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A 3-D Binocular Range Sensor LSI with an Enhanced Correlation Signal

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Introduction

In recent years measures to prevent traffic accidents are being developed. Among them is the research of cameras and radars that are used in obstacle detection systems. These systems are able to successfully detect obstacles, but they remain impractical because of their high cost.

We developed a binocular range sensor LSI that solves this problem[1][2]. This LSI is a passive-type sensor, and its operation is based on the stereo vision. We achieved a low cost and small size obstacle recognition system by integrating two image sensors and all the processing circuits on a single chip. High speed processing was also achieved by using parallel processing of the data.

The binocular range sensor LSI we developed is capable of detecting objects in 3-Dimensions and has improved obstacle detection ability. Because of these improvements, we can detect the 3-D position of multiple objects.

Chip Level Configuration

The binocular range sensor LSI we developed is composed by two image sensors, 2 sets of 128 APWC (Analog voltage to Pulse Width Conversion) circuits, difference circuits, ICC (Invalid Correlation Canceling) circuits, 2 sets of 256 DSWM (Differential Signal Width Modulation) circuits and an array of correlation circuits.

Figure 1 shows a microphotograph of the binocular range sensor LSI. The left and right image sensors have an array of 128 columns by 16 rows each. By processing their output data we are able to obtain the 3-D distance information of multiple objects. The APWC circuit changes the photosensor output voltage into a corresponding pulse width. Figure 2 shows the difference and the ICC circuit. The difference circuit compares the output of two adjacent APWC circuit. The difference circuit's output is determined by the difference between the two pulses. The ICC circuit observes the validity of the differential signal. In the case of no differential signal (no pulse appears) the output is a fixed pulse. The correlation circuit is shown in Figure 3, an example of the operation time chart is shown in Figure 4. The voltage Vc on the capacitor Cx represents the correlated value. This Vc changes according to the coincidence degree of the input signals from the left and right ICC circuits. When the left and right inputs are exactly the same, the reset voltage is stored as Vc. Vc decreases as long as there is a difference of inputs from left and right ICC circuits. When there is no input pulse (differential value is zero) Vc is forcibly decreased by the fixed pulse from the ICC circuit. This operation eliminates the correlation of the places with no brightness difference. There is a 128x127 correlation circuit matrix on the LSI chip. This circuit matrix matches and measures, at the same time, the coincidence degree of all the differential outputs of 1 row of photo sensor in the left and right image sensors. That coincidence value is stored as a charge on a capacitor in each correlation circuit. This correlation process is done in 1μsecond. When the stored value is outputted, the next row of photosensors is processed and outputted. This operation is repeated 16 times.

Correlation Signal Enhancement

In conventional binocular range sensor LSI the correlation signal is weak. The conventional correlation output is shown in Figure 5. The correlation signals from the same object should be stronger than the correlation signals from different objects. But in the measurement results we can see that both correlations are almost the same. This is because the decrease of Vc is small in the correlation signals from different objects, when the input pulse width is short.

We equipped a circuit that modulates the differential signals to improve the correlation response. Figure 6 shows this DSWM circuit. This circuit modulates the signal and removes the noise generated by the characteristic dispersion of the APWC circuit and the difference circuit. We realized these functions by controlling the response time adjusting the gate voltage of two inverters. The width of the pulse to be removed is determined by the control voltage Vnc. Also, the modulation of the pulse width is determined by the control voltage Vpm. The correlated signals become clear by the enlargement of the differential signals. As a result, the recognition ability of multiple objects has been improved.

Measurement Results

The developed LSI chip was produced using a process of 0.35μm CMOS 1-poly 3-metal and has a die size of 4.20mm x 3.33mm. The chip uses a 3.0V supply voltage and has a power consumption of 280mW at a clock frequency of 10MHz.

The measurement view of the 3-D positions is shown in Figure 7. It also shows the results for 3 of the 16 lines. The correlation signals from the same object become clear, but when the signals from different objects correlate they are not recognized as an obstacle. As a result, we were able to simultaneously detect the 3-D position of three different objects. The output time for one 3-D frame is 26msec. The frame rate is limited to 38 frames per second at the most.

Conclusion

We improved the obstacle detection ability of the binocular range sensor LSI by equipping it with a circuit that modulates the differential output signal of the photosensors. Therefore, this LSI was able to simultaneously detect the position of multiple objects. Furthermore, we were able to confirm that detection of the 3-D position of multiple objects by integrating two sets of 128x16 photosensors.

Acknowledgement

This work was partly supported by a grant of Knowledge Cluster Initiative implemented by Ministry of Education, Culture, Sports, Science & Technology (MEXT). Also, we are grateful for the technical support provided by Vitec System Engineering Inc. and Stanley Electric Co Ltd.

References

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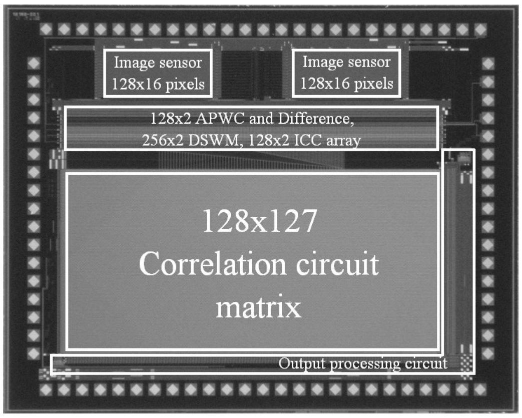

Fig.1 Chip microphotograph

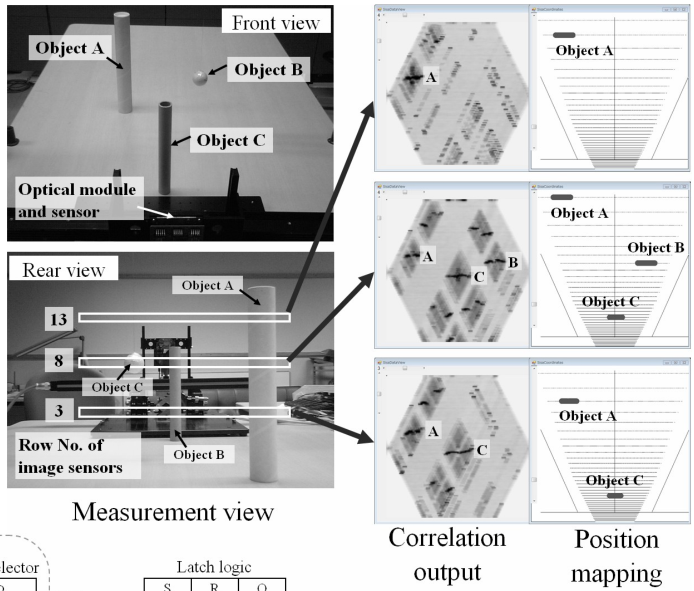

Fig.7 Measurement results of detect 3-D position

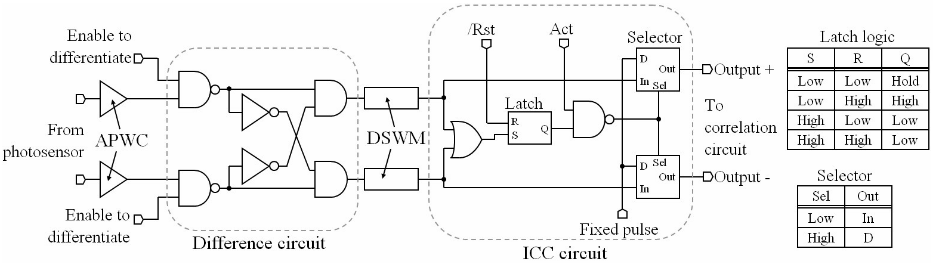

Fig.2 Configuration of difference circuit and ICC circuit

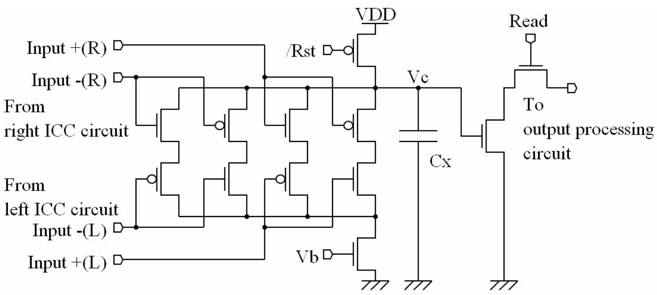

Fig.3 Configuration of correlation circuit

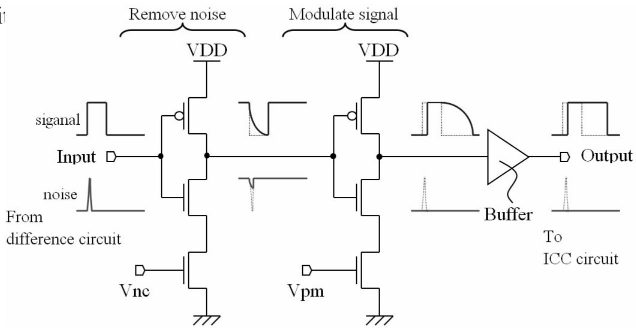

Fig.6 Configuration of DSWM circuit

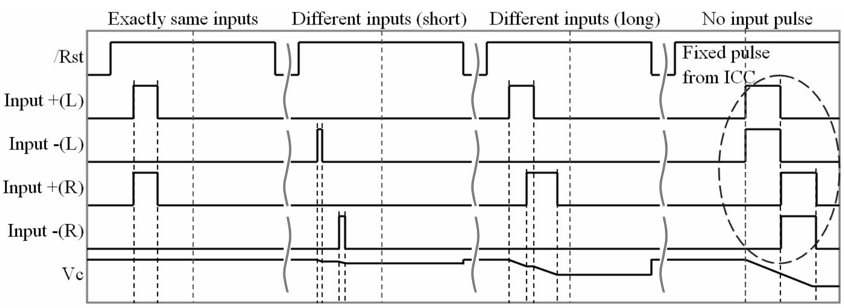

Fig.4 Timing chart of correlation circuit

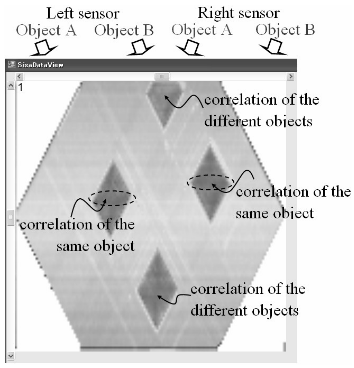

Fig.5 Conventional correlation output