

## DESIGN AND IMPLEMENTATION OF A DIGITAL CAMERA USING AVR MICROPROCESSOR

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### ABSTRACT

*This paper introduces a basic design and implementation of intermediate circuit between a CMOS camera and a computer. The circuit enables the user to take pictures with the camera and transfer it to computer. The circuit uses an AVR microprocessor (ATMEGA16) as the central processing unit. The camera is ov6620 produced by Omnivision. It is an IR camera and has both digital and analogue output.*

**Keywords:** Digital Camera, AVR, I<sup>2</sup>C, RS-232

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## 1. INTRODUCTION

This research aims designing and developing an intermediary circuit to connect a camera - CMOS-C3088- to computer using an AVR microprocessor. The design is based on a project conducted by (Oiza, 2004) There are two data flows: first the commands which are transmitted from computer to the camera and second, the picture taken by the camera from the camera to the computer.

The interface between computer and AVR uses serial port RS232, while the interface between camera and AVR uses I<sup>2</sup>C protocol for accessing camera's registers and a 8-bit port for reading the picture. These 8 bits are transferred using 8 pins of IDC. The camera can also be connected to a TV using analogue output. The schematic is shown in figure 1.

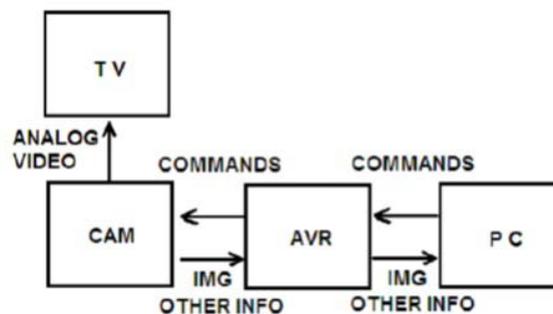


Figure 1: Interconnection Schematic

## 2. HARDWARE

The C3088 camera has a digital output and benefits from a visual CMOS sensor OV6220 from OmniVision. The digital port transmits the data as 8 or 16 bits data flow. All the functionality of the camera is configurable by changing the camera registers with I<sup>2</sup>C interface.

The output of the camera can be shown as different RGB or UYV channels. In this project we use the Y channel with 8 bits to represent the intensity of each pixel. The U and V channels are not used. The information is send sequentially and synchronization is done by HREF, YSINK and PCLK signals. YSINK signal shows the start of new frame, HREF signal is the time when data is valid and PCLK is the clock signal. This is enough for reading the picture from camera by microcontroller without any extra hardware. These signals are shown in figure 2.

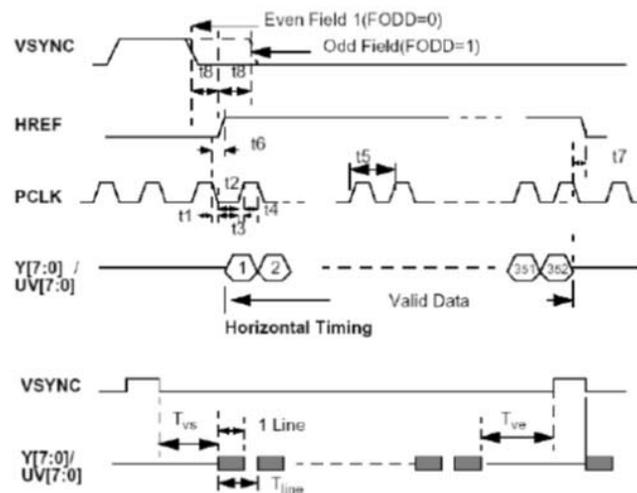


Figure 2: Signals on the Bus

The ID address of camera for writing is 0xc0 and 0xc1 for reading. The pin configuration of camera is as follows:

- Y0 to Y7: digital bus of Y output
- UV0 to UV7: output bus of UV
- PWDN: Power down mode and RST Reset
- SDA: serial I<sup>2</sup>C input
- SCL: input I<sup>2</sup>C serial clock

Hardware configuration is discussed here. The VCC voltage is 5v.

## 2.1 RESET and CLK

The reset part is pulled up with a 10K resistor and a switch to ground on reset. A 16 MHz crystal with two 2pf capacitors are used as external oscillator. The crystal is connected on XTAL1 and XTAL2 pins. These circuits are shown in figure 3.

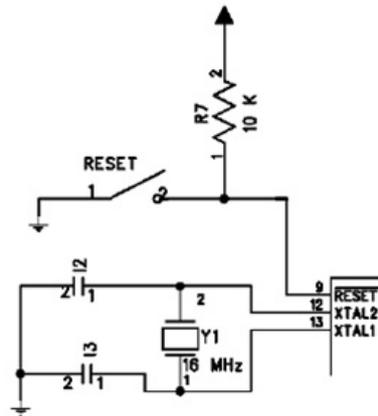


Figure 3: External Crystal Circuit

## 2.2 LED and SWITCH

And LED is used on PD7 pin for debugging purposes. Also a pulled up switch is connected to PD6. This configuration is showed in figure 4.

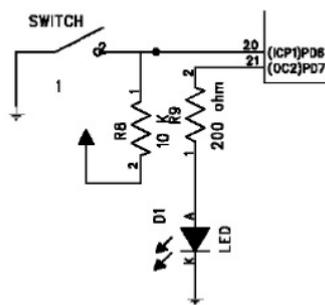


Figure 4: LED and SWITCH Circuit

## 2.3 Serial Connection

As the TTL level of microprocessor is not compatible with computer, we should use a Max232. PD0 (RXD) and PD1 (TXD) should be connected to ports 2 and 3 of RS232. This is depicted in figure 5. All the capacitors (except the two used for crystal) are 1 micro farad.

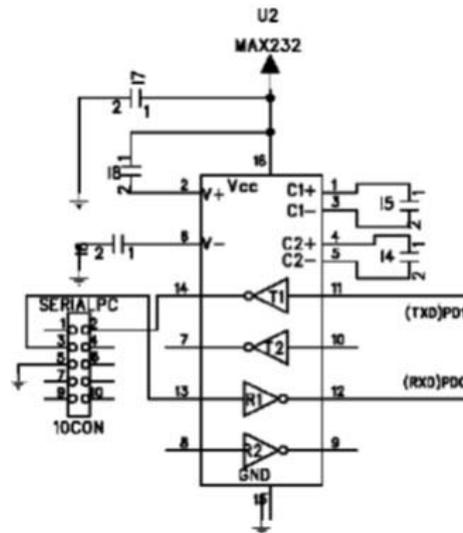
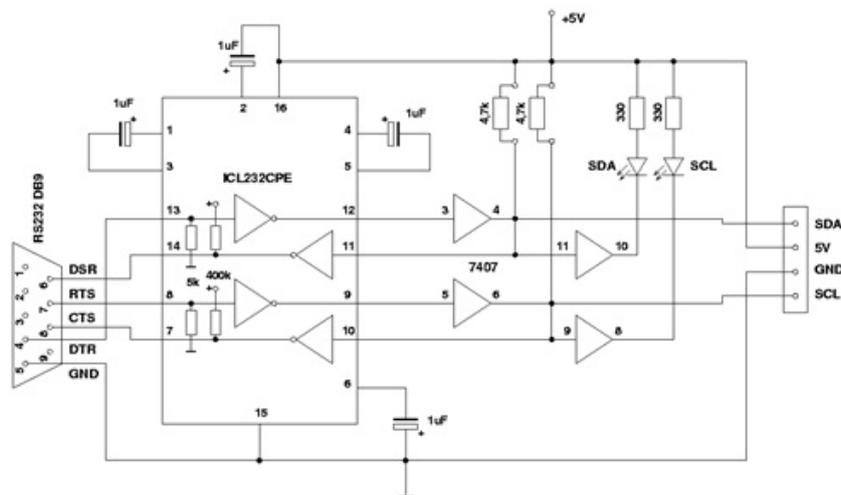


Figure 5: Serial Connection Circuit

## 2.4 I<sup>2</sup>C and RS-232

Due to wide use of RS-232 in connecting different devices, an interface that is capable of connecting RS-232 to I<sup>2</sup>C can give so much flexibility to electronic designers. A sample circuit is shown in figure 6.

Figure 6: RS-232 Serial Interface Adapter for the I<sup>2</sup>C Bus

In this project AVR microcontroller works as master and the camera is slave. Camera registers can be written or read by AVR. At first master puts the address of the devices that want to read from, on the bus. Then the address of read register is put on the bus. At last, the slave puts the requested data on the bus.

I<sup>2</sup>C protocol in this project is written by customizing TWI (two wire interface) which is built in ATMEGA 16.

## 2.5 C3088 camera

The operation voltage of this camera is 5v. This voltage is connected directly to pins 20 and 22 of the camera. Ports 31, 21 and 15 are connected to common ground. As all the reset are commanded via software, PWDN and RST ports are grounded.

Y0 to Y7 (Y bus of camera) are connected to port A of microcontroller (PA0 to PA7).

PCLK is connected to PD2, HREF is connected to PD3 and VSYNC is connected to PD4. As UV is not used in this configuration it is not necessary to connect the specified bus to microcontroller. To use I<sup>2</sup>C protocol appropriately, SDA and SCL pins of camera should be connected to PC1 and PC0 pins of microcontroller. These two pins are connected to TWI hardware of microcontroller which run I<sup>2</sup>C protocol. VTO pin is analogue video output which can be connected to TV via RCA connector. The schematic is shown in figure 7.

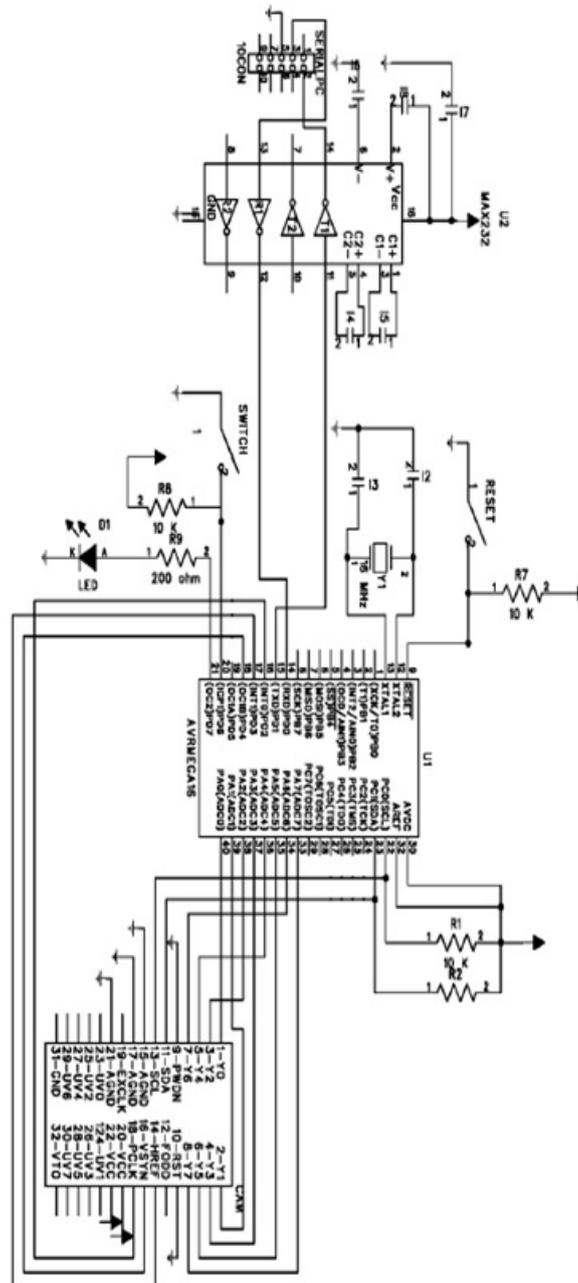


Figure 7: C3088 Camera Circuit Schematic

### 3. SOFTWARE

All the codes in this project are in C language. Some of the parts are described here.

#### 3.1 Serial Communication

The communication using serial port would implement the communication between computer and microprocessor. We can prove that the system is working by communicating via this channel. A serial communication program like HyperTerminal can be used on computer to communicate with the microprocessor.

The appropriate code is fetched from ATMEL USART library for GCC compiler. The code has been customized for this project. The bytes would be received by an interrupt and saved in a buffered. This is the only interrupt used by the system. There is no buffer to send the bytes.

### 3.2 I<sup>2</sup>C Communication

One of the most important parts of control systems is data communication. Researchers are working to develop a reliable, fast and secure protocols for this aim. The I<sup>2</sup>C protocol has been invented by Philips in 1980's to communicate between TVs and processors. It has been widely used by electronic manufacturers because of its simplicity and speed.

I<sup>2</sup>C stands for Inter IC that represents its aim, providing a communication link between integrated circuits. Nowadays, this protocol is used generally in electronic industry beyond audio/video instruments. There are more than 1000 ICs which implement and support this protocol.

#### 3.2.1 I<sup>2</sup>C benefits

I<sup>2</sup>C brings simplicity and speed for designing integrated circuits. Operation block diagram is fully compatible with real ICs and designer can gain the final schematic rapidly. There is no need to design an interface because it is implemented on-chip and impedance matching calculations would be omitted. It is controllable via hardware or software. We can add or remove appropriate ICs. Software design time would be reduced so much because of presence of prepared libraries.

Also due to the technology of manufacturing I<sup>2</sup>C compatible devices, they can gain the benefits mentioned below:

1. Low current consumption
2. Acceptable noise tolerance
3. Wide range of working voltage
4. Wide range of temperature tolerance

#### 3.2.2 I<sup>2</sup>C bus hardware

There are two main data lines:

- Serial Data Line (SDA)
- Serial Clock Line (SCL)

As these two lines transmit data in both ways, we can have more than one master or each device can work as master or slave.



means that the byte has not been received, otherwise if SDA goes down it means that the byte has been received properly.

#### 4.1 Synchronizing clock pulse

Clock pulses are made by Masters. Each master puts its clock pulse on SCL. As the wired-AND bus is used, the clock pulses are AND and there would be common clock pulse. Clock synchronization is shown in figure 11.

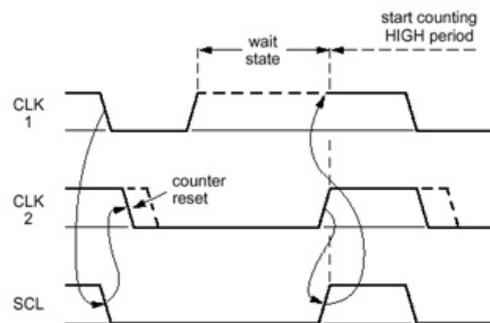


Figure 11: Clock Synchronization during the Arbitration Procedure

#### 4.2 Addressing:

To address each device in this protocol we need an addressing method. For each device some of the bits are addressed on-chip and others are address by hardware. At first 7-bit address was used, but now by developing the bus and using more devices an address with 10 bits is used.

#### 4.3 BMP

Bitmap image (BMP) is the selected format for transferring the captured image to computer. This selection is because only the information of each pixel is transmitted after header. This specification allows us to transfer the image just while capturing it. This properties is so important as there is no need for extra memory nor any program to render the image in the computer.

The format of BMP file follows:

- Header: contains file information and is 14 bytes long
- Info Header: contains image information
- Palette: translates each pixel's information to color
- Data: contains all data pixels. In our program each byte represents a pixel



Figure 12: BMP File Format

As the basic frequency of PCLK is 17.73 MHz and AVR is not so fast to read each pixel two solutions would be used:

- Using extra hardware for reading and saving image
- Reducing PCLK frequency by writing in 0x11 register

In this project we use the second solution. The appropriate frequency for reading the image depends on the method used for reading. If we read the image as horizontal lines, the minimum frequency 69.25 KHz must be used. This allows us to save the image in the AVR's memory as soon as a line is read. Another method is to read a vertical line of image in each frame. In this method the maximum frequency is 260 KHz. But we need to read a lot of frames as vertical lines to complete an image. Nevertheless we use the later method because in the first method the captured image is so bright.

When we want to transmit the image to computer, headers and palette are transmitted first and then we read the image from camera. We read the first frame and column and the transmit it to the computer pixel by pixel.

## 5. RESULTS

The image is ready to be seen on computer after interconnecting the hardware and loading the software. After running HyperTerminal on computer and hitting enter key the message is shown:

```
....Control Camera Program....  
... Mostafa, Safar and Mohsen Winter 2012 ...
```

Type HELP and return for help

By typing Help the menu is shown:

```
ACK
HELP MENU-Commands:
RESET
MIRRORON
MIRROROFF
PHOTO
TESTBMP
```

The commands are as follows:

- RESET: reset all registers of camera to their initial value
- MIRRORON: mirrors the picture
- MIRROROFF: turns the mirror property off
- PHOTO: sends a BMP file to the computer which contains the captured photo by camera. The frequency of PCLK is reduced by microcontroller and one column is read for each frame. As a result, the image would be captured in 90 seconds and sent to computer at that time. Because of long time of capturing only static images would be captured. The resolution is 352x244 pixels. We should save the received information in the computer terminal and create a bmp file.
- TESTBMP: sending a software created BMP to computer. This photo is created by some control loops in the microcontroller.

Some of the captured photos are shown below.

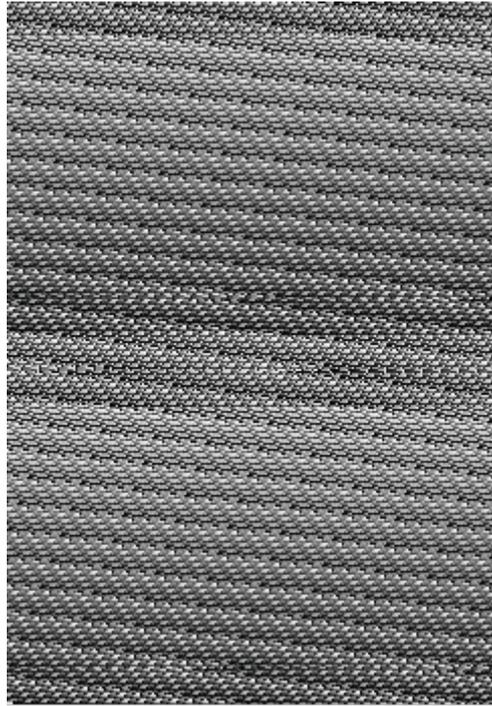


Figure 13: Test BMP

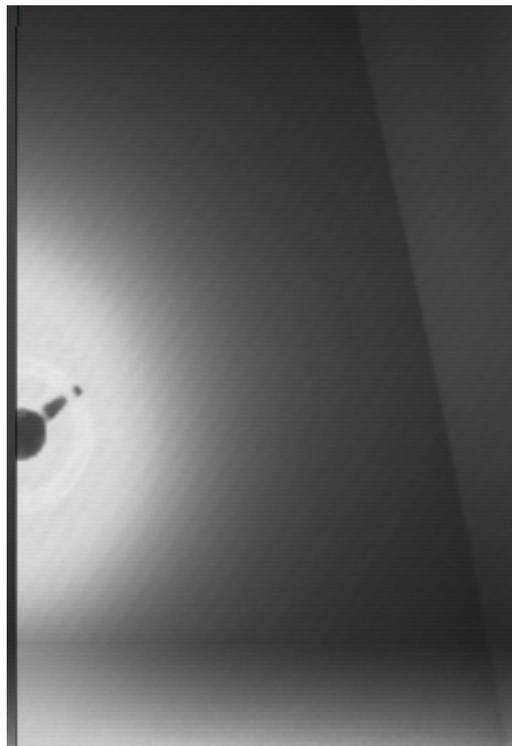




Figure 14: Some of Captured Photos

Some photos of the camera and implemented circuits are shown below.

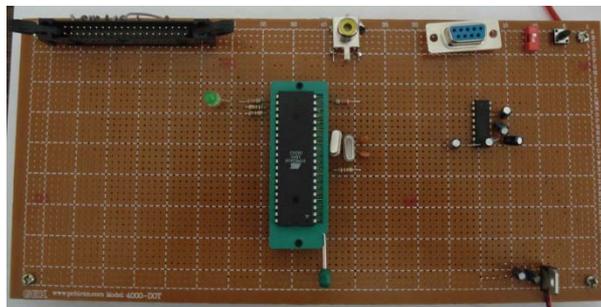


Figure 15: Photos of Camera and Implementd Circuits

## 6. REFERENCES

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