STEREO VIDEO

How to Generate Stereoscopic 3D Video Using Cheap Board Cameras

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Revision history

8/25/02 Updated text, schematic and bill of materials for sync board to include description of hardware for stereo ranging capability.

1. Introduction

This booklet will show you how to generate stereoscopic 3D video, which can be displayed a television or VGA monitor, and viewed using liquid crystal shutter glasses. Applications for such a camera include robots, telepresence experiments, stationary observatories, radio-controlled vehicles and other vehicles where the operator would benefit from viewing the world three-dimensionally.

In August 2002 the book was revised recently to include stereo ranging, which deals with how the stereo camera hardware can be used in robotics as the video source for determining spatial relationships between objects.

The text is broken into several sections. Section 2, *How the System Works* describes, well, how it works. This section introduces the basic ideas behind synchronizing board cameras and generating the stereo view, and describes system component options. Section 2 also discusses stereo ranging, how the stereo camera module can be applied to robot vision, and some of the problems that are associated with stereo ranging.

Sections 3 and 4, *Cameras* and *Synchronization Circuit Board,* comprise the main part of the book because they deal with how to identify the cameras that can be used, how to modify them, and, at the circuit level, how to synchronize them. *Cameras* describes which board cameras can be used for stereoscopic viewing, how the cameras should be modified for use in the module, and the method of synchronizing the cameras. Several board cameras are identified which can be used; vendors' contact information is included. *Synchronization Circuit Board* describes the circuit functions needed for the module, including the video switch, reset timer, and shutter control. This section includes timing diagrams for the more interesting signals, schematic and bill of materials.

Sections 5 covers camera module construction and basic operation, including camera alignment and shutter control.

Section 6 deals with shutter glasses and the various adapters and equipment needed to get the video onto a display for viewing. These include the adapters needed to connect to the shutter glasses, the RF modulator and the VGA converter.

Section 7 describes a video transmitter and receiver set used to test remote operation. This particular set was chosen because of its cost, its ability to carry stereo audio, its cost, the fact it is intended to carry NTSC video, and its cost. Several sources are included.

Section 8 winds up with last words about what else could have been covered if I had another year to spend on the project.

Section 9 lists the sources for the parts, components and equipment used in the project.

The camera module and VGA adapter printed circuit boards were created using ExpressPCB version 2.6.0 from Engineering Express. This is a free software package available at www.expresspcb.com. The package will allow you to create artwork for small double-sided prototype boards, order them over the Internet and receive 2 or more boards within a week. Their Mini-board service is very cost effective for prototypes, but does not support multiple layers (beyond two-sided), or silkscreen or solder mask layers.

ExpressPCB only supports Windows platforms. The artwork (pcb) files were included in the download with this book. Understandably Mac users cannot use them, but printouts of the top and bottom copper layers, silkscreen and soldermask for the two boards were scanned into jpeg files and included in the package. These pictures are not to scale, but will at least provide a representation of the component layout and signal routing. To request replacements for these files, or to order circuit boards, send an email to stereo-video@worldnet.att.net.

Many features and functions are not mentioned that, if implemented, would cause this project to go on forever. These include camera focus and camera separation; stereo audio; camera lenses; light filters for outdoor use; battery power for mobile use. More of this in section 8.

The scope of the book has narrowed greatly from the original idea of building a free-roaming, radio-controlled vehicle that did not have to stay within sight in order to control it. In fact, what started this was the idea of not only driving such a vehicle to places I could not see, but to places that I could not *go*.

Remember that this is all “stereo video on the cheap.” While the stereoscopic effect is very good, it may not look anything like the computer-generated video that you may be accustomed to seeing. Some people will be disappointed with the result.

Many things can cause the results to be less than satisfactory. Of course, the cameras need to be from the same manufacturer. And cameras, even from the same manufacturer, and even the same model, are not created equal. Fabrication differences at both the chip and board level can cause discernible differences in output between any two cameras.

The hardware techniques used to synchronize the two cameras and convert NTSC video to VGA will degrade video quality. First, half the picture is thrown away to create a stereoscopic video stream, and second, the necessary conversion from analog to digital and then back to analog again will reduce resolution and introduce distortion. Liquid crystal shutter glasses may suffer from “ghosting,” where the alternate eye will see a ghost of the wrong image. Shutter glasses will also limit the amount of light from the display.

While viewing 60-frame-per-second video with shutter glasses, you will experience flicker caused by each eye receiving only half the number of fields displayed on the screen. This flicker may cause headaches. And using shutter glasses (as well as any stereoscopic viewing device) for prolonged periods may cause disorientation.

Using a radio transmitter and receiver for remote viewing will introduce more opportunities for video quality to be degraded. The ISM (Industrial, Scientific and Medical) frequency band of 2.4GHz may be convenient, but it is also where you will find interference from many devices, including microwave ovens and wireless networked devices (such as Bluetooth).

SVGA displays and head-mounted displays had to be dropped from the project because it was discovered during development that the methods used to convert NTSC video to SVGA are incompatible with the field-sequential stereoscopic video stream that this hardware generates.

Special problems arise when using the video module for stereo ranging. The software that must extract spatial information from the video expects to see the same data on the exact same data on corresponding lines of alternate fields. This means the two cameras must be aligned perfectly, and the mounting base must be strong enough to maintain that alignment. The mounting technique discussed in this book is only adequate for stereoscopic viewing. The reliable and precise alignment needed for stereo ranging may need to be augmented in the software.

But enough of that. On with the project.

2. How the System Works

The heart of the system is the module that holds the two cameras. In order for stereo video to be possible, two cameras must be synchronized. The secret lies in the fact that many cheap board cameras can be synchronized together.

A stream of NTSC video is composed of frames, which in turn are made up of fields. One field will contain the odd-numbered lines of the display, and the other field will contain the even-numbered lines. The lines from the two fields *interlace* with each other to create a complete picture on a television set. The two fields that make up the single frame are generated separately. Two pictures are displayed on the picture tube in such a way that the lines of each field fills in the spaces between lines of the other field. This method of video display is called *interlacing*. All television sets use interlacing, and at one time computer monitors were also interlaced.

Computer monitors no longer use interlacing, and the entire picture is displayed in a single field. So a television displays 30 frames per second, and a VGA monitor displays 60 frames per second. For the rest of this booklet, the difference between frames and fields is only important when speaking of the video stream from the camera to circuit board that combines the two streams. After that, once the two streams have been combined, frames are the individual video pictures that make up the stream, alternating between left and right eyes.

Synchronizing video cameras

Two cameras can be considered synchronized when both are generating video using the same timing. This means the vertical sync pulse from each camera occurs at the exact same time. Synchronization is necessary so that when the field generated by one camera has been sent out, the other camera is starting the next field.

Figure 1 shows what happens as the two video streams are combined. The individual fields emerging from the left and right cameras can be labeled L1, L2, L3, … and R1, R2, R3, and so on. To combine two video streams a circuit will switch every other field from each camera, into the outgoing stream, which then becomes a series of alternating fields, one from each camera. The result will be L1 from the left camera, R2 from the right camera, and so on. You should be able to see that it is not possible to combine both L1 and R1, because they represent fields that are being generated at the same time.

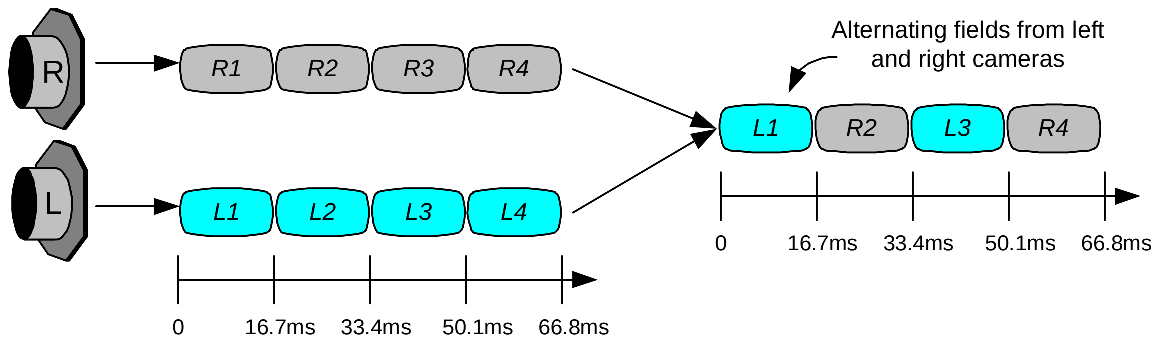

Figure 1a Combining video streams

The single idea central to this system is that many cheap board cameras are available that provide a field sync output, as well as a field sync input. If you inject a positive TTL-level pulse on the sync input to the camera, you will reset the camera to the beginning of the frame. *Therefore, if you connect the sync output of one camera to the sync input to the other camera, you synchronize the cameras.*

Note that this form of synchronization does not put the two cameras into lockstep. It simply forces one camera to start generating video at a time dictated by the other camera. Timing differences that can still occur at the line or pixel level should be negligible.

Stereo Ranging

Stereo ranging describes the process of using video from two or more cameras to help identity objects and their spatial relationships. It is used in medical instruments, in ocean floor mapping, and in vehicle navigation systems. NASA, for example, uses stereo ranging on the Mars Pathfinder rover to determine landing site topography and identify obstacles. The video camera pair (or set of cameras) and any controlling electronics is called a stereo sensor head or stereo ranging sensor.

The sensor head consists of the stereo camera module that has been specially configured to be used for stereo ranging. The video that is generated in this mode is not useable for viewing. While it was not tested on a computer monitor, when applied to a television it showed a picture distorted by the receiver's inability to synchronize on the input. This is because the input video consists, not of a standard NTSC frame, consisting of alternating odd and even fields, but of a series of odd fields, with no even field. Of course there's no guarantee all televisions would have that problem.

The output of the sensor head is normally connected to a frame grabber, which digitizes and stores the fields. Software (like the mounting base, is beyond the scope of this book) will then analyze the data, line by line, and provide information regarding objects and distances. A list of sources of software for stereo ranging is provided in the appendix.

The idea behind the stereo ranging sensor consists of two parts. First, each camera shows the same view of the scene. Because the cameras are separated by about two inches, the two captured images are rotated a few degrees away from each other. In fact, it is this disparity between the two images that is analyzed to provide information about depth.

Second, the video that is captured is the same field from both cameras -- the odd field, and that the two cameras are so well aligned that the same line in each left and right field holds exactly the same information, differing only by the angular difference between the two views.

Figures 1b and 1c show how the camera module's two video modes differ. Figure 1b shows the odd and even fields alternating to generate a frame that can be displayed. The timing of the right camera is controlled so that its odd field coincides with the left camera's odd field.

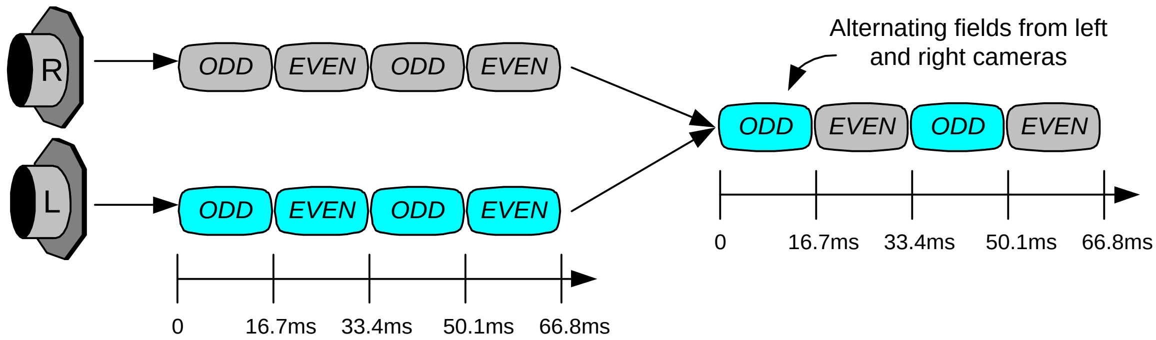

Figure 2b Odd/Even Fields for Stereo Display

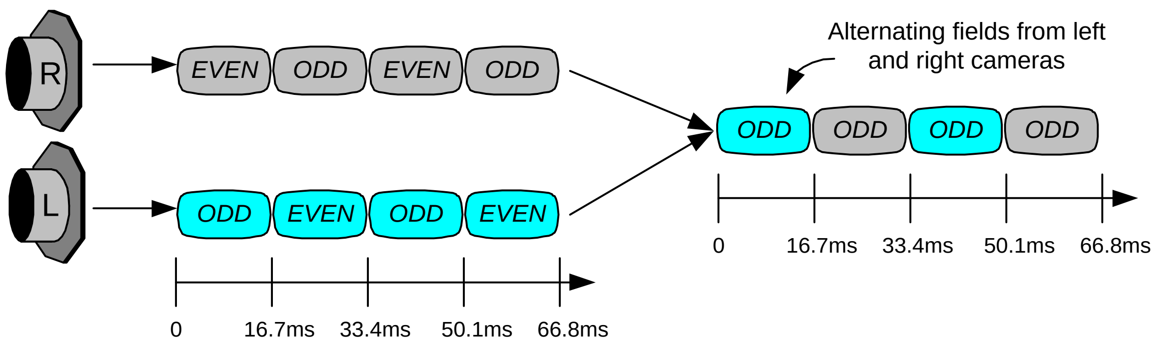

Figure 3c Odd Fields for Stereo Ranging

Figure 1c shows fields are still selected from each camera alternatively, but the right camera has had its timing adjusted so that its odd field coincide with the left camera's even field. As a result, only odd fields are included in the video stream.

The camera mounting scheme that is described in section 5 is intended only for use with the stereo display mode. Those who wish to operate the module as a stereo sensor should find a better mount for the cameras.

Configurations

There are four configurations based on display type: television or VGA monitor, and whether the camera module is local (direct cable link) or remote (wireless link). These four configurations are described below.

Local Camera with Television

Figure 2 shows the most basic configuration, which consists of the camera module, a television receiver, an RF modulator, a pair of LCD shutter glasses and a “TV dongle”. The shutter glasses connect directly to the camera module, which provides the signal needed to control the glasses. The TV dongle is just a 25-pin female D-sub connector that imitates the parallel port on a PC. It applies the shutter control signal from the camera module to pin 4 of the connector. This is normally one of the bi-directional data bits on the parallel port. The shutter glass adapter (the one that comes with the glasses), then picks up the signal from that pin and uses it to control the glasses. The TV dongle is described further in section 6.

The cable that carries video from the camera module to the RF modulator should be short, just a few inches. The camera module uses an RCA connector for video out. The RF modulator may have an RCA jack, a coax connector, or just two points to solder to (like the one used in this project). A 75 Ohm coaxial cable should be used to carry the video signal from the RF modulator to the television’s cable input connector.

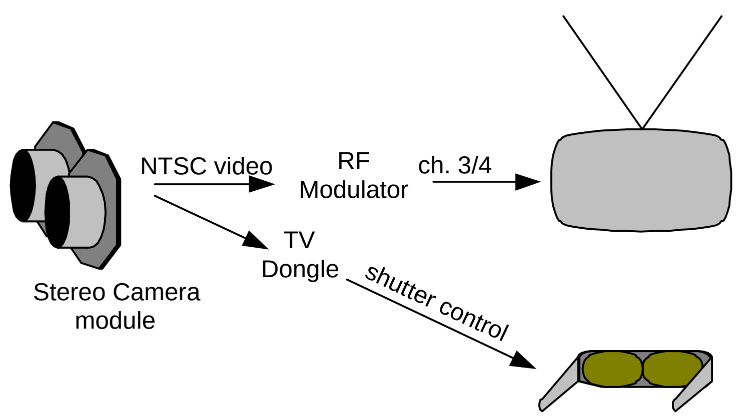

Figure 4 Local Camera with Television

Remote Camera with Television

Figure 3 shows a camera module (and stereo microphone) connected directly to a radio transmitter. The video output of the receiver is sent to the RF modulator where it is modulated onto a channel 3 or channel 4 TV carrier.

The video is also sent to an adapter called the shutter dongle. Among other things, this adapter will generate the odd/even shutter control signal from the received video. The shutter dongle is described in section 6.

The stereo audio output function was not implemented.

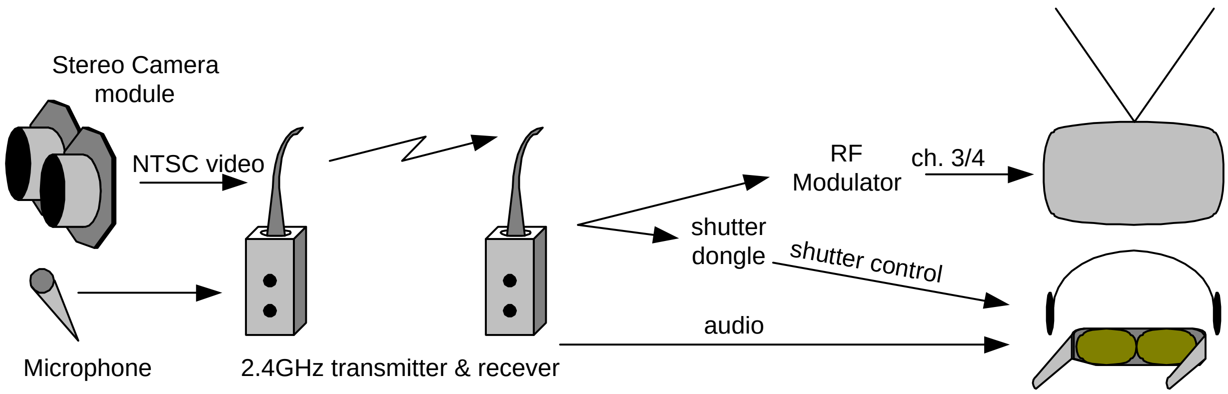

Figure 5 Remote Camera with Television

Local Camera with VGA Monitor

Figure 4 shows a camera module connected directly to a VGA converter (also called a line doubler), which converts the NTSC video to VGA format video. From there it is sent to a VGA monitor. One of the signals generated by the converter is vertical sync. This signal is sent to VGA dongle, which uses it to create the shutter control signal. The circuit that creates the control signal is essentially the same shutter control circuit that is on the camera module.

The shutter control can also be taken from the camera module itself; in other words, instead of tapping off the vertical sync with the VGA adapter, just connect the TV adapter between the camera module and the shutter glasses.

The VGA Adapter is described in section 6.

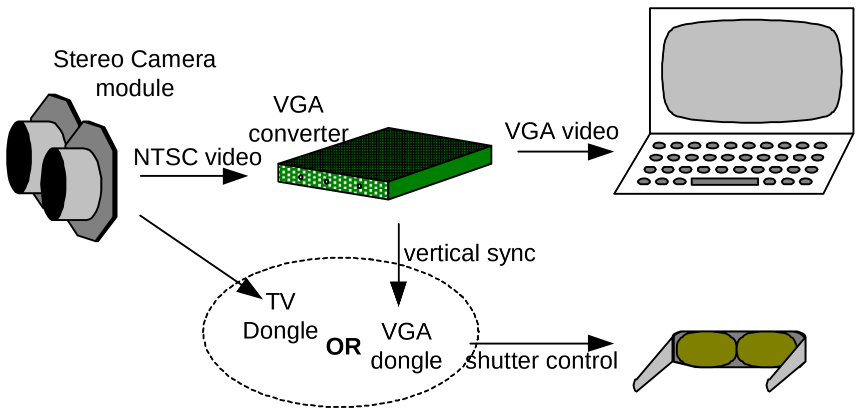

Figure 6 Local Camera with VGA Monitor

Remote Camera with VGA Monitor

Figure 5 shows a camera module (and stereo microphone) connected directly to a radio transmitter. After the video is received, it is sent to the VGA converter, which generates the video for the monitor. The vertical sync output of the converter is used by the VGA dongle to generate the shutter control signal.

Other than the transmitter and receiver, the other difference between Figure 5 and Figure 4 is the microphone included with the camera module. The transmitter and receiver set can often carry stereo audio along with the video.

The transmitter and receiver are described in section 7.

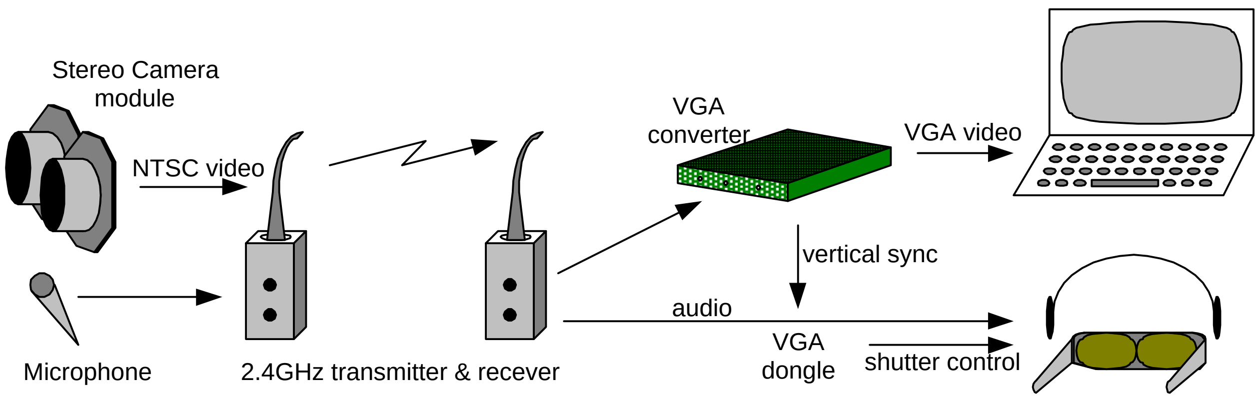

Figure 7 Remote camera with VGA Monitor

3. Cameras

Requirements

The board cameras that are candidates for this project must meet certain requirements: it should use a single-chip sensor, generate NTSC video, provide three signals needed for synchronization, and operate at power levels that allow battery operation.

Single-chip sensor

The very first requirement is that the camera should be based on a single-chip video sensor. Mulit-chip cameras would require access to documentation for the various chips to identify pin functions and timing. Since a lot of this documentation may be no longer available (remember, we're talking about obsolete cameras no longer in production), qualifying a single-chip camera is a more manageable challenge. Just probe the pins for a signal that looks like a positive-going vertical sync pulse, with a period of either 16.6ms (field sync) or 33.2ms (frame sync). If that's available, look for another signal nearby that looks like a square wave with a 33.2ms period (odd/even field). If these two are available, then another pin nearby will be the field sync input. Identify pins near the FSO and FODD outputs that are at or near ground level. Then turn off the camera and check those pins for ground. The one that's not connected to ground (hopefully there's only one in the area) should be the field sync input pin. Section 4 contains timing diagrams for these signals.

NTSC video format

The camera must generate video compatible with American television receivers and the VGA converters described earlier. While this book is limited in scope to NTSC video, cameras do exist that provide PAL video output, and VGA converters are available that can use the PAL format for input.

Sync Input and Output Signals

Three signals are needed to synchronize two cameras: FSI (Field Sync Input), FSO (Field Sync Output), and FODD (Field Odd/Even). The input signal, FSI, is absolutely required. You can't get away from it. If the camera does not have this signal input, then it can not receive any synchronization pulse from the other camera.

FSO is a vertical sync pulse that occurs during the vertical refresh period of the video signal. Figures 6 and 7 show FSO timing, and relationship to the video signal.

The third signal, FODD, indicates whether the current field in an interlaced frame is the first (odd) or second (even) field. The reason this signal is needed is to establish a predictable start to each frame. The first field is taken from the left camera. Since the right camera is reset on each incoming sync pulse, all fields generated by the right camera are the first (odd) field in the frame. It is important that the odd/even signal be used, in other words, that the video timing of each field fits the requirements of the television receiver. In order to display the field-sequential stereo video on a television set, two adjacent fields must add up to a frame, otherwise the displayed picture will tear and be distorted.

The odd/even flag is used by the sync circuit board to gate the left camera's odd field, and the right camera's even field, to the output video stream.

If the odd/even signal is not present it can be created using the LM1881 Sync Separator chip. See the VGA Adapter in section 5 for an implementation of the chip.

Battery Power

The camera should be able to be powered by a battery. Single-chip video cameras are able to operate with an input supply of 7-12V, and consume 35mA or less. The camera used in this project consumes about 28mA at 12V. Some cameras require regulated 5VDC rather than the range of 7 to 12V. In those instances, an external regulator will be needed.

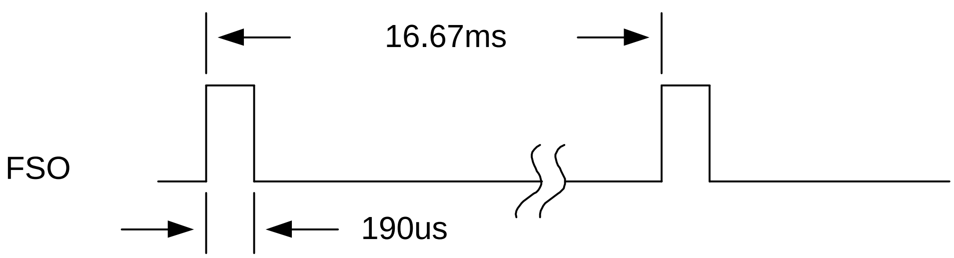

Figure 8 Frame Sync Out Signal Timing

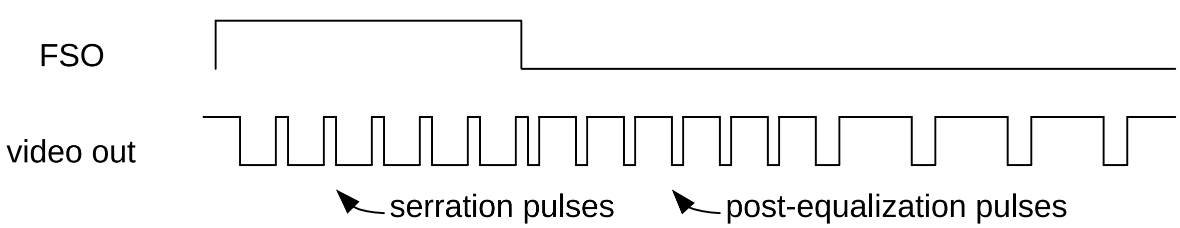

Figure 9 Relationship between FSO and Video Out

The camera used in this project

Smart Vision Products manufactures various types of CMOS sensor chips, including single-chip CMOS color cameras, and also board cameras using these devices. The camera module used in this project uses a board camera, which contains one of their chips, the SVP-OV7500. Today, this board camera can be found on the surplus market. The URLs and addresses of two sources are listed at the end of this chapter.

There are at least two varieties of this board camera on the market using this chip. These are the V-X0095 and the V-XA095. The difference between them is the connector on the back of the board: the V-X0095 has a 6-pin connector, and the V-XA095 has a 4-pin connector. Table 1 shows the pinout of the connectors, and figure 9 shows connector placement. It is also important to know which way is up, since the camera is commonly shown in the literature lying on its side.

It’s also important to note that I have never seen the V-X0095; Table 1 and Figure 9 use information taken from the vendors’ website, and only assumes the camera is oriented the same way as the V-XA095. The V-X0095 has not been available from the two vendors I am aware of that advertise it, and both vendors will ship you the V-XA095 in its place.

The three signals needed for synchronizing two cameras are FSI Pin (36), FSO (pin 33) and FODD (pin 34). These signals are also referred to as Frame Sync In, Frame Sync Out, and Odd/Even, respectively. See figure 10.

Figure 10 Project Camera Modified with Connector and Base Mounting

Pin	V-X0095	V-XA095
1	Video	Video
2	Ground	Ground
3	Power 7-12V	Power 7-12V
4	Frame Sync Out	Ground
5	Frame Sync In	-----------
6	Pixel Clock Out	-----------

Table 1 Connector pinouts

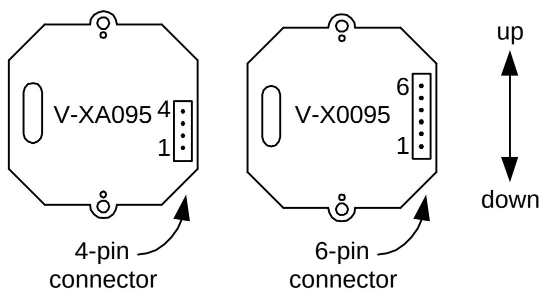

Figure 11 Rear View of SVP Cameras

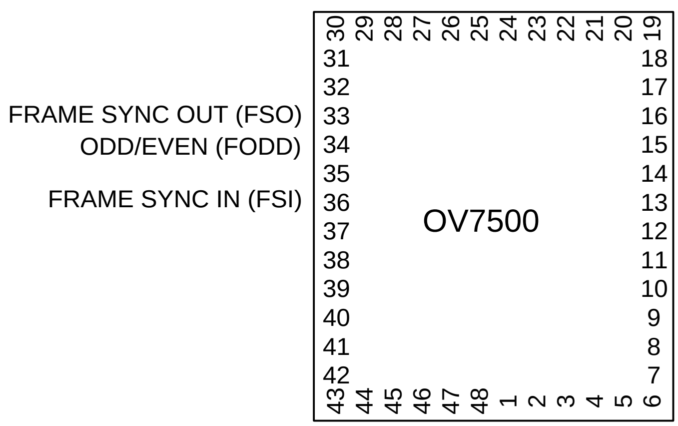

Figure 12 OV7500 Pinouts for Sync Signals

Modifying the Camera

In order to get to the signals needed for synchronization the V-XA095 must be opened up and wires soldered to three pins.

Things you will need:

- low-power soldering iron
- soldering tip with a narrow enough point to solder fine-pitch components
- low temperature solder
- magnifying glass
- holder for the magnifying glass and the board
- three short lengths (around 4”) of 30 gauge solid wire, preferably of different colors

Remove the lens housings of both cameras by unscrewing the two screws located in the protruding notches. Once the housing has been removed, be very careful not to touch the transparent lid of the sensor element. Not only will you leave smudges, but also you could damage the device through the lid by electrostatic discharge, if not through the initial handling, then through rubbing the lid to clean off the skin oil.

It is not necessary to solder all three wires to both cameras. One camera will be dedicated to the left side, and the other to the right side. The left camera only needs the frame sync and odd/even wires added and the right camera only needs to the frame sync input wire added, cutting the number of wires to solder by half. On the left camera, the wire colors should be different so you can determine which signal is which. So for the rest of this section there will be a “left” camera and a “right” camera.

Modifying the left camera

The two lengths of wire should be differentiated by either color, or some sort of attached label, so that if you solder both wires to each camera, you can tell in from out. The length of wire needed to go from any pin around the chip, out the exit hole and down to the PCB shouldn’t need to be more than about four inches.

Figure 11 shows a drawing of the front of the camera with the lens removed. The three wires shown, one blue, one red and one black, show connections for both cameras. The red and blue wires are soldered to the left camera, and the black wire is soldered to the right camera. Figure 12 shows a photo of the left camera wiring.

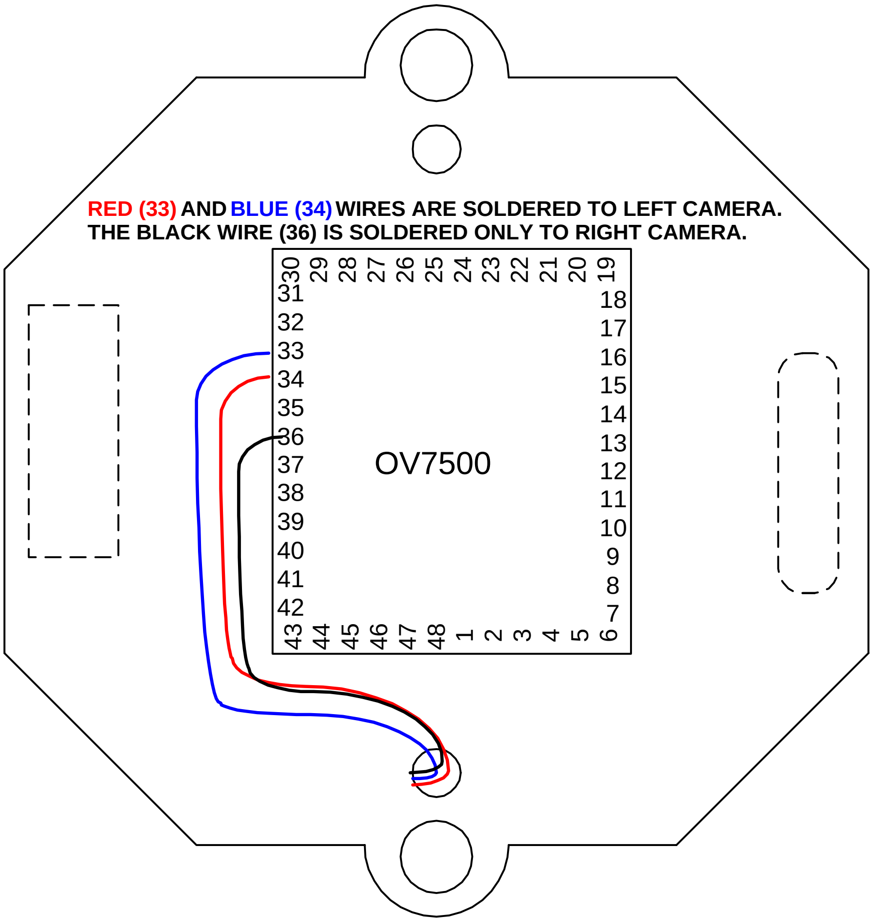

Figure 13 View of front of the camera with lens removed

For orientation, an outline of the connector and the oscillator crystal are shown in Figure 11.

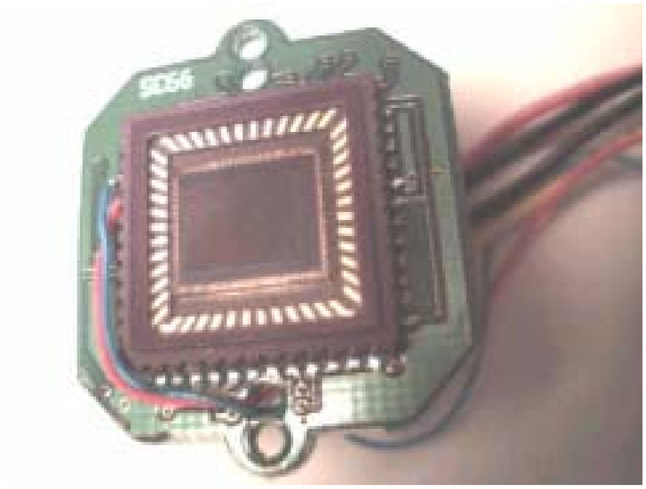

Figure 14 Photo of the modified left camera chip

Solder a 30 gauge solid wire on pin 33. On the right camera, solder another 30 gauge wire to pin 34. Route the wires around the chip to the small hole right next to the lens mounting hole. Re-install the lens housing. Be sure the wires are kept as close as possible to the chip to avoid getting them caught under the housing.

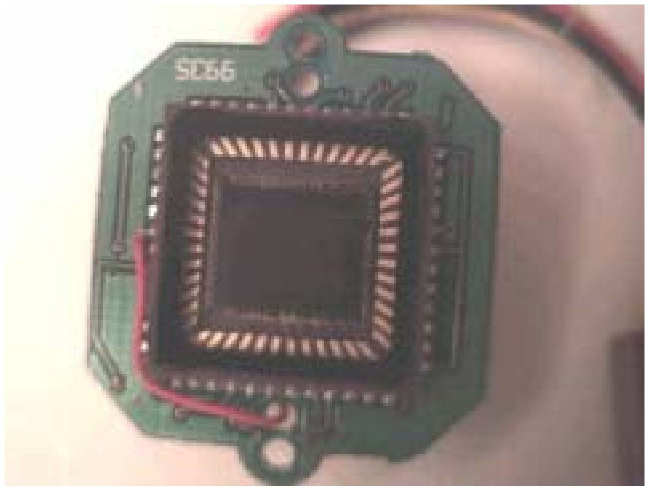

Figure 15 Photo of the modified right camera chip

Anchor the wires at the rear of the camera to prevent them breaking through metal fatigue. Create a small harness by tying the power and video pigtails together the two wires added with a piece of string.

Modifying the right camera

The right camera is modified in the same way, with this exception. Don't solder any wire to pins 33 or 34 (unless you really want to do all that soldering) and solder a wire to pin 36 (frame sync in) instead. See figures 11 and 13.

Preparing the camera mount

Since the V-XA095 camera does not lend itself to easy mounting, a mount must be built for each camera. Figure 15 shows pieces of Lexan added to the bottom of the camera, which can then be attached to the base.

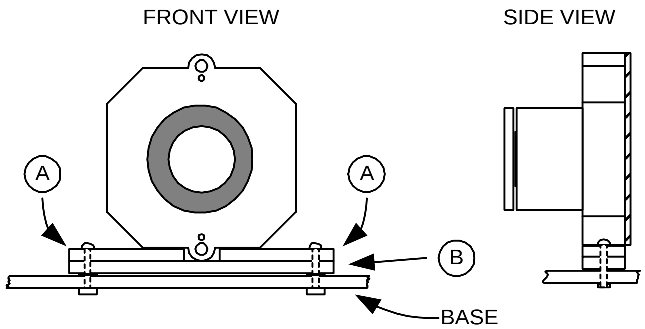

Figure 16 Camera mounting detail

Figure 17 Photo of camera mount

The base and parts A and B in figure 14 are composed of approximately 3/32" thick clear Lexan. Part B is about 1½" long and 3/16" wide. The two pieces labeled A are about 5/8" long and 3/16" wide. The two A pieces are glued on top of the B, keeping a gap between them of about 1/8" for the bottom camera PCB mounting screw. After giving the glue time to set, two holes are drilled on each end of the mount for 4-40 screws.

The camera lens housing is then glued on top of this assembly, taking care the glue doesn't touch the PCB.

Now the cameras can be mounted onto the base using 4-40 screws, nuts and washers.

There is one last step to finish the mounting. Later, while checking out the video on a TV or VGA screen, you may discover that the vertical height of objects in one view may be different from the other view. This is caused by the two cameras not being exactly parallel. If one view appears to be lower than the other, remove that camera, and lay down two to four layers of cellophane tape along the front edge of the area where the camera is mounted. Then install the camera and check again. Continue until the same point in both views is in the same horizontal plane.

Installing connectors

The cameras that are used will have several wires that need to be attached to the printed circuit board. The V-XA0095, for example, has a connector and harness with four 24-gauge stranded wires – input power, output video, and a ground return for each. Then there are the solid 30-gauge wires that were soldered to the video chip.

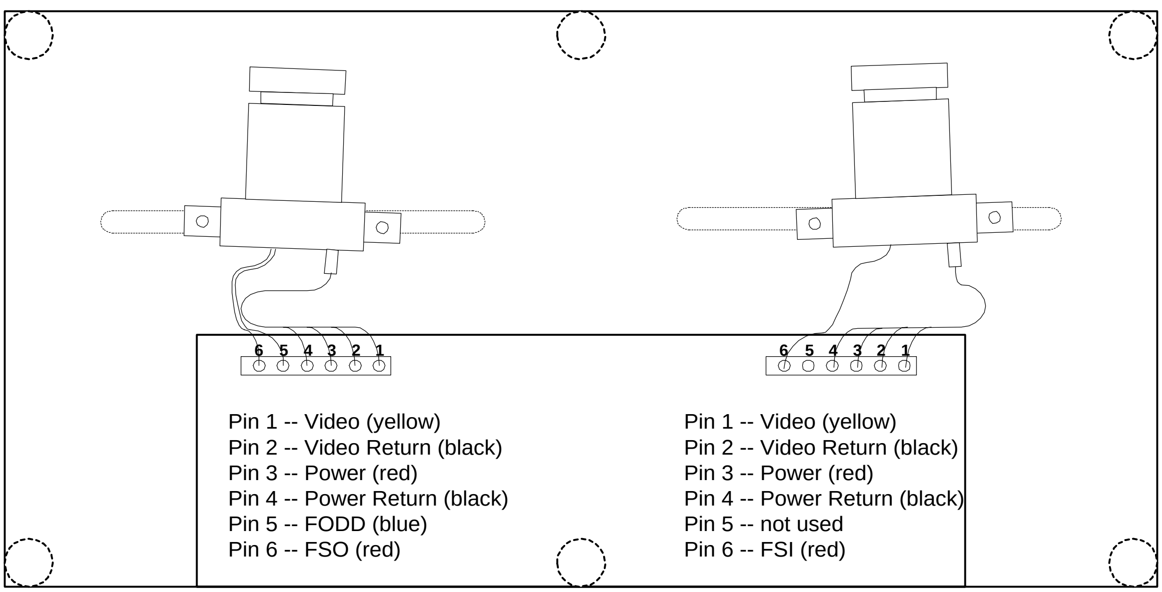

Figure 18 Camera to PCB connections

The bill of materials specifies a Molex PCB housing, connector body and crimp pins to terminate the camera wires on the printed circuit board. The crimping tool used to attach the pins is a Waldom W-HT-1921, which crimps 30 through 18-gauge wire onto .063" and .093" pins. If necessary, the wires can be soldered directly to the printed circuit board.

Other Camera Sources

The V-X0095 was chosen for the project before other cameras were found which also provide the necessary signals. The OV7500 is not the only chip camera that has the signals needed to generate stereo video.

Unfortunately, it is not always easy to tell which cameras do and which do not, but a small investment in cheap board cameras has shown that many do. In fact, many color and monochrome single-chip cameras have Smart Vision Products sensors.

And also, because these cameras are obsolete and surplus items bought in bulk, there is usually very little documentation to accompany them.

Jameco (http://www.jameco.com) has a color board camera (part number 171011, $59.95) which has the same signals on the same pins (FSI on pin 36, FSO on pin 33 and FODD on pin 34) as the OV7500. It is reasonable to assume that this board camera is also based on a Smart Vision Products sensor.

A cable is included with this camera that matches the six-pin connector at the rear of the camera. The cable breaks out to an RCA connector for video and a power connector for 7 – 12V DC input.

Figure 19 Jameco's Camera, front view

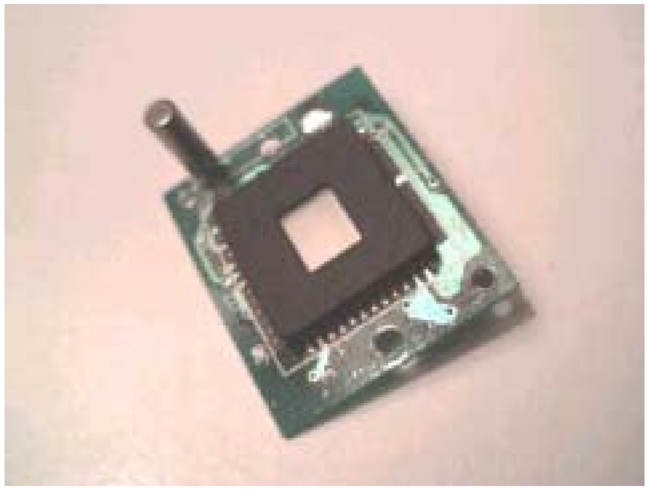

Figure 20 Jameco Camera, Video Chip

Figure 21 Jameco Camera with Cable

I purchased two cameras from Jameco using the 171011 part number. What I received was two slightly different cameras. While they had identical lens housings, the printed circuit boards were subtly different. The cameras were only tested for output video, and for presence of the signals needed for synchronization. Building mounts for the two cameras and testing them as a pair are tasks that are still pending, but I suspect there is some chance, though probably small, that the two cameras may not play well together.

There is a chance Jameco considered the two cameras to be adequately similar to be sold under the same part number. It is also possible they are indeed the same camera, though probably a different version (or revision).

Qkits (http://www.qkits.com) sells the QM3086, which is a monochrome, single-chip board camera. The QM3086 has a sync input and output, but these signals are really *frame* sync, not *field* sync. This is not a real problem, since the sync circuit board will take *field* sync from the left camera and convert it to *frame* sync to send to the right-side camera.

However, the odd/even signal needed to switch the left and right video outputs is not available. Without this signal, extra circuitry will be needed to generate that signal from the video stream of the left camera.

Figure 22 Qkits camera, Front View

Figure 23 Qkits Camera Video Chip

The QM3086 probably does not use a Smart Vision Products sensor, because of the lack of the odd even signal, and because the sync input and output signal pins are not in the same positions seen on other sensors.

The odd/even signal can be generated using a flip-flop that is clocked by the FSO signal. On the camera module circuit board, the FODD signal is needed to differentiate between odd and even fields coming from the left camera, since it generates a vertical sync signal for every field.

For example, the QM3086 generates only one sync signal for each frame. Simply reset the right camera with that sync pulse (through the reset-conditioned analog switch, of course). It doesn't matter which field comes from each camera, as long as the stereo video output stream contains alternating odd and even fields. If the flip-flop enables the left camera for the even field, then the right camera will be enabled for the odd field. The next time the circuit is powered up, it could enable the left camera for the odd field, and then the right camera will be enabled for the even field.

Electronickits (http://www.electronickits.com/spy/finish/video/cm2.htm) offers the CM2. The datasheet at the site reports this camera is based on the OV5016 single-chip sensor. Examination of the camera shows the three signals are present at the expected pins for an OV7500. This camera is entirely enclosed by a two-piece housing. Three long pins protrude through small holes in the rear section for power, ground and video. The camera is oriented with the three pins aligned vertically on the right side, as seen from the rear. (In figure 23, the camera is resting on its left side.)

Figure 24 Front View of CM2

Figure 25 Rear View of CM2

Also note that this camera requires regulated 5VDC, not the usual 7 to 12 volts that other cameras use.

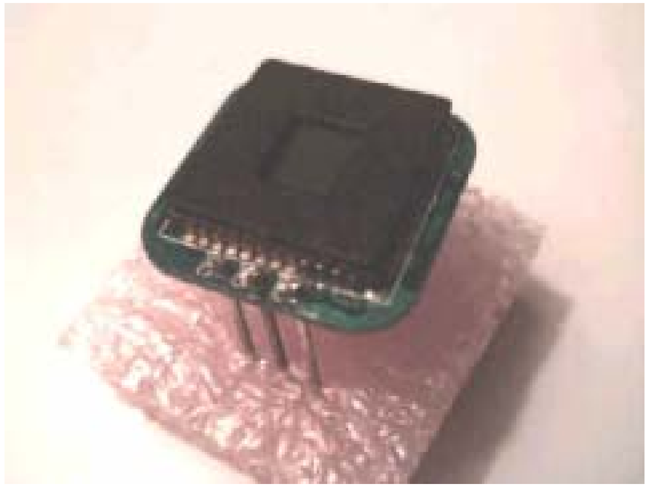

Figure 26 CM2 Video Chip

As you can see, none of these cameras has a way of bringing the 30 gauge wires toward the rear of the camera for attachment to the printed circuit board. In each case the housing will need to have a small hole drilled into the side for access to the wires. Figure 25 shows a CM2 with a 1/16" hole drilled in the side of the front housing.

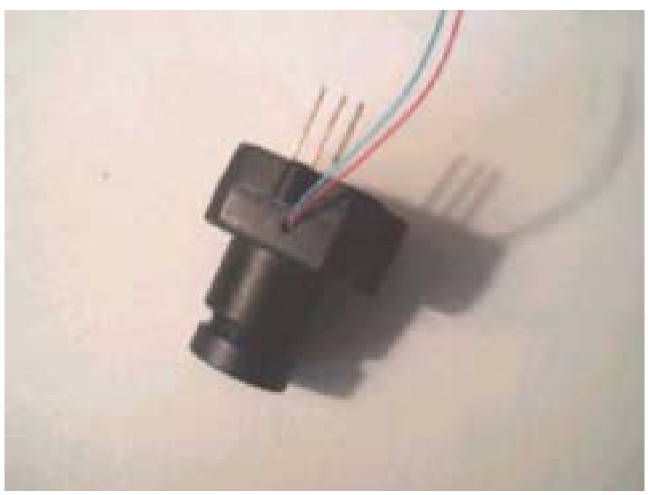

Figure 27 CM2 with modified housing

And of course there are many other places where board cameras are sold. The challenge will be to find those sites that provide enough information about the products that they sell.

4. Synchronization circuit board

The sync board sits right behind the two cameras on the base. It has three basic jobs: combine the right and left camera video streams into a single serial stream, control the synchronization input to the right camera, and generate the LCD shutter control signal. The double-sided board measures 4” by 1 5/8”. All components are through-hole for easier hand soldering. See the schematic in figure 32 for references to components.

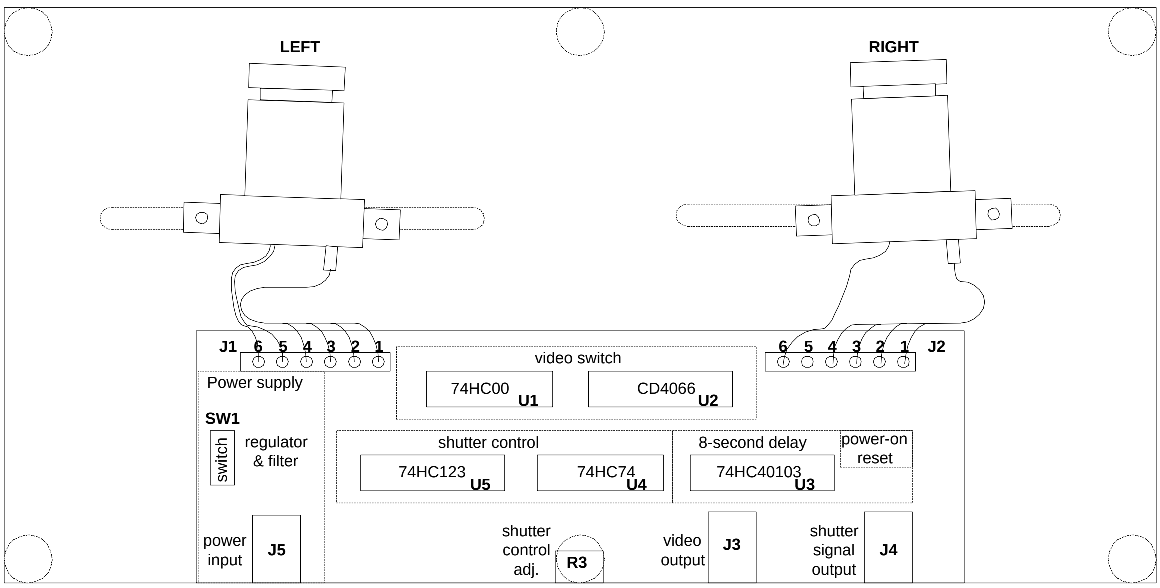

Figure 28 Camera module – function and connector placement

Video switch

The video signal from each camera is received at inputs to U2, a CD4066 analog switch. Three sections of U2 are used: one for each camera video signal, and one for the right camera sync signal. The odd/even signal (FODD) from the left camera is applied to the U2’s enable input for the right camera video, and the inverse of FODD enables the left camera video. The output of the two sections are tied together, and go to the video output RCA connector, J3

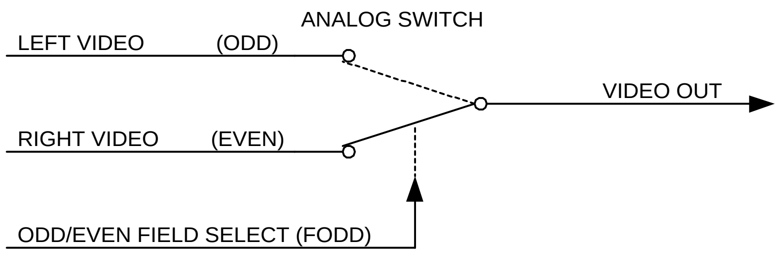

Figure 29 Video Switch Simplified Diagram

FODD will be low for the odd field, and high for the even field, and changes at the time of vertical sync. This signal enables the left camera video (L_video) when low, and the right camera video (R_video) when high.

Power-on reset timer

The V-XA095 has the peculiar characteristic of not powering up properly if there is any signal applied to its frame sync input. To overcome this, a power-up delay circuit keeps that signal tri-stated for about eight seconds. The frame sync output signal (FSO) is applied to section C of U2, which becomes the input sync signal to the right camera. The enable for this section comes from the power-up delay circuit, made up of U3 and U4A. U3 is a 74HC40103, which is an eight-stage down counter. All of its inputs are tied high except the clock (CP) and the master reset (MR). The inverted FODD signal is used as a clock. The inverted signal is used in order to load camera output signals as little as possible.

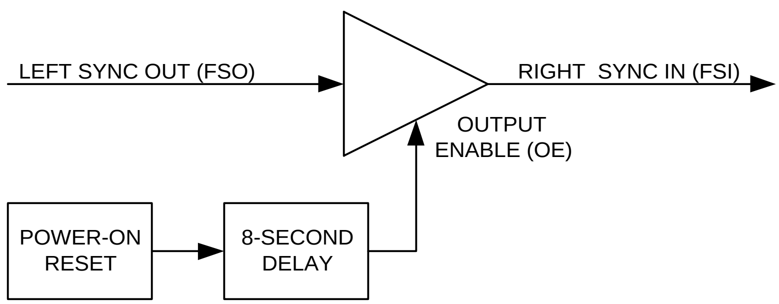

Figure 30 Right Sync Enable

The power-on reset (POR) signal comes from an RC network that keeps U3 and U4A in reset until +5V power is stable. The down counter's outputs are all high while in the reset state. Once the POR signal has gone high, positive transitions on the clock input will decrement the count from 255 down to zero. When zero is reached, the TC (terminal count) output goes low. The next clock resets the chip to its maximum count, and TC returns to the high state. This transition of TC is sent to U4A. U4A's D input is held high, so when its clock input rises, its output (oe) goes high, enabling the analog switch. The frame sync output from the left camera is now connected to the frame sync input to the right camera.

Since the clock input to U2 has 30 rising edges every second, the delay from POR going high to FSI being enabled is about 8 ½ seconds. Figure 29a shows the timing relationship between FSO, FODD, OE and FSI for stereo viewing Figure 29b shows the timing necessary generate FSI for stereo range sensing.

Referring to the schematic in figure 32, the odd/even signal from the left camera (L_odd_even) is applied to pin 2 of U1A, and inverted to become por_clk. P1 in is then used to select either the odd/even signal from the left camera for stereo viewing, or its inverse for stereo ranging.

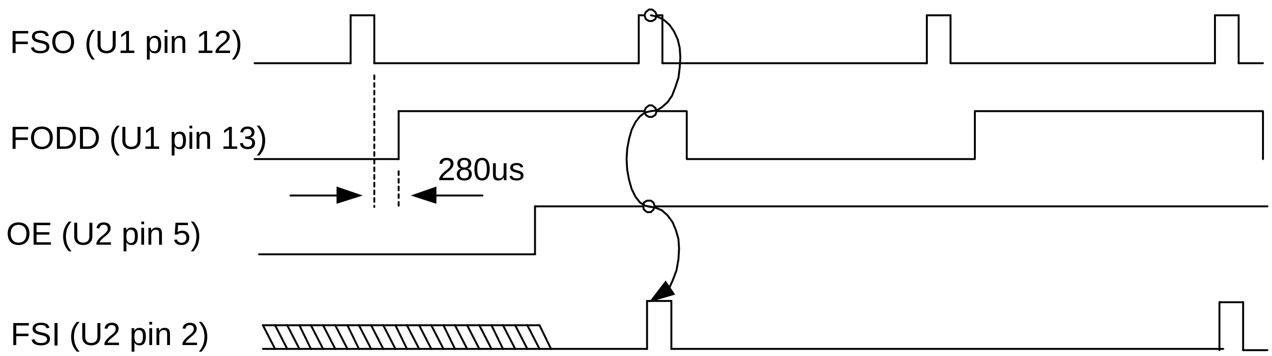

Figure 31a Generating FSI for Odd/Even Fields

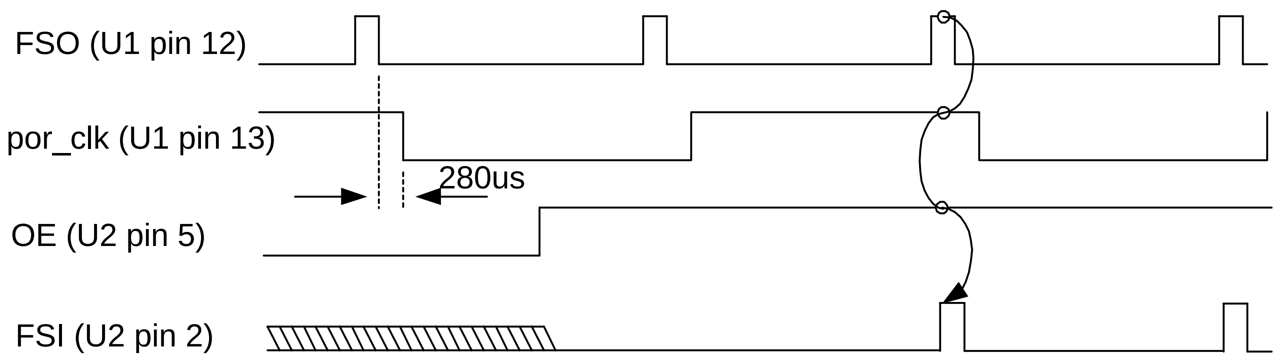

Figure 329b Generating FSI for Odd Fields (Stereo Ranging)

Shutter control

The shutter control is made up of one half of a 74HC123 dual multivibrator and the other half of the 74HC74. This circuit has two jobs. First, shutter glasses have some delay between the change of signal and the actual switching of the glasses. This circuit will allow the user to control the moment the LCD glasses are switched.

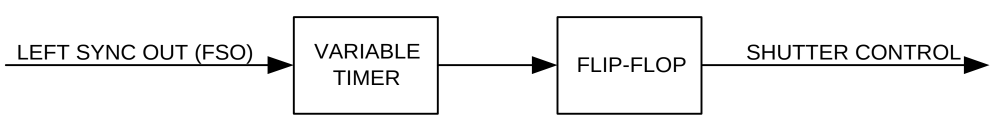

Figure 33 Shutter Control Delay

The second job is to help the user to get the correct camera video to the correct shutter LCD. Since there is no way for the circuitry to tell which is frame is intended for which eye, the user must have a way to move the LCD shutter transition so that the correct view is seen by each eye. This is done using the two capacitors, C7 and C8, the resistor R2 and the potentiometer R3. These are the timing components for the one-shot. The values of the caps and resistors were selected to allow enough range to select either frame for either eye. When using the glasses, adjusting the pot will allow you to see a black bar that indicates the LCD shutter switching between the two frames. As the pot is adjusted, that bar can move up or down; when the bar is at the very bottom of the screen (far enough to be not visible) one view is going to each eye. When the pot is adjusted the other way so the bar moves up the screen to the top (and beyond where it isn't visible) the opposite view is going to each eye. The pot can also be adjusted far enough so that the delay period of the one-shot will be longer than the 16.67 millisecond period of odd/even frame signal. When that happens, the both LCD shutters are enabled, and the pot should be backed off until it is evident (from the flicker) that the shutters are again being operated. Figure 31 shows shutter control timing for minimum and maximum values of R3.

The shutter control output connector is the same as that used for the power supply.

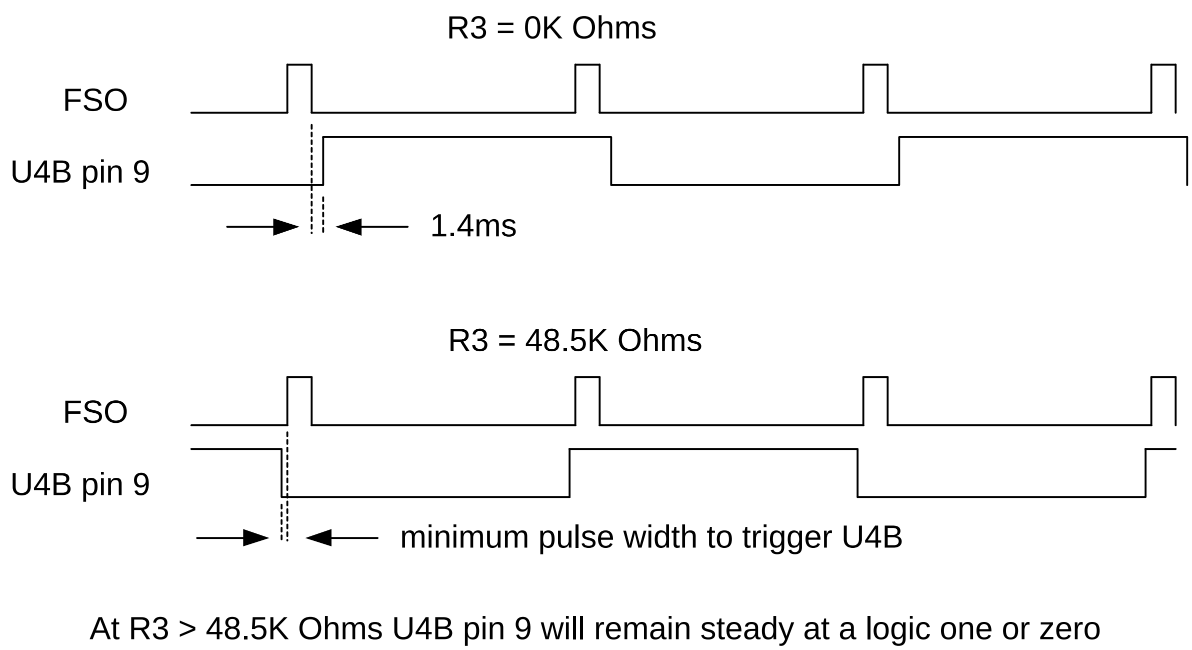

Figure 34 Shutter Control Timing

Power Supply

The power input section consists of an input DC connector, SPDT switch, a 78L05 voltage regulator and filter and decoupling capacitors. DC power brought in from an AC to DC converter goes straight to the switch. The top position of the switch (towards the camera connectors J1 and J2) turns power off, and the bottom position, towards the power connector, turns power on.

The current draw for each cameras is about 25mA, and about 33mA for the board. The module can accommodate 9 – 12V from an AC-DC adapter, which should be able to supply at least 100ma. The adapter power connector is a 2.1mm female adapter, wired positive-center. (All power supply adapters in the project are wired positive-center except the VGA converter.)

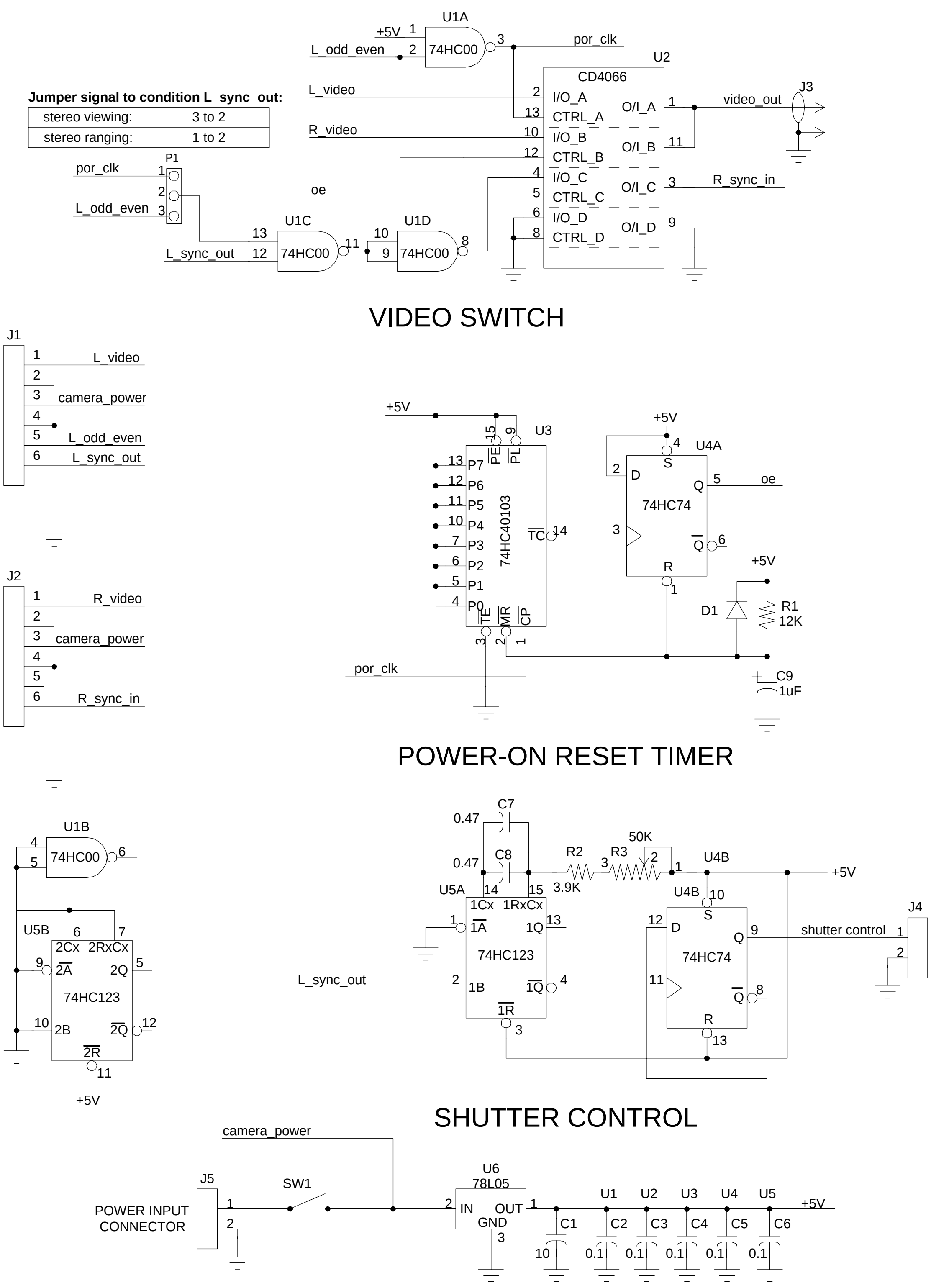

Figure 35 Schematic, Sync Board

Item	Digikey P/N	Description	Value	Qty	Refdes
1	296-1563-5-ND	74HC00 quad NAND		1	U1
2	296-2061-5-ND	CD4066 analog switch		1	U2
3	296-9200-5-ND	74HC40103 8-bit counter		1	U3
4	296-1602-5-ND	74HC74 dual D-flip-flop		1	U4
5	296-9171-5-ND	74HC123 dual timer		1	U5
6	296-1365-ND	UA78L05ACLP 5V regulator		1	U6
7	1N4148MSCT-ND	1N4148 diode		1	D1
8	P5134-ND	Capacitor, Electrolytic	10uF	1	C1
9	BC1127CT-ND	Capacitor, ceramic	0.1uF	5	C2-C6
10	P4967-ND	Capacitor, ceramic	0.47uF	2	C7, C8
11	P2105-ND	Capacitor, electrolytic	1.0uF	1	C9
13	12KEBK-ND	Resistor, 1/8W	12K	1	R1
12	3.9KEBK-ND	Resistor, 1/8W	3.9K	1	R2
14	3310C-1-503-ND	Potentiometer	50K	1	R3
15	CKN5001-ND	on-on SPDT PCB switch		1	SW1
16	CP-1400-ND	Phono jack, R/A PCB		1	J3
17	SC1153-ND	Power jack, R/A PCB		2	J4, J5
18	WM4004-ND	Header 6-pin		2	J1, J2
19	929400-01-36-ND	Header 3-pin		1	P1
20	929950-00-ND	0.1” shunt for item 16		1	
21		PCB, Sync Board		1	
For camera harness end:					
22	WM2605-ND	6-pin connector housing		2	
23	WM2200-ND	.062” crimp terminals		11	

Table 2 Sync Board Bill of Materials

Both the Sync and the VGA Adapter circuit board bills of materials show Digikey as the source for all components. Other sources are available, such as Jameco, Mouser, Allied, etc., and in many cases may be cheaper. A single source was used in order to make parts ordering easier.

5. Camera Module Construction

Section 3 described the camera used in the project, as well as how to modify them and how to mount them to the base. Then section 4 described the sync circuit board. Much of the information included here has been provided in previous sections, but the intent is to tie everything together into a module that can be connected to and operated. The focus of this section will be the base, the assembly of the cameras and circuit board onto it, and operation.

The camera module consists of two board cameras, a printed circuit board that holds the synchronization and other control circuitry, and a mounting base. The base is composed of a 3" by 6" piece of 1/8" thick clear Lexan.

Each camera is mounted in a 2 1/8" long narrow channel by #4-40 machine screws, nuts and washers; each channel is long enough to move the two cameras together or apart. Spacing between cameras can range from about two to four inches. An adult's eyes are typically spaced about two and a half inches. Moving the cameras further apart will enhance the stereoscopic effect, but spacing them greater than about three and a half inches can cause eyestrain, especially when viewing close-up objects. In fact, testing in "close quarters" had to be done with separation at its minimum of about 2". Trying to view objects closer than about six feet caused a great deal of eyestrain. Because the disparity between the two view was so great, it felt like having to cross your eyes to get an object into view. (Try to focus on a finger touching your nose.)

Each mounting channel is about 3/16" wide. This was done to allow the camera to be rotated a few degrees within the channel, so that the line of sight from the cameras will converge at a fixed distance. However, experimentation showed that this has no benefit. The cameras should be aligned on either the front edge of the channel or the rear edge. There is no accommodation for focusing the cameras beyond the lens provided with the cameras.

The two cameras should be at the same vertical height and vertical angle. It is much easier to make them achieve the *same* angle, whether greater or less than ninety degrees, than to make them exactly vertical. Vertical height will depend on tolerances of the camera lens housings (out of our control), tolerances of the mounting hardware, and how the cameras are mounted. Section 3 explains how to use cellophane tape to elevate the front (or rear) edge of one camera to make both cameras the same approximately vertical angle. Once the tape has been applied, that camera shouldn't be moved – all camera separation adjustments should be done with the "other" camera – the one not leveled with the tape. Not moving the leveled camera is necessary in order to prevent the tape from being wrinkled or pulled up.

The cameras connect to the circuit board by way of up to six wires from each camera. (See Figure 16.) The left camera connection will require six wires, and the right camera requires only five wires. A Molex wire-to-board connection scheme is specified in the Bill of Materials (Table 2), consisting of connector housings and crimp pins. However, the wires can also be soldered directly to the circuit board.

Three connectors at the rear of the circuit board provide power input, video output, and shutter glass control signal output. There is also the potentiometer that is used to adjust the timing of the shutter control signal.

The circuit board is mounted using #4-40 screws, nuts and washers. A #4-40 nut is also used as a spacer to hold the circuit board above the base to accommodate IC and connector pins and component leads.

The base rests on six clear rubber feet, one in each corner, and one each centered on the front and rear edges.

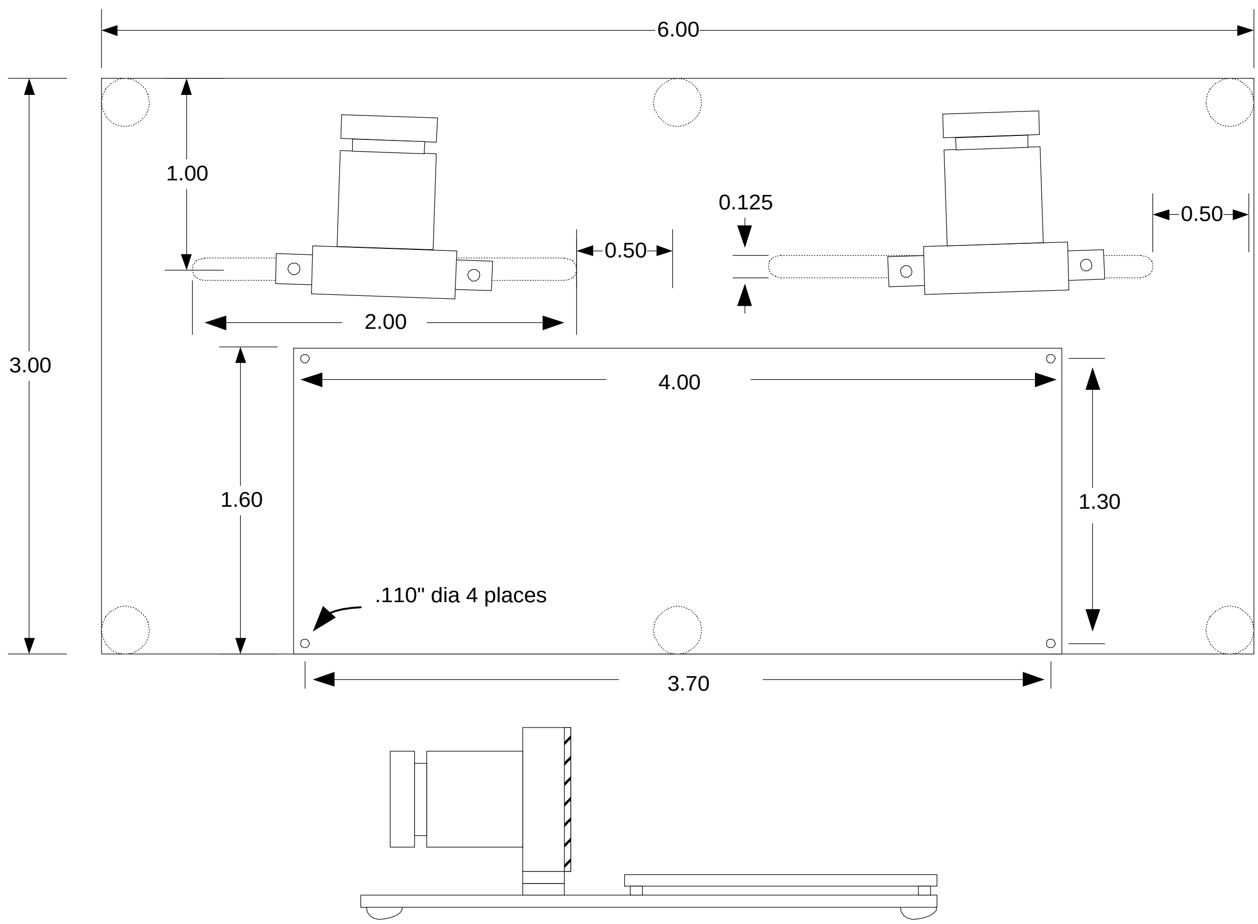

Figure 36 Camera Module Base Dimensions

Figure 37 Camera Base

Figure 38 Camera Base with Sync PCB

Figure 39 Camera Base with Sync PCB and Cameras

Operation

The module is pretty basic, and there are only two things that can be operated (other than the on-off switch): camera separation, and shutter control.

Camera Separation

The cameras are mounted in the channels in the base. The nuts and screws that hold the cameras to the base are loosened and each camera is moved laterally in its channel.

The distance between the two cameras determines the magnitude of the stereo effect at any specific distance. In his book *The World of 3-D,* Jac. G. Ferwerda explains that a “standard” separation of 65mm (about 2 ½” – the average distance between an adult’s eyes) will provide a good stereoscopic effect for distances of about six feet to about 200 feet. Therefore, separation should be reduced to minimum for viewing distances of less than six feet. The shortest separation that is possible with the carved-into-Lexan dimensions described above is about 2 inches.

Shutter Control

Here’s how to determine which camera is being enabled for each eye. While wearing the shutter glasses and viewing stereo video on a TV or VGA monitor, close your right eye and wiggle your finger in front of the right camera, around two or three inches away. If you can see your finger wiggling, then the correct video field is being enabled for each eye. If you don’t see a finger, then R3 (the pot) must be adjusted. As you turn the pot, you will see a bar going up or down the screen. Move this bar to the top (or bottom) of the screen. If the bar is moved to a position opposite of its original location, the video enabled for each eye will be reversed. So if the bar is at the top and you can’t see your finger wiggling in front of the left camera while your right eye is shut, move the pot so the bar moves down the screen. If you move the pot too far clockwise the glasses fail to alternate, and both lenses become transparent. This happens because the pot was adjusted to a value that keeps the timer from expiring, and the shutter control signal has become a DC level.

If the camera module is in a remote location, then obviously the previous paragraph won’t work. Then the technique will be to view the scene with each eye, one eye at a time. When the shutters are displaying the correct view to each eye, each eye will see the same scene, but at a slightly different angle. Let’s say we’re looking at a book, face on. If the left view shows the front and a bit of the spine on the left side of the book, the right view will also show the front, but will be more square on. That is, the spine that was seen in the left view may be much less visible in the right view, and possibly not visible at all. Another way of saying it is objects in the left view will be rotated slightly to the right, and the same objects in the right view will be rotated slightly to the left.

6. Display Adapters

There are three types of display adapters used in this project. First, there are two LCD shutter adapters, which carry or generate the control signal for the LCD shutter glasses. There is the RF modulator, which modulates the NTSC video onto a television channel, and finally the VGA converter, which converts the NTSC video format to VGA format for display on a VGA monitor.

Shutter Adapters

Two different adapters were developed for this project. These are devices that use vertical sync (or generate a signal like it) to create the alternating left/right signal to turn each LCD shutter panel on and off. Shutter glasses such as the ones used in this project have a small circuit that generates an AC signal that powers the LCD panels in the glasses. This circuit resides in a small adapter, which has three connectors: power jack, stereo audio jack, and a DB-25 parallel port connector. The stereo audio connector carries the AC signal to each panel. The DB-25 connector usually mates to the DB-25 female connector on the rear of a PC or laptop. The shutter adapters described here will present a signal to a DB-25 connector on pin 4, which is where the shutter circuit expects to find it. And because there is no PC available to adjust the time at which the shutter glasses change between left and right eye, something is needed to perform that function, which is where the shutter control circuit comes in.

TV adapter

This adapter consists of a DB-25 female connector, two short pieces of stranded wire, a DC power connector (same as the one used on AC-DC adapters – see the parts list below) and optional DB-25 backshell.

Since the signal needed to operate the LCD shutter glasses is readily available from the camera module, all that's needed to get the signal to the glasses is this adapter, which connects to the 3D-Spex adapter. The 3D-Spex adapter will expect to see the left/right signal on pin 4 of its own DB-25 connector.

A 22- to 24-gauge wire is soldered from the metal frame of the connector to the outside conductor of the power connector, and another wire is soldered between pin 4 of the D-sub and the center conductor of the power connector.

Figure 40 TV Adapter

Item	Digikey P/N	Description
1	3225F-ND	DB-25 female connector, .25” clinch nuts, solder cup
2	925GM-ND	DB-25 backshell
3	CP-004A-ND	2.1mm power plug
4	--	two short pieces of 24 AWG stranded wire. Use different colors.

Table 3 TV Adapter Parts List

VGA Adapter Module

The VGA adapter generates the LCD shutter control signal directly from the video signal for those applications where the camera module is somewhere at the end of a radio link.

When the video is going to be displayed on a television set, the output of the radio receiver is connected to one of the RCA jacks on the VGA adapter. The video is sampled as it then travels to the RF modulator to be modulated onto channel 3 or 4, and used to generate vertical sync.

When the video is being displayed on a VGA monitor, the radio receiver output is first sent to a VGA converter. This device converts the composite video signal from the cameras into separate red, green and blue signals, and horizontal and vertical sync. The output of the VGA converter is sent to the VGA adapter by one of the 15-pin connectors, where the vertical sync is sampled as the VGA signals continue on to the monitor.

Once the vertical sync is generated from the received composite video, or taken from the incoming VGA video signal group, the shutter control signal is generated using virtually the same circuit as on the sync board.

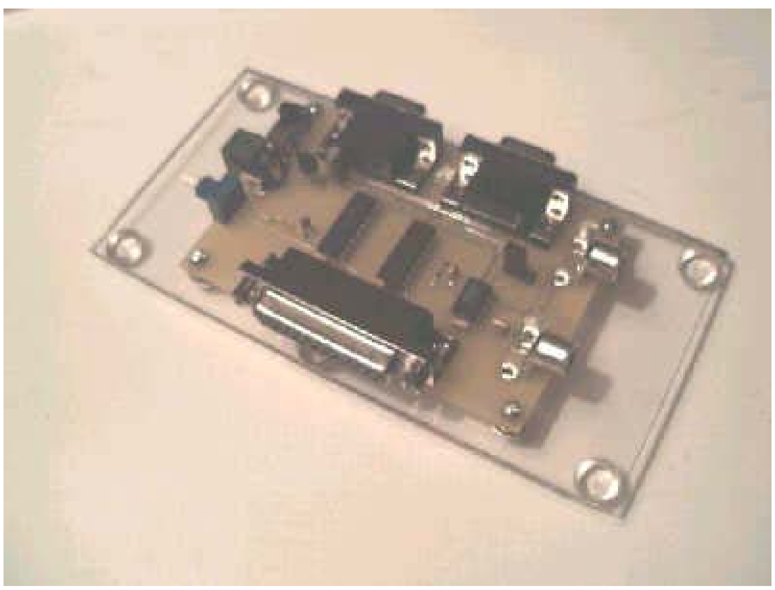

Figure 41 VGA Adapter module

VGA Adapter Circuit Board

The VGA adapter circuit board provides three functions: vertical sync extraction from composite video, vertical sync source selection, and shutter control circuit.

The two RCA jacks make the normal connection between the radio receiver and the RF modulator, as well as make the video signal available so the vertical sync can be extracted. Likewise, the two DB-15 connectors provide a place to tap into the VGA signal path so the vertical sync can be available for the shutter control. Without these pairs of connectors, it would be necessary to fabricate special breakout cables with tiny surface mount printed circuit boards mounted inside the connector housings. I tried it, and it was messy. This is better.

A National LM1881 receives the composite video signal and generates the vertical sync (among other signals). The LM1881 is the sync separator box in figure 39. The vertical sync is tapped off the VGA signal group that's coming in one DB-15 from the VGA converter and out the other to the monitor.

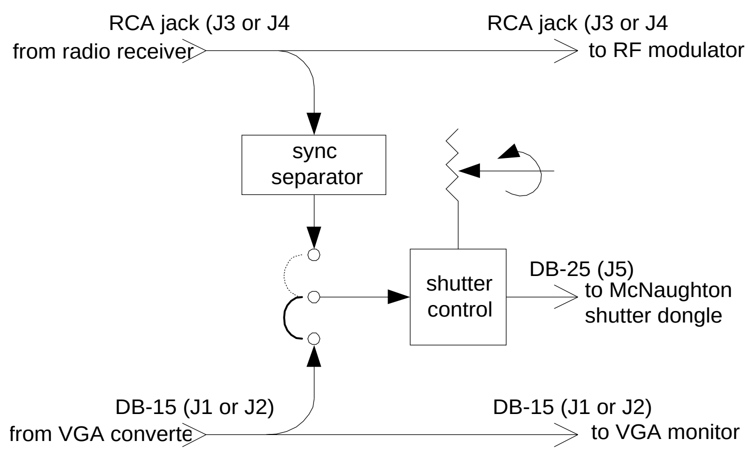

Figure 42 VGA Adapter Block Diagram

The vertical sync signals from the LM1881 and the VGA signal group meet at J7. J7 is a 3-pin header, with the middle pin (J7 pin B) connected to the input to the shutter control circuit. When a shorting plug is connected across pins A and B of J7 the vertical sync output of the LM1881 is used to generate the shutter control signal. When pins B and C are connected together, the vertical sync from the VGA converter is being used.

The shutter control circuit is virtually identical to the shutter control circuit on the Sync board.

The output of the shutter control circuit is sent to a DB-25 connector that mates to the one on the McNaughton shutter adapter (which generates the AC signal needed to operate the shutter glasses).

Connectors J1 and J2, as well as J3 and J4, are bi-directional. It is not required to use one connector as input and the other as output.

There is one or two circuits available on the Internet that illustrate the operation of the Nuvision adapter. In fact, it should be possible to use the circuit at http://www-wjp.cs.uni-sb.de/~jofis/shutter.html to combine the Nuvision adapter and the VGA adapter. The world could use one less adapter. However, that circuit would not able to adjust the timing of the shutter signal. It is usually assumed the LCD shutters are controlled by application software or graphics card driver adjusts the shutter timing.

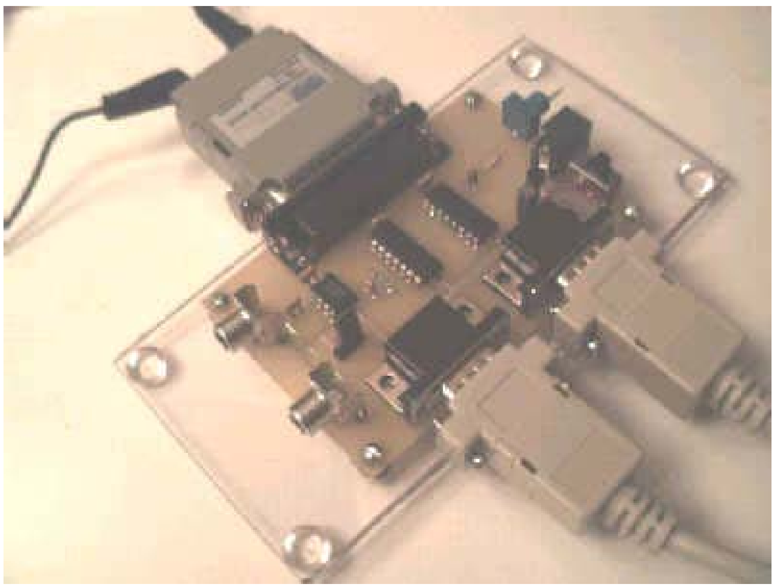

Figure 43 VGA Adapter attached to VGA Cable

The ExpressPCB circuit board is 2.5” by 3.8”, which makes it a “mini-board” special, qualifying for the $62 price for three boards. (The price was $59 when the project started.) As usual, for this price there is no silkscreen or solder mask.

The board is mounted on a 3” by 6” by 1/8” piece of clear Lexan (cut from the same piece as the camera module), held there by 4-40 screws, nuts and washes.

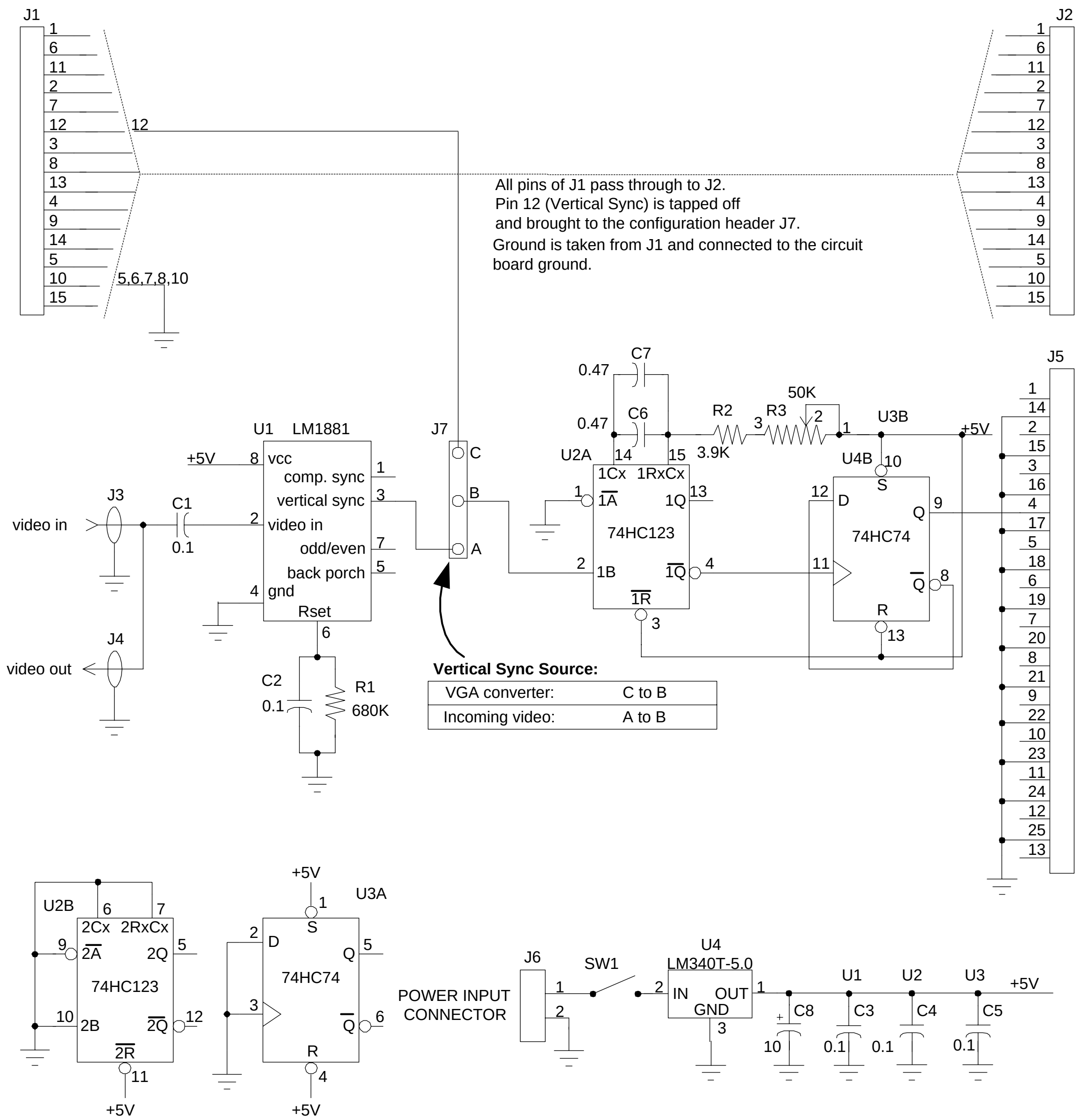

Figure 44 Schematic, Shutter Adapter

Item	Digikey P/N	Description	Value	Qty	Refdes
1	LM1881N-ND	LM1881 Sync Separator		1	U1
2	296-1602-5-ND	74HC74 dual D-flip-flop		1	U3
3	296-9171-5-ND	74HC123 dual timer		1	U2
4	296-1365-ND	UA78L05ACLP 5V reg.		1	U4
5	P5134-ND	Capacitor, Electrolytic	10uF	1	C8
6	BC1127CT-ND	Capacitor, ceramic	0.1uF	5	C1-C5
7	P4967-ND	Capacitor, ceramic	0.47uF	2	C6, C7
8	BC680KXCT-ND	Resistor, 1/8W 1%	680K	1	R1
9	3.9KEBK-ND	Resistor, 1/8W	3.9K	1	R2
10	3310C-1-503-ND	Potentiometer	50K	1	R3
15	CKN5001-ND	on-on SPDT PCB switch		1	SW1
11	815RF-ND	Conn, DB-15, female, R/A, PCB		2	J1, J2
12	CP-1400-ND	RCA jack, R/A PCB		2	J3, J4
13	182-15F-ND	Conn, DB-25, female, R/A, PCB		1	J5
14	SC1153-ND	Power jack, R/A PCB		1	J6
15	929400-01-36-ND	Header 3-pin		1	J7
16	929950-00-ND	0.1” shunt for item 16		1	
17		Shutter Adapter PCB		1	

Table 4 VGA Shutter Adapter Bill of Materials

The Digikey part, 929400-01-36-ND is actually a 36-pin header; Digikey doesn't provide the header 3 pins wide.

RF modulator

The RF modulator is used to modulate the video stream onto a television channel, usually either channel 3 or 4.

The one used in this project (www.jameco.com, P/N 141639) uses an F-type RF connector for output to the television. There are many varieties of the RF modulator. There are some that provide connectors for both input and output video as well as DC power. This $4.95 version will require soldering of video input and DC power connectors.

Figure 45 RF modulator

VGA Converter

A VGA converter is also called a line doubler, or an up-converter. It has two basic functions: convert NTSC video to VGA format, and increase frame rate from NTSC's 30 frames per second to 60 fps for VGA.

It is beyond the scope of this book (to say nothing of my ability) to explain how NTSC is converted into separate red, blue and green signals, and horizontal and vertical sync, but line doubling is straightforward.

First, an NTSC video frame is made up of two fields, one containing the odd- and the other containing the even-numbered lines of the complete frame. A line doubler will convert a line of analog video into digital at the 30 frames per second rate, and store it in a buffer. Once the line has been completely received and stored, the buffer contents are read out and converted back to analog at double the incoming rate, and sent to the monitor. Then it will send it out again. For each line of video received, two identical lines are read out.

VGA converters are used to interface video games, VCRs, DVD players and even television to personal computer monitors. But this convenience is going to cost you in video quality, and we haven't even mentioned stereoscopic 3D.

As just explained, the converter will turn each field into a frame. This means each frame will have half the video content of the original frame. One result of this will be a "flickering" of lines that are almost perfectly horizontal: in the original frame, a line that traverses between two fields is now partly there in one frame, and partly not-there in the next.

Now we add stereoscopic 3D. The sync adapter board in the camera module is going to throw away every other field from each camera's output, and combine the remaining fields into a single video stream of alternating left and right views. This is presented to the VGA converter (or to the RF modulator for viewing on a television screen). Viewing 60fps stereo video on either a VGA monitor or television screen with LCD shutter glasses means each eye will see only every other frame, or 30 frames per second. Not only will there be a lot of flicker, but it could cause headaches.

Two different VGA converters were tried during the project. One was an incredibly cheap bare-bones device that got the job done, but had problems just staying in one piece. The other not only had better quality construction, but it turned out to be not that much more expensive, and had other features as well.

The minimum I recommend is the CM-330 sold by Avtoolbox. It is also available on the Web from other sources. This unit handles the basic converter function and also provides controls for adjusting brightness, contrast, color and tint, as well as other special effects.

Figure 46 AVToolbox's CM-330 VGA Converter, front view

Figure 47 CM-330 VGA Converter, rear view

Shutter glasses

There are three basic types of shutter glasses, based on their interface to the computer. These interfaces are called interlace, page flipping and sync doubling. And since at the hardware level page flipping is basically the same as interlace, we will consider them the same.

Shutter glasses that use interlace expect to get a signal that alternates high and low for each displayed video frame. The electronics required by the shutter glasses is minimal – usually just an oscillator that generates the AC signal for the glasses, and a left/right control generated by the incoming interlace signal. These glasses will be the cheaper models; not that there's less quality, but they are very basic in operation. Their advantage for generating live 3D video is that no computer, graphics card or programming is needed. All that's necessary is a small electronic circuit that converts the vertical sync pulse into an alternating left/right signal that can be used to control the LCD glasses.

Shutter glasses that use sync doubling will get a pulse from the computer that will have timing similar to vertical sync. The glasses will have a small circuit board that doubles the frequency of the pulse and then sends it to the monitor to be used in place of vertical sync. The picture starts out as two pictures compressed together. When the doubled sync pulse is received at the monitor it effectively doubles the refresh rate of the monitor. One half of the original picture is shown at a time on the display, and the shutter circuit will use the doubled sync pulse to create its own left-right signal.

The advantage of sync doubling is the shutter glasses do most of the work and the computer doesn't need to generate two different scenes. The disadvantage is it's more expensive because more electronics has to be crammed into the frame of the glasses, or into a dangling umbilical. Besides, it can't be used for generating live 3D video when using the method described in this book to create the stereo video stream.

The shutter glasses used in this project are the 3D-Spex from McNaughton (formerly Nuvision). These are probably the simplest, most basic shutter glasses. They are reported by McNaughton to be good for 60Hz to 160Hz frame rates.

The 3D-Spex has a cable from the glasses that terminates in a 3-wire stereo audio jack. This plugs into an adapter, which contains the electronics to operate the glasses. The adapter also has a jack for a 9V AC-DC power supply. The other end of the adapter is a male 25-pin D-sub connector.

Figure 48 Mcnaughton 3D-Spex shutter glasses

7. RF Transmitters and Receivers

The radio link is not exactly a part of the project, but one was purchased with the expectation of a possible future R/C project that carried a stereo camera module.

The specific 2.4GHz transmitter/receiver set was selected for several reasons. First, I don't have an FCC license to operate any radio transmitter, second, the 2.4GHz band is becoming more popular, which means more and cheaper equipment is becoming available. On the negative side, that popularity may also pose a problem. Some household appliances, such as microwave ovens, and even some wireless phones, operate in that band, and may cause interference with the video signal. Finally, it was the cheapest radio set that I could find.

The radio was purchased from Circuit Specialists, Inc. (Web-Tronics.com), Item # CSI-HTR2400U, $109 (and on sale for $89). This includes the transmitter, receiver, a power supply for each, and two sets of three audio cables. The radio is designed to be a link for video and stereo audio. While the stereo audio was not implemented in the project, this product could carry the audio part of the stereo video signal.

Figure 49 Hung Chang 2.4GHz Transmitter

The transmitter output is one tenth of a milliwatt of RF power, so it would be a miracle to me if reception is really possible at the advertised distance of 100 meters, even in clear line of sight. Both the receiver and transmitter use a unidirectional antenna. An omnidirectional antenna would be more suitable for an R/C vehicle, unless you expect to have someone to run after it to adjust the antenna at every turn. During one brief test of the unit, the transmitter and receiver were placed about thirty feet apart. The camera and transmitter set up at a window at the rear of the house overlooking the deck, the fence and the houses beyond. The receiver and television were at the opposite end of the house.

Figure 50 Hung Chang 2.4GHz Receiver

Figure 51 Rear View of Transmitter or Receiver (they're identical from the rear)

Even with the antennas oriented toward each other, standing directly in front of the receiver could easily disrupt reception. While some signal noise was noticed, it would not have seriously interfered with controlling a vehicle. Some random snow came and went, and occasionally there were wide white bars of noise. In a mobile unit the directional antenna may need to be controlled somehow – perhaps with an R/C servo. However, if you don't turn it in time, you'll end up not being able to see where you're going… A possible solution would be to make the transmitting antenna omnidirectional, and the receiver unidirectional.

Video quality was much better than I expected, since more signal conversions were added between the cameras and the monitor. During this test, the camera module was used for the first time to view an outdoor scene. The sky was overcast, and there was no washout of the video.

During the test, the camera separation was set at minimum possible – about 2 inches. This minimum setting had been used for “indoor” testing, where the camera was pointed at objects less than six feet away. As described in section 5, close objects should be view with a narrower camera separation to avoid eyestrain. It’s a lot like putting your finger tip at the end of your nose, and then trying to bring it into focus. When the camera was pointed at the back yard at the same minimum camera separation, the stereoscopic effect was still very evident at distances of about fifteen to twenty feet.

8. Last Words

And that ends the project. Many other things could have been covered; several ideas that I wanted to pursue include:

- displaying stereo video at SVGA/XVGA rates;
- finding or developing a display method that didn't require camera synchronization;
- Anaglyphic video: *mixing* the video instead of multiplexing fields, and using color filters to provide video that can be viewed with colored glasses;
- saving the video in an mpeg or avi file;
- actually using the stereo module in an radio-controlled vehicle;
- finding filter material to allow outdoor (sunlight) operation;
- implementing R/C servo motor controls for focus, camera separation, X-Y axis movements independent of vehicle direction, antenna rotation, etc.;
- racing other R/C vehicles on a miniature racetrack – the closest thing to driving at Watkins Glen, or Daytona Beach. Or armored tanks meeting on a sandlot battlefield. 3D Battlebots, anyone?

SVGA video

Displaying stereo video at 120 frames per second requires a different VGA converter. What I believe is happening during SVGA conversion is this: a video field is converted to digital, stored in memory, and then read back out – twice – at double the rate. This means the same field, say the left camera, would be displayed twice before the other camera video would be displayed. So the technique used here will not work. However, the necessary circuit modification is not complicated. First, the shutter control circuit would need to be changed so that the left/right control signal would alternate on every other frame, and a control added to select two adjacent (identical) frames to be displayed during each shutter period. But then the problem disappears altogether if a head-mounted display is used instead of an SVGA monitor and shutter glasses.

Stereo Video movies

AVToolbox also sells a device that converts the video signal to digital and sends it to a PC over the USB bus. Unfortunately, it won't work with my laptop. But there are plenty of frame grabbers available for the desktop or tower PC. Creating a video file would then require some method of controlling shutter glasses. Perhaps the driver software accompanying the glasses could be used (and allow the glasses to be used in the manner they were intended).

Anaglyphic video
Mixing two video streams, as opposed to multiplexing them, should allow the full video signal to be used, and there would be no annoying 60-cycle flicker.

I hope I've done the job of providing you with useful, practical information that will enable you to try out your own experimentation with stereoscopic 3D video. If you have any questions, suggestions or corrections, please contact me at stereo-video@worldnet.att.net.

9. Sources

Cameras

www.bbelectronics.com/cameras-ccd/vx0095.htm

www.starkelectronic.com/vx0095.htm

www.qkits.com

www.jameco.com

www.electronickits.com/

Interlace and Page-Flipping Shutter Glasses

www.kasan.co.kr	3D-Max, Kasan Electronics
www.vrex.com	VR Surfer
www.stereographics.com	Simuleyes
www.nuvision3d.com	3D-Spex

RF Modulator

www.jameco.com

VGA Converters

www.avtoolbox.com

www.tvone.com/upconverters.htm

www.startech.com/ststore/itemdetail.cfm?/product_id=COMP2VGA

2.4GHz Transmitters and Receivers

www.web-tronics.com/24avsenrecsy.html

www.northcountryradio.net

home.earthlink.net/~efficienttec/etwebpage/transmit.htm

www.surveillance-spy-cameras.com/transmitter-receiver.htm

Circuit Level Components

www.digikey.com

www.jameco.com

Printed Circuit Boards

www.expresspcb.com

Links

www.epanorama.net/links/video.html Actually, *anything* on epanorama.net is worth checking out, and there's a lot there.

www.stereo3d.com/hmd.htm

www.ntsc-tv.com

www.neotek.3dtheory.htm

http://cyborganic.com/People/mister3d/chaff/3d_theory.html

http://www.ray3d.com/

http://dogfeathers.com/3d/stereojps.html

www.ee.washington.edu/conselec/CE/sp95reports/mortenso/project.htm

http://vered.rose.utoronto.ca/people/david_dir/DND93/DND93.html

http://www.3dimagetek.com/encoder.htm

August 2001 issue of Poptronics:
VIDEO VIEWERS By J. Ronald Eyton; pp. 25-29, 56; a construction article featuring an "infrared video viewer", and a "video stereogram viewing system".

April 2000 issue of Poptronics;
Amazing Science - Telepresence by John Lovine; pp 49-51, 56; an R/C vehicle-based roving video system (non-stereo, unfortunately).

Stereo vision software for robotics:
http://www-2.cs.cmu.edu/~cil/v-source.html

https://sourceforge.net/projects/rodney/

Glossary

Board camera
A fully functional camera, composed of one or more printed circuit boards, usually provided without an external case

CMOS
Complementary Metal Oxide Semiconductor; a type of semiconductor composed of positive (PMOS) and negative (NMOS) elements, which are operated in such a way the CMOS chip requires much less power than conventional transistor circuits. CMOS chips are commonly used in battery-powered devices.

Compositte Video
Also called NTSC video; A single video signal that is composed of four other signals: luminance, which determines brightness, blanking, which turns off the beam during horizontal and vertical retrace, synchronization, which determines when the next display will start, and chrominance, which detemines color of the display.

HMD
Head Mounted Display is a video display device that is often worn like a helmet, with the visual display mounted where a visor would normally be. The HMD is often used for stereoscopic displays when small LCD screens are installed that can be dedicated to each eye

Horizontal Sync
A synchronizing pulse used to control the horizontal sweeps of the monitor's electron beam. During each horizontal sweep one line of video is painted on the screen.

Interlace
Describes the method of displaying a complete fame of video as two separate fields, where one field contains the even lines, and the other contains the odd lines. The lines of each field are interleaved, making a complete picture.

Line Doubler
A device that converts NTSC, or S-video and related video formats to VGA format. In order to convert the original video signal's 15.75KHz horizontal line rate to VGA's 31.5KHz rate, each line of the original signal is duplicated at the VGA rate. Each 240-line field of the original video signal becomes a 480-line VGA frame.

LCD, Liquid Crystal Display
A display material that consists of a liquid crystal solution squeezed between a pair of polarizing sheets. An electric current will cause the crystals in the solution

to align themselves in such a way that light is blocked. When the current is removed the crystals resume random orientation, allowing light to pass through the material.

NTSC
National Television System Committee; the name of the standard used in North American television transmission (also the name of the organization that sets the standard). NTSC specifies a display rate of 29.97 frames per second. Each frame consists of two fields, one containing odd numbered lines, and another containing the even numbered lines. The resulting picture consists of the two "interlaced" fields, with the television monitor's phosphor persistence keeping the odd field displayed while the even field is written.

PAL
Phase Alternating Line is a video transmission standard used in Europe. The most obvious difference between NTSC and PAL is the number of lines per frame, and the number of frames displayed per second. NTSC provides 525 lines at 60 fields (30 frames) per second, and PAL provides 625 lines at 50 fields (25 frames) per second.

Stereoscopic
Refers to viewing a scene with two eyes, where information is taken from the environment, or provided in a representational view that allows depth and spatial relationships to be discerned. The term is commonly used to differentiate between a "flat" two-dimensional representation of a three-dimensional scene, and one that provides the spatial cues, making it almost equivalent to a scene in real three-dimensional space.

Vertical Sync
A synchronizing pulse that is derived from (or accompanies) a video signal, and used to indicate to the monitor when it's time to move the electron beam to the upper left corner of the display to start the next field.

VGA
Video Graphics Adapter. Refers to a) a circuit card that translates text and graphics in a PC's memory to signals that display that information on a computer monitor; b) the video signal format that describes the red, blue and green video, and horizontal and vertical synchronization signals as well as the signal timing used to display video on a PC monitor.

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