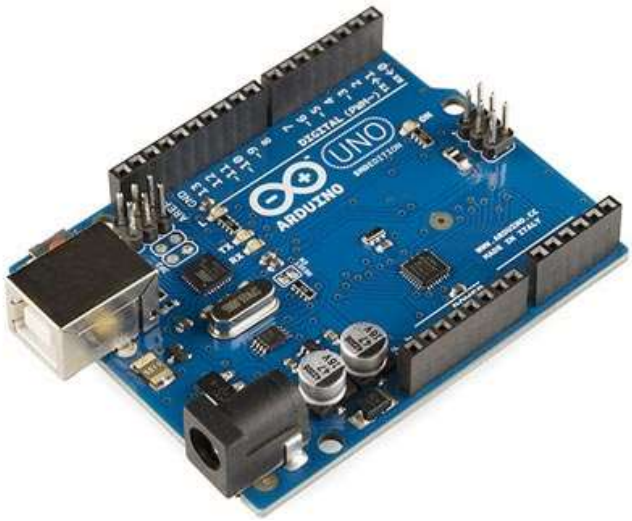
OV7670 Camera Module with Arduino

Content

How to Use OV7670 Camera Module with Arduino.



Cameras have always dominated the electronics industry as it has lots of applications such as visitor monitoring system, surveillance system, attendance system etc. Cameras that we use today are smart and have a lot of features that were not present in earlier cameras. While today's digital cameras not only capture images but also captures high-level descriptions of the scene and analyze what they see. It is used extensively in Robotics, Artificial Intelligence, Machine Learning etc. The Captured frames are processed using Artificial Intelligence and Machine Learning, and then used in many applications like Number plate detection, object detection, motion detection, facial recognition etc.

In this tutorial we will interface most widely used camera module OV7670 with Arduino UNO. The camera module OV7670 can be interfaced with Arduino Mega with same pin configuration, code and steps. The camera module is hard to interface because it has large number of pins and jumbled

wiring to carry out. Also the wire becomes very important when using camera modules as the choice of the wire and length of the wire can significantly affect the picture quality and can bring noise.

We have already done ample projects on Cameras with different kind of Microcontrollers and IoT Devices such as:

- Visitor Monitoring System with Raspberry Pi and Pi Camera
- IOT based Raspberry Pi Home Security System with Email Alert
- Raspberry Pi Surveillance Camera with Motion Capture

The Camera OV7670 works on 3.3V, so it becomes very important to avoid Arduino which gives 5V output at their Output GPIO pins. The OV7670 is a FIFO camera. But in this tutorial, the picture or frames will be grabbed without FIFO. This tutorial will have simple steps and simplified programming to interface OV7670 with Arduino UNO.

Components Required

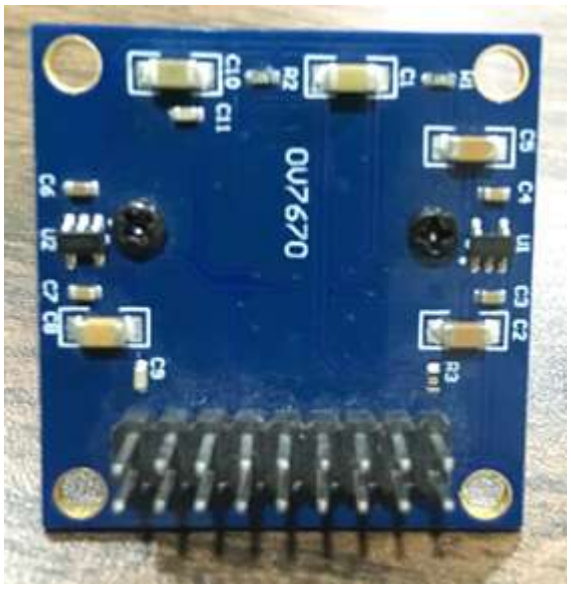
- Arduino UNO
- OV7670 Camera Module
- Resistors (10k, 4.7k)
- Jumpers

Things to Remember about Camera Module OV7670

OV7670 Camera Module is a FIFO camera Module available from different Manufacturers with different pin Configurations. TheOV7670 provides full frame, windowed 8-bit images in a wide range of formats. The image array is capable of operating at up to 30 frames per second (fps) in VGA. The OV7670 includes

- Image Sensor Array (of about 656 x 488 pixels)
- Timing Generator
- Analog Signal Processor
- A/D Converters
- Test Pattern Generator
- Digital Signal Processor (DSP)
- Image Scaler
- Digital Video Port
- LED and Strobe Flash Control Output

The OV7670 image sensor is controlled using Serial Camera Control Bus (SCCB) which is an I2C interface (SIOC, SIOD) with a maximum clock frequency of 400KHz.



The Camera comes with handshaking signals such as:

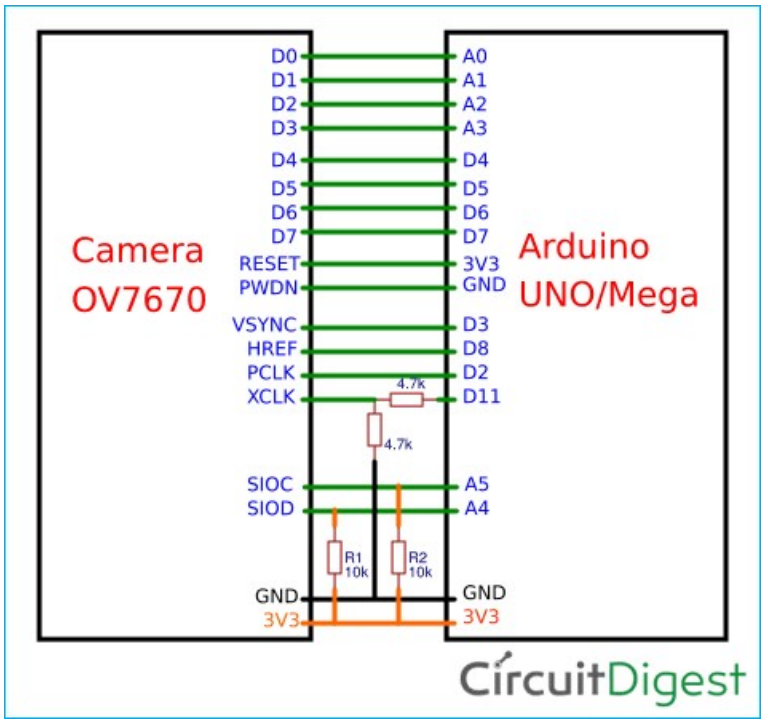
- VSYNC: Vertical Sync Output – Low during frame
- HREF: Horizontal Reference – High during active pixels of row
- PCLK: Pixel Clock Output – Free running clock. Data is valid on rising edge

In addition to this, it has several more signals such as

- D0-D7: 8-bit YUV/RGB Video Component Digital Output
- PWDN: Power Down Mode Selection – Normal Mode and Power Down Mode
- XCLK: System Clock Input
- Reset: Reset Signal

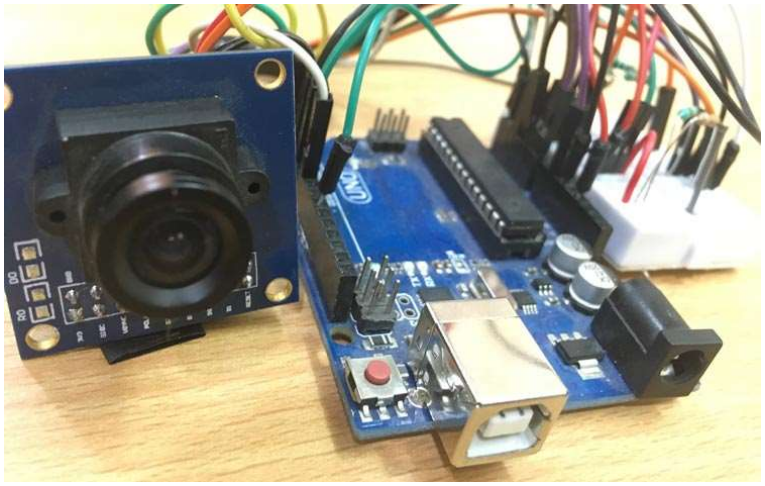
The OV7670 is clocked from a 24MHz oscillator. This gives a Pixel Clock (PCLK) output of 24MHz. The FIFO provides 3Mbps of video frame buffer memory. The test pattern generator features 8-bar color bar pattern, fade-to-gray color bar patter. Now let's start programming the Arduino UNO for testing Camera OV7670 and grabbing frames using serial port reader.

Circuit Diagram



Programming Arduino UNO

The programming starts with including required library necessary for OV7670. Since OV7670 runs on I2C interface, it includes <util/twi.h> library. The libraries used in this project are built-in libraries of Arduino IDE. We just have to include the libraries to get the job done.



After this, the registers need to be modified for OV7670. The program is divided into small functions for better understanding.

The *Setup()* comprises all the initial setups required for only image capturing. The first function is arduinoUnoInut() which is used to initialize the Arduino uno. Initially it disables all the global

interrupts and sets the communication interface configurations such as the PWM clock, selection of interrupt pins, presclaer selection, adding parity and stop bits.

```
arduinoUnoInut();
```

After configuring the Arduino, the camera has to be configured. To initialize the camera, we only have the options to change the register values. The register values need to be changed from the default to the custom. Also add required delay depending upon the microcontroller frequency we are using. As, slow microcontrollers have less processing time adding more delay between capturing frames.

```
void camInit(void){
 writeReg(0x12, 0x80);
  _delay_ms(100);
  wrSensorRegs8_8(ov7670_default_regs);
 writeReg(REG_COM10, 32);//PCLK does not toggle on HBLANK.
}
```

The camera is set to take a QVGA image so the resolution needs to be selected. The function configures the register to take a QVGA image.

```
setResolution();
```

In this tutorial, the images are taken in monochrome, so the register value is set to output a monochrome image. The function sets the register values from register list which is predefined in the program.

```
setColor();
```

The below function is written to register function which writes the hex value to register. If you get the scrambled images then try to change the second term i.e. 10 to 9/11/12. But most of the time this value works fine so no need to change it.

```
writeReg(0x11, 10);
```

This function is used to get the image resolution size. In this project we are taking pictures in the size of 320 x 240 pixels.

```
captureImg(320, 240);
```

Other than this, the code also has the I2C configurations divided in to several parts. Just to get the data from camera, the I2C configurations has Start, Read, Write, Set Address function which are important when using I2C protocol.

You can find the complete code with a demonstration video at the end of this tutorial. Just Upload the code and open the Serial Port Reader and grab the frames.

How to Use Serial Port Reader for reading Images

Serial Port Reader is a simple GUI, download it from here. This captures the base64 encode and decodes it to form an image. Just follow these simple steps to use Serial Port Reader

Step 1: Connect Your Arduino to any USB Port of your PC
Step 2: Click on “Check” to find your Arduino COM Port
Step 3: Finally click on “Start” button to start reading serially.
Step 4: One can also save this picture by just clicking on “Save Picture”.

Precautions when using OV7670

- Try to use wires or jumpers as short as possible
- Avoid any loose contact to any pins on Arduino or OV7670
- Be careful about connecting as large number of wiring can lead short circuit
- If the UNO gives 5V output to GPIO then use Level Shifter.
- Use 3.3V Input for OV7670 as exceeding voltage than this can damage the OV7670 module.

This project is created to give overview of using a camera module with Arduino. Since Arduino has less memory, so the processing may not be as expected. You can use different controllers which has more memory for processing.

Code

```
#include <stdint.h>
#include <avr/io.h>
#include <util/twi.h>
#include <util/delay.h>
#include <avr/pgmspace.h>

#define F_CPU 16000000UL
#define vga   0
#define qvga  1
#define qqvga   2
#define yuv422  0
#define rgb565  1
#define bayerRGB  2
#define camAddr_WR  0x42
#define camAddr_RD  0x43

/* Registers */
#define REG_GAIN    0x00  /* Gain lower 8 bits (rest in vref) */
#define REG_BLUE    0x01  /* blue gain */
#define REG_RED      0x02  /* red gain */
#define REG_VREF    0x03  /* Pieces of GAIN, VSTART, VSTOP */
#define REG_COM1    0x04  /* Control 1 */
#define COM1_CCIR656  0x40    /* CCIR656 enable */

#define REG_BAVE    0x05  /* U/B Average level */
#define REG_GbAVE   0x06  /* Y/Gb Average level */
#define REG_AECHH   0x07  /* AEC MS 5 bits */
#define REG_RAVE    0x08  /* V/R Average level */
#define REG_COM2    0x09  /* Control 2 */
#define COM2_SSLEEP        0x10  /* Soft sleep mode */
#define REG_PID          0x0a  /* Product ID MSB */
#define REG_VER          0x0b  /* Product ID LSB */
#define REG_COM3    0x0c  /* Control 3 */
#define COM3_SWAP        0x40  /* Byte swap */
#define COM3_SCALEEN         0x08  /* Enable scaling */
#define COM3_DCWEN         0x04  /* Enable downsamp/crop/window */
#define REG_COM4    0x0d  /* Control 4 */
#define REG_COM5    0x0e  /* All "reserved" */
#define REG_COM6    0x0f  /* Control 6 */
#define REG_AECH    0x10  /* More bits of AEC value */
#define REG_CLKRC   0x11  /* Clocl control */
#define CLK_EXT          0x40  /* Use external clock directly */
#define CLK_SCALE   0x3f  /* Mask for internal clock scale */
#define REG_COM7    0x12  /* Control 7 */ //REG mean address.
#define COM7_RESET         0x80  /* Register reset */
#define COM7_FMT_MASK        0x38
#define COM7_FMT_VGA         0x00
#define COM7_FMT_CIF         0x20  /* CIF format */
#define COM7_FMT_QVGA        0x10  /* QVGA format */
```

```
#define COM7_FMT_QCIF        0x08  /* QCIF format */
#define COM7_RGB         0x04  /* bits 0 and 2 - RGB format */
#define COM7_YUV         0x00  /* YUV */
#define COM7_BAYER         0x01  /* Bayer format */
#define COM7_PBAYER        0x05  /* "Processed bayer" */
#define REG_COM8    0x13  /* Control 8 */
#define COM8_FASTAEC         0x80  /* Enable fast AGC/AEC */
#define COM8_AECSTEP         0x40  /* Unlimited AEC step size */
#define COM8_BFILT    0x20  /* Band filter enable */
#define COM8_AGC    0x04  /* Auto gain enable */
#define COM8_AWB    0x02  /* White balance enable */
#define COM8_AEC    0x01  /* Auto exposure enable */
#define REG_COM9    0x14  /* Control 9- gain ceiling */
#define REG_COM10   0x15  /* Control 10 */
#define COM10_HSYNC        0x40  /* HSYNC instead of HREF */
#define COM10_PCLK_HB        0x20  /* Suppress PCLK on horiz blank */
#define COM10_HREF_REV         0x08  /* Reverse HREF */
#define COM10_VS_LEAD        0x04  /* VSYNC on clock leading edge */
#define COM10_VS_NEG         0x02  /* VSYNC negative */
#define COM10_HS_NEG         0x01  /* HSYNC negative */
#define REG_HSTART    0x17  /* Horiz start high bits */
#define REG_HSTOP   0x18  /* Horiz stop high bits */
#define REG_VSTART    0x19  /* Vert start high bits */
#define REG_VSTOP   0x1a  /* Vert stop high bits */
#define REG_PSHFT   0x1b  /* Pixel delay after HREF */
#define REG_MIDH    0x1c  /* Manuf. ID high */
#define REG_MIDL    0x1d  /* Manuf. ID low */
#define REG_MVFP    0x1e  /* Mirror / vflip */
#define MVFP_MIRROR        0x20  /* Mirror image */
#define MVFP_FLIP   0x10  /* Vertical flip */

#define REG_AEW          0x24  /* AGC upper limit */
#define REG_AEB          0x25    /* AGC lower limit */
#define REG_VPT          0x26  /* AGC/AEC fast mode op region */
#define REG_HSYST   0x30  /* HSYNC rising edge delay */
#define REG_HSYEN   0x31  /* HSYNC falling edge delay */
#define REG_HREF    0x32  /* HREF pieces */
#define REG_TSLB    0x3a  /* lots of stuff */
#define TSLB_YLAST    0x04  /* UYVY or VYUY - see com13 */
#define REG_COM11   0x3b  /* Control 11 */
#define COM11_NIGHT        0x80  /* NIght mode enable */
#define COM11_NMFR         0x60  /* Two bit NM frame rate */
#define COM11_HZAUTO         0x10  /* Auto detect 50/60 Hz */
#define COM11_50HZ         0x08  /* Manual 50Hz select */
#define COM11_EXP   0x02
#define REG_COM12   0x3c  /* Control 12 */
#define COM12_HREF         0x80  /* HREF always */
#define REG_COM13   0x3d  /* Control 13 */
#define COM13_GAMMA        0x80  /* Gamma enable */
#define COM13_UVSAT        0x40  /* UV saturation auto adjustment */
#define COM13_UVSWAP         0x01  /* V before U - w/TSLB */
#define REG_COM14   0x3e  /* Control 14 */
```

```
#define COM14_DCWEN        0x10  /* DCW/PCLK-scale enable */
#define REG_EDGE    0x3f  /* Edge enhancement factor */
#define REG_COM15   0x40  /* Control 15 */
#define COM15_R10F0        0x00  /* Data range 10 to F0 */
#define COM15_R01FE        0x80  /*      01 to FE */
#define COM15_R00FF        0xc0  /*      00 to FF */
#define COM15_RGB565         0x10  /* RGB565 output */
#define COM15_RGB555         0x30  /* RGB555 output */
#define REG_COM16   0x41  /* Control 16 */
#define COM16_AWBGAIN        0x08  /* AWB gain enable */
#define REG_COM17   0x42  /* Control 17 */
#define COM17_AECWIN         0xc0  /* AEC window - must match COM4 */
#define COM17_CBAR         0x08  /* DSP Color bar */
/*
* This matrix defines how the colors are generated, must be
* tweaked to adjust hue and saturation.
*
* Order: v-red, v-green, v-blue, u-red, u-green, u-blue
* They are nine-bit signed quantities, with the sign bit
* stored in0x58.Sign for v-red is bit 0, and up from there.
*/
#define REG_CMATRIX_BASE  0x4f
#define CMATRIX_LEN          6
#define REG_CMATRIX_SIGN  0x58
#define REG_BRIGHT    0x55  /* Brightness */
#define REG_CONTRAS        0x56  /* Contrast control */
#define REG_GFIX    0x69  /* Fix gain control */
#define REG_REG76   0x76  /* OV's name */
#define R76_BLKPCOR        0x80  /* Black pixel correction enable */
#define R76_WHTPCOR         0x40  /* White pixel correction enable */
#define REG_RGB444         0x8c  /* RGB 444 control */
#define R444_ENABLE        0x02  /* Turn on RGB444, overrides 5x5 */
#define R444_RGBX   0x01  /* Empty nibble at end */
#define REG_HAECC1    0x9f  /* Hist AEC/AGC control 1 */
#define REG_HAECC2    0xa0  /* Hist AEC/AGC control 2 */
#define REG_BD50MAX        0xa5  /* 50hz banding step limit */
#define REG_HAECC3    0xa6  /* Hist AEC/AGC control 3 */
#define REG_HAECC4    0xa7  /* Hist AEC/AGC control 4 */
#define REG_HAECC5    0xa8  /* Hist AEC/AGC control 5 */
#define REG_HAECC6    0xa9  /* Hist AEC/AGC control 6 */
#define REG_HAECC7    0xaa  /* Hist AEC/AGC control 7 */
#define REG_BD60MAX        0xab  /* 60hz banding step limit */
#define REG_GAIN    0x00  /* Gain lower 8 bits (rest in vref) */
#define REG_BLUE    0x01  /* blue gain */
#define REG_RED          0x02  /* red gain */
#define REG_VREF    0x03  /* Pieces of GAIN, VSTART, VSTOP */
#define REG_COM1    0x04  /* Control 1 */
#define COM1_CCIR656         0x40  /* CCIR656 enable */
#define REG_BAVE    0x05  /* U/B Average level */
#define REG_GbAVE   0x06  /* Y/Gb Average level */
#define REG_AECHH   0x07  /* AEC MS 5 bits */
#define REG_RAVE    0x08  /* V/R Average level */
```

```
#define REG_COM2    0x09  /* Control 2 */
#define COM2_SSLEEP        0x10  /* Soft sleep mode */
#define REG_PID         0x0a  /* Product ID MSB */
#define REG_VER         0x0b  /* Product ID LSB */
#define REG_COM3    0x0c  /* Control 3 */
#define COM3_SWAP        0x40  /* Byte swap */
#define COM3_SCALEEN         0x08  /* Enable scaling */
#define COM3_DCWEN         0x04  /* Enable downsamp/crop/window */
#define REG_COM4    0x0d  /* Control 4 */
#define REG_COM5    0x0e  /* All "reserved" */
#define REG_COM6    0x0f  /* Control 6 */
#define REG_AECH    0x10  /* More bits of AEC value */
#define REG_CLKRC   0x11  /* Clocl control */
#define CLK_EXT         0x40  /* Use external clock directly */
#define CLK_SCALE   0x3f  /* Mask for internal clock scale */
#define REG_COM7    0x12  /* Control 7 */
#define COM7_RESET         0x80  /* Register reset */
#define COM7_FMT_MASK        0x38
#define COM7_FMT_VGA         0x00
#define COM7_FMT_CIF         0x20  /* CIF format */
#define COM7_FMT_QVGA        0x10  /* QVGA format */
#define COM7_FMT_QCIF        0x08  /* QCIF format */
#define COM7_RGB    0x04  /* bits 0 and 2 - RGB format */
#define COM7_YUV    0x00  /* YUV */
#define COM7_BAYER         0x01  /* Bayer format */
#define COM7_PBAYER        0x05  /* "Processed bayer" */
#define REG_COM8    0x13  /* Control 8 */
#define COM8_FASTAEC         0x80  /* Enable fast AGC/AEC */
#define COM8_AECSTEP         0x40  /* Unlimited AEC step size */
#define COM8_BFILT    0x20  /* Band filter enable */
#define COM8_AGC    0x04  /* Auto gain enable */
#define COM8_AWB    0x02  /* White balance enable */
#define COM8_AEC    0x01  /* Auto exposure enable */
#define REG_COM9    0x14  /* Control 9- gain ceiling */
#define REG_COM10   0x15  /* Control 10 */
#define COM10_HSYNC        0x40  /* HSYNC instead of HREF */
#define COM10_PCLK_HB        0x20  /* Suppress PCLK on horiz blank */
#define COM10_HREF_REV         0x08  /* Reverse HREF */
#define COM10_VS_LEAD         0x04  /* VSYNC on clock leading edge */
#define COM10_VS_NEG         0x02  /* VSYNC negative */
#define COM10_HS_NEG         0x01  /* HSYNC negative */
#define REG_HSTART    0x17  /* Horiz start high bits */
#define REG_HSTOP   0x18  /* Horiz stop high bits */
#define REG_VSTART    0x19  /* Vert start high bits */
#define REG_VSTOP   0x1a  /* Vert stop high bits */
#define REG_PSHFT   0x1b  /* Pixel delay after HREF */
#define REG_MIDH    0x1c  /* Manuf. ID high */
#define REG_MIDL    0x1d  /* Manuf. ID low */
#define REG_MVFP    0x1e  /* Mirror / vflip */
#define MVFP_MIRROR        0x20  /* Mirror image */
#define MVFP_FLIP   0x10  /* Vertical flip */
#define REG_AEW         0x24  /* AGC upper limit */
```

```
#define REG_AEB         0x25  /* AGC lower limit */
#define REG_VPT         0x26  /* AGC/AEC fast mode op region */
#define REG_HSYST   0x30  /* HSYNC rising edge delay */
#define REG_HSYEN   0x31  /* HSYNC falling edge delay */
#define REG_HREF    0x32  /* HREF pieces */
#define REG_TSLB    0x3a  /* lots of stuff */
#define TSLB_YLAST    0x04  /* UYVY or VYUY - see com13 */
#define REG_COM11   0x3b  /* Control 11 */
#define COM11_NIGHT       0x80  /* NIght mode enable */
#define COM11_NMFR        0x60  /* Two bit NM frame rate */
#define COM11_HZAUTO        0x10  /* Auto detect 50/60 Hz */
#define COM11_50HZ        0x08  /* Manual 50Hz select */
#define COM11_EXP   0x02
#define REG_COM12   0x3c  /* Control 12 */
#define COM12_HREF        0x80  /* HREF always */
#define REG_COM13   0x3d  /* Control 13 */
#define COM13_GAMMA       0x80  /* Gamma enable */
#define COM13_UVSAT       0x40  /* UV saturation auto adjustment */
#define COM13_UVSWAP        0x01  /* V before U - w/TSLB */
#define REG_COM14   0x3e  /* Control 14 */
#define COM14_DCWEN       0x10  /* DCW/PCLK-scale enable */
#define REG_EDGE    0x3f  /* Edge enhancement factor */
#define REG_COM15   0x40  /* Control 15 */
#define COM15_R10F0       0x00  /* Data range 10 to F0 */
#define COM15_R01FE       0x80  /*      01 to FE */
#define COM15_R00FF       0xc0  /*      00 to FF */
#define COM15_RGB565        0x10  /* RGB565 output */
#define COM15_RGB555        0x30  /* RGB555 output */
#define REG_COM16   0x41  /* Control 16 */
#define COM16_AWBGAIN       0x08  /* AWB gain enable */
#define REG_COM17   0x42  /* Control 17 */
#define COM17_AECWIN        0xc0  /* AEC window - must match COM4 */
#define COM17_CBAR        0x08  /* DSP Color bar */

#define CMATRIX_LEN           6
#define REG_BRIGHT    0x55  /* Brightness */
#define REG_REG76   0x76  /* OV's name */
#define R76_BLKPCOR       0x80  /* Black pixel correction enable */
#define R76_WHTPCOR       0x40  /* White pixel correction enable */
#define REG_RGB444        0x8c  /* RGB 444 control */
#define R444_ENABLE       0x02  /* Turn on RGB444, overrides 5x5 */
#define R444_RGBX   0x01  /* Empty nibble at end */
#define REG_HAECC1    0x9f  /* Hist AEC/AGC control 1 */
#define REG_HAECC2    0xa0  /* Hist AEC/AGC control 2 */
#define REG_BD50MAX       0xa5  /* 50hz banding step limit */
#define REG_HAECC3    0xa6  /* Hist AEC/AGC control 3 */
#define REG_HAECC4    0xa7  /* Hist AEC/AGC control 4 */
#define REG_HAECC5    0xa8  /* Hist AEC/AGC control 5 */
#define REG_HAECC6    0xa9  /* Hist AEC/AGC control 6 */
#define REG_HAECC7    0xaa  /* Hist AEC/AGC control 7 */
#define REG_BD60MAX       0xab  /* 60hz banding step limit */
#define MTX1          0x4f  /* Matrix Coefficient 1 */
```

```
#define MTX2          0x50  /* Matrix Coefficient 2 */
#define MTX3          0x51  /* Matrix Coefficient 3 */
#define MTX4          0x52  /* Matrix Coefficient 4 */
#define MTX5          0x53  /* Matrix Coefficient 5 */
#define MTX6          0x54  /* Matrix Coefficient 6 */
#define REG_CONTRAS       0x56  /* Contrast control */
#define MTXS          0x58  /* Matrix Coefficient Sign */
#define AWBC7         0x59  /* AWB Control 7 */
#define AWBC8         0x5a  /* AWB Control 8 */
#define AWBC9         0x5b  /* AWB Control 9 */
#define AWBC10          0x5c  /* AWB Control 10 */
#define AWBC11          0x5d  /* AWB Control 11 */
#define AWBC12          0x5e  /* AWB Control 12 */
#define REG_GFI         0x69  /* Fix gain control */
#define GGAIN         0x6a  /* G Channel AWB Gain */
#define DBLV          0x6b
#define AWBCTR3         0x6c  /* AWB Control 3 */
#define AWBCTR2         0x6d  /* AWB Control 2 */
#define AWBCTR1         0x6e  /* AWB Control 1 */
#define AWBCTR0         0x6f  /* AWB Control 0 */

struct regval_list{
  uint8_t reg_num;
  uint16_t value;
};

const struct regval_list qvga_ov7670[] PROGMEM = {
  { REG_COM14, 0x19 },
  { 0x72, 0x11 },
  { 0x73, 0xf1 },

  { REG_HSTART, 0x16 },
  { REG_HSTOP, 0x04 },
  { REG_HREF, 0xa4 },
  { REG_VSTART, 0x02 },
  { REG_VSTOP, 0x7a },
  { REG_VREF, 0x0a },

  { 0xff, 0xff }, /* END MARKER */
};

const struct regval_list yuv422_ov7670[] PROGMEM = {
  { REG_COM7, 0x0 },  /* Selects YUV mode */
  { REG_RGB444, 0 },  /* No RGB444 please */
  { REG_COM1, 0 },
  { REG_COM15, COM15_R00FF },
  { REG_COM9, 0x6A }, /* 128x gain ceiling; 0x8 is reserved bit */
  { 0x4f, 0x80 },   /* "matrix coefficient 1" */
  { 0x50, 0x80 },   /* "matrix coefficient 2" */
  { 0x51, 0 },    /* vb */
  { 0x52, 0x22 },   /* "matrix coefficient 4" */
```

```
 { 0x53, 0x5e },   /* "matrix coefficient 5" */
 { 0x54, 0x80 },   /* "matrix coefficient 6" */
 { REG_COM13, COM13_UVSAT },
 { 0xff, 0xff },   /* END MARKER */
};

const struct regval_list ov7670_default_regs[] PROGMEM = {//from the linux driver
 { REG_COM7, COM7_RESET },
 { REG_TSLB, 0x04 }, /* OV */
 { REG_COM7, 0 },  /* VGA */
 /*
 * Set the hardware window.  These values from OV don't entirely
 * make sense - hstop is less than hstart.  But they work...
 */
 { REG_HSTART, 0x13 }, { REG_HSTOP, 0x01 },
 { REG_HREF, 0xb6 }, { REG_VSTART, 0x02 },
 { REG_VSTOP, 0x7a }, { REG_VREF, 0x0a },

 { REG_COM3, 0 }, { REG_COM14, 0 },
 /* Mystery scaling numbers */
 { 0x70, 0x3a }, { 0x71, 0x35 },
 { 0x72, 0x11 }, { 0x73, 0xf0 },
 { 0xa2,/* 0x02 changed to 1*/1 }, { REG_COM10, 0x0 },
 /* Gamma curve values */
 { 0x7a, 0x20 }, { 0x7b, 0x10 },
 { 0x7c, 0x1e }, { 0x7d, 0x35 },
 { 0x7e, 0x5a }, { 0x7f, 0x69 },
 { 0x80, 0x76 }, { 0x81, 0x80 },
 { 0x82, 0x88 }, { 0x83, 0x8f },
 { 0x84, 0x96 }, { 0x85, 0xa3 },
 { 0x86, 0xaf }, { 0x87, 0xc4 },
 { 0x88, 0xd7 }, { 0x89, 0xe8 },
 /* AGC and AEC parameters.  Note we start by disabling those features,
 then turn them only after tweaking the values. */
 { REG_COM8, COM8_FASTAEC | COM8_AECSTEP },
 { REG_GAIN, 0 }, { REG_AECH, 0 },
 { REG_COM4, 0x40 }, /* magic reserved bit */
 { REG_COM9, 0x18 }, /* 4x gain + magic rsvd bit */
 { REG_BD50MAX, 0x05 }, { REG_BD60MAX, 0x07 },
 { REG_AEW, 0x95 }, { REG_AEB, 0x33 },
 { REG_VPT, 0xe3 }, { REG_HAECC1, 0x78 },
 { REG_HAECC2, 0x68 }, { 0xa1, 0x03 }, /* magic */
 { REG_HAECC3, 0xd8 }, { REG_HAECC4, 0xd8 },
 { REG_HAECC5, 0xf0 }, { REG_HAECC6, 0x90 },
 { REG_HAECC7, 0x94 },
 { REG_COM8, COM8_FASTAEC | COM8_AECSTEP | COM8_AGC | COM8_AEC },
 { 0x30, 0 }, { 0x31, 0 },//disable some delays
 /* Almost all of these are magic "reserved" values.  */
 { REG_COM5, 0x61 }, { REG_COM6, 0x4b },
 { 0x16, 0x02 }, { REG_MVFP, 0x07 },
 { 0x21, 0x02 }, { 0x22, 0x91 },
 { 0x29, 0x07 }, { 0x33, 0x0b },
```

```
{ 0x35, 0x0b }, { 0x37, 0x1d },
{ 0x38, 0x71 }, { 0x39, 0x2a },
{ REG_COM12, 0x78 }, { 0x4d, 0x40 },
{ 0x4e, 0x20 }, { REG_GFIX, 0 },
/*{0x6b, 0x4a},*/{ 0x74, 0x10 },
{ 0x8d, 0x4f }, { 0x8e, 0 },
{ 0x8f, 0 }, { 0x90, 0 },
{ 0x91, 0 }, { 0x96, 0 },
{ 0x9a, 0 }, { 0xb0, 0x84 },
{ 0xb1, 0x0c }, { 0xb2, 0x0e },
{ 0xb3, 0x82 }, { 0xb8, 0x0a },

/* More reserved magic, some of which tweaks white balance */
{ 0x43, 0x0a }, { 0x44, 0xf0 },
{ 0x45, 0x34 }, { 0x46, 0x58 },
{ 0x47, 0x28 }, { 0x48, 0x3a },
{ 0x59, 0x88 }, { 0x5a, 0x88 },
{ 0x5b, 0x44 }, { 0x5c, 0x67 },
{ 0x5d, 0x49 }, { 0x5e, 0x0e },
{ 0x6c, 0x0a }, { 0x6d, 0x55 },
{ 0x6e, 0x11 }, { 0x6f, 0x9e }, /* it was 0x9F "9e for advance AWB" */
{ 0x6a, 0x40 }, { REG_BLUE, 0x40 },
{ REG_RED, 0x60 },
{ REG_COM8, COM8_FASTAEC | COM8_AECSTEP | COM8_AGC | COM8_AEC | COM8_AWB },

/* Matrix coefficients */
{ 0x4f, 0x80 }, { 0x50, 0x80 },
{ 0x51, 0 },    { 0x52, 0x22 },
{ 0x53, 0x5e }, { 0x54, 0x80 },
{ 0x58, 0x9e },

{ REG_COM16, COM16_AWBGAIN }, { REG_EDGE, 0 },
{ 0x75, 0x05 }, { REG_REG76, 0xe1 },
{ 0x4c, 0 },     { 0x77, 0x01 },
{ REG_COM13, /*0xc3*/0x48 }, { 0x4b, 0x09 },
{ 0xc9, 0x60 },   /*{REG_COM16, 0x38},*/
{ 0x56, 0x40 },

{ 0x34, 0x11 }, { REG_COM11, COM11_EXP | COM11_HZAUTO },
{ 0xa4, 0x82/*Was 0x88*/ }, { 0x96, 0 },
{ 0x97, 0x30 }, { 0x98, 0x20 },
{ 0x99, 0x30 }, { 0x9a, 0x84 },
{ 0x9b, 0x29 }, { 0x9c, 0x03 },
{ 0x9d, 0x4c }, { 0x9e, 0x3f },
{ 0x78, 0x04 },

/* Extra-weird stuff.  Some sort of multiplexor register */
{ 0x79, 0x01 }, { 0xc8, 0xf0 },
{ 0x79, 0x0f }, { 0xc8, 0x00 },
{ 0x79, 0x10 }, { 0xc8, 0x7e },
{ 0x79, 0x0a }, { 0xc8, 0x80 },
```

```
 { 0x79, 0x0b }, { 0xc8, 0x01 },
 { 0x79, 0x0c }, { 0xc8, 0x0f },
 { 0x79, 0x0d }, { 0xc8, 0x20 },
 { 0x79, 0x09 }, { 0xc8, 0x80 },
 { 0x79, 0x02 }, { 0xc8, 0xc0 },
 { 0x79, 0x03 }, { 0xc8, 0x40 },
 { 0x79, 0x05 }, { 0xc8, 0x30 },
 { 0x79, 0x26 },
 { 0xff, 0xff }, /* END MARKER */
};

void error_led(void){
 DDRB |= 32;//make sure led is output
 while (1){//wait for reset
  PORTB ^= 32;// toggle led
  _delay_ms(100);
 }
}

void twiStart(void){
 TWCR = _BV(TWINT) | _BV(TWSTA) | _BV(TWEN);//send start
 while (!(TWCR & (1 << TWINT)));//wait for start to be transmitted
 if ((TWSR & 0xF8) != TW_START)
  error_led();
}

void twiWriteByte(uint8_t DATA, uint8_t type){
 TWDR = DATA;
 TWCR = _BV(TWINT) | _BV(TWEN);
 while (!(TWCR & (1 << TWINT))) {}
 if ((TWSR & 0xF8) != type)
  error_led();
}

void twiAddr(uint8_t addr, uint8_t typeTWI){
 TWDR = addr;//send address
 TWCR = _BV(TWINT) | _BV(TWEN);   /* clear interrupt to start transmission */
 while ((TWCR & _BV(TWINT)) == 0); /* wait for transmission */
 if ((TWSR & 0xF8) != typeTWI)
  error_led();
}

voidwriteReg(uint8_t reg, uint8_t dat){
 //send start condition
 twiStart();
 twiAddr(camAddr_WR, TW_MT_SLA_ACK);
 twiWriteByte(reg, TW_MT_DATA_ACK);
 twiWriteByte(dat, TW_MT_DATA_ACK);
 TWCR = (1 << TWINT) | (1 << TWEN) | (1 << TWSTO);//send stop
 _delay_ms(1);
}
```

```
static uint8_t twiRd(uint8_t nack){
 if (nack){
  TWCR = _BV(TWINT) | _BV(TWEN);
  while ((TWCR & _BV(TWINT)) == 0); /* wait for transmission */
  if ((TWSR & 0xF8) != TW_MR_DATA_NACK)
    error_led();
  return TWDR;
 }
 else{
  TWCR = _BV(TWINT) | _BV(TWEN) | _BV(TWEA);
  while ((TWCR & _BV(TWINT)) == 0); /* wait for transmission */
  if ((TWSR & 0xF8) != TW_MR_DATA_ACK)
    error_led();
  return TWDR;
 }
}

uint8_t rdReg(uint8_t reg){
 uint8_t dat;
 twiStart();
 twiAddr(camAddr_WR, TW_MT_SLA_ACK);
 twiWriteByte(reg, TW_MT_DATA_ACK);
 TWCR = (1 << TWINT) | (1 << TWEN) | (1 << TWSTO);//send stop
 _delay_ms(1);
 twiStart();
 twiAddr(camAddr_RD, TW_MR_SLA_ACK);
 dat = twiRd(1);
 TWCR = (1 << TWINT) | (1 << TWEN) | (1 << TWSTO);//send stop
 _delay_ms(1);
 return dat;
}

void wrSensorRegs8_8(const struct regval_list reglist[]){
 uint8_t reg_addr, reg_val;
 const struct regval_list *next = reglist;
 while ((reg_addr != 0xff) | (reg_val != 0xff)){
  reg_addr = pgm_read_byte(&next->reg_num);
  reg_val = pgm_read_byte(&next->value);
  writeReg(reg_addr, reg_val);
  next++;
 }
}

void setColor(void){
 wrSensorRegs8_8(yuv422_ov7670);
// wrSensorRegs8_8(qvga_ov7670);
}

void setResolution(void){
 writeReg(REG_COM3, 4); // REG_COM3 enable scaling
```

```
 wrSensorRegs8_8(qvga_ov7670);
}

void camInit(void){
 writeReg(0x12, 0x80);
 _delay_ms(100);
 wrSensorRegs8_8(ov7670_default_regs);
 writeReg(REG_COM10, 32);//PCLK does not toggle on HBLANK.
}

void arduinoUnoInut(void) {
 cli();//disable interrupts

  /* Setup the 8mhz PWM clock
 * This will be on pin 11*/
 DDRB |= (1 << 3);//pin 11
 ASSR &= ~(_BV(EXCLK) | _BV(AS2));
 TCCR2A = (1 << COM2A0) | (1 << WGM21) | (1 << WGM20);
 TCCR2B = (1 << WGM22) | (1 << CS20);
 OCR2A = 0;//(F_CPU)/(2*(X+1))
 DDRC &= ~15;//low d0-d3 camera
 DDRD &= ~252;//d7-d4 and interrupt pins
 _delay_ms(3000);

  //set up twi for 100khz
 TWSR &= ~3;//disable prescaler for TWI
 TWBR = 72;//set to 100khz

  //enable serial
 UBRR0H = 0;
 UBRR0L = 1;//0 = 2M baud rate. 1 = 1M baud. 3 = 0.5M. 7 = 250k 207 is 9600 baud rate.
 UCSR0A |= 2;//double speed aysnc
 UCSR0B = (1 << RXEN0) | (1 << TXEN0);//Enable receiver and transmitter
 UCSR0C = 6;//async 1 stop bit 8bit char no parity bits
}

void StringPgm(const char * str){
 do{
    while (!(UCSR0A & (1 << UDRE0)));//wait for byte to transmit
    UDR0 = pgm_read_byte_near(str);
    while (!(UCSR0A & (1 << UDRE0)));//wait for byte to transmit
 } while (pgm_read_byte_near(++str));
}

static void captureImg(uint16_t wg, uint16_t hg){
 uint16_t y, x;

 StringPgm(PSTR("*RDY*"));

 while (!(PIND & 8));//wait for high
 while ((PIND & 8));//wait for low
```

```
   y = hg;
  while (y--){
       x = wg;
     //while (!(PIND & 256));//wait for high
   while (x--){
     while ((PIND & 4));//wait for low
          UDR0 = (PINC & 15) | (PIND & 240);
         while (!(UCSR0A & (1 << UDRE0)));//wait for byte to transmit
     while (!(PIND & 4));//wait for high
     while ((PIND & 4));//wait for low
     while (!(PIND & 4));//wait for high
    }
    //  while ((PIND & 256));//wait for low
  }
    _delay_ms(100);
}

void setup(){
  arduinoUnoInut();
  camInit();
  setResolution();
  setColor();
 writeReg(0x11, 10); //Earlier it had the value:writeReg(0x11, 12); New version works better for me :)
!!!!
}

void loop(){
  captureImg(320, 240);
}
```