STH-DCAM Stereo Head
User's Manual

Updated – Rev 2

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1   Introduction

The STH-DCAM (Dual-DCAM) is a compact, low-power digital stereo head with an IEEE 1394 digital interface. It consists of two VGA (640x480), progressive scan CCD imagers and associated IEEE 1394 electronics, mounted in a rigid, milled Delrin frame.

The CCD imagers are Sony HAD ¼" devices, with square pixels and progressive scan output. They have 648 H by 484 V pixels, and are colorized using a standard Bayer pattern. These imagers have excellent dynamic range, sensitivity, anti-blooming, and noise characteristics. They are fully controllable via the IEEE 1394 interface, in both manual and automatic modes. The user can set exposure, gain, binning, etc., or have the stereo head electronics do it automatically.

The STH-DCAM uses standard 12 x 0.5 mm miniature lenses for user-changeable optics. Wide-angle to telephoto options are available, depending on the application.

There are software drivers for the STH-DCAM for MS Windows 98/2000/XP, and for Linux 2.4.x kernels.

SRI's Small Vision System (SVS) software has an interface to the STH-DCAM. You can simply and automatically calibrate the stereo head, perform stereo correlation, and view the results as a 3D set. The SVS software includes all of the capture software described in this document.

2   Quick Start

The STH-DCAM comes assembled, with 3.6 mm lenses as standard.

To set up and test the STH-DCAM, you will need the following:

1. Host computer with a 1394 PCI or PCMCIA card, OHCI compliant.

2. 1394 6-pin cable.

3. Capture software or Small Vision System installed on the host computer.

Install the 1394 host card, if necessary, according to the directions in Section 7.1. Install the video capture software (included with the STH-DCAM) or Small Vision System software (see Section 7.2). This is the not-so-quick part of the Quick Start.

The STH-DCAM has a single IEEE 1394 port, for plugging in an IEEE 1394 cable. Plug one end of a 6 pin – 6 pin IEEE 1394 cable into the port, and the other end into any port of the host card. Note: for PCMCIA cards, and laptops with a 4-pin Sony iLink port, an external power supply should be plugged into the STH-DCAM to supply power to the stereo head, using the 2.1 mm power jack. Standard IEEE 1394 PCI cards supply enough power, and the power adapter is not necessary.

Start the video capture program, smallvcap(.exe), on the host computer. You should see a screen as in Figure 2-1. The message window should indicate that the STH-DCAM interface is present. If not, go back to software installation (Section 7.2), and follow the instructions for configuring the correct capture library.

Pull down the Input chooser, and select the Video option. If everything has been set up, the driver software will recognize and configure the stereo head after a few seconds, and a success message will appear in the info text window. If not, the Input chooser will go back to None, and an error
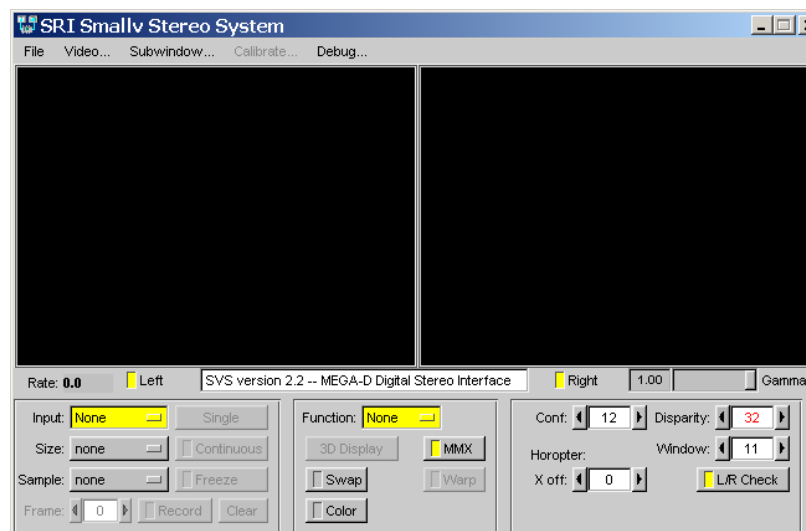

Figure 2-1 Video capture program window.

message will appear in the info window. Please see Section 7 for troubleshooting.

To view stereo video, press the Continuous button. Left and right images should appear in the application windows. If the message "Image timed out" appears, then there is a problem with the IEEE 1394 drivers; please see Section 7. After a few seconds, the images, which are initially dark, should lighten as the auto exposure mode adjusts to ambient lighting (Section 6.2). Images can be saved using the File menu.

A more complete description of the video capture program is in Section 6. The SVS programs are described in the documentation that comes with that software. It is helpful to review Section 6 in conjunction with the SVS documentation.

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3   Hardware Overview

Figure 3-1 shows the hardware configuration of the STH-DCAM.

The imager module has a milled Delrin frame that rigidly holds two Sony HAD CCD color imagers, separated by a fixed distance of 9 cm. Lens mounts are attached to the frame, and standard miniature lenses are screwed into these holders. There is an IR curoff filter, with a knee at approximately 700 nm, permanently mounted inside the lens holder. See Section 4 for appropriate lens characteristics.

There is a IEEE 1394 port on the left side of the device. The cable carries the data and signals for both imagers. Internally, the imagers are synchronized so that they are exposed at the same time, a requirement for stereo processing whenever there is any motion (including camera motion).

Typically, the cable is plugged into the host computer IEEE 1394 card. Power for the STH-DCAM is supplied from the card, or through a separate power supply that plugs into the power supply port of the device (7-40 VDC).

There are no user-settable switches on the STH-DCAM.

Figure 3-1. Physical layout of the STH-DCAM stereo head.

3.1   Hardware Schematic

Figure 3-2 shows the design of the internal hardware of the STH-DCAM. In the stereo imager module, two Sony CCD imagers, each of size 648x486 pixels, digitize incoming light into a digital stream. A full frame is captured at once, and then read out line by line. The imagers operate in progressive mode only, that is, each line is output in succession from the full frame.

The imagers are synchronized to a common clock, so that the corresponding pixels from each imager are output at the same time. Each imager sends out its own video stream, on a separate IEEE 1394 cable. There are two such cables coming out of the STH-DCAM module. Each video stream has a maximum rate of 200 Mbps; the whole IEEE 1394 bus runs at 400 Mbps.

Each imager is supplied with power from its cable. In order to synchronize correctly, power must be applied to the imagers at the same time. Typically, the two cables are connected to a small 3-port IEEE 1394 hub, which is then connected to the host IEEE 1394 port.

3.2   Color and Monochrome

The Sony CCDs are color imagers, with a standard Bayer color pattern. Processing in the STH-DCAM can produce either a color or monochrome output from the imagers. Monochrome output is 1 byte/pixel, and color outputs are either 2 or 3 bytes/pixel, depending on the format. If color isn't necessary, monochrome output should be selected, to save on movement of data.

3.3   Frame Rates

The IEEE 1394 interface supports a maximum rate of 200 Mbps on each imager. The maximum frame rates depend on whether monochrome or color output is used. Frame rates up to 30 Hz at 640x480 are supported. See Table 3-1 below for a complete list of frame rates.

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STH-DCAM
Digital Stereo
Head
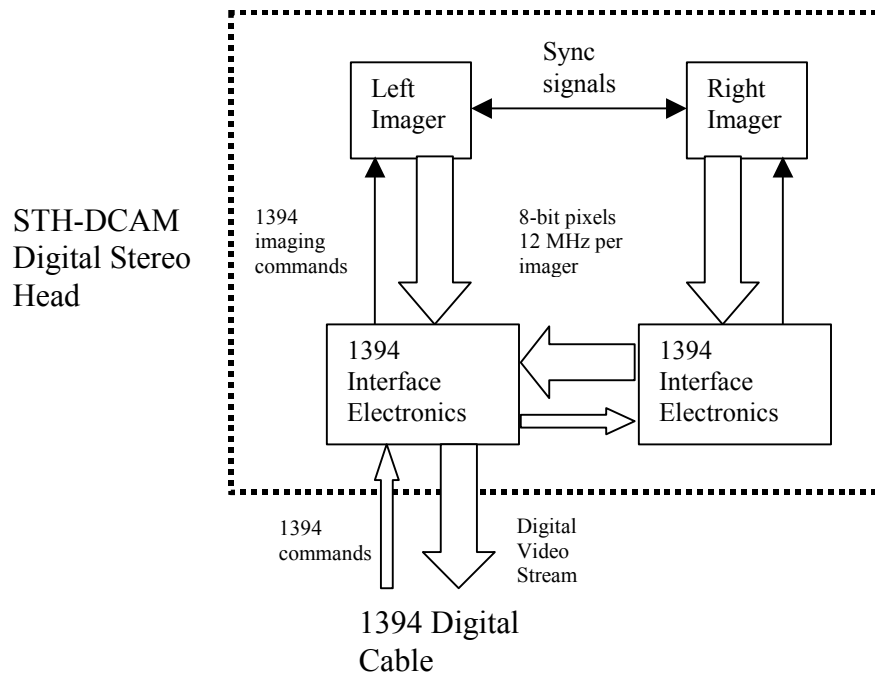
Frame Size	Frame rate, monochrome	Frame rate, color
640x480	30 Hz	30 Hz
	15 Hz	15 Hz
	7.5 Hz	7.5 Hz
320x240	30 Hz	30 Hz
	15 Hz	15 Hz
	7.5 Hz	7.5 Hz

Table 3-1 Supported frame rates for the STH-DCAM, 400 Mbps IEEE 1394 bus.

Figure 3-2 Schematic of the STH-DCAM electronics.

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4   Lenses

The STH-DCAM uses standard miniature lenses (12 x 0.5 mm). Good-quality, fixed-focus lenses with low distortion and high light-gathering capability are best.

Lenses are characterized optically by imager size, F number, and focal length. Following subsections discuss the choice of these values.

4.1   Changing Lenses

Standard miniature lenses have a 12 mm diameter, 0.5 mm pitch screw on their back end. The screw mates with the lens holder opening. To insert a lens, place it back end on the lens holder opening as straight as possible, and gently turn it clockwise (looking down at the lens) until it engages the threads of the lens holder. If you encounter a lot of resistance, you may be cross-threading the lens. Forcing it on will damage the plastic lens holder threads.

Once the threads are engaged, continue screwing it on until most of the thread is in the holder. Turn on the device, and check the focus, adjusting it until there is a clear image. The depth of focus of most miniature lenses is very large, from several inches to infinity.

Removing the lens is the reverse process: unscrew the lens counter-clockwise.

Normal care should be used in taking care of the lenses, as with lenses for any good-quality camera.

4.2   Cleaning the Imagers

It should not be necessary to clean the imagers, since they are sealed off by an IR filter inside the lens mount.

If dirt and dust are present on the IR filter surface, they can be cleaned in the same manner as a lens. Wet a non-abrasive optic cleaning tissue with a small amount of methyl alcohol or similar lens-cleaning solvent, and wipe the imager glass surface gently. Dry with a similar tissue.

4.3   Imager Size

The *imager size* is the largest size of imager that can be covered by the lens. For the STH-DCAM, the lens must be 1/4" or larger.

4.4   F Number

The *F number* is a measure of the light-gathering ability of a lens. The lower the F number, the better it is at pulling in light, and the better the STH-DCAM will see in low-illumination settings. For indoor work, an F number of 1.8 is acceptable, and 1.4 is even better. For outdoors, higher F numbers are fine. Miniature lenses have no mechanical iris for exposure adjustment. Instead, they have electronic exposure and gain control to automatically compensate for different light conditions.

4.5   Focal Length

The *focal length* is the distance from the lens virtual viewpoint to the imager. It defines how large an angle the imager views through the lens. The focal length is a primary determinant of the performance of a stereo system. It affects two important aspects of the stereo system: how wide a field of view the system can see, and how good the range resolution of the stereo is. Unfortunately there's a tradeoff here. A wide-angle lens (short focal length) gives a great field of view, but causes a drop in range resolution. A telephoto lens (long focal length) can only see a small field of view, but gives better range resolution. So the choice of lens focal length usually involves a compromise. In typical situations, one usually chooses the focal length based on the narrowest field of view acceptable for an application, and then takes whatever range resolution comes with it.
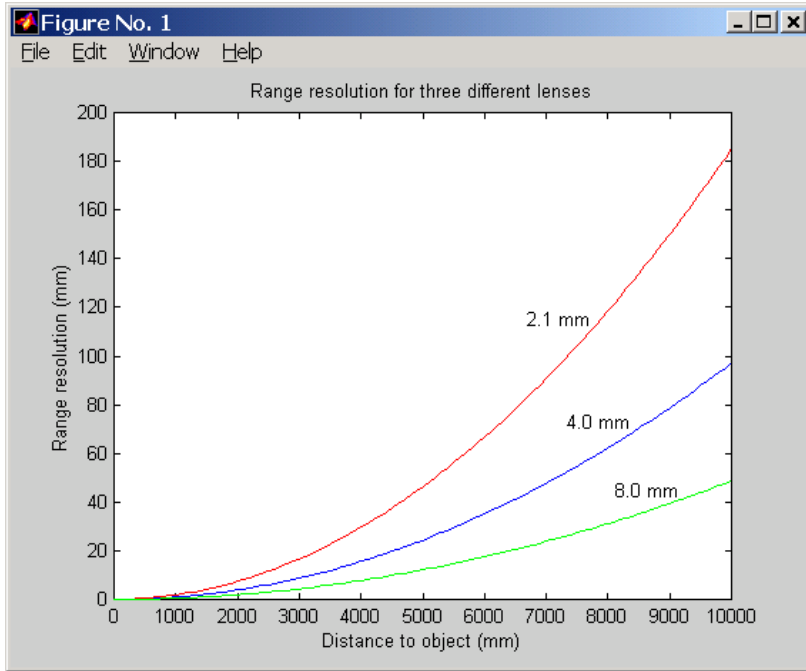
Figure 4-1 Range resolution in mm as a function of distance, for several different lens focal lengths.

4.6 Range Resolution

Range resolution is the minimum distance the stereo system can distinguish. Since stereo is a triangulation operation, the range resolution gets worse with increasing distance from the stereo head. The relationship is:

$$\Delta r = \frac{r^2}{bf} \Delta d \; ,$$

where b is the baseline between the imagers, f is the focal length of the lens, and Δd is the smallest disparity the stereo system can detect. For the STH-DCAM, b is 90 mm, and Δd is 0.35 um (pixel size of 5.6 um, divided by the interpolation factor of 16).

Figure 4-1 plots this relationship for several focal lengths. At any distance, the range resolution is inversely proportional to the focal length.

4.7 Field of View

The field of view is completely determined by the focal length, given a fixed imager. The formulas for the FOV in horizontal and vertical directions are:

$$HFOV = 2\arctan(1.792/f)$$

$$VFOV = 2\arctan(1.344/f)$$

where f is in millimeters. For example, a 4.0 mm lens yields a horizontal FOV of 48 degrees. The following table shows the FOV for some standard focal lengths.

Lens focal length	Horizontal FOV	Vertical FOV
2.1 mm	81 deg	65 deg
4.0	48	37
8.0	25	19

Table 4-1 Horizontal and vertical field of view for different lens focal lengths.

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5   1394 Interface

Digital image information is transferred from the STH-DCAM to the host PC via an IEEE 1394 cable. The cable sends a video stream from the imagers to the PC, and sends commands from the PC to the stereo head to control exposure, color balance, etc. The cable also supplies power to the stereo head. Alternatively, power can be supplied through a separate power jack located on the STH-DCAM.

5.1   1394 Cable

The STH-DCAM has an IEEE 1394 port on the left side of the device. Plug a cable from the STH-DCAM into a free port on the host controller. The maximum length for such a cable is 4.5 m (about 15 feet). The cable supplies both signals and power to the stereo head; alternatively, power can be supplied at the device using a separate power supply.

The distance between the stereo head and the PC can be extended by using an IEEE 1394 repeater.

Several 1394-enabled devices can be connected together, as long as the connection topology doesn't have any loops. The STH-DCAM is always a leaf of the bus. At a maximum, it will need about 60% of the bandwidth of a 400 MBps connection.

5.2   1394 Host Interface

The host computer must have an available 1394 port. Some portables and desktops come with built-in ports. If these are 6-pin ports, they can be connected directly to the STH-DCAM. Sony laptops also support an alternative 4-pin 1394 cabling, which has the signal pins but no power. Use a 4-pin to 6-pin cable on these ports, and supply power to the STH-DCAM using the separate power port.

If the host PC doesn't have a built-in 1394 port, one can be added by installing an IEEE 1394 PCI card or PCMCIA card for laptops. IEEE 1394

PCI cards have 6-pin ports, and supply power. PCMCIA cards do not have the capability of supplying power, and power can be supplied through the power jack. In some cases, the PCMCIA card has an input for external power. Plug the STH-DCAM cables into a port, and supply power through the external input.

Any 1394 card is suitable, as long as it conforms to OHCI (open host controller interface) specifications. All current cards do, but some older cards may not.

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6   User Controls

The CCD imagers are fully controllable via the IEEE 1394 interface. User programs may input color images, set video digitization parameters (exposure, gain, red and blue balance), and frame size. All of these parameters can be set with the included capture application, or with the SRI Small Vision System. They are also accessible to user programs through the capture API (Section 8).

User controls for frame size and sampling modes are on the main capture window dialog. Video digitization and Subwindowing controls are accessed through a dialog invoked with the *Video…* menu item. Figure 6-1 shows the dialog.

6.1   Color

Color information from the STH-DCAM digital head is input as raw colorized pixels, and converted by the interface library into two
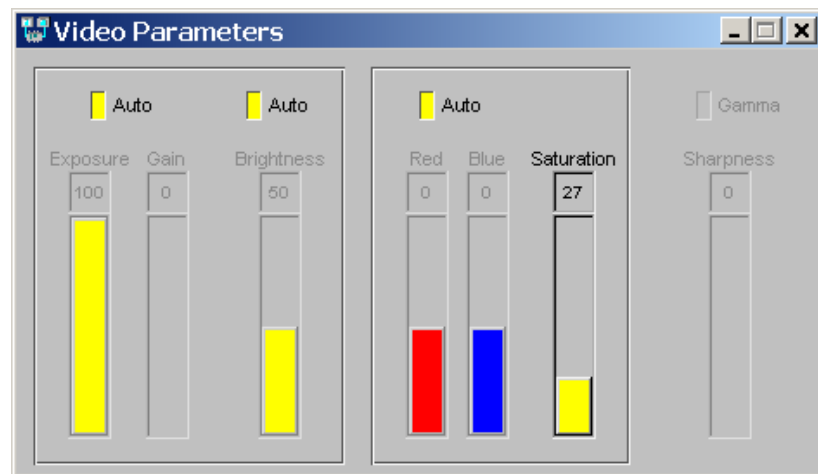

Figure 6-1 Video Parameters dialog.

monochrome channels and one RGB color channel. The color channel corresponds to the left image, which is the reference image for stereo. The color image can be de-warped, just like the monochrome image, to take into account lens distortion (see the Small Vision System User's Manual).

Color information from the camera is input only if the `Color` buttons are pressed on the main window (Figure 2-1). Color/monochrome can only be changed while the STH-DCAM is not outputting images.

Because the typical color camera uses a colorizing filter on top of its pixels, the color information is sampled at a lower resolution than a similar non-colorized camera samples monochrome information. In general, a color camera has about ¼ the spatial resolution of a similar monochrome camera. To compensate for the reduced resolution, use binning (Section 6.3) to increase the fidelity of the image. For example, if you need a 320x240 frame size, use 640x480 and binning x2.

The relative amounts of the three colors, red/green/blue, affects the appearance of the color image. The STH-DCAM CCD imagers have attached processors that automatically balance the offsets among these colors, to produce an image that is overall neutral (called *white balance*). Alternatively, the application program can control the color balance manually. Manual balance is useful in many machine vision applications, because automatic white balance continuously changes the relative amount of color in the image.

The manual gain on red and blue pixels is adjusted using the *Red* and *Blue* controls on the *Video Parameters* dialog. For a particular lighting source, try adjusting the gains until a white area in the scene looks white, without any color bias.

6.2   Video Digitization Parameters

The CCD imagers have electronic exposure and gain controls to compensate for varying lighting conditions. The exposure can vary from a maximum of a full frame time to a minimum of one line time. Gain is an additional amplification of the video signal, for low-light situations. It is settable from 0 to 18 dB.

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Both imagers are treated in exactly the same manner. It is not possible to set a different exposure or gain on each imager.

Digitization control can operate in either manual or automatic mode. Refer to Figure 6-1 for the controls in the video capture program.

In manual mode, the user program sets the exposure and gain. The exposure and gain are based on a 0 to 100 scale. Here are some tips for setting exposure and gain.

- In general, keep the gain as low as possible, since it introduces additional noise into the system. Use it only if the exposure is set to maximum, or if the exposure must be kept low to minimize motion blur.

- Adjust the manual iris of the lens to as small an opening as possible for your application, without having to use gain. This will increase the depth of field and give better optical performance.

6.3 Subsampling

In many applications it is not necessary to work with the the full 640x320 pixel array. The CCD image processors are capable of reducing the amount of information contained in the digital video stream sent back to the host. They do this by averaging the values from neighboring pixels, giving a higher signal-to-noise ration. This technique is called *binning*. Binning occurs automatically when a smaller frame size is selected.

Figure 6-2 shows the frame size control on the video capture application. The two frame sizes allowed are 640x480 (full frame) and 320x240 (x2 binning).

6.4 Subwindowing
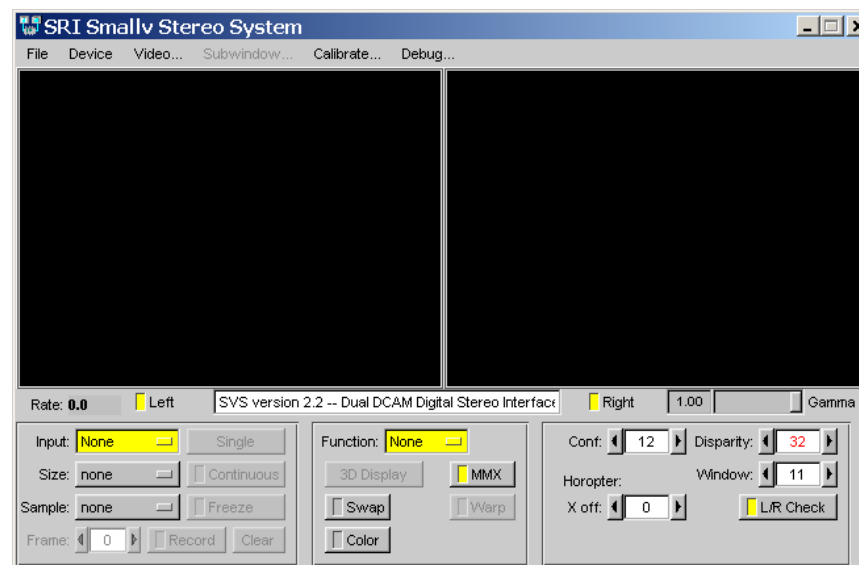
The STH-DCAMs do not support subwindowing..

Figure 6-2 Frame size control in the main capture window.

6.5 Frame Rates

Frame rates from the STH-DCAM depend on the frame size and color mode. Frame rates can be set under program control with the SetRate() function; see the Small Vision System User's Manual. For the smallv and smallvcap applications, frame rates are set at 30 Hz.

Frame Rates, Hz	Monochrome	Color
320x240	30, 15, 7.5	30, 15, 7.5
640x480	30, 15, 7.5	30, 15, 7.5

Table 6-1 Allowable frame rates for the STH-DCAM in different modes.

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7   Installing the 1394 Host Card and Capture Software

The STH-DCAM connects to a host computer via a digital 1394 interface. The host PC must have a 1394 port, and software to interface to the video stream from the camera. This interface software presents the video stream from the 1394 hardware as a set of stereo frames to the user program (see Figure 7-1). The STH-DCAM comes with interface software for either MS Windows 98/2000 or Linux.

7.1   1394 Hardware and Drivers

Before installing the software interface, the PC must be equipped with a 1394 port. If there is one already present, on the motherboard, then you can skip this section. Otherwise you have to install a PCI or PCMCIA card. The card must be OHCI compliant, which all current cards are.

Please see the Videre Design website (www.videredesign.com/support.htm) for the latest information about installing hardware and software drivers.

After installing the card, install the STH-DCAM driver software.

7.2   STH-DCAM Software

The STH-DCAM comes with interface software and several sample applications, including the capture application described in this manual.
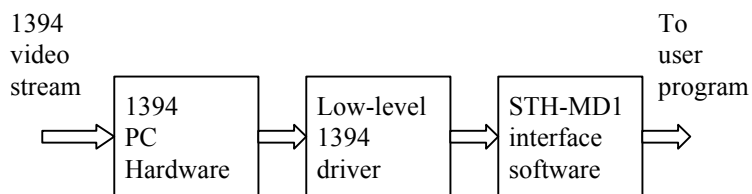

Figure 7-1 Host PC low-level software structure.

7.2.1   MS Windows Installation

To install the software under MS Windows, execute the file `svscap22X.exe`. The installation process will add the relevant interface and application software.

The directory structure for the software is:

```
bin\
    smallvcap.exe
    stcap.exe
    svsgrab.dll, .lib
    dcamcap.dll, .lib
src\
    svs.h
    svsclass.h
samples\
    *.cpp
    *.dsp, samples.dsw
```

There are two applications. `smallvcap.exe` is a GUI-based application that allows the user to exercise the capture functions of the STH-DCAM. It is described in earlier sections of this document.

`stcap.exe` is a simple application that connects to the stereo head and displays stereo images. It can serve as a template for user programs that integrate stereo capture from the STH-DCAM.

`libcap.dll` is the capture library for Linux. These libraries must be set to the correct ones for the STH-DCAM. Copy the following files in the `bin\` directory:

```
    svsdcam.dll -> svsgrab.dll
    svsdcam.lib -> svsgrab.lib
```

You can check that the correct interface library is installed, by looking at the information text when the capture application is started. It should say "Dual DCAM digital stereo interface". If not, the wrong interface library is installed in `svsgrab.dll`.

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7.2.2 Linux Installation

To install the software under Linux, untar the file `svscap22X.tgz` in a new directory, which will become the top-level directory of the software. Add `bin/` to your LD_LIBRARY_PATH variable.

The directory structure for the software is:

```
bin/
    smallvcap
    stcap
    libsvscap.so
    pixcap.so
    dcamcap.so
 src/
    svs.h
    svsclass.h
 samples/
    *.cpp
    makefile
```

There are two applications. `smallvcap` is a GUI-based application that allows the user to exercise the capture functions of the STH-DCAM. It is described in earlier sections of this document.

`stcap` is a simple application that connects to the stereo head and displays stereo images. It can serve as a template for user programs that integrate stereo capture from the STH-DCAM.

`libsvscap.so` is the capture library for Linux. These libraries must be set to the correct ones for the STH-DCAM. Copy the following files in the bin/ directory:

```
dcamcap.so -> libsvscap.so
```

You can check that the correct interface library is installed, by looking at the information text when the capture application is started. It should say "Dual DCAM digital stereo interface". If not, the wrong interface library is installed in `libsvscap.so`.

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8 Interface Software API

Please see the Small Vision System User's Manual for information about the software API for capturing and saving images.

9   Technical Specifications

9.1   Geometry

Housing
>Rigid milled Delrin frame

Baseline
>9 cm, fixed

Imager size
>1/4 inch diagonal

Lens type
>12 mm miniature, interchangeable

9.2   Interface

Type
>Digital 1394 [Firewire], OHCI compliant

Speed
>Maximum 20 megapixels / second

Host interface
>Any 1394 OHCI card

Host OS
>Windows 98 / 2000 / XP, Linux

9.3   Imagers

Type
>Sony Wfine HAD CCD

Format
>Color, 8 bits / pixel, Bayer pattern

Scan mode
>Progressive

Pixel size
>5.6 um square

Sensitivity
>1 lux

Exposure
>Electronic, 292 us to frame time

Gain

>18 dB

Resolution
>640 H x 480 V

9.4   Frame formats and rates

Monochrome, 640x480 and 320x240

RGB Color, 640x480 and 320x240

30, 15, 7.5 Hz

RGB 640x480 at 15 and 7.5 Hz only

9.5   Physical

Power

>2 watts

Ports

>One IEEE 1394 port (power and signal)
>One power jack (7-40 VDC, 2W)

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Stereo module size
        6" x 2.6" x 1"

Weight (with lenses)
        8 ounces

10 Technical Support

For technical support, please contact Videre Design by email or FAX.

Videre Design
P.O. Box 585
Menlo Park, CA 94026-0585
Fax: (650)323-3646
Email: mclaughl@dnai.com

Technical information about stereo algorithms and stereo calibration can be found at `www.ai.sri.com/~konolige/svs`.

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