US005489772A

United States Patent [19]

Webb et al.

[11] **Patent Number: 5,489,772**

[45] **Date of Patent: Feb. 6, 1996**

[54] **VARIABLE OPTICAL SAMPLING RATE DEPENDENT ON REQUESTED SCAN RESOLUTION**

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[21] Appl. No.: **339,107**

[22] Filed: **Nov. 14, 1994**

[51] **Int. Cl.**[6] **H01L 27/00**

[52] **U.S. Cl.** **250/208.1**; 250/234; 348/297; 358/482

[58] **Field of Search** 348/362, 294, 348/297; 358/482, 474, 483; 250/208.1, 234, 235, 236

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,591,727	5/1986	Gaebelein et al.	250/578
5,032,712	7/1991	Ito	250/208.1
5,047,871	9/1991	Meyer et al.	358/486
5,265,039	11/1993	Curbelo et al.	364/574
5,336,878	8/1994	Boyd et al. .	
5,373,372	12/1994	Loewen	358/486

OTHER PUBLICATIONS

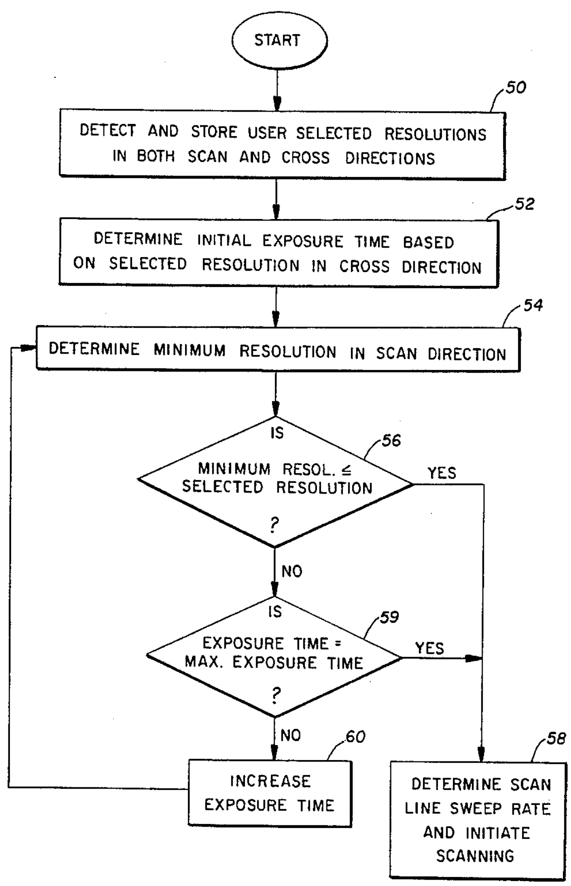
United States Patent Application Ser. No. 08/174,868 filed Dec. 29, 1993 for Procedure for Reducing Time for Image Elements by Combining Charge of Adjacent Pixels into a New Composite Pixel of Greg A. Degi.

Primary Examiner—Edward P. Westin
Assistant Examiner—Stephen Calogero

[57] **ABSTRACT**

A method of determining an exposure time for a photosensor based on a desired resolution along a scan direction and a desired resolution in a cross direction may comprise the steps of determining an initial exposure time based on the desired resolution in the cross direction; determining a minimum resolution in the scan direction based on the initial exposure time; comparing the minimum resolution in the scan direction to the desired resolution in the scan direction; and increasing the initial exposure time if the minimum resolution in the scan direction is greater than the desired resolution in the scan direction.

20 Claims, 2 Drawing Sheets



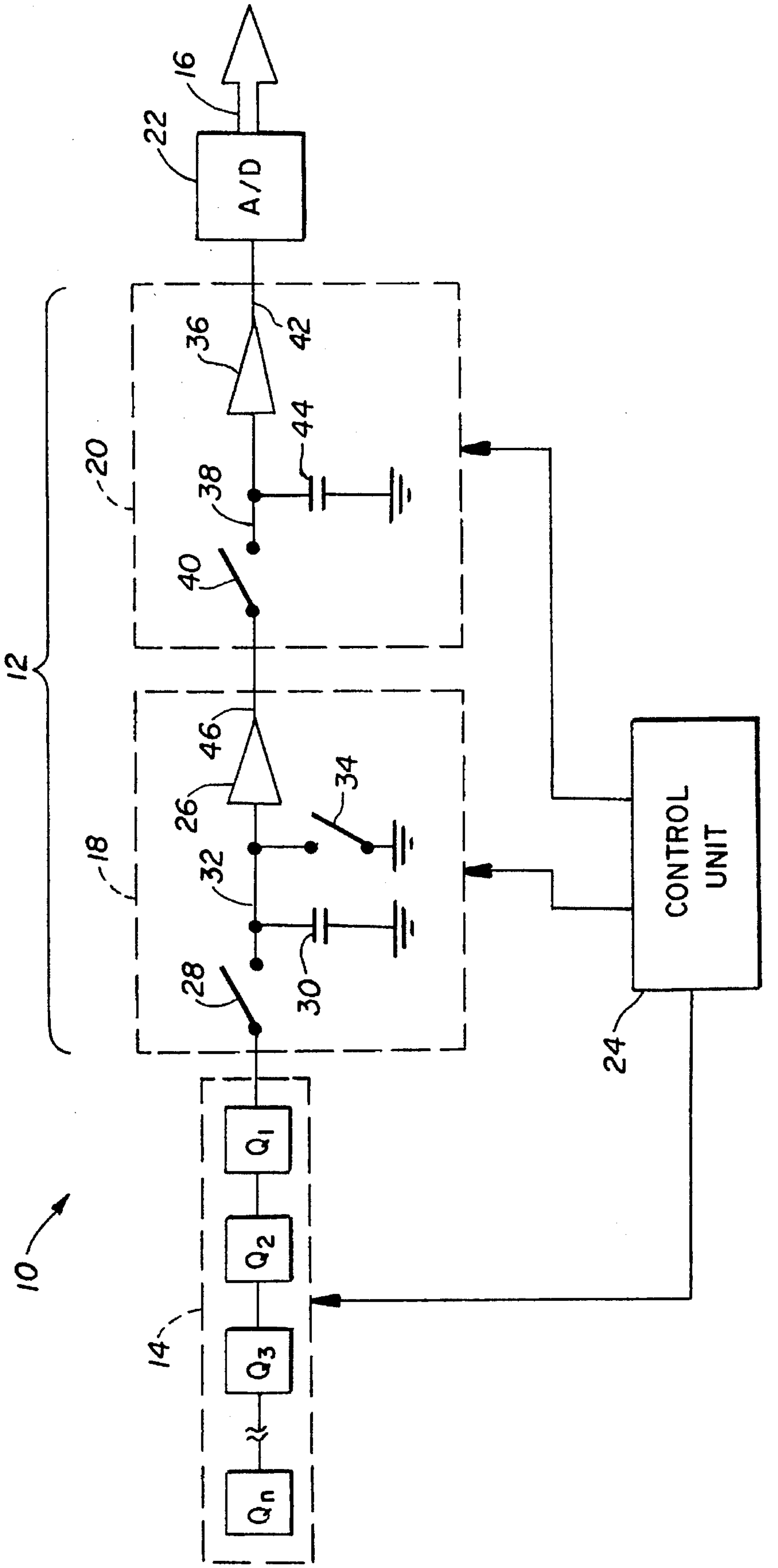

A/D
CONTROL UNIT
Q1
Q2
Q3
Qn
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46

FIG.1

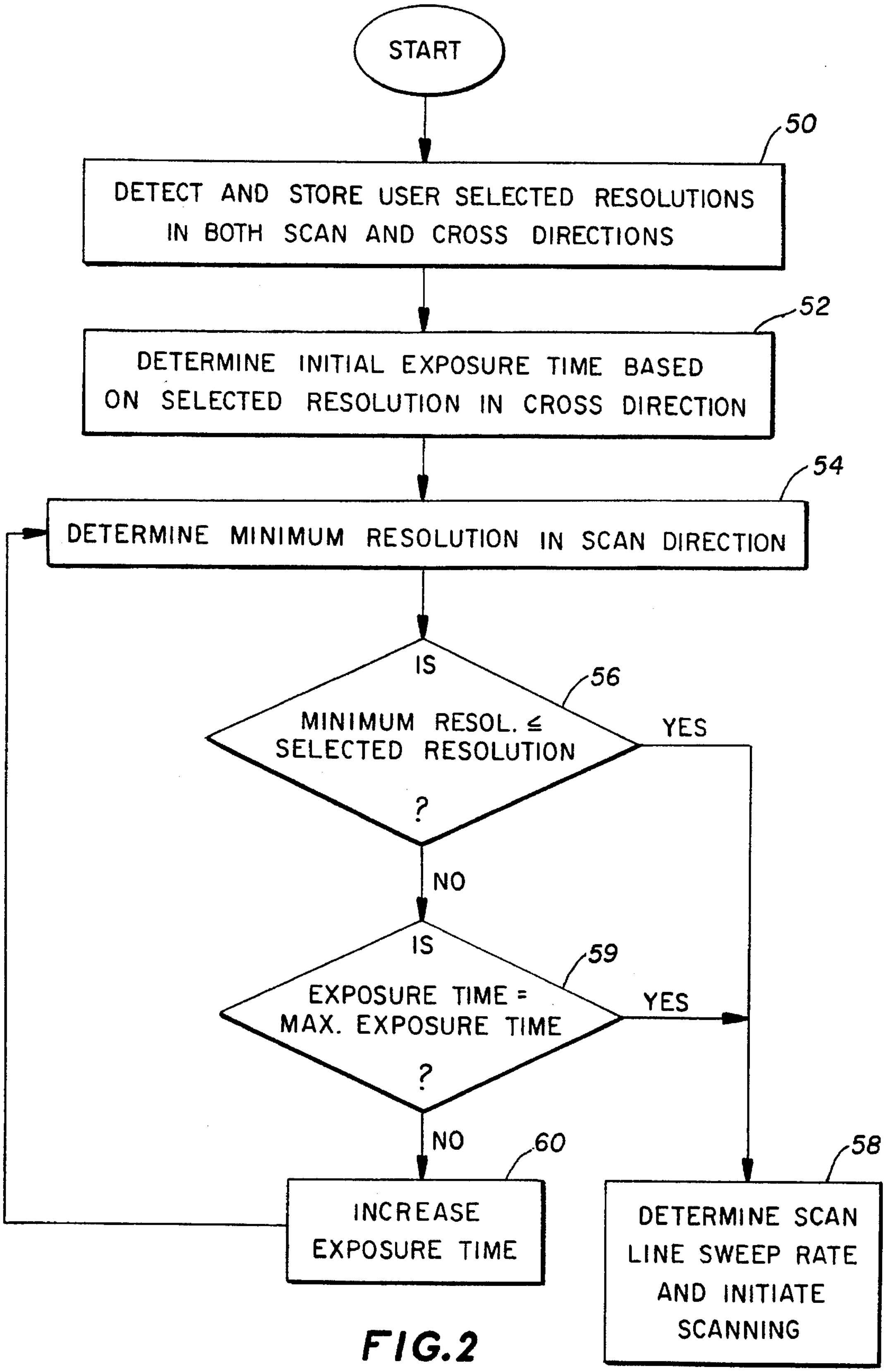

START
50
DETECT AND STORE USER SELECTED RESOLUTIONS IN BOTH SCAN AND CROSS DIRECTIONS
52
DETERMINE INITIAL EXPOSURE TIME BASED ON SELECTED RESOLUTION IN CROSS DIRECTION
54
DETERMINE MINIMUM RESOLUTION IN SCAN DIRECTION
56
IS MINIMUM RESOL. ≤ SELECTED RESOLUTION ?
YES
NO
59
IS EXPOSURE TIME = MAX. EXPOSURE TIME ?
YES
NO
60
INCREASE EXPOSURE TIME
58
DETERMINE SCAN LINE SWEEP RATE AND INITIATE SCANNING

FIG.2

VARIABLE OPTICAL SAMPLING RATE DEPENDENT ON REQUESTED SCAN RESOLUTION

BACKGROUND

The present invention relates to image scanner technology in general and more specifically to a method for varying the optical sampling rate of an image scanner.

Optical scanners generate data signals representative of an object or document by projecting an image of the object or document onto an optical photosensor array. The data signals may then be digitized and stored for later use. For example, the data signals may be used by a personal computer to produce an image of the scanned object or document on a suitable display device.

Most optical scanners use illumination and optical systems to illuminate the object and focus a small area of the illuminated object, usually referred to as a "scan line," onto the optical photosensor array. The entire object is then scanned by sweeping the illuminated scan line across the entire object, either by moving the object with respect to the illumination and optical assemblies or by moving the illumination and optical assemblies relative to the object.

A typical scanner optical system will include a lens assembly to focus the image of the illuminated scan line onto the surface of the optical photosensor array. Depending on the particular design, the scanner optical system may also include a plurality of mirrors to "fold" the path of the light beam, thus allowing the optical system to be conveniently mounted within a relatively small enclosure. In order to allow a smaller photosensor array to be used, most optical systems also reduce the size of the image of the scan line that is focused onto the surface of the photosensor. For example, many optical systems have a lens reduction ratio of about 8:1, which reduces the size of the image of the scan line by a factor of about 8.

While various types of photosensor devices may be used in optical scanners, a commonly used sensor is the charge coupled device or CCD. As is well-known, a CCD may comprise a large number of individual cells or "pixels," each of which collects or builds-up an electrical charge in response to exposure to light. Since the size of the accumulated electrical charge in any given cell or pixel is related to the intensity and duration of the light exposure, a CCD may be used to detect light and dark spots on an image focused thereon. In a typical scanner application, the charge built up in each of the CCD cells or pixels is measured and then discharged at regular intervals known as exposure times or sampling intervals, which may be about 5 milliseconds or so for a typical scanner. Since the charges (i.e., image data) are simultaneously collected in the CCD cells during the exposure time, the CCD also includes an analog shift register to convert the simultaneous or parallel data from the CCD cells into a sequential or serial data stream. A typical analog shift register comprises a plurality of "charge transfer buckets" each of which is connected to an individual cell. At the end of the exposure time, the charges collected by each of the CCD cells are simultaneously transferred to the charge transfer buckets, thus preparing the CCD cells for the next exposure sequence. The charge in each bucket is then transferred from bucket to bucket out of the shift register in a sequential or "bucket brigade" fashion during the time the CCD cells are being exposed to the next scan line. The sequentially arranged charges from the CCD cells may then be converted, one-by-one, into a digital signal by a suitable

In most optical scanner applications, each of the individual pixels in the CCD are arranged end-to-end, thus forming a linear array. Each pixel in the CCD array thus corresponds to a related pixel portion of the illuminated scan line. The individual pixels in the linear photosensor array are generally aligned in the "cross" direction, i.e., perpendicular to the direction of movement of the illuminated scan line across the object (also known as the "scan direction"). Each pixel of the linear photosensor array thus has a length measured in the cross direction and a width measured in the scan direction. In most CCD arrays the length and width of the pixels are equal, typically being about 8 microns or so in each dimension.

The resolution in the cross direction is a function of the number of individual cells in the CCD. For example, a commonly used CCD photosensor array contains a sufficient number of individual cells or pixels to allow a resolution in the cross direction of about 600 pixels, or dots, per inch (dpi), which is referred to herein as the "native resolution in the cross direction."

The resolution in the scan direction is inversely related to the product of the scan line sweep rate and the CCD exposure time (i.e., the sampling interval). Therefore, the resolution in the scan direction may be increased by decreasing the scan line sweep rate, the CCD exposure time, or both. Conversely, the resolution in the scan direction may be decreased by increasing the scan line sweep rate, the CCD exposure time, or both. The "minimum resolution in the scan direction" for a given exposure time is that resolution achieved when scanning at the maximum scan line sweep rate at that exposure time. For example, a maximum scan line sweep rate of about 3.33 inches per second and a maximum exposure time of about 5 milliseconds will result in a minimum resolution in the scan direction of about 60 dpi.

The resolution in the cross direction may be decreased below the native resolution in the cross direction by using any one of a number of pixel dropping algorithms to ignore, or drop, data from certain cells in the CCD. For example, the resolution in the cross direction in a CCD having a native resolution of 600 dpi may be decreased to 300 dpi by ignoring or dropping data from every other pixel. Most commonly used pixel dropping techniques ignore or drop the pixel data after it has been converted into a digital signal by the analog-to-digital converter. It is also possible to increase the resolution in the cross direction over the native resolution in the cross direction by using various data interpolation techniques to increase the effective resolution in the cross direction. For example, some data interpolation techniques can be used to increase the effective resolution in the cross direction to 1200 dpi or more with a CCD having a native resolution in the cross direction of only 600 dpi.

As mentioned above, the resolution in the scan direction is a function of the scan line sweep rate as well as the CCD exposure time. Therefore, the resolution in the scan direction can be varied by changing the scan line sweep rate, the CCD exposure time, or both. It should be noted that resolution in the scan direction corresponding to a given maximum scan line sweep rate and CCD exposure time is fixed and represents the minimum resolution in the scan direction for that exposure time. However, the resolution in the scan direction may be further reduced by ignoring or dropping whole lines of data. Such line dropping techniques are analogous to the pixel dropping techniques described above.

One problem associated with scanners that drop pixels to to decrease the resolution in the scan direction, or both, is that the pixel and line dropping processes tend to introduce various artifacts and distortions into the image data, such as alising and moire patterns.

Another problem associated with pixel and line dropping processes is that the pixel and line dropping functions are usually performed after the charge data from the individual CCD cells have been converted into digital form. Consequently, the maximum sampling rate, thus scanning speed, is limited to the data conversion rate of the analog to digital (A/D) converter. Since most scanners operate at the maximum effective sampling rate of the A/D converter, the scanning rate when scanning at reduced resolution is essentially the same as when scanning at maximum resolution. Put in other words, selecting a decreased resolution will not usually result in an increased scan rate.

Even if faster analog to digital converters are used, there is a limit to the maximum scan rate that can be achieved. For example, the provision of a faster analog-to-digital converter will allow faster scan rates at a given resolution only if the exposure time (i.e., sampling interval) is decreased. However, since the amount of charge produced by a given CCD cell is proportional to the exposure time, shorter exposure times will result in proportionally lower signal levels. Assuming constant system noise, such lower signal levels will yield a lower signal to noise ratio, which noise usually appears in the image data as "snow."

Therefore, there remains a need for an image scanner that can scan at a wide range of resolutions but without the image degradation problems, such as alising, and the generation of moire patterns, that are typically associated with the line dropping processes typically used in currently available scanners. Ideally, the selection of a decreased scanning resolution should also result in a corresponding increase in scanning speed, but without the need to resort to expensive, high-speed analog-to-digital converters and without reducing the signal-to-noise ratio of the resulting image data signal.

SUMMARY OF THE INVENTION

A method of determining an exposure time for a photosensor based on a desired resolution along a scan direction and a desired resolution in a cross direction may comprise the steps of determining an initial exposure time based on the desired resolution in the cross direction; determining a minimum resolution in the scan direction based on the initial exposure time; comparing the minimum resolution in the scan direction to the desired resolution in the scan direction; and increasing the initial exposure time if the minimum resolution in the scan direction is greater than the desired resolution in the scan direction.

BRIEF DESCRIPTION OF THE DRAWING

Illustrative and presently preferred embodiments of the invention are shown in the accompanying drawing in which:

FIG. 1 is a schematic diagram of a data sampling and conversion circuit for selectively combining and digitizing pixel charges from a CCD; and

FIG. 2 is a flow chart of the steps performed by the control unit shown in FIG. 1 to determine an appropriate CCD exposure time (i.e., sampling rate).

DETAILED DESCRIPTION OF THE INVENTION

The data sampling and conversion circuit 10 of an optical

rate dependent on requested scan resolution according to the present invention is best seen in FIG. 1. Essentially, the data sampling and conversion circuit **10** comprises a conversion circuit **12** for converting pixel charges stored in a photosensor, such as a charge-coupled-device (CCD) **14** into a digital data stream **16**. As is well-known, CCD **14** includes n charge transfer buckets Q_1, Q_2, Q_3, through Q_n, which sequentially transfer the charges that were simultaneously collected from each of the individual pixels in the CCD. A charge-to-voltage converter **18** connected to the last charge transfer bucket Q_1 of CCD **14** converts the charge stored in the last bucket Q_1 into a voltage, which voltage is then converted into a digital signal by an analog to digital (A/D) converter **22**. When scanning at certain resolutions, the converter **18** converts into a voltage only the charge from one of the buckets Q, which, of course, corresponds to the charge from a single pixel. However, when scanning at other resolutions, the voltage converter circuit **18** collects the charge from two or more buckets Q before converting the total charge into a voltage. A hold circuit **20** may be connected to the voltage converter circuit **18** to act as a buffer in the event data are shifted out of the last bucket Q_1 faster than they can be converted into digital signals by the A/D converter **22**. A control unit **24** connected to the CCD array **14**, charge-to-voltage converter **18**, hold circuit **20**, and A/D converter **22** controls the timing and operation of each circuit. While any circuit may be used that accomplishes the functions of the data sampling and conversion circuit **10** shown and described herein, the data sampling and conversion circuit may be of the type disclosed in U.S. patent application Ser. No. 08/174,868 of Degi and filed on Dec. 29, 1993, which is incorporated herein by reference for all that it discloses.

When scanning at the "native" resolution in the cross direction and at the minimum resolution in the scan direction, the control unit **24** operates the CCD at a predetermined maximum exposure time (i.e., sampling interval) and sweeps the scan line over the object at a predetermined maximum scan sweep rate. When operating at the maximum exposure time and scan line sweep rate, a single scan line comprises data from each and every pixel of the CCD **14**, and the resolution in the scan direction corresponds to the minimum resolution in the scan direction. When operating at other resolutions, however, the control unit **24** determines the optimum exposure time and the number of CCD cells for which charge data should be combined in order to maximize the scan line sweep rate, but without substantially reducing the signal to noise ratio and without having to resort to line dropping techniques.

A significant advantage of the present invention is that it allows scanning over a wide range of resolutions, but without the need to resort to line dropping processes, which can create alising or moire patterns in the image data. Moreover, since the data sampling and conversion circuit **10** may combine the signals from several CCD pixels before they are digitized, scanning at certain resolutions may allow a proportionate decrease in the number of analog to digital conversions that need to be performed by the A/D converter **22**. This excess conversion capacity allows the CCD exposure time (i.e., sampling interval) to be reduced, which may be followed by a corresponding increase in scan sweep speed at a given resolution. Unlike prior scanners, the decreased exposure times made possible by the present invention may result in only a slight reduction the signal to noise ratio of the CCD, since the signals from several pixels are combined when scanning at such decreased exposure times.

The details of the data sampling and conversion circuit 10

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