APN-004

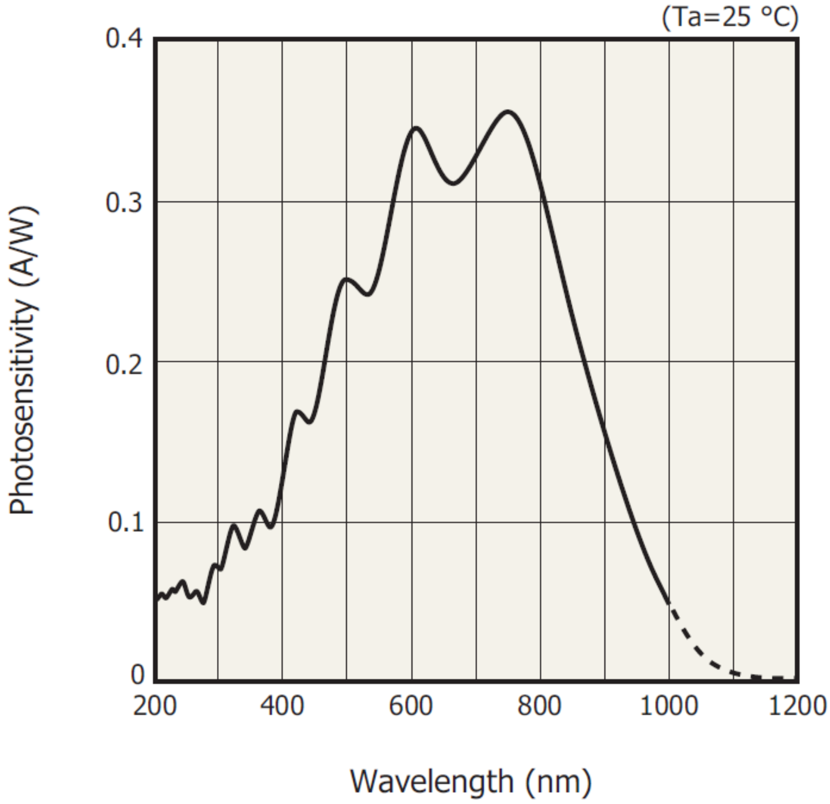
Quantum efficiency of CMOS sensors

Overview

Most sensor datasheets don't provide the quantum efficiency (QE) directly. Instead, they provide photosensitivity graphs of A/W versus wavelength. In this article we show how to calculate QE from photosensitivity graphs.

Photosensitivity graphs

Below is an example of a typical CMOS photosensitivity graph:



The photosensitivity is given in [A/W] and can be converted to QE using the following steps:

1. Extract the image of the graph from the datasheet
2. Digitize the graph using either AI or a graph digitizing tool and generate a CSV file
3. Import the digitized data (CSV of [A/W] versus [nm]) into Excel
4. Postprocess the data and calculate the QE

Calculate QE from photosensitivty

Photosensitivty consists of:

- Current in [A]: This gives the number of electrons per second
- Light power in [W]: This gives the number of photons per second

Electrons per second (Fe)

The electron flux, Fe, can be calculated by dividing the current by the elementary charge e^-:

$$Fe\ [e^-/s] = Current\ [A] / Q_e = Current\ [A] / 1.60217663 \times 10^{-19}\ [Coulomb]$$

Photons per second (Fp)

The photon flux can be calculated by using Planck's law for the energy of a photon:

$$Ep\ [J] = h.F = h.c / L,$$

where h is Planck's constant ($6.62607015 \times 10^{-34}\ J.Hz^{-1}$), c the speed of light ($299.792458 \times 10^6\ m.s^{-1}$) and L the wavelength in [m]. The photon flux, Fp, is the number of photons required to provide 1 W of power:

$$Fp\ [p/s] = 1\ W / Ep$$

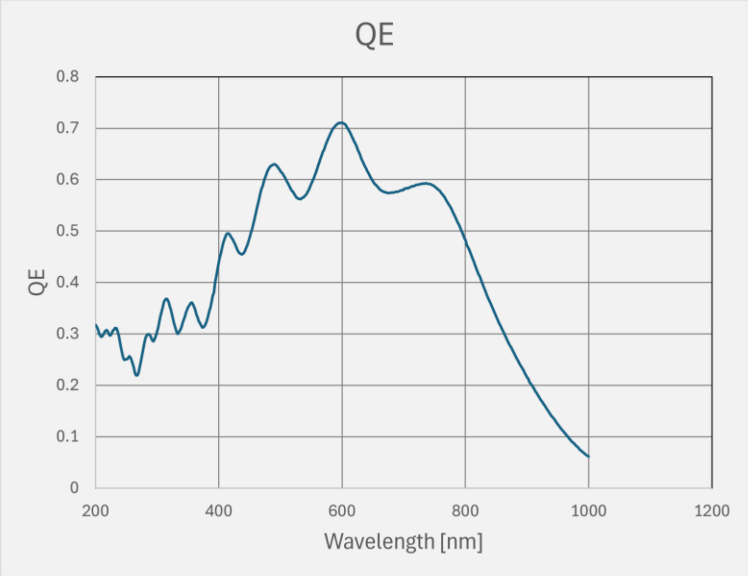
Quantum efficiency

The QE is given by the number of electrons per photon:

$$QE = Fe / Fp$$

Results

The above graph was digitized and postprocessed as described. This is the equivalent QE vs. wavelength:



Observations about CMOS sensors:

- The peak QE is around 70% @ 600 nm
- The QE in the UV range is around 30%
- Above 800 nm the QE drops sharply and is around 10% @ 1000 nm