

MICRO-523: Optical Detectors

Week Six: CCD cameras – Exercises

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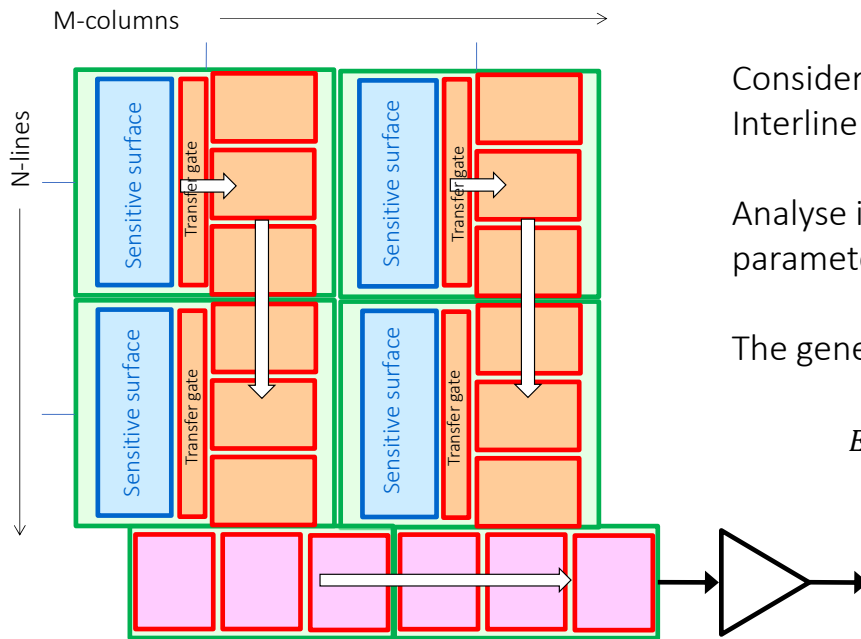
TAs: Samuele Bisi, Kodai Kaneyatsu

The logo of the École polytechnique fédérale de Lausanne (EPFL), consisting of the letters 'EPFL' in a bold, red, sans-serif font.

Outline

- 6.1 Consumption of CCDs
- 6.2 Fill factor
- 6.3 Charge transfer efficiency

Exercise 6.1: Consumption of CCDs



Consider a CCD camera with Interline Transfer.

Analyse its consumption using the parameters given below.

The generic formula for energy is:

$$E = \frac{1}{2} CV^2$$

EN:

N lines, M columns (N=1000, M = 1000, making it a 1Mpix camera)

The sensitive surface of each pixel is $C_1=3 \cdot C_0=30$ fF.

3 CCD cells per pixel for vertical registers, as well as for the horizontal output register. Each cell has a capacity of $C_0=10$ fF.

A voltage of $V=10$ V is used to create potential wells in a cell.

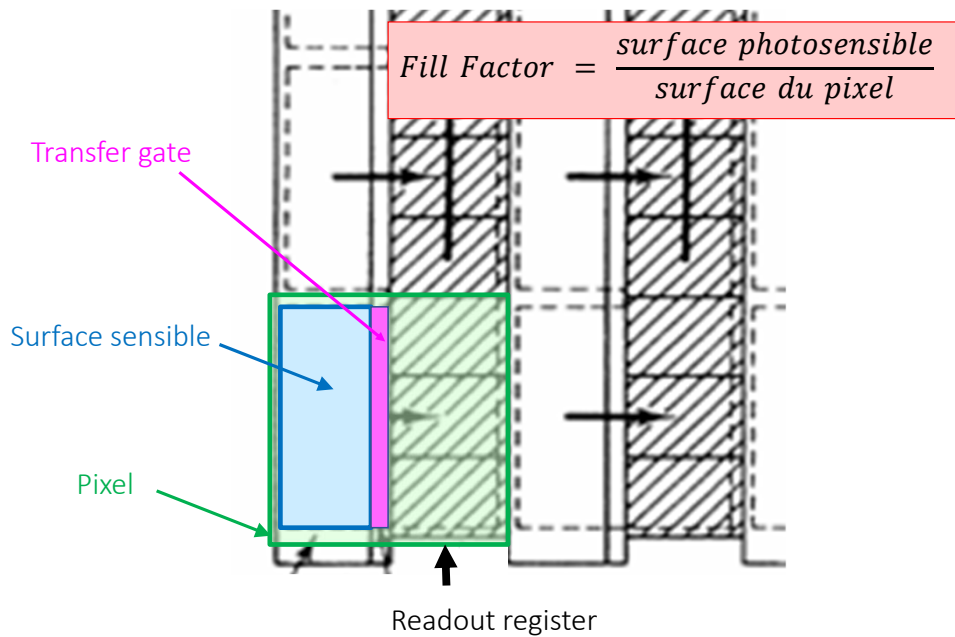
Calculate for an image:

- The energy consumption in the photosensitive zone, as well as that for the transfer to the vertical registers.
- The energy consumption of the vertical registers and that of the output register.

We take $r = 25$ images / s. Determine:

- The power consumed by the camera as a whole.
- The total electric current that has to be supplied.

Exercise 6.2: Fill Factor



Pour la récolte des photo-charges, le Fill Factor est un paramètre central.

Le Fill Factor (FF) décrit le rapport entre la surface photosensible et la surface totale du pixel. Il donne donc la proportion de lumière arrivant sur la zone sensible par rapport à la lumière totale sur le pixel.

Nous devons maximiser le Fill Factor pour obtenir une grande sensibilité de la caméra.

Remarque:

La lumière qui arrive sur la zone photosensible n'est pas toute transformée en photo-charges. Il faut encore introduire l'efficacité quantique η . Le produit du Fill Factor par l'efficacité quantique ($FF \cdot \eta$) donne le rapport entre les photo-charges récoltées et la lumière arrivant sur tout le pixel.

EN:

The Fill Factor is a key parameter for photo-charges collection.

The Fill Factor (FF) describes the ratio between the photosensitive area and the total area of the pixel. It therefore gives the proportion of light arriving on the sensitive area in relation to the total light on the pixel.

We need to maximize the Fill Factor to achieve high camera sensitivity.

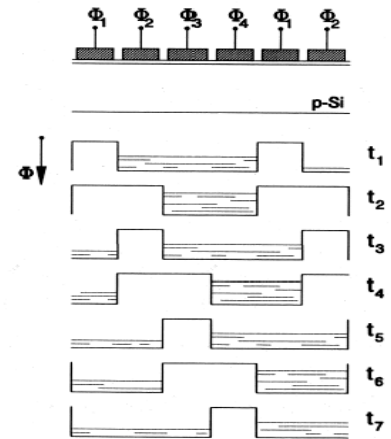
Note:

Not all the light arriving on the photosensitive area is transformed into photo-charges. We still need to introduce the quantum efficiency η . The product of the Fill Factor and the quantum efficiency ($FF \cdot \eta$) gives the ratio between the photo-charges collected and the light arriving on the entire pixel.

Exercise 6.3: Charge Transfer Efficiency CTE

- CTE: Charge Transfer Efficiency = ability to transfer all the charge from storage site to storage site
- (1-CTE) Charge Transfer Inefficiency

The net efficiency varies with the pixel position in the array. The farthest pixel from the sense node suffers higher loss: For a **1,000x1,000 pixels sensor with 4 phases**, the charge packet farthest from the output has to travel 2,000 pixels or **pass through 8,000 wells**.



→ Which CTE is needed to keep the information in the right cell after several thousand transfers?

Pour le transport des photo-charges, le paramètre central est le « Charge Transfer Efficiency » (CTE).

Il décrit, **pour une étape** de transfert, la proportion (en %) de charges transférées d'un puits à l'autre. Le terme (1-CTE) correspond aux charges non-transférées.

Il est capital d'obtenir un excellent CTE. En effet, les caméras modernes ont un grand nombre de pixels. Considérons un système de transfert à 4 phases avec une matrice de 1000x1000 pixels. Chaque pixel est composé de 4 cellules CCD, il faut donc 4 transferts pour passer l'information d'un pixel au suivant. Pour amener l'information des pixels les plus éloignés vers la sortie, il faudra traverser 1000 pixels en vertical et 1000 pixels dans le registre horizontal de lecture (total 2000 pixels). Au final, il faut effectuer 8000 transferts de charges.

EN:

For photo-charge transport, the central parameter is Charge Transfer Efficiency (CTE).

For a given transfer step, it describes the proportion (in %) of charges transferred from one well to another. The term (1-CTE) corresponds to non-transferred charges.

It's vital to achieve an excellent CTE. Modern cameras have a large number of pixels. Consider a 4-phase transfer system with a matrix of 1000x1000 pixels. Each pixel is made up of 4 CCD cells, so 4 transfers are needed to pass information from one pixel to the next. To bring the information from the furthest pixels to the output, 1000 pixels must be traversed vertically and 1000 pixels in the horizontal readout register (total 2000 pixels). All in all, 8,000 charge transfers are required.