Raj Patel
Advisor: Xiaoli Ma
Team #18: Meterrific

Efficient Distance Sensing Technology for Smart Parking Meters

Introduction

Curb-side parking is often difficult and time-consuming to locate, especially on busy days. Since parking meters are typically available within city parking, parking meters can be upgraded to broadcast the presence of vehicles in parking spots and decrease the time spent on searching for open parking spots. The process of physically tracking vehicles requires low current draw but relatively high maximum range distance sensing technology so as to not burden the available power of the parking meter. This paper reviews distance sensing applications, underlying technology, and the implementation of distance sensing in a smart parking meter.

Commercial Applications of Distance Sensors

For the power and location constraints of a parking meter, a technology with an efficient balance between lower current drawn and higher maximum distance range is required. More specifically, a vertical-cavity light-emitting laser (VCSEL) offers a focused, circular, and perpendicular-to-surface beam for a trade-off of lower current drawn and lower, but manageable, maximum distance range not found in other technologies; for example, another light-based technology is the conventional edge-emitting laser which produces a divergent and parallel-to-surface beam and, although a higher maximum distance range is achieved than VCSEL, it requires a higher threshold current [1].

Since VCSEL only emits light and does not sense it, STMicroelectronics manufacturing combines VCSEL and Single Photon Avalanche Diode (SPAD), a technology used to sense light, into various time-of-flight sensor packages [2]. DigiKey distributes the STMicroelectronics VL6180X module with a price break of 1 for \$4.64 and price break of 5000 for \$2.176 [3]. The VL6180X model has a maximum distance sensing range of around 10 cm, a maximum current draw of 4 mA, a default sampling rate of 10 Hz, and an accuracy of about ± 5 mm [4].

Pimoroni Ltd manufactures a breakout board for another one of STMicroelectronics's time-of-flight models, VL53L1X. DigiKey distributes this breakout board with a price break of 1 for \$15.30 [5]. The VL53L1X model has the same sampling rate of 10 Hz as the VL6180X model. It also has a maximum distance sensing range of around 4 m, which is 40 times better than the distance measurable by the VL6180X model. Although the VL53L1X offers a much farther maximum distance sensing range, it has an accuracy of ± 25 mm, which is five times worse than the accuracy of the VL6180X model, and it also has a maximum current draw of 18 mA [6]. The breakout board itself includes reverse polarity protection and a Python library to easily operate the time-of-flight sensor package on board [7].

Technology of Time-of-Flight Distance Sensors

As mentioned earlier, the time-of-flight distance sensing package is a combination of VCSEL and SPAD technology. The sensor operates on the premise of emitting and sensing light and the time between the two actions. The VCSEL component emits a burst of photons towards a target perpendicular to the component. The target reflects a portion of the photons sent out. The SPAD component senses the partially reflected photons as small pulses. The sensor then measures the time between sending out the photons and the generated pulses from receiving the photons to get a time-of-flight. Then, the time is converted to distance based on the speed of light [2].

VCSELs have been around for decades and have been commercially used in optical-solution consumer products, like the optical mouse. Recently, VCSELs have seen more research and development as interest increases for applications like facial and gesture recognition and is shown by patents making accuracy and reliability improvements [8]-[9].

Implementation of Time-of-Flight Distance Sensors in Smart Parking Meters

Time-of-flight distance sensing technology is primarily available in terms of I^2C communication [4]. A microcontroller with an I^2C module is a bare minimum requirement to run a time-of-flight distance sensor. With a microcontroller capable of running RTOS, the time-of-distance can be combined with other I/O devices which otherwise would be difficult with the sampling necessary for smooth operation. In terms of software, a bare metal I/O device driver will be necessary to operate the time-of-flight sensor and perform the necessary calculations for accurate distance measurements. To operate the time-of-flight sensor, a minimum of 2.7 V and, on average, 1.7 mA must be allocated when determining a power source; these specifications are specifically based on the VL6180X model [4].

References

[1] "Comparing Edge-Emitting Laser and VCSELs," *dentonvacuum.com*, July 23, 2019. [Online]. Available: https://www.dentonvacuum.com/comparing-edge-emitting-lasers-and-vcsels/. [Accessed Sept. 25, 2019].

[2] J. Kvam. Lecture, Topic: "Time of Flight: Principles, Challenges, and Performance." ST Technology Tour, 2017. Available: https://www.st.com/content/dam/technology-tour-2017/session-1_track-4_time-of-flight-technology.pdf. [Accessed Sept. 25, 2019].

[3] "Optical Sensors – Ambient Light, IR, UV Sensors," *digikey.com*, Sept. 25, 2019. [Online]. Available: https://www.digikey.com/products/en/sensors-transducers/optical-sensors-ambient-light-ir-uv-sensors/536?k=VL6180X. [Accessed Sept. 25, 2019].

[4] STMicroelectronics, "Proximity and ambient light sensing (ALS) module," VL6180X datasheet, Sept. 2013 [Revised Mar. 2016].

[5] "Pimoroni Ltd PIM373," *digikey.com*, Sept. 25. 2019. [Online]. Available: https://www.digikey.com/product-detail/en/pimoroni-ltd/PIM373/1778-1228-ND/9565561. [Accessed Sept. 25, 2019].

[6] STMicroelectronics, "A new generation, long distance ranging Time-of-Flight sensor based on ST's FlightSense™ technology," VL53L1X datasheet, Feb. 2018 [Revised Nov. 2018].

[7] Pimoroni Ltd, "VL53L1X Time of Flight (ToF) Sensor Breakout," PIM373 datasheet, Aug. 2018.

[8] A. Weigl, "Vertical cavity surface emitting laser (vcsel) device with improved reliability," European Patent 3493337A1, 30 Nov., 2017.

[9] G. Overton, "Yole says Apple 3D sensing strategy VCSEL growth," *laserfocusworld.com*, July 27, 2018. [Online]. Available: https://www.laserfocusworld.com/lasers-sources/article/16571638/yole-says-apple-3d-sensing-strategy-is-pushing-vcsel-growth. [Accessed Sept. 25, 2019].