Single-chip 8K full-resolution imaging using a 133Mpixel 60-fps CMOS image sensor

Ryohei Funatsu, Science & Technology Research Laboratories (STRL), NHK, Tokyo, Japan
Tomohiro Nakamura, STRL, NHK, Tokyo, Japan
Hiroshi Shimamoto, STRL, NHK, Tokyo, Japan

Introduction

8K ultra-high-definition television (UHDTV) is a next generation broadcasting system that offers an extremely high sense of presence and reality. The video parameters of 8K UHDTV are standardized in Recommendations ITU-R BT.2020 and ITU-R BT.2100 [1][2]. 8K UHDTV requires a high resolution of 7680 x 4320 pixels, higher frame frequency of up to 120 fps, wider color gamut than conventional high-definition television (HDTV), 12-bit gradation, and high dynamic range (HDR). 8K technology is applicable in a wide range of areas such as medical imaging, image inspection, physical investigation, and security.

Conventional 8K cameras used 33Mpixel image sensors. A 33Mpixel three-chip camera [3] can acquire a full-resolution (33Mpixel for each RGB color) image, but the size of the required camera becomes large. By contrast, a 33Mpixel single-chip camera [4] is compact, but the image quality is lower than with three-chip cameras. To overcome the trade-off between camera size and image quality, we developed a 133Mpixel image sensor that enables full-resolution 8K video shooting using single-chip imaging. In this study, we describe the 133Mpixel 60-fps image sensor technology [5] as well as the compact single-chip full-resolution camera [6] using the 133Mpixel image sensor. The full-resolution camera can acquire both full-resolution 8K 60-fps video as well as inter-line scanned 8K 120-fps high-speed video.

1. Methods

A block diagram and the appearance of the 133Mpixel 60-fps CMOS image sensor are provided in Figure 1. The total pixel array size is 15488 x 8680, which includes optical black pixels. The pixel design is a 2.45-μm two-way vertically shared pinned photodiode. The diagonal length of the active pixel area is 43.2 mm, which is equivalent to the diameter of the image circle of 35-mm full-frame lenses. To achieve this high-speed of 133Mpixel 60-fps readout, 484 high-speed analog-digital converters (ADCs) are used. An ADC has a 1.85-radix redundant successive approximation register (SAR) architecture with 12-bit resolution. Thus, the output data has 2-bit redundancy. Each ADC serially multiplexes 32 columns and converts them into 14-bit digital data at a conversion rate of 17.95 Ms/s. The output data from ADCs are multiplexed into 16 parallel readout ports and each readout port outputs 960 columns. CML output drivers are used to output 7-bit-wide data at a 574.56-MHz DDR, achieving an aggregate data rate of 129-Gbps. The temporal noise at 60 Hz is 7.7 e-RMS and the full well capacity is approximately 10000 e-. Thus, the dynamic range of the sensor is approximately 62 dB. Although the sensor has a high data rate, its total power consumption is 11 W.

Figure 1. Block diagram and appearance of 133Mpixel image sensor
A portable single-chip 8K camera system was developed using the color 133Mpixel 60-fps CMOS image sensor with a Bayer color filter array. The camera system consists of a camera head and camera control unit (CCU). The camera head is shown in Figure 2(a). The weight of the camera head is 6.3 kg, which is approximately one-seventh that of the conventional three-chip full-resolution 8K camera [3]. Signals from the image sensor are transmitted to the CCU using a 100-Gbps CFP4 optical transceiver. The camera head and CCU can be connected by a fiber-optic camera cable. The size of the CCU is 3U in a 19-inch rack shown as Figure 2(b), which is considerably smaller than that of conventional three-chip full-resolution 8K cameras. The CCU processes the 100-Gbps signal in real-time. The process circuit includes HDR and wide color gamut signal processing. The CCU outputs an 8K video using a multi-link optical interface known as Ultrahigh-definition Signal/Data Interface (U-SDI) [7].

This camera system can acquire both full-resolution 8K 60-fps and inter-line scanned 8K 120-fps high-speed videos. When the camera acquires 120-fps video, the sensor reads only even or odd lines at every 1/120 s alternatively by inter-line scanning. The skipped lines in an inter-line scanned image are interpolated by local motion detection. If motion is detected around the target area, the missing pixel is interpolated by the upper and lower pixels of the missing pixel in the current frame. By contrast, if the motion is not detected, the missing pixel is interpolated by prior frames. By applying these techniques, the limiting resolution of 4320 TV lines was obtained when it is still image. The modulation transfer function (MTF), at 4320 TV lines, achieves 20% using a 35-mm full-frame lens. The S/N is 51 dB measured at a sensitivity of 2000 lux / F5.6 with a dynamic range setting of 200% and 60-fps operation.

![Figure 2. Portable single-chip camera system using a 133Mpixel CMOS image sensor](image)

**References**


