Testing of a Novel Custom Made CMOS Imaging Sensor

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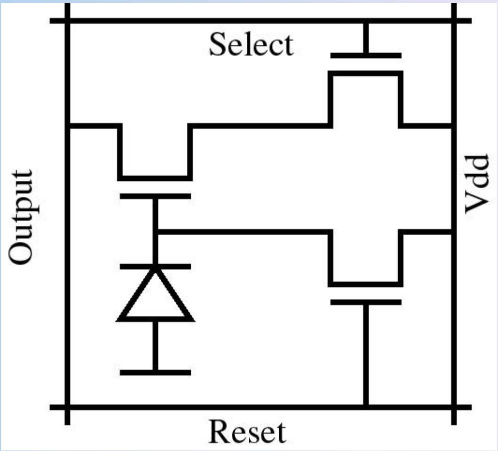
Background

- In the world today CMOS image sensors are used everywhere. These imagers are so commonly used because they have low power consumption, have a 2 mega-pixel capability, and can be put in very small devices

- It is projected that about 700 million cell phones with these devices will be sold by 2008

- In this project our objective is to test a custom made CMOS image sensor



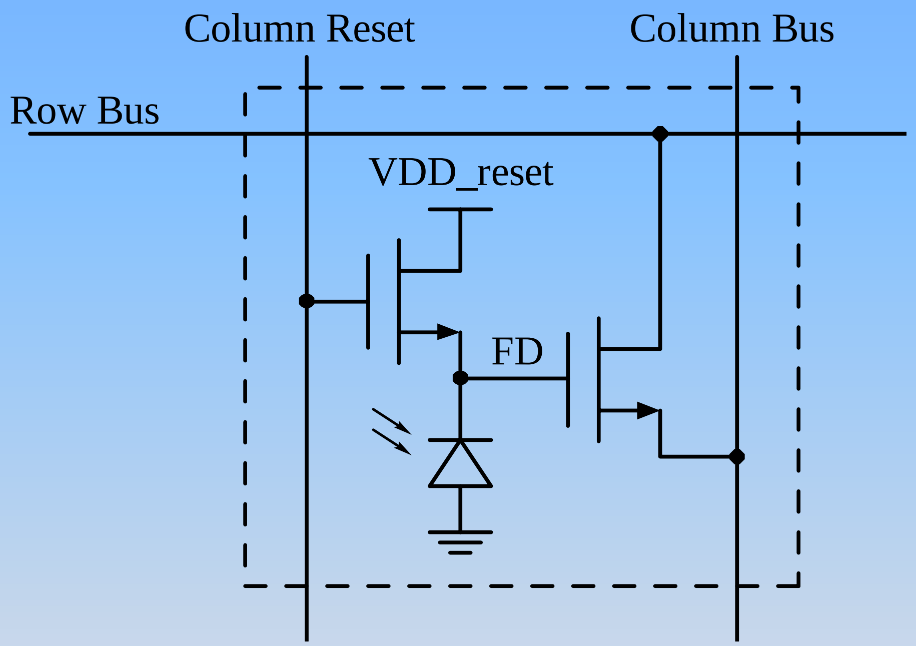
This is today's conventional way to construct a CMOS image sensor by using a three transistor system with a photodiode

Overview

- Our image sensor, unlike the conventional image sensors, consists of only two transistors

- This enables our image sensor to have a greater pixel capacity, fit in smaller places, and have less power consumption

- The possibilities for such a technology where imaging systems are becoming so widespread are endless



Previous Work

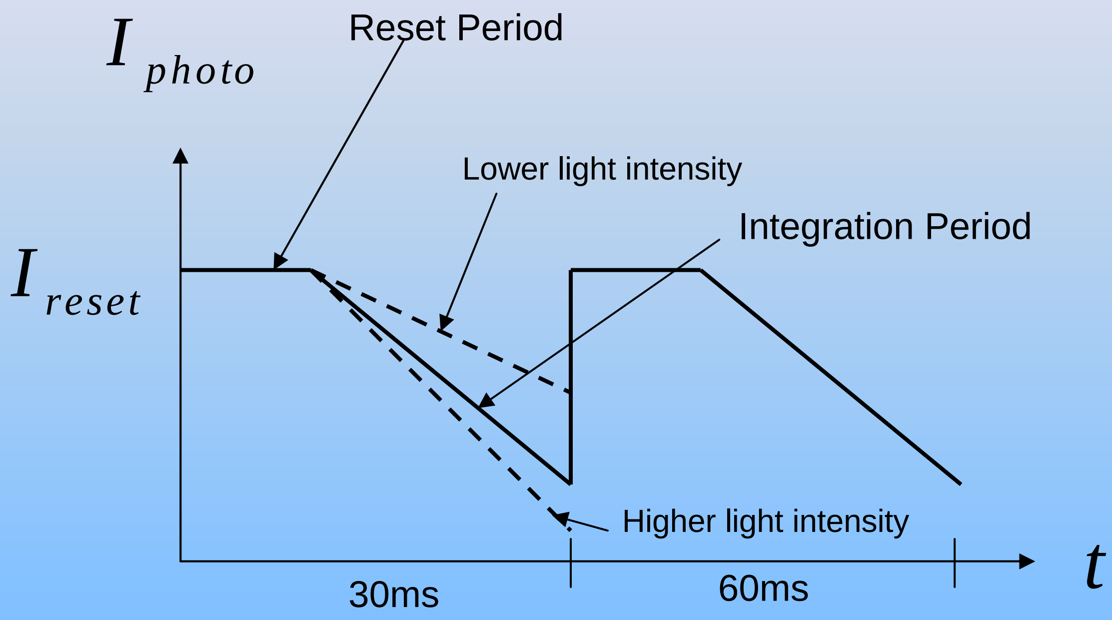
- Construction of the PCB board that contains all the parts needed to control the CMOS camera

- I started practicing writing programs on a smaller Sx28 microcontroller until I could program our Sx52 microcontroller witch we put on our PCB board

- Before I could begin to work on the microcontroller, I had to write an initialization program for the digital to analog converter using a timing diagram

- Programming our microcontroller

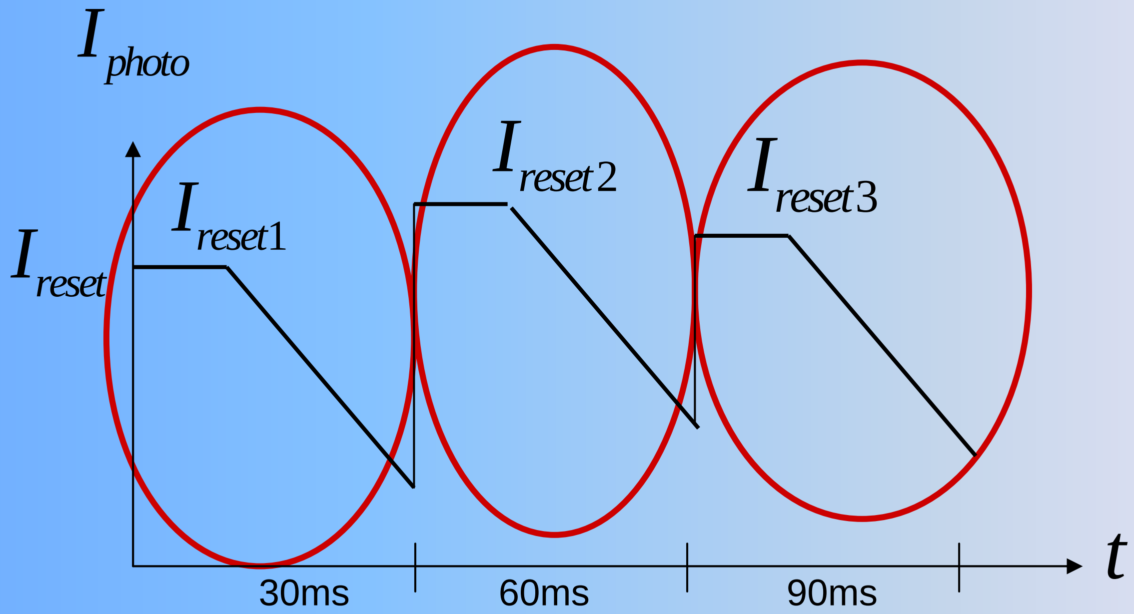
Photo pixel Operation



➢Two modes of operation:

- Reset mode – 1ms
- Integration mode – 30ms

Reset level mismatches



- ➢Reset level for different pixels are different due to inherent variations within each pixel

- ➢Final current level will be different among different pixels for same illuminations

- ➢Relative change of integrated photocurrent is important

- ➢How do we compute/record the relative photocurrent change?

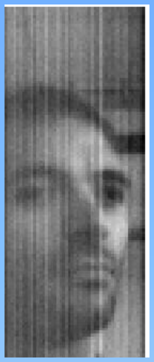
CDS (Correlated Double Sampling)

- Correlated Double Sampling is used in all of the modes in our current mode image sensor to decrease noise values

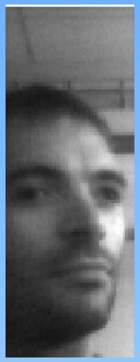
- Because each transistor connected to each pixel has it own current reset values, there is a large variation between the mean values of all the pixels which produces noise

- To account for this variation, CDS is used where the current is sampled twice for each pixel. Once at the beginning of the current reset and once at the end of integration of that pixel

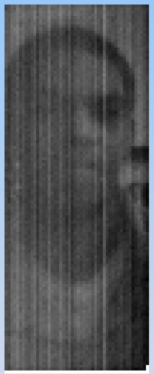
- Then the mean value of all the pixels is taken which accounts for much of the noise created



Before CDS



After CDS



4% noise levels

3% noise levels

Linear Mode Of Operation

➢To open up a channel for electrons to flow, Vgs must be greater than Vt

➢In order to operate in linear mode, Vds must be less than (Vgs-Vt)

➢Problems:

•Vref is constant within ~100mV (it does not cancel Vt very well) which means that you could have about 20% variation due to manufacturing of the chip

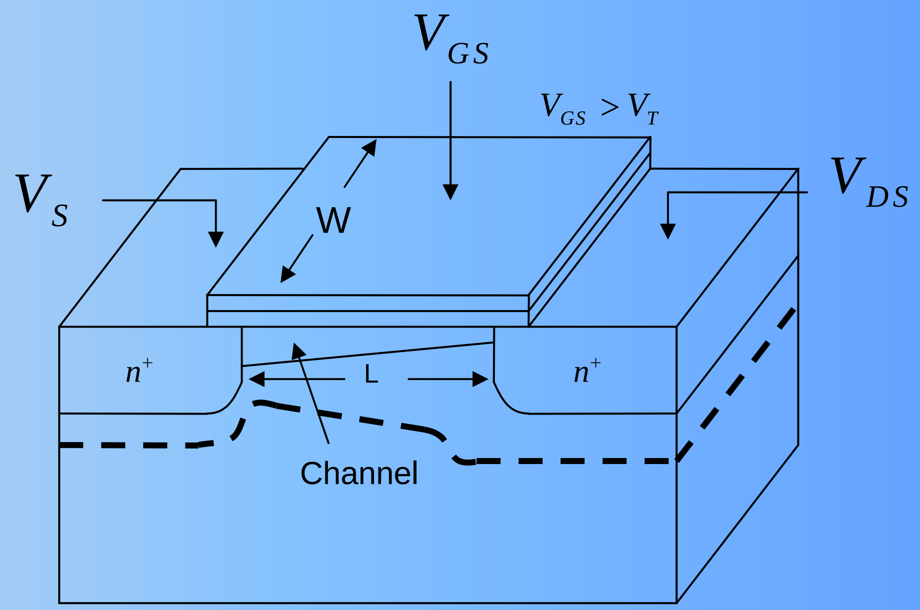
•Mobility varies with Vphoto

•Size of the transistor can vary (W and L)

$$\mathrm{I}_{\mathrm{photo}} = \mu_p C_{OX} \frac{W}{L}[(V_{photo} - V_t)V_{ref} - \frac{V_{ref}^2}{2}]$$

$$\mathrm{I}_{\mathrm{reset}} = \mu_p C_{OX} \frac{W}{L}[(V_{reset} - V_t)V_{ref} - \frac{V_{ref}^2}{2}]$$

$$\mathrm{I}_{\mathrm{out}} = \mathrm{I}_{\mathrm{photo}} - \mathrm{I}_{\mathrm{reset}} = \mu_p C_{OX} \frac{W}{L} V_{ref}(V_{reset} - V_{photo})$$



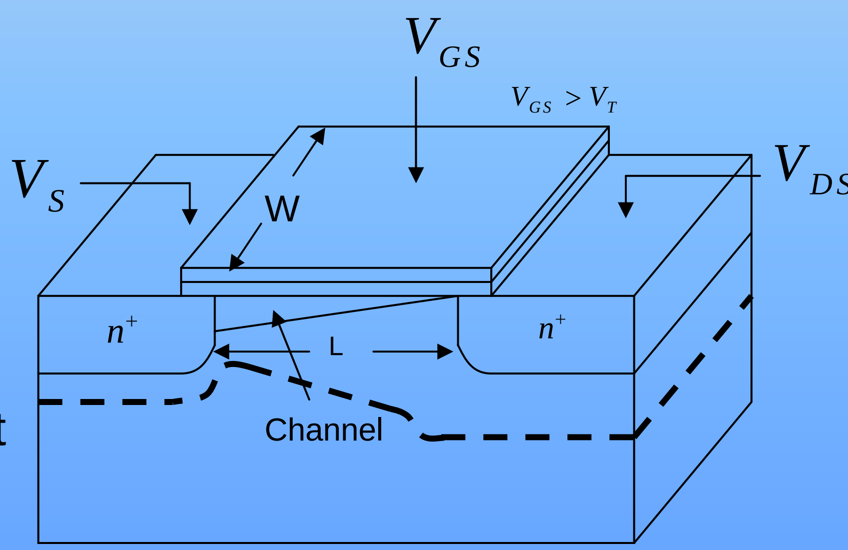
Velocity Saturation Mode of Operation

- As with the Linear mode of operation, Vgs must be greater than Vt so that electrons can flow through the channel
- In order to operate in velocity saturation, Vds must be much greater than (Vgs-Vt), at generally about 6V and above
- The mobility of the electrons in the channel must be saturated which means they must be moving at maximum velocity therefore errors due to mobility are eliminated
- Length variations are eliminated
- In velocity saturation mode there are no variations due to Vds
- Problems:
- With the transistor, (W) variations still exist but are small
- Power consumption is higher due to high current

$$\mathrm{I_{photo}} = \mu_{sat} C_{OX} W[(V_{photo} - V_t - V_{ds}^{sat}]$$

$$\mathrm{I_{reset}} = \mu_{sat} C_{OX} W[(V_{reset} - V_t - V_{ds}^{sat}]$$

$$\mathrm{I_{out}} = \mathrm{I_{photo}} - \mathrm{I_{reset}} = \mu_{sat} C_{OX} W(V_{reset} - V_{photo})$$



Measurements

- Fixed Pattern Noise
  - Linear Mode = In the linear mode of operation, .5% fixed pattern noise after CDS (about 8 bits of grayscale resolution)
  - Velocity Saturation Mode = In this mode about .3% fixed pattern noise after CDS (about 8.5 bits of grayscale resolution
  - Fixed pattern noise of commercial imagers operating in voltage mode starts at around 8 bits of resolution

Challenges

- Having never worked with microcontrollers before the entire process of making a program for one was completely new and I've had to work from scratch
- Another challenge was having to interpret the timing diagram. Having never done anything like that before, I found it difficult to interpret the different lines like the DIN, SYNC, and LDAC into lines of code
- One my greatest challenges was having to create a program for the microcontroller that not only has to have 16 bit values knowing that the microcontroller can only process 8 bits at a time. Knowing this I have to figure out a way to put in a 16 bit value by using two sets of 8 bits that is also modular
- Understanding how our transistors work also proved to be a challenge

Acknowledgments

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