

Development of CMOS Imager Block for Capsule Endoscope

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Abstract. This paper presents the development of imager block to be associated in a capsule endoscopy system. Since the capsule endoscope is used to diagnose gastrointestinal diseases, the imager block must be in small size which is comfortable for the patients to swallow. In this project, a small size 1.5V button battery is used as the power supply while the voltage supply requirements for other components such as microcontroller and CMOS image sensor are higher. Therefore, a voltage booster circuit is proposed to boost up the voltage supply from 1.5V to 3.3V. A low power microcontroller is used to generate control pulses for the CMOS image sensor and to convert the 8-bits parallel data output to serial data to be transmitted to the display panel. The results show that the voltage booster circuit was able to boost the voltage supply from 1.5V to 3.3V. The microcontroller precisely controls the CMOS image sensor to produce parallel data which is then serialized again by the microcontroller. The serial data is then successfully translated to 2fps image and displayed on computer.

1. Introduction

Nowadays endoscopy is essential in internal disease diagnosis. Endoscopy is the process of diagnosing the gastrointestinal tract of the patients, which is conducted by either inserting a tube through the mouth that is esophagogastroduodenoscopy or through rectum that is colonoscopy. Normally, a camera is mounted at the end of the endoscope and images are taken and sent to a display monitor. This is an effective way of diagnosis but the disadvantages are it causes pain and uncomfortable to the patients. Patients undergo gastroscopy may suffered from mild sore throat or feeling of distention from the insufflate air used during the procedure. Moreover, colonoscopy causes discomfort and pain to the patients as the tube needs to be pushed into the intestine. Apart from the discomfort, conventional endoscopes have its limitation, where it was not able to fully evaluate the disorder in the small intestine¹. This is due to small intestine is very long and convoluted, therefore no available scopes are able to traverse the entire length of small intestine², resulted in some small intestine diseases to be hardly diagnosed. Therefore, the capsule endoscopy is a solution for abovementioned problems. The evolution of endoscopy started around 10 years ago when Given Imaging produced the first ever capsule endoscope named M2A³. The design and development of CMOS imager block requires several important characteristics need to be taken into account, particularly the image quality such as resolution and frame rate, and the power consumption of the system as the system is a battery operated device. The power supply must be able to sustain for



approximately 8 hours, for a full cycle of digestion until the capsule reaches the bowel⁴. Therefore, the selection of CMOS image sensor, microcontroller, LED and power management device is very important. The CMOS imager block can be connected to high data rates transmitter to transfer the image wirelessly to the receiver. The mentioned characteristics obscure the development of the capsule endoscope and it is really challenging in realizing the proposed system.

2. Imager Block Design and Components Selection

Designing the system aims at optimizing the power consumption and reduced the circuit board size by selection of electronics components to be associated in the CMOS imager block. The block diagram of the proposed CMOS imager block is shown in Figure 1.

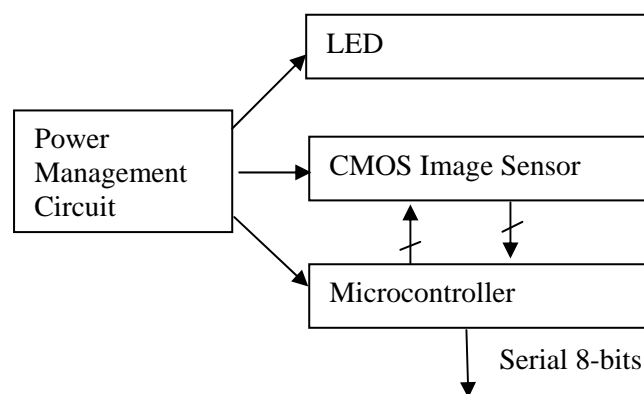


Figure 1. Block diagram of CMOS imager

2.1. Power Management Circuit

A voltage booster has been developed based on the Microchip MCP1654 IC to boost from the supply voltage from 1.5V to 3.3V. This IC consumes only 19 μ A during operation and 1 μ A at no load. A diode is used in the circuit to prevent reverse bias which will damage the components. Then, regulators are used to supply necessary voltages to the CMOS Image sensor, LED and microcontroller. The CMOS image sensor requires 2.8V and 1.5V of voltage to function properly, while the microcontroller only requires single voltage of 2.8V. The LED can use any of them based on the circuit design. Figure 2 shows the circuit diagram of the proposed power management circuit and its PCB layout.

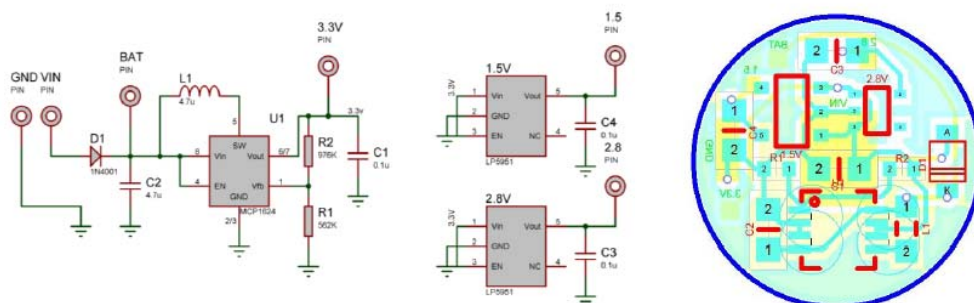


Figure 2. Power Management Circuit and its PCB Layout

2.2. CMOS image sensor

The CMOS image sensor with wide dynamic⁶⁻⁸ range ability and with global shutter⁹ is preferable for better image quality. However such type of image sensor is either too expensive or not available in the current market. Therefore, the low cost, small size Toshiba TCM8230MD CMOS image sensor has been chosen as the imager for this project. It provides VGA colour pixel resolution, able to capture up to 30fps, small size with the dimension of 6(W) × 6(D) × 4.5(H) and consumes low power. However in this design we are focusing of using the VGA image resolution with the frame rate of 2fps only. The CMOS image sensor can be controlled by I²C bus with 2 wires in which one wire is used for clock line and another for the data line. The PIC 18F26K20 is used to produce the necessary clock and control pulses to operate the CMOS Image sensor. Figure 3 show the circuit diagram and PCB layout of the integrated CMOS image sensor, LED and microcontroller.

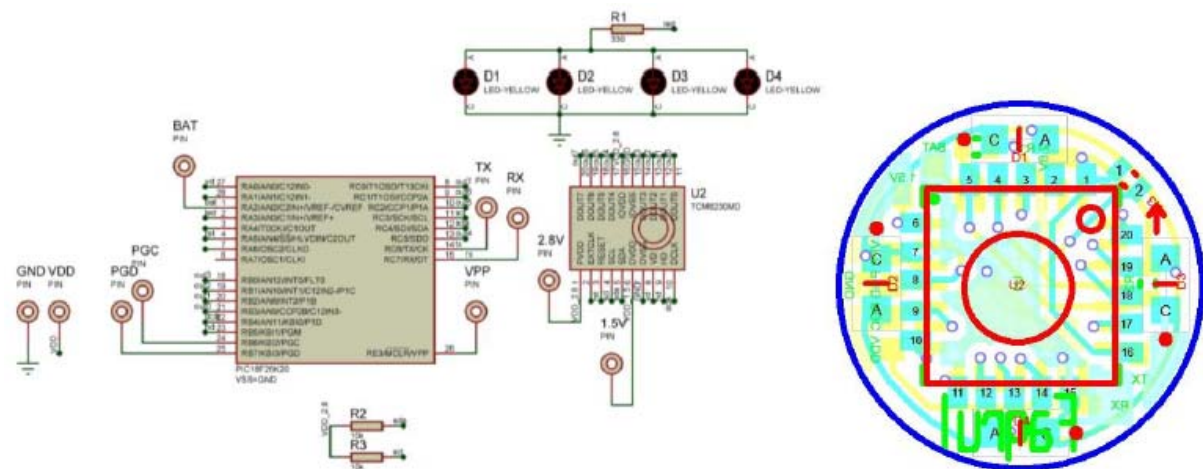


Figure 3. Circuit diagram and PCB layout of the integrated CMOS image sensor, LED and microcontroller.

2.3. Microcontroller as parallel to serial converter

The PIC 18F26K20 Microcontroller can act as parallel to serial converter in which the coding has been design as in Figure 4. The MSB and LSB are from DOUT7 to DOUT0, respectively. Table 1 shows the pin assignment for the microcontroller and CMOS image sensor.

Table 1. Pins for PIC18F26K20 and TCM8230MD

PIC 18F26K20	TCM8230MD
B0	DOUT3
B1	DOUT2
B2	DOUT1
B3	DOUT0
C0	DOUT7
C1	DOUT6
C2	DOUT5
C5	DOUT4

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if (DOUT7==1)      get7=0b100000000;
else if (DOUT7==0) get7=0b000000000;
if (DOUT6==1)      get6=0b010000000;
else if (DOUT6==0) get6=0b000000000;
if (DOUT5==1)      get5=0b001000000;
else if (DOUT5==0) get5=0b000000000;
if (DOUT4==1)      get4=0b000100000;
else if (DOUT4==0) get4=0b000000000;
if (DOUT3==1)      get3=0b000010000;
else if (DOUT3==0) get3=0b000000000;
if (DOUT2==1)      get2=0b000001000;
else if (DOUT2==0) get2=0b000000000;
if (DOUT1==1)      get1=0b000000100;
else if (DOUT1==0) get1=0b000000000;
if (DOUT0==1)      get0=0b000000010;
else if (DOUT0==0) get0=0b000000000;

gettotal=get7+get6+get5+get4+get3+get2+get1+get0;

```

Figure 4. C language Coding to convert data from parallel to serial

3. Results and Discussion

The Imager block has successfully developed and measured. It consumes low power and small space area. The voltage booster in power management circuit was able to boost voltage supply from 1.5V to 3.3V as shown in Figure 5. From the figure, the input range can be vary from 0.6V to 3.3V, that means if the batteries voltage reduced to less than 1.5V, the components such as CMOS image sensor, LED and microcontroller can still operate correctly. The voltage regulator also regulates voltage supply to 2.8V and 1.5V as required by the components.

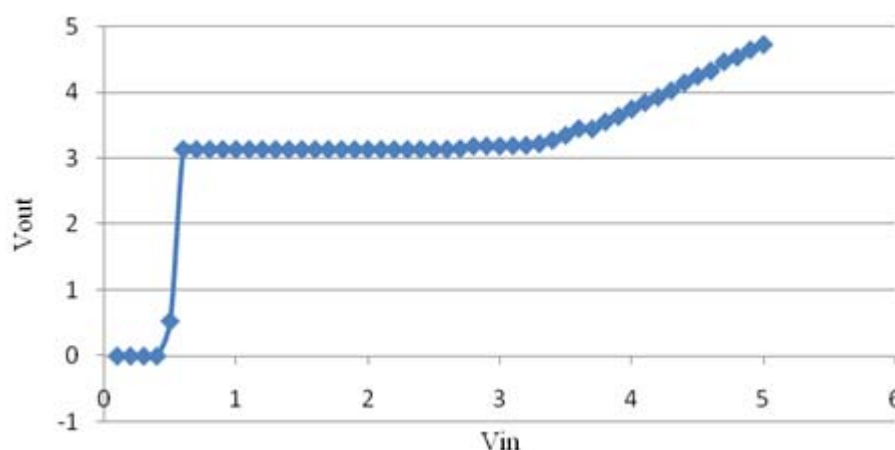


Figure 5. Measured output from the voltage booster circuit

The parallel data from CMOS image sensor output successfully converted to serial data by the microcontroller. The results are shown in Figure 6 where the measurement has been done using the logic analyser. In the figure, parallel data represented by DOUT7-DOUT0 while the serial data represented by R_X .

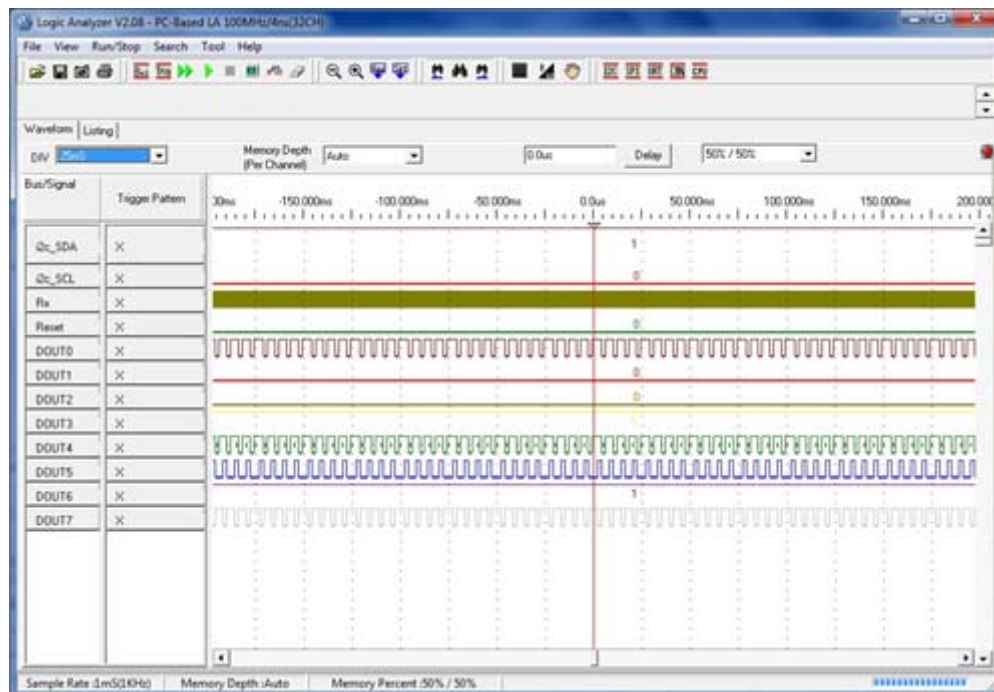


Figure 6. Parallel and Serial data

Figure 7 shows the matrix array data captured by developed imager block which has been transferred to the computer. This matrix array can easily be translated to the video image by using MATLAB graphical user interface. The value of each cell will decide the colour of reproduced image. In this project, RGB565 with 16 bits data string has been chosen.

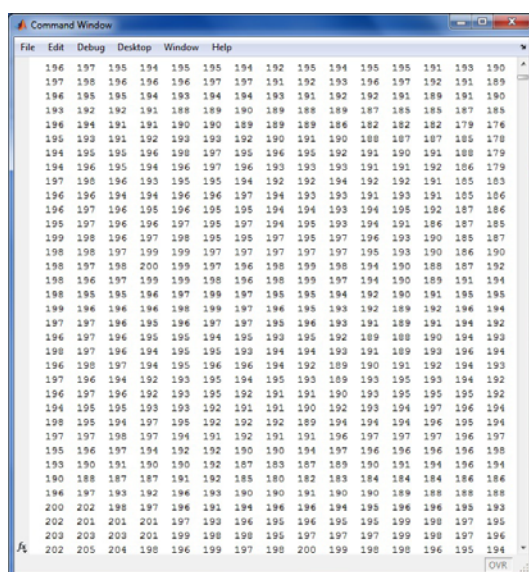


Figure 7. Matrix array of captured image and captured sample image

4. Conclusion

The imager block for capsule endoscope has successfully been developed and the functionality was verified. The power management circuit is able to boost up input voltage from 1.5V to 3.3V, as power supply requirement for components. Processor successfully generates control pulses for CMOS image sensor. Mounted 4 LED's produce relatively bright lighting for CMOS image sensor to capture sample image in dark environment, and finally parallel to serial converter was able to produce the desired outputs. The video image with 2 fps has been successfully formed from matrix array via developed MATLAB graphical user interface.

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Acknowledgments

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