TI TechNotes

PGA460-Q1 in Ultrasonic Park Assist (UPA)

Brian Rodriguez and Akeem Whitehead, Sensor Products

TEXAS INSTRUMENTS

Ultrasonic park assist is also known as a parking assist system, parking guidance system and reverse park assist. These systems vary from simply detecting an object's presence and alerting the driver with a noise to autonomously parking the car with little to no driver interaction. Typically, these systems have between four and 16 sensors placed strategically around the car to provide the desired detection coverage, see Figure 1.

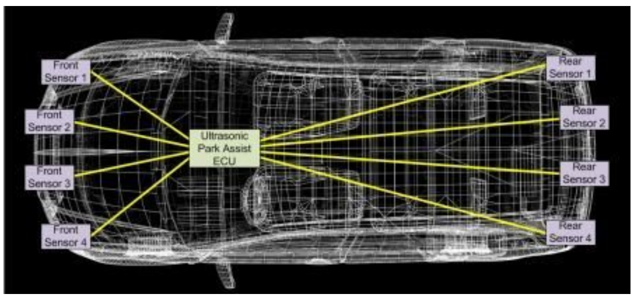

Figure 1. Ultrasonic Park Assist Star Configuration Using The PGA460-Q1

Engineers designing these types of applications should seek out integrated circuits (ICs) driving an ultrasonic transducer (transmitter) while receiving, conditioning and processing the ultrasonic echo that determines the distance of an object from the vehicle. For example, the PGA460-Q1 can reliably detect an International Organization for Standardization (ISO) pole (polyvinyl chloride [PVC] pipe used in ultrasonic park assist as a performance standard) up to 5m away. The device has also passed stringent electrostatic discharge (ESD) and bulk-current injection (BCI) testing – common tests performed during ultrasonic park assist system developments.

Ultrasonic park assist cost pressures will continue to increase over the next several years as original equipment manufacturers (OEMs) face the need to add more ultrasonic sensors per vehicle. The PGA460-Q1 supports a competitive cost structure for high-volume Tier-1 suppliers.

Common requirements in today's ultrasonic park assist modules include:

- Object detection from 30cm to 5m (for today's UPA systems)
- Time command interface (TCI) or Local Interconnect Network (LIN) communication from the module to a local electronic control unit (star configuration) or directly to the body control module (BCM) (LIN bus configuration).
- Low average active current
- A digital processing engine such as a state machine
- Automotive qualification with ambient temperature ratings for 40°C - 105°C

In order to meet the needs of autonomous vehicles, short-and long-distance object-detection standards will become more stringent. In longer term platform developments, ultrasonic modules will be required to detect objects from <10cm to 7m+ away. Improvements in analog front end (AFE) sensitivity and advanced digital processing by semiconductor ASIC suppliers will be crucial in meeting these distance requirements.

TCI and LIN are the two most common communication interfaces in ultrasonic park assist systems today. However, as vehicles advance in their advanced driver-assistance system (ADAS) vision-processing abilities, expect the use of higher-speed protocols like Peripheral Sensor Interface (PSI) 5, Distributed Systems Interface (DSI) 3 or Controller Area Network (CAN) to communicate larger amounts of ultrasonic echo data.

Performance Considerations

The ability for the ultrasonic system to accurately convert a time-of-flight measurement to a one-way distance is based on temperature, humidity, transducer sensitivity, emitted sound pressure level, transmission medium, and target characteristics. In automotive systems, hermetically sealed transducers with minor drift in resonant frequency and decay time across temperature and humidity are necessary to maintain the quality and robustness of the sensor's performance as it is exposed to various climates, severe weather scenarios, hot-and-cold seasons, and road debris. TI has worked closely with several transducer manufacturers, such as muRata Electronics, to test and ensure the PGA460-Q1 is able to function properly in conjunction with passively tuned automotive grade transducers to provide a completely optimized and partnered ultrasonic parking assist solution.

Due to the additional protection offered by automotive grade transducers, the emitted sound pressure level (SPL) is weaker in magnitude when compared to standard ultrasonic transducers. A loss in SPL results in the ultrasonic echo attenuating to an undetectable level much sooner as the echo travels through the medium of air. For this reason, PGA460-Q1 ranging is typically limited to a maximum of 5 to 7m when targeting the ISO pole object. The ISO-pole is considered to be a worst-case target due to its single axis of sonar cross section returning the echo towards the immediate direction of the transducer.

When maximum ranging requirements are less stringent (sub-3m), automotive ultrasonic sensor modules can substitute the traditional boost-transformer with a bridge-driver solution to excite the transducer. Since the boost-transformer is used to excite the automotive transducer with a sinusoidal drive voltage equivalent to the maximum rated drive voltage of the transducer (>100Vp-p) in order emit the maximum amount of SPL, a bridge-driver will suffice when only a fraction of the maximum SPL is required. The percentage of maximum SPL rises logarithmically as a function of excitation voltage, thus transducer excitation can be controlled by driver type and referenced voltage.

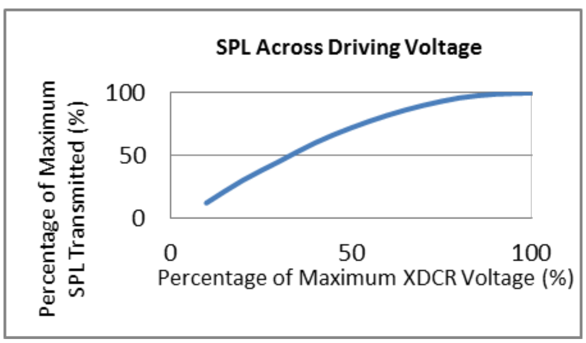

Figure 2. Transducer Sound Pressure Level as a Function of Excitation Voltage

Transducer manufacturers are advancing piezoelectric technology to produce next generation automotive transducers. These transducers will be more sensitive and require lower maximum drive voltages to generate maximum SPL for use with bridge-driver types to achieve ranging beyond 7m and minimize decay ringing to sub-10cm. At present, the transformer driven solution offers superior long distance ranging and the ability to fine-tune the transducer decay ring time due to the inductance introduced by the transformer's secondary side. Thus, the transformer driven solution is recommended for most ultrasonic parking assist applications today (2017).

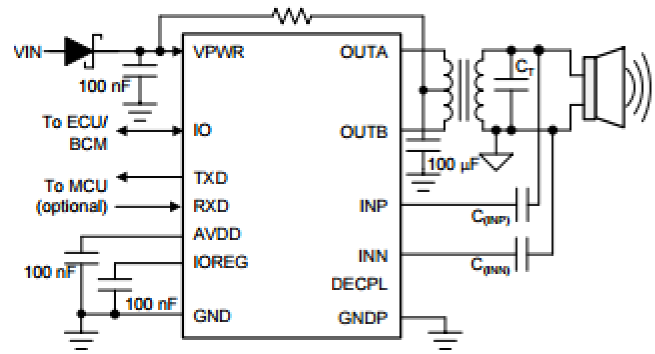

Figure 3. PGA460-Q1 Transformer Driven Schematic

PGA460-Q1 Automotive Ultrasonic Signal Processor and Transducer Driver

The PGA460-Q1's system on-chip approach incorporates all the requirements of an SoC for ultrasonic park assist solution. The output driver can be used to set the number of pulses and limit the drive current to control the amount of SPL generated. By optimizing both variables, the user is able to balance the ringing decay time while maximizing the signal-to-noise (SNR) of the return echo amplitude at long distances. Simply maximizing the number of pulses and drive current limit will saturate the SNR for maximum ranging, but will extend the ringing decay time, dissipate excess excitation energy as heat, and reduce the lifetime of the transducer. Therefore, limiting these variables is recommended to optimize overall module performance.

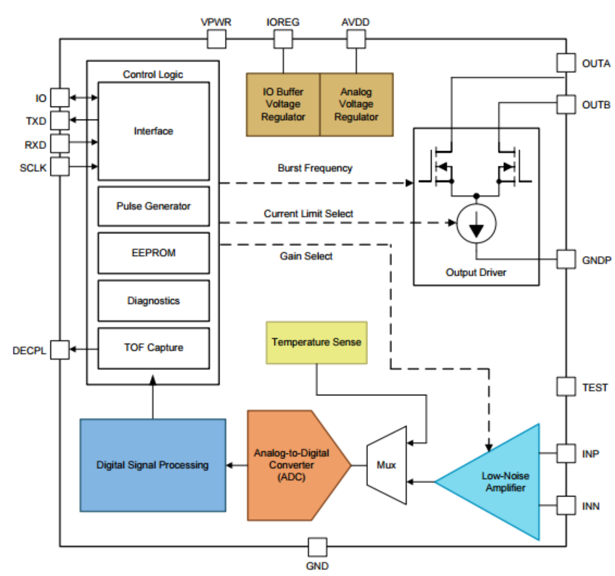

Figure 4. PGA460-Q1 Block Diagram

When receiving the returning ultrasonic echo, the low noise amplifier (LNA) and programmable gain amplifier (PGA) at the analog front end ensure the return echo strength's magnitude is large enough to be digitized for digital signal processing. The implementation of a time variable gain allows for both short and long range reflections to be captured in a single window without saturating or attenuating the amplitude of either. The digital signal processing block attempts to extract and compare the ultrasonic echo details to a user configured threshold. This threshold comparator is used to indicate when a reflected echo has been detected, and records the time-of-flight, peak amplitude, and width of the echo. The user is able to read the resulting ultrasonic measurement values, or read and plot the echo data.

For automotive implementations using the PGA460-Q1's One-Wire UART (OWU) interface, or LIN equivalent, the aforementioned means of data extraction must be used. However, when using the Time Command Interface (TCI), the threshold comparator forces a real time response on the PGA460-Q1's IO pin by pulling the pin low while the return echo signal exceeds and crosses the threshold level. TCI is limited to a star topology implementation, while OWU can be either star or 8-device bus topology since the PGA460-Q1's 3-bit UART address is utilized in this communication mode.

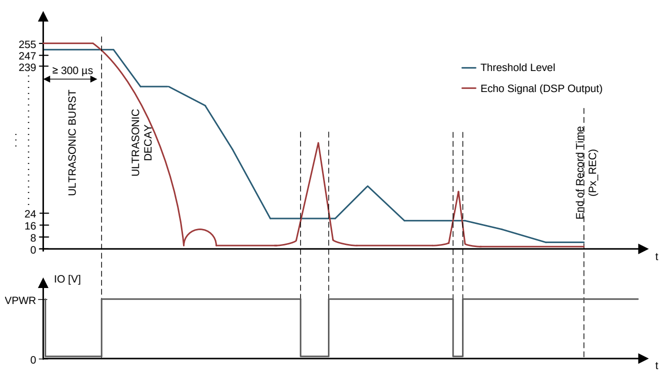

Figure 5. Time Command Interface and Threshold Comparator

The PGA460-Q1 offers an on-chip temperature sensor to monitor changes in temperature to inform the user that the speed of sound must be updated and set as a function of the current temperature. In addition to temperature, the PGA460-Q1 includes system diagnostics to monitor the transducer's resonant frequency, ringing decay time, excitation voltage and ambient ultrasonic noise level to determine if the ultrasonic sensor module is operating as intended or if the sensor is obstructed with a foreign substance, such as ice, mud, or dirt on the bumper.

Due to the flexibility in driver and receiver configuration, as well as the ability to monitor and diagnose the health of the sensor module, the PGA460-Q1 can be paired with most automotive transducers to enable the ultrasonic parking assist module.

Additional Resources

- Order the PGA460-Q1 Evaluation Module (EVM).
- Watch PGA460-Q1 EVM Training Video Series.
- Download the PGA460 Frequently Asked Questions (FAQ) and EVM Troubleshooting Guide.
- Download the PGA460 Ultrasonic Module Hardware and Software Optimization application report.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (July 2017) to A Revision	Page
• Added added author Akeem Whitehead to TechNote	1

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