TOSHIBA

White Paper

Single-Layer CCD Technology for Linear CCD Image Sensors

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Highlights

- Provides an examination of the new, evolving home/small office and business markets for linear CCD image sensors with requirements for new levels of performance and advanced features.
  - Discusses characteristics of the fast-growing multifunction printer segment
- Gives a technical overview of new single-layer CCD technology, a Toshiba imaging innovation that is the future direction of CCD image-sensor technology.
  - Achieves higher data rates, higher resolution, lower power dissipation and higher pixel density
  - Allows creation of higher resolution products in the same form factor with higher data rates
- Introduces the TCD2914BFG, Toshiba's first CCD linear imaging product based on a single-layer CCD structure

Introduction

Charge-coupled devices (CCDs) are at the heart of a wide range of digital imaging devices, such as digital cameras, scanners and multifunction computer peripherals. CCD image sensors typically come in two different forms: linear array image sensors and matrix/area image sensors.

Today, multifunction printers have become the fastest growing segment for CCD linear image sensors. In small office or home settings, these sophisticated All-in-One (AIO) products combine a printer, a copier, a scanner and sometimes a fax along with memory card readers for digital photography. The scanner portion is commonly used for scanning old photos/negatives or paper files for archives.

The AIO market is highly competitive, facing margin pressure and the need to continually offer performance and feature improvements. Performance improvements include:

- High resolution for rich details
- True color representation
- Higher speed of operation

Features

Improvements include:

- Low acquisition cost/cost of ownership
- Compactness or footprint space

Historically, the main application area of linear CCD image sensors was photocopiers or fax machines for offices. For that purpose, CCDs were optimized for high-speed operation but not for high-quality color reproduction. However, the changing market landscape demands new levels of performance and features as listed above. New markets for high-speed digital color copiers/printers for offices and high-resolution/high-quality scanners for homes are sweeping the market landscape. To meet these new market requirements, Toshiba, a recognized leader in imaging technology, developed an innovative new single-layer CCD structure and introduced its first product in a series of products based on this technology.

Imaging Innovation: Single-Layer CCD Technology

The term "charge-coupled device" refers to the means of transferring the charge from a photo diode to a read-out stage and the charge is then converted to measurable voltage. The charge that accumulates under the photodiode is stored in a MOS capacitor and is then transferred to a CCD analog shift register located adjacent to the photodiode. From the CCD analog shift register, the charge is transferred sequentially to the output circuit stage. The CCD linear image sensor architecture is illustrated in Figure 1.

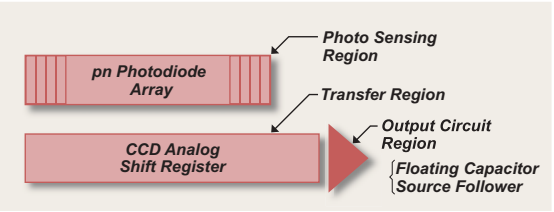


Figure 1

CCD technology poses a few technical challenges. The CCD architecture consists of successive MOS capacitors, which have huge inherent capacitances and consequently require high power-supply current to drive CCDs. Also, most CCD registers use a two-layer poly-silicon structure of overlapping electrodes and these have associated coupling capacitances. These capacitances increase the instances of electro-magnetic interference (EMI). Lowering or eliminating these capacitances will contribute to several benefits, such as higher speed of operation, reduced EMI, etc.

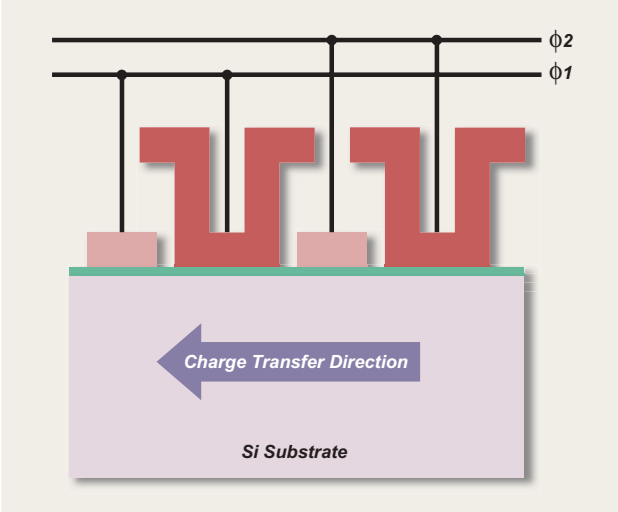
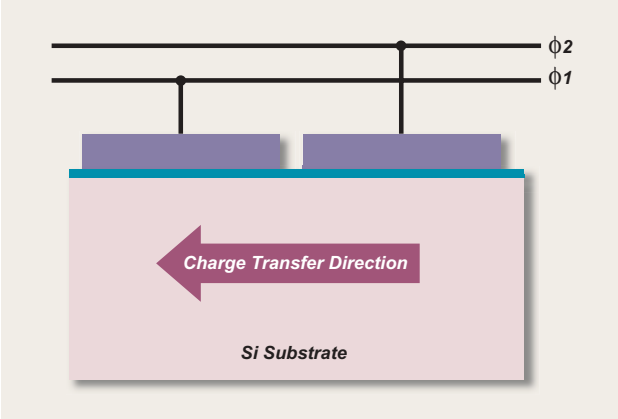


Figure 2

Figure 2 shows the cross-section of a conventional two-layer CCD structure with overlapping electrodes. The first- and second-layer electrodes are located alternately on the silicon substrate. A pair of first- and second-layer electrodes connects to the same clock pulse wire. Signal charges move under the CCD electrodes in the substrate.

The concept of a single-layer CCD image sensor structure is not new. However, Toshiba took the bold step of developing and commercializing a new CCD linear image sensor structure to overcome some of the technical challenges inherent in conventional two-layer CCD architectures and meet the new, evolving market opportunities discussed earlier. Toshiba researchers developed a new CCD linear image sensor structure with thin single-layer electrodes to reduce the CCD capacitance. This single-layer CCD structure delivers many benefits for design engineers as well as end-users/consumers.

Employing a sensor that had a 2.625um pitch, 10k pixel linear array with a single-sided CCD register[1], Toshiba researchers were able to reduce the coupling capacitance to less than 40 percent compared to the conventional two-layer CCD electrode structure. The total power dissipation for the CCD drive was reduced to 45 percent that of a conventional CCD and high transfer efficiency of greater than 99 percent was obtained at 20 MHz. In addition, the size of the area around the CCD for the contact between the electrode and clock applying wire was reduced by eliminating the second-layer electrode.



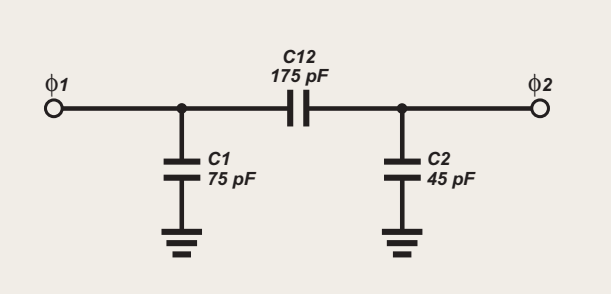
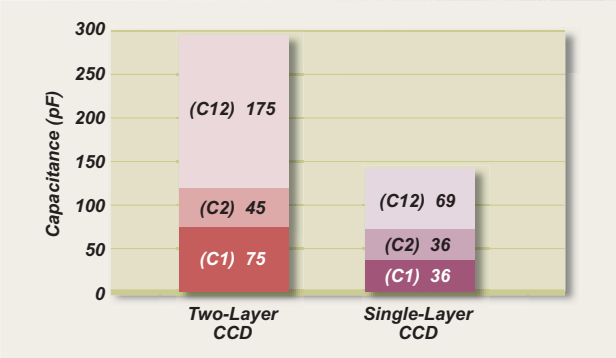


Figure 3

Figure 3 above shows the capacitances associated with conventional two-layer CCD architecture. With single-layer CCD technology, the coupling capacitance at C12 is reduced significantly. The resulting performance improvements include higher data rates, higher resolution, and lower power dissipation. Similarly, eliminating one of the electrodes allowed more pixels to be packed. This allows the creation of higher resolution products in the same form factor with higher data rates. Figure 4 provides a comparison of the capacitance and power dissipation in two-layer and single-layer CCD architectures.

[1]. These CCD linear sensor product specifications were used for all of the tests referenced in this white paper.



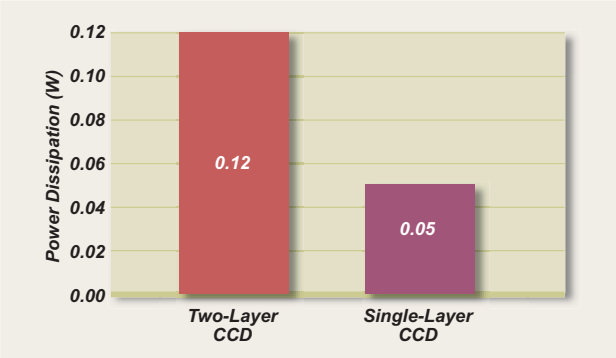
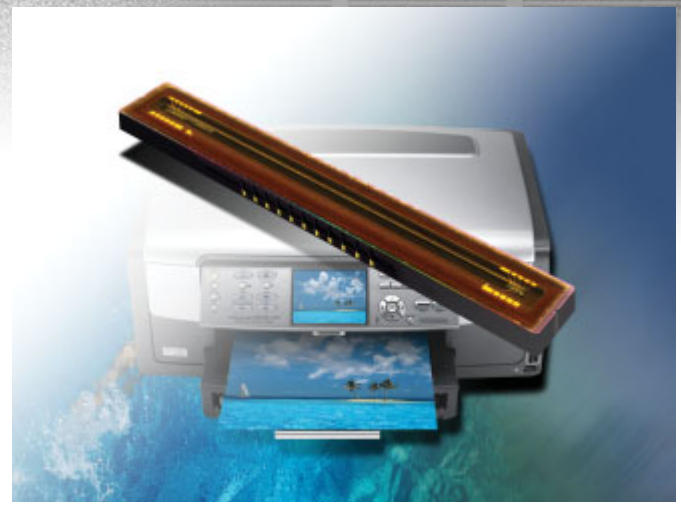


Figure 4.

Introducing the TCD2914BFG



The TCD2914BFG is Toshiba's first CCD linear imaging product based on a single-layer CCD structure. It is a high sensitive and low dark current 10680 elements x 3-line CCD color image sensor with a 10680 elements x 1 line CCD B/W image sensor, a CCD drive circuit and a clamp circuit. Engineered for scanner applications, the device provides a 48-lines/mm 1200 dpi resolution across A4-size paper. It is operated by a 5.0 volt (V) pulse and 12V power supply.

Future developments

Toshiba plans to introduce many more products based on the single-layer CCD architecture. The benefits realized by both design engineers and consumers are indisputable. Achieving high data rates, high resolution and low-power dissipation, this technology represents the future direction of CCD image sensor innovation.

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