Introduction:
Nowadays, the CMOS technology has grown rapidly. With characteristics of low manufacturing cost and power consumption, CMOS imager has been widely used in different electronic handheld devices.

Aims:
In our final year project, we designed a CMOS imager based on digital pixel sensor technology with on-chip data compression scheme. Differential Pulse Code Modulation and Huffman Encoding Scheme are used in our project.

Why data compression is important?
- Minimize memory size
- Minimize the silicon area and the size of the sensor
- Speed enhancement due to reduction in parasitic capacitance

Why single chip solution?
- Low cost as multiple functions can be implemented
- Low noise as routing between chips can be avoided
- Low power consumption

Methodology:
The imager can be divided into 3 parts:
- Pixel sensor
- Huffman Encoder
- Control Unit

A CMOS Imager with Compact Digital Pixel Sensor

Differential Pulse Code Modulation
DPCM is done in the pixel level. By storing the differential value between 2 successive pixels, DPCM can be performed.

Pixel Sensor
The sensor consists of a photodiode, a comparator and a memory inside. By implementing a reconfigurable 5-bit up/down counter, DPCM can be performed.

With DPCM, we found that the peak of the differential sample value centers at 0 as there is usually a high redundancy in images. So we can use 5 bits differential signal instead of 8 bits original signal.

Schematic of the reconfigurable up/down counter

Huffman Encoding Scheme
It is lossless compression scheme in which fewer numbers of bits are used to represent the most frequently occurred signal. It provides further compression to the differential signal obtained in each pixel.

To implement the Huffman Encoder, combinational logic circuit has been designed. With a 5 bits differential signal input, a 2 to 8 bits long Huffman Codeword and its corresponding length can be obtained.

Control Unit
In order to provide serial connection to the outside environment, 8-bit shift register is implemented to convert the parallel Huffman Codeword into serial format. A 4-bit counter is also implemented to control the time for the shift register to get a new codeword from the Huffman Encoder.

Result:
With Differential Pulse Code Modulation, the compression ratio is 37.5%. After processing with Huffman Encoding Scheme, the compression ratio can be as high as 55%

The figure on the left hand side is the layout of the pixel sensor. The right hand top corner is the photo diode. It occupies about 12% of the total area of the chip. In other words, the fill factor is 12%. The higher the fill factor, the higher the quality of the image that we can obtain.