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Advanced LiDAR SoC for Automobile Range-Imaging

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Abstract:

For ultimate reduction of traffic jams and car accidents, automobile makers and software developers are enthusiastically developing self-driven cars. Upon realizing a self-driven car, long-range (200m) and high image quality depth sensors are essential for launching safe and reliable self-driving programs of Level 4 and above. Conventional sensors fail to cover both two aspects, mm-radars measure long distances but its resolution is limited. Cameras deliver high resolution 2-D images but transferring to 3-D with machine learning introduce uncertainly for long range objects. LiDAR can achieve both by directly measuring the distance to the object with time-of-flight (ToF).

LiDARs are based on mainly two types of ToF detection technique, Indirect-ToF (I-ToF) and Direct-ToF (D-ToF). IToF-based LiDAR once converts ToF information to charge or voltage by using a linear-mode avalanche photodiode (APD) and detects the target distance in similar manner as CMOS image sensors to obtain high pixel resolution. However, I-ToF is not suitable for long-range measurement, since APD has relatively low-gain compared to a high-gain Geiger-mode operated APD with quenching circuits also known as Single-photon avalanche diode (SPAD).

D-ToF based LiDAR directly measure ToF information by using high-sensitivity SPAD, hence, suitable for long-range measurement.

This paper presents advanced D-ToF LiDAR SoC to realize reliable self-driving systems. Proposed SoC adopts the smart accumulation technique (SAT) to improve a LiDAR Signal-to-Background Ratio (SBR) and to achieve both 200m and high-pixel-resolution range imaging, which was untrodden with conventional LiDARs. The “smart” accumulation is realized by utilizing simple object recognition with small circuit overhead and when compared to conventional “simple” accumulations, the LiDAR range is enhanced without degrading the pixel resolution. However, to realize and implement the SAT algorism, amplitude detection by high-cost ADC is necessary. We also present a TDC/ADC hybrid architecture to achieve a wide-distance-range LiDAR with a small silicon area and short-range precision. Moreover, to minimize the ADC cost, a residue-quantizing noise-shaping (RQNS) SAR ADC is proposed.

LiDAR measured with 240x96pixels at 10FPS achieves a measurement range of 200m with a 70klux direct sunlight: the measurement range is 2x longer than conventional designs. Furthermore, our LiDAR achieves 4x higher effective-pixel-resolution compared to conventional designs using simple accumulation. Furthermore, a 3D point-cloud image acquired with a real-life environment is disclosed