needed to be transmitted, and thus reduce the transmission time to provide more efficient image transmission, as described earlier in this Declaration. Therefore, such a person would find it obvious and straightforward to use image decompression in the camera phone described by

Morita, in order to efficiently receive compressed image data from other devices.

106. Regarding dependent claim 8, Morita teaches that the camera phone includes an A/D converter (3) which provides image data in a digital format. (*See* 3:20-24; Fig. 10; 8:10-15; Fig. 1, elements 2, 3, 7 and 8).

107. Regarding dependent claim 10, Morita teaches that the camera phone includes a display (8), which is used to display the images from the image sensor so that the camera operator can determine the composition of the image. (*See* 8:10-15; Fig. 1)

108. Regarding dependent claims 11 and 15, Morita teaches that an A/D converter (3) is used to provide digital image data which is processed by image processing circuit (4) and supplied to display (8) using driver (7), as shown in Fig. 1. See, also 8:10-15; 3:20-24; Fig. 10.

109. Regarding dependent claims 13, 23, 25, 28 and 31 Morita describes a camera phone having a display (8) which can be used both as a viewfinder to compose images as they are captured and as a playback screen (*See* 3:8-9). Sarbadhikari teaches an electronic viewfinder which is used to both compose the captured images (*See* 5:27-31) and to display images after storage in the removable memory card (*See* 7:28-30). Sarbadhikari also teaches that a separate view screen could be used to select images that are stored in the

removable memory card, which necessarily requires that stored images be displayed on the view screen. Therefore, Sarbadhikari teaches a digital camera which includes a viewfinder and a separate display screen, and which displays visual images using the stored image data.

110. It would have been obvious to a person of ordinary skill in the art to modify the camera phone described by Morita in order to provide a display screen which displays images for viewing and which is separate from the viewfinder. Such a person would understand, for example, that the viewfinder could be an optical viewfinder, as described earlier in this Declaration, and that a separate display screen would be required in order to view the digital images captured by the camera phone. The use of an optical viewfinder at the time of the 168 Patent would have provided a sharper and more responsive visual image for composing the digital image to be captured. Such a person would also understand that the viewfinder could be a small electronic viewfinder which is held up to the eye when composing an image to be captured, and is therefore not subject to reflections in bright sunlight which can reduce the usability of a larger display screen. It would have been just as straightforward and obvious to use a portion of the larger display, such as a window within the display, to operate as a viewfinder. The larger display screen could be used to display images for viewing by multiple people, or to more conveniently access the

user controls on the camera phone , for example in order to select particular images for viewing.

111. Regarding dependent claim 14, Morita teaches that the display (8) can be a liquid crystal display (LCD) (*See* 4:10-13).

112. Regarding dependent claim 21, Morita teaches a camera phone housing having a lens (1) which is in a fixed relation to the display (8), as shown in Fig. 2(a).

113. It is therefore my opinion that the combination of Morita and Sarbadhikari renders claims 1-6, 8, 10-11, 13-15, 21-29 and 31 obvious and unpatentable.

Table 1 - Claims 1-6, 8, 10-11, 13-15, 21-29 and 31 Mapping Based on Morita and Sarbadhikari

Claim of US 7643168	Prior ART Morita, Sarbadhikari
1. **[A1]** Apparatus comprising: a portable housing, the portable housing being wireless;	See Morita, Title; 3:14-15; 7:1-6; 7:17-19; 11:21-22; Fig; 1; Figs. 2(a) and 2(b); Figs. 4(a) to 4(d)
[B1] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See Morita, Title; 3:20 to 4:5; Fig. 10; 3:14-15; 7:1-15; Fig. 1, section A
[C1] a display supported by the portable housing, the display being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data;	See Morita, 3:20-26; Fig. 10; 7:23-25; 8:9-18; 13:6-18; Figs. 1, 2(a) and 10, elements 7 and 8, Figs. 7 and 8
[D1] memory supported by the	See Morita, 3:26 to 4:5; 8:9-18; 9:1-4;

portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	10:1-6; 11:2-4; Fig. 1, elements 26 10
[E1] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	See Morita, 3:21-24; 7:7-9; 7:23-25; 8:9-18; 11:2-4; Figs. 1 and 2(a), element 12
[F1] media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	See Morita, 3:24-25; Fig. 10, element 4 Sardabhikari, Abstract; 4:47 to 5:40, 5:55 to 6:40; Fig. 2, elements 20, 22 and 28
[G1] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See Morita, 3:22-25; 7:7-9; 8:10-15; Figs. 1 and 10, elements, 4, 5 and 25 Sarbadhikari, 5:55 to 6:53
[H1] and a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the	See Morita, Title; 3:14-15; 3:22-25; 7:1-19; 8:15-18; 9:7-19; Fig; 1, element B; Figs. 2(a) and 2(b)

compressed digital image data;	
[I1] and movement by the user of the portable housing commonly moving the image collection device, movement by the user of the portable housing commonly moving the display.	See Morita, 7:17 to 8:7; 11:21 to 12:2; Figs. 2 and 4
2. The apparatus according to claim 1 and further comprising: the processing platform including at least one processor.	See Morita, 3:23-24; 5:20; 8:9-18; Figs. 1 and 10, elements 4, 5, 11, 25
3. The apparatus according to claim 1 and further comprising: the portable housing including a handset.	See Morita, 3:14-15; 7:17 to 8:7; 11:21 to 12:2; Fig; 1; Figs. 2(a) and 2(b); Figs. 4(a) to 4(d)
4. The apparatus according to claim 1 and further comprising: a microphone supported by the portable housing, the microphone being associated with the mobile phone; a speaker supported by the portable housing, the speaker being associated with the mobile phone.	See Morita, 4:24-26; 5:2-3; 7:17-22; Figs. 1, 2(a) and 11, elements 13 and 15
5. The apparatus according to claim 1 and further comprising: the mobile phone being selectively operable to send to a remote recipient a wireless transmission, the wireless transmission conveying a voice transmission.	See Morita, 2:7-8; 4:20 to 5:3
6. The apparatus according to claim 1 and further comprising: the mobile phone being selectively operable to receive from a remote sender an incoming wireless transmission the	See Morita, 2:7-8; 3:24-25; 4:20 to 5:3; 11:1-12; Fig. 10, element 6 See also Morita, 5:24-25

incoming wireless transmission conveying at least one of: incoming compressed digital image data, an incoming voice transmission, and both incoming compressed digital image data and an incoming voice transmission.	See Sarbadhikari, 6:33-40;
8. The apparatus according to claim 1 and further comprising: the image collection device being suitable to provide the visual image data in digital format.	See Morita, 3:20-24; Fig. 10; 8:10-15; Fig. 1, elements 2 and 3
10. The apparatus according to claim 1 and further comprising: the display including a viewfinder, the viewfinder being suitable to receive the visual image data, the viewfinder being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data.	See Morita, 3:8-9; 4:10-12; 6:7-12; 8:2-4 See also Morita, 3:20-24; Fig. 10; 8:10-15; Fig. 1, elements 2 and 3
11. The apparatus according to claim 10 and further comprising: the viewfinder being suitable to receive the visual image data in digital formal.	See Morita, 3:20-24; Fig. 10; 8:10-15; Fig. 1, elements 2, 3, 7 and 8
13. The apparatus according to claim 1 and further comprising: the display including a display screen, the display screen being defined apart from a viewfinder, the display screen being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data.	See Morita, 3:8-9; 4:10-12; 6:7-12; 8:2-4 See Morita, 3:20-24; Fig. 10; 8:10-15; Fig. 1, elements 2 and 3 See Sarbadhikari, 10:55-58

14. The apparatus according to claim 13 and further comprising: the display including an LCD, the LCD being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data.	See Morita, 3:8-9; 4:10-12; 6:7-12; 13:13-17; Figs. 1, 2(a) and 10, element 8, Fig. 8(a), element 36 See Morita, 3:20-24; Fig. 10; 8:10-15; Fig. 1, elements 2 and 3
15. The apparatus according to claim 14 and further comprising: the LCD being suitable to receive the visual image data in digital format.	See Morita, 3:20-24; Fig. 10; 4:10-12; 8:10-15; Fig. 1, elements 2, 3, 7 and 8
22. **[A22]** Apparatus comprising: a portable housing, the portable housing being wireless:	See Element [A1] of claim 1; See Morita, Title; 3:14-15; 7:1-6; 7:17-19; 11:21-22; Fig; 1; Figs. 2(a) and 2(b); Figs. 4(a) to 4(d)
[B22] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See, Element [B1] of claim 1; See Morita, Title; 3:20 to 4:5; Fig. 10; 3:14-15; 7:1-15; Fig. 1, section A
[C22] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See Element [D1] of claim 1; See Morita, 3:26 to 4:5; 8:9-18; 9:1-4; 10:1-6; 11:2-4; Fig. 1, elements 26 and/or 10
[D22] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user	See Element [E1] of claim 1; See Morita, 3:21-24; 7:7-9; 7:23-25; 8:9-18; 11:2-4; Figs. 1 and 2(a),

enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	element 12
[E22] media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	See Element [F1] of claim 1; See Morita, 3:24-25 Sardabhikari, Abstract; 4:47 to 5:40, 5:55 to 6:40; Fig. 2, elements 20, 22 and 28
[F22] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See Element [G1] of claim 1; See Morita, 3:22-25; 7:7-9; 8:10-15; Figs. 1 and 10, elements, 4, 5 and 25 Sarbadhikari, 5:55 to 6:53
[G22] a display supported by tile portable housing, the display being operable to display for viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from the visual image data in digital format;	See Element [C1] of claim 1; See Morita, 3:20-26; Fig. 10; 7:23-25; 8:9-18; 13:6-18; Figs. 1, 2(a) and 10, elements 7 and 8, Figs. 7 and 8
[H22] a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the	See Element [H1] of claim 1; See Morita, Title; 3:14-15; 3:22-25; 7:1-19; 8:15-18; 9:7-19; Fig; 1, element B; Figs. 2(a) and 2(b)

compressed digital image data;	
[I22] and movement by the user of the portable housing commonly moving the image collection device, movement by the user of the portable housing commonly moving the display	See Element [I1] of claim 1; See Morita, 7:17 to 8:7; 11:21 to 12:2; Figs. 2 and 4
23. The apparatus according to claim 22 and further comprising: the display including at least one of: a viewfinder, and a display screen apart from the viewfinder.	See Morita, 3:8-9; 3:20-24; Fig. 10; 4:10-12; 6:7-12; 8:2-4; 8:10-15; Fig. 1, elements 2 and 3 See Sarbadhikari, 10:55-58
24. **[A24]** Apparatus comprising: a portable housing, the portable housing being wireless:	See Element [A1] of claim 1; See Morita, Title; 3:14-15; 7:1-6; 7:17-19; 11:21-22; Fig; 1; Figs. 2(a) and 2(b); Figs. 4(a) to 4(d)
[B24] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See, Element [B1] of claim 1; See Morita, Title; 3:20 to 4:5; Fig. 10; 3:14-15; 7:1-15; Fig. 1, section A
[C24] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See Element [D1] of claim 1; See Morita, 3:26 to 4:5; 8:9-18; 9:1-4; 10:1-6; 11:2-4; Fig. 1, elements 26 and/or 10
[D24] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user	See Element [E1] of claim 1; See Morita, 3:21-24; 7:7-9; 7:23-25; 8:9-18; 11:2-4; Figs. 1 and 2(a),

enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	element 12
[E24] media supported by/the portable housing, the media being suitable to embody at least one compression algorithm;	See Element [F1] of claim 1; See Morita, 3:24-25 Sardabhikari, Abstract; 4:47 to 5:40, 5:55 to 6:40; Fig. 2, elements 20, 22 and 28
[F24] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See, Element [G1] of claim 1; See Morita, 3:22-25; 7:7-9; 8:10-15; Figs. 1 and 10, elements, 4, 5 and 25 Sarbadhikari, 5:55 to 6:53
[G24] a display supported by the portable housing, the display being operable to display the viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from the retained visual image data in digital format;	See Element [C1] of claim 1; See Morita, 3:20 to 4:5; Fig. 10; 7:23-25; 8:9-18; 11:2-4; 11:7-8; 13:6-18; Figs. 1, 2(a) and 10, elements 7 and 8, Figs. 7 and 8 Sarbadhikari, 6:27-49; 7:29-30; 10:55-58; Fig. 2, elements 18, 24 and 29;
[H24] a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless	See Element [H1] of claim 1; See Morita, Title; 3:14-15; 3:22-25; 7:1-19; 8:15-18; 9:7-19; Fig; 1, element B; Figs. 2(a) and 2(b)

transmission conveying the compressed digital image data;	
[I24] and movement by the user of the portable housing commonly moving the image collection device, movement by the user of the portable housing commonly moving the display.	See Element [I1] of claim 1; See Morita, 7:17 to 8:7; 11:21 to 12:2; Figs. 2 and 4
25. The apparatus according to claim 24 and further comprising: the display including at least one of: a viewfinder, and a display screen apart from the viewfinder.	See claim 23;
26. **[A26]** A mobile handset comprising: a portable housing, the portable housing being wireless;	See Element [A1] of claim 1;
[B26] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See Element [B1] of claim 1;
[C26] a display supported by the portable housing, the display being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data;	See Element [C1] of claim 1;
[D26] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image	See Element [D1] of claim 1;

data in digital format,	
[E26] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	See Element [E1] of claim 1;
media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	See Element [F1] of claim 1;
[F26] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See Element [G1] of claim 1;
[G26] and a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the compressed digital image data.	See Element [H1] of claim 1;
27. **[A27]** Apparatus comprising: a	See Element [A1] of claim 1;

portable housing, the portable housing being wireless;	See Morita, Title; 3:14-15; 7:1-6; 7:17-19; 11:21-22; Fig; 1; Figs. 2(a) and 2(b); Figs. 4(a) to 4(d)
[B27] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See, Element [B1] of claim 1; See Morita, Title; 3:20 to 4:5; Fig. 10; 3:14-15; 7:1-15; Fig. 1, section A
[C27] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See, Element [D1] of claim 1; See Morita, 3:26 to 4:5; 8:9-18; 9:1-4; 10:1-6; 11:2-4; Fig. 1, elements 26 and/or 10
[D27] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	See, Element [E1] of claim 1; See Morita, 3:21-24; 7:7-9; 7:23-25; 8:9-18; 11:2-4; Figs. 1 and 2(a), element 12
[E27] media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	See, Element [F1] of claim 1; See Morita, 3:24-25 Sardabhikari, Abstract; 4:47 to 5:40, 5:55 to 6:40; Fig. 2, elements 20, 22 and 28
[F27] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at	See, Element [G1] of claim 1; See Morita, 3:22-25; 7:7-9; 8:10-15; Figs. 1 and 10, elements, 4, 5 and 25

least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	Sarbadhikari, 5:55 to 6:53
[G27] a display supported by the portable housing, the display being operable to display for viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from the retained visual image data in digital format;	See, Element [C1] of claim 1; See Morita, 3:20 to 4:5; Fig. 10; 7:23-25; 8:9-18; 11:2-4; 11:7-8; 13:6-18; Figs. 1, 2(a) and 10, elements 7 and 8, Figs. 7 and 8 Sarbadhikari, 6:27-49; 7:29-30; 10:55-58; Fig. 2, elements 18, 24 and 29;
[H27] the mobile phone being selectively operable to send to a remote recipient a wireless voice transmission, the mobile phone being selectively operable to receive from a remote sender an incoming wireless image transmission; and the display being operable to display for viewing by a user a perceptible visual image of the incoming wireless image transmission.	See, Element [H1] of claim 1; See Morita, Abstract; Title; 2:7-8; 3:14-15; 3:22-25; 4:20 to 5:3; 7:1-19; 8:15-22; 9:7-19; 11:6-7; 11:7-10; 12:22-25; Fig; 1, element B; Figs. 2(a) and 2(b)
28. The apparatus according to claim 27 and further comprising: the display including at least one of: a viewfinder, and a display screen apart from the viewfinder.	See claim 23;
29. **[A29]** Apparatus comprising: a portable housing, the portable housing being wireless;	See Element [A1] of claim 1; See Morita, Title; 3:14-15; 7:1-6; 7:17-19; 11:21-22; Fig; 1; Figs. 2(a) and

	2(b); Figs. 4(a) to 4(d)
[B29] an image collection device supported by the portable housing, the image collection device being operable to provide in digital format visual image data of a field of view;	See, Element [B1] of claim 1; See Morita, Title; 3:20 to 4:5; Fig. 10; 3:14-15; 7:1-15; 8:10-15; Fig. 1, section A, elements 2 and 3
[C29] memory supported by the portable housing, the memory being suitable to receive the visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See, Element [D1] of claim 1; See Morita, 3:26 to 4:5; 8:9-18; 9:1-4; 10:1-6; 11:2-4; Fig. 1, elements 26 and/or 10
[D29] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	See, Element [E1] of claim 1; See Morita, 3:21-24; 7:7-9; 7:23-25; 8:9-18; 11:2-4; Figs. 1 and 2(a), element 12
[E29] at least one compression algorithm embodied at least in part in suitable programmed media, the media being supported by the portable housing;	See, Element [F1] of claim 1; See Morita, 3:24-25 Sardabhikari, Abstract; 4:47 to 5:40, 5:55 to 6:40; Fig. 2, elements 20, 22 and 28
[F29] at least one processor supported by the portable housing, the at least one processor being operable to execute the at least one compression algorithm, the at least one processor being provided the retained visual image data in digital format, execution of the at least one	See, Element [G1] of claim 1; See Morita, 3:22-25; 7:7-9; 8:10-15; Figs. 1 and 10, elements, 4, 5 and 25 Sarbadhikari, 5:55 to 6:53

compression algorithm providing compressed visual image data;	
[G29] at least one display supported by the portable housing, the at least one display being operable to display for viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from at least one of: the visual image data in digital format, and the retained visual image data in digital format;	See, Element [C1] of claim 1; See Morita, 3:20 to 4:5; Fig. 10; 7:23-25; 8:9-18; 11:2-4; 11:7-8; 13:6-18; Figs. 1, 2(a) and 10, elements 7 and 8, Figs. 7 and 8 Sarbadhikari, 6:27-49; 7:28-30; 10:55-58; Fig. 2, elements 18, 24 and 29
[H29] a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the compressed digital image data.	See, Element [H1] of claim 1; See Morita, Title; 2:7-8; 3:14-15; 3:22-25; 4:20 to 5:3; 7:1-19; 8:15-18; 9:7-19; 11:6-7; 11:7-10; Fig; 1, element B; Figs. 2(a) and 2(b)
31. The apparatus according to claim 29 and further comprising: the at least one display including at least one of: a viewfinder; and a display screen apart from the viewfinder.	See claim 23;

B. GROUND 2: CLAIMS 16-18 ARE UNPATENTABLE UNDER 35 U.S.C. § 103(a) AS BEING OBVIOUS OVER MORITA AND SARBADHIKARI, COMBINED WITH LONGGINOU

114. In my opinion, claims 16-18 are unpatentable as obvious over Morita in view of Sarbadhikari, combined with Longginou.

115. Longginou is a United States Patent which was published on Aug. 31, 1995 and is therefore prior art to the 168 Patent under 35 U.S.C. § 102(e). Longginou was not cited by either the Patent Owner or the Examiner during the prosecution of the 168 Patent.

116. Longginou describes a multi-mode communications system which includes a hand-held phone (11) and a base unit (10). In a first mode of operation, the handset is used to select cellular telephone operation, and initiates a call over the cellular phone communications protocol to the public cellular telephone network. (*See* 10:9-15). Longginou teaches that the cellular phone communication protocol may be compliant with one of many different cellular phone standard protocols, including the AMPS, GSM, CDMA, and TDMA protocols which were described earlier in the Technology Background section of this Declaration. (*See* 10:18-20). The device includes the appropriate modules and software for communicating with another device using the supported transmission protocol. This includes integrated circuitry specific to the transmission mode, such as a channel coder/decoder for a GSM digital protocol. (*See* 12:12-23).

117. **Table 2** below provides a detailed mapping of exemplary sections of the Morita, Sarbadhikari and Longginou Prior Art references to Claims 16-18 of the 168 Patent. Further, in the below paragraphs, I have provided

explanations regarding some of the claim limitations and the associated description to be used as a companion to **Table 2**.

118. It is my opinion that the cited sections in **Table 2**, which are also included in the IPR petition, establish that Morita, Sarbadhikari and Longginou teach or suggest all of the limitations in Claims 16-18 and render those claims obvious and unpatentable.

119. Regarding Claim 16, Morita describes the transmission of voice and image information over a single line using packet transmission (*See* 11:11-12). A person of ordinary skill in the art at the time of the 168 Patent would understand that packet transmission requires the use of a standard transmission protocol, to ensure that the receiving device can identify and separate the voice information and the image information in order to properly display images and reproduce voices. Morita also describes a modulation circuit 29 and a transmission circuit 21. These components provide a processing platform which embodies the transmission protocol algorithm used for packet transmission, and which receives image data which has been compressed by encoding circuit 5 and stored in the internal memory 26 or memory card 10. The output of the transmission circuit 21 provides visual image data in a transmission format which is necessarily compatible with the wireless transmission provided by the mobile camera phone.

120. Longginou describes a hand-held phone module which initiates a call over a cellular phone communications protocol to the public phone network, and teaches that the cellular phone communication protocol may be compliant with one of many different cellular phone protocols, including the GSM protocol. (*See* 10:13-15 and 10:18-21) Longginou also teaches that the handset includes a module adapted to operate according to a particular protocol. The digital module may include a microprocessor and integrated circuitry, and the handset will contain the software needed for the module. (*See* 12:12-15 and 12:19-23). Therefore, the module is a processing platform associated with a transmission protocol algorithm, such as GSM, and the transmission protocol algorithm is embodied in the media which contains the software.

121. A person of ordinary skill in the art at the time of the 168 Patent would understand that the Camera Phone described by Morita would necessarily use a standardized wireless transmission protocol in order to function as a mobile phone, and to ensure that transmitted digital images could be received by compatible receivers. Such a person would understand that the GSM wireless transmission protocol, or one of the other wireless transmission protocols, described in Longginou would necessarily be used in the camera phone of Morita in order to transmit images. Moreover, such a person would

understand that it would be obvious and straightforward to use the digital module described by Longginou, including a microprocessor and integrated circuitry, as well as software needed for the module, in the Camera Phone described by Morita. The use of a microprocessor controlled processing platform to execute a transmission protocol algorithm could reduce development costs and could provide the flexibility to more quickly update the protocol as new cellular phone transmission protocols are developed.

122. Regarding Claim 17, a person of ordinary skill in the art at the time of the 168 Patent would understand that the Camera Phone described by Morita would necessarily use a standardized wireless transmission protocol in order to function as a mobile phone, and to ensure that transmitted digital images could be received by compatible receivers. Such a person would understand that the GSM wireless transmission protocol, or one of the other wireless transmission protocols, described in Longginou would necessarily be used in the camera phone of Morita in order to transmit images that can be received by another mobile phone.

123. The additional limitations of claim 18 are met by the same teachings discussed above under this Ground in regard to claim 16 and 17.

Table 2 - Claims 16-18 Mapping Based on Longginou

Claim of US 7643168	Prior ART Morita, Sarbadhikari

	and Longginou
16. The apparatus according to claim 1 and further comprising; at least one transmission protocol algorithm embodied in suitable media; a processing platform associated with the at least one transmission protocol algorithm, the associated processing platform being operable to execute the at least one transmission protocol algorithm, the associated processing platform being provided the compressed visual image data, execution of the at least one transmission protocol algorithm providing the compressed visual image data in a transmission format, the visual image data in a transmission format being compatible with the mobile phone for wireless transmission by the mobile phone.	See Longginou, Abstract; 1:21 to 2:4;2:8-23; 6:14-17; 8:6-13; 10:13-15; 10:27 to 11:7; 12:11-23; 13:4-13; 14:7-8; 16:claim 3; Fig. 6 See Morita, 4:20 to 5:1; 3:24-25; 11:11-12 See Sarbadhikari, 6:27-40
17. The apparatus according to claim 16 and further comprising: the mobile phone being operable according to a specified wireless transmission protocol, the at least one transmission protocol algorithm providing the visual image data in a compatible data transmission format, the compatible data transmission	See claim 16; See Longginou, Abstract; 1:21 to 2:4; 2:8-23; 6:14-17; 8:6-13; 10:27 to 11:7; 14:7-8

format being compatible with the specified wireless transmission protocol.	
18. The apparatus according to claim 17 and further comprising: at least one transmission protocol algorithm embodied in suitable media; a processing platform associated with the at least one transmission protocol algorithm, the associated processing platform being operable to execute the at least one transmission protocol algorithm, execution of the at least one transmission protocol algorithm providing compressed visual image data in a compatible format, the compatible format being compatible with at least one transmission protocol, the compressed visual image data in a compatible format being suitable for transmission by the mobile phone according to at least one wireless transmission protocol.	See claims 16 and 17; Longginou, Abstract; 1:21 to 2:4; 2:8-23; 8:6-13; 10:27 to 11:7; 12:8-23 See Morita, 3:24-25 See Sarbadhikari, 6:27-40

C. GROUND 3: CLAIMS 1-6, 8, 10-11, 16-18, 21-22, 24, 26-27 AND 29 ARE UNPATENTABLE UNDER 35 U.S.C. § 103(a) AS OBVIOUS OVER WILSKA IN VIEW OF YAMAGISHI-992

124. In my opinion, claims 1-6, 8, 10-11, 16-18, 21-22, 24, 26-27 and 29 are unpatentable as obvious over Wilska in view of Yamagishi-992. Wilska was

published on Nov. 22, 1995 and is therefore prior art to the 168 Patent under 35 U.S.C. § 102(b). Yamagishi-992 was published on April 5, 1994 and is therefore also prior art to the 168 Patent under 35 U.S.C. § 102(b). Neither Wilska nor Yamagishi-992 was cited by either the Patent Owner or the Examiner during the prosecution of the 168 Patent.

125. Wilska describes a small, portable, battery operated integrated device which is roughly 6.7 x 3.3 x 1.2 inches in size, so that it can be easily handheld by the user and carried in the user's pocket. Integrated within the portable housing is a camera, digital memories, a display, a processor, user controls, and a cellular mobile phone unit. The user can capture digital images, which are processed by the processor and stored in memory. Pictures captured by the camera can be viewed immediately on the display, and can also be used by application programs executed by the processor. These digital images can be wirelessly transferred over a cellular network to anther device using, for example, telefax and electronic mail services. The device can also make and receive phone calls, as well as receive and store digital images that it receives from another device. Today, this device would be called a "smart phone". Because the device does not include an optical viewfinder, one of ordinary skill in the art at the time of the 168 Patent would have understood that the display serves as an electronic viewfinder when capturing images.

126. Yamagishi-992 describes an invention that is applicable to a combination digital camera and portable telephone set which uses a wireless line. The digital camera can capture, store, and transmit images and audio signals using an internal modem, as shown in Fig. 43. The digital camera includes a display, speaker, and user interface to permit the user to select images and associated sounds which are to be transmitted using the modem, as depicted in Fig. 52.

127. A person of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to combine the teachings of Yamagishi-992 into the device of Wilska. Both Wilska and Yamagishi-992 describe devices which function as both digital cameras and mobile telephones, and include similar components to capture, store, process, and display images. Yamagishi-992 describes in detail how an LCD display is used to display and select particular stored images to be transmitted over a modem.

128. **Table 3** provides a detailed mapping of exemplary sections of the Wilska and Yamagishi-992 Prior Art references Claims 1-6, 8, 10-11, 16-18, 21-22, 24, 26-27 and 29 of the 168 Patent. Further, in the paragraphs below, I have provided explanations regarding some of the claim limitations and the associated description to be used as a companion to **Table 3**.

129. It is my opinion that the cited sections in **Table 3** which are also included in the IPR petition, establish that Wilska and Yamagishi-992 teach or suggest all of the limitations in Claims 1-6, 8, 10-11, 13-18, 21-29 and 31 and render those claims obvious and unpatentable.

130. As noted previously, independent claims 1, 22, 24, 26, 27 and 29 include many overlapping limitations. These limitations are all described by Wilska and Yamagishi-992.

131. Wilska describes and depicts an apparatus which functions as a smart phone, and which is housed in a wireless portable housing, as shown for example in Fig. 1.

132. Wilska teaches that the portable housing contains an electronic camera, which includes a CCD image sensor and which serves as an image collection device that provides visual image data of a field of view.

133. The manually portable housing in Wilska supports an LCD display, as shown in Fig. 1 of Wilska. The display is used to immediately display images captured by the camera. (7:26-27)

134. Yamagishi-992 also describes an apparatus which combines a digital camera and a portable telephone (147:3-13). Yamagishi-992 teaches a display, for example image display device 3038 in Fig. 43, including an electronic viewfinder incorporated into the body of the device which visually displays an

image signal. (35:54-36:7). Yamagishi-992 also provides detailed teachings concerning how images can be selected to be reproduced and transmitted, for example as depicted in Figs. 50-53. It would have been obvious to one of ordinary skill in the art at the time of the 168 Patent to combine the teachings of Yamagishi-992 into the smart phone of Wilska, in order to display perceptible visual images for viewing by a user. The combination of Wilska and Yamagishi-992 provides an electronic viewfinder for the camera and permits the user to select images for viewing and transmission, which were useful and well known features of digital cameras at the time.

135. Wilska includes volatile and non-volatile memories 24 (See Fig. 5) which receive and store the digital images that have been captured using the CCD sensor, and which are within and therefore supported by the portable housing.

136. Wilska teaches that the portable housing includes alphanumeric input keys, for example keyboard 10 in Fig. 1, as well as a mouse / track ball 11. These are input devices which are operable by the user. One of ordinary skill in the art at the time of the 168 Patent would understand that one of these input devices is necessarily used in order for the camera unit 14 to take a picture of a scene at a particular moment.

137. Yamagishi-992 also describes an input device operated by the user, for example the group of switches 3056 shown in Fig. 43. These switches include

a release switch 3064 which is used for "inputting an instruction to start a photographic operation" (when the switch is partially depressed) and "an instruction to record photographic image data in the recording medium" when the button is fully pressed. One of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to combine this well-known shutter button functionality described in Yamagishi-992 into the device described by Wilska, in order to capture images at the desired moment.

138. Wilska describes application software which is stored in memory unit 13. Using this software, the user controls different functions of the smart phone. These functions include facsimile services, electronic mail, and camera functions to record images. (6:4-12). The image information provided by the camera can be used in facsimile/telefax transmission. A person of ordinary skill in the art at the time of the 168 Patent would understand that the facsimile transmission would use the T.4 (Group III) standard described earlier in the Technology Background section of this Declaration, which requires that the image information is compressed prior to transmission. Therefore, the memory unit 13 necessarily provides a media which embodies at least one compression algorithm.

139. Yamagishi-992 teaches a compression circuit, for example image compressing circuit 22 in Fig. 1, which compresses image data using an adaptive discrete

cosine transform (ADCT) based compression algorithm, which is the basis of the JPEG compression algorithm. (12:53-57). The data compression method and the compression ratio can be controlled by the camera operator using switch 68. (14:19-30). Switch 68 is included in switch group 56, which inputs operating instructions to system controlling circuit 50. Operating programs which control the operation of the controller 50 are stored in control data memory 52. Since data memory 52 stores the software programs which are used to permit the user to select a compression ratio using switch 68, the combination of the data memory 52, controller 50 and image compressing circuit 22 include media (e.g. data memory 52) which embody multiple compression algorithms, corresponding to the different compression ratios that can be selected by the user.

140. A person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to apply the teachings of Yamagishi-992 in the device of Wilska, in order to, for example, provide (ADCT-based) JPEG image compression of captured images using different compression ratios. JPEG compression, which uses ADCT, was well known and widely used at the time of the 168 Patent, and provided efficient compression of continuous-tone images, which reduced the amount of memory used to store an image and reduced the image transmission time. Permitting the user to select the

compression ratio, which Yamagishi-992 also teaches, enables the user to select the appropriate quality level for captured images, which was a well-known and useful feature of JPEG image compression at the time of the 168 patent.

141. Wilska describes a processing platform which includes data processing unit 2 and image processing unit 14c. The data processing unit 2 includes a processor 4, and the image processing unit 14c includes a microprocessor 23. As described above, Wilska also describes application software which is stored in memory unit 13 and used to control facsimile services. A person of ordinary skill in the art at the time of the 168 Patent would understand that the facsimile transmission would use the T.4 (Group III) standard described earlier in the Technology Background section of this Declaration, which requires that the image information is compressed prior to transmission. Such a person would understand that the data processing unit 2 (shown in Fig. 3) is a processing platform which is operable, when using the application software for facsimile services stored in memory unit 13, to execute the T.4 (Group III) fax compression algorithm in order to compress the visual image data from the camera in the Wilska device so that it can be transmitted using the T.4(Group III) fax standard.

142. Yamagishi-992 teaches a processing platform, for example the system controlling circuit 3050, memory 3052, interface 3026, memory controlling circuit 3020, memory 3024, and compressing expanding circuit 3022 shown in Fig. 43. This processing platform executes the compression algorithm selected by the camera operator using switch 3068, when the user selects the compression method and compression algorithm. (121:39-44). As described above, since memory 3052 stores the software programs which are used to permit the user to select a compression ratio using switch 3068, the combination of the memory 3052, controller 3050 and compressing / expanding circuit 3022 include media (data memory 3052) which embody multiple compression algorithms, corresponding to the different compression ratios that can be selected by the user.

143. As described above, a person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to apply the teachings of Yamagishi-992 in the device of Wilska, to provide JPEG image compression of captured images using different compression ratios, since ADCT-based compression algorithms such as JPEG compression was well known and widely used at the time of the 168 Patent, and provided efficient compression of continuous-tone images, reducing the amount of memory used to store an image and the image transmission time.

144. Wilska describes a mobile phone supported by the device housing, as shown for example in Fig. 1. The mobile phone sends and receives digital images captured with the integrated camera, for example using facsimile transmission. (9:23-10:7). When transmitting an image using facsimile, the camera operator can select the recipient information from a phone list. (13:4-13).

145. Yamagishi-992 also describes a combination digital camera and portable telephone (147:3-10) and teaches how compressed digital images can be selected and transmitted in Figs. 52-53. A person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to use the teachings of Yamagishi-992 in the Wilska device, in order to send compressed digital images to a remote recipient. Such a person would understand that image compression would greatly reduce the amount of data to be transmitted, thus shortening the transmission time.

146. Wilska shows, for example in Fig. 1, that the camera 14 and the display 9 are commonly moved when the housing is moved.

147. Regarding independent claim 24, Fig. 6 of Wilska depicts a picture of a business card which is transferred from the camera unit14a to the memory unit 13, and then transferred via data processing unit 2 to display 9. (8:21-25). The

business card picture is generated from the digital image data retained in memory unit 13.

148. Yamagishi-992 teaches that image data is stored in memory and then read from memory and displayed on an image display device. (119:26-35; 120:26-32). The displayed image is therefore generated from the digital image data retained in memory.

149. A person of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to include the ability to display images which were retained in memory for viewing by the user. Such a person would understand that this was a very useful feature, since it could be used to determine if a suitable image had been captured, or if another picture of the same subject should be taken because, for example, the stored image was blurry or the subject had their eyes closed.

150. Regarding independent claim 27, Wilska's device is selectively operable to send to a remote recipient a wireless image transmission since the operator can select whether or not to send an image, using a fax wireless transmission, and also because the operator can select the recipient from the phone list stored in Wilska's device. (13:2-7).

151. Yamagishi-992 teaches that an operator can select whether or not to use the transmission mode (S3011 in Fig 44) and which particular images should be

transmitted. (Fig 52-53). A person of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to apply the detailed teachings of Yamagishi-992 in the device described by Wilska, in order to permit the user to select between a recording mode, a reproduction mode, and a transmission mode, and to select images for transmission. Such a person would have understood that the user would not necessarily transmit all of the stored images that had been taken by the device, and would often prefer to transmit only a subset of the stored images to a recipient.

152. Regarding independent claim 29, Wilska discloses providing visual image data of a field of view in a digital format, and displaying the retained visual image data in digital format since Wilska discloses, for example, displaying a picture of a business card taken by camera 14a that has been transferred to memory unit 13. (8:21-24) Memory unit 13 stores retained visual image data which is displayed by display 9 as a perceptible visual image of the field of view captured by camera 14a.

153. Yamagishi-992 also describes the display of images obtained by its camera upon capture by an image pickup circuit, A/D conversion and temporary storage and/or after storage of the image in a recording media (119:26-35; 120:26-32).

154. A person of ordinary skill in the art at the time of the 168 Patent would understand that the memory unit 13 of Wilska must be a digital memory and therefore the data provided by memory unit 13 via data processing unit 2 to display 9 must be in a digital format. Further, such a person would understand that display of image data before, after, or both before and after storage in memory, as described in Wilska and Yamagishi-992, is an obvious function of any digital camera that would permit the user to review images.

155. As noted in claim 1, Wilska also discloses that software stored in memory unit 13 can be used to control different functions of the device, including camera functions and facsimile services. The image information provided by the camera can be used in facsimile/telefax transmission.

156. A person of ordinary skill in the art at the time of the 168 Patent would understand that the facsimile transmission using Wilska's device would use the T.4 (Group III) standard described earlier in the Technology Background section of this Declaration, which requires that the image information is compressed prior to transmission. Therefore, the memory unit 13 necessarily provides a media which embodies at least one compression algorithm.

157. As noted regarding claim 1, Yamagishi-992 teaches a compression circuit, for example image compressing circuit 22 in Fig. 1, which compresses image data using an adaptive discrete cosine transform (ADCT) based compression

algorithm, which is the basis of the JPEG compression algorithm. (12:53-57). The data compression method and the compression ratio can be controlled by the camera operator using switch 68. (14:19-30). Switch 68 is included in switch group 56, which inputs operating instructions to system controlling circuit 50. Operating programs which control the operation of the controller 50 are stored in control data memory 52. Since data memory 52 stores the software programs which are used to permit the user to select a compression ratio using switch 68, the combination of the data memory 52, controller 50 and image compressing circuit 22 include media (e.g. data memory 52) which embody multiple compression algorithms, corresponding to the different compression ratios that can be selected by the user.

158. As noted in claim 1, a person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to apply the teachings of Yamagishi-992 in the device of Wilska, in order to, for example, provide JPEG image compression of captured images using different compression ratios. JPEG compression was well known and widely used at the time of the 168 Patent, and provided efficient compression of continuous-tone images, which reduced the amount of memory used to store an image and reduced the image transmission time. Permitting the user to select the compression ratio, which Yamagishi-992 also teaches, enables the user to select the appropriate

quality level for captured images, which was a well-known and useful feature of JPEG image compression at the time of the 168 patent.

159. Regarding dependent claim 2, Wilska teaches a processing platform including central processor 4 and microprocessor 23.

160. Regarding dependent claim 3, Wilska teaches a handset which includes components such as speaker 19, microphone 20, keyboard 10, data processing unit 5 and cellular mobile phone unit 17.

161. Regarding dependent claim 4, Wilska teaches speaker 19 and microphone 20 which are supported by the portable housing as shown, for example, in Fig. 1.

162. Regarding dependent claim 5, the smart phone described by Wilska can be used as a normal telephone to make voice transmissions, and the user can simply select the remote recipient from a phone list, which can contain telephone number information of different people in memory (13:7-11).

163. As described earlier in this Ground for claim 27, Yamagishi-992 teaches that an operator can select whether or not to use the transmission mode (S3011 in Fig. 44) and which particular images and the associated sound recordings should be transmitted. (128:42-46; Fig. 52-53). A person of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to apply the detailed teachings of Yamagishi-992 in the device described by Wilska, in order to permit the user to select a transmission mode,

and to select images and the accompanying sound for transmission. Such a person would have understood that the user would not necessarily transmit all of the stored images/sound recordings that had been taken by the device, and would often prefer to transmit only a subset of the stored images/sound recordings to a recipient.

164. Regarding dependent claim 6, Wilska's device could be used as a wireless voice phone for receiving phone calls, and could also receive image data from remote devices, such as for example incoming fax messages. (9:24-26). A person of ordinary skill in the art at the time of the 168 Patent would understand that the incoming facsimile transmission would use the T.4 (Group III) standard described earlier in the Technology Background section of this Declaration, which requires that the image information is compressed prior to transmission.

165. Yamagishi-992 also teaches compression and decompression, for example in compressing – expanding circuit 3022 of Fig. 43, to permit the user to view compressed images stored in recording medium 3100. A person of ordinary skill in the art at the time of the 168 Patent would understand that selectively receiving compressed image and voice data would provide more efficient communication of images and voice, since the compression would eliminate

redundant information and therefore reduce the amount of data that needed to be communicated.

166. Claims 8 and 10: Regarding dependent claim 8, Wilska teaches that the camera 14a stores images in a memory unit 24 such as a RAM, which requires that the image data be in a digital format. Regarding dependent claim 10, Wilska teaches that the display 9 shown in Fig. 1 can be used to immediately view the picture. (Wilska 7:21-8:2) One of ordinary skill in the art at the time of the 168 Patent would have understood that a digital camera requires a viewfinder so that the user can frame the image prior to capturing and storing a digital still image. This function could be provided by an optical viewfinder, by a small electronic viewfinder which is held up to the user's eye, or by a display panel which is viewed while held away from the user's eye, such as display 9 shown in Fig. 1 of Wilska. Since Wilska does not state or suggest that the device includes an optical viewfinder or a small electronic viewfinder, one of ordinary skill in the art would have understood that the display 9 would serve as a viewfinder, displaying a perceptible visual image for viewing by a user, prior to capturing and storing a digital image in memory.

167. Yamagishi-992 teaches that a display in the housing can be used as an electronic viewfinder to allow the user to view the image scene that is

temporarily stored in an image memory 1024, prior to storage on a recording medium 1100 such as a removable memory card. (See 35:54 to 36:19). A person of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to combine the teachings of Yamagishi-992 and Wilska in order to provide a display for framing images,

168. Regarding dependent claim 11, Fig. 6 of Wilska depicts a picture of a business card which is transferred from the camera unit14a to the memory unit 13, and then transferred via data processing unit 2 to display 9. (8:21-25). The display 9 receives the visual image data corresponding to the business card picture from the digital image data in memory unit 13, so it must receive the visual image data in digital form.

169. Yamagishi-992 teaches that digital image data stored in a memory 3024 can be converted to analog form by D/A converter 3036 for display on image display device 3038, as shown in Fig. 43. A person of ordinary skill in the art at the time of the 168 patent would understand that an image display unit, comprising D/A converter 3036 and image display device 3038 could together form an image display unit that receives image data in digital format, and serves as a viewfinder, to permit the user to compose images to be captured.

170. Regarding claim 16, Wilska describes a smart phone which uses the digital GSM system. (13:20-22) As described earlier in the Technology Background

section of this Declaration, GSM (Global System for Mobile) was introduced in Europe in 1991, in order to provide a unified cellular telephony standard and a wide range of network services including facsimile and data services, and therefore provides a standard transmission protocol algorithm. The central processor (4), cellular mobile phone controller (8), and cellular mobile telephone and modem (17) provide a processing platform with necessarily support the GSM protocol, in order to communicate over the GSM network in a compatible manner. A person of ordinary skill in the art at the time of the 168 Patent would understand that transmitting a fax of an image from camera 14a over a GSM network would use the T.4 (Group III) standard described earlier in the Technology Background section of this Declaration, which requires that the image information is compressed prior to executing the GSM transmission protocol.

171. As noted earlier regarding claim 1, Yamagishi-992 teaches a compression circuit, for example image compressing circuit 22 in Fig. 1, which compresses image data using an adaptive discrete cosine transform (ADCT) based compression algorithm, which is the basis of the JPEG compression algorithm. (12:53-57). A person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to apply the teachings of Yamagishi-992 in the device of Wilska, in order to, for example, provide

ADCT-based JPEG image compression of captured images prior to GSM data transmission. JPEG compression was well known and widely used at the time of the 168 Patent, and provided efficient compression of continuous-tone images, which reduced the amount of memory used to store an image and reduced the image transmission time.

172. Regarding claim 17, Wilska's smart phone uses the standardized GSM protocol (13:20-22) which necessarily provides data in a format which is compatible with the GSM format.

173. Regarding claim 18, as noted with respect to claims 16 and 17, Wilska's smart phone operates in a digital GSM system (13:20-22). The cellular mobile telephone and modem 17, and the data processing unit 2 therefore must provide a processing platform which embodies the GSM wireless transmission protocol, in either the software stored in memories 13 and which is used by the data processing unit 2 and/or the circuitry in data processing unit 2 and cellular mobile telephone and modem 17. A person of ordinary skill in the art at the time of the 168 Patent would understand that transmitting a fax of an image from camera 14a over a GSM network would use the T.4 (Group III) standard described earlier in the Technology Background section of this Declaration, which requires that the image information is compressed prior to executing the GSM transmission protocol.

174. Yamagishi-992 teaches a compression circuit, for example image compressing circuit 22 in Fig. 1, which compresses image data using an adaptive discrete cosine transform (ADCT) based compression algorithm, which is the basis of the JPEG compression algorithm. (12:53-57). A person of ordinary skill in the art at the time of the 168 Patent would find it obvious and straightforward to apply the teachings of Yamagishi-992 in the device of Wilska, in order to, for example, provide ADCT-based JPEG image compression of captured images prior to GSM data transmission. JPEG compression was well known and widely used at the time of the 168 Patent, and provided efficient compression of continuous-tone images, which reduced the amount of memory used to store an image and reduced the image transmission time.

175. Regarding claim 21, Wilska teaches a camera 14a which is supported by the portable housing in a fixed relationship to the display 9, as shown in Fig. 1.

Table 3 - Claims 1-6, 8, 10-11, 16-18, 21-22, 24, 26-27 and 29 Mapping Based on Wilska and Yamagishi-992

Claim of US 7643168	Prior ART Wilska and Yamagishi-992
1. **[A1]** Apparatus comprising: a portable housing, the portable housing being wireless;	Wilska, Abstract; 3:22-26; 10:20-24; claims 1 and 9; Figs. 1-2, 6-9, element 1 See also Wilska, 5:22-28; claim 4; Fig. 3, element 17
[B1] an image collection device supported by the portable housing,	Wilska, Abstract; 4:28-30; 5:9-10;

the image collection device being operable to provide visual image data of a field of view;	7:21-23; Fig. 3, element 17 See also Wilska, 4:27 to 5:7; 7:1-15; 7:21-26; Fig. 1, elements 14a, 14b, 14c; Fig. 5 See also Wilska, 5:5-7; 6:28-29
[C1] a display supported by the portable housing, the display being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data;	Wilska, 4:6-11; Figs. 1-3; 6-7, element 9 See also Wilska, 7:23-31; 8:21-24; 10:5-7 See also Yamagishi-992, Abstract, 147:3-10 See also Yamagishi-992, 35:54 to 36:10; Fig. 13, element 1038; 119:53 to 120:4; Fig. 43, element 3038 See also Yamagishi-992 119:7-37; Fig. 43
[D1] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	Wilska, 4:21-23; 7:1-7; 7:11-15; 7:23-26; 8:21-24; 9:7-13; 9:23-24; 9:28-30; 10:9-13; Fig. 5, elements 14c and 24; 12:23-26; Fig. 3, element 13
[E1] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	Wilska, 4:13-14; Figs. 1-3 and 6-8; elements 10 and 11 See also Yamagishi-992, 13:52-55; 121:21-24; Fig. 1, element 56; Fig. 43, element 3056 See also Yamagishi-992 14:5-11; 121:30-33

[F1] media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	Yamagishi-992, 12:53 to 13:13; 119:38-52; Fig. 1, element 22; Fig. 43, element 3022 See also Yamagishi-992, 13:52-55; 14:27-30; Fig. 1 See also Yamagishi-992, 51:7-15; 58:47-57 See also Yamagishi-992, 50:57 to 51:6
[G1] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	Wilska, 3:28-30; 6:4-12; Fig. 3, element 2 See also Wilska, 5:2-5; 7:1-7; 7:15-26; Fig. 5, elements 14c and 23 See also Wilska, 7:1-15; 7:23-26; Fig. 5 See also Yamagishi-992, 97:17-53; 99:26-35; 118:40 to 120:53; Fig. 32, including elements 2018, 2020, 2022, 2050; Fig. 43, including elements 3018, 3020, 3022, 3050 See also Yamagishi-992, 97:23-46; 99:26-28; 118:49-53; 119:38-52; 121:55-56
[H1] and a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the compressed digital image data;	Wilska, 5:22 to 6:2; 6:6-8; 9:28 to 10:2; 13:2-18; 15:claim 4; Fig, 3, element 17 See also Yamagishi-992, Abstract, 118:58 to 119:9; 119:26-37; 147:3-10
[I1] and movement by the user of the portable housing commonly moving	Wilska, Abstract:1-2; 3:22-26; 10:20-

the image collection device, movement by the user of the portable housing commonly moving the display.	24; Figs. 1-2, 6-9
2. The apparatus according to claim 1 and further comprising: the processing platform including at least one processor.	Wilska, 3:28-30; Fig. 3, element 3 See also Wilska, 5:2-5; Fig. 5, element 23
3. The apparatus according to claim 1 and further comprising: the portable housing including a handset.	Wilska, Abstract; 4:13-14; 5:22 to 6:2
4. The apparatus according to claim 1 and further comprising: a microphone supported by the portable housing, the microphone being associated with the mobile phone; a speaker supported by the portable housing, the speaker being associated with the mobile phone.	Wilska, 5:31 to 6:1; 10:27-30; 14:1-3; 15:claim 5; Figs. 1-2 and 6-9, elements 19 and 20
5. The apparatus according to claim 1 and further comprising: the mobile phone being selectively operable to send to a remote recipient a wireless transmission, the wireless transmission conveying a voice transmission.	Wilska, 5:22 to 6:2; 6:6-9 See also Yamagishi-992, 47-50; Fig. 43, elements 3056 and 3074 See also Yamagishi-992, 128:42-46; 128:47 to 130:2; 147:3-13
6. The apparatus according to claim 1 and further comprising: the mobile phone being selectively operable to receive from a remote sender an incoming wireless transmission the incoming wireless transmission conveying at least one of: incoming compressed digital image data, an	Wilska, 6:4-12; 9:12-13; 9:30-32 See also Wilska, 6:1-2; 6:6-9 See also Wilska, 9:24-26; 10:2-7 See also Yamagishi-992, 119:38-52; Fig. 43, element 3022

incoming voice transmission, and both incoming compressed digital image data and an incoming voice transmission.	
8. The apparatus according to claim 1 and further comprising: the image collection device being suitable to provide the visual image data in digital format.	Wilska, 7:21-26 See also Wilska, 9:23-25 See also Wilska, 10:5-7
10. The apparatus according to claim 1 and further comprising: the display including a viewfinder, the viewfinder being suitable to receive the visual image data, the viewfinder being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data.	Yamagishi-992, 35:5-22; 35:54 to 36:15; Fig. 13, element 1038
11. The apparatus according to claim 10 and further comprising: the viewfinder being suitable to receive the visual image data in digital formal.	Yamagishi-992, 35:54 to 36:4 See also Wilska, 7:21-26; 8:11-27; 9:23-25; 10:5-7; Figs. 1-2, element 9
16. The apparatus according to claim 1 and further comprising; at least one transmission protocol algorithm embodied in suitable media; a processing platform associated with the at least one transmission protocol algorithm, the associated processing platform being operable to execute the at least one transmission protocol algorithm,	Wilska, 5:27-31; 13:20-22 See also Wilska, 5:22 to 6:2; 9:28 to 10:2 See also Wilska, 6:4-12; 12:29 to 13:4 See also Yamagishi-992, 119:38-52; Fig. 43, element 3022 See also Yamagishi-992, 147:3-13

the associated processing platform being provided the compressed visual image data, execution of the at least one transmission protocol algorithm providing the compressed visual image data in a transmission format, the visual image data in a transmission format being compatible with the mobile phone for wireless transmission by the mobile phone.	
17. The apparatus according to claim 16 and further comprising: the mobile phone being operable according to a specified wireless transmission protocol, the at least one transmission protocol algorithm providing the visual image data in a compatible data transmission format, the compatible data transmission format being compatible with the specified wireless transmission protocol.	Wilska, 5:27-31; 13:20-22 See also Wilska, 5:22 to 6:2; 9:28 to 10:2; 6:4-12 See also Wilska, 9:23-26; 9:30 to 10:2
18. The apparatus according to claim 17 and further comprising: at least one transmission protocol algorithm embodied in suitable media; a processing platform associated with the at least one transmission protocol algorithm, the associated processing platform being operable to execute the at least one transmission protocol algorithm, execution of the at least one	Wilska, 5:22 to 6:2; 6:4-12; 9:23 to 10:2; 13:20-22 See also Yamagishi-992, 119:38-52; Fig. 43, element 3022 See also Yamagishi-992, 147:3-13

transmission protocol algorithm providing compressed visual image data in a compatible format, the compatible format being compatible with at least one transmission protocol, the compressed visual image data in a compatible format being suitable for transmission by the mobile phone according to at least one wireless transmission protocol.	
21. The apparatus according to claim 1 and further comprising: the image collection device being supported by the portable housing in fixed relation to the display.	Wilska, 4:6-8; Figs. 1 and 2
22. **[A22]** Apparatus comprising: a portable housing, the portable housing being wireless:	See Element [A1] of claim 1;
[B22]an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See Element [B1] of claim 1;
[C22]memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See Element [D1] of claim 1;
[D22]an input device supported by the portable housing, the input device being operable by the user; operation	See Element [E1] of claim 1;

of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	
[E22]media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	See Element [F1] of claim 1;
[F22]at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See Element [G1] of claim 1;
[G22]a display supported by tile portable housing, the display being operable to display for viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from the visual image data in digital format;	See Element [C1] of claim 1; See also Wilska, 5:5-7; 6:28-29; 7:23-26; 9:23-25
[H22]a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the compressed digital image data;	See Element [H1] of claim 1;

[I22]and movement by the user of the portable housing commonly moving the image collection device, movement by the user of the portable housing commonly moving the display	See Element [I1] of claim 1;
24. **[A24]** Apparatus comprising: a portable housing, the portable housing being wireless:	See Element [A1] of claim 1;
[B24] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See Element [B1] of claim 1;
[C24] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See Element [D1] of claim 1;
[D24] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	See Element [E1] of claim 1;
[E24] media supported by/the portable housing, the media being suitable to embody at least one compression algorithm;	See Element [F1] of claim 1;

[F24] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See Element [G1] of claim 1;
[G24] a display supported by the portable housing, the display being operable to display the viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from the retained visual image data in digital format;	See Element [C1] of claim 1; See also Wilska, 8:21-25 See also Yamagishi-992, Yamagishi-992, 119:7-37 See also Yamagishi-992, 119:53 to 120:4; 127:13-43; Fig. 50
[H24] a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the compressed digital image data;	See Element [H1] of claim 1;
[I24] and movement by the user of the portable housing commonly moving the image collection device, movement by the user of the portable housing commonly moving the display.	See Element [I1] of claim 1;
26. **[A26]** A mobile handset comprising: a portable housing, the	See Element [A1] of claim 1;

portable housing being wireless;	See also Wilska, 4:13-14; 5:22 to 6:2; 15:claims 4 and 5; Figs. 1 and 2
[B26] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See Element [B1] of claim 1;
[C26] a display supported by the portable housing, the display being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data;	See Element [C1] of claim 1;
[D26] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See Element [D1] of claim 1;
[E26] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	See Element [E1] of claim 1;
[F26] media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	See Element [F1] of claim 1;
[G26] at least one processing platform supported by the portable	See Element [G1] of claim 1;

housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	
[H26] and a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the compressed digital image data.	See Element [H1] of claim 1;
27. **[A27]** Apparatus comprising: a portable housing, the portable housing being wireless;	See Element [A1] of claim 1;
[B27] an image collection device supported by the portable housing, the image collection device being operable to provide visual image data of a field of view;	See Element [B1] of claim 1;
[C27] memory supported by the portable housing, the memory being suitable to receive visual image data in digital format, the memory being suitable to retain the visual image data in digital format,	See Element [D1] of claim 1;
[D27] an input device supported by the portable housing, the input device being operable by the user; operation	See Element [E1] of claim 1;

of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	
[E27] media supported by the portable housing, the media being suitable to embody at least one compression algorithm;	See Element [F1] of claim 1;
[F27] at least one processing platform supported by the portable housing, the at least one processing platform being operable to execute the at least one compression algorithm, the at least one processing platform being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See Element [G1] of claim 1;
[G27] a display supported by the portable housing, the display being operable to display for viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from the retained visual image data in digital format;	See Element [C1] of claim 1;
[H27] a mobile phone supported by the portable housing, the mobile phone being selectively operable to send to a remote recipient a wireless image transmission, the wireless transmission conveying the	See Element [H1] of claim 1; See also Yamagishi-992, 47-50; Fig. 43, elements 3056 and 3074 See also Yamagishi-992, 128:42-46

compressed digital image data	See also Yamagishi-992, 128:47 to 130:2 See also Yamagishi-992, 147:3-13 See also Wilska, 6:6-8; 9:28 to 10:2; 13:2-18; Fig, 3, element 17 See also Wilska, 9:28-32; 13:4-7
[I27] the mobile phone being selectively operable to send to a remote recipient a wireless voice transmission, the mobile phone being selectively operable to receive from a remote sender an incoming wireless image transmission; and the display being operable to display for viewing by a user a perceptible visual image of the incoming wireless image transmission.	Wilska, 5:22 to 6:2; 15: claims 4-5 See also Wilska, 9:28 to 10:7
29. **[A29]** Apparatus comprising: a portable housing, the portable housing being wireless;	See Element [A1] of claim 1;
[B29] an image collection device supported by the portable housing, the image collection device being operable to provide in digital format visual image data of a field of view;	See Element [B1] of claim 1; See also Wilska, 7:21-26 See also Wilska, 9:23-25 See also Wilska, 7:26-27
[C29] memory supported by the portable housing, the memory being suitable to receive the visual image data in digital format, the memory being suitable to retain the visual	See Element [D1] of claim 1;

image data in digital format,	
[D29] an input device supported by the portable housing, the input device being operable by the user; operation of the input device by the user enabling the memory to retain the visual image data in digital format, the memory being suitable to provide retained visual image data in digital format;	See Element [E1] of claim 1;
[E29] at least one compression algorithm embodied at least in part in suitable programmed media, the media being supported by the portable housing;	See Element [F1] of claim 1; See Yamagishi-992, 12:53 to 13:13; 119:38-52; Fig. 1, element 22; Fig. 43, element 3022 See also Yamagishi-992 50:57 to 51:6; 51:7-15; 58:47-57
[F29] at least one processor supported by the portable housing, the at least one processor being operable to execute the at least one compression algorithm, the at least one processor being provided the retained visual image data in digital format, execution of the at least one compression algorithm providing compressed visual image data;	See Element [G1] of claim 1;
[G29] at least one display supported by the portable housing, the at least one display being operable to display for viewing by a user a perceptible visual image of the field of view, the perceptible visual image being generated from at least one of: the	See Element [C1] of claim 1; See also Wilska, 8:21-25 See also Yamagishi-992, 119:7-37 See also Yamagishi-992, 119:31-37;

visual image data in digital format, and the retained visual image data in digital format;	120:26-32; 127:13-36
[H29] a mobile phone supported by the portable housing, the mobile phone being operable to send to a remote recipient a wireless transmission, the wireless transmission conveying the compressed digital image data.	See Element [H1] of claim 1;

D. GROUND 4: CLAIMS 13-15, 23, 25, 28 AND 31 ARE UNPATENTABLE UNDER 35 U.S.C. § 103(a) AS BEING OBVIOUS OVER WILSKA AND YAMAGISHI-992, COMBINED WITH MCNELLEY

176. In my opinion, claims 13-15, 23, 25, 28 and 31 are unpatentable as obvious over Wilska in view of Yamagishi-992 combined with McNelley.

177. McNelley is a United States Patent which issued on Aug. 27, 1996 and is therefore prior art to the 168 Patent under 35 U.S.C. § 102(b). McNelley was not cited by either the Patent Owner or the Examiner during the prosecution of the 168 Patent.

178. McNelley describes a teleconferencing camcorder, or "telecamcorder", which serves as both a portable video camera-recorder and as a video-conferencing terminal. McNelley combines the functions of a cellular telephone and a digital video camera into an integrated, hand-held device. The Telecamcorder includes a camera, a display (100), and a viewfinder (166). The display and

viewfinder can be implemented as a single display functioning both as a viewfinder and a teleconferencing display, or as separate components. The telecamcorder also includes a microphone, a speaker, a system controller, a memory which can be a solid state microelectronic memory, user interface controls, and a network access block which sends and receives audio and video signals.

179. A person of ordinary skill in the art at the time of the 168 patent would have found it obvious and straightforward to combine the teachings of Wilska, Yamagishi-992 and McNelley. Wilska, McNelley and Yamagishi-992 all describe devices which function as both digital cameras and mobile telephones, and include similar components to capture, store, process, and display images. McNelley teaches that the display (100) and the viewfinder (166) can be implemented as separate components.

180. It would have been obvious to a person of ordinary skill in the art to modify the smart phone described by Wilska according to the teachings of McNelley, in order to provide a display screen which displays images for viewing and which is separate from the viewfinder. Such a person would understand, for example, that the viewfinder could be an optical viewfinder, as described earlier in this Declaration, and that a separate display screen would be required in order to view the digital images captured by the camera phone.

The use of an optical viewfinder at the time of the 168 Patent would have provided a sharper and more responsive visual image for composing the digital image to be captured. Such a person would also understand that the viewfinder could be a small electronic viewfinder which is held up to the eye when composing an image to be captured, and is therefore not subject to reflections in bright sunlight which can reduce the usability of a larger display screen. It would have been just as straightforward and obvious to use a portion of the larger display, such as a window within the display, to operate as a viewfinder. The larger display screen could be used to display images for viewing by multiple people, or to more conveniently access the user controls on the camera phone , for example in order to select particular images for viewing.

181. **Table 4** provides a detailed mapping of exemplary sections of the Wilska, Yamagishi-992 and McNelley Prior Art references Claims 13-15, 23, 25, 28 and 31 of the 168 Patent. Further, in the paragraphs below, I have provided explanations regarding some of the claim limitations and the associated description to be used as a companion to **Table 4**.

182. It is my opinion that the cited sections in **Table 4** which are also included in the IPR petition, establish that Wilska, Yamagishi-992 and McNelley teach or

suggest all of the limitations in Claims 13-15, 23, 25, 28 and 31 and render those claims obvious and unpatentable.

183. Regarding claim 13, McNelley describes a teleconferencing camcorder, or "telecamcorder", as shown in Fig. 8, which serves as both a portable video camera-recorder and as a video-conferencing terminal. The device includes a larger teleconferencing display 100 and a single-eye viewfinder 166. As described above, a person of ordinary skill in the art would find it obvious and straightforward to apply the teachings of McNelley to the combination of Wilska and Yamagishi-992 to provide a display screen with is defined apart from the viewfinder.

184. Regarding claim 14, Wilska describes an LCD display 9 for viewing visual images. LCD displays were well known and widely used to display images on digital cameras and other digital devices, because of their compact size and low power consumption relative to, for example, CRT displays.

185. Regarding claim 15, Wilska includes an LCD display 9 which receives visual image data from the digital memory unit 13, which must be in digital form.

186. Regarding dependent claims 23, 25, 28, and 31, McNelley teaches that a display (100) and a viewfinder (166) can be implemented as separate components. A person of ordinary skill in the art at the time of the 168 Patent would have found it obvious and straightforward to include two separate

displays, as discussed earlier in this Ground. Such a person would understand, for example, that the viewfinder could be an optical viewfinder, and that a separate display screen would be required in order to view the digital images captured by the camera phone. The use of an optical viewfinder at the time of the 168 Patent would have provided a sharper and more responsive visual image for composing the digital image to be captured. Such a person would also understand that the viewfinder could be a small electronic viewfinder which is held up to the eye when composing an image to be captured, and is therefore not subject to reflections in bright sunlight which can reduce the usability of a larger display screen. It would have been just as straightforward and obvious to use a portion of the larger display, such as a window within the display, to operate as a viewfinder. The larger display screen could be used to display images for viewing by multiple people, or to more conveniently access the user controls on the camera phone , for example in order to select particular images for viewing.

Table 4 - Claims 13-15, 23, 25, 28 and 31 Mapping Based on Wilska, Yamagishi-992 and McNelley

Claim of US 7643168	Prior ART Wilska, Yamagishi-992, and McNelley
13. The apparatus according to claim 1 and further comprising: the display including a display screen, the display screen being defined apart from a	McNelley, Abstract; 6:35 to 7:24

viewfinder, the display screen being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data.	
14. The apparatus according to claim 13 and further comprising: the display including an LCD, the LCD being operable to display for viewing by a user a perceptible visual image, the perceptible visual image being generated from the visual image data.	Wilska, 4:6-11;7:23-27 See also McNelley, 6:41-43
15. The apparatus according to claim 14 and further comprising: the LCD being suitable to receive the visual image data in digital format.	Wilska, 4:6-11; 7:21-26; 9:23-25; 10:5-7; Figs. 1-2, element 9
23. The apparatus according to claim 22 and further comprising: the display including at least one of: a viewfinder, and a display screen apart from the viewfinder.	McNelley, 6:35-43 to 7:4-24
25. The apparatus according to claim 24 and further comprising: the display including at least one of: a viewfinder, and a display screen apart from the viewfinder.	See claim 22;
28. The apparatus according to claim 27 and further comprising: the display including at least one of: a viewfinder, and a display screen apart from the viewfinder.	See claim 22;
31. The apparatus according to claim 29 and further comprising: the at least	See claim 22;

one display including at least one of: a viewfinder; and a display screen apart from the viewfinder.	

187. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001.

188. I declare under the penalty of perjury that the foregoing is true and correct.

Executed June 12, 2014 in Rochester, New York.

KENNETH PARULSKI

ATTACHMENT A: Résumé of Kenneth Parulski

KENNETH A. PARULSKI
225 IMPERIAL CIRCLE, ROCHESTER, NY 14617
KAPARULSKI@GMAIL.COM 585-338-1839

PROFILE

- Widely recognized digital photography pioneer and inventor, with over 200 issued US patents. Many have been broadly licensed, providing earnings of over $2 billion dollars from 2005 to 2010.
- Proven ability to work with a wide range of disciplines, and across companies and cultures, to develop new technologies, products, systems, industry standards & business partnerships.
- Extensive experience in digital imaging research, product development, and new business development. Expertise includes intellectual property strategy development, licensing & litigation.

Chief Scientist and Managing Member, **aKAP Innovation, LLC, Rochester, NY** (June 2012 – Present)
- Providing innovation and digital photography consulting services to local and international clients.
- Co-founder of TourBlend, a start-up company focused on digital tourism.
- Invited speaker for university and industry seminars in the US, Europe, and Asia.

Chairman, IT10 Technical Committee for Digital Photography Standards (1994 – Present)
- Lead group which provides official US position on international standards for digital cameras.
- Serving as project leader for ISO standards on image formats (ISO 12234), resolution measurements (ISO 12233), and ISO speed (ISO 12232).
- Elected chair of US Technical Advisory Group to ISO/TC42 in May 2013.

Chairman, ISO Technical Committee 42 – Photography (March 2007 – February 2013)
- Leader of ISO/TC42, which includes more than 100 experts from 12 participating countries. TC42 has developed more than 170 international standards for digital and conventional photography.
- Built consensus on standards goals and priorities, and chaired international plenary meetings.
- Lead the effort to move the sponsorship of ISO TC42 from the I3A trade association to the IS&T imaging society in 2010, which greatly improved the efficiency while reducing costs.

PAST EMPLOYMENT - Eastman Kodak Company, Rochester, New York (Retired June 2012)

Research Fellow and Chief Scientist, Digital Cameras and Devices (Jan. 2010 to May 2012)
- Responsibilities included inventing and prototyping new digital photography technologies and systems, setting the intellectual property strategy and filing priorities for a $1 Billion business, and supporting corporate patent licensing and litigation efforts.
- Lead a cross-organizational team which rapidly developed, prototyped, and patented new personalized, interactive digital imaging systems using cloud processing and printing.

Research Fellow and Director, IP & Standards, Consumer Digital Group (2001 to 2009)
- Technical leader of Kodak's digital camera IP licensing program. Worked with Kodak lawyers and outside licensing agents to create an extremely successful licensing business.
- Developed new features for digital cameras and digital photography systems, including personalized and dual-lens cameras, on-line sharing systems, and dock printers.
- Managed an $8 Million R&D collaboration with ITRI in Taiwan. Projects included components such as compact zoom lenses and optical films, and systems such as media players and 3D cameras.

Chief Architect, Kodak Digital Cameras, Digital & Applied Imaging Division (1995 to 2001)
- Inventor of key patents related to preview, processing, and wireless sharing of digital images.
- Developed new digital camera and digital system architectures and formats, including panoramic camera systems and retail, wholesale, and on-line systems for printing digital camera images.
- Managed all IP issues for the divestiture of a $50 million industrial camera subsidiary.

Platform Leader, Electronic Imaging Platform Center (1992 to 1995)

- Architect of Kodak's first generation consumer digital still cameras, including the Apple QuickTake 100 and QuickTake 150 cameras and the Kodak Digital Science DC40 camera.
- Lead projects to develop novel digital video cameras for commercial and medical applications.
- Kodak representative to the Advanced Television Research Program at MIT, which developed the source adaptive compression technologies used worldwide in digital TV systems. Co-inventor of a TV decoding patent which has been widely licensed by MIT.

Group Leader, Electronic Photography Laboratory, Kodak Research Laboratories (1985 to 1991)

- Led a Kodak R&D project to build the world's first color megapixel digital camera prototype, producing prints which were displayed at Photokina in 1986.
- Developed an image processing VLSI chipset for digital video cameras. Designed high performance cameras for industrial and government applications using these Kodak ICs.
- Led a major research study which developed and documented methods for comparing the image quality of megapixel CCD and 35mm film-based photographic systems.
- Key inventor of Kodak's CD based photo storage and TV display system.

Research Scientist, Image Science Laboratory, Kodak Research Laboratories (1980 to 1984)

- Developed color image processing algorithms and hardware.
- Key member of the team which developed a CCD scanner for displaying consumer film on TV, using a Kodak color imager. This film video player was the highlight of Kodak's 1982 Photokina exhibit.

PUBLICATIONS AND PRESENTATIONS

- Over 60 external publications and presentations, including numerous invited talks on digital cameras and digital imaging systems in the US, Europe and Japan.
- Author of the "Digital Photography" chapter in the *Consumer Digital Electronics Handbook* by MacGraw-Hill 1997; the "Color Image Processing for Digital Cameras" chapter in the *Digital Color Imaging Handbook*; CRC Press 2003; and the "Digital Camera Image Storage Formats" chapter in *Single-Sensor Imaging: Methods and Applications for Digital Cameras*, CRC Press 2008.
- Author of "Source Adaptive Encoding Options for HDTV and NTSC", which received the SMPTE Journal award in 1992.
- Created and taught Kodak courses on video technology and digital photography from 1983 to 2002.

AWARDS

- International Imaging Industries Association (I3A) Achievement Award, for "significant contributions to the advancement and growth of the imaging industry" – 2008.
- Fellow, Society of Motion Picture and Television Engineers – 2002.
- Photo-imaging Manufacturing & Distributors Association Technical Achievement Award for "pioneering work in the development of digital imaging technology" – 2002.
- Eastman Award (Kodak's top technical honor) for the development of digital cameras – 2001.
- Emmy Award (presented to Kodak) for developing the 24P HDTV standard – 2001.
- Kodak 'Team Achievement Awards' for VLSI chipset (1989) and PhotoCD System (1990).

EDUCATION

Massachusetts Institute of Technology – Cambridge, MA

- Master of Science in Electrical Engineering – May 1980
- Bachelor of Science in Electrical Engineering and Computer Science, minor in Political Science
  - Student Employment
    - Motorola Corporate Research Labs - Developed a wireless mobile digital image transmission system for Master's thesis, supervised by Prof. William Schreiber.
    - U.S. Senate, Washington DC, Fall 1976 - Legislative Intern to Senator William Proxmire.

#	Patent No.	Published	Priority	Title	Inventor(s)
205	8,675,112	3/18/2014	6/24/2011	Imaging device providing capture location guidance	Arujunan, Nichols, Parulski, Murray, O'Keefe
204	8630496	1/14/2014	12/26/2001	Method for creating and using affective information in a digital imaging system	Matraszek, Fedorovskaya, Endrikhovski, Parulski
203	8612308	12/17/2013	3/24/2000	System and method for providing a configured camera, image products, and services	Wolcott, McIntyre, Parulski
202	8589241	11/19/2013	5/19/2000	System and method for facilitating imaging services using a service identification number stored in an image capture device	Wolcott, McIntyre, Parulski
201	8508623	8/13/2013	4/15/1997	Image file for storing digital images and ancillary data values using mul iple encoding methods	Parulski, Ward, Lathrop, Houchin, Jennings, Vansprewenburg
200	8405740	3/26/2013	6/24/2011	Guidance for image capture at different loca ions	Nichols, Parulski, Arujunan, Murray, O'Keefe
199	8358358	1/22/2013	7/11/2005	Identifying collection images with special events	Gallagher, Fryer, Loui, Oliver, Eckhaus, Parulski
198	8320025	11/27/2012	12/6/2000	Providing multiple payment schedules for storing images and utilizing the stored images	Jackson, Parulski
197	8184916	5/22/2012	12/26/2001	Method for creating and using affective information in a digital imaging system	Matraszek, Fedorovskaya, Endrikhovski, Parulski
196	8139126	3/20/2012	3/19/2004	Digital video system for assembling video sequences	Manico, Fredlund, Parulski, Telek, McCoy
195	8046270	10/25/2011	5/19/2000	System and method for providing image products and/or services	Wolcott, McIntyre, Parulski
194	8036467	10/11/2011	12/26/2001	Method for creating and using affective information in a digital imaging system	Matraszek, Fedorovskaya, Endrikhovski, Parulski
193	8035747	10/11/2011	3/12/2007	Image digital processing based on edit status	Fredlund, Deever, Bryant, Parulski, Parada
192	7999860	8/16/2011	4/15/1997	Image file for storing digital images and ancillary data values using mul iple encoding methods	Parulski, Ward, Lathrop, Houchin, Jennings, Vansprewenburg
191	7978239	7/12/2011	3/1/2007	Digital camera using multiple image sensors to provide improved temporal sampling	Deever, Parulski, Fredlund, Rabbani, Kurtz, Manico
190	7965310	6/21/2011	5/11/2000	System and camera for transferring digital images to a service provider	Endsley, Bryant, Fredlund, Parulski
189	7952616	5/31/2011	4/24/1995	Transmitting digital images to a plurality of selected receivers over a radio frequency link	Parulski, Schueckler
188	RE42337	5/10/2011	2/20/1997	Network configuration file for automatically transmitting images from an electronic still camera	Ward, Parulski, Allen
187	7936391	5/3/2011	2/20/1997	Digital camera wi h communications interface for selectively transmit ing images over a cellular phone network and a wireless LAN network to a destination	Ward, Parulski, Allen
186	7933474	4/26/2011	12/26/2001	Method for creating and using affective information in a digital imaging system	Matraszek, Fedorovskaya, Endrikhovski, Parulski
185	7893963	2/22/2011	5/19/2005	Digital camera which estimates and corrects small camera rotations	Gallagher, Parulski
184	7859588	12/28/2010	3/9/2007	Method and apparatus for operating a dual lens camera to augment an image	Parulski, Janson, Border, Fredlund, Manico, Parada
183	7840634	11/23/2010	6/26/2001	System and method for managing images over a communication network	McIntyre, Parulski
182	7782372	8/24/2010	2/24/1998	Image file for storing digital images and ancillary data values using mul iple encoding methods	Parulski, Ward, Lathrop, Houchin, Jennings, Vansprewenburg
181	RE41542	8/17/2010	4/24/1995	Cellular telephone and electronic camera system with programmable transmission capability	Parulski, Schueckler
180	RE41524	8/17/2010	12/20/1995	Electronic still camera for capturing and categorizing images	Paurulski, Napoli, Lewis
179	7755662	7/13/2010	4/4/1997	Digital camera providing image processing for an attachable printer	Parulski, Small, Couwenhoven, VanBlargan, Wess
178	7743110	6/22/2010	1/18/2002	System, method and software product for ordering image products over a communication network from a plurality of different providers having various business relationships, using images stored on a digital storage device	Chauvin, Bussey, Dobbs, Parulski, Thompson, Foster, Gotham
177	7742084	6/22/2010	2/20/1997	Network configuration file for automatically transmitting images from an electronic still camera	Ward, Parulski, Allen
176	7729602	6/1/2010	3/9/2007	Camera using multiple lenses and image sensors operable in a default imaging mode	Janson, Parulski
175	7701490	4/20/2010	2/20/1997	Automatically transmitting images from an electronic camera to a service provider using a network configuration file	Ward, Parulski, Allen

#	Patent No.	Published	Priority	Title	Inventor(s)
174	7676146	3/9/2010	3/9/2007	Camera using multiple lenses and image sensors to provide improved focusing capability	Border, Palum, Janson, Parulski, Jacoby
173	7675556	3/9/2010	8/7/2002	Cameras, other imaging devices, and methods having non-uniform image remapping using a small data-set of distortion vectors	Smith, Parulski
172	7643704	1/5/2010	2/4/2005	Cropping a digital image and preserving reserves	Jackson, Parulski,McGarvey
171	7620270	11/17/2009	12/26/2001	Method for creating and using affective information in a digital imaging system	Matraszek, Fedorovskaya, Endrikhovski, Parulski
170	7616248	11/10/2009	7/17/2001	Revised recapture camera and me hod	Parulski, Malloy-Desormeaux
169	7587337	9/8/2009	3/24/2000	Leasing configured camera system	Parulski, Kenneth A.
168	7586532	9/8/2009	6/2/1999	Customizing a digital camera using firmware components provided by a service provider over a network	Prabhu, Miller, Akyuz, Wasula, Tintera, Parulski
167	7561191	7/14/2009	2/18/2005	Camera phone using multiple lenses and image sensors to provide an extended zoom range	May, Ludington, Parulski, Janson
166	7525680	4/28/2009	10/18/2000	Effective transfer of images captured by a digital camera to a remote location	Berarducci, Parulski, Fredlund
165	7509668	3/24/2009	3/24/2000	Leasing a configured camera system	Parulski, Kenneth A.
164	7495697	2/24/2009	2/20/1997	Network configuration file for automatically transmitting images from an electronic still camera	Ward, Parulski, Allen
163	7492389	2/17/2009	2/20/1997	Electronic camera having an interface for selecting users permitted to view transferred images	Parulski, Ward, Hopwood
162	7466336	12/16/2008	9/5/2002	Camera and method for composing multi-perspective images	Regan, Parulski
161	7453605	11/18/2008	7/1/2005	Capturing digital images to be transferred to an e-mail address	Parulski, Ward, Hopwood
160	7453498	11/18/2008	12/8/2005	Electronic image capture device and image file format providing raw and processed image data	Prentice, Yamagata, Parulski
159	7443418	10/28/2008	4/11/2003	Method for producing electronic job pages	Bryant, Parulski, Lyon, Wolf
158	7418116	8/26/2008	4/30/2007	Imaging method and system	Fedorovskaya, Endrikhovski, Matraszek, Parulski, Zacks, Taxier, Telek, Marino, Harel
157	7408582	8/5/2008	5/20/2004	Methods for configuring a digital camera and for display digital images	Prabhu, Miller, Akyuz, Wasula, Tintera, Parulski
156	7369164	5/6/2008	4/11/2003	Using favorite digital images to organize and identify electronic albums	Bryant, Parulski, Lyon, Wolf
155	7349010	3/25/2008	4/11/2003	Digital camera including an on-line sales mode	Bryant, Parulski, Lyon, Wolf
154	7327505	2/5/2008	2/19/2002	Method for providing affective information in an imaging system	Fedoroyskaya, Endrikhorski, Matrasszek, Parulski, Mir
153	7319780	1/15/2008	11/25/2002	Imaging method and system for health monitoring and personal security	Fedoroyskaya, Endrikhorski, Parulski, Zacks, Taxier, Telek, Manico, Harel
152	7307636	12/11/2007	12/26/2001	An image format including affective information	Matraszek, Fedorovskaya, Endrikhovski, Parulski
151	7305180	12/4/2007	2/18/2005	Digital camera using multiple lenses and image sensors to provide an extended zoom range	Labaziewicz, Janson, Parulski
150	7304677	12/4/2007	6/2/1999	Customizing a digital camera based on demographic factors	Keelan, Wheeler, Parulski, Prabhu
149	7301568	11/27/2007	8/7/2002	Cameras, other imaging devices, and methods having non-uniform image remapping using a small data set of distortion vectors	Smith, Parulski
148	7295244	11/13/2007	3/26/2002	System for capturing and archiving mo ion video segments	Manico, Fredlund, Parulski
147	7292267	11/6/2007	9/12/1996	Dual mode digital imaging and camera system	Prentice, Berarducci, Parulski
146	7289663	10/30/2007	7/24/2002	Producing an extended color gamut luminance-chrominance digital image from a captured image	Spaulding, Parulski, Prentice
145	7275044	9/25/2007	8/22/2001	System, method and software product for ordering image products over a communication network from a plurality of different providers having various business relationships	Chauvin, Bussey, Dobbs, Parulski, Thompson, Foster, Gotham
144	7271832	9/18/2007	4/15/1997	JPEG compatible image file format using multiple application segments	Parulski, Ward, Lathrrop, Houchin, Jennings, Vansprewenburg
143	7271809	9/18/2007	2/19/2002	Method for using viewing time to determine affective information in an imaging system	Fedorovskaya, Endikhovski, Matraszek, Parulski, Mir
142	7260546	8/21/2007	3/24/2000	Method for providing image goods and / or services to a customer	McIntyre, Willand, Brumlow, White, Parulski
141	7256944	8/14/2007	2/18/2005	Compact image capture assembly using multiple lenses and image sensors to provide an extended zoom	Labaziewicz, Parulski, Janson
140	7256823	8/14/2007	2/20/1997	Network configuration file for automatically transmitting images	Ward, Parulski, Allen

#	Patent No.	Published	Priority	Title	Inventor(s)
139	7236306	2/18/2005		Digital camera using an express zooming mode to provide expedited operation over an extended zoom range	Janson, Parulski
138	7233684	6/19/2007	11/25/2002	Imaging method and system using affective information.	Fedorovskaya, Endikhovski, Matraszek, Parulski, Zacks, Taxier, Telek, Marino, Harel
137	7231359	6/12/2007	12/17/2004	Configuring image storage devices to enable imaging services	Parulski
136	7212229	5/1/2007	3/6/2001	Digital camera providing image processing for an attachable printer	Parulski, Small, Couwenhoven, VanBlargan, Wess
135	7210161	4/24/2007	2/20/1997	Automatically transmitting images from an electronic camera to a service provider using a network configuration	Ward, Parulski, Allen
134	7206136	4/17/2007	2/18/2005	Digital camera using multiple lenses and image sensors to provide an extended zoom range	Paurulski, Janson, Labaziewicz
133	7171113	1/30/2007	11/22/2000	Digital camera for capturing images and selec ing metadata to be associated with the captured images	Parulski, McCoy
132	7170552	1/30/2007	3/26/1998	Digital imaging system and file format for storage and selective transmission of processed and unprocessed image data	Parulski, Houchin
131	7158945	1/2/2007	11/30/2001	System and method for providing image products and/or services	Wolcott, McIntyre, Parulski
130	7158175	1/2/2007	11/30/2001	System including a digital camera and a docking unit for coupling to the internet	Belz, Chambers, Parulski
129	7146179	12/5/2006	10/24/2002	Portable imaging device employing geographic information to facilitate image access and viewing	Parulski, Schaeffer, Endsley
128	7136837	11/14/2006	5/10/2004	Providing a discounted payment schedule for utilizing and deleting stored images	Jackson, Parulski
127	71333597	11/7/2006	7/5/2001	Recording audio enabling software and images on a removable storage medium	Tingey, Gilman, Parulski
126	7127164	10/24/2006	6/27/2006	Method for rating images to facilitate image retrieval	Parulski, McCoy
125	7111317	9/19/2006	5/19/2000	Method for providing image goods and/or services to a customer	McIntyre, Willand, Brumlow, White, Parulski
124	7110025	9/19/2006	10/11/2000	Digital camera for capturing a sequence of full and reduced resolution digital images and storing motion and still digital image data	Loui, Parulski, Berarducci, Jackson, Joshi
123	7088396	8/8/2006	12/21/2001	System and camera for crea ing lenticular output from digital images	Fredlund, Parulski, Manico, Wess, Parker
122	7088388	8/8/2006	2/7/2002	Method and apparatus for calibrating a sensor for highlights and for processing highlights	MacLean, Morton, Parulski, Rodriguez
121	7057648	6/6/2006	3/29/2001	Capturing digital images to be trasferred to an service provider for storage	Parulski, Ward, Hopwood
120	7053953	5/30/2006	12/21/2001	Method and camera system for blurring portions of a verification image to show out of focus areas in a captured archival image	Belz, Adams, Parulski
119	7038714	5/2/2006	5/16/2000	Printing system and method having a digital printer that uses a digital camera image display	Parulski, Romano, Perry, Hadley
118	7035534	4/25/2006	6/16/2004	Photographic lightmeter-remote, system, and method	Shih, Noble, Parulski
117	7034880	4/25/2006	11/20/2000	System and camera for transferring digital images to a service provider	Endsley, Bryant, Fredlund, Parulski
116	7034871	4/25/2006	3/29/2001	Capturing digital images to be transferred to an e-mail address	Parulski, Ward, Hopwood
115	7027172	4/11/2006	8/15/2000	Color digital printer having a graphical user interface for displaying and selecting images for local and remote printing	Parulski, Romano
114	7024054	4/4/2006	9/27/2002	Method and system for generating a foreground mask for a composite image	Cahill, Parulski, Luo, Gindele
113	7024051	4/4/2006	12/8/2000	Customizing a digital imaging device using preferred images	Miller, Parulski
112	7019778	3/28/2006	4/14/2000	Customizing a digital camera	Prabhu, Miller, Akyuz, Wasula, Tintera, Parulski
111	7015955	3/21/2006	12/22/2000	Camera having verifica ion display wi h viewer adaptation compensation for reference illuminants and method	Funston, Parulski
110	7003139	2/21/2006	2/19/2002	Method for using facial expression to determine affective information in an imaging system	Endrikhovski, Fedorovskaya, Matraszek, Parulski, Mir
109	6999111	2/14/2006	6/26/2001	Electronic camera and system for transmitting digital over a communication network	McIntyre, Parulski, Zacks
108	6989859	1/24/2006	12/22/2000	Camera having user interface ambient sensor viewer adaptation compensation and method	Parulski
107	6989221	1/24/2006		Photographic article	Wexler, Hall, Parulski

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106	6985248	1/10/2006		Printing digital images using a print utilization file	Parulski, Ward, Hopwood
105	6950198	9/27/2005	10/18/2000	Effective transfer of images from a user to a service provider	Berarducci, Parulski, Fredlund
104	6947079	9/20/2005	12/22/2000	Camera having verifica ion display wi h reverse white balanced viewer adaptation compensation and method	Parulski, Funston
103	6937997	8/30/2005	3/24/2000	Configuring and purchasing imaging devices	Parulski
102	6930718	8/16/2005	7/17/2001	Revised recapture camera and me hod	Parulski, Malloy-Desormeaux
101	6915273	7/5/2005	5/23/2000	Method for providing customized photo products over a network using images captured from a digital camera	Parulski
100	6909463	6/21/2005	12/22/2000	Camera having verification display and white-compensator and imaging method	Parulski
99	6903762	6/7/2005	12/13/2000	Customizing a digital camera for a plurality of users	Prabhu, Miller, Akyuz, Wasula, Tintera, Parulski
98	6890690	5/10/2005	3/14/2003	Photographic article	Wexler, Hall, Parulski
97	6885395	4/26/2005	9/7/2000	Selectively adjusting the resolution levels or the quality levels of digital images stored in a digital camera memory	Rabbani, Joshi, Parulski
96	6870567	3/22/2005	12/22/2000	Camera having user interface wi h verification display and color cast indicator	Funston, Parulski, Walker
95	6856427	2/15/2005	5/20/1999	System for printing correct exposure in a rendered digital image	Gilman, Parulski, Spaulding, Collette, Hamilton
94	6836617	12/28/2004	3/24/2000	Purchasing configured photographic film products	Parulski
93	6812962	11/2/2004	5/11/2000	System and apparatus for automatically forwarding digital images to a service provider	Fredlund, Simon, Cloutier, Parulski, Wess
92	6812961	11/2/2004	5/11/2000	System and camera for automatically forwarding digital images to a service provider	Parulski, Fredlund
91	6785423	8/31/2004	5/26/2000	Producing a compressed digital image organized into layers having information relating to different viewing conditions and resolutions	Joshi, Brower, Rabbani, Parulski
90	6784924	8/31/2004	1/7/1998	Network configuration file for automatically transmitting images from an electronic still camera	Ward, Parulski, Allen
89	6781713	8/24/2004	5/20/1999	Correcting exposure in a rendered digital image	Gilman, Parulski, Spaulding, Collette, Hamilton
88	6760485	7/6/2004	5/20/1999	Nonlinearly modifying a rendered digital image	Gilman, Parulski, Spaulding, Collette, Hamilton
87	6760128	7/6/2004	12/6/2000	Providing a payment schedule for utilizing stored images using a designated date	Jackson, Parulski
86	6731952	5/4/2004	12/29/2000	Mobile telephone system having a detachable camera / battery module	Schaeffer, Parulski, Schueckler
85	6714249	3/30/2004	12/31/1998	Producing panoramic digital images by digital camera systems	May, Parulski, Rinas, VanSprewenburg, Vermillion, Dunsmore.
84	6661454	12/9/2003	6/14/1999	Digital camera wi h memory card fullness icon	Hwang, Venturino, Lathrop, Parulski
83	6650366	11/18/2003	3/26/1998	Digital photography system using direct input to output pixel mapping and resizing	Parulski, Adams
82	6629104	9/30/2003	11/22/2000	Method for adding personalized metadata to a collection of digital images	Parulski, McCoy
81	6600510	7/29/2003	7/27/2000	Transmitting digital images to a plurality of selected receivers over a radio frequency link	Parulski, Schueckler
80	6573927	6/3/2003	11/24/1997	Electronic still camera for capturing digital image and creating a print order	Parulski, Ward, Hopwood.
79	6567119	5/20/2003	3/26/1998	Digital imaging system and file format for storage and selective transmission of processed and unprocessed image data	Parulski, Houchin
78	6539177	3/25/2003	7/17/2001	Warning message camera and method	Parulski
77	6516154	2/4/2003	7/17/2001	Image revising camera and method	Parulski, Cannon, Malloy Desormeaux
76	6400908	6/4/2002	3/6/2000	Camera and photography system with multiple, encoded area modes and modification states	Parulski
75	6389159	5/14/2002	1/12/2001	Method for producing prints from digital image files scanned from film	Gilman, Chang, Parulski, Pink.
74	6366316	4/2/2002	1/11/1999	Electronic imaging system for generating a composite image using the difference of two images	Parulski, Luo, Gindele
73	6310647	10/30/2001	2/24/1998	Image format for storing digital images and including multiple application segments	Parulski, Ward, Lathrop, Houchin, Jennings, Vansprewenburg
72	6292219	9/18/2001	3/18/1997	Motion processing system using an effects-enhanced motion storage medium	Fredlund, Parulski.
71	6292218	9/18/2001	7/16/1997	Electronic camera for initiating capture of s ill images while previewing motion images	Parulski, Tredwell

#	Patent No.	Published	Priority	Title	Inventor(s)
70	6208770	3/27/2001	9/18/1998	Digital colored corrected prints produced from colored film	Gilman, Chang, Parulski, Pink.
69	6122526	9/19/2000	1/19/1999	Cellular telephone and electronic camera system with programmable transmission capability	Parulski, Schueckler
68	6097901	8/1/2000	9/18/1998	Camera having locator for image modification areas	Parulski
67	6072962	6/6/2000	9/18/1998	Camera and photography system with multiple, encoded area modes and modification states	Parulski
66	6070013	5/30/2000	9/18/1998	Transmogrifying photography systems, film packages, and cameras	Cosgrove, Parulski
65	5983229	11/9/1999	6/5/1997	Extension persistence mechanism for a digital image format	Houchin, Couwenhoven, Parulski
64	5943603	8/24/1999	4/24/1997	Electronic camera system with programmable transmission capability	Parulski, Schueckler
63	5914748	6/22/1999	8/30/1996	Method and apparatus for generating a composite image using the difference of two images	Parulski, Luo, Gindele
62	5900909	5/4/1999	7/17/1997	Electronic still camera having automatic orientation sensing and image correction	Parulski, Severin, Ohmori, Izumi, Mizukoshi
61	5874994	2/23/1999	12/11/1995	Filter employing arithmetic operations for an electronic sychronized digital camera	Xie, Parulski.
60	5859927	1/12/1999	5/13/1997	Method and system for he reduction of memory capacity required for a digital representation of an image	Adams, Spaulding, Parulski.
59	5841471	11/24/1998	9/12/1996	Timing control for a digitally interfaced camera using variable line readout intervals	Endsley, Berarducci, Parulski
58	5828406	10/27/1998	12/30/1994	Electronic camera having a processor for mapping image pixel signals into color display pixels	Parulski, Tredwell
57	5708729	1/13/1998	4/12/1995	Method and system for he reduction of memory capacity required for digital representation of an image	Adams, Spaulding, Parulski.
56	5696850	12/9/1997	12/21/1995	Automatic image sharpening in an electronic imaging system	Parulski, Axman
55	5682562	10/28/1997	5/16/1996	Digitally controlled quench flash circuit	Mizukoshi, Izumi, Lynch, Uebelacker, Parulski, Dunsmore
54	5668597	9/16/1997	12/30/1994	Electronic camera with rapid automatic focus of an image upon a progressive scan image sensor	Parulski, Izumi, Mizukoshi
53	5666159	9/9/1997	4/24/1995	Electronic camera system with programmable transmission capability	Parulski, Schueckler
52	5633678	5/27/1997	12/20/1995	Electronic still camera for capturing and categorizing images	Parulski, Napoli, Lewis
51	5610654	3/11/1997	3/6/1996	Automatic camera exposure control using variable exposure index CCD sensor	Parulski, McGarvey.
50	5595389	1/21/1997	12/30/1993	Method and apparatus for producing personalized" video games using CD discs"	Parulski, Baumeister, Ellson
49	5563658	10/8/1996	12/16/1994	Electronic camera with rapid automatic focus of an image upon an image sensor	Parulski, Lathrop
48	5555098	9/10/1996	4/26/1994	Method and apparatus for providing multiple programmed audio/still image presentations from a digital disc image player	Parulski
47	5523786	6/4/1996	12/22/1993	Color sequential camera in which chrominance components are captured at a lower temporal rate than luminance components	Parulski
46	5519452	5/21/1996	6/17/1994	Mechanism for improving television display of still images using image motion-dependent filter	Parulski
45	5506617	4/9/1996	12/10/1992	Electronic camera incorporating a computer-compatible bus interface	Parulski, Bouvy, Smi h, Acello
44	5493335	2/20/1996	6/30/1993	Single sensor color camera with user selectable image record size	Parulski, Vogel, Ohmori
43	5477264	12/19/1995	3/29/1994	Electronic imaging system using a removable software-enhanced storage device	Sarbadhikari, Fredlund, Parulski.
42	5475441	12/12/1995	12/10/1992	Electronic camera with memory card interface to a computer	Parulski, Bouvy, Tredwell, Smith
41	5475428	12/12/1995	9/9/1993	Method for processing color image records subject to misregistration	Hintz, Hibbard, Parulski.
40	5453840	9/26/1995	1/27/1994	Cross correlation image sensor alignment system	Parker, Parulski
39	5440401	8/8/1995	9/14/1990	Image database incorporating low resolution index image data	Parulski, Kristy, O'Brien, Donald E.
38	5440343	8/8/1995	2/28/1994	Motion/still electronic image sensing apparatus	Parulski, Stevens, HibbardH.
37	5428456	6/27/1995	3/15/1991	Method and apparatus for adaptively reducing interline flicker of TV-displayed image	Parulski, AxmanS.
36	5414811	5/9/1995	2/25/1994	Method and apparatus for controlling rapid display of multiple images from a digital image database	Parulski, Funston.
35	5410415	4/25/1995	9/30/1993	Recorded digital image presentation control files	Parulski, Brownstein, Caine, Axman.

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34	5406325	4/11/1995	7/6/1992	Method and apparatus for forming a source-independent image data metric from second generation photographic films	Parulski, Johnson, Bellis.
33	5402170	3/28/1995	8/31/1992	Hand-manipulated electronic camera tethered to a personal computer	Parulski, Hamel, Acello.
32	5355178	10/11/1994	10/24/1991	Mechanism for improving television display of still images using image motion-dependent filter	Parulski
31	5301244	4/5/1994	7/15/1993	Computer input scanner incorporating mul iple scanning modes	Parulski
30	5295204	3/15/1994	7/18/1991	Method for color balancing a computer input scanner incorporating multiple scanning modes	Parulski
29	5285237	2/8/1994	9/16/1991	Photoprint retaining platen for digitizing image scanner	Parulski, Manley, Reddig
28	5270839	12/14/1993	9/16/1991	Dual imaging station photoprint scanner	Parulski, Smith, Manley, Bilson
27	5270831	12/14/1993	9/14/1990	Storage and playback of digitized images in digital database together with presentation control file to define image orientation/aspect ratio	Parulski, Brownstein, Caine, Axman.
26	5251021	10/5/1993	8/5/1992	Color sequential scanner incorporating a synchronized variable exposure shutter	Parulski, Geisbuesch, Rutter.
25	5251019	10/5/1993	7/24/1992	Solid state color image sensor using a field-staggered color filter pattern	Moorman, Hibbard, ParulskiA.
24	5250948	10/5/1993	12/19/1991	High level resolution enhancement for dual-range A/D conversion	Berstein, Parulski
23	5241659	8/31/1993	9/14/1990	Auxiliary removable memory for storing image parameter data	Parulski, O'Brien, Funston.
22	5218459	6/8/1993	9/16/1991	Print scanner with soft key variable magnifica ion	Parulski, Cochrane, Rutter.
21	5189511	2/23/1993	3/19/1990	Method and apparatus for improving he color rendition of hardcopy images from electronic cameras	Parulski, Bellis, Jr., Hibbard, Giorgianni, McInerney
20	5177698	1/5/1993	6/5/1992	Selectable power of two coefficient signal combining circuit	Parulski
19	5173789	12/22/1992	7/18/1991	Image scanner incorporating manually operable magnification and brightness control	Renner, Shelley, Parulski
18	*5161006*	*12/3/1992*	*7/26/1990*	*Method for separating chrominance and luminance components of a television signal*	*Monta, Lim, Parulski*
17	5138454	8/11/1992	9/16/1991	Megapixel video previewer framestore and display	Parulski
16	5109273	4/28/1992	5/11/1990	Signal processing circuit for performing a pipelined matrix multiplication upon signals from several linear sensors	Parulski, Cook, D'Luna
15	5101269	3/31/1992	9/18/1990	Stereoscopic electronic slide and print viewer	Shelley, Parulski
14	5086344	2/4/1992	5/11/1990	Digital correlated double sampling circuit for sampling the output of an image sensor	D'Luna, Cook, Parulski
13	5086343	2/4/1992	5/11/1990	Method and apparatus for compensating for sensitivity variations in he output of a solid state image sensor	Cook, Parulski, D'Luna
12	5065229	11/12/1991	9/27/1990	Compression method and apparatus for single-sensor color imaging systems	Tsai, Parulski, Rabbani
11	5053861	10/1/1991	7/24/1989	Compression method and apparatus for single-sensor color imaging systems	Tsai, Parulski, Rabbani
10	5047861	9/10/1991	7/31/1990	Method and apparatus for pixel non-uniformity correction	Houchin, Parulski
9	5040068	8/13/1991	12/28/1989	Electronic imaging apparatus with interchangeable pickup units	Parulski, Moorman
8	5025313	6/18/1991	10/16/1989	System for minimizing optical distortions and chromatic aberrations in a linear color scanner	Parulski, Kessler
7	5008739	4/16/1991	2/13/1989	Real- ime digital processor for producing full resolution color signals from a mul i-color image sensor	D'Luna, Hibbard, Parulski
6	5001663	3/19/1991	5/3/1989	Programmable digital circuit for performing a matrix multiplication	Parulski, Hibbard, D'Luna
5	4994901	2/19/1991	12/23/1988	Method and apparatus for increasing the gamut of an additive display driven from a digital source	Parulski, Bellis
4	4967264	10/30/1990	5/30/1989	Color sequential optical offset image sampling system	Parulski, Nutting, Moore
3	4962419	10/9/1990	2/13/1989	Detail processing method and apparatus providing uniform processing of horizontal and vertical detail components	Hibbard, Parulski, D'Luna
2	4896207	1/23/1990	6/17/1988	Color imaging apparatus employing a horizontal stripe color filter to reduce rise-time artifacts	Parulski
1	4876590	10/24/1989	6/17/1988	Low resolution verifier for a s ill video image	Parulski

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2. K. A. Parulski, "Color Filters and Processing Alternatives for One-chip Cameras," *IEEE Trans. Electron Devices*, Vol. ED-32, No. 8, pp. 1381-1389, Aug. 1985.

3. G. Kennel, K. A. Parulski, et. al. "Determination of an Exposure Index for Electronic Cameras", *1985 SMPTE Conference*, October 1985.

4. M. Kriss, K. A. Parulski, et. al., "Critical Technologies for Electronic Still Imaging Systems, Proc SPIE, vol. 1082, *Applications of Electronic Imaging* (1989), pp 157-184.

5. L. J. D'Luna, K. A. Parulski, et al., "A Digital Video Signal Processor for Color Image Sensors," *ISSCC '89 Technical Digest*, pp. 158-159, Feb. 1989.

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8. K. A. Parulski, et al. "A Digital Color CCD Imaging System Using Custom VLSI Circuits," *IEEE Trans. on Consumer Electronics*, Vol. 35, No. 3, pp. 382-389, Aug. 1989.

9. W. A. Cook, K. A. Parulski, et al., "A Digital Signal Processor for Linear Sensors", IEEE Custom Integrated Circuits Conference, 1990, pp. 7.5.1-7.5.4.

10. K. A. Parulski, et. al, "A High-performance Digital Color Video Camera", SPIE Vol.1448, *Camera and Input Scanner Systems* (1991), pp. 45-58, Feb. 1991.

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24. G. E Lathrop and K. A. Parulski, "Advantages of Tag-Based Formats for Electronic Still Photography", IS&T's 47th Annual Conference Proceedings, Vol. 2, May 1994, pp. 630-633.

25. W. Hintz, K. A. Parulski, et. al., "Automatic Misregistration Correction for a Color Sequential Digital Still Camera", IS&T's 47th Annual Conference Proc., Vol. 2, May 1994, pp. 655-657.

26. T. J. Tredwell, K. A. Parulski, et. al., "Electronic Photography Applications of a 6.4 Megapixel Image Sensor", IS&T's 47th Annual Conference Proceedings, Vol. 2, May 1994, pp. 660-664.

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Digital, Still-Optimized Architecture for Electronic Photography

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Eastman Kodak Company, Rochester, New York
Seishi Ohmori and Yoshinori Takizawa
Kodak Japan Ltd., Yokohama, Japan

Introduction

This paper describes an architecture for electronic camera systems targeted at low cost computer imaging applications. These applications primarily use images to convey information rather than to create consumer or professional photographs. The architecture includes a custom image sensor optimized for still images, in-camera compression optimized for data from single-chip color sensors, and image storage using nonvolatile solid-state memory. Extensive signal processing is performed in the host computer, as the image is downloaded from the camera. The cost, image quality, and ease-of-use advantages of this digital software driven architecture are described. The architecture enables low cost color cameras to be developed to meet a variety of customer needs.

Background

Early electronic photography systems, such as those based on the still video floppy (SVF), used analog video capture and TV display driven formats.[1] These systems were initially targeted at the home consumer photography market, as a replacement for conventional film-based cameras. More recently, digital cameras, using miniature hard drives or removable IC memory cards, have been developed for professionals. These cameras are used in certain photojournalism and desktop publishing applications when there is a need for immediate access to images in digital form. One example is the Kodak professional DCS 200c digital camera, which uses a standard Nikon film camera body, and a custom image sensor with 1.6 million pixels.[2] Because of the high resolution sensor and the use of digital image processing and storage, the image quality from the DCS 200c camera far exceeds that available from SVF cameras, although it is still below that provided by 35 mm film systems. However, the current high cost of megapixel-based cameras prevents their widespread use as computer image input devices.

The Kodak photo CD system is a cost-effective method of inputting photographic quality images into desktop computers.[3] The format of the Kodak photo CD master disc preserves the high resolution and dynamic range of the film image, by creating a "digital negative" with 2048 rows and 3072 columns of data per image. The images are stored on a write-once disc that can be viewed on a home television set, or accessed by a computer using a CD-ROM drive. For some electronic imaging applications, only low resolution images are necessary. Recently, Kodak photo CD portfolio discs and authoring software have been introduced. This format allows 512 x 768 pixel BASE resolution images to be stored along with audio and branching instructions. Over 700 images can be stored per disc, so that the cost of archival storage is only pennies per image.

System Architecture

Figure 1 shows a block diagram of the complete digital electronic photography system. The electronic camera, shown in Fig. 2, captures and stores up to 32 images in Flash EPROM memory ICs. The images are downloaded via a standard serial interface to the host computer. Either an Apple MacIntosh or PC compatible desktop or portable computer may be used. The camera data is processed as it is downloaded to the computer. The software-based image processing both reduces the cost of the camera and allows more elaborate algorithms to be used. The host computer allows the images to be viewed, manipulated, and transmitted. Unlike video-based cameras, no new hardware is required for these features. Images are archived using a Kodak CD writer and portfolio CD discs. The disks can then be played on nearly all computers featuring a CD-ROM drive. Hardcopy prints are created using a thermal dye sublimation printer.

A serial interface connection is presently the most convenient method of transferring images between an electronic camera and a computer. Floppy disk-based cameras typically require a special video frame grabber board in the computer. Memory card-based cameras require a special reader, because few existing desktop computers have slots that accept memory cards. The serial interface data ~~rate~~ depends on the host. Rates of over 800 kbits/s can be supported on some computers, while lower rates are used on others. The camera image file includes low resolution "thumbnail" images[4] that are downloaded first. The user can quickly preview all of the thumbnails, and decide which images to download from the camera.

Camera Architecture

A simplified block diagram of the digital camera architecture is shown in Fig. 3. The scene is imaged by a fixed focal length camera lens, through an optical prefilter, and onto the color CCD. The image is digitized using a single A-to-D converter, which nonlinearly quantizes the CCD output signal. The DSP preprocesses the color filter array (CFA) image data into a luminance (green) and two color difference ($R-G_{int}$ and $B-G_{int}$) channels. The preprocessing also increases the immunity to decompression artifacts.[5] The DSP then performs a proprietary ADPCM compression algorithm, to reduce the stored image size. The camera includes a medium resolution mode having 256 x 384 pixels, and a full resolution mode having 512 x 768 pixels. This is a valuable feature, because the Flash EPROM memory storage is the most expensive camera subsystem. Because the camera storage uses a few small ICs, instead of magnetic disks or removable cards, the size and weight is minimized and the form factor constraints are reduced.

The DSP that implements the preprocessing and compression for the two resolution modes is controlled by firmware that can be uploaded from the host computer. The host computer software includes three components: an application program, an image processing module (IPM), and an I/O driver. The application provides the interface to allow users to display, store, and edit images, or to remotely trigger the camera for "tethered" applications. The IPM provides camera image processing functions. The I/O driver provides two-way communications with the camera. Both the camera firmware and host software can be modified to add improved algorithms or enhanced features without hardware changes.

Still-Optimized Image Sensor

A custom image sensor has been developed for the camera. The sensor, shown in Fig. 4, has 512 lines and 768 pixels per line, to match the BASE resolution of the photo CD format. It uses a full-frame architecture, where the scene is imaged directly onto the vertical CCD registers. Because the camera has a mechanical shutter, a separate storage register is not needed. The sensor is fabricated using a two-phase NMOS process with one electrode per phase. This is achieved by using implanted barrier regions under the polysilicon electrodes.[6] The dynamic range is significantly enhanced by using accumulation mode integration and readout.[7] A lateral overflow drain is used for blooming control, and the sensor has no lag or smear.

The sensor has square pixels and progressive scan (noninterlaced) readout to match computer displays and printers. The aspect ratio is 3:2, the same as 35 mm film. Images with 480 x 640 pixels can be provided by storing only the center elements of the array. Because progressive scan readout is used, there is no temporal displacement between adjacent lines. With interlaced readout, some misregistration caused by motion is possible between the two fields. Progressive scan readout also allows the color filter array to be designed for improved vertical spatial sampling. The sensor includes a CFA layer[8] with the checkerboard color pattern[9] shown in Fig. 4. Each photosite is sensitive to only one of the three colors.

Image Processing Module

The key IPM functions are shown in Fig. 5. The CFA interpolation creates red, green, and blue (RGB) values for all of the photosites. People have much higher acuity for luminance, which is composed primarily of green, than chrominance. Therefore, more photosites are used to determine the green luminance signal than to determine the color difference signals. The CFA interpolation adaptively interpolates the highly sampled green record, which also provides high frequency luminance details to the sparsely sampled red and blue records.[10]

The color correction uses fast color matrixing techniques to provide improved color saturation.[11] The red, green, and blue sensitivities of a color CCD have responses that are always positive, and typically include some amount of color crosstalk. For example, the blue photosites may have unwanted response to red light. This crosstalk is removed by a matrix operating on the linear sensor signals. The edge sharpening is implemented using adaptive FIR filters. The vertical and horizontal high-frequency "details" are extracted from the green channel before matrixing, processed, and added back to the red, green, and blue signals.[12] This makes the picture look subjectively "sharper".

Summary

This paper has described a computer-based still camera architecture that offers image quality superior to NTSC video-based still cameras. The digital computer provides capabilities for storing, manipulating, transmitting, and viewing digital pictures. By designing the image sensor specifically for still applications, it is possible to provide both higher image quality and a universal image format. The quality is further improved by digitally processing the image.

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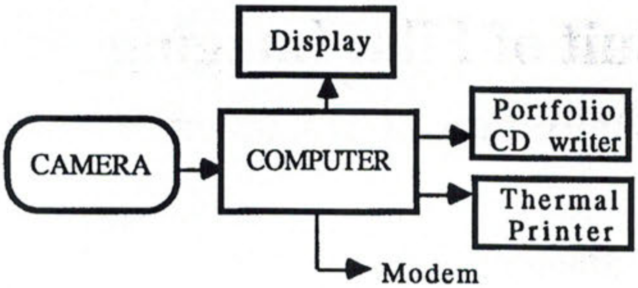

Figure 1. Digital Electronic Photography System

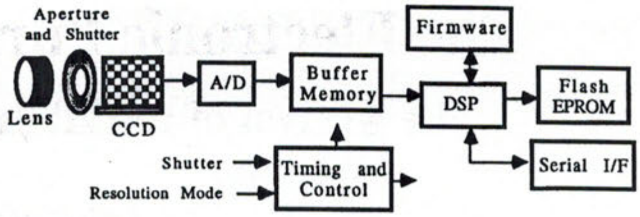

Figure 3. Digital Camera Architecture

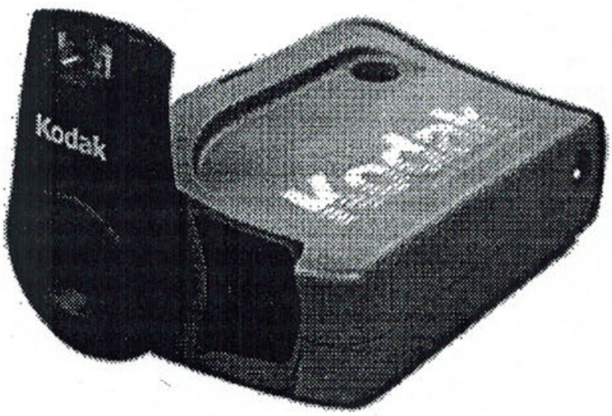

Figure 2. Digital Electronic Still Camera

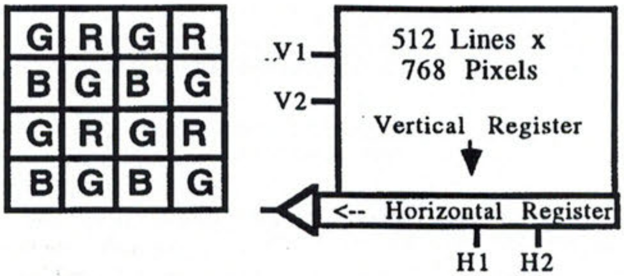

Figure 4. Still Optimized Image Sensor

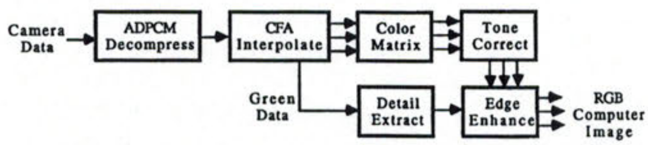

Figure 5. Imaging Processing Module Functions

ATTACHMENT C: “Chapter 21 Digital Photography in Jurgen, Digital Consumer Electronics Handbook, 1997, McGraw-Hill Professional Publishing, pp. 21.5” (ISBN-10: 0070341435)

CHAPTER 21
DIGITAL PHOTOGRAPHY

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21.1 FUNDAMENTALS OF DIGITAL PHOTOGRAPHY

Digital photography is a rapidly growing field that is enhancing, augmenting, or replacing conventional silver halide–based photographic systems in many applications. In digital photographic systems, images may be captured by a solid-state imager in a digital camera, or scanned from photographic film or prints. Image-capable computers in the home, office, or photofinishing lab allow these digital images to be organized, modified, or transmitted to other locations via digital networks. The microprocessors, memory, modems, and displays developed for desktop and portable computers can process, store, transmit, and display color pictures. The image sensors used in digital still cameras use the same fabrication technology as those in camcorders and fax machines. As this technology development produces smaller, faster, and less expensive devices, digital cameras will increase in performance while becoming more affordable.

Digital photography was first applied in professional applications such as graphic arts, where images captured from film-based cameras were scanned and manipulated electronically to correct for the printing process or provide artistic modifications to the image. Digital still cameras first replaced film cameras in applications where immediate access to the image in digital form was more important than obtaining the highest image quality. One such application is photojournalism, for example, sports photography. To meet tight deadlines with late-breaking stories, photojournalists use digital cameras to capture images that can be immediately transmitted by the wire service and distributed to newspapers worldwide.

Lower-cost "point-and-shoot" cameras were first successfully targeted at business and industrial applications. In these applications the images are typically used as "information" to create more powerful presentations or newsletters, or to document building construction or insurance claims. Recently, digital cameras have been targeted directly at the consumer market. For example, digital still cameras with LCD displays allow images to be instantly captured and shared during social occasions, much like "instant" photography. It is unclear, however, whether digital still cameras will replace film cameras in many homes in the foreseeable future. Instead, current digital still cameras may be displaced by future digital camcorders offering the capability to easily capture and organize high-quality still images as well as motion video images.

21.1.1 Early Still Video Floppy Based Analog Cameras

During the 1980s, analog electronic still cameras were developed by many Japanese companies.[1] One example is the Sony Mavica camera,[2] first demonstrated in 1981. The cameras used the Still-Video Floppy (SVF) standard, which allows 50 single field or 25 frame images to be recorded on a 5-cm magnetic floppy disk within the camera. The SVF standard uses the NTSC and PAL interlaced scanning standards, though progressive scanning is more appropriate for still cameras. The floppy disk was developed specifically for this application and spins at 3600 rpm in NTSC cameras and 3000 rpm in PAL cameras. Therefore, the same camera could not be used worldwide. SVF cameras use image sensors and recording technology adapted from video camcorders. Analog video processing is used to form a 4.5-MHz luminance signal and a 1.0-MHz line-sequential R-Y and B-Y color signal. The signals are recorded using analog FM recording.

These SVF cameras were used in limited industrial applications but were not successful consumer products because the high-priced cameras offered limited image quality. The horizontal luminance limiting resolution of 350 TV lines was acceptable for TV display, but inadequate for even small-size photographic prints. The analog recording limited the noise and stability of the image. The cameras provided poor connectivity to computers, which required a video frame grabber in order to access the images. In the 1990s, digital still cameras were developed to address these issues.

21.1.2 The Photographic Imaging Chain

To better understand the applications of digital photography, it is useful to consider the "photographic imaging chain." Both conventional film and digital cameras are seldom complete systems by themselves. They are normally just one part of an imaging system or imaging chain.[3] The chain includes functions such as capture, storage, manipulation, transmission, soft copy, and hard copy (Fig. 21.1). Each link in the chain is important, because the quality of the final image, and the happiness of the user, is determined by the "weakest" link in the chain. Each function can be implemented in different ways. For example, a traditional photographic chain begins with a camera loaded with a roll of photographic film. The film is used to both capture the incident light from the scene, and store it as a latent image. The film is developed, and the developed images can be (1) enlarged and cropped by optical printing, (2) enhanced by optical techniques, or (3) combined with other images using complex optical processes or a pair of scissors. The pictures are transmitted by physically moving them from place to place. To provide "soft copy," slide film is used. Hard copies are made by optically printing the color negatives onto photographic paper.

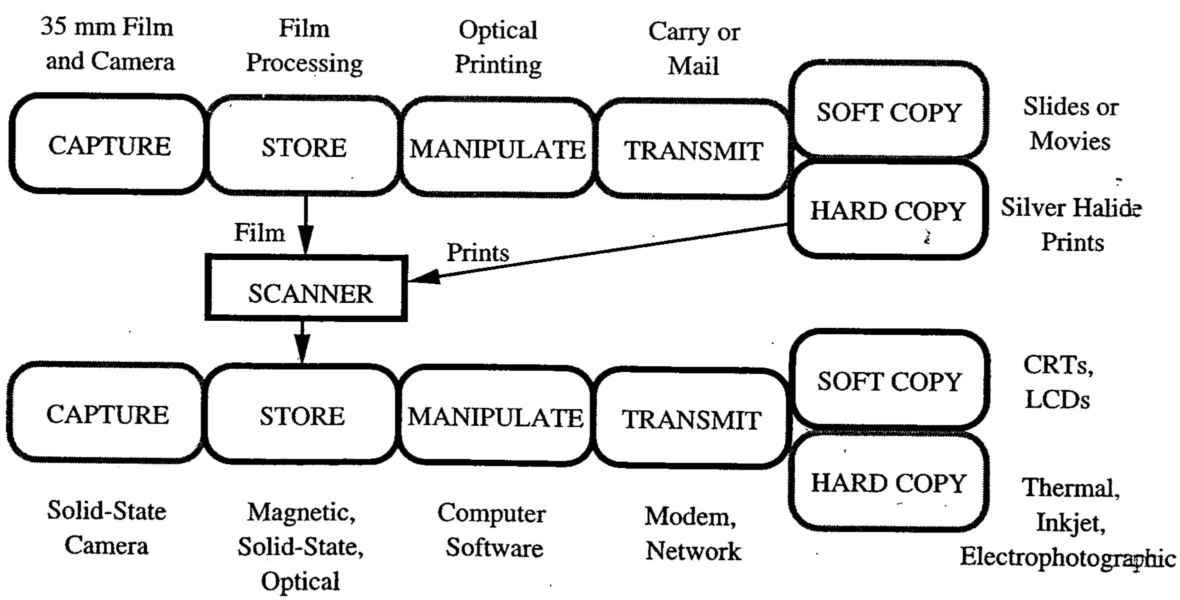

FIGURE 21.1 Conventional, electronic, and hybrid imaging chains.

The bottom of the figure shows a second type of imaging chain using only electronic links. The images can be captured using a solid-state sensor in a digital camera, and stored as electric signals on a magnetic hard drive. These digital images can be manipulated in complex ways using computer software and transmitted via computer networks. The soft-copy display may be a computer CRT or an LCD display on a digital camera. A variety of hard-copy output devices are available to print digital images, including color inkjet and thermal printers. In a third type of imaging chain, the film or prints from conventional photography systems can be scanned to create digital images. These "hybrid" systems are described in Section 21.7.

21.1.3 Comparing Conventional and Digital Photography Systems

Electronic systems have some significant advantages over film-based systems, as shown in Table 21.1. When the image is captured, it is immediately converted into signals that can be stored, manipulated, and transmitted. There is no need for the time, equipment, and chemicals necessary to develop and print photographic film. The media used to store the images can be erased and reused. Silver-halide photography has advantages in other attributes, however. The cameras are low in cost compared to digital alternatives, and often easier to use. The photofinishing infrastructure allows prints to be quickly and inexpensively produced. Finally, the image quality offered by low-cost film cameras can be approached only by the highest-cost digital alternatives.

TABLE 21.1. Comparison of Digital and Conventional Cameras

Attribute	Digital still cameras	Conventional film cameras
Equipment cost	High but decreasing	Low
Media	Erasable	Nonerasable but archival
Image access	Immediate	Requires chemical processing
Ease of use	More complex but flexible	Simple to learn
Printing	Requires new equipment	Existing photofinishers
Image quality	Depends on camera cost	Excellent

The image quality required from a digital camera depends on the type of hard copy or soft display used, as well as the size and purpose of the final image. The most significant limitation of digital cameras is their resolution, because the number of photosites in the imager array sets an upper limit on the maximum resolution of the image. The sharpness of the final image is a function of the "acutance" of the photographic system, which depends on the modulation transfer function (MTF) of the camera lens, sensor, and printer, as well as the print size and viewing distance.[4] The quality of images from low-cost digital cameras is limited compared to film-based systems (see Table 21.2), but it is rapidly improving. However, the information-recording

TABLE 21.2. Image Quality Attributes

Attribute	Digital still camera	Conventional film camera
Resolution	Limited by image sensor	Excellent
Exposure latitude	Limited	Wide for color negative films
Sensitivity	Variable	Function of film ISO speed
Tone/color fidelity	Adjustable	Function of film, photofinisher
Image quality	Function of cost	Excellent
Noise and artifacts	Noise, streaks, aliasing	Grain is function of film speed

ATTACHMENT C

capability of silver-halide technology also continues to advance,[5] creating photographic emulsions with increased resolution, enhanced photographic speed, and reduced granularity. This technology is applied in new film-based photography systems such as the advanced photo system. This system allows digital data to be stored on a magnetic coating on the film, providing new capabilities for film-based photography.

21.2 DIGITAL CAMERA ARCHITECTURES AND APPLICATIONS

Digital photography is rapidly growing in many diverse applications covering a range of requirements. To meet these needs, digital cameras using a range of image sensors, digital storage devices, and display capabilities have been developed. Some cameras operate as stand-alone systems where the captured image can be instantly viewed, whereas others use a computer to "finish" the image as the first step in a computer-based imaging application.

21.2.1 High-Resolution Cameras for Professional Use

High-resolution digital cameras have been developed for professional photographers, whose business depends on taking high-quality pictures. These cameras often use existing 35-mm or medium-format film camera bodies and lenses.[6] This allows the photographers to easily operate the camera and to use their existing equipment. However, the imager's photosensitive area is often smaller than the film area. As a result, the relative magnification of the lens is larger than for 35-mm film. A relay lens can be used to correct the magnification,[7] but this limits the usable f-number range of the lens.

A block diagram of the Kodak Professional DCS 460 digital camera,[8] the first portable 6.3-megapixel digital camera, is shown in Fig. 21.2. The camera uses a Nikon N90 35-mm format single-lens reflex (SLR) camera body and interchangeable lenses. The scene is focused through the camera lens onto the imager. The camera body automatically controls the exposure time and the lens aperture. The image may be focused manually or by using an autofocus lens. The image sensor has 3072 columns and 2048 rows of photosites, providing a total of 6.3 million pixels. The output of the image sensor is amplified and digitized using a linear 12-bit flash A/D controlled by a 5-MHz pixel rate clock. The output of the A/D is processed by logic arrays programmed by the camera firmware, and temporarily stored in DRAM. The digital images are converted to a TIFF (tag image file format) compatible record and stored as a DOS file on a removable PCMCIA (Personal Computer Memory Card Industry Association) type-III hard drive. To download the images, the camera is connected to the SCSI interface of the host computer. A 340-Mbyte hard drive can store over fifty 6.3-megapixel images.

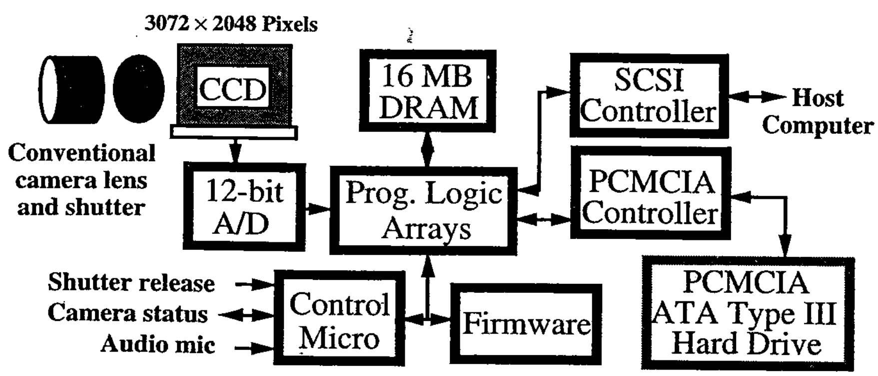

FIGURE 21.2 Block diagram of the Kodak Professional DCS 460 digital camera.

Image processing is done entirely in the digital domain, rather than using analog circuits. This minimizes noise and allows sophisticated image processing algorithms to be employed. Some digital processing is performed in the camera, before the image is stored. More complex algorithms are implemented in the host computer as the image is downloaded. A small color "thumbnail" image is stored along with each high-resolution image. When the camera or removable memory is connected to the computer, the thumbnail images are downloaded first to allow the user to select images of interest. This software- and firmware-based processing enables the cameras to use sophisticated image-processing algorithms that can be easily upgraded in the field and customized for special customer requirements.

21.2.2 Cameras for Consumer Applications

A wide variety of medium- and low-resolution digital cameras have been developed for business and consumer use. These cameras are less expensive than the digital cameras used by professional photographers, but they offer more limited image quality. They are used to add images to documents or presentations and for entertainment purposes. Most of these cameras include a serial connection to a desktop computer as well as a removable memory card. Some offer immediate viewing of the images by using an attached LCD or by providing an analog video output signal that can be connected to a home TV.

A block diagram of the QV-10 LCD digital camera developed by Casio Computer Co., Ltd., Japan,[9] is shown in Fig. 21.3. This was the first digital camera to incorporate a built-in color LCD image display. The scene is focused through a 5.2-mm camera lens onto the imager, which has 320 columns and 240 rows of photosites to provide a total of 77,000 pixels. The camera automatically controls the sensor exposure time. The lens has a fixed-focus setting. The output of the image sensor is amplified and A/D converted in a first LSI (large-scale integration) IC and then processed by a second LSI to provide an NTSC video signal. This NTSC signal is displayed on a 1.8-inch diagonal TFT (thin film transistor) LCD, which serves as the camera viewfinder.

When the user presses the shutter button, the captured still image is temporarily stored in the 0.5-Mbyte DRAM. The image is compressed by the coprocessor block in the second LSI, which performs 8 × 8 block DCT compression and Huffman coding. The compressed images are stored in 2 Mbytes of flash EPROM memory, which can hold up to 96 images. The stored images can be decompressed and viewed on the LCD screen. This enables the images to be immediately shared in social settings, much like instant photos. The images can be downloaded to a host computer via a serial port. However, the limited number of pixels provided by the camera significantly limits the quality of the image on the computer monitor or hard-copy printer.

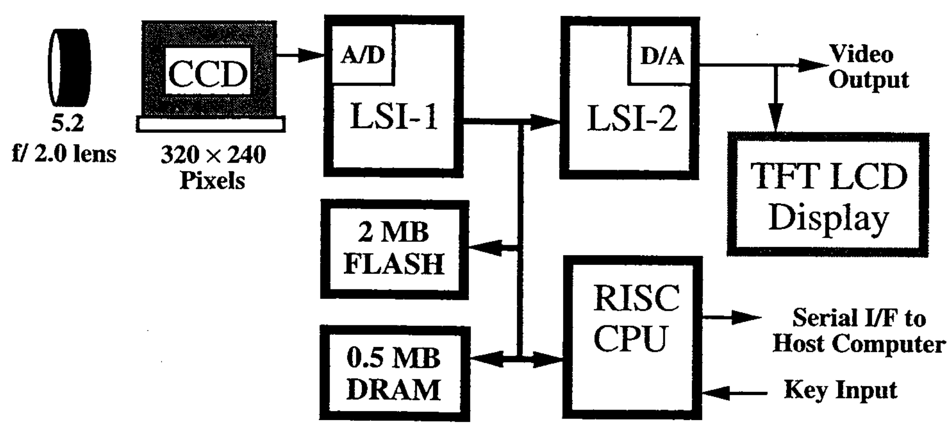

FIGURE 21.3 Block diagram of the Casio QV10 digital camera.

21.3 IMAGE SENSORS FOR DIGITAL CAMERAS

The image sensor is the most important component of a digital camera because it sets the maximum resolution, sensitivity, and signal-to-noise ratio capabilities of the camera. There are many different image sensor architectures, including frame transfer devices,[10] interline devices,[11] frame-interline transfer (FIT) devices,[12] MOS x-y addressed devices,[13] and active pixel sensors (APS).[14]

21.3.1 Full-Frame Transfer Image Sensors

The image sensors used in most professional digital cameras employ a full-frame architecture,[15] shown in Fig. 21.4. A full-frame imager consists of a parallel, light-sensitive CCD (charge-coupled device) array, also called the "vertical" shift register; an opaque serial or "horizontal" CCD shift register; and an output amplifier. It is similar to a frame transfer CCD, without the separate light-shielded storage array. When the camera shutter is opened, the camera lens focuses the image onto the parallel array, which is precisely positioned in the camera's film plane. The parallel array is composed of discrete photosites, each the same size. When photons of incident light from the scene penetrate into the photosites, the energy of the photons may be absorbed by the silicon. This interaction releases an electron-hole pair from the silicon lattice structure. The electrons are collected into "charge packets" in a "well" created at each photosite. The number of electrons collected is proportional to the number of photons of light hitting that particular photosite. Therefore, the photosites in bright image areas collect a relatively large number of electrons, and those in dark areas collect relatively few electrons.

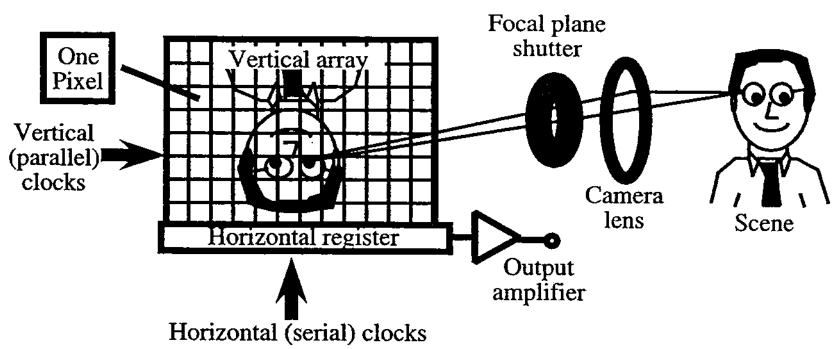

FIGURE 21.4 Full-frame CCD image sensor.

In very bright areas of an image (e.g., specular reflections) the number of electrons generated in particular photosites may exceed the charge capacity of the photosite. These excess electrons must be eliminated or they will contaminate nearby photosites, causing the specular reflection to grow into a blob or a streak. Image sensors used in digital cameras normally include a lateral or vertical overflow drain to direct the excess charge into the sensor substrate and prevent it from spilling into neighboring pixels.

The number of electrons collected at each photosite continues to increase as long as the camera shutter remains open. At the end of the exposure time, the mechanical shutter closes to block the light, and the electron charge packets at each photosite are transported to the output amplifier. This is accomplished by applying the proper vertical (parallel) clocks to shift each row of the vertical registers down by one row, so that the bottom row of the array (corresponding to the top of the image) is transferred into the horizontal (serial) register. Next, a series of many horizontal clocks are applied in order to shift the charge packets to the right, toward the output amplifier. This process repeats until all rows are transferred from the parallel register to the serial register, and then to the output amplifier, in order to read out the entire image. The output amplifier provides an output voltage that varies with the number of electrons in each charge packet. This analog voltage is later converted to a digital code value. The digital code value for each pixel—corresponding to each photosite on the CCD—is therefore proportional to the number of electrons collected by the photosite.

In the "true two-phase" CCD shown in Fig. 21.5, each photosite is composed of two slightly overlapping layers of polysilicon. Underneath a portion of each polysilicon layer is a 1.6-micron-wide implanted barrier region that creates a stepped electric potential field. The two layers are electrically isolated from one another by a thin layer of silicon dioxide. Each photosite is separated from its horizontal neighbors by 1.2-micron-wide, vertically oriented, thick layers of silicon dioxide called *channel stops*. The photosite spacing is 9 microns, both vertically and horizontally, providing a "square" sampling grid.

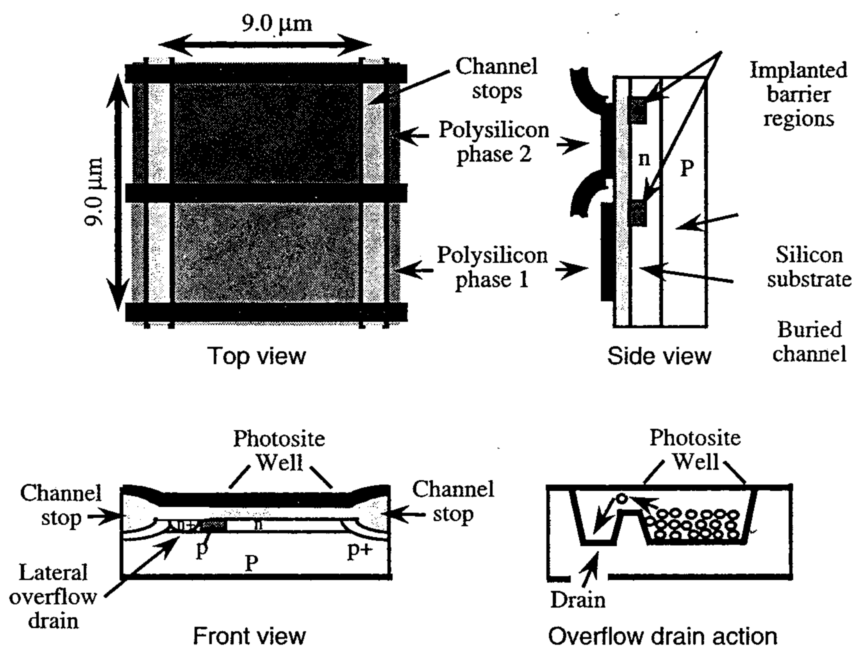

FIGURE 21.5 Full-frame photosite.

21.3.2 Interline Image Sensors

To eliminate the need for a mechanical shutter and to allow motion images to be captured, an electronic camera can use an interline CCD architecture. Most interline sensors use interlaced readout to conform to video-scanning standards. They have one vertical register stage for every two pixels. For still camera applications a progressive scan architecture is preferred. This requires one vertical register stage for each line of pixels. Figure 21.6 shows the pixel used in a megapixel interline transfer CCD with a progressive scan architecture.[16]

The pixels are 9 microns square, the same as in the full-frame sensor shown in Fig. 21.5. The photodiode is formed using a *pnpn* structure. This allows the *n*-layer to be fully depleted, eliminating lag and allowing fast electronic shuttering. Electronic shuttering is accomplished by clocking the *n*-type substrate to a sufficient voltage to sweep the accumulated charge from the photodiodes into the substrate. The photodiode comprises only a 3.4-by-7 micron area of the

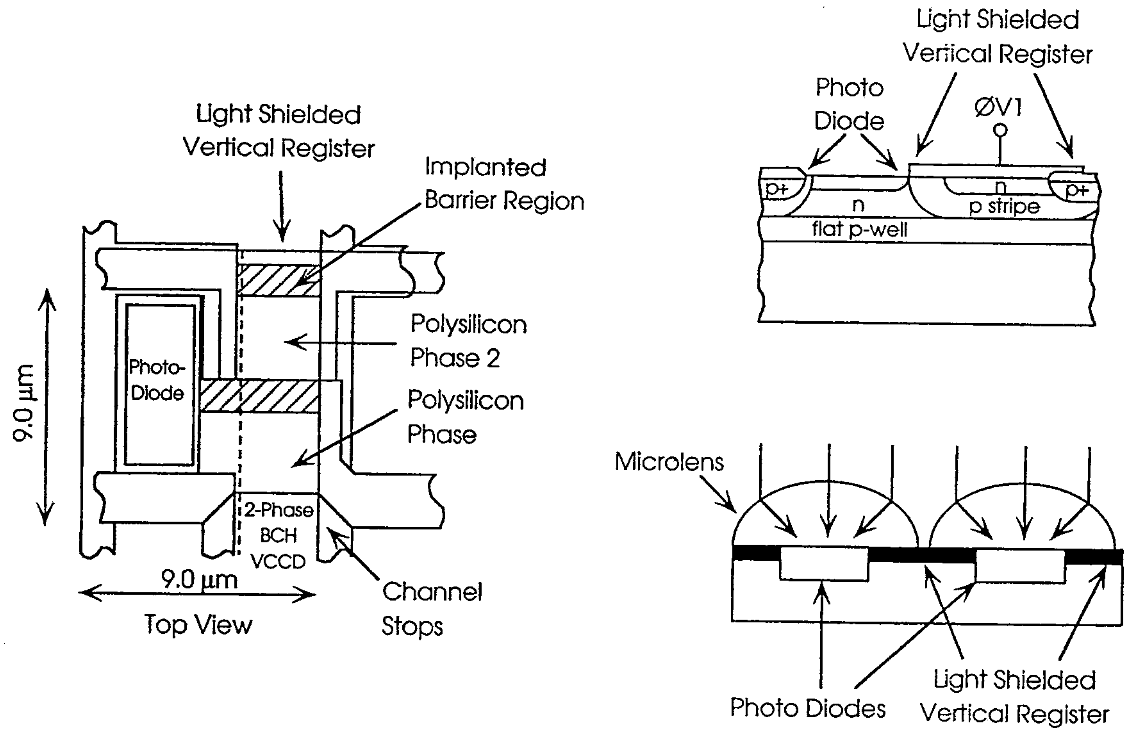

FIGURE 21.6 True two-phase charge transfer process.

9-by-9 micron cell. Thus, the sensitivity is reduced by the 30-percent fill factor. To improve the sensitivity, a microlenticular array is fabricated on top of the CCD.[17] These microlenses focus the light away from the opaque light-shield regions and into the center of the photodiodes. This increases the sensitivity by a factor of almost 2.5.

21.3.3 Charge Transfer

Charge transfer in CCD imagers can use four-phase, three-phase, pseudo two-phase, true two-phase, or virtual phase clocking, which use a corresponding number of clock lines per pixel. The imagers shown in Figs. 21.5 and 21.6 use two-phase CCD clocking, since there are two polysilicon gates per pixel in both the vertical and horizontal registers. To transfer the electron charge packets, complementary clock voltages are applied to the phase 1 and phase 2 electrodes, as shown in Fig. 21.7. At time t_1, the phase 1 voltage is positive (for example, +6 V) relative to the phase 2 voltage (for example, −4 V). This creates a "potential well" in the buried channel underneath the phase 1 polysilicon layer, because the negatively charged electrons are attracted by the positive electric field under the phase 1 gate. The lower phase 2 voltage creates a potential barrier under the phase 2 polysilicon gate, because the electrons are repelled by the negative electric field. As a result, the electric charge packets are confined under the phase 1 gate. To transfer the charge packets to the right at time t_2, the phase 1 voltage is switched negative and the phase 2 voltage is switched positive. At this point, the phase 2 gate becomes a well, whereas the phase 1 gate becomes a barrier, so each charge packet moves to the right. Note that the implanted barrier regions under each polysilicon gate create a "step" barrier, which forces the charge to move to the right instead of the left. Finally, at time t_3, the phase 1 and phase 2 voltages are returned to the same levels as at time t_1. This causes the charge to again move to the right, into the potential well under the phase 1 gate. Thus, cycling the phase 1 clock negative and then

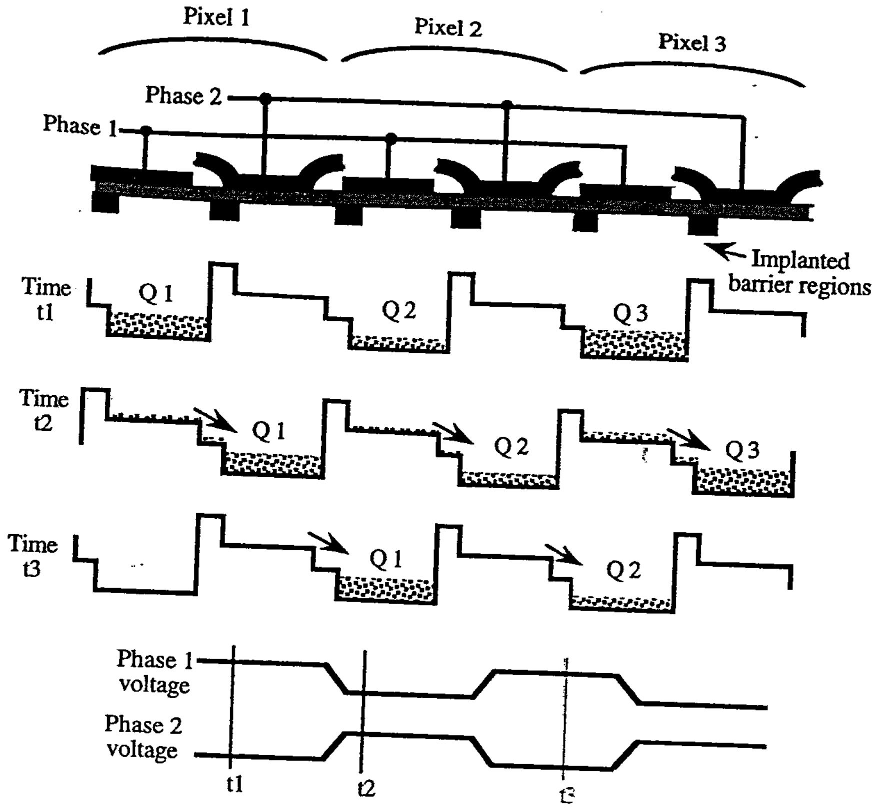

FIGURE 21.7 Full-frame photosite.

back positive while phase 2 cycles with the opposite polarity causes the charge packets to all shift one pixel to the right. Imagers using this charge transfer technique are called *charge-coupled devices* because the charge is coupled from beneath one polysilicon gate to the next—like water being poured from one bucket to the next—as the gate voltages are cycled positive and negative.

21.3.4 Charge Readout

At the end of the horizontal shift register is an output converter. This structure normally includes a floating diffusion sense node and an output amplifier, as shown in Fig. 21.8. When the phase 1 gate is switched to a negative potential, the charge spills over the output gate (OG) and onto the floating diffusion. The voltage of the floating gate is modified by the transferred charge according to the following equation:

$$\Delta V_{fd} = \Delta Q / C_{fd} \tag{21.1}$$

where ΔQ is the amount of charge transferred and C_{fd} is the capacitance of the floating diffusion. The floating diffusion is connected to the input of a current amplifier, normally a 2-stage or 3-stage source follower, which provides a CCD output signal capable of driving external electronic circuits. After the charge is transferred to the floating diffusion, the charge is removed by turning on a reset FET (field-effect transistor), which resets the voltage on the floating diffusion to its initial value. To eliminate the thermal noise associated with resetting the floating diffusion, as well as the "1/f" output amplifier noise, *correlated double sampling* (CDS) is often used.[18]

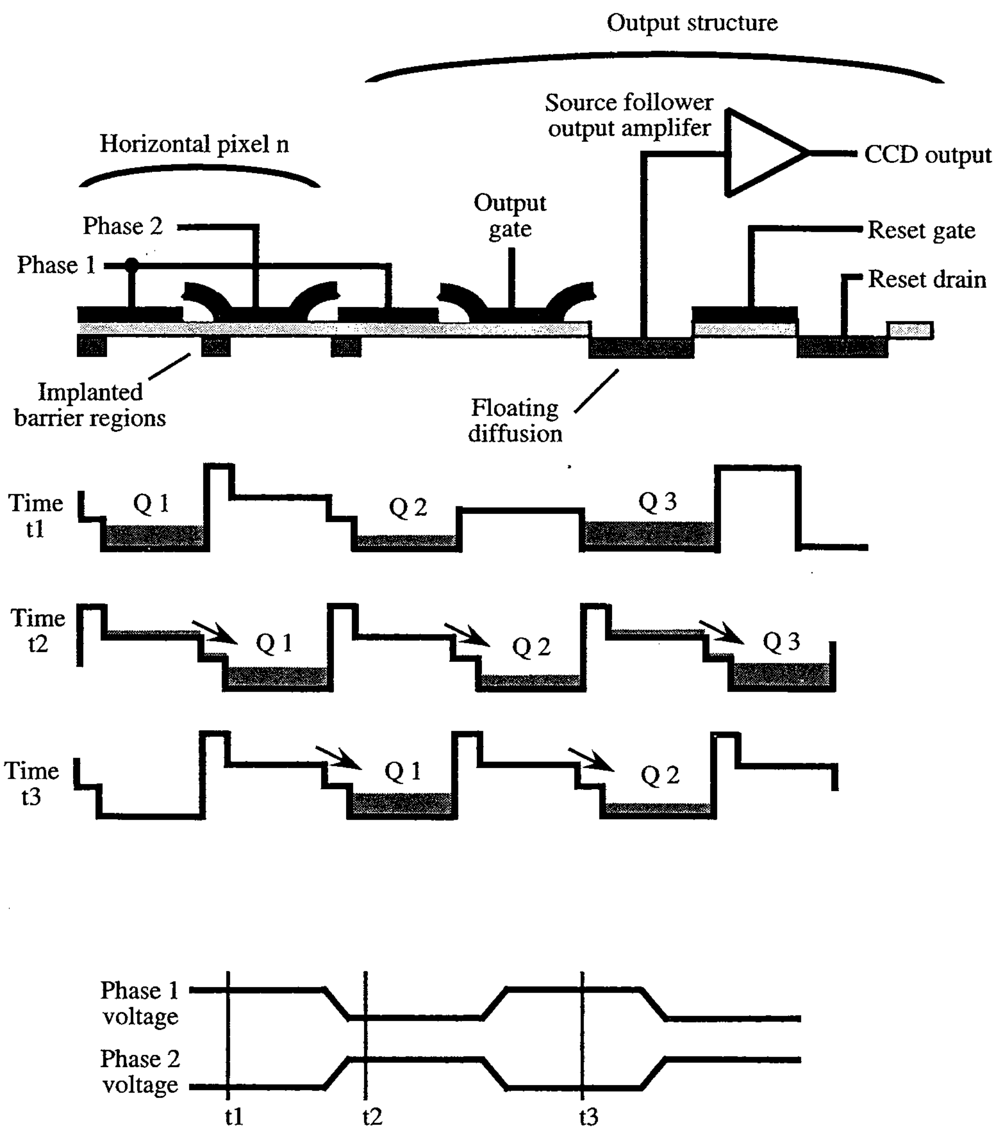

FIGURE 21.8 Output structure.

21.3.5 Color Separation Methods

Color negative films are coated with separate layers sensitive to red, green, and blue (RGB) light. Unfortunately, silicon-based image sensors have no natural ability to determine the varying amounts of RGB information in the image. There are three methods of capturing color images using a solid-state sensor:

- *Color sequential.* A color image can be created by taking three successive exposures while switching in optical filters having the desired RGB characteristics. The resulting color image is then formed by combining the three color separation images. The filters may be dichroic or absorptive RGB filters mounted in a color wheel or a tunable LCD filter. The disadvantage of this technique is that the subject must remain stationary during the three exposures, because any subject or camera motion will result in colored edges.
- *Multisensor color.* A multisensor digital camera typically uses a dichroic prism beam-splitter to separate the light into red, green, and blue components that are focused onto three separate

monochrome image sensors.[19] Cameras with a combined red/blue imager,[20] and one or two green imagers, have also been developed. The disadvantages of the multisensor approach are the high cost of the sensors and beam-splitter and the difficulties of maintaining image registration.

- *Color filter arrays (CFAs).* A single CCD sensor can provide a color image by integrating a mosaic pattern of colors, known as a *color filter array* (CFA), on top of the individual photosites. Many different arrangements of colors are possible.[21] Each photosite is sensitive to only one color spectral band.

21.3.6 Single-Chip Color Sensors

Two popular CFA patterns for single chip color sensors are shown in Figs. 21.9 and 21.10. The Bayer pattern[22] has 50 percent green photosites arranged in a checkerboard and alternating lines of red and blue photosites. The complementary mosaic pattern[23] has equal proportions of magenta-(Mg), green-(G), yellow-(Ye), and cyan-(Cy) sensitive photosites arranged in magenta-green and yellow-cyan rows. The position of the yellow-cyan columns is staggered by one pixel on alternate yellow-cyan rows. The Bayer pattern is normally fabricated on a sensor employing progressive scan readout, so that each color pixel is converted to a separate digital value. The complementary mosaic pattern is normally fabricated on an interlaced readout sensor using field integration mode. After the image is integrated, two rows of photosites are summed together in the vertical readout register. For example, in the bottom two rows, the Mg and Ye photosites are summed and the G and Cy photosites are summed. This reduces the vertical image sharpness but increases the signal level.

G	R	G	R
B	G	B	G
G	R	G	R
B	G	B	G

FIGURE 21.9 Bayer CFA pattern.

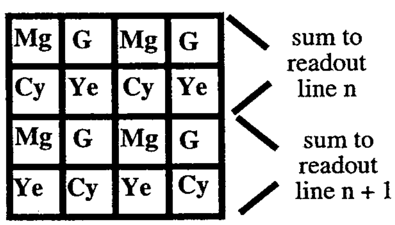

FIGURE 21.10 Complementary mosaic CFA pattern.

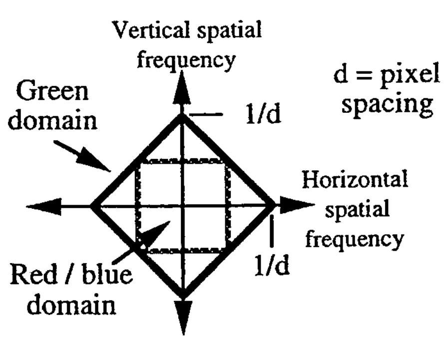

FIGURE 21.11 Nyquist domains for Bayer CFA.

The color photosites sample the image differently, depending on the color. Some properties of the two-dimensional sampling process can be shown using the "Nyquist-domain" plot in Fig. 21.11. This indicates the limiting resolution of a Bayer-pattern color sensor in all directions. It is possible to properly recover scene details that have spatial frequencies falling inside the Nyquist-domain boundary. Scene details falling outside this boundary are aliased to lower spatial frequencies by the color image sensor, causing artifacts in the digital image. When the image falling on the sensor is sampled by the colored photosites, the original image spectrum is replicated around frequencies that are inversely proportional to photosite spacing d, as shown in Fig. 21.12. The Nyquist-domain border is the lowest spatial frequency at which these replicated spectra just touch the original spectrum centered at the origin.

The checkerboard arrangement of the green photosites in the Bayer CFA results in a diamond-shaped Nyquist domain for green and smaller rectangular-shaped Nyquist domains

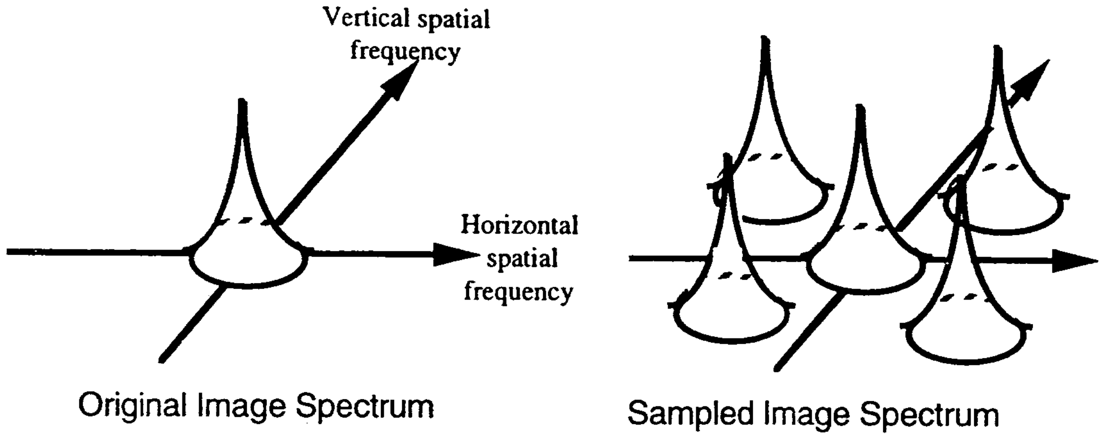

FIGURE 21.12 Image spectra.

for red and blue. The RGB Nyquist domains are vertically and horizontally symmetric if the photosite pitch is "square," so the limiting resolution due to the sensor sampling is the same in the vertical and horizontal directions. People are more sensitive to high spatial frequencies in luminance than in chrominance, and luminance is composed primarily of green light. Therefore, the Bayer CFA improves the perceived sharpness of the digital image by allocating more photosites to the green image record.

21.4 OPTICS FOR DIGITAL CAMERAS

Many of the optical issues for digital cameras are the same as for conventional film cameras, but there are two key differences. First, imagers normally have a much smaller active area than film, so the lens focal length must be correspondingly shorter to provide the same field of view. Second, the image sensor can create visible aliasing artifacts, particularly with color imagers. Aliasing is normally minimized by optically low-pass filtering the image. To obtain a high-quality image, the lens focus and sensor exposure must be properly adjusted.

21.4.1 Lens Formats and Magnification

The magnification of a lens is proportional to the focal length and inversely proportional to the size of the detector. Except for close-up photography, the height of the largest object, O, within the field of view captured by a digital camera is given by

$$O = D \times I/F \tag{21.2}$$

where D is the distance from the object to the lens, I is the height of the image sensor, and F is the lens focal length. The sensor height I equals the vertical pixel pitch times the number of active lines on the imager. Smaller sensors require correspondingly smaller-focal-length lenses in order to maintain a normal field of view. For example, a "normal" 50-mm-focal-length lens on a 35-mm SLR film camera, which has an image height of 24 mm, has the same field of view as a 7.5-mm lens on a 1/3-inch format image sensor, which has an image height of 3.6 mm.

The lens normally includes an adjustable aperture or iris that controls the cone angle of light illuminating the image sensor. The lens f-number, A, equals F/d, where d is the aperture diameter. The sensor illuminance is proportional to $(1/A)^2$, so the sensor illumination with an f-number setting of 2.0 is twice that of an f-number setting of 2.8. Decreasing the aperture diameter provides less light to the sensor but also provides a larger depth of field.

21.4.2 Lens Depth of Field and Autofocus Methods

Objects in the scene that are not located at the lens focus distance will be blurred to some extent. Although a slight amount of blurring is acceptable, larger amounts cause a noticeable loss of sharpness in objects located at distances significantly nearer or farther than the lens focus distance. The minimum and maximum distances where the camera is acceptably focused is called the *depth of field.* The depth of field increases for larger lens f-numbers and smaller focal lengths. A point light source at the near or far depth of field limit creates a "circle of confusion," Cc, on the image sensor. The diameter of this circle is the value that causes a "just noticeable" amount of blurring in the final digital image. The proper value of Cc depends on the size and viewing conditions of the output image, which depends on the camera application. In practice, Cc is usually set to a value between 1 and 2 times the pixel pitch.

The hyperfocal distance[24] H of a camera lens can be calculated using the following formula:

$$H = \frac{F^2}{A \times Cc} \tag{21.3}$$

where F is the lens focal length, A is the lens f-number, and Cc is the circle of confusion. If the camera is focused at H, all objects at distances between $H/2$ and infinity will be in acceptable focus. Fixed-focus cameras are normally focused at the hyperfocal distance. They are usually designed to work with relatively wide-angle (low-focal-length) lenses in bright-light situations, where the lens f-number can be relatively large. For example, if $F = 8$ mm, $A = 2.8$, and Cc $= 12$ microns, then $H = 1.9$ meters and the depth of field is approximately 3 feet to infinity.

If this camera instead has a zoom lens with a maximum focal length of 20 mm, the hyperfocal distance for the telephoto position is approximately 12 meters. Therefore, an adjustable focus lens is needed in order to focus on objects closer than 20 feet. Zoom lenses normally use an autofocus system to set the focus distance. The near depth of field is equal to $(H \times D)/(H + D - F)$, and the far depth of field is equal to $(H \times D)/(H - D + F)$, where D is the focus distance. There are two main methods of automatically determining D, *contrast autofocus* and *correlation autofocus.*

Through-the-lens correlation autofocus methods are used in most 35-mm SLR cameras. These systems use a special optical assembly within the lens to form two images that are asymmetric with respect to the optical axis of the camera lens. The two images are focused side by side onto an autofocus sensor, normally a one-dimensional or "linear" image sensor. The two images are digitally correlated, and the separation between the images provides a measure of the subject defocus. The lens focus motor is then driven to the location providing the separation distance corresponding to the best focus.

Contrast autofocus systems are used in most consumer camcorders. A contrast autofocus method normally uses the image sensor signal to determine if the lens is properly focused. The signal from the central portion of the image is bandpass-filtered, rectified, and either averaged or peak-detected, in order to form a *focus value.* Next, the lens focus position is adjusted slightly, and the focus value from the new position is compared to the value at the previous position. If the value increases, the lens focus is stepped again in the same direction. If not, the lens position is stepped in the opposite direction. This process is continued until the peak focus value is determined. At this point a second bandpass filter with a characteristic more sensitive to fine image details may be used to determine the final focus position. The image may also be divided into multiple zones, with a separate focus value computed for each zone. A "fuzzy logic" approach, as described in Chapter 6, may be used to determine how to set the lens focus position based on the focus values from the various zones.[25] Because contrast autofocus methods are iterative, they require a longer focusing time than correlation methods.

21.4.3 Optical Prefilters for Aliasing Suppression

Most single-chip color digital cameras use an optical prefilter to suppress aliasing artifacts. Aliasing occurs when there is significant information in the scene at spatial frequencies above the

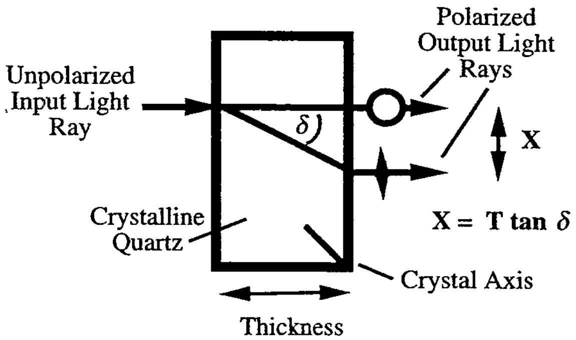

FIGURE 21.13 Birefringent quartz antialiasing filter.

Nyquist limit set by the number and arrangement of photosites on the imager. In this situation, high spatial frequencies take on the appearance, or *alias,* of lower spatial frequencies. Aliasing is a particular problem with single-chip color cameras because the different colors are sampled at different spatial locations.

Aliasing can be reduced by using an optical prefilter or "blur" filter, positioned in front of the sensor.[26] The blur filter is typically made of birefringent quartz, with the crystal axis oriented at a 45-degree angle, as shown in Fig. 21.13. In this orientation the birefringent quartz exhibits the double refraction effect. An unpolarized input ray emerges as two polarized output rays. The output ray separation is proportional to the filter's thickness. A 1.5-mm-thick plate will give a separation of about 9 microns—equal to the pixel pitch of the sensors described earlier. Figure 21.13 shows a simple "two-spot" filter, but typical filters use three or more pieces of quartz cemented in a stack.

21.4.4 Exposure Determination and Control

Digital cameras include an exposure determination system in order to provide a properly exposed digital image. The exposure of the image sensor depends on the lens f-number, sensor exposure time, scene illumination level, and scene reflectance, as well as many other secondary factors. The fundamental relation between the scene luminance and the sensor exposure is expressed by the following equation:

$$H = \frac{\pi v T \cos^4(\theta) L t F^2}{4A^2 i^2} + H_f = \frac{qLt}{A^2}\left(\frac{F}{i}\right)^2 + H_f \qquad (21.4)$$

where $q = (\pi/4)Tv[\cos^4(\theta)]$
A = lens f-number
F = lens focal length (meters)
H = sensor focal plane exposure (lux-seconds)
H_f = sensor exposure due to flare light (lux-seconds)
i = image distance (meters)
L = scene luminance (candelas per square meter)
T = transmission factor of the lens
t = exposure time (seconds)
v = vignetting factor
θ = angle of image point off axis

When the camera is focused on infinity, $H_f \ll H$, $T = 0.90$, $v = 0.98$, and $\theta = 10°$ so that $\cos^4 q = 0.94$; then q is equal to 0.65, so that the equation reduces to the following:

$$H = 0.65L \cdot t/A^2$$

To obtain an acceptable image, the sensor exposure H for all important areas must be less than the saturation level of the image sensor, yet large enough so that the resulting signal level provides an adequate signal-to-noise ratio. Scenes contain a wide range of luminance values. The simplest camera exposure controls use a single photosensor to measure the average luminance in the lower-center portion of the image. This reduces underexposure problems with many outdoor images having bright sky in the top portion of the image. More sophisticated methods use a multisegment light meter or use the image sensor to provide exposure control data. Standard methods have been developed to measure the ISO speed rating of digital cameras.[27]

21.5 IMAGE PROCESSING IN DIGITAL CAMERAS

Digital photography systems usually utilize extensive digital image processing. Prior to digital processing, the output of the image sensor is typically processed by an analog CDS circuit[28] to reduce noise from the sensor's output amplifier, amplified by a programmable gain amplifier, and A/D converted. In a professional camera a linearly quantized A/D converter having 12 to 16 bits is normally used. In lower-cost consumer cameras, a nonlinear 8-bit A/D is typical. The quantization characteristic uses more bits for low signal levels, because the human visual system has a nonlinear response to the luminances of objects in a scene.[29]

The digital image processing normally includes processing to provide good color and tone reproduction and enhance the sharpness of the image. In single-chip color cameras the processing also includes a reconstruction algorithm to create the necessary color pixel values at each photosite. The processing may also include image compression, typically using the JPEG algorithm described in Chapter 9. The various processing steps may be performed in the camera, or in a host computer as the images are downloaded. The camera processing can be done using a firmware-based processor,[30] or using custom integrated circuits.[31]

21.5.1 Color Pixel Reconstruction in Single-Sensor Cameras

To produce a high-quality color image, the color samples from a single-sensor color camera must be processed to provide red, green, and blue values (or luminance and chrominance values) for each pixel, because each CCD photosite can capture only one of the three colors. The process of filling in the "missing" color values is known as *color pixel reconstruction.* The simplest reconstruction algorithms use nonadaptive linear interpolation, where the missing values are always estimated by calculating the average of the vertically or horizontally adjacent sample values of the appropriate color. For example, the missing green values of the Bayer pattern would be estimated using the average of the four values from the adjacent green photosites. This approach is simple to implement but reduces the sharpness of the image while increasing the visibility of false color artifacts due to aliasing of high-spatial-frequency luminance patterns in the scene.

More sophisticated color pixel reconstruction algorithms can provide sharper images with reduced false color artifacts. These algorithms may use template matching[32] or a gradient-based approach[33] to adaptively interpolate the missing color pixel values. In the latter method, vertically and horizontally oriented gradients are calculated in order to deduce whether the missing green pixel lies along a vertical or horizontal image edge. If it does, the missing green value is formed by averaging values along the edge. For example, the horizontally adjacent green pixel values are averaged if the missing green pixel is located along a vertically oriented edge. Once the missing green values have been estimated, the ratios of the red or blue photosite values and the estimated green values can be calculated. These ratios can be linearly interpolated at all of the missing blue and red sample positions. This approach calculates the missing red and blue values by effectively adding high-frequency luminance details from the green record to the sparsely sampled red and blue records.

The color pixel reconstruction method used with the complementary mosaic pattern in Fig. 21.10 normally recovers luminance (Y) and color difference signals R-Y and B-Y. Luminance is obtained by low-pass filtering the CCD output pixel values, which contain the sum of a magenta/green line and a yellow/cyan line. The color difference signals are decoded by bandpass filtering the CCD output. This method reduces the sharpness of the luminance because of the low-pass filtering and can cause false color artifacts. More elaborate algorithms exploit the correlation between the luminance and color difference signals to provide a sharper image with reduced false color artifacts.[23]

21.5.2 Tone Reproduction and Noise

In conventional CCD image sensors the number of electrons collected by a photosite is linearly related to the illumination level until the maximum capacity, or "saturation," signal level is reached. Beyond this point the output is "clipped" to the saturation value, as shown in Fig. 21.14. The figure also shows the film density–versus–log exposure curve of a typical color negative film. Note that the film curve has a "toe" at low exposure levels, a straight-line region for normal exposure levels, and a gradual "shoulder" for high illumination levels. The straight-line portion of the film curve has a slope or "gamma" of approximately 0.6, whereas the CCD curve has a gamma of 1.0. The higher gamma limits the exposure latitude of the solid-state image sensor. Setting the proper camera exposure level is critical because overexposure will clip the image highlights. Underexposures can be corrected by digitally adjusting the code values of the final image, but this will also increase the noise.

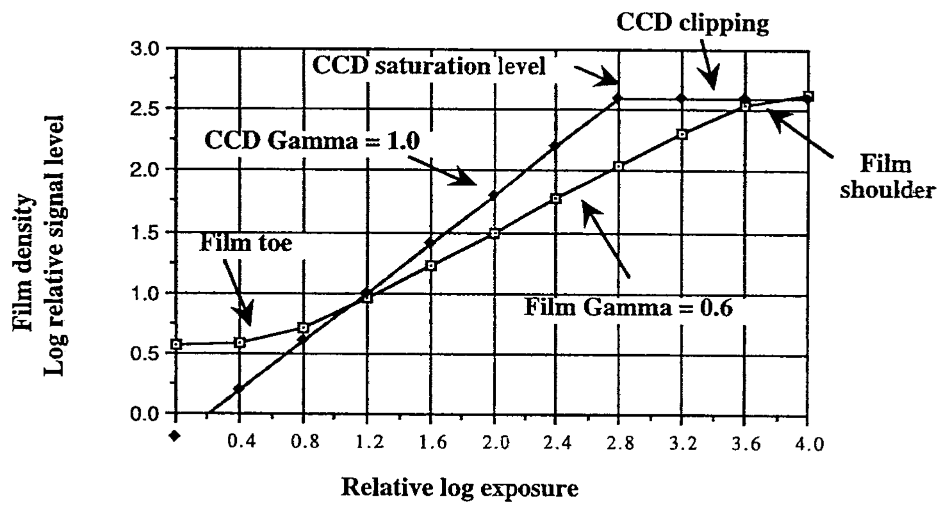

FIGURE 21.14 CCD and film D–$\log E$ curves.

Although there are many sources of noise in a digital camera, the most significant is often the dark-current variability of the image sensor. This noise is caused by minute imperfections or impurities in the sensor structure that generate a spatially and temporally varying number of "noise" electrons in each sensor photosite, independent of the sensor illumination level. The signal from each photosite includes electrons resulting from incident photons of light and electrons due to dark current. The number of dark current electrons is proportional to the photosite integration time and an exponential function of the sensor temperature. Therefore, some professional cameras use thermoelectric coolers to reduce the sensor temperature in order to reduce the dark-current noise level.

The average dark-current level can be compensated for by masking off some sensor pixels at the edges of the image sensor, forming an average of these black pixel values, and subtracting this average value from each image pixel value. This ensures that the signal levels of dark objects do not change with varying sensor temperatures or drifting dc circuit levels. The black level–corrected pixel values are normally requantized to provide an output signal that is a nonlinear function of the scene luminance. This allows the image to be represented by 8 or 10 bits while minimizing the visibility of quantization distortion in the final image. The requantization is often called *gamma correction,* since it has a functional form that compensates for the exponential light output–versus–voltage input characteristic of CRT displays. A typical requantizer uses the ITU-R BT.709 optoelectronic conversion function:[34]

$$V = 1.099L^{0.45} - 0.099; \qquad \text{for } 1 \geq L \geq 0.018 \qquad (21.5)$$
$$V = 4.5L; \qquad \text{for } 0.018 > L \geq 0$$

where L is the relative scene luminance and V is the relative output code value. This function is typically implemented on the individual RGB signals using a digital lookup table after the signals have been color corrected. The optoelectronic conversion function can be measured using standard techniques.[35]

21.5.3 White Balance and Color Correction

To provide acceptable color reproduction, digital cameras normally utilize white balance and color correction algorithms. White balance requires adjusting the RGB values from the camera to correct for the color temperature of the light source used to illuminate the subject. The amounts of red and blue light in daylight sources are approximately equal, as shown in Fig. 21.15. However, many artificial light sources, such as tungsten light bulbs, provide a much higher proportion of red light than blue light. Images taken using these illuminants must have the blue signal amplified to prevent white objects from appearing unnaturally yellow in the reproduced image.

White balance is performed by amplifying the red and blue signal levels so that they equal the green signal level for neutral (white or gray) objects in the scene. The most foolproof way to

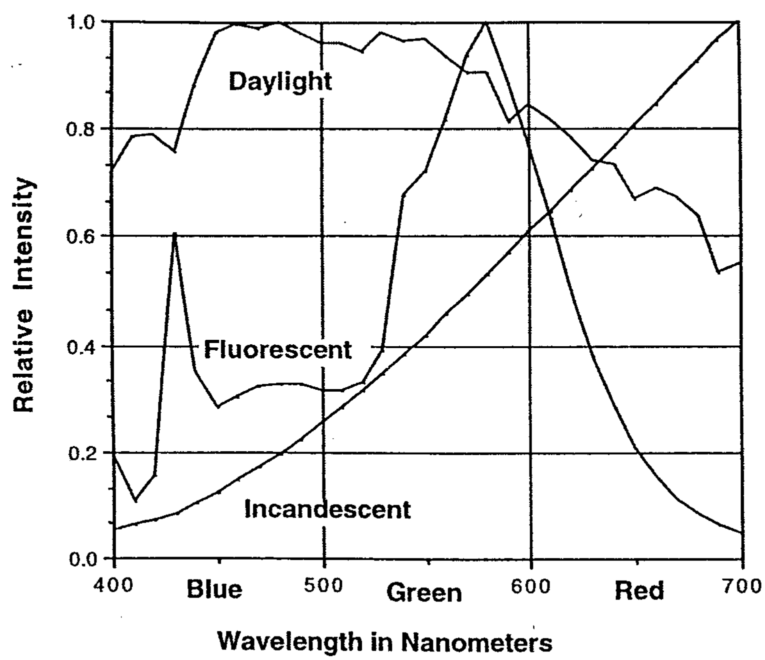

FIGURE 21.15 Spectral intensity of various illuminants.

achieve proper white balance is to have the camera user either capture a test image of either a white or gray card held in the scene or select a neutral object in the scene as the image is downloaded. This is appropriate for professional cameras, but for consumer applications an automatic method for determining the illuminant color temperature is necessary. One such method uses a set of photodiodes covered by RGB filters on the front or top of the camera, aimed upward toward the light source. However, this approach can give incorrect results because of reflections from walls or other colored objects. Better results are normally obtained by estimating the proper white balance setting from the image sensor data. The captured image average RGB values are computed for different regions. These average values, along with the absolute scene light level, are used by a scene classifier or fuzzy-logic control that decides on the most likely illuminant color temperature.

After white balancing, the image data can be processed to improve the color reproduction.[36] The red, green, and blue sensitivities of a color CCD have responses that are always positive and typically include some amount of color cross-talk. For example, the blue photosites may have some slight response to red light. On the other hand, the optimum camera sensitivities for the reference primaries, such as those specified by ITU-R BT.709, are negative at some wavelengths. Therefore, a 3×3 color correction matrix is often used to improve the color reproduction by correcting the camera responsivities properly for the reference display chromaticities. The matrix has the following form:

$$R_o = a_{11}R_i + a_{12}G_i + a_{13}B_i$$

$$G_o = a_{21}R_i + a_{22}G_i + a_{23}B_i$$

$$B_o = a_{31}R_i + a_{32}G_i + a_{33}B_i$$

where R_i, G_i, and B_i are the linearly quantized white balanced matrix input signals, and R_o, G_o, and B_o are the color-corrected matrix output signals. The coefficients a_{ij} depend on the responsivities of the RGB signals prior to matrixing, including the optics and color sensor. The off-diagonal matrix terms, such as a_{12}, are normally negative values and serve to increase the color saturation of the image.

21.5.4 Edge Sharpening

The processing used in digital cameras often includes edge sharpening. This is done to compensate for the image blurring due to the lens, optical antialiasing filter, and CCD aperture, and to provide a subjectively sharper image. The appropriate amount of sharpening depends on the size and distance at which the final image is viewed. An image that appears "crisp" when printed at a small size may appear artificially overenhanced when enlarged.

Edge enhancement can be implemented using a two-dimensional filter kernel, for example:

$$\begin{array}{ccc} & -1/4 & \\ -1/4 & 1 & -1/4 \\ & -1/4 & \end{array}$$

In this case the filter kernel output equals the present luminance pixel value minus the average of the four vertically and horizontally adjacent values. The filter output is zero in uniform areas of the image, but nonzero for edges. More elaborate filter kernels can be used to tailor the frequency response. The filter output may be "cored" by setting small output values to zero, because these small values are often the result of noise. The signal is then amplified and added back to the original luminance signal or to the red, green, and blue signals to increase the image sharpness.

21.5.5 Image Compression for Digital Cameras

Digital cameras often employ image compression to allow more images to be stored in the camera's digital memory. Standard JPEG compression is often used. Typically, the fully processed 24-bit-per-pixel RGB data is converted to luminance and subsampled color difference values and then compressed. The average amount of data after compression is often selectable and is normally in the range of 1 to 4 bits per pixel. The advantage of using JPEG compression is that the image data can be decompressed by standard computer software applications if the JPEG image data is stored using a standard image file format.

An alternate approach is to use a compression algorithm optimized for data from one-chip color sensors.[37] This can provide more efficient compression because it operates on the 8-bit-per-pixel CFA data prior to color pixel reconstruction. On playback the images are decompressed and then processed by the color pixel reconstruction, color correction, and other algorithms implemented on a host computer. This approach requires less digital processing in the camera but creates a nonstandard compressed-image record that must be processed after decompression using algorithms appropriate for the particular sensor CFA pattern.

21.6 DIGITAL IMAGE STORAGE

Many digital storage technologies may be used in digital cameras. These include ICs, magnetic disks and tape, and optical disks. All of the digital storage technologies and standards used in digital cameras were first developed for high-volume computer or consumer audio applications. Digital photography systems use three different types of storage: (1) an image buffer for temporarily storing data for one or more images during in-camera processing; (2) transfer storage, normally in the form of a removable card or disk, for holding a larger group of images that will be transferred to a computer or other playback device; and (3) long-term storage for hundreds or thousands of digital images. The buffer storage is normally one or more dynamic random access memory (DRAM) ICs. The transfer storage is typically nonvolatile flash EPROM ICs or magnetic hard disks so that the images are retained without drawing power. The long-term storage may be a recordable optical disc or a magnetic hard drive or removable disk cartridge.

21.6.1 Solid-State Memory and Memory Cards

Most digital cameras use some amount of IC memory for image buffering. The buffer memory uses volatile storage, such as static or dynamic RAM, which requires continuous battery power to maintain the image data. The memory write speed must match the data rate from the image sensor. Digital cameras often use programmable microprocessors or DSPs that are controlled by firmware stored in ROM or EPROM. The EPROM approach allows the firmware to be upgraded in the field.

Flash EPROM memory is often used for transfer storage in low-resolution digital cameras. One advantage of an IC memory is that it has no moving parts. This allows the cameras to be small and rugged. However, IC memory is more expensive than magnetic memory if a large capacity is required. Therefore, digital cameras that use IC memory for transfer storage always include image compression to reduce the size of the image files. Many flash EPROM devices have a relatively slow write rate, which limits the camera frame rate.

Flash memory ICs may be mounted on a PC board inside the camera to reduce the cost, or on a removable memory card. The latter approach provides a higher camera image storage capacity, limited only by the type and number of cards the user wishes to purchase. It also allows the images to be transferred to any computer or reader with the appropriate card interface. A number of card formats, listed in Table 21.3, have been developed. They include the PCMCIA (Personal

TABLE 21.3. Memory Card Formats

	PCMCIA	CompactFlash	MiniatureCard	SSFD
Dimensions (mm)	54 × 86	36 × 43	33 × 38	37 × 45
Thickness (mm)	3.3, 5.0, 10.5	3.3	3.5	0.76
Connect type	Pin in socket	Pin in socket	Elastomeric	Contact
Connector pins	68	50	60	22
Flash technology	All	All	NOR	NAND
Other memories	RAM, hard drive	None	RAM, ROM	None
File system	DOS FAT	DOS FAT	DOS FAT	Proprietary
Host software	ATA or FTL	ATA	FTL	ATA controller
Supply voltage	5 V or 3.3 V	5 V or 3.3 V	5 V or 3.3 V	5 V or 3.3 V

Computer Memory Card Industry Association) PC Card, CompactFlash, MiniatureCard, and SSFD (solid-state floppy disk) formats.

21.6.2 Magnetic Recording Options

A magnetic recording is created by a varying magnetic field from an electromagnetic head in relative motion with a magnetic storage medium.[38] The medium may be a magnetic hard drive, floppy disk, or magnetic tape. Digital magnetic tape recording—used in the digital camcorders described in Chapter 20—is the least expensive digital storage medium. However, it requires a complex and therefore expensive recording mechanism. Magnetic tape does not offer random access and can be damaged by repeatedly playing the same videotape tracks. The capacity of videotape far exceeds that necessary for digital still photography. Therefore, digital tape recording is not used in still-only digital cameras, although digital video camcorders incorporating special still photography features have been developed.

Magnetic disks offer the advantage of random access and a simple recording mechanism. Standard 3.5″-diameter floppy disks are considered too large and too low in capacity (i.e., 1.44 Mbyte) to be used in digital cameras. Nevertheless, because most computers can read these disks, they are often used to distribute limited-resolution, compressed images.

Magnetic hard drives allow many gigabytes of information to be stored in a relatively small volume. The capacity of a hard drive depends on the head gap, the track spacing, the diameter of the disk, and the number of platters. Hard drives are available in the PCMCIA-ATA type III PC Card format, which are small enough for many digital camera applications. For memory sizes greater than about 10 Mbyte, magnetic PCMCIA hard drives are less expensive than PCMCIA memory cards. Disadvantages of hard drives include the time and power needed to spin up the disk before recording can begin. Hard drives are also less robust than IC memory cards when mishandled by users.

High-capacity 3.5″ Winchester disk drives have been introduced with capacities up to 1.3 gigabytes. The cost per Mbyte for these removable disks is much lower than for PCMCIA format hard drives, but the size is too large for in-camera applications. These drives are attractive for longer-term storage of digital images, however.

21.6.3 Optical Recording Options

Most optical discs, such as the CD and DVD discs described in Chapter 12, are created by pressing many duplicate discs from the same master recording. To store images from digital cameras, however, write-once or erasable techniques[39] must be used to create unique discs for each user. Write-once systems use a semiconductor laser to burn holes, form bubbles, or change the phase of a thin layer of material coated on the disc substrate. The recorded "pits" are then read back by a low-power laser to recover the digital image. It is advantageous to design the write-once discs so that they can be read by standard CD-ROM or DVD players. Write-once discs that can be played on conventional CD and CD-ROM drives are called *CD-R discs.* They use a 120-mm-diameter injection-molded polycarbonate substrate, and store up to 600 Mbyte of image data. The Photo CD system described in Section 21.7.1 uses CD-R discs.

Erasable optical discs use phase-change or magneto-optical methods. Phase-change erasable discs use different laser intensities to heat the disc to two different temperatures. Pits are formed at the higher temperature because the material remains in the amorphous state as it cools rapidly, providing low reflectivity. At the lower temperature the material crystallizes as it cools, providing higher reflectivity. One such system stores 256 Mbyte on a 3.5″-diameter disc.

Magneto-optical discs use materials exhibiting the Kerr effect. Data are recorded by heating the material with a laser while applying a modulated magnetic field. The playback signal is obtained by analyzing the polarization of light reflected from the disc as it is scanned with a low-power laser. The 64-mm-diameter Mini Disc (MD), developed for audio applications, uses magneto-optical recording to provide 140 Mbyte per disc.

Recordable CDs are too large for portable camera applications and require too much recording power. They are well-suited for archival storage of images, however. They cannot be inadvertently erased or easily damaged and are very stable. They have high capacity and are less expensive than any other type of digital memory except tape. Most multimedia computers include CD-ROM drives that can be used to read write-once CDs. However, the relatively high cost of CD writers has limited the use of recordable CDs to commercial and photofinishing applications. Erasable discs, such as MD discs, are smaller and more suitable for in-camera recording, since the discs can be erased and re-used. However, there are relatively few readers available.

21.6.4 Storage Requirements for Digital Cameras

Table 21.4 lists some of the important parameters for digital storage. The storage capacity is the number of megabytes per unit area or per unit volume. The size of each image file depends on the number of pixels and the compression level. A highly compressed image from a low-resolution digital camera may be as small as 50 kbyte, whereas an uncompressed image from a high-resolution, color sequential camera may exceed 20 Mbyte. In most applications the transfer memory stores from 20 to 100 images, so the required capacity for the transfer storage can range from 1 Mbyte to 2 Gbyte.

The transfer rate is the speed at which image data are stored or retrieved. The storage speed should be less than 5 seconds per image, so the required transfer speed can range between 10 kbyte/s and 4 Mbyte/s. To quickly select desired images from the dozens or hundreds of images

TABLE 21.4 Digital Image Storage Attributes

	Solid-state	Magnetic	Optical
Types	Flash EPROM RAM	Tape Floppy disk Hard disk	CD-R MD
Relative cost	No "drive" cost Low cost for $\leq$ 1 Mbyte Very high for $>$ 10 Mbyte	Medium-priced drives Tape is very low cost Disks are medium cost	High-priced drives Low-cost media
Size	Very small for $\leq$ 10 Mbyte		Relatively large discs
Advantages	No moving parts	Low media cost	Low media cost
Disadvantages	Cost	Ruggedness	Recorder cost and size

stored on the transfer memory, small thumbnail images are often recorded along with the full-resolution image data. The thumbnails can be quickly transferred and displayed as a composite image.

The digital storage must maintain the integrity of the digital information. Digital magnetic and optical-based recording systems always include error detection and correction to handle random and burst errors caused by electrical noise or physical defects or debris. All digital recordings have a finite life, limited not only by the media but also by the availability of playback devices. As a result, digitally archived images may need to be transferred to current storage media every decade or two, or the images may be unrecoverable. One advantage of photographic film is that the stored image is human-readable, so a playback device is always available.

21.6.5 Image Formats for Digital Cameras

To gain broad market acceptance, digital cameras must produce images that can be seamlessly transferred into other digital devices for editing, display, transmission, archival storage, and printing. This requires a standard image data format, not just standards for the physical and electrical compatibility of the transfer media. A flexible image format is desirable in order to accommodate a range of storage media, image types and sizes, and optional ancillary information. This nonimage data may include parameters such as the time and date, camera zoom position and focus distance, illumination level, camera calibration data, subject, and copyright owner.

A number of standard image formats have been developed for digital camera applications.[40] These include TIFF/EP (tag image file format for electronic photography),[41] based on the TIFF specification, and Exif (exchangeable image format),[42] based on the JPEG file interchange format. Both of these formats, as well as FlashPix, a recent hierarchical image format employing structured storage,[43] support both uncompressed and JPEG compressed image data. To provide good color rendition, the meaning of the digital color values produced by a camera must be standardized or communicated to the printer and the display. This can be done by using an ICC color profile[44] to unambiguously define the RGB reference primaries, white point, and optoelectronic conversion function of the camera.

21.7 HYBRID FILM/DIGITAL PHOTOGRAPHIC SYSTEMS

The strengths of silver halide and electronics can be combined to create hybrid digital photographic systems. This is accomplished by scanning either the film or prints produced by conventional photographic systems. Scanning the original film produces images with higher resolution and wider dynamic range than scanning prints. The scanned images may be stored on many different types of media, including recordable optical discs, magneto-optical discs, and floppy disks. The images may also be stored on an *image server* so that they can be downloaded and viewed on a home computer via networks.

21.7.1 Photo CD System

The Kodak Photo CD System, shown in Fig. 21.16, was introduced in 1992 as the first consumer hybrid film/digital photographic system.[45] Conventional cameras and 35-mm film are used to produce images that are developed and printed. The developed film is scanned on a high-resolution scanner, where it is converted to a digital image with 2048 rows and 3072 columns of "square" pixels and a 3:2 image aspect ratio.[46] The data are processed by a computer workstation and stored on a write-once optical disc. Each disc is a unique digital data set recorded with a laser in a CD writer. The images on the disc can be viewed on a home television using a Photo CD or

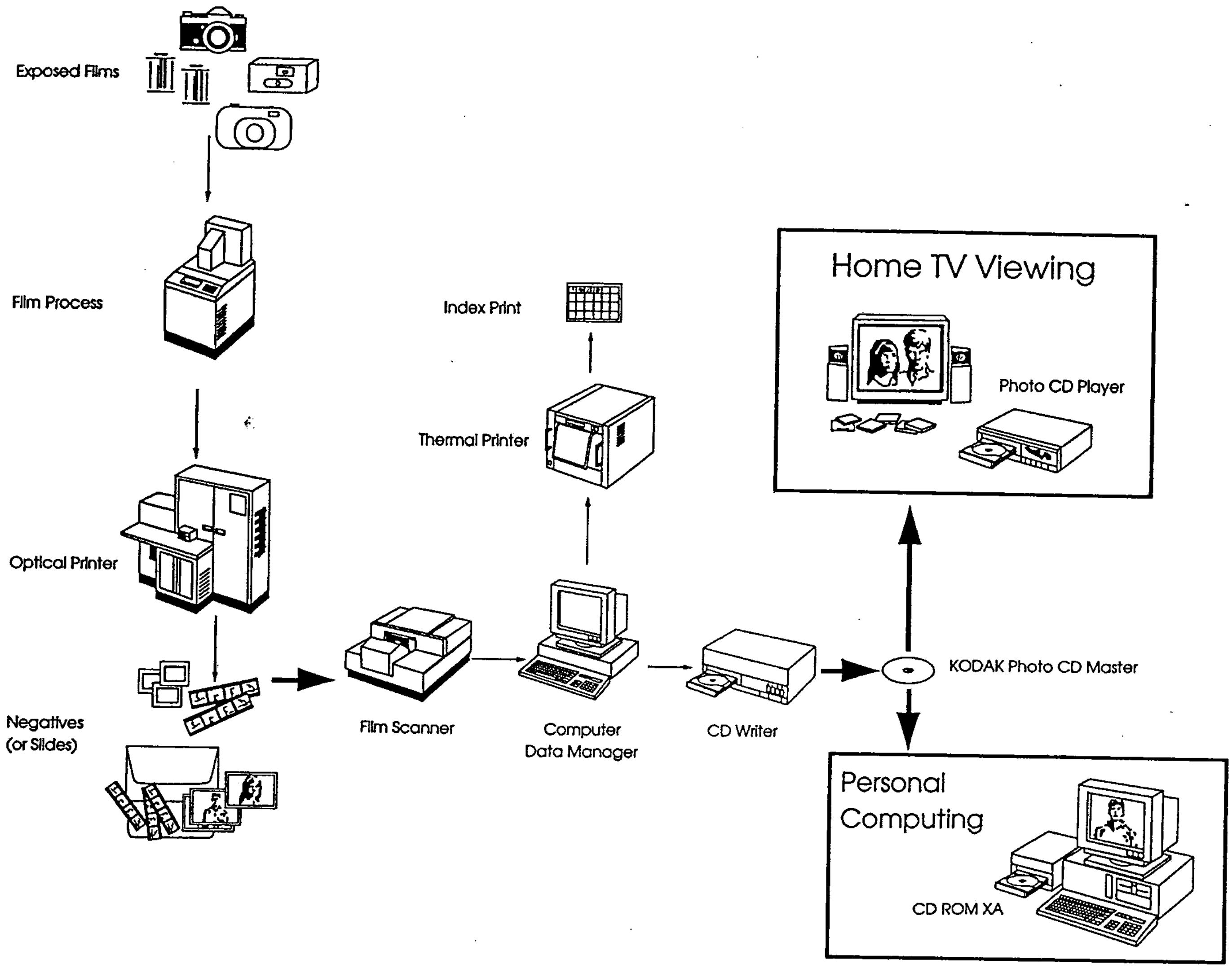

FIGURE 21.16 Kodak Photo CD System.

CD-I player, or accessed by a computer using a CD-ROM drive. Computer software packages allow users to manipulate, organize, and transmit the images.

The hierarchical format used with Photo CD master discs has five resolution levels—ranging from 128 to 2048 lines—to allow rapid access for various applications. The Base image has 512 lines, the 4Base image has 1024 lines, and the 16Base image has 2048 lines. The 4Base and 16Base images are compressed using adaptive DPCM compression of the *residual,* obtained by subtracting the up-sampled lower-resolution image, so that the stored file is less than 6 Mbyte per image. The same Photo CD can be played on any computer platform and on TV receivers worldwide using a player with the appropriate TV standard. The optical disc has a capacity of approximately 600 Mbytes. This enables one disc to hold up to 100 "digital negatives" that store essentially all of the image information recorded on each 35-mm film frame.

21.7.2 Magnetic Disk–Based Systems

A number of systems have been developed that allow consumers to receive their photographic images on standard 3.5″ computer floppy disks. Because of the limited capacity of these disks, both the number of images per disk and the image quality is limited. These systems normally use an image having 640 × 480 or fewer pixels per frame, with aggressive image compression, in order to fit from 12 to 36 images on a disk. Some systems also store an application program on the disk to allow users to view, manipulate, and print their images.

In one system, for example, up to 28 images can be stored on a 1.44-Mbyte floppy disk along with a 500-kbyte application program. Therefore, each image must be compressed to about 30 kbyte. Images are scanned at high resolution, low-pass filtered, and subsampled to obtain 600 × 400 pixel images. The images are compressed using JPEG 4:2:0 baseline compression with an average of 1 bit/pixel. Thumbnail images are also stored on the disk so that the disk contents can be quickly previewed.

Another type of hybrid system has been developed using the 64-mm-diameter MD disks originally introduced for music.[47] The disk capacity is 140 Mbytes, with a transfer rate of 150 kbyte/s. The system includes image formats having 480 × 640 pixels with a 4:3 image aspect ratio, 480 × 848 or 1080 × 1920 pixels with a 16:9 aspect ratio, and 1024 × 1536 or 2048 × 3072 pixels with a 3:2 aspect ratio. The customer selects their desired image format when placing the order. JPEG 4:2:0 baseline compression is used on the main image, and an 80 × 60 pixel thumbnail image is also stored along with each image.

21.7.3 Network-Based Systems

Many home computers are connected to on-line services and can download and display true color images. A number of hybrid imaging systems transfer digital images to home customers using these networks instead of optical or magnetic disks. In an example system, shown in Fig. 21.17, film images are developed, scanned, and stored as high-resolution files on an image server located at the photofinisher or service provider. Low-resolution versions of these images can be downloaded from the network and viewed by the customer. The customer may then decide which images to print or enlarge, or may e-mail the images to others or place them on their personal home page. With some services the customer can decide how to crop or otherwise modify the

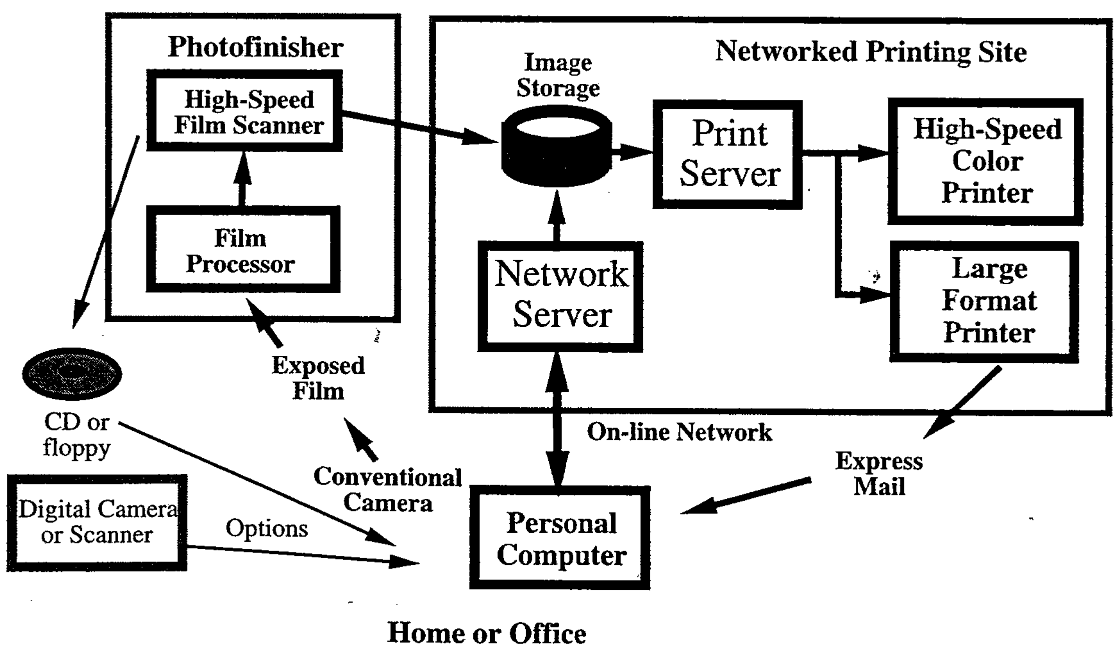

FIGURE 21.17 Network-based systems.

image prior to printing. Images can also be combined together or merged with "creative" backgrounds.

Some systems allow digital images to be transmitted via the network from home computers to the networked printing site. At this site, color hard-copy printers are used to provide different types and sizes of hard-copy output. These systems can also be used to print digital images from optical or magnetic disk-based hybrid systems, or from digital cameras.

21.8 DIGITAL COLOR HARD COPY

Digital photography systems can produce color prints using many technologies.[48] These include thermal wax and dye transfer, color inkjet, color electrophotography, and silver-halide photography methods. Some methods, such as inkjet and thermal wax transfer, can be used in low-cost home printers. Others, such as silver-halide printers, are more appropriate for high-throughput printers used by service providers.

The quality of the final print depends on both the printer hardware and the print media. The media include the inks, dyes, or toner particles used to form the image, as well as the characteristics of the paper or transparency substrate. To produce high-quality prints, the tone reproduction of the print must be carefully controlled and must provide a wide density range. The densities on a print can be produced by three methods:[49] (1) a continuous-tone pixel composed of a single continuous-tone dot, (2) a fixed number of dots having a fixed density level to form a binary halftone, or (3) a smaller number of dots having variable size and therefore variable density levels. The last two methods reduce the perceived resolution of the printed image, because the number of continuous-tone pixels per inch is a small fraction (typically 1/6 or smaller) of the number of dots per inch.

21.8.1 Thermal Dye Printers and Media

Most thermal printers use a resistive head to heat a thermal dye or wax donor, as shown in Fig. 21.18. The heads normally have from 100 to 400 resistive elements per inch and print one

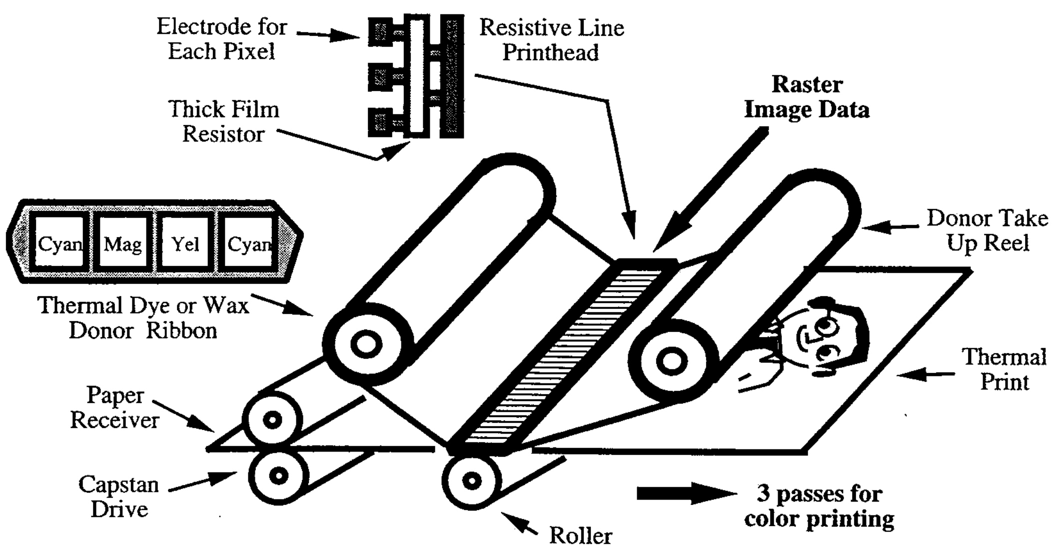

FIGURE 21.18 Thermal printer.

column at a time. The head has a continuous thick-film resistor that is locally heated to different temperatures due to the varying currents supplied by each electrode. A servo-controlled capstan drive motor moves the donor web and receiver (paper or transparency) through a three-pass printing process. The donor web is coated with cyan, magenta, and yellow sequential patches, equal in size to the print. A four-pass process, using an additional black donor, is used in some applications. When a thermal sublimation dye is heated, the amount of colorant transferred to the paper is proportional to the amount of heat applied. This allows each pixel (dot) of the print to provide continuous-tone values, which is an important aspect of providing photographic-quality prints.

With a thermal wax donor the wax melts and adheres to the receiver. Either all or none of the dye is transferred. A binary halftone method is needed to produce intermediate density levels, so that each continuous-tone pixel must be represented by a group of binary dots. This limits the range of tones that can be produced and also limits the print resolution while introducing patterns into the image.

After the colorant is transferred to the paper, the paper may be "finished" by heating and pressing the paper to drive the dyes into the receiver. This keeps the dyes from easily transferring from the paper when it is handled or contacted by other materials. Some very high-quality sublimation dye printers use a laser diode, rather than a resistive head, to heat the dye donor.[50]

21.8.2 Inkjet Printers

Inkjet printers propel droplets of ink from a reservoir, through the air, and onto the paper, as shown in Fig. 21.19. The ink may be supplied in liquid form or as a solid wax stick that is melted into the reservoir. The ink is piped from the reservoir to an ink chamber, which creates a stream of ink drops from a group of ultrafine nozzles. The stream of ink drops may be modulated by resistive heaters (which expand the liquid in the chambers) or by piezoelectric crystals (which flex to reduce the chamber volume). In color printers, multiple ink chambers are used to supply cyan, magenta, yellow, and, in some systems, black ink. The printhead may be a disposable unit that includes the ink supply, nozzles, and thin-film resistor headers that control the output of each nozzle.

Inkjet printers do not provide true continuous-tone capability, but it is possible for variable-dot-size devices to produce acceptable-quality continuous-tone images. Solid-ink systems dry when the dots contact the paper. The image is then pressed by fuser rollers to improve the surface texture. Liquid systems provide the best image quality when used with specially treated paper, which prevents the ink from running or soaking into the paper.

21.8.3 Laser Electrophotographic Printers

Color electrophotographic printers use a four-stage system, with cyan, magenta, yellow, and black toner particles, as shown in Fig. 21.20. A photoconductive belt or drum is first exposed to a corona discharge in order to impart a uniform electrostatic charge. The photoconductor is then illuminated to discharge selective areas and create a latent image. In a printer this is normally done by modulating the output of a gallium arsenide (GaAs) diode laser. As the laser beam scans the photoconductive belt or drum, it modifies the electrostatic charge. Colored toner particles are electrostatically attracted to the charged photoconductor. The toner particles are then transferred to a separate electrostatically charged drum.

The photoconductor belt is cleaned, and the process continues using the next color for a total of four cycles, until the drum contains all four toner colors. The image is then rolled onto the paper, which is heated and pressed to fuse the image. Halftoning methods are normally used to create continuous-tone images. Other methods may be used to form the latent image on the photoconductor, such as a light-emitting diode (LED) printhead assembly incorporating thousands of LED emitters.

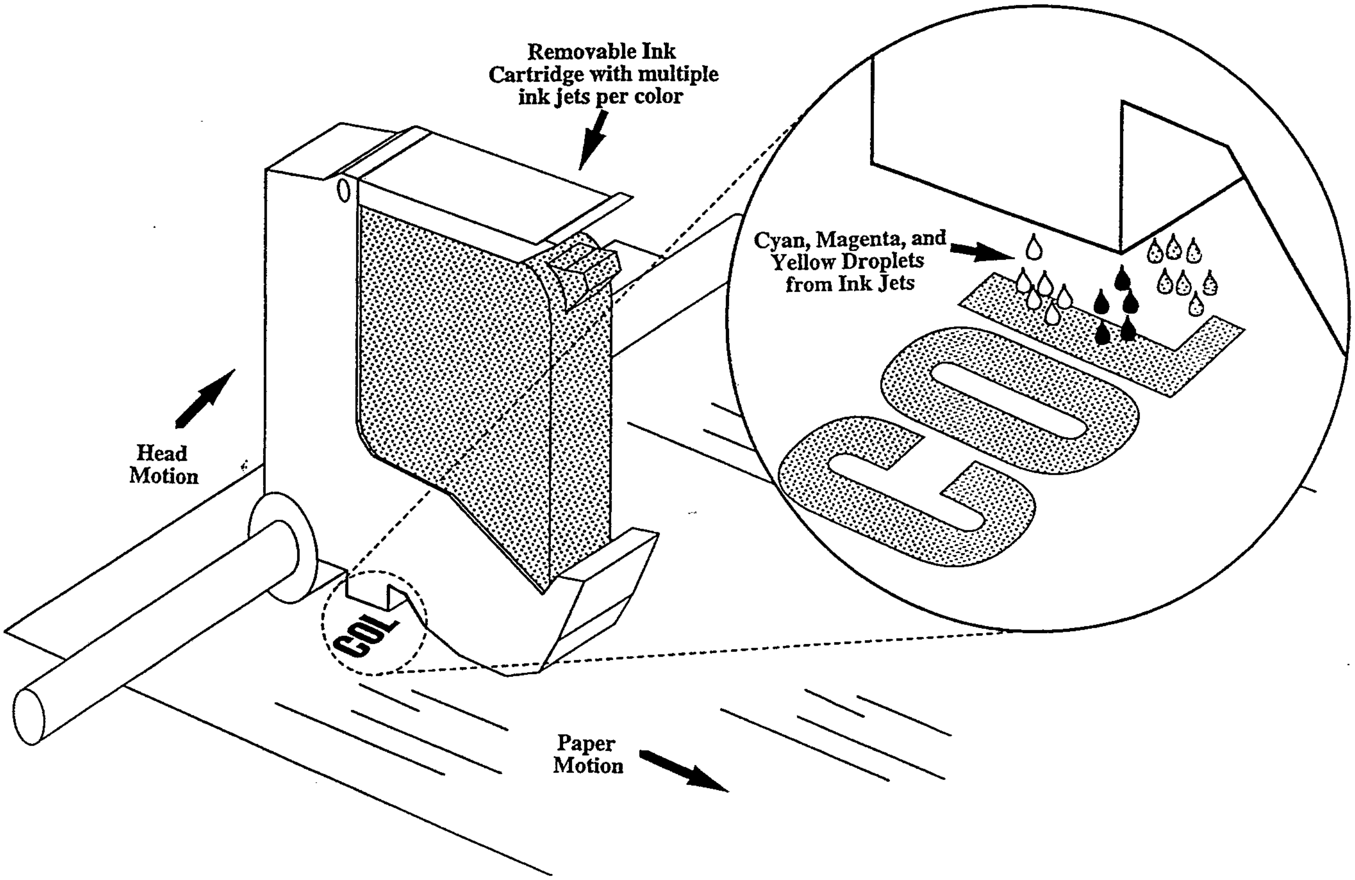

FIGURE 21.19 Inkjet printer.

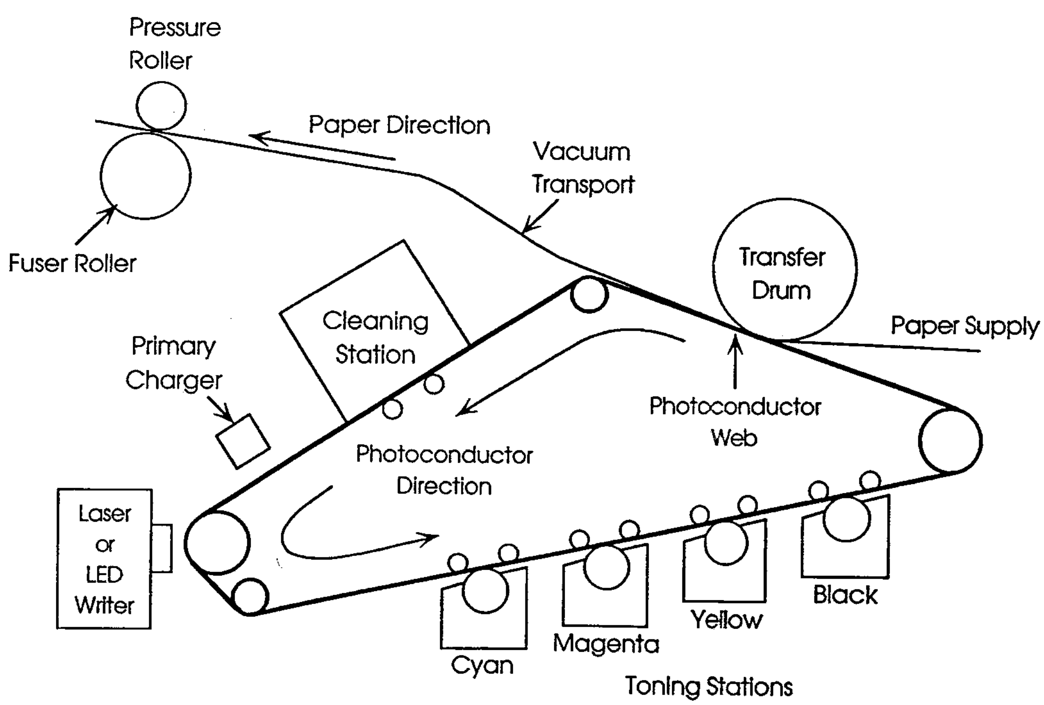

FIGURE 21.20 Color electrophotographic printer.

21.8.4 Silver-Halide Printers

Most silver-halide printers use standard color photographic paper that is developed in the conventional manner. The printers are typically used by photofinishers and other service providers who require very high throughput. Some printers include the chemical-based paper development process in the printer unit. Others provide a light-tight roll of exposed prints, which are processed using the same high-speed equipment used to develop conventional optical prints.

The photographic paper may be exposed by a cathode ray tube (CRT), as shown in Fig. 21.21, or by a modulated laser or liquid-crystal light valve. In a CRT printer, color sequential exposures are obtained by a color wheel, which has RGB filters specially tuned for the sensitivities of the color paper.

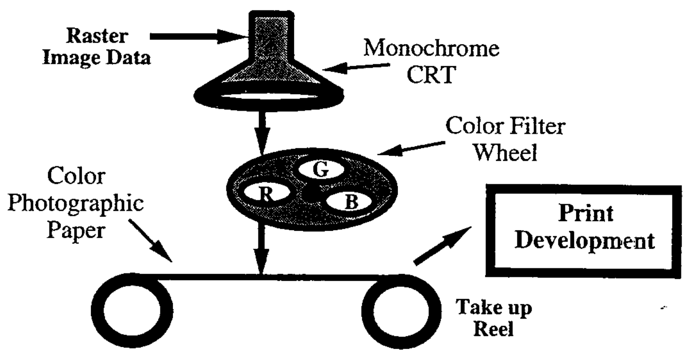

FIGURE 21.21 Silver-halide printer.

GLOSSARY

Aliasing Image artifacts in captured images caused by significant energy in the scene at frequencies higher than the Nyquist limit of the sensor. In single-chip color cameras, aliasing can produce unexpected color patterns in highly detailed monochrome objects.

Analog-to-digital converter (A/D or ADC) A circuit that converts an analog signal, having a continuously varying amplitude, to a digitally quantized representation using binary output signals.

Charge-coupled device (CCD) A type of silicon integrated circuit used to convert light into an electronic signal.

Color filter array (CFA) A mosaic or stripe layer of colored transmissive filters fabricated on top of an imager in order to obtain a color image from a single-image sensor.

Color pixel reconstruction An algorithm that creates a fully populated color image record from the output of a CFA-type sensor by interpolating values for each color at each pixel location.

Correlated double sampling (CDS) A circuit commonly used to process the output signal from a CCD image sensor in order to reduce low-frequency noise components.

Depth of field The difference between the maximum and minimum distances from a camera to objects in a scene that can be captured in acceptably sharp focus.

Digital camera An electronic camera that captures images using a solid-state image sensor, and then outputs a digital signal representing the images or records the images on a digital storage medium.

Edge enhancement A signal-processing operation that accentuates edge details within an image to increase the apparent sharpness. Such operations may also be called *aperture correction, sharpening,* or *peaking.*

Exposure determination A method for setting the appropriate lens aperture and exposure time for a scene to be captured.

Full-frame imager A type of image sensor consisting of a single light-sensitive array of photoelements that also store the image during the sensor readout period.

Gamma correction A signal-processing operation that changes the relative signal levels in order to adjust the image tone reproduction, typically to correct for the nonlinear (nonunity gamma) light output–versus–signal input characteristic of the display. The relationship between the camera light input and the camera output signal level, called the *optoelectronic conversion function* (OCEF), provides the camera's gamma correction curve shape.

Hybrid photography A type of digital photography system in which original scenes are captured using traditional silver-halide–based photography, and the resulting film or prints are scanned to provide digital images that may be displayed, manipulated, transmitted, etc.

Hyperfocal distance The focus distance of a camera lens that offers the greatest depth of field. When a camera is focused at the hyperfocal distance, all objects from half the hyperfocal distance to infinity are within the camera's depth of field.

Imaging chain A flow diagram that indicates all of the components used to produce a final image in a digital photography system.

Image compression A process that alters the way image data are encoded in order to reduce the average size of an image file.

Image data format A specification for storing image data and related information in a digital file. One example is TIFF, tag image file format, which can be used to store various types of monochrome or color bit-mapped images.

Interline sensor A type of image sensor consisting of a two-dimensional array containing light-sensitive photoelements adjacent to light-shielded vertical storage registers.

Memory card A small, thin, removable memory unit, containing digital integrated circuit memory chips, housed in a rugged package.

Optical prefilter An optically transmissive device, such as a stack of birefringent quartz plates, that limits the high-frequency content of an image focused on a solid-state image sensor in order to reduce aliasing.

Photo CD disc A compact disc–recordable (CD-R) optical write-once disc that stores scanned photographic images using the Image Pac image data format.

Still-video floppy (SVF) A standardized recording medium for analog electronic still cameras developed in the early 1980s. SVF cameras use a 2-in.-diameter floppy disk capable of storing either 50 field images or 25 frame images.

White balance A process for adjusting the relative signal levels of the red, green, and blue channels from a camera to correct for the color of the light source illuminating a scene, so that objects that appear to be white in the scene are reproduced as white on the soft-display or hard-copy print.

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Ken Parulski is chief architect for digital camera development at the Eastman Kodak Company in Rochester, N.Y. He joined the physics division of the company's research laboratories after receiving the B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology in 1980. He has worked at Kodak on the development of digital still cameras, video cameras, film scanners, HDTV, and the Kodak Photo CD system. Parulski chairs the U.S. delegation to the ISO standards group on electronic still picture imaging. He has authored more than 30 technical papers and has given invited lectures on digital photography to audiences in the United States, Europe, and Japan. He has been granted over 50 U.S. patents related to digital photography.

ATTACHMENT D: “Kodak SV9600 still video transceiver”, Hadley, SPIE Vol. 1071, Optical sensors and electronic photography, 1989, pp. 238-245” (http://spie.org/Publications/Proceedings/Paper/10.1117/12.952523)

Kodak SV9600 Still Video Transceiver

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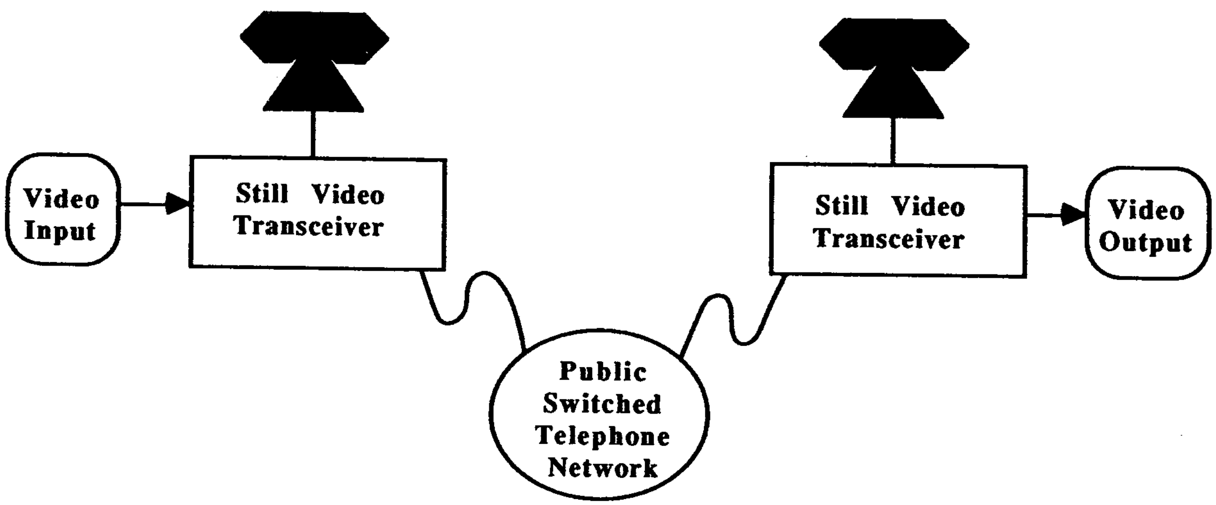
ABSTRACT

The Kodak SV9600 Still Video Transceiver is designed to electronically transmit and receive high quality video images over standard telephone lines. The transceiver captures a full frame of video, digitizes and stores it in memory for manipulation and display of the image data. The data is compressed using a highly sophisticated algorithm developed at Kodak. The compressed image data is transferred to a built-in modem for high-speed communication over standard telephone lines.

1) SYSTEM CONCEPT

The objective of the Kodak SV9600 Still Video Transceiver is to develop and market a system for electronically transmitting and receiving NTSC-quality color video images using the public dial-up telephone network.



The input to the system can be any source of NTSC composite or RGB video in still or motion form. The output from the system can be connected to any device that accepts NTSC composite or RGB video.

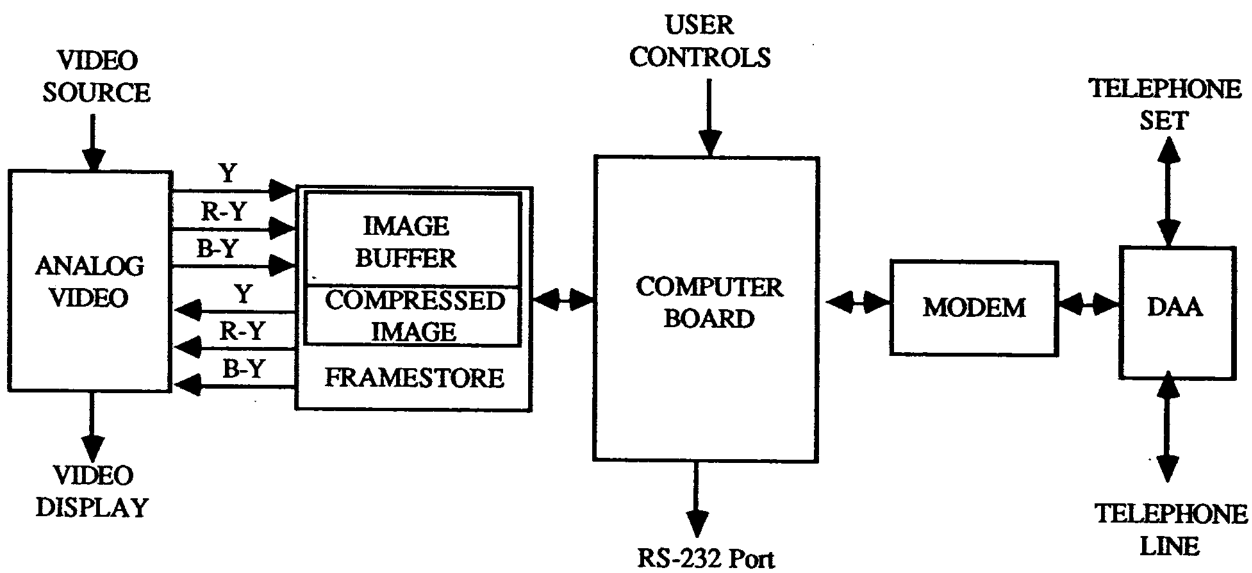
The transceiver captures a full frame of video and stores it in digital form in memory for purposes of manipulation and display of the image data. This data is then compressed using highly sophisticated image compression techniques to minimize the transmission time and storage requirements. The compressed data is then transmitted via a high-speed modem to another transceiver over standard voice-grade dial-up telephone lines. At the receiving transceiver, the compressed image is expanded and converted back to an analog video signal for display on a video monitor.

2) PRODUCT SPECIFICATIONS

* The image compression/expansion algorithm allows transmission of continuous-tone color video images over normal dial-up telephone lines in less than 1 minute.
* Preview mode provides a color image in about 10 seconds for immediate verification.
* Field mode eliminates flicker from motion images.
* External computer interface allows for storage of images in compressed digital form on a PC diskette.
* External computer interface also permits auto sequencing of images in batch form, auto-dial, auto-answer, storage of uncompressed digital images, and different modes of transmission.
* Standard NTSC composite and RGB video inputs and outputs.
* Standard RJ11C jacks for telephone line and telephone set.

3) HARDWARE OVERVIEW

The major functional blocks of the transceiver are the printed circuit board assemblies. The analog video board converts the NTSC composite or RGB input signal to luminance and color difference analog video signals. The framestore board contains the A/D converters which digitize these signals and store the values in memory. The memory contents are converted back to analog luminance and color difference signals. The analog video board converts these signals to the NTSC composite and RGB analog video output signals.



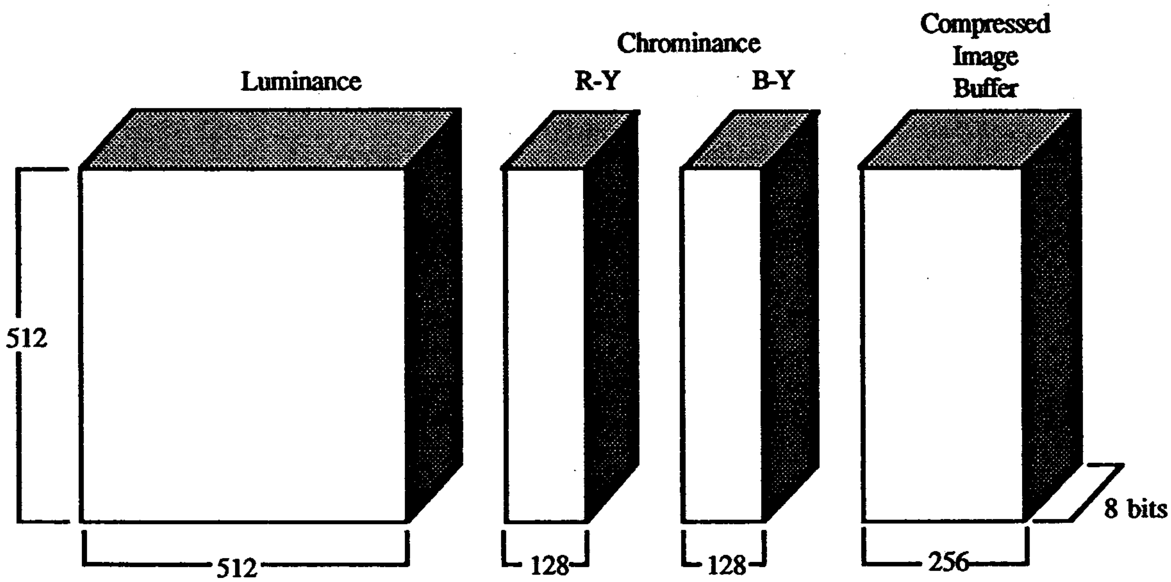
The computer board contains the microprocessor which controls the operation of the transceiver. User controls and the RS-232 serial port for the external computer interface provide the inputs and outputs to and from the microprocessor. The microprocessor along with a digital signal processor execute the compression algorithm on the image data in the framestore and store the compressed image data in memory. These two processors also perform the expansion algorithm on the compressed image data and store the resulting image data in the framestore. The computer board also contains the channel coder which is used to control the operation of the internal modem and detect errors during the transmission of the image.

The modem board supports four different data rates; 9600, 7200, 4800, & 2400 bps. In addition to the interface to the channel coder on the computer board, the modem has an interface to the microprocessor which is used to configure the modem to the different data rates and obtain diagnostic information from the modem.

In order to meet FCC requirements for connection to the telephone network, the modem board is isolated from the telephone line by the DAA (Data Access Arrangement) board. The DAA board also provides capability for auto-dialling and auto-answer.

4) FRAMESTORE ARCHITECTURE

The framestore is organized as luminance and color difference samples in order to take advantage of the human visual system. The human visual system is more sensitive to detail in luminance, or black and white, than it is in chrominance. For this reason, the color difference signals are sampled at the rate of 128 samples per line of video, while the luminance signal has 512 samples per line. This scheme is similar to the bandwidth of the Y, I and Q signals which make up the standard NTSC composite video signal. All three video signals have vertical resolution of 512 lines, although the color difference samples are averaged and subsampled vertically to a resolution of 128 lines by the microprocessor before being compressed.

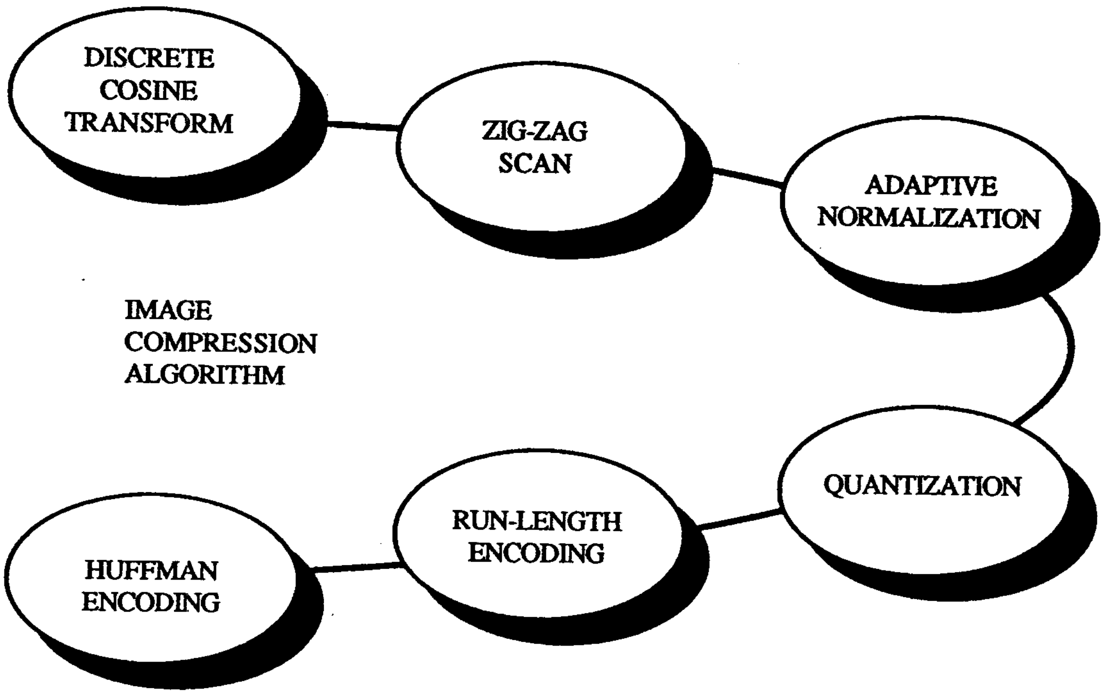


The framestore board, which has a total capacity of 512 kbytes, includes memory space for the compressed image data. The original uncompressed image occupies 384 kbytes of memory, therefore 128 kbytes are available to be used as the compressed image buffer.

The device used to control the video display and dynamic memory of the framestore allows the host microprocessor to directly address all the framestore memory locations or indirectly address the framestore by automatically adjusting the address during each access to the framestore for the next access. This indirect method is very useful in high-speed data transfers to and from the framestore.

5) COMPRESSION ALGORITHM

The image compression algorithm is based on the Discrete Cosine Transform. A 16 x 16 block of image data is used as the input to the discrete cosine transform. This 16 x 16 block can either represent original image data, or it can be the result of a 64 x 64 block of image data that has been averaged and subsampled. The discrete cosine transform is used to reduce the correlation between pixels, it can be quickly executed, and it avoids the spurious spectral components associated with a Discrete Fourier Transform.



The results of the transform, which are coefficients representing the spatial energy within the block, are then scanned into a one-dimensional array so that the first term represents the lowest spatial frequency and the last term represents the highest spatial frequency.

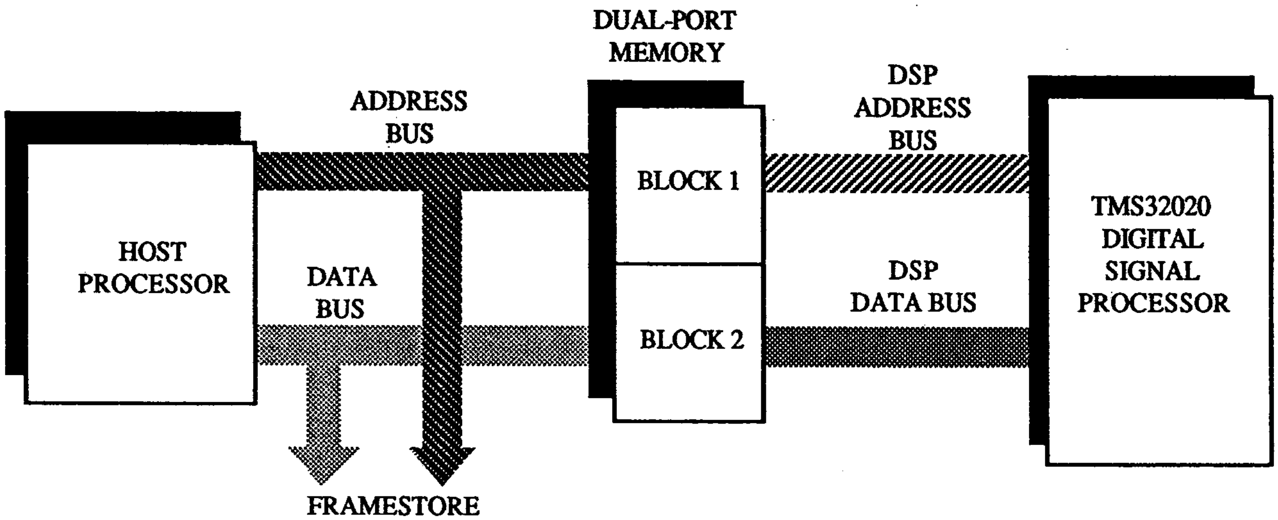
These coefficients are then normalized using an adaptive normalization process developed by Majid Rabbani and Scott Daly in the Kodak Research Labs. The normalization process is done for two reasons: 1) reduce the values of the coefficients to a smaller range for subsequent Huffman encoding; 2) create strings of very small coefficients which can be set to zero for run-length encoding. This adaptive normalization process takes into account the human visual system and is designed to be a single-pass algorithm which is necessary for it to be executed as fast as possible. The artifacts caused by this process are distributed so that they are less visible or invisible to the observer by introducing more distortion in areas where it will be less noticeable. The normalized coefficients are quantized to the nearest integer.

Up to this point no compression has been accomplished. It is in the following steps that the compression occurs. The strings of zero coefficients are run-length encoded, and finally the nonzero coefficients and run-length values are Huffman encoded using a look-up table developed in the Kodak Research Labs to be optimized for values obtained from continuous-tone color images.

6) COMPRESSION/EXPANSION HARDWARE

The TMS32020 Digital Signal Processor (DSP) is used as a parallel-processing element on the computer board. It performs a portion of the image compression/expansion algorithm while the microprocessor performs the remaining portion of the algorithm.

This is accomplished by using a dual-port memory , thereby allowing both processors simultaneous access to the data memory. The memory is divided into two blocks which are alternately accessed by the DSP and microprocessor in an alternating manner. While the microprocessor operates on the second half of the memory, the DSP works on the first half. When the microprocessor has finished with the second half, it proceeds to the first half where the DSP has placed its resulting values. Meanwhile, the DSP operates on the data of the second block.



This switching back and forth is repeated until the entire image is processed. A single memory location is defined for each block as the communication link between the two processors. Writing to its location allows the microprocessor to instruct the DSP as to which operation should be performed, and the DSP notifies the microprocessor it has completed its processing on the block by writing to its location.

7) COMPRESSION RATIO/TRANSMISSION TIME

If the image was stored as red, green and blue (RGB) with 512 samples per line in all three colors, and the vertical resolution was 512 lines of video, the digital image would require 786,432 bytes for memory space. This assumes each sample has 8 bits per pixel which is equivalent to a bit rate of 24 bits per pixel. The stored image in the transceiver only requires 393,216 bytes, but only 294,912 bytes are used since the color difference samples are subsampled and averaged vertically. Therefore, the architecture of the framestore has already provided a 2.7:1 compression ratio relative to the original RGB image. The compression algorithm typically provides a compression ratio of 6:1, which gives a total compression ratio relative to the RGB image of 16:1. In other words, the resulting bit rate of the compressed image is 1.5 bits per pixel. Therefore, a typical compressed image requires 48k bytes of memory space.

It should be pointed out that the compression algorithm will result in a compressed image size and bit rate that is dependent on the amount of spatial frequency information contained in the image. Images with more detail will have a higher bit rate.

If the original RGB image was sent at 1200 bps, the transmission time would be 90 minutes. Increasing the data rate to 9600 bps would lower that time to 11 minutes. Using the framestore architecture and image compression algorithm of the SV9600 transceiver will lower that time to just 41 seconds !!!!

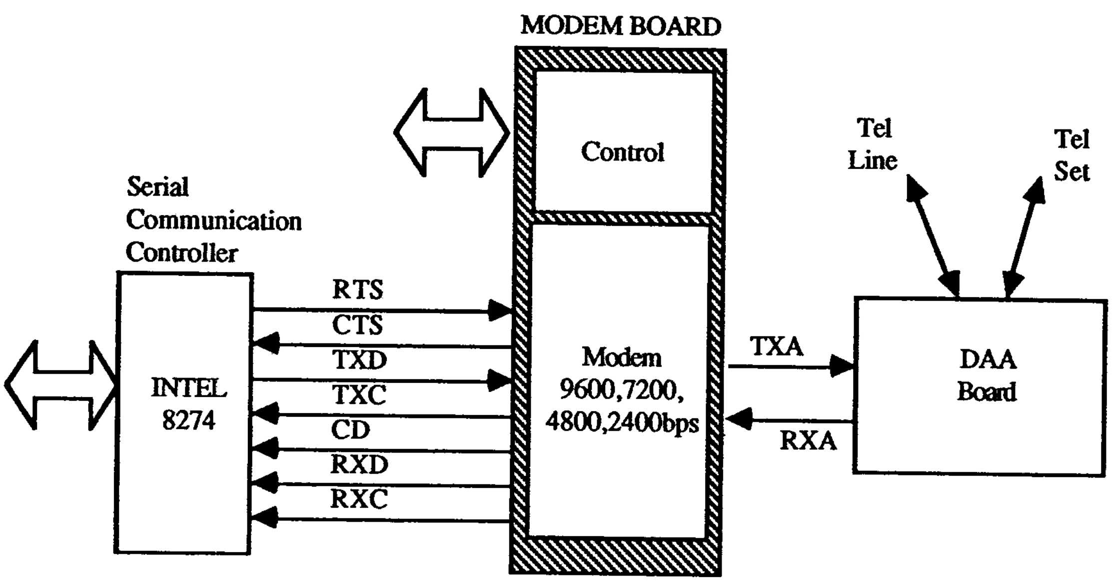
8) COMMUNICATION HARDWARE

The Intel 8274 Serial Communication Controller is used to control the operation of the internal modem, and check for errors on the data received by the transceiver. A variation of the bit-oriented SDLC, Synchronous Data Link Control, protocol is used which sends data in frames with a check sum added for error detection. The 8274 automatically generates the check sum for each frame of data at the transmitting unit, and the 8274 at the receiving unit uses this check sum to verify the integrity of the received frame of data. If errors are detected, the 8274 notifies the microprocessor, which will then send a message to the transmitting unit to resend that particular frame of data.

The Modem Board is a synchronous serial 9600 bps (CCITT Recommendations V.29) modem that is designed for half-duplex operation over the public switched telephone network. Fallback configurations compatible with CCITT Recommendations V.29 for 7200 and 4800 bps and V.27ter for 2400 bps are used on telephone lines that cannot support 9600 bps.

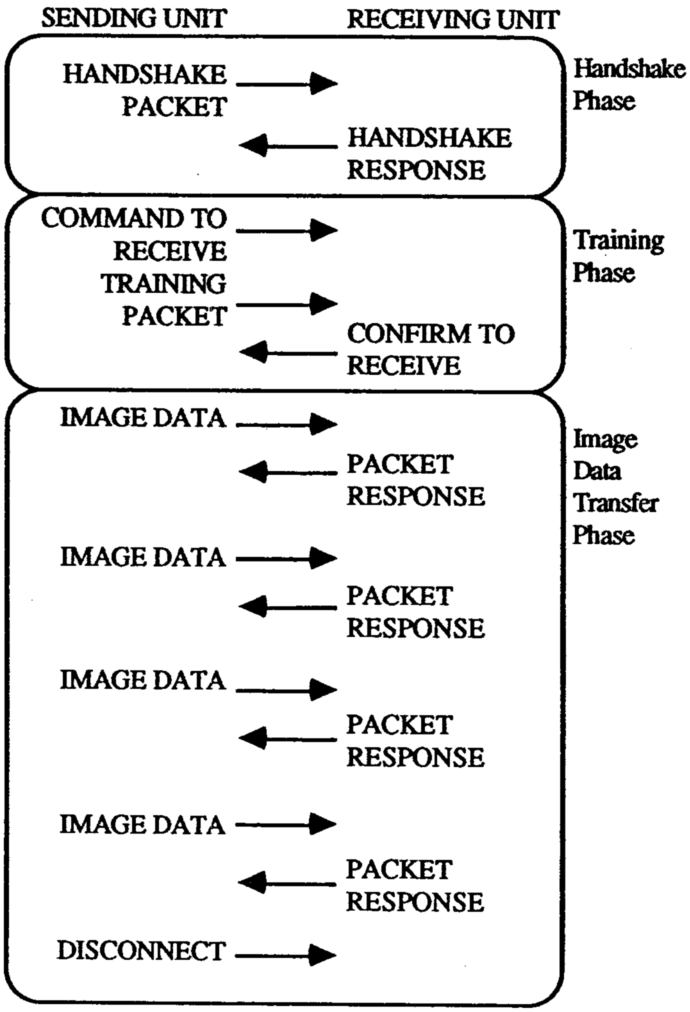
A microprocessor interface is provided so the microprocessor can access registers which are on the modem. Diagnostic information relating to the quality of the telephone line is provided by reading data from these registers. The data rate of the modem, its transmit level, equalizers and other parameters are changed by writing to these registers.

The DAA, Data Access Arrangement, Board is included to interface between the modem and the public dial-up telephone network. The DAA Board is designed so that the transceiver will meet FCC (Federal Communications Commission) and Canada's DOC (Department of Communications) regulations for devices connected to the telephone network. It also allows the user to connect a telephone set to the transceiver so that voice conversation can be maintained while a transmission is not taking place. The DAA board also provides for auto-dial and auto-answer features.



9) COMMUNICATION PROTOCOL

The image communication protocol consists of three main phases: the Handshake Phase, the Training Phase, and the Image Data Transfer Phase.



During the Handshake Phase, the sending unit sends a handshake message at 2400 bps to the receiving unit to notify it that an image transfer is being attempted. This causes the receiving unit to automatically switch from voice mode to data mode. The receiving unit includes capability/version information in its handshake response message which is also sent at 2400 bps.

After the receiving unit responds to the handshake message, the sending unit sends a command to receive message at 2400 bps followed by a training sequence at 9600 bps. If the receiving unit determines the telephone line condition will not support that data rate, it responds accordingly with a failure to train message at 2400 bps and the process is repeated at a slower data rate until the receiving unit decides the particular data is acceptable. The receiving unit then responds with a confirm to receive message at 2400 bps.

After the receiving unit selects a data rate, the transfer of image data is begun. Image data is sent at the selected data rate in packets which consist of several frames of compressed image data. The receiving unit will send a response at 2400 bps for each packet indicating if any of the frames within the packet need to be resent because errors were detected within the frame. The sending unit will include these frames in the next packet of frames. Because of the telephone line turnaround time involved in a half-duplex communication protocol, the amount of data included in each frame and packet for each data rate is selected to optimize the throughput on both good and poor telephone line conditions. This process continues until all the data has been correctly received. The sending unit sends a disconnect message at 2400 bps to notify the receiving unit that another image will not be sent and the telephone line can be released for voice communications.

10) APPLICATIONS

The SV9600 transceiver is intended primarily for commercial and industrial applications in the US and Canada only, although successful transmissions have been completed between the US and England. The SV9600 is currently being marketed, and listed below are some of the applications that have been developed with the Kodak SV9600 Still Video Transceiver:

Industrial : A field service engineer sends images back to a central location to help determine the cause of a failure.

News gathering : A TV news crew captures an image off a video tape and sends it via cellular phone to the studio.

Law enforcement : A surveillance team sends an image to the police station for identification of a criminal

Medical : A laboratory evaluating slides under a microscope can retrieve similar images from a remote central library for comparison.

Government : The FBI, Army, Navy, Air Force all have a need to send images from a remote location to some central facility such as the Pentagon.