Course Description

Course name	**#020 - Advanced Course on Image Sensor Technology**
Duration	**3 days**
Format	**Public Classroom or Inhouse Event. Not suitable Online**

Overview

Professor Albert J.P Theuwissen, Harvest Imaging, Belgium, is teaching this 3-day advanced course that is focusing on the solid-state image sensor technology.

Highly sophisticated CMOS image sensors are key components of modern cameras. Technology as well as device architectures are optimized to obtain peak performance of the image sensor and the camera system. The most advanced CMOS image sensors show pixel sizes beyond 1 µm. The imagers demonstrate a light sensitivity comparable to that of the human eye.

This course is intended for specialists in the field. A very good background of digital imaging is needed to get the most out of this course.

Technical Focus

Highly sophisticated **CMOS image sensors** are key components of modern cameras. Technology as well as device architectures are optimized to obtain peak performance of the image sensor and the camera system. The most advanced CMOS image sensors show pixel sizes far beyond 1 µm. The imagers demonstrate a light sensitivity comparable to that of the human eye.

Another feature, the back-side illumination in combination with stacking technology, is no longer limited to high-end professional applications. In addition, the modern camera systems can present a dynamic range of 120 dB or more. The equivalent noise level is in the range of sub-electron noise.

Furthermore, the image sensor fabrication technology is not yet pushed to its ultimate limits. Image sensors make use of CMOS technologies that are lagging 2 or 3 generations behind those of digital integrated circuits or solid-state memories. Even more interesting developments can thus be expected in the near future. Will imagers ever outperform the human eye as far as light sensitivity is concerned?

Course Content

This is an advanced course focusing on the **solid-state image sensor technology**. It is intended for the specialists in the field. A very good background of digital imaging is needed to get the most out of this course.

It can be regarded as a continuation to course **#013 - Digital Imaging: Image Capturing Image Sensors, Technologies and Applications**. The content is based on comments, suggestions, and remarks received from previous participants in courses #013 and **#014 - Digital Camera Systems.**

Who should attend?
This course is intended for specialists in the field.
A very good background in digital imaging is needed to get the most out of this course.

Course Daily Schedule

Day 1
CMOS PIXELS
Pinned Photodiode
What is new in CMOS image sensor pixels after the introduction of the pinned photodiode? The pinning layer created a real breakthrough in CMOS imaging, but does the pixel development stop with the pinned photodiode? An interesting concept to create very small pixels is the so-called shared pixel architecture, primarily based on pinned photodiodes as well. Advantages and disadvantages of the shared pixels will be discussed.

Global Shutter Pixels
The Rolling Shutter is still an issue in CMOS imagers that are being used for instance in broadcast, machine vision, and other applications. What are the alternatives in pixel design to turn the rolling shutter into a global shutter? Pixels with 4, 5, 6, 7 and 8 transistors will be compared to each other, as well as global shutter options in the charge domain and voltage domain.

Wide-Dynamic Range Pixels
Pixels are getting smaller and the specs on dynamic range are becoming tighter. What kind of architectures can be implemented to extend the dynamic range?

Day 2
CMOS IMAGER SYSTEMS
Noise on Pixel Level
At present, the pixels and the in-pixel circuitry are the limiting noise factors. From where is the remaining noise coming? What kind of new developments can be expected? Topics such as Transfer Gate noise, RTS noise and 1/f noise will be discussed.

Noise on System Level
Noise can be used as an interesting measurement tool in the so-called Photon Transfer Curve method. Parameters such as conversion gain, dynamic range, saturation level, noise floor, quantum efficiency, PRNU can be deduced. If the method is performed in darkness, dark current levels as well as DRNU can be measured. Further elaboration of the method will explain that this technique is not only a useful measurement tool but a diagnostic tool as well.

Day 3
NEW TECHNOLOGIES
Back-Side Illumination
Back-side illumination to obtain extremely high quantum efficiencies is becoming very popular. Several fabrication methods will be compared. A crucial part of the technology is the passivation of the backside of the sensors. The background of the passivation issues will be highlighted.

Electron Multiplication

In case of extremely low light level, the EM-CCD is a very interesting and powerful image sensor. This device is characterized by the fact that an electron multiplication stage is included just before the output amplifier. In this way a gain can be applied to the signal in the CCD without amplifying the noise of the output stage. Equivalent noise levels of sub-electrons are being reported.

Time-of-Flight

Sensing depth or the third dimension (3D) is becoming more and more important. The course will discuss one of the most appealing techniques to measure the distance of object in front of the camera lens by means of a non-contact method: time-of-flight (ToF). The principle of ToF will be explained, and an analysis of the accuracy will be given.

Theoretical Calculations

If time permits, the first and the second day will end with a few calculations: for instance, a noise analysis of a pixel or a calculation of the number of electrons in an illuminated pixel.

Instructor Biography

Professor Albert J.P Theuwissen, CEO of Harvest Imaging, Belgium**.**

Dr. Theuwissen received his M.Sc. (1977) and his Ph.D. (1983) degree in electrical engineering from the Catholic University of Leuven, Belgium.

In the ESAT laboratory he focused on semiconductor technology for linear CCD image sensors. From 1983 till 2002 he was involved in research in the field of solid-state image sensing, SDTV- and HDTV-imagers, CCD as well as CMOS solid-state image activities at Philips Research Laboratories in Eindhoven, the Netherlands. From 2001 till 2023 Dr. Albert Theuwissen joined the Delft University of Technology as part-time professor and in 2002 he joined DALSA Corp. to act first as the company's Chief Technology Officer and later as the Chief Scientist of DALSA Semiconductors.

In 2007 Dr. Theuwissen founded Harvest Imaging and since then he has been fully focusing on training, coaching and consulting in the field of solid-state imaging technology.

Dr. Theuwissen is the author or co-author of many technical papers in the solid-state imaging field, has issued several patents, authored a textbook "Solid-State Imaging with Charge-Coupled Devices" in 1995, and been appointed an IEEE distinguished lecturer. He is the founder of the Walter Kosonocky Award, which highlights the best technical paper in the field of solid-state image sensors. He was general chair of the International Image Sensor Workshop in 1997, 2003, 2009 and 2015. Since 1998 he has served as a member of the Technical Program Committee of ISSCC, and in 2010 he was Chair of the International Technical Program Committee of ISSCC. Dr. Theuwissen is an IEEE Fellow. In 2008 he also received the Fuji Gold Medal for his research, development and education work in the field of solid-state imaging. Furthermore, Dr. Theuwissen was elected Electronic Imaging Scientist 2011 at the Electronic Imaging conference held in San Francisco, USA. In 2013 he received the Exceptional Service Award of IISS and in 2014 the SEMI Award. From 2017 till 2021 he was the president of the International Image Sensor Society, which is a non-profit organization that he founded in 2007 together with his peer Nobukazu Teranishi and Prof. Eric Fossum.

Dr. Theuwissen has been a member of the CEI-Europe Faculty since 1999 and completed over 120 courses for CEI-Europe.