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Development of a 32-Channel Readout Circuit for X-ray Cargo Inspection

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1. Introduction

In recent years, the X-ray cargo inspection system has been rapidly being installed at ports, airports, and borders to strengthen the security of baggage and the prohibition of transaction with drugs and contraband. Now, we at Korea Atomic Energy Research Institute (KAERI) are developing the X-ray cargo inspection system to meet these trends. This system is composed of a linear accelerator (LINAC) X-ray source, detector arrays for converting X-rays to electronic charges, a readout circuits for collecting and amplifying signal charges, a data acquisition (DAQ) system for converting analog image signals to digital image signals, and a control unit for processing the image. Among these components, it is the detector array and the readout circuit that determine the quality of the X-ray image, that is, sensitivity and dynamic range. In this study, a 32-channel charge sensitive readout circuit was developed. The implementation of readout approach is described and the experimental results are presented.

2. Methods and Results

2.1 Circuit Design and Fabrication

The block diagram of the 32-channel readout circuit is shown in Fig. 1. It is composed of 8 photodiode arrays (4 photodiodes per array, 2 mm pitch), 32 hold switches, 32 charge integrators, 32 reset switches, 32 sample-and-holds, 32 output switches, an output buffer, a frequency divider (divide by 4), and a 32 bit shift register.

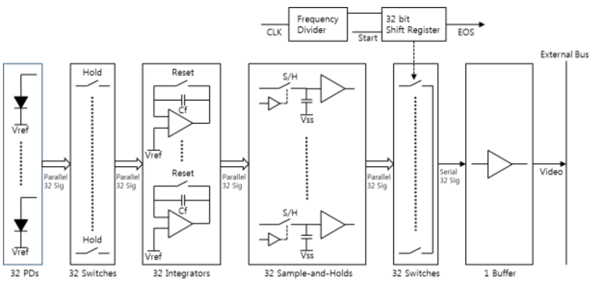

Fig. 1. Block diagram of the 32-channel readout circuit.

The charge integrators and sample-and-holds were designed using commercially available operational amplifier having low noise, low power consumption, high open loop gain, high gain bandwidth product characteristics, and low input capacitance. The frequency divider was constructed with two J-K flip-flops which are serially connected to acquire frequency divide by 4 and the 32 bit shift register was also constructed with four 8 bit shift registers in the same way.

The timing diagram of the 32-chnnel readout circuit is shown in Fig. 2 (low level effective). In the reset phase, the charges on the feedback capacitor of the integrator are discharged with the photodiodes floated. In the integration phase, the signal charges generated by the photodiode arrays is integrated and converted to voltage signal by the charge integrator. In the sample phase, the voltage signal is stored by sample-and-hold and the voltage signal per channel is serially read out through one output buffer by the sequential switching of the shift register. All the input pulses such as hold, reset, S/H, start, and clock to control the switches are from the control unit.

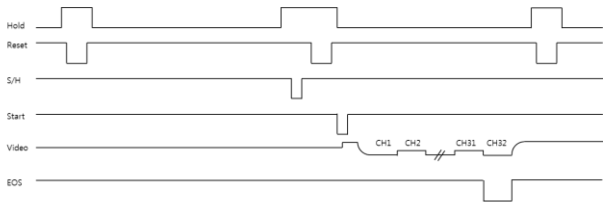

Fig. 2. Timing diagram of the 32-channel readout circuit.

To verify the operation of the 32-channel readout circuit, the PSpice circuit simulation was performed for 4-channel readout circuit shown in Fig. 3 when four current pulses having different amplitudes are applied to each channels. Green lines are the output pulses, and it was found the all the components comprising the readout circuit normally operate. Based on these simulation results, the readout circuit was extended to 32 channels.

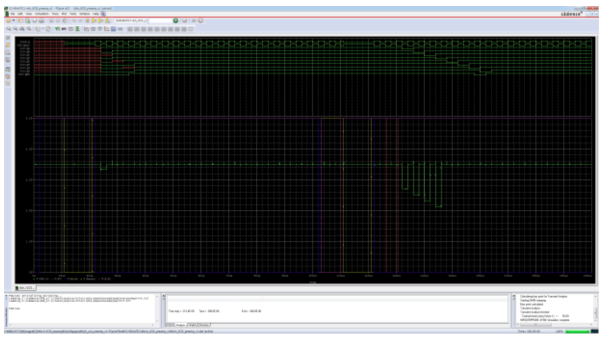

Fig. 3. PSpice simulation results of the 4-channel readout circuit.

The printed circuit board (PCB) was designed considering placement of the devices, routing and ground plane to minimize noise and signal loss. The PCB of this readout circuit has eight female headers for mounting the photodiode arrays on and one male header for communicating to DAQ system. The size of this board is 135 mm × 71.5 mm.

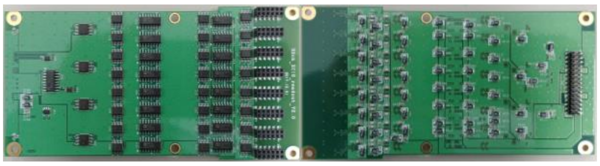

Fig. 4. The fabricated 32-channel charge sensitive readout circuit having eight female headers for mounting photodiode arrays and one male header for communicating to DAQ system. The board size is 135 mm × 71.5 mm.

2.2 Experimental Results

To test the performance of the 32-channel readout circuit, the experimental setup was configured with two 32-channel readout boards, 64-channel DAQ system, control unit, and image capture software. The 64-channel DAQ system is developed by our group, and the others such as photodiode arrays, control unit, and image capture software are supplied by Detection Technology Oyj. To investigate the variation of the output video signal according to the light intensity (including without light), any 8 ones among the 16 headers were used by mounting 8 photodiode arrays on.

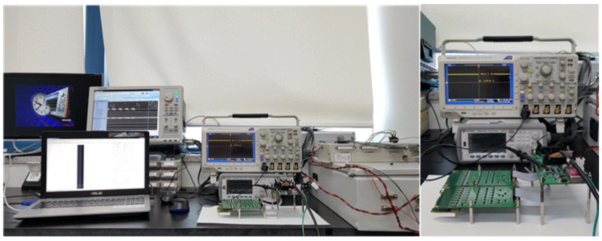

Fig. 5. Experimental setup configured with two 32-channel readout circuits mounting 8 photodiode arrays, 64-channel DAQ system, control unit, and image capture software.

The output pulses (video signal) of the readout circuits were measured through the oscilloscope when the visible light was exposed to photodiode arrays shown in Fig. 6. The positions of the headers equipped with 8 photodiode arrays are 1, 2, 6, 8, 9, 12, 13, and 15. In the absence of mounted photodiode, there is no signal current flowing through this channel. Since there is no change in the output signal voltage, the output pulses maintains 5 V. On the other hand, in a channel equipped with photodiode arrays, the signal current continuously flows, so that the output pulses saturate to about 380 mV. In same conditions, the acquired image is shown in Fig. 7. The rightmost is channel 1. When the amplitude of the readout output pulse is 5 V, the color of the image is black, and it becomes brighter as is decreases to 0 V.

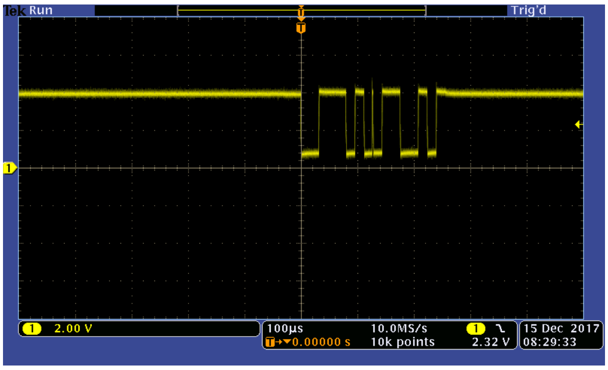

Fig. 6. Output pulses (video signal) of the readout circuits measured through the oscilloscope.

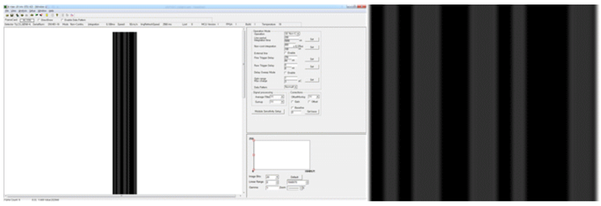

Fig. 7. Image captured when the visible light is exposed to 8 photodiode arrays.

3. Conclusions

The 32-channel readout circuit for X-ray cargo inspection system was developed. It is known that the 32-channel readout circuit successfully operates through measuring the amplitude and pattern of the output pulse and acquiring the corresponding images.

ACKNOWLEDGEMENTS

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