STH-MDCS3-VAR(X)(-C) Stereo Head
User's Manual

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1 Introduction

The STH-MDCS3-VAR(X) is the third generation of Videre's compact, low-power digital stereo head with an IEEE 1394 digital interface. It consists of two 1.3 megapixel, progressive scan CMOS imagers mounted in separate enclosures, each with its own 1394 peripheral interface module. The imagers are joined in on a mounting bar, and can be moved relative to each other.

The CMOS imagers are ½" format, with a resolution of 1280 H by 1024 V pixels, and come in either monochrome (STH-MDCS3-VAR) or colorized (STH-MDCS3-VAR-C) versions. These imagers have excellent dynamic range, sensitivity, anti-blooming, and noise characteristics. They are fully controllable via the 1394 interface: the user can set exposure, gain, decimation, etc. They can be used interchangeably with the same interface module.

The interface electronics synchronizes each camera to the 8 KHz clock on the IEEE 1394 bus. Thus, each camera takes images at exactly the same time, and the timing of the cameras is synchronized. Any Videre Design MDCS3 camera will synchronize to all other cameras on the bus, so multiple STH-MDCS3-VAR/-C stereo devices will operate synchronously.

The STH-MDCS3-VAR/-C uses standard CS-mount lenses for user-changeable optics. Wide-angle to telephoto options are available, depending on the application.

SRI's Small Vision System (SVS) software has an interface to the STH-MDCS3-VAR, and is included with each stereo head. You can simply and automatically calibrate the stereo head, perform stereo correlation, and view the results as a 3D point set. The SVS software includes software drivers for the STH-MDCS3-VAR for MS Windows 2000/XP, and for Linux 2.4.and 2.6 kernels.

The standard VAR baseline is adjustable anywhere from 5 to 20 cm (monochrome), or 9 to 20 cm (color). There is also an extended version, the VARX, with a very rigid milled aluminum mount, with baselines from 18 to 60 cm, in steps of 7 cm.

1.1 Characteristics

- *Micron MT9M001/MT9T001 CMOS imagers*
  Rollingl shutter
  Simultaneous exposure and readout
  1280x1024 image size
  1/2" format
  High sensitivity, low noise
  Low pixel cross-talk

- *Fully synchronized stereo – left and right cameras are synchronized on the IEEE 1394 bus, to within 60 us*

- *Monochrome or Bayer Color*

- *High frame rates – 30 Hz for 640x480, 15 Hz for 1024x768 (color only), 7.5 Hz for 1280x960*

- *Extensive control of video parameters*
  Automatic or manual control of exposure and gain
  Automatic control of black level
  Manual control of color balance

- *50 Hz mode – reduces indoor light interference in countries with 50 Hz electrical line frequency*

- *Stereo calibration information can be stored on the device, and downloaded automatically to the PC*

- *IEEE 1394 interface to standard PC hardware – carries power and commands to device, data to PC*

- *Standard C/CS mount lenses, interchangeable – standard focal lengths 3.5, 4.5, 6.0 mm*

- *Variable baseline – 5 cm to 20 cm (VAR monochrome)*
  9 cm to 20 cm (VAR color)
  18 cm to 60 cm (VARX)

- *Anodized aluminum alloy chassis, high rigidity*

2   Quick Start

The STH-MDCS3-VAR/-C normally comes assembled with the lenses mounted. If you need to change the lenses, or if you are supplying your own, please see Section **Error! Reference source not found.**.

To set up and test the STH-MDCS3-VAR/-C, you will need the following:

1. Pair of C-mount lenses, for 1/2" or larger imager (normally included and mounted with the STH-MDCS3-VAR/-C kit).

2. Host computer with an IEEE 1394 PCI (desktop) or PCMCIA (laptop) card, OHCI compliant; or a built-in IEEE 1394 port.

3. IEEE 1394 6-pin to 6-pin cables (2x).

4. Small Vision System installed on the host computer.

Install the IEEE 1394 host card, if necessary, according to the directions in Section **Error! Reference source not found.**. Install the Small Vision System software (see Section **Error! Reference source not found.**).

If the lenses are not mounted on the device, follow the directions in Section **Error! Reference source not found.** for installing them.

Plug one end of the IEEE 1394 6-pin video cable into the 1394 jack on the back of the STH-MDCS3-VAR/-C, and the other into an IEEE 1394 port on the host PC.

> **Note: The STH-MDCS3-VAR draws power from the IEEE 1394 bus. PCI cards, or built-in ports for desktop machines, normally supply this power. For PCMCIA cards (PC Cards), and laptops with a built-in port, no power is available. In this case, external power must be supplied – see Section 5.3.**

The PC operating system will normally recognize the STH-MDCS3-VAR, and install the correct system drivers. Please see the Videre support web pages (www.videredesign.com/support.htm) for specific information about installation for your OS. At this point, you should check to see that the

STH-MDCS3-VAR has been recognized by the system. There should be two devices, one for each of the cameras.

Start the SVS main program, smallv(.exe) or smallvcal(.exe), on the host computer. You should see a screen as in Figure 2-1. The message window should indicate that the "DCS Digital Stereo Interface" is present. If not, go back to software installation (Section **Error! Reference source not found.**), 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 correctly, the SVS interface will recognize and configure the stereo head, and a success message will appear in the info text window. If not, the Input chooser will go back to None, and an error message will appear in the info window. Please see Section **Error! Reference source not found.** for troubleshooting.
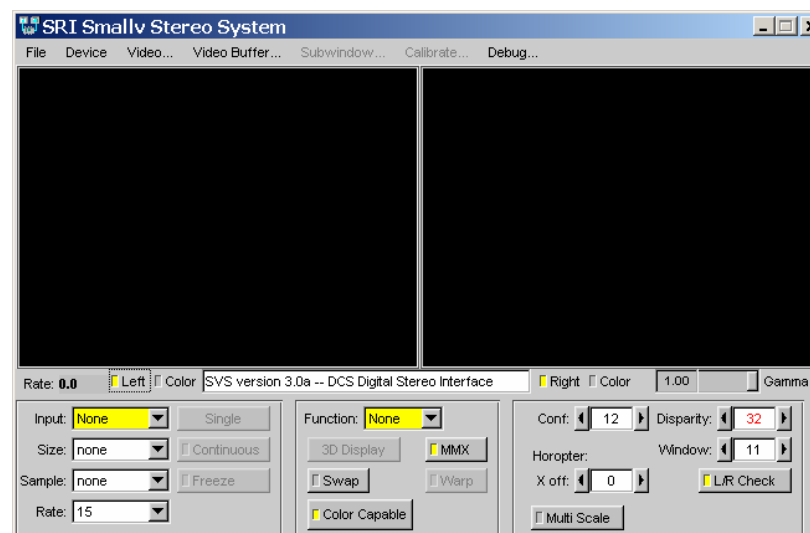
Figure 2-1 SVS main program window.

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 **Error! Reference source not found.**. If the images are too light or too dark, you can open the manual iris of the cameras, or change the exposure and gain settings (Section 7.3). Images can be saved using the File menu.

A more complete description of the video capture program is in Section 7. The SVS programs are described in the SVS User's Manual, and the SVS Calibration Addendum, documentation that comes with that software. It is helpful to review Section 7 in conjunction with the SVS documentation.

3   Hardware Overview

Figure 3-1 shows the hardware configuration of the STH-MDCS3-VAR/-C.

There are two camera modules. Each module has a milled aluminum alloy frame that rigidly holds a megapixel imager. The cameras are mounted on two milled aluminum bars for rigidity. They are held from the bottom by two 6-32" screws. The distance between the cameras can be adjusted from about 5 cm to 20 cm. The cameras can also be dismounted and attached to other rigs. There are mounting holes on both the top and bottom of the cameras, and a ¼-20" mounting hole in the middle of the bar.

Lens mounts are an integral part of the each module, and standard CS-mount lenses are screwed into these holders. There is an IR cutoff filter, with a knee at approximately 680 nm, permanently mounted inside the lens holder. See Section 5 for appropriate lens characteristics.
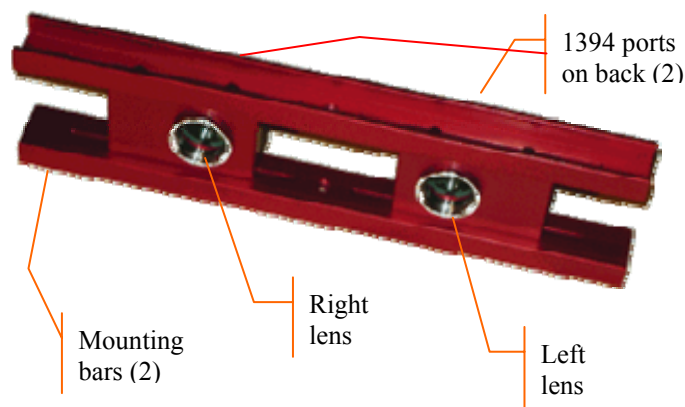

Figure 3-1. Physical layout of the STH-MDCS3-VAR/-C stereo head.

An interface card is mounted on the back of each module. One IEEE 1394 port is placed at the back of each module, and should be connected via an IEEE 1394 6-pin cable to an IEEE 1394 controller card.

There are no user-settable switches on the STH-MDCS3-VAR/-C.

3.1   Extended Baseline

The VARX model has an extended baseline from 18 cm to 60 cm, in steps of 7 cm. The chassis is a channel shape for rigidity, and the camera modules are inserted into holes in the face of the channel at 7 cm intervals. The shape of the chassis is extra rigid for holding calibration in the extended baseline.

The cameras are mounted using four 6-32" screws, two on the top and two on the bottom. The cameras are positioned as shown in Figure XXX, with the lens mount inserted into the hole in the chassis.

The chassis itself has three ¼-20" mounting holes on the bottom of the chassis.

3.2   Hardware Schematic

Figure 3-2 shows the design of the internal hardware of the STH-MDCS3-VAR/-C. In each camera module, a CMOS imager, of size 1280x960 pixels, digitizes incoming light into a digital stream. The imagers operate in progressive mode only, that is, each line is output in succession from the full frame.

The maximum video rate is 24 megapixels per second from each imager. The imagers are synchronized to a the IEEE 1394 8 KHz clock, so that the corresponding pixels from each imager are output at the same time.

The video stream is transferred to the IEEE 1394 interface module, which communicates to the host PC over an IEEE 1394 digital cable. The module also accepts commands from the host PC over the cable, and uses these commands to control imaging modes such as exposure or frame size.

The 1394 interface module can communicate at the maximum 1394 data rate, 400 MBps.

3.3   Frame Formats and Rates

The IEEE 1394 interface electronics supports a maximum rate of 24 megapixels per second. At this rate, there is no need for large buffer memories to hold video data on the stereo device. The STH-MDCS3-VAR/-C conforms to the IIDC version 1.30 camera specification. Frame
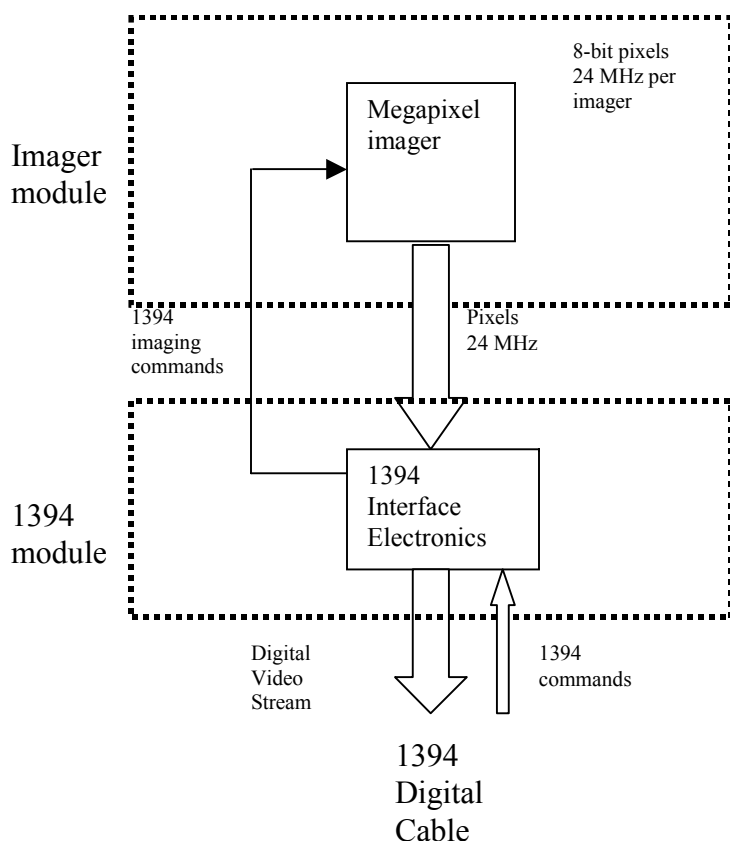
Format	Frame size	Frame rates, 60HZ	Frame rates, 50Hz
Format 0, Mode 5 Y 8 bits	640x480	3.75, 7.5, 15, 30 Hz	3.125, 6.25, 12.5 25 Hz
(color only) Format 1, Mode 5 Y 8 bits	1024x768	3.75, 7.5, 15 Hz	3.125, 6.25, 12.5 Hz
Format 2, Mode 2 Y 8 bits	1280x960	3.75, 7.5 Hz	3.125, 6.25 Hz

Table 1 Frame formats and sizes for the STH-MDCS3-VAR/-C.

rates and frame sizes are set by this standard.   The STH-MDS/-C implements the formats shown in Table 1.

The Digital Camera Specification was set up with monocular cameras in mind. To conform to this specification, the STH-MDS/-C uses the Y (monochrome) data type. Each image from a camera has 8-bit pixels. In the case of the color version (STH-MDCS3-VAR-C), the color information is encoded as a Bayer pattern in the same 8-bit pixel image.

Each camera can actually send images at faster frame rates – up to 60 Hz at 640x480, and 15 Hz at 1280x960. However, because the IEEE 1394 bus is restricted to 32 MB/s in transferring video data, there is not enough bandwidth to accommodate two video streams at the highest rate.

 On the host computer, the SVS interface software takes the two video streams, finds the images that are taken at the same time, and makes them available as a stereo pair in computer memory. The camera modules are coded individually as left or right, so the software knows in which part of the stereo pair to place its image.   The software also performs color processing, for the STH-MDCS3-VAR-C, converting the Bayer pattern into full-color RGB images.

Smaller frame sizes are also available using on-host *binning*. Binning averages neighboring pixels to produce a smaller image with improved

Figure 3-2 Schematic of the STH-MDCS3-VAR/-C electronics for a single camera module.

noise characteristics. Hardware binning on the camera produces 640x480 images from 1280x960 input. Binning available through the SVS software produces 320x240 images from 640x480 input.

3.4   50 Hz Operation

Indoor lighting, especially from fluorescent fixtures, can oscillate at the frequency of the electrical supply. If the image frame rate does not divide evenly into this frequency, there can be moving horizontal bands of alternating light and dark moving in the output.

For countries with 60 Hz power such as the United State, the frame rates of Table 1 are ideal. In many other countries, the electrical line frequency is 50 Hz. For these countries, there is a mode to change the frame rates of the STH-MDCS3-VAR to sub-multiples of 50 Hz. These frame rates are shown in the last column of Table 1.

The frame rate mode of the STH-MDCS3-VAR device can be changed by using the Firmware Parameter dialog – see Section **Error! Reference source not found.**.

3.5   Multiple Devices

Multiple STH-MDCS3-VAR devices can be attached to the same IEEE 1394 bus. When streaming video at the same frame rate, they are synchronized, so that they capture images at the same time.

Each IEEE 1394 PC Card or PCI Card defines a separate IEEE 1394 bus. The two or three ports on the card all belong to the same bus, as does any

IEEE 1394 hub connected to these ports. Separate PC Cards and PCI Cards cannot be connected to each other.

The number of devices that can simultaneously send video is determined by the maximum bandwidth of the bus for isochronous transfers: 32 MB/s. This rate cannot be exceeded by the combined video streams on the bus.

Table 2 shows the bandwidth requirements for the STH-MDCS3-VAR in various modes and for various frame rates. Using this table, it is possible to determine the maximum number devices that can stream video simultaneously. For example, at 15 Hz and 640x480 resolution, a maximum of 3 STH-MDCS3-VAR devices can send video information at the same time.

The bus bandwidth consumed by a device is more than would be expected from just counting the number of bytes in each frame, because there are blank cycles on the bus, when no data is being transmitted, even though the bandwidth is reserved. Thus, it makes no difference whether the rate is 30 Hz or 25 Hz, the bus bandwidth consumed is the same.

Frame size	Bus MB per frame - stereo	30 / 25 Hz	15 / 12.5 Hz	7.5 / 6.25 Hz	3.75 / 3.125 Hz
640x480	0.683 MB	20.5 MB	10.2 MB	5.12 MB	2.6 MB
1280x960	2.732 MB	NA	NA	20.5 MB	10.3 MB

Table 2 Bus bandwidth requirements at different frame rates.

4 Installing the 1394 Host Card and Capture Software

The STH-MDCS3-VAR/-C connects to a host computer via a digital 1394 interface. The host PC must have two 1394 ports, 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 **Error! Reference source not found.**). The STH-MDCS3-VAR/-C comes with interface software for either MS Windows 2000/XP or Linux.

4.1 1394 Hardware and Drivers

Before installing the software interface, the PC must be equipped with two 1394 ports. If there are two already present, built-in ports, 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.

4.1.1 MS Windows Hardware Installation

For the most up-to-date information about installation, please see the Videre Design website (www.videredesign.com/support_svsmsw2.htm).

MS Windows 2000, or XP is required.

For a PCI card, insert the card into a free PCI slot with the computer power off, and start the computer. With a PCMCIA card, insert it into the
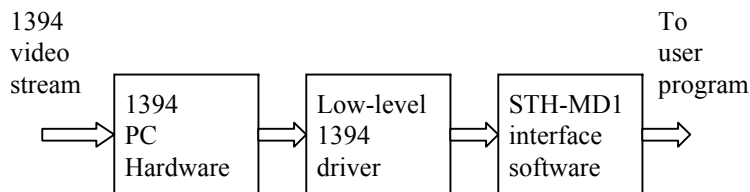

Figure 4-1 Host PC low-level software structure.

PCMCIA slot. In either case, the New Hardware wizard will walk you through installation steps for the low-level drivers. You may need your MS Windows OS CD to install some files.

The STH-MDCS3-VAR must be powered from the IEEE 1394 bus. Desktop PCs supply power to the bus; laptops do not. See Section 5 for information about cabling and power for the IEEE 1394 bus.

4.1.2 Linux Hardware and Driver Installation

Linux kernels 2.4 or 2.6 kernels are required for operation. Please see the Videre Design website (www.videredesign.com/support_svslnx.htm) for current information. GCC 3.x is recommended as the compiler; there is a separate SVS distribution for GCC 2.95.x, but it is not as reliable.

4.2 STH-MDCS3-VAR Software

The STH-MDCS3-VAR/-C comes with the SVS stereo software, and several sample applications, including the GUI application described in this manual.

For the most up-to-date information about installation, please see the Videre Design website (www.videredesign.com/support.htm).

To install the software under MS Windows, execute the file `svsXXX.exe`. If you have installed a previous version of SVS, the installation wizard will ask you if you want to un-install the old version. It is best to uninstall the old version, then start the installation file again and install the new one.

The installation process will add the relevant interface and application software.

To install the software under Linux, untar the file `svsXXX.tgz` in a new directory, which will become the top-level directory of the software. You should also set the environment variable SVSDIR to this directory, and add `bin/` to your LD_LIBRARY_PATH variable.

`libsvscap.so` and `svsgrab.lib/dll` are the capture libraries for Linux and MS Windows, respectively. These are the default libraries for

the SVS distribution. If for some reason they are not configured correctly, you can set them up easily using the following instructions.

- In MSW Windows, execute the file `bin\setup_dcs.bat`. This will copy `svsdcs.dll/lib` as the interface libraries.

- Under Linux, copy the following file in the `bin/` directory:

```
dcscap.so -> libsvscap.so   (Linux)
```

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 "DCS digital stereo interface". If not, the wrong interface library is installed in `svsgrab.dll` or `libsvscap.so`.

The directory structure for the software is:

```
bin/
    smallv(.exe)
    smallvcal(.exe)
    smallvmat(.exe)

    svsgrab.dll/lib
    libsvscap.so
    interface libraries
    stereo calculation libraries
src/
    flwin.cpp
    image_io.cpp
    svsclass.h
    svs.h
    flwin.h
samples/
    smallv.cpp
    fldispx.cpp
    *.dsw, *.dsp, makefile
```

There are several applications – see the SVS User's Manual for more information. The source code for all applications is included in the

distribution. The stereo calculation libraries are also included, so that user applications can link to them. The calibration libraries are *not* included; the only way to run the SVS calibration procedures is through the `smallvcal(.exe)` application.

`smallv(.exe)` is a GUI-based application that allows the user to exercise the capture and stereo functions of the STH-MDCS3-VAR/-C. It is described in earlier sections of this document.

`smallvmat(.exe)` is similar to `smallv`, with the addition of a MatLab interface for sending images and stereo information to MatLab. You must have installed the R13 release of MatLab to run this program. There is also a version of SVS that can be invoked directly from MatLab – again, see the SVS User's Manual.

`smallvcal(.exe)` is the same as `smallv`, with the addition of a calibration package for calibrating a stereo rig. Use this application to perform calibration on your stereo system.

`stcap(.exe)` is a simple application that connects to the stereo head and displays images. It can serve as a template for user programs that integrate stereo capture from the STH-MDCS3-VAR/-C.

`stdisp(.exe)` is a simple application that connects to the stereo head, grabs images and performs stereo analysis, and displays the results. It can serve as a template for user programs that integrate stereo capture and computation from the STH-MDCS3-VAR/-C.

5 IEEE 1394 Interface

Digital image information is transferred from the STH-MDCS3-VAR/-C to the host PC via two 1394 cables. The cables send video streams from the cameras to the PC, and send commands from the PC to the cameras to control exposure, subsampling, etc. The cables also supply power to the cameras.

5.1 IEEE 1394 Cable

The STH-MDCS3-VAR/-C must be connected to the host PC via two 6-pin male-male IEEE 1394 cable. The maximum length for standard cable is 4.5 m (about 15 feet). The cable supplies both signals and power to the stereo head.

Videre also sells a special 10 m cable for longer distances from the PC. The distance can also be extended by using a 1394 repeater.

Several 1394-enabled devices can be connected together, as long as the connection topology doesn't have any loops. The STH-MDCS3-VAR/-C can be connected at any point in such a topology. At a maximum, it will need about 60% of the bandwidth of a 400 MBps connection.

5.2 IEEE 1394 Host Interface

The host computer must have two available 1394 ports. Some portables and desktops come with built-in ports. If these are 6-pin ports, they can be connected directly to the STH-MDCS3-VAR/-C. Sony laptops also support an alternative 4-pin 1394 cabling, which has the signal pins but no power. There are cables that convert from 4-pin to 6-pin styles; these cables must be used with an IEEE hub, to supply power to the cameras.

If the host PC doesn't have a built-in 1394 port, one can be added by installing a 1394 PCI card or PCMCIA card for laptops. 1394 PCI cards have 6-pin ports, and supply power. PCMCIA cards do not have the capability of supplying power, and come with an adapter for supplying power to the 1394 cable through a wall transformer.

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.

5.3 Supplying Power

Power to the STH-MDCS3-VAR is supplied through the IEEE 1394 cables. The IEEE 1394 system must supply this power, about 1 Watt per camera.

There are two typical PC systems: desktops and laptops.

- Desktop PCs have either a built-in IEEE 1394 port, or a PCI card with IEEE 1394 ports. In both cases, the desktop should supply sufficient power to run the STH-MDCS3-VAR.

- Laptop PCs have either a built-in IEEE 1394 port, or a plug-in PC Card (sometimes called a PCMCIA card) with several IEEE 1394 ports. In both cases, the laptop does *not* supply power to the IEEE 1394 bus, and a source of external power must be used – see below.

External power to the IEEE 1394 bus must have the following characteristics:

7 to 16 VDC, > 2 W

The IEEE 1394 spec allows up to 40 VDC on the bus, but in practice many devices such as PC Cards will fail if a voltage higher than 16 VDC or so is used. We recommend using a 12 VDC source.

Power can be supplied to the bus through an IEEE 1394 hub or PC Card with an external port. Most hubs have such a port; most PC Cards do not. The PC Card supplied by Videre has a power port.

The format of the power plug can vary with the hub or PC Card, so please check the specifications for the device. Generally, the positive terminal of the plug is on the inside, and the negative is the outside cylinder.

Figure 5-1 shows the two configurations for supplying power. A wall transformer converts line voltage to 12 VDC, and is plugged into a hub or the PC Card.
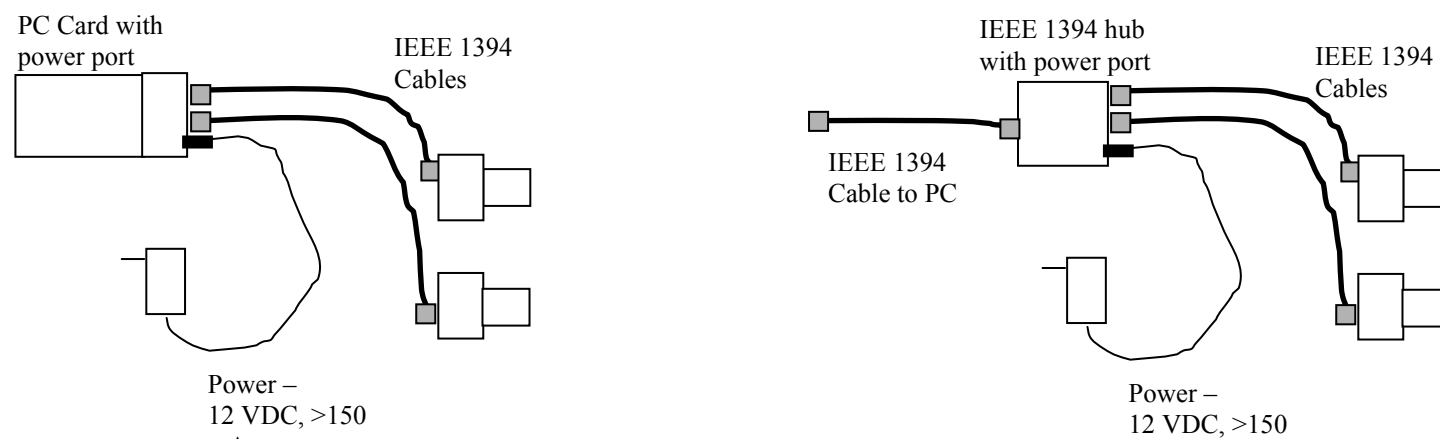

Figure 5-1 External power supply connections. On the left is power supplied to a PC Card with a power port. On the right, power is supplied through a hub with a power port. Power should be 7 to 16 VDC, at > 2 W. Check the PC Card or hub for the type of power connector.

6 Lenses

The STH-MDCS3-VAR/-C uses standard C/CS-mount lenses. 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.

6.1 Locking Lenses

Some lenses come with thumbscrew locks for holding the focus and iris settings. We recommend these locking lenses for all applications in which the device is moving, or in which people or objects may touch the lens. Locking lenses are the standard lenses from Videre.

6.2 C and CS-Mount Lenses

The STH-MDCS3-VAR will accommodate either C or CS-mount lenses. CS-mount lenses have a mounting distance of 12.5 mm from the imager. C- mount lenses have a mounting distance of 17.5 mm. Normally, 1/3 format lenses are of the CS-mount variety. C-mount lense require an additional 5 mm spacer to focus properly. If you use C-mount lenses, you must use a spacer (Videre can supply them free of charge).

6.3 Changing Lenses

Standard CS-mount lenses have a 1" diameter, 28 threads-per-inch 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 it seats firmly. You can snug it down, but do not tighten it excessively, since this can damage the lens and the lens holder threads.

Removing the lens is the reverse process: unscrew the lens counter-clockwise. There will be some initial resistance, and then it should unscrew smoothly.

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

6.4 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.

6.5 Imager Size

The *imager size* is the largest size of imager that can be covered by the lens. For the STH-MDCS3-VAR, the lens must be 1/2" format or greater. For some wide-angle lenses, there will be a little vignetting (darkening) on the corners of the image. Calibration and rectification of the image will usually eliminate this vignetting.

6.6 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-MDCS3-VAR 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. In any case, it is useful to have a manual iris for high light situations. While the imagers can have electronic exposure and gain control to automatically compensate for different light conditions, the
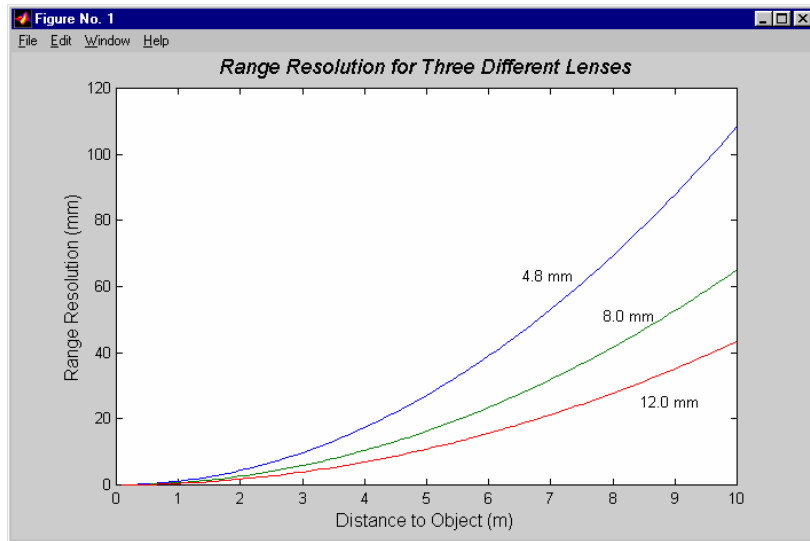
Figure 6-1 Range resolution in mm as a function of distance, for several different lens focal lengths.

acceptable illumination range can be extended by mechanical adjustment of the lens opening.

6.7   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.

6.8   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-MDCS3-VAR/-C, b is 90 mm, and Δd is 0.375 um (pixel size of 6.0 um, divided by the interpolation factor of 16).

Table 3 plots this relationship for several focal lengths. At any distance, the range resolution is inversely proportional to the focal length.

6.9   Field of View

The field of view is completely determined by the focal length and the image size. The color and monochrome versions have slightly different imagers, and so the calculation depends on the imager type. The formulas for the FOV in horizontal and vertical directions are:

For monochrome:
$$HFOV = 2\arctan(3.84/f)$$
$$VFOV = 2\arctan(2.88/f)$$

For color 1280x960 or 640x480:

16

$$HFOV = 2\arctan(2.05/f)$$
$$VFOV = 2\arctan(1.54/f)$$

For color 1280x960 or 640x480:

$$HFOV = 2\arctan(3.28/f)$$
$$VFOV = 2\arctan(2.46/f)$$

where f is in millimeters. For example, a 3.5 mm lens yields a horizontal FOV of 95.3 degrees for monochrome devices. This is about the smallest practical focal length for the STH-MDCS3-VAR.

The following table shows the FOV for some standard focal lengths.

Lens focal length	Horizontal FOV (deg)			Vertical FOV (deg)		
	mono	color 1280x640	color 1024x768	mono	color 1280x640	color 1024x768
3.5 mm	95.3	60.7	86.2	78.9	47.5	70.2
6.0	65.2	37.7	57.3	51.3	28.8	44.6
12	35.5	19.4	30.6	27.0	14.6	23.2
16	27.0	14.6	23.1	20.4	11.0	17.5

Table 3 Horizontal and vertical field of view for different lens focal lengths.

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7   User Controls

The CMOS imagers are fully controllable via the IEEE 1394 interface. User programs may input color images (STH-MDCS3-VAR-C only), set video digitization parameters (exposure, gain, red and blue balance), and subsampling modes. All of these parameters can be set 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 controls are accessed through a dialog invoked with the *Video…* menu item. Figure 7-1 shows the dialog.

7.1   Color

Color information from the stereo head (STH-MDCS3-VAR-C only) is input as raw colorized pixels, and converted by the interface library into
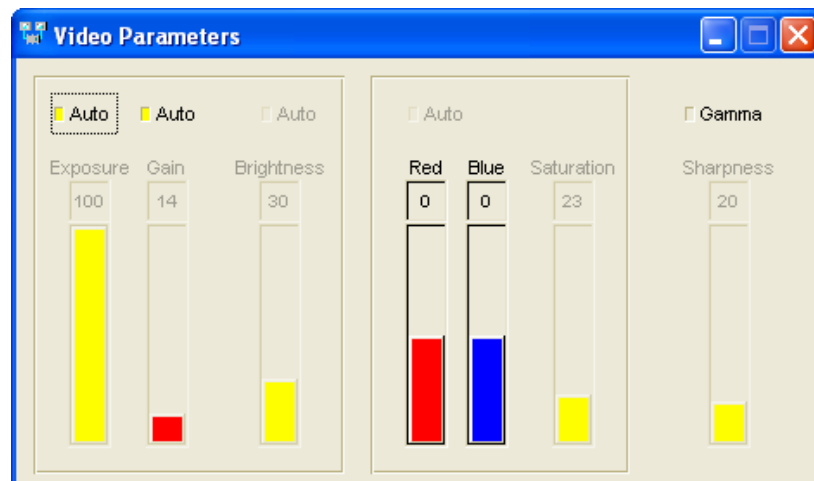

Figure 7-1 Video Parameters dialog.

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

Color information from the camera is processed only if the `Color` button is pressed on the main window (Figure 2-1).

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 7.4) to increase the fidelity of the image. The cameras have on-imager binning from 1280x960 to 640x480. Whenever the 640x480 frame size is requested, binning is automatically performed on-camera, and all the pixels are used. For 320x240 frame sizes, binning is performed by the SVS software.

The relative amounts of the three colors, red/green/blue, affect the appearance of the color image. Many color CCD imagers have attached processors that automatically balance the offsets among these colors, to produce an image that is overall neutral (called *white balance*). The STH-MDCS3-VAR-C provides manual color balance by allowing variable gain on the red and blue pixels, relative to the green pixels. 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.

7.2   Gamma Correction

To display properly for human viewing, most video images are formatted to have a nonlinear relationship between the intensity of light at a pixel and the value of the video signal. The nonlinear function compensates for loss

of definition in low light areas. Typically the function is x^γ, where γ is 0.45, and the signal is called "gamma corrected." Digital cameras, such as the STH-MDCS3-VAR/C, do not necessarily have gamma correction. This is not a problem for stereo processing, but does cause the display to look very dark in low-light areas. You can add gamma correction to the displayed image by choosing an appropriate gamma value in the slider under the right display window (Figure 7-2).

7.3 Video Digitization Parameters

The CMOS 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 16 dB.

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 7-1 for the controls in the video capture program. Manual mode is the only currently supported mode for the STH-MDCS3-VAR/C.

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.

There are automatic modes for both exposure and gain. In auto mode, gain and exposure are controlled by the imager, which samples the incoming image and sends changes the exposure and gain parameters. The auto algorithm will try to reduce gain as much as possible, while still maintaining overall light levels in the image.

Auto mode for gain and exposure can be set separately. For the STH-MDCS3, if there is relatively slow motion, it is recommended to use a manual mode for gain, and auto mode for exposure. Indoors, set the gain to a higher value; outdoors, set it to a low value. With exposure in auto mode, the light on the image will be adjusted by changing the exposure.

For high-speed motion, it is better to set the exposure to a fixed, low value, and then use auto-gain to keep reasonable light levels on the imager.

7.4 Subsampling

In many applications it is not necessary to work with the full 1280 x 960 image. The CMOS imagers are capable of sampling the pixels in the array. Sampling allows the video stream to send less data, for faster frame rates or less bus activity. A sampled image shows the same scene as the original image, but it uses fewer pixels to do so, and has less detail. Sampling differs from *subwindowing*, which picks a rectangular portion of the image, but doesn't change its resolution.

Binning is a subsampling technique in which several adjacent pixels are averaged into one. Binning reduces video noise, sometimes quite substantially. Binning is available both on-chip and on the host PC. On-chip binning allows the STH-MCDS3-VAR/-C to convert the entire 1280x960 image into a 640x480 image *before* it is sent down the IEEE 1394 bus. The binning is color-aware for the STH-MDCS3-VAR-C, so that pixels of like color are combined.
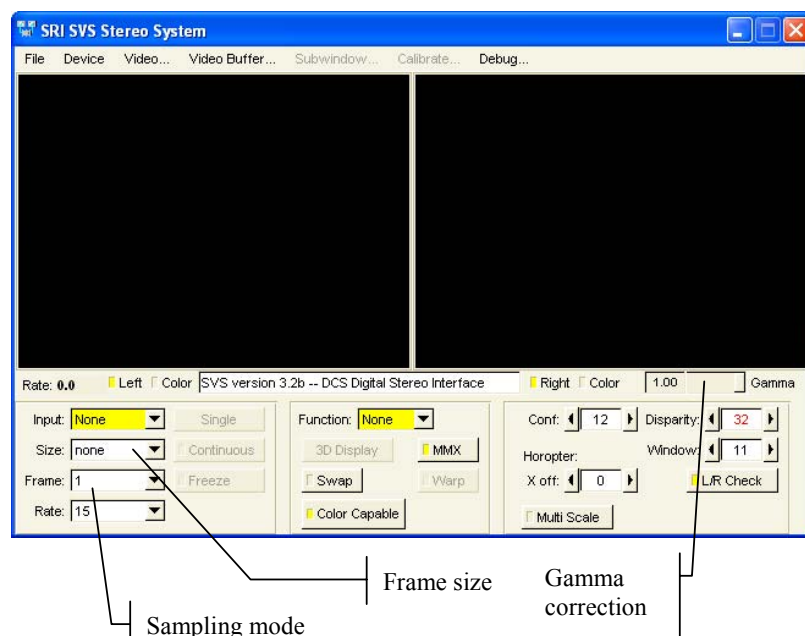
Frame size

Gamma
correction

Sampling mode

Figure 7-2 Frame size and sampling controls in the main capture window.

Binning can also take place on the host computer, giving an additional x2 subsampling of the image. Host binning is used to convert 640x480 images to 320x240 images, or 1280x960 images to 640x480 images.

Figure 7-2 shows the frame size and subsampling controls on the video capture application. With SVS version 3.2b, the sampling control has been changed to a simple Frame Division control. For the STH-MDCS3-VAR, the only value possible is "1", which means that a full frame is returned at every resolution.   The system picks the appropriate mode for each resolution – the non-grey lines in Table 4.

Refer to Table 4 for a complete list of allowed modes, and how the frame size and sampling setting affect the output image. Explicit control over the sampling mode is accomplished with the SetSample() function from the

SVS API. At 1280x960, the full image is sent to the host PC, and there is no binning. At 640x480, there are two choices: binning on the imager, or binning on the host. Using `SetSample(1,1)` means that binning will take place on the imager, which then transmits a 640x480 imager. Using `SetSample(1,2)` means that binning will take place on the host. In this case, the imager transmits all 1280x960 pixels, so the maximum frame rate is lower. For 320x240, binning will take place on the host PC and the imager. The imager will transmit a 640x480 image, and the host will bin that down to 320x240.   The subsampling must be set with `SetSample(1,2)`.

7.5   Frame Rates

Frame rates from the STH-MDCS3-VAR/-C depend on the frame size. Table 4 shows the frame rates available for each of the frame sizes.

7.6   Firmware Parameters

There are several firmware parameter that affects the overall behavior of the STH-MDCS3-VAR.

• Vertical offset between the images

• 50 Hz operation

These parameters can be changed by using the Firmware Parameter dialog, accessible from the `smallv` menubar. Choosing this menu brings up the dialog, which is shown in Figure 7-3.

Output Size	Sample Setting	Frames per Second
1280x960	x1	3.75, 7.5
1024x768 (color only)	x1	3.75, 7.5, 15
640x480	x1	3.75, 7.5, 15, 30
640x480	bin x2 (on host)	3.75, 7.5
320x240	bin x2 (on host)	3.75, 7.5, 15, 30

The dialog lists many of the internal parameters of the device, which are fixed in the firmware. The changeable parameters are for 50 Hz or 60 Hz operation (Section 3.4), and for vertical offset. The Firmware Parameter dialog is only available after the STH-MDCS3-VAR has been opened by pulling down the `Video` item of the `Input` chooser.

7.6.1 50 Hz Operation

To use 50 Hz operation, check the box, and then press the `Save` button. This choice is downloaded and stored in the device, and will cause 50 Hz operation every time the STH-MDCS3-VAR is accessed. To change back to 60 Hz, uncheck the box and again save it to the device.

7.6.2 Vertical Offset and Image Inversion

The STH-MDCS3-VAR (monochrome) is normally supplied with the left image inverted, and the left image module turned upside-down. In this configuration, the cables stick out the ends of the device, allowing the imagers to be placed closer together for small baselines. The range of baselines is 5-20 cm.

The STH-MDCS3-VAR-C (color) does not have the capability to invert the camera image. Both cameras are oriented the same. The –C version can attain a baseline of 9-20 cm.

In the monochrome version, each camera is separately invertible from the firmware parameters. For special applications, for example, it may be useful to invert the right image, and leave the left image right-side up.

Because the camera modules are moveable within the frame, there can be slight rotational offsets that cause the images to be misaligned vertically. Misalignment be a few lines is not a problem, but when it is larger, the firmware can adjust the alignment by choosing a different set of active rows in each camera. The initial adjustment is done at the factory. If further adjustment is necessary, after moving the cameras, the Voff slider bars can be used to move the images in each camera vertically. Align the images by looking at some object that touches the top edge of one image, and adjust the other image until it is in the same vertical position.

7.6.3 Calibration Parameters

It is also possible to clear any calibration parameters that are saved on the STH-MDCS3-VAR firmware. If the calibration parameters are present, the
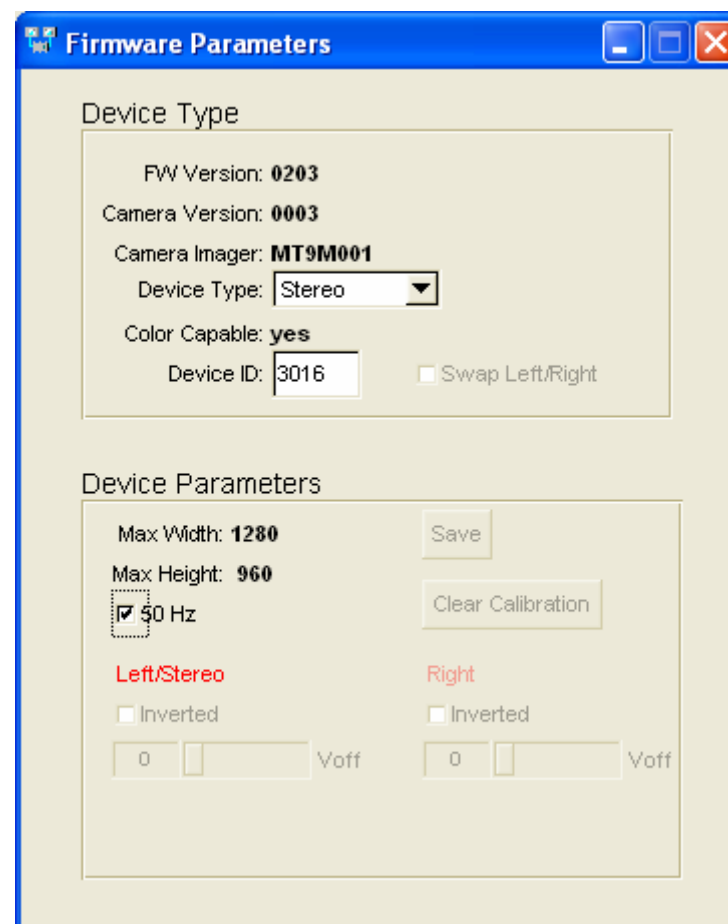

Figure 7-3 Firmware parameters dialog.

Clear Calibration button will be activated. Pressing this button will clear the parameters. See the SVS Users' Manual for information on saving and loading calibration parameters on the device.

8   Interface Software API

Please see the Small Vision System manual for information about the software API for capturing and saving images.

9 Physical Dimensions and Mounting Diagram

The diagram below shows the physical dimensions for each of the STH-

MDCS3-VAR/-C camera modules. The larger hole is threaded for a ¼-20 machine screw (standard tripod mounting screw). The two smaller holes are threaded for 6-32 machine screws. Each module is attached to the mounting bar by the two 6-32 screws. The mounting bar has a standard ¼-20 machine thread in the center for tripod mounting.
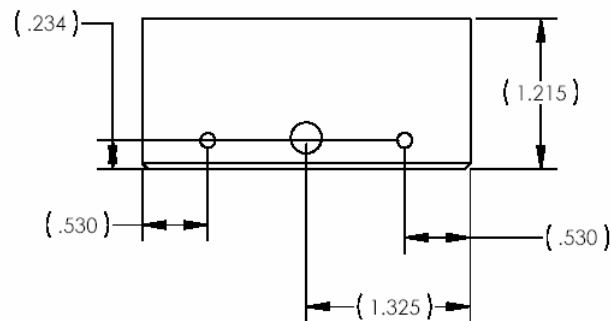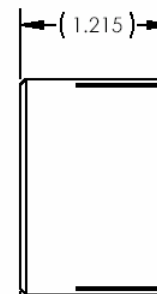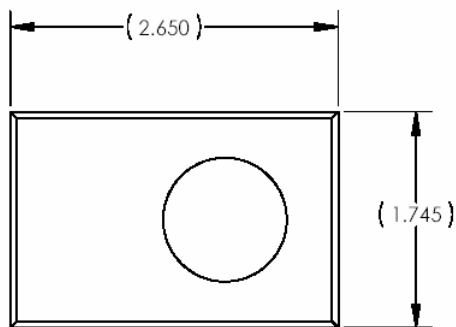

Videre Design
650 323-6769 Fax 650 323-3646

MDCS Camera Module
REV A

Delrin and Aluminum

1/4-20 center mounting hole
6-32 offset mounting holes

10 VARX Chassis

The VARX chassis is a rigid aluminum channel with holes for the camera modules. The camera modules are mounted into the channel with the IEEE 1394 port towards the center, then screwed onto the rails on the top and bottom of the module, with four 6-32" screws.

The chassis mounts with three ¼-20" holes on the bottom rail of the chassis. The empty camera module holes may also be used as chassis mounts.
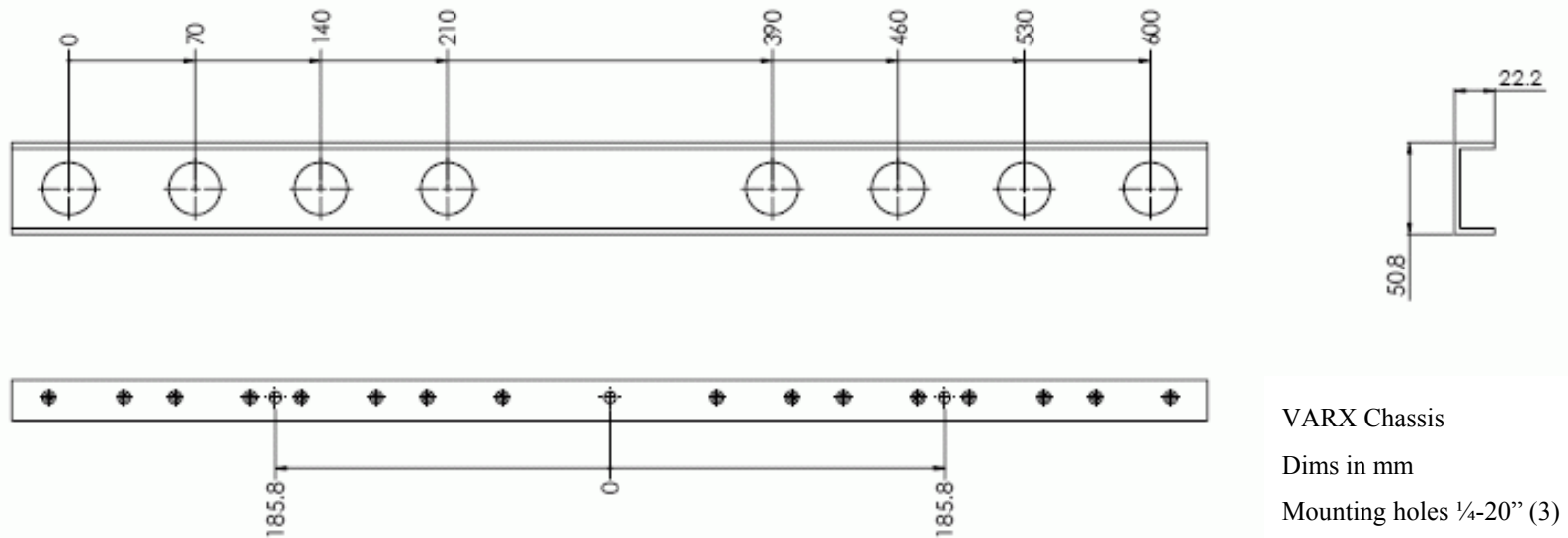
VARX Chassis

Dims in mm

Mounting holes ¼-20" (3)

SVS software	Linux kernel 2.4 MSW 2000 and XP

11 Technical Specifications

Specifications

Imagers	½" format CMOS 1280x960 active area Progressive scan Color or monochrome
Digital Camera Specification	Version 1.30
Formats	1280x960, 640x480 8 bit monochrome or Bayer color pattern
Frame Rates	3.75, 7.5, 15, 30 Hz Max 7.5 Hz at 1280x960
Exposure	1 line time to full frame; rolling integration
Gain	0 – 16 dB
Sensitivity	2.5 V/lux-sec
S/N	> 55 dB, no gain
Power	< 2 W
Synchronization	External: 60 us
Lens	6.0 mm F 1.4 C mount included 3.5 mm and 12 .0mm lenses optional
Size	1.5" high x 2.6" long x 1" deep (excluding lenses), each module
Stereo Baseline	8 cm to 20 cm

12 Technical Support

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

Videre Design
865 College Avenue
Menlo Park, CA 94025
Fax: (650)323-3646
Email: support@videredesign.com

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