WHITE PAPER

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Transforming Performance to Safety in Automotive Applications

Abstract

Automotive vehicles clearly bring great value to society, providing a cost-effective means of transporting goods and people all over the world. Unfortunately, there are a corresponding number of automotive accidents and fatalities which continue to increase worldwide, prompting the World Health Organization to project automotive-related deaths as the number three cause of death by the year 2010, up from number nine in 2002. Together, the auto industry has been working with governments around the world, from both a regulatory and technology standpoint, to reduce the number of automotive-related deaths. Through increased driver education and awareness of potential hazards, the automotive industry is striving to promote accident avoidance and prevention to increase overall automotive safety.

Active safety and advanced driver assistance systems (ADAS) are the primary focus of current efforts to implement improved safety in vehicles.

(Continued next column)

Touted by automotive analysts as the top new technology for 2010, active safety and ADAS promise either increased accident avoidance or a reduction in crash severity. High-growth application areas, with projected unit CAAGRs in excess of 50 percent over the next five years (source: *Automotive Semiconductor Forecast 2004–2013: Safety and Convenience Electronics Key to Growth*, page 10) include lane departure warning systems (LDWS), drowsiness detection, and night vision.

When married with marketing efforts focused on educating consumers as to the benefits provided by these systems, high consumer acceptance and demand is anticipated. For automotive OEMs, active safety and ADAS provide the added benefit of offering product differentiation as engine, passive safety systems, and infotainment equipment becomes standard in today's intelligent vehicles. TI, with its DaVinci™ technology and new TMS320DM643x processors specifically designed and optimized for automotive safety applications, brings the advanced technology OEMs need to bring active safety and ADAS to market today.

Active Safety and ADAS System Basics

Active safety and ADAS, however, are not protection systems designed to take over automotive control from human drivers. Rather, these systems are designed to improve overall automotive safety by providing the driver with relevant information about the operating and environment conditions surrounding a vehicle. Typically, these systems will issue appropriate warnings that alert drivers to potential danger, although in specific instances active safety systems may intervene, such as in adaptive cruise control. Active safety systems are currently in the early phases of implementation in luxury cars and the technology is expected to become available in all classes of automobiles, bringing higher volumes and greater cost economies as the relevant technologies mature.

Examples of active safety systems currently being developed and deployed in vehicles include lane departure warning, lane keep assistance, traffic sign recognition, blind spot detection and drowsiness detection. Many active safety systems use an image sensor to collect visual data. This data is then processed to extract features that allow object detection and object tracking.

Across ADAS applications it is possible to use different types of sensors to collect environmental information: blind spot detect system usually uses an infrared sensor or imaging sensor, adaptive cruise control utilizes RADAR or LIDAR, and ultrasound sensors are used to aid applications such as parking assist, to name a few. Traffic sign recognition application usually relies upon forward facing color image sensor. Grayscale image sensors are more widely used for other applications since they are more sensitive to light. Image sensors used in some active safety applications have dynamic range exceeding 8 bits per pixel. At high level, data processing steps for each of these applications are similar: capture data, prepare it for processing, perform specialized processing, evaluate the results, and then take action (see Figure 1).

For example, to implement lane departure warning, the system needs to recognize road lanes and track their position. In case the car is crossing over the lane without a turn signal, the system alerts the driver accordingly. Similarly, the traffic sign recognition system is using data captured from an imaging sensor to detect and recognize individual sign types. For example, it may be appropriate for a driver to accelerate when coming up on a 65 MPH sign, but not if the driver is approaching a stop sign. The drowsiness detection application is highly computationally intensive and it warns when a driver is "nodding off" or falling asleep behind the wheel.

Given the types of safety functions desired, it is necessary to place multiple sensors around a vehicle to increase overall coverage. For example, lane departure uses data collected from front-view- or rear-view-facing sensors, traffic sign recognition system uses a front-facing sensor, and drowsiness detection uses a sensor mounted inside the vehicle and aimed directly on the driver.

Recognizing, tracking, and evaluating driving-related objects, however, is quite a complex process. Driving conditions can vary in a number of substantial ways, which affects

Figure 1. Sensors used to collect environmental information, regardless of type, produce data sets are essentially images. The overall processing chain for active safety systems is to 1) capture data, 2) pre-process captured data for operational and environmental conditions, 3) process safety algorithms, 4) evaluate results, and 5) take action.

the quality of data collected by sensors. For example, these systems must be able to operate during day or night, whether the vehicle is moving quickly or slowly, as the vehicle changes lanes, and under a variety of weather conditions including bright sunlight, rain, fog, and snow, all of which can obscure important details necessary for evaluating driving conditions. Additionally, all processing must be done in real-time with processing latency not greater than 30 ms. A half-second of latency in warning may be the difference between a driver responding in time to an alert and an accident.

Sensors installed on a vehicle provide a piecemeal picture of the environment inside and outside the vehicle. Every sensor installed on a car is going to provide some kind of additional information. It is necessary to coordinate all of the active safety and ADAS systems in a vehicle. While a number of the functions can be evaluated independently, in many cases, more accurate risk evaluation is possible when information from all of the sensors can be taken into account. Part of the challenge in designing these systems is determining not only if to signal an alert, but also when.

For example, consider a vehicle that has begun to drift out of its lane. This is a standard occurrence during a lane change and drivers will not tolerant an alarm going off every time they want to change lanes on the highway and forget to use the turn signal. However, if the driver is not currently looking at the road – i.e., looking to the side or nodding downward, as determined by the drowsiness detect function – then the lane departure function will increase the likelihood of signaling an alert. Clearly, where a driver is facing and focused has a direct impact on the effectiveness of an alert. When the driver is facing the direction of a potential hazard, the alert need not be triggered as quickly. Many other instances can be entertained: the vehicle is quickly approaching a stopped or slow vehicle in the current lane. A fast lane change is probably called for, and suppressing the lane departure alarm will avoid distracting the driver from successfully completing the maneuver. However, if Blind Spot recognition detects an object to the left of the car, the system should override the suppression.

Each stage of an active safety system requires significant signal processing resources. Overall, the systems require high-performance, real-time processing to implement driver assistance accurately and in a timely fashion. Given the signal processing nature of this task, digital signal processors (DSPs) provide the most efficient, high performance, and cost-effective approach to implementing such active safety systems.

Single-Chip Architecture Advantage

Since the many stages of active safety and ADAS systems are intimately tied to each other with a significant sharing of data taking place, it makes sense to run more than one application on a single processor. For example, the video captured from a forward-facing image sensor can be used to implement both lane departure warning and traffic sign recognition. The ability to process multiple algorithms simultaneously on a single DSP reduces latency and keeps the number of chips down, leading to fewer points of failure, increased system reliability, and lower system cost, all key factors to consider when developing robust automotive applications.

TI has designed its TMS320DM643x devices to meet the high-performance requirements and to minimize the cost. Consistent with DaVinci™ technology, these devices will also be wrapped with a complete development environment and software from TI to speed product development and implementation in early 2007.

Extreme Flexibility

An essential part of developing a robust active safety system is flexibility. As companies improve algorithms, they need to be able to implement them easily. A programmable software architecture gives developers such flexibility with high performance in a way that fixed ASIC implementations simply cannot. Programmable processors are also the ideal platform for fostering emerging technologies because innovation can be easily captured in software and then deployed.

Flexibility also plays an important role in managing the migration of active safety system intellectual property across international product lines. For example, traffic signs are slightly different from country to country. Speed limit traffic signs in European countries are round with red circle boundary, while in the US they have rectangular shape.

Efficient recognition techniques enable effective compression of traffic signs to a database of primitives. Programmable processors enable developers to easily swap out sign libraries/primitive databases. For many applications, it makes the most sense to store these libraries in flash memory. This way, currently active database of primitives can be dynamically swapped with the appropriate replacement from flash memory as a vehicle crosses between countries.

Dynamic flexibility of programmable DSPs can also increase overall processing accuracy and performance. A wide range of pre- and post-processing algorithms may be in use as well, depending upon the particular environmental conditions. For example, some OEMs choose a single algorithm to handle all environmental conditions. Others might use one algorithm to handle bright daylight environment and another for night driving.

However, driving environments can change in an instant, such as when a vehicle enters a tunnel. The system must be able to adapt as quickly.

The DaVinci™ development environment takes software programmability a step further by simplifying development and speeding time-to-market by enabling developers to create applications in C, as working in a high-level programming environment enables rapid prototyping of new algorithms. TI also provides a robust framework, which integrates key software components, such as the DSP/BIOS™ real-time kernel and system drivers for developers.

TI's industry-leading development environment, powerful application-specific tools, and extensive imaging libraries provide the final pieces developers need to be able to cut development time by months. The DM643x DaVinci processor is backwards compatible with TI's proven TMS320C64x™ DSP core. Not only does this enable designs based on DaVinci technology to leverage existing software IP, it demonstrates TI's commitment to maintaining stability across the TMS320DM64x™ devices, guaranteeing that automotive OEMs will be able carry their products based on DaVinci technology long into the future.

The DaVinci Effect

DaVinci technology offers the right processors for digital video applications, combining digital signal processing and video accelerator technology. The DM643x processors based on DaVinci technology provide all of the processing capacity required to handle multiple safety functions on a single chip, and these processors are integrated with all of the peripherals necessary for a complete video/imaging processing system. As a result, developers don't need to spend valuable time getting multiple components to work together as they have already been integrated.

For example, the TMS320DM6437 processor provides a powerful video front-end to handle key preprocessing functionality. A video back-end is also provided so that processed images can be displayed, such as for rear-view parking assist and night vision applications (See Figure 2 on the following page). From a peripheral perspective, three of the DM643x devices have an integrated high-end CAN controller, and SPI and UART peripherals, enabling it to tie into CAN or LIN bus of any automotive system. DDR2 memory support provides higher throughput to maximize system performance.

DM643x processors also provide specialized functionality optimized for active safety and ADAS applications. The video port front-end, for example, has several preprocessing blocks which can offload processing from the main processor, enabling more value-added active safety functions to be implemented on a single DSP. Specifically, the front-end offers a resizer block which can upscale and downscale an image to an appropriate

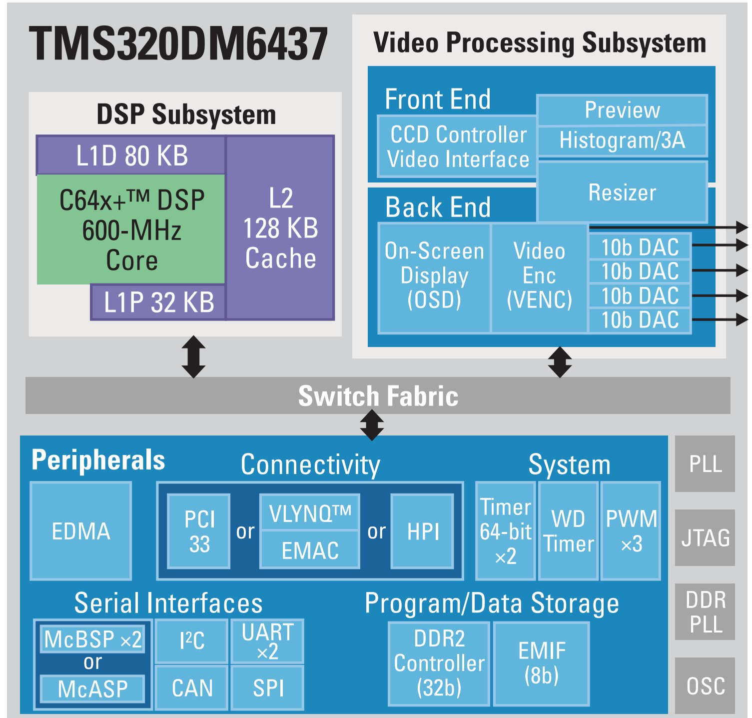

Figure 2. TMS320DM6437 digital media processor block diagram.

resolution without using CPU cycles. The resizer block can free the CPU cycles when a section of an image (region of interest) needs to be normalized to a predefined size.

The TMS320DM643x processor video port front-end supports BT656, YCrCb, or Bayer format. The video port front-end on the TMS320DM6435 and TMS320DM6437 processors also offers a histogram function which provides distribution of pixel intensities of the captured frame. Using information from the histogram, the DSP can adjust the contrast to improve recognition accuracy. The video port front-end is also capable of conversion from Bayer to YCrCrb color space freeing up the TMS320C64x+™ DSP core to perform other tasks.

Video processing involves large blocks of data. Processors have limited on-chip memory resources, so these must be managed carefully to minimize overall latency, especially when multiple algorithms are operating in parallel and sharing available resources.

Developers can ease the burden on memory resources by focusing on areas of interest and with the use of a fast L2 cache and enhanced DMA (EDMA). By using EDMA to preload the internal memory before data is needed, overhead of the CPU accesses to external memory can be reduced.

The DM643x processor EDMA v3.0 is capable of performing three-dimensional data transfers. The ports on predecessor EDMA v2.0 were limited to only two-dimensional transfers. Two-dimensional DMA transfer is sufficient when only one section of the image needs to be transferred from source to destination memory. In case multiple regions of the image need to be moved around support for the third DMA dimension is essential. Therefore, three dimensional transfers are useful when multiple regions-of-interest need to be transferred between external and on-chip memory that directly translates to higher efficiency.

The value of the DM643x processors is also enhanced by the many different configurations available and its extensive roadmap within DaVinci™ technology. With such scalable devices, developers have the option of designing using high-performance, large memory devices to ease development and then scaling back after proof of concept to performance and cost-optimized designs.

Finally, the DM643x DaVinci devices will be AEC-Q100 qualified. Such qualification is essential to OEMs desiring to place their products in automotive applications, as it ensures an acceptable defective parts per million (DPPM) rating. The DaVinci DM643x architecture has been designed from the ground up to ensure that OEMs will successfully meet challenging AEC-Q100 specs.

TI believes that engineers and business leaders are obligated to step forward and provide the appropriate technology to enable the automotive industry to drive down the number of automotive-related deaths by increasing focus on active safety and ADAS in vehicles. Such progress must also be coupled with a strong educational push to consumers to clearly define the benefits. TI's strong passion for innovation brings to customers the key technology and components required to enable the growing number of active safety and ADAS applications that are certain to reduce automotive accidents and deaths as they gain adoption. With its substantial investment in innovative hardware, software, and tools, as well as its recent creation of a team dedicated to developing active safety and ADAS technology, TI continues to demonstrate its industry leadership and its long-term commitment to vehicle safety and the automotive industry.

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