Course Description

Course name	**004 Hands-on Characterization of Solid-State Image Sensors**
Duration	**2 days**
Format	**Public Classroom or Inhouse Event. Not suitable Online**

Overview

Professor Albert J.P Theuwissen; Delft University of Technology, the Netherlands and Harvest Imaging, Belgium is the instructor for this 2-day advanced course in image sensors and digital cameras, focusing on hands-on evaluation and measurements of existing image sensors and cameras.

This training is the very first one of its kind and offers the participants the opportunity to work in the classroom with existing cameras and do the evaluation of the devices themselves. Laptops, cameras, light sources, power supplies, test charts and other equipment needed will be provided. The number of participants in the classroom is limited to allow optimal interaction between the trainer and trainees. The theoretical background of the measurements will be explained first.

Technical Focus

CMOS image sensors are becoming increasingly complicated. In the mid-nineties the devices were simple image sensors, but over the recent years they have become complete camera systems.

Characterization and evaluation of these highly sophisticated SoC's (system-on-chip) is no longer straightforward.

Furthermore, the pixels of the sensors are becoming extremely small, and their limited size can have negative effects on dynamic range, light sensitivity, noise, and speed.

In the context of further optimization of the imaging functionality, it is of great importance to have a good understanding of performance-limiting parameters of the system. These can only be revealed by performing dedicated measurements on the image sensors and/or on the complete camera systems.

That is what this course is all about: learning to characterize an imaging system by means of hands-on experience.

Course Content

This is an advanced course focusing on the characterization and evaluation of solid-state image sensors and digital cameras. It is the first course ever and still the only one in digital imaging that will be almost solely conducted based on hands-on experimental equipment.

The theoretical background of the measurements will be explained first. The participants will then perform the measurements by means of the hardware and software available in the classroom. To get the best learning effect, the maximum number of participants will be limited to 16.

The following equipment will be available: Commercially available cameras (monochrome and color), light sources, power supplies, and standard software tools to grab images running on laptops. Critical camera performance parameters will be measured.

Who should attend?

This course is intended for engineers that already have some experience in the field.
It can be regarded as a continuation of:

- Course 013 Digital Imaging: Image Capturing Image Sensors, Technologies and Applications and/or
- Course 014 Digital Camera Systems

Course Daily Schedule

Day 1
Getting Acquainted
The first session will allow the participants to get familiar with the equipment present in the classroom. The cameras provided are all USB compatible and make use of standard software (supplied by the camera manufacturer) to download images onto the computer. The complete concept of the course is designed/optimized in such a way that everyone can easily work with it. Number crunching, data plotting, and data extraction will be done by commercially available software tools.

The very first measurements we perform together to become familiar with two important evaluation methods: measuring/calculating temporal noise and measuring/calculating fixed-pattern noise.

After the introductory session, the group of participants will be split in sub-groups to give everyone exposure to the hands-on experience.

Measurements in Dark
It is astonishing how many parameters of a sensor/camera can be measured without any light input. The photodiodes of the image sensors are collecting charges and in principle it does not matter whether these charges are being generated by photons or whether they come through leakage currents in the structure. Once a charge packet is collected in a photodiode, it can be used to characterize the imager!

By means of dedicated dark measurements the following parameters can be evaluated:

- Dark Current Density
- Dark-Signal Non-uniformities on Pixel Level, Column Level and Row Level
- Dark Reference Lines/Pixels
- Leaking Pixels

Day 2

The measurements in the dark will continue the second day, focusing on the temporal noise effects in the imager/camera.

Extra parameters evaluated are:

- RTS Pixels
- Defect Pixels
- Temporal Noise on Pixel Level, Column Level and Row Level
- Conversion Gain (if the dark current is large enough)

Measurements with Light

Image sensors and cameras are being developed to convert incoming photons into a measurable quantity. Therefore, it is also of great importance to evaluate the light characteristics of the devices.

Parameters that can be measured when photons are impinging on the sensor are:

- Light Non-uniformities (PRNU or Photo-Response Non-Uniformity)
- Linearity (INL and DNL)
- Blooming Characteristics
- Black Sun
- Green-Green Differences
- Reciprocity Effect
- Saturation Level
- Dynamic Range

Different participant subgroups will work on different set-ups, not necessarily performing the same measurements. However, at the end of the course, everyone will get copies of the outcome of all characterizations performed by all groups.

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.