Best Practices for Embedding Megapixel Sensors

The use of sensors in medical devices has been increasing and will continue to do so with newer technologies. As such, learning more about the specifics of these components is essential for designers to be successful and provide the greatest array of capabilities in their products. This article looks specifically at image sensors and provides an excellent overview of the technology.

By Niels Wartenberg

Like most electronic devices, image sensors are smaller, faster, and far more economical than they were even a few years ago. The capabilities of image sensors today have dramatically increased, due in large part to the advancements of megapixel technology. Depending upon the application, engineers could replace four to ten sensors inside their device with a single megapixel unit, reducing the complexity of the device's design while also lowering its total cost of ownership (Figure 1).Imagers and other sensors are one of the most important components for ensuring accuracy of instrumentation. They can also be one of the most expensive. It is important to understand the key differences among the types of imagers available, the performance and value they provide, and their ease of integration.

Image Sensor Technology Advancements

To understand the performance advantages and application opportunities megapixel imagers provide, careful review of imaging technology options and the limitations of each is recommended. Laser scanners have historically been the most common type of data collection device embedded into medical devices. While laser has a distinct speed advantage, it is unlikely to remain the most commonly used technology because it is limited to strictly reading bar codes, where as an imager can perform a broader range of functions (Figure 2).An image sensor is a device that converts a visual image into an electric signal. Image sensors rely on a variety of technologies to perform this, but the majority use an array of CCD (charge-coupled device) or CMOS (complementary-metal oxide semiconductor) sensors such as active-pixel sensors. CCD-based imagers typically perform faster and collect light more efficiently. In general, they are often recommended for challenging, very low contrast or high-speed applications. CMOS sensors are usually less costly to manufacture and therefore provide a more cost-efficient solution. In the past, there has been a trade-off between cost and performance. However, CMOS technology

has improved so rapidly, that some sensors today rival the performance of CCDs.

Mini Megapixel Imagers

Most array imagers (both CCD and CMOS) read at VGA resolution (640 480) with 307,200 pixels. This has forced instrument designers to choose between resolution and field of view. The introduction of miniature (mini) megapixel imagers with SXGA resolution (1280 1024) and higher offers an array of more than 1,000,000 pixels (one megapixel), delivering a much larger field of view without sacrificing resolution (Figure 3). The large field of view allows the imager to read combinations of 1D and 2D symbols in a single pass. By reading large quantities and various types of codes at one time, the entire data capture process can be faster and more efficient.A few mini imagers take megapixel technology a step further by incorporating vision capabilities such as shape recognition and color identification. Designers have access to some of the functionality of a vision system with the footprint and price point of a mini imager designed for embedded applications. Besides reading both linear 1D and 2D symbols, an imager can serve as a presence/absence detector for tubes and caps, provide dimensional information for piercing, decapping and sorting systems, identify cap color, and more.

The trade-off to collecting a larger amount of information is the imager takes longer to process and output the data. The more information the imager collects, the longer the processing time. Subsequently, most mini imagers are not designed for high-speed applications, but are better suited for stationary or low speed applications.

Optical Sensors

If speed is a necessity, optical sensors may provide a solution. Optical sensors are considerably less expensive than an imager and can collect data at high speeds. However, a separate sensor may be needed for each type of data to be collected, and in some cases, several may be needed. For example, a multi-sensor solution integrated into a tube handling system designed for cap presence detection typically will only provide height information. Subsequently, this requires all the tubes to be properly seated in the rack. An improperly seated tube without a cap may be mistaken for a tube with a cap. In contrast, many mini imagers utilize shape information to determine cap absence or presence. Subsequently, mini imagers will yield the same absence/presence answer whether the tube is properly seated or not.In some applications, a general measurement is all that is needed. Other applications require absolute precision to ensure process errors do not occur. Careful consideration should be given to the capabilities and the limitations of the

imaging technology itself before choosing an imaging solution.

Accommodating Present and Future Data Needs

New data capture capabilities enable manufacturers and users alike to develop more efficient equipment and processes. As with all changes to established processes, integrating an imager requires planning and careful consideration of the effects the new system may have on the device and its relationship with supporting software systems. It is well known that devices typically enjoy a long life once they are installed within a medical facility. The challenge device designers face is how to accommodate legacy systems while, at the same time, building in functionality that will address tomorrow’s applications.Unlike many new technologies, megapixel imagers are completely compatible with legacy systems and do not obsolete older data collection systems. Their unique capabilities allow the device to address current needs, while also including future data capture capabilities that can be easily enabled by a software command. Multifunctional imagers also help reduce product cost and complexity by reducing the number of embedded sensors and components a device may be using to accomplish the same tasks.

Design Considerations

While megapixel imagers can help simplify the design process, specific requirements must be met for an imaging system to function properly within a medical device or diagnostic device. Imagers vary significantly in their suitability for embedded applications. Important variables include reliability, tolerance for environmental variables, speed, input/output capabilities, power draw and space requirements. Understanding these differences is essential for finding the best component for a specific device.

Calculating the Data Collection Envelope

Designers value compact components, and imagers are no exception. However, more important than the physical dimensions of the imager is the space required for capturing the desired data. This space, also referred to as the read envelope, is the total dimensional space required by the imager to decode a symbol at a specified distance. The read envelope is especially important in space-constrained situations such as embedded applications. The challenge in reading a symbol at a close distance is achieving a field of view large enough to span the entire symbol, or large enough to capture an object of interest. Imager size, read angle, and the distance from the imager to the symbol all comprise the read envelope and directly affect

how much space must be provided within the device for a specific imager to capture the desired information (Figure 4).Since each imager's optics are a little different, the required distance between imager and object will vary from imager to imager. Smaller envelopes have the advantage of less physical space required between the imager and the object of interest. Megapixel imagers offer additional positioning flexibility. Their larger field of view and omni-directional reading capabilities allow them to read bar codes in any orientation and in various directions of travel. High resolution sensors enable them to be more forgiving of damaged or poorly printed symbols as well as the ability to read tiny high density codes. Sometimes the optical path can be folded by using first-surface mirrors to manage the envelope size and shape (Figure 5).

Additional factors may also affect the imager's read envelope for a specific application. These include orientation, speed, ambient light, and symbol density (if the object of interest is a bar code). All should be taken into consideration.

Lighting Considerations

Lighting plays a very important role in imaging applications and can also be very application-specific. Imagers provide excellent performance in low-light conditions and many designed for embedded applications have an integrated light source. Typically, this is an array of LEDs. For vision applications employing color identification, white LEDs are ideal because they provide color-neutral illumination necessary for accurate color identification (Figure 6).Additional factors to consider depend on the type of data to be collected. For measurement and color identification, the color of the background behind the object to be captured is particularly important. A solid background is required for efficient shape recognition. The preferred color of the background is dependent on the illumination color and the optical filter used. For example, a black background has proven to be effective with white illumination.

Regulatory Concerns

The quality of the imagers and the quality certification of the vendor must also be considered, especially for medical device manufacturers. Because medical devices are under scrutiny by the FDA and other certifying bodies worldwide, it is in their best interest for medical device designers to choose products from responsible vendors. For example, the European parliament and the Council of the European Union established the RoHS-WEEE directive restricting the use of certain hazardous substances in imported electrical and electronic equipment. It is much easier to earn RoHS-WEEE certification for a medical device if the internal components themselves are already RoHS-WEEE certified.

Conclusion

Successful integration of a mini imager and the data collection system directly affects the successful operation of the device. A device is only as good as the data it receives. In the medical industry where patient lives can be affected, it is critical that the information collected by the imager is as complete and accurate as possible. By working closely with imaging vendors early in the process, device designers will dramatically increase the performance and accuracy of their data capture process while significantly lowering the total cost of ownership of the entire device.

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