A Design of Image Sensor for In-Pixel Background Suppression and Frequency Detection

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Abstract 3D range finding is a very challenging topic in strong ambient light like sunlight. There are various methods using the amplitude of the reflected light to overcome the strong ambient light in 3D range finding. In this paper, we propose a 3-D range finding system based on triangulation with the structured light encoded in the frequency and the image sensor that can detect the specific frequency information of light while suppressing the background light. The simulated signal to background ratio (SBR) is 40.2dB.

Keywords: Background Suppression, Frequency Detection, Light-section Method, Modulated light, Image Sensor

1. Introduction

Three-dimensional (3-D) measurement systems are widely used in various fields and scenes. Especially on mobile devices and automotive, the measurement stability and reliability are strongly required under a strong ambient light like a sunlight. The projected and reflected light is often much weaker than the strong ambient light [1]. Therefore, an image sensor, which is not disturbed by the background light, is required. The smart image sensor systems [2-3] based on time-of-flight method have the possible solutions to suppress the background light. But these image sensors are weak against the background light modulated with the same frequency by which the projected light is modulated.

This paper presents a new 3-D Range-finding method which is based on light-section method with the modulated light and the image sensor that can detect the specific frequency of light intensity while suppressing the background light. The demodulation pixel is used for the frequency detection. And Adaptive Charge Unit (ACU) in pixel is employed to overcome the saturation problem by the background light.

2. Proposed range-finding system

Fig. 1 illustrates the proposed 3-D range-finding system based on light-section method with the structured light and the image sensor that can detect the specific frequency of light intensity. In the range-finding system, the laser beam source is modulated by a pulse generator. The modulated light sheet is projected on a target object. The image sensor receives the reflection of the projected light sheet and background light. The image sensor is controlled by the same pulse with the laser beam source. The sensor can detect the light with a specific frequency. Then, the range data are calculated based on the triangulation method.

3. Pixel Circuit with Background Suppression

Fig. 2 shows a schematic of the pixel circuit. The pixel circuit mainly consists of two parts: a demodulation pixel and Adaptive Charge Unit (ACU). The Pixel has two gate transistor G1, G2. The gate G1 turns on '1' with the same phase of the projected light, whereas the gate G2 turns on '1' with the reverse phase of the projected light. Illustrated in Fig. 4, ACU prevents the saturation problem by strong ambient light. ACU consists of two comparators, Charge Pulse Generator (CPG), FD Charge Source (FCS). Fig.3 shows a schematic of the CPG. FCS is cascade current mirror. For exposure, the two comparators are comparing the voltages of Two node FD1, FD2 with VREF1, VREF2 respectively. When the voltages of all FDs are lower than VREF1 and VREF2, two node are charged by FCS. The charge amount can be controlled by charge pulse width using delay unit in CPG and VCH of FCS. After exposure, the 8bit digital data of the difference of the voltage between NODE1 and NODE2 are generated by readout circuit.

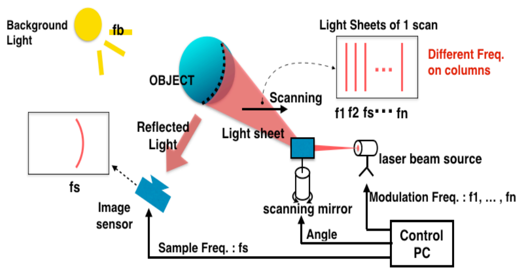

Fig. 1. Proposed 3-D Range-finding system.

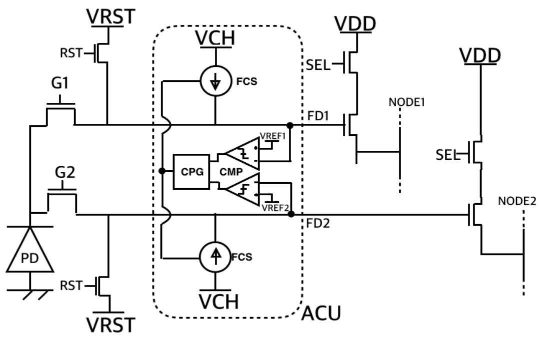

Fig. 2. Pixel circuit.

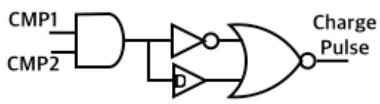

Fig. 3. CPG Circuit.

4. Chip Implementation

The proposed image sensor has been designed and being fabricated in 0.18-um CIS process. Fig. 5 show a layout of the

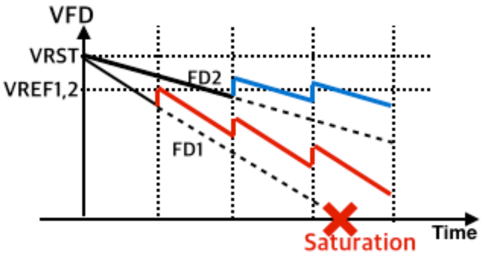

Fig. 4. ACU Behavior

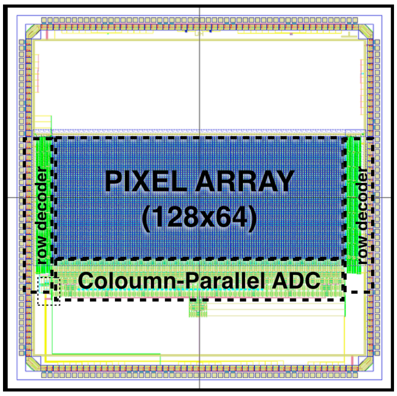

Fig. 5. Chip Layout

image sensor. The chip has a 128x64 pixel array. The pixel area occupies 28.1um x 21.2um with 1.8% fill factor.

5. Simulation results

Fig. 6 shows the difference voltage of the FDs in pixel circuit, which is NODE2 - NODE1, at modulated light with various frequencies. In this simulation, the sampling frequency fs is 1MHz and the integration time is 16us. The modulated light without the sampling frequency fs is suppressed. The suppression ratios with even harmonics of fs are less than 0.04. Therefore, the modulated light with each even-harmonics frequency can be detected independently.

Fig. 7 shows the relationship between the minimum projected light intensity that can be detected and the background intensity. In this simulation, the sampling frequency fs is 1MHz and the integration time is 4.3us ~ 16us. To simulate the sensitivity of the pixel circuit, the background light intensity and the modulated light intensity are replaced by the photo current I_{BG} and I_{SIGMIN} respectively. The Signal-to-background ratio (SBR) is defined as below.

$$SBR = 20\log\frac{I_{SIG_{MIN}}}{I_{BG}} \qquad (1)$$

The simulated results of the pixel circuit are shown in Fig. 7. Fig. 7 means that the reflected light can be weaker than the background light. The minimum signal-to-background ratio (SBR) is -40.2dB. The dynamic range is 64dB.

6. Conclusion

A new range-finding system, which is based on light-section method with the modulated light and the image sensor that can detect the modulated light, has been proposed. Adaptive charge unit (ACU) is employed to avoid saturation for wide dynamic range. Simulated results show that the proposed image sensor can detect the modulated light. The minimum SBR is -40.2dB and the dynamic range is 64dB in simulation. Our future work is the measurement of the present image sensor and the development for advanced 3-D measurement applications.

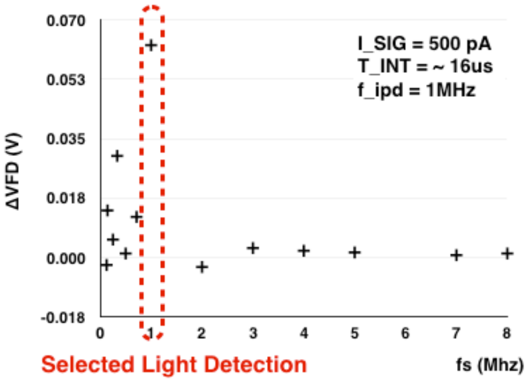

Fig. 6. Frequency Detection

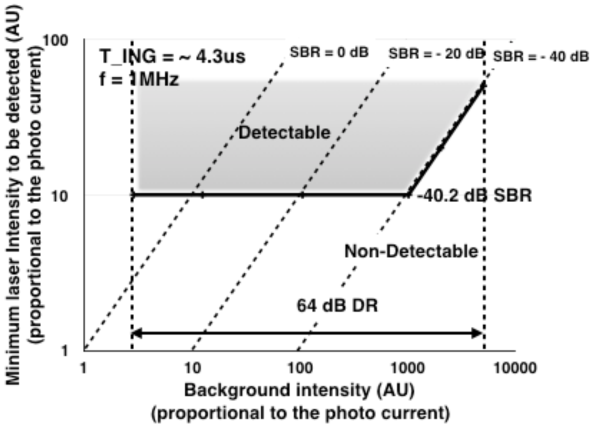

Fig. 7. Signal Background Ratio

7. Acknowledgment

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