CS24D
Color Sensors

150622

Contents

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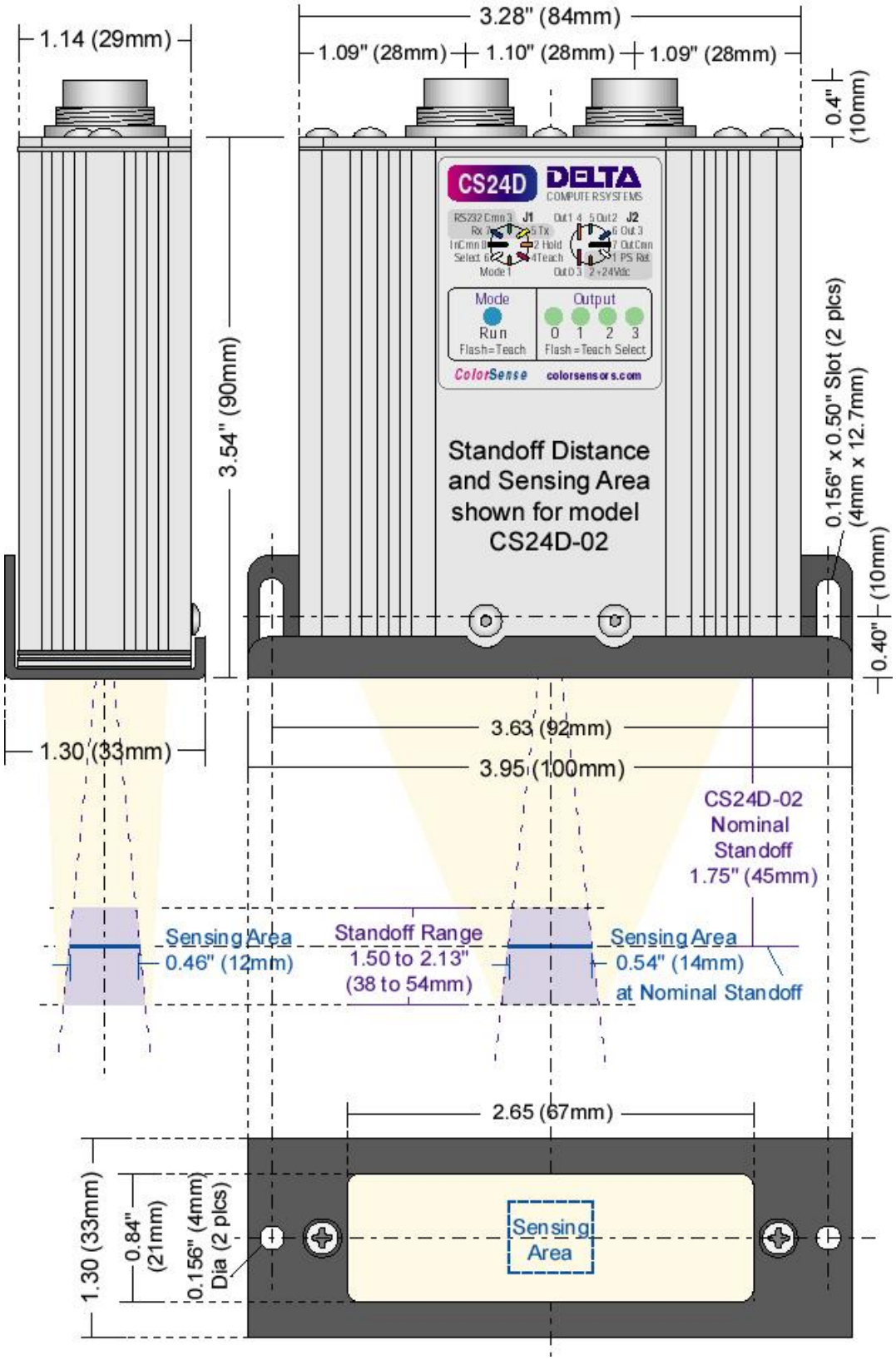


Figure 1: Sensing Area and Standoff Range for model CS24D-02

1. Specifications

Model	CS24D-00	CS24D-01	CS24D-02	CS24D-03
Standoff Distance	0.75 to 0.88" *(20-22mm)* optimum		1.75 to 2.00" *(45-50mm)* optimum	
Standoff Range	0.63 to 1.00" *(16-25mm)*		1.50 to 2.25" *(38-57mm)*	
Sensing Area	0.28 x 0.32 @ 0.75" *(7 x 8 @ 20mm)*	0.15 x 0.17 @ 0.75" *(3.8 x 4.4 @ 20mm)*	0.47 x 0.54 @ 1.75" *(12 x 14 @ 45mm)*	0.32 x 0.28 @ 1.75" *(7 x 8 @ 45mm)*
Response Time	2-4 milliseconds plus averaging time (with no serial communications activity).			
Averaging	1-4096 readings in an exponential moving average (The response time with averaging can be as low as 9ms or as high as 25 seconds or more, depending on a number of factors—see page 25)			
Sorting Modes	Closest Color, Closest Match*, Unique Match* (*User-settable Error Limit)			
Sort Criteria	Color Only, Color and Intensity, or Optimized for Teach samples			
Sort Outputs	Fifteen, (binary-coded into four discrete outputs, 0 = no match)			
Discrete Inputs	Four, opto-isolated, 12-24V at 5mA max (Teach, Select, Mode, Hold)			
Discrete Outputs	Four, opto-isolated SSR, rated 12-24V at 100mA max (0, 1, 2, 3 (binary-coded outputs))			
Indicator LEDs	One Mode (blue), four Output (green), Flash to indicate Teach status			
RS232 Serial	Compatible with PC running Delta's ColorSense software (Windows 98 or XP)			
Ratio Variation with Sensing Distance	0.6% max per 0.13" *(3mm)* change in standoff distance (<2% max over sensing range)		0.6% max per 0.25" *(6mm)* (<2% max over sensing range)	
Stability	With temperature, Color Ratios 0.1%/C typical			
Supply Voltage	+12 or 24VDC (11 to 29V range)			
Supply Current	50mA continuous maximum, 500mA startup maximum			
Enclosure	Dust tight; 1.3 x 4.0 x 3.9" *(33 x 100 x 99mm)* excluding connectors; 0.5 lb *(2.75 kg)*			
Environment	+10 to +40C operating; -25 to +85C storage; 0 to 90% humidity, non-condensing			

1.1 Ordering Information*

CS24D-00 – 0.75" *(20mm)* nominal standoff distance, 0.30" *(8mm)* sensing area

CS24D-01** – 0.75" *(20mm)* nominal standoff distance, 0.16" *(4mm)* sensing area

CS24A-02 – 1.75" *(45mm)* nominal standoff distance, 0.50" *(13mm)* sensing area

CS24A-03** – 1.75" *(45mm)* nominal standoff distance, 0.27" *(7mm)* sensing area

***Order cables individually or order **CS24D-xx Kit** to include standard cable set:

C2CB-D1-10S – Standard Serial/Input Cable 10'*(3m)* with straight connectors

C2CB-D2-10S – Standard Power/Output Cable 10'*(3m)* with straight connectors

C2CB-D1-Serial – Serial Only Cable for demo/programming, **USB-Serial** USB-to-Serial Adapter for demo/programming, and **C2CB-D2-PS-120VAC** Power Supply only for demo/programming or **CS24D-xx Demo Kit** to include with sensor.

CS24 Window – Replacement sensor window (polycarbonate)

**Special Order. Other color sensors are available with standoff distances to 5", analog outputs and other color combinations and options. Contact Delta or your local Delta color sensor distributor for more information, or visit our web page at www.colorsensors.com.

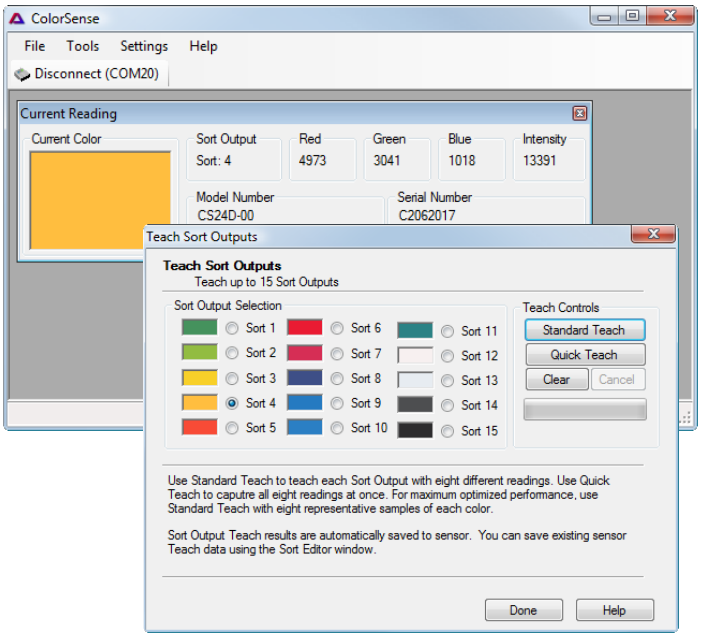
2. Introduction

The CS24D color sensor can sort up to fifteen different colors by comparing against Teach values. The CS24D is well suited for on-line color sensing applications, including:

- Distinguish between objects to ensure the correct color object is being processed on automated production lines, such as vehicle headliners, door and body panels, and seats
- Sort objects by color – into as many as fifteen categories
- Detect presence of metal coatings or wood varnish
- Detect paint marks where bar coding is impractical

The CS24D is available in several models with nominal standoff distances of 0.75 or 1.75 inches and several sensing area sizes. The large sensing area, good tolerance for sensor-to-target distance variation, and diffuse lighting of these sensors improve performance on textured materials and other challenging applications. And the CS24D's unique eight-reading Teach Mode allows more accurate teaching and sorting.

The CS24D will operate satisfactorily in many applications with the default settings, and may be optimized quickly and easily using Delta's ColorSense software (included with the CS24D color sensors). The ColorSense program, which runs on a PC and communicates to the CS24D via RS232, can be used to Teach the CS24D, optimize sorting parameters for a given set of Teach values, adjust parameters and set options.



The convenient Setup Wizard quickly guides the user through Teaching and setting parameters.

The Sort Editor screen allows the Teach data to be viewed, uploaded from or downloaded to the sensor, and saved and retrieved from a file. The Analyze screen shows the detailed performance of the sensor for the Sort data and provides for additional optimization.

Teaching the CS24D can be accomplished via discrete inputs as well as the ColorSense program.

Figure 2: Delta's ColorSense software makes Teaching and optimizing easy and intuitive

After teaching, the CS24D indicates the detected color by turning on one or more of the four discrete outputs in a binary coded sequence. If four or less colors are needed, the outputs can be used directly by teaching Sort Outputs 1, 2, 4, and 8.

The CS24D has two connectors; one containing the Teach inputs and ColorSense serial port and the other handling the outputs and power input. The connectors are environmental din-style. The standard cables for the CS24D are ten feet long with straight connectors and pigtails. Other cable options are available—see ordering information.

The discrete inputs and outputs are compatible with 12-24 Volt systems and are polarity independent for compatibility with virtually any PLC. Inputs and outputs are not individually isolated but have separate common pins and are fully isolated from the power input as well as the CS24D internal circuitry and RS232 port. The power input accepts 12-24Vdc and is isolated from other pins. (The RS232 port is not isolated from the internal circuitry and is not intended to be connected during regular use of the sensor).

The CS24D has five indicator LEDs. The blue Run LED indicates that the unit is on and flashes when in Teach mode. The four green Output LEDs indicate which outputs are on (which color is detected) during run mode and flash to indicate which output is being taught in Teach mode (actual outputs remain off when in Teach mode).

The CS24D contains high intensity LEDs in multiple wavelengths to illuminate the object to be sensed, and a precision silicon photodiode to read the diffuse reflected light from the object—no additional lighting is required for operation. The CS24D reads the average color within the sensing area. The CS24D's lighting system is much more intense than it appears because of the low duty cycle of its light emitting diodes (LEDs). The CS24D is not affected by normal room lighting, however very strong light (e.g. sunlight) should be kept out of the sensing area and light should not be allowed to shine directly into the sensor.

The high-intensity LEDs in the CS24D's lighting system have a typical life of 50,000 hours. The intensity of all LEDs varies with temperature and time due to the properties of the semiconductor materials used. The CS24D compensates for both types of variations greatly reducing the need for periodic teaching.

2.1 CS24D Features

- Handle up to fifteen colors with one sensor
- ColorSense program optimizes sorting parameters
- Superior color detection on a wide range of materials
- Versatile discrete outputs allow connection to any PLC
- Long sensing range and standoff distance
- Able to differentiate between materials such as leather, vinyl, and cloth even if they are the same color
- Robust LED lighting system—no light bulbs to burn out
- Compensation for LED temperature, aging, and ambient light

For more information on Delta's growing lines of color sensors, motion controllers, and other industrial products, visit our web site at:

www.colorsensors.com

3. Mounting

The CS24D-00 and -01 should be mounted such that the bottom is 0.75 to 0.88 inches from the average target object position (standoff distance). This will allow for sensor to object variation of ±1/8 inch. The longer standoff CS24D-02 and -03 should be mounted such that the bottom is 1.75 to 2.00 inches from the average target object position for a standoff tolerance of ±1/4. (See Specifications for standoff and range for other models).

An additional 3.50" (90mm) of clearance should be allowed above the sensor for standard cables, with optional right-angle connectors, this can be reduced to 1.75" (45mm).

The CS24D color sensors can be mounted in any position—if mounted such that the bottom window is facing up, care should be taken such that excessive amounts of dirt will not accumulate.

The CS24D is not affected by normal room lighting, however very strong light (e.g. sunlight) should be kept out of the sensing

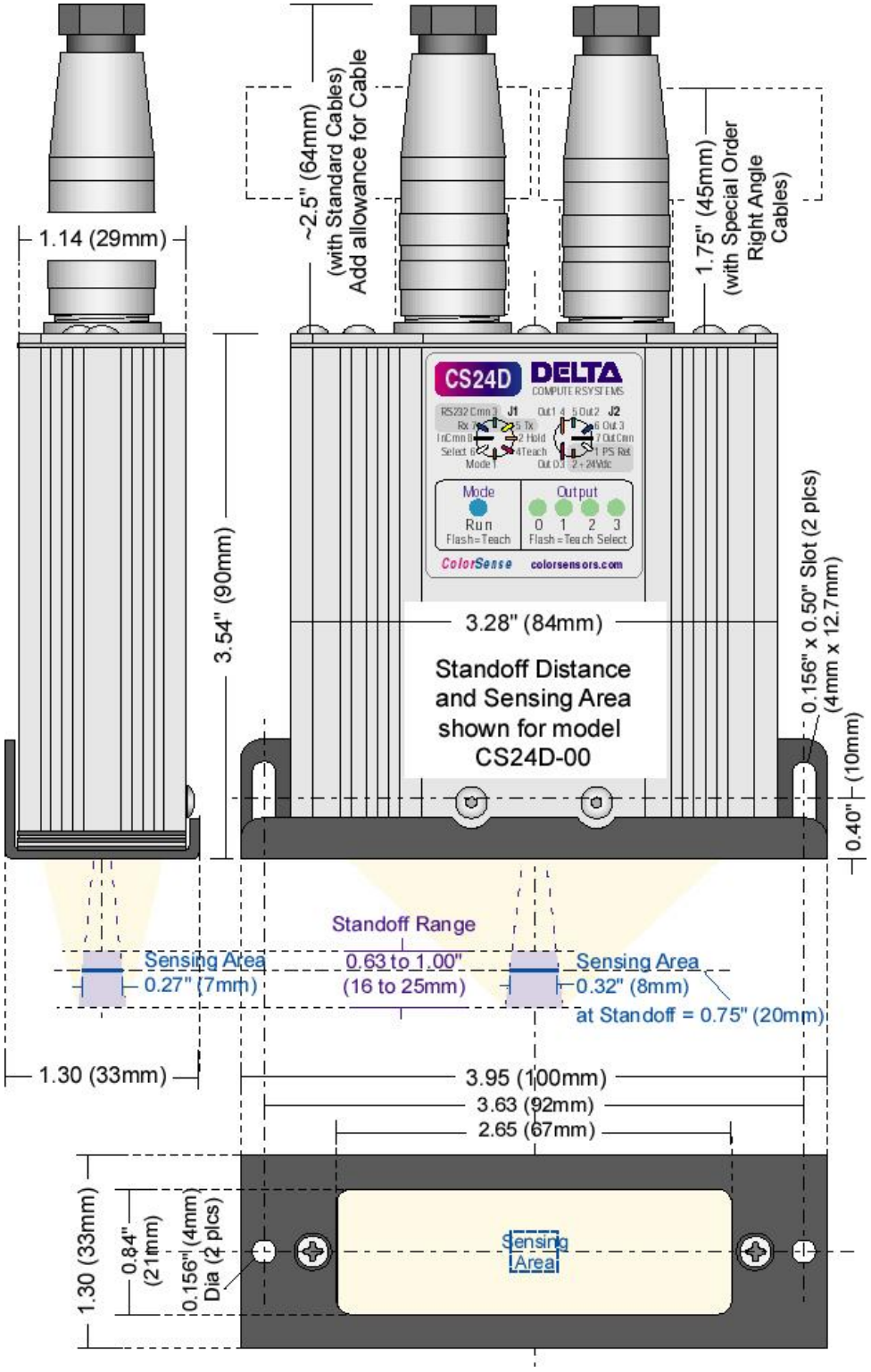


Figure 3: CS24D Mounting Information

area. The sensing area includes not only the area that is directly read by the sensor (0.27 x 0.32" for the CS24D-00), but also the immediate surrounding surfaces since light will reflect into the direct sensing area.

If it is possible that the CS24D could be bumped hard enough to cause damage, it should be mounted such that it is protected. To minimize electrical noise, the CS24D enclosure should be grounded.

4. Interface and Wiring

The CS24D discrete inputs and outputs are compatible with 12-24 Volt systems and are polarity independent for compatibility with virtually any PLC.

Four (4) discrete outputs convey the sensing results. These results are binary coded which allows for sixteen conditions—fifteen Sort Outputs plus a No Match output (all outputs off).

These solid state relay (SSR) outputs are optically isolated from all other circuitry. They are polarity independent and share a common pin, so all four outputs must be the same polarity (high side or low side switching).

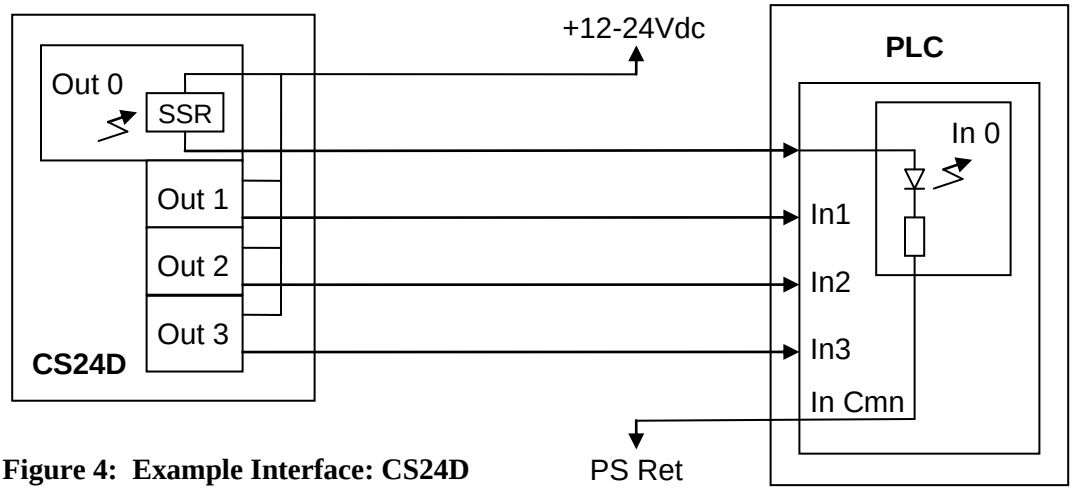


Figure 4: Example Interface: CS24D Outputs to PLC sink-type inputs

The CS24D also has four (4) discrete inputs. Three of the inputs are used to Teach the sensor (Teaching can also be done using the ColorSense program), and the fourth input is used to synchronize the output data. See Options sections for more information on synchronization.

These opto-coupler inputs are isolated from all other circuitry. They are polarity independent and share a common pin, so all four inputs must be the same polarity (sink or source inputs).

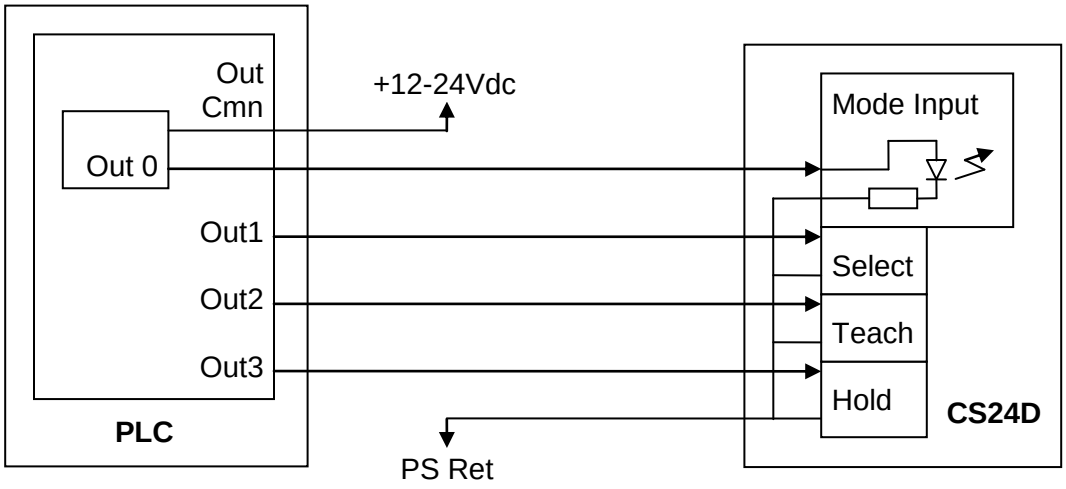


Figure 5: Example Interface: PLC sourcing-type outputs to CS24D inputs

4.1 Discrete I/O Specifications

CS24D Discrete I/O Specifications	
Inputs	Four (one group with common)
Input type	12-24VDC; sinking (sourcing drive)
Input Isolation	500VAC RMS optically isolated (see Section 4.3)
Input "High" range	(Teach and Hold) 7 to 29Vdc (polarity independent), 3mA maximum (Mode and Select) 8 to 29Vdc (polarity independent), 3mA maximum
Input "Low" range	(Teach and Hold) 0 to 3.5VDC (polarity independent), <1mA (Mode and Select) 0 to 2VDC (polarity independent), <0.1mA
Propagation delay	(Hold) 1.5ms maximum to respond to Hold (Teach, Mode and Select) 15 ms maximum (de-bounced)
Outputs	Four (one group with common)
Output type	Solid State Relay (SSR)
Output Isolation	500VAC RMS optically isolated
Rated voltage	12-24V, ±30V maximum (DC or peak AC)
Rated current	±50mA maximum continuous, ±100mA maximum peak
Propagation delay	1.5ms maximum
Logic 0 (On)	Low impedance (50 ohm, maximum)
Logic 0 (Off)	High Impedance (<1uA leakage current at 250V)

4.2 Hold Input

The **Hold** input provides a way to synchronize output data as follows. Once known good data is present, turn on the Hold input to the CS24D. The outputs will stay in their current state until the Hold input is removed. This prevents erroneous readings of the output condition. (Whenever unsynchronized binary-coded data is read, there is always a possibility that the output may change during the time the outputs are read, resulting in an incorrect reading).

If you wish to avoid using a PLC output to drive the Hold input on the CS24D, an alternate method of ensuring correct data is to read twice and make sure the readings are identical.

When both **Hold** Input and **Stretch Outputs** are used, outputs will remain ON for the longer of the Hold time or the Stretch time. (See section 7.1 for Stretch Outputs information).

4.3 Power Supply and Isolation

The CS24D requires a 12-24Vdc power source capable of supplying 50mA continuous and 500mA peak startup current. In very critical applications, use a dedicated linear power supply that does not supply other loads. A 250mA fast blow fuse must be used between the power supply and the sensor.

Inputs and outputs share a common pin but are fully isolated from the power input as well as the CS24D internal circuitry and RS232 port. The power input is isolated from other pins. The RS232 port is not isolated from the internal circuitry and is not intended to be connected during regular use of the sensor.

Internal to the CS24D, a 1.00 Mohm resistor and small capacitor are connected between circuit common and the enclosure in order to reduce noise picked up by the photodiode. For optimum noise performance in some applications, it may be necessary to directly connect the CS24D internal common to the CS24D enclosure. This can be accomplished by connecting Pin 3 of J1 (green wire) to shield.

4.4 Wiring and Cable Details

The CS24D has two connectors: one containing the Teach inputs and ColorSense serial port and the other handling the outputs and power input. The connectors are environmental din-style. The standard cables for the CS24D are ten feet long with straight connectors and pigtails. Other cable options are available—see ordering information.

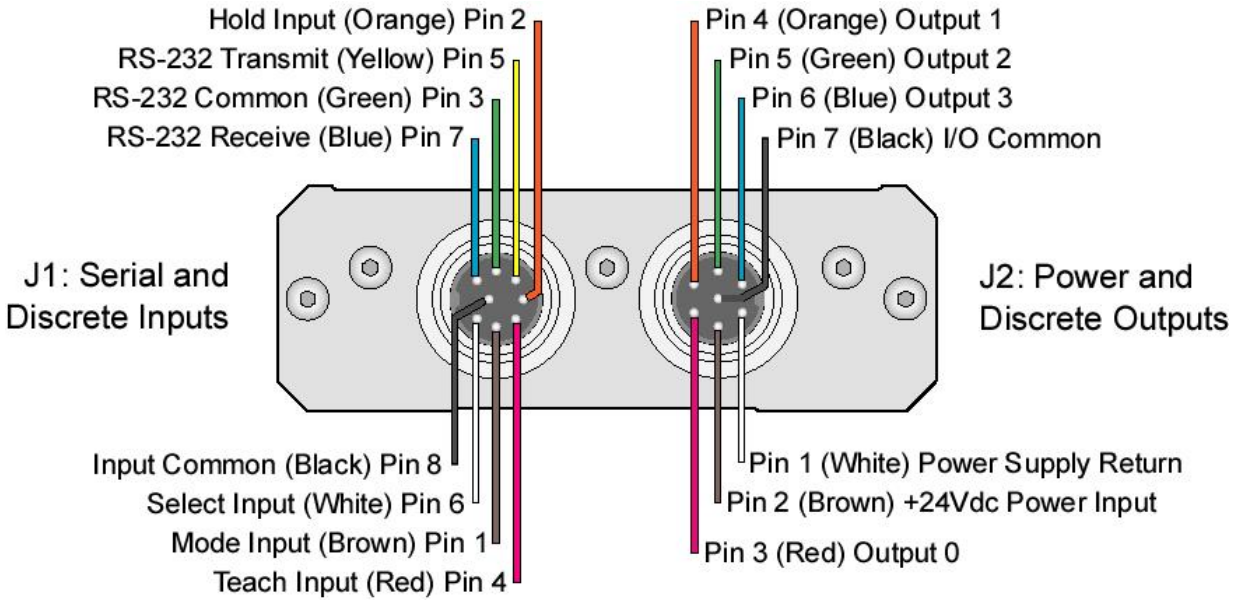


Figure 6: CS24D connector pin designations (wire colors are for standard cables).

The standard cables are pigtailed using seven and eight conductor, shielded cables. To fit the standard connectors, the outside diameter (OD) of the cables must be limited to 0.23" (6mm).

The standard cables use Beldon 9537 (seven conductor) and 9538 (eight conductor) or equivalent cable. These cables have an overall foil shield. For longer distances or noisy environments, heavier gauge wire and better shielding may be required. For high flex or other challenging environments, an appropriate special cable should be used.

The standard cables have a pigtail (no connector) on one end and a straight environmental DIN connector on the other end. These connectors require approximately 3.5" clearance. (See **Mounting** section for more information). Right angle connectors can be used to reduce this clearance requirement. Contact Delta for availability of standard and special connectors.

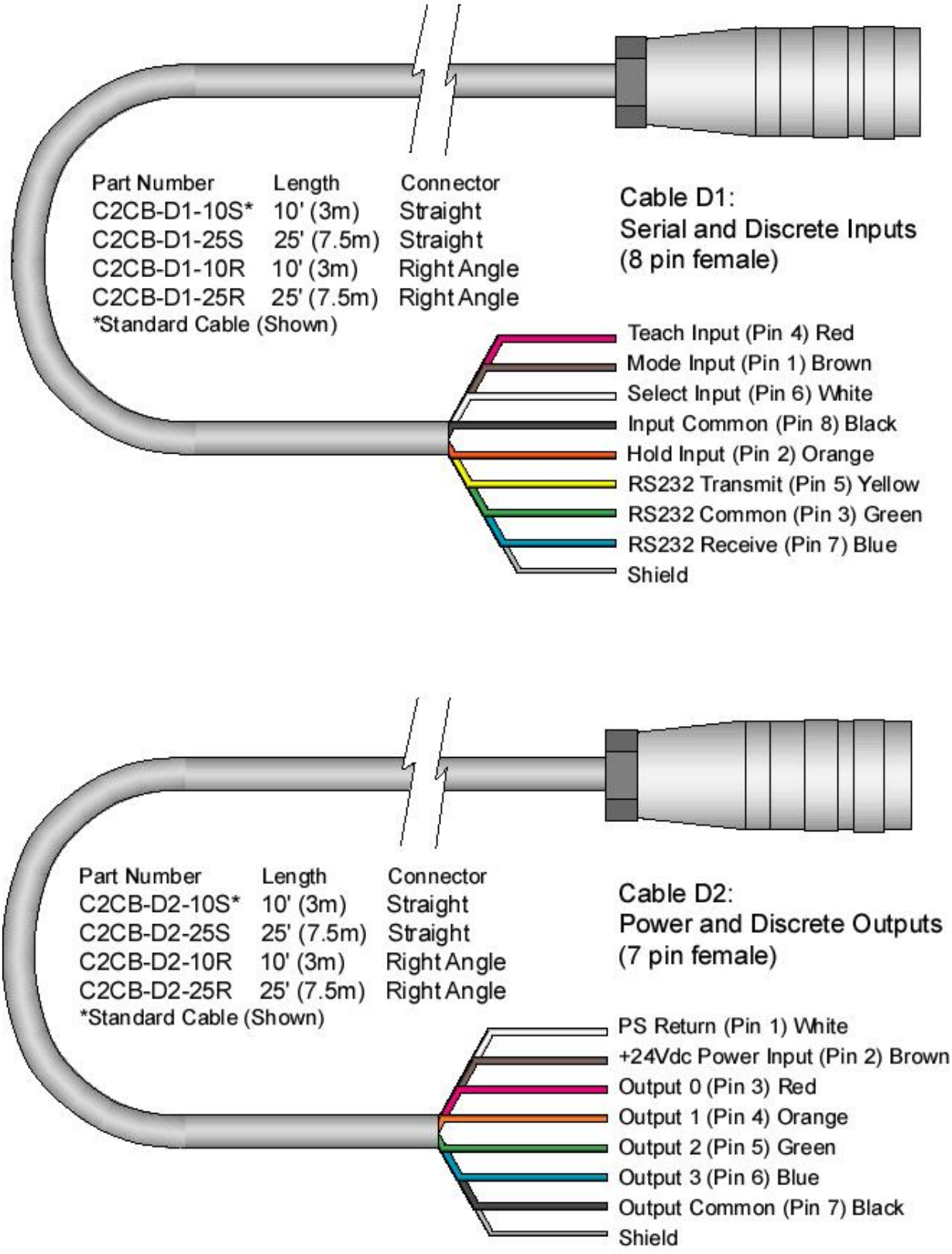


Figure 7: CS24D standard cables. (Order CS24D-xx Kit to include with sensor).

5. Teaching

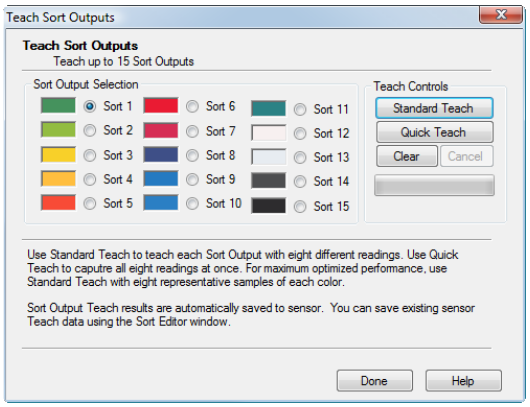
The CS24D has the unique capability of being taught with eight samples for each Sort Output (each color to be recognized). The mean and standard deviation (SD) are used to improve sorting performance.

Caution: It is very important to teach each Sort Output using eight different samples that represent the normal distribution of colors for the given Sort Output. The orientation of the objects to the sensor must be exactly as during actual operation—include normal variations. Failure to do this could reduce the performance of the CS24D to that of typical color sensors.

Teaching can be done via discrete inputs or through an RS-232 link to a PC running the ColorSense program. Generally, a means to easily Teach (and re-Teach) the sensor should be provided using PLC I/O or switches. (ColorSense should not be left connected during production use, since the CS24D serial port is not electrically isolated and serial activity slows the sensor response time).

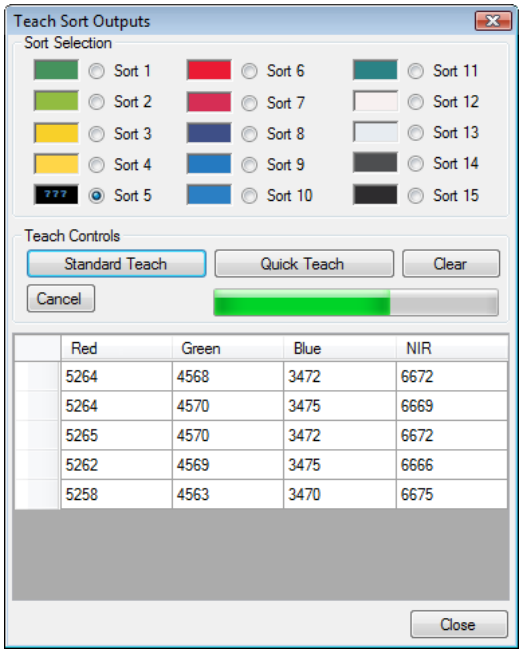
Teaching using the ColorSense program is very convenient for initial analysis and setup. It is done using the **Setup Wizard** or the **Teach** screen. (If the sensor has Sort data that you wish to save, use the **Sort Editor** screen to save it to a file before Teaching). Set up the sensor in its normal operating position and conditions, and follow one of these procedures for each sample color.

5.1 Teaching using the Setup Wizard



1. From the **Setup Wizard** second screen, select **Teach**.
2. Click on the Sort Output that you wish to Teach.
3. Place the sample in the sensing area.
4. Press the **Standard Teach** button eight times. Each click will complete one reading. After eight readings, the output will be taught.
5. For a quick demonstration, you can click the **Quick Teach** button once. All eight readings will be taken. ***See caution above***.

5.2 Teaching using the Teach Outputs screen



1. From the ColorSense program main screen, select **Teach** from the **Tools** menu.
2. Click on the Sort Output that you wish to Teach.
3. Place the sample in the sensing area.
4. Press the **Standard Teach** button eight times. Each click will complete one reading. After eight readings, the output will be taught.
5. For a quick demonstration, you can click the **Quick Teach** button once to take all eight readings. ***See caution above***.

The CS24D's LEDs show the Teach status. At the first Teach command, the blue Mode LED will go off, and the Output indicator LED(s) for that output will begin to flash. When teaching is complete, the Mode LED will come on and the Output LED(s) will stay on until the sample is removed from the

sensing area.

5.3 Teaching using Discrete Inputs

The CS24D discrete inputs can be exercised via PLC outputs or mechanical switches. They are compatible with 12-24V DC signals and are accessed via the 8-pin connector. See **Interface and Wiring** section for details.

To Teach the CS24D using discrete inputs, set up the sensor in its normal operating position and conditions, and follow this procedure for each sample color:

1. Select Teach mode by activating the Mode input. The CS24D blue Run LED will flash indicating Teach mode.
2. Select the output that you wish to use by pulsing the Select input. (One pulse selects output 1, two pulses selects output 2, etc.). The Output indicator LED(s) for that output will begin to flash.
3. Place the sample in the sensing area.
4. Complete Teach by pulsing the Teach input eight (8) times. (At the first Teach pulse, the blue Run light will go off. After 8 pulses, teaching is complete, and the Output LED(s) will stay on until sample is removed. The Run light goes back to blinking until Mode input is turned off or another Teach sequence is initiated).

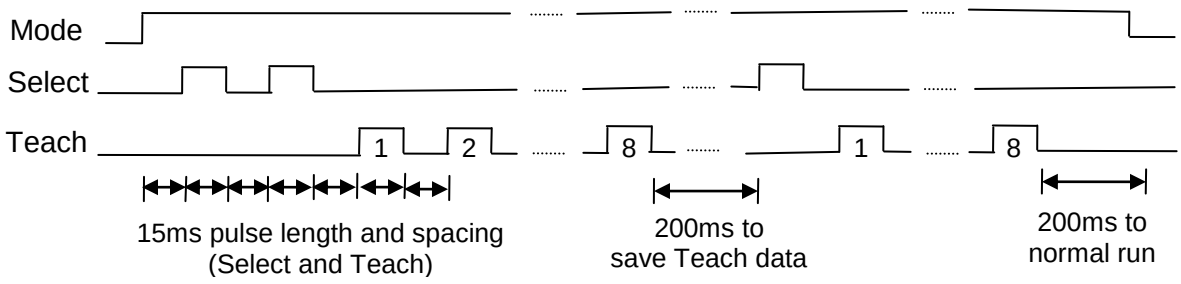


Figure 8: Teach Mode Timing

The first Teach pulse after selecting a Sort output inserts the current data into the first location in the temporary Teach memory. Subsequent Teach pulses continue to fill the memory until all 8 readings have been obtained. During this time the Select input is ignored (a different Sort output cannot be trained until the current one is complete) and deactivating the Mode input will exit Teach mode without saving the readings for the selected output. As soon as the 8th Teach pulse is received, the sensor saves the mean and standard deviations of the 8 readings to its non-volatile FLASH memory. If the Teach input is pulsed more than 8 times (without pulsing the Select input) those after the 8th time will be ignored.

The 8th Teach pulse for any output resets the select counter, so the same number of pulses is used to select a given Sort output regardless of which output was previous trained. Removing and reapplying the Mode Input also resets the select counter, so that the first pulse received via the Select input will always select Sort Output 1. Since the new data is not saved until the 8th Teach pulse, changing only the Mode and Select Inputs will not affect stored Teach data.

The eight Teach readings allow the CS24D to be taught with several samples or with several presentations to improve sorting performance. After teaching, the CS24D's parameters can be optimized for the set of Teach date using the ColorSense program. See **Optimizing** section.

5.4 General Teach Information

Once an output is taught, the mean and SD for the Sort Output are immediately stored in the color sensor (overwriting any previous data) and the individual data from the eight readings is deleted.

When the sensor is in Teach mode, the outputs are held OFF (No Match condition when in Run mode). In Teach mode, the Output LEDs show the output being taught, not the actual output state. The output LEDs use binary coding to indicate which channel is active:

Output	LED 0	LED 1	LED 2	LED 3
0 (No Match)	OFF	OFF	OFF	OFF
1	ON	OFF	OFF	OFF
2	OFF	ON	OFF	OFF
3	ON	ON	OFF	OFF
4	OFF	OFF	ON	OFF
5	ON	OFF	ON	OFF
6	OFF	ON	ON	OFF
7	ON	ON	ON	OFF
8	OFF	OFF	OFF	ON
9	ON	OFF	OFF	ON
10	OFF	ON	OFF	ON
11	ON	ON	OFF	ON
12	OFF	OFF	ON	ON
13	ON	OFF	ON	ON
14	OFF	ON	ON	ON
15	ON	ON	ON	ON

If four or less Sort output (colors) are needed, Teaching outputs 1, 2, 4, and 8 will result in a single LED and discrete output dedicated to each Sort output.

Output	LED 0	LED 1	LED 2	LED 3
0 (No Match)	OFF	OFF	OFF	OFF
1	ON	OFF	OFF	OFF
2	OFF	ON	OFF	OFF
4	OFF	OFF	ON	OFF
8	OFF	OFF	OFF	ON

For best results, Teach the CS24D at normal operating temperature and in a normal mounting position, etc. Let it warm up for at least 15 minutes.

The LEDs have a typical operating life of 50,000 hours or about 5 years of continuous operation. The intensity of LEDs varies with temperature and aging due to the properties of the semiconductor materials used. The CS24D sensors have automatic compensation that greatly reduces the effect of these variations.

Dust, dirt and scratches on the viewing window are another source of variation over time. This type of error affects Intensity (amplitude) more than Colors (ratios). Also, the colors themselves may vary from batch to batch.

Since the CS24D's automatic compensation will not eliminate 100% of the variations, it may be necessary to re-Teach periodically. The re-Teach period depends on the application. In many cases, every three to six months or more may suffice, while in very critical applications, it may be necessary to re-Teach every week or every shift.

5.5 Saving Teach Data

Using the **Sort Editor** screen in the ColorSense program, Teach data can be uploaded from the sensor, downloaded to sensor, read from a file, and saved to a file. (The Teach data can also be modified using this screen; however, this is for advanced applications and care must be taken to prevent degradation of the sensor performance).

To access this function, select the **Sort Editor** screen from the **Tools** menu. Next, press the **Upload from Sensor** icon to read the Teach data from the CS24D sensor.

To save Teach data to a file, press the **Save to File** icon. Choose a file name and directory and press **Save**.

To transfer previously saved Teach data to a CS24D sensor, press the **Read from File** icon to read the Teach data, then the **Download to Sensor** icon. Note: this will overwrite current Teach data in the CS24D. Be sure to save any data first if it will be needed again.

The ability to save and retrieve Teach data can be of great benefit if multiple sets of target colors are run on the same line. However, due to differences from sensor to sensor, ***Teach data from one CS24D should not be used with another CS24D.***

5.6 CS24D LED Operation Summary

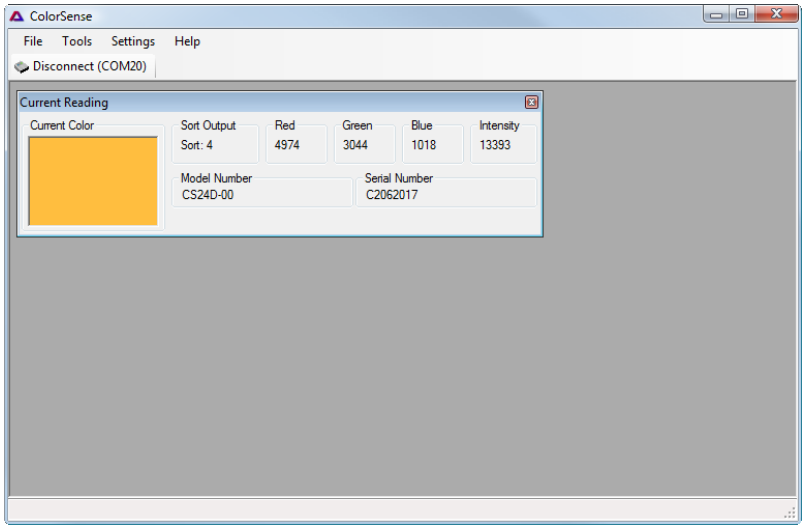
In Teach mode, the Output LEDs show the output being taught, not the actual output state. The output LEDs use binary coding to indicate which channel is active. The following chart shows the operation of the indicator LEDs on the CS24D.

Condition	RUN LED	Output LEDs
No Power	Off	Off
Run mode, No Match	Steady Blue	ALL Off
Run mode, Match	Steady Blue	Steady Green shows Match Output
Teach mode, No Output Selected	Blinking Blue	ALL Off
Teach mode, Output Selected, No Teach commands	Blinking Blue	Blinking Green shows Selected Sort Output
Teach mode, 1 - 7 Teach commands	Off	Blinking Green shows Selected Sort Output
Teach mode, 8 Teach commands	Blinking Blue	Steady Green shows Taught Sort Output

(The blink rate of the LEDs is about 2 times per second).

6. ColorSense Program Main Screen

The main ColorSense screen has a large window for all of the sub-screens and a menu bar across the top. To get started, connect between the CS24D color sensor's serial port and the PC serial port (or USB port through an adapter), and click on the **Connect (auto)** button.



The program will automatically find the correct port and establish the connection. Once connected the button will change to read **Disconnect (COMn)** and the **Current Reading** screen will appear.

The **Current Reading** screen shows the current data (for whatever is in the sensing area), the Sort Results (either "No match" or the number of the Sort Output that is active), and the Model and Serial number of the sensor.

The main menu is across the top of the screen. It is explained in detail below.

6.1 ColorSense Main Menu Summary

The four menu items across the top of the main ColorSense screen are as follows:

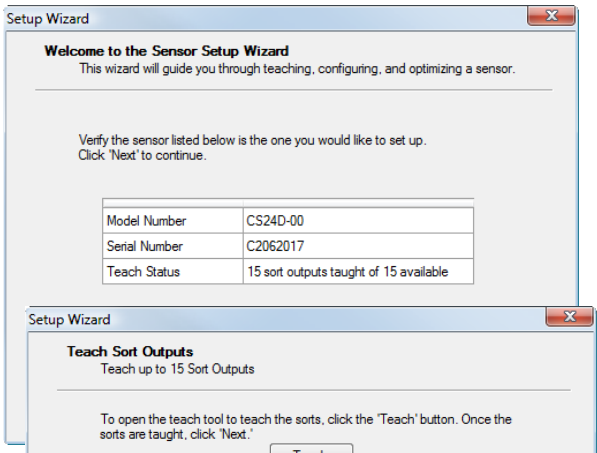
Menu	Options	Purpose	For More Information
File	Serial Port	Choose Serial Port on PC	
	Connect or Disconnect (COM*n*)	Opens or closes connection to Sensor	
	Exit	Exits ColorSense program	
Tools	Setup Wizard	Open **Setup Wizard**	See **Setting Options** section
	Teach Outputs	Open **Teach** screen	See **Teach** section
	Sort Editor	Open **Sort Editor** screen	See section 5.5 – **Saving Teach Data**
	Current Reading	Open **Current Reading** screen	(Opens by default)
	Analyze	Open **Analyze** screen	See **Optimizing** section
Settings	Sensor Options	Open **Sensor Options** screen	See **Options** section
Help	About	Provide information about the ColorSense program	(To be expanded)

7. Setting Options using the Setup Wizard

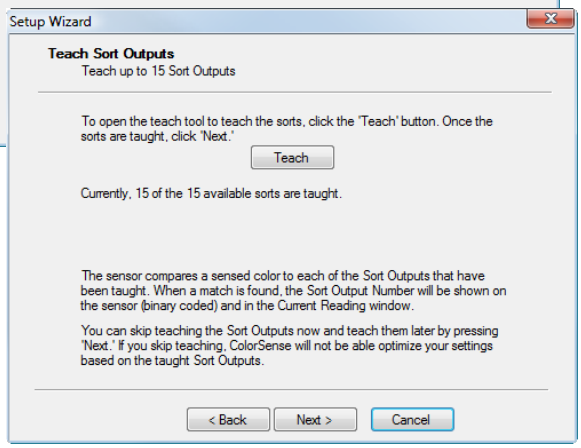
For many applications, the CS24D sensor will perform adequately using default settings. However, with the Setup Wizard in Delta's ColorSense program, it is easy to enhance performance by tailoring the parameters to the needs of your application.

From the ColorSense program, select **Setup Wizard** from the **Tools** menu.

When you start the Setup Wizard, it will open to an informational screen showing the model and serial number of the sensor and the number of Sort Outputs that have been taught.



Pressing **Next** brings up a screen asking if you are ready to Teach. (If you are not ready to Teach, you can press the **Next** button to see the remainder of the Wizard).



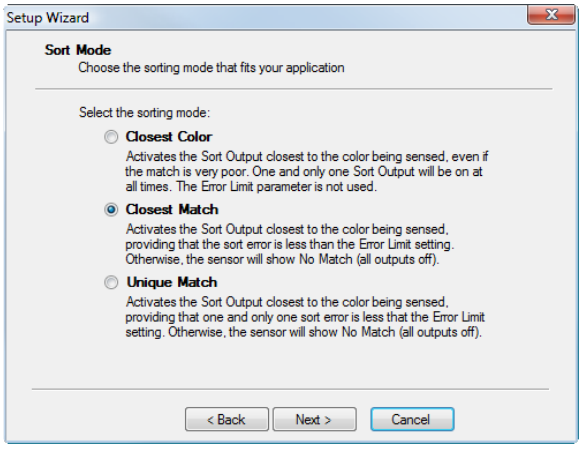
Pressing the **Teach** button will bring up the Teach screen. See section 5, **Teaching**, for complete information. Click the **Done** button when the sensor has been trained to all of the samples.

As soon as the sensor has been trained, it will immediately start recognizing colors based on the default configuration. Although the default parameters may provide acceptable performance, the next screens of the Setup Wizard cover selecting modes and parameters for better performance.

7.1 Sorting Options

The next section of the **Setup Wizard** prompts you to set up all of the Color Sensor user-settable options.

Note that changes may be freely made while sensor is operating. Pressing the Finish button on the last Setup Wizard screen will download the new parameters to the sensor. Pressing Cancel will leave previous settings in place.



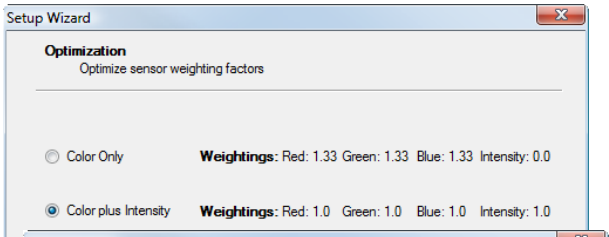
The **Sorting Mode** selection is dependent on the application. The choices are; **Closest Color**, **Closest Match**, and **Unique Match**.

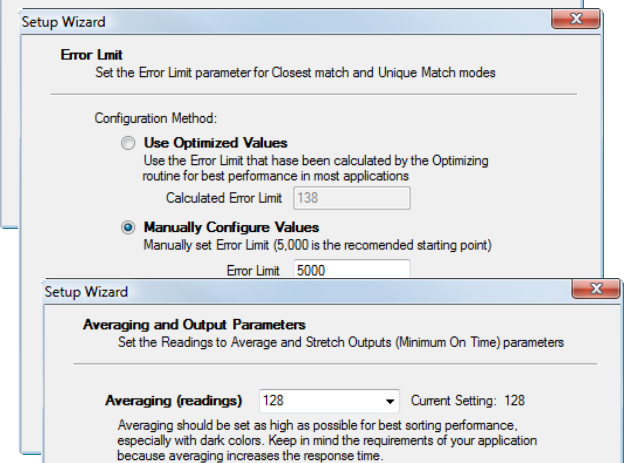
- **Closest Color** activates the Sort output that most closely matches the color that the sensor is seeing, regardless of how well the color matches. The **Error Limit** parameter is not used in this mode and the No Match condition (all outputs off) is never seen.
- **Closest Match** activates the Sort output that most closely matches the color that the sensor is seeing, *providing* that the sort error is less than the Error Limit setting. Otherwise, the sensor goes to the No Match condition (all outputs off). This is the default setting.
- **Unique Match** activates the Sort output that most closely matches the color that the sensor is seeing, providing that *one and only one* sort error is less than the Error Limit setting. Otherwise, the sensor goes to the No Match condition (all outputs off).

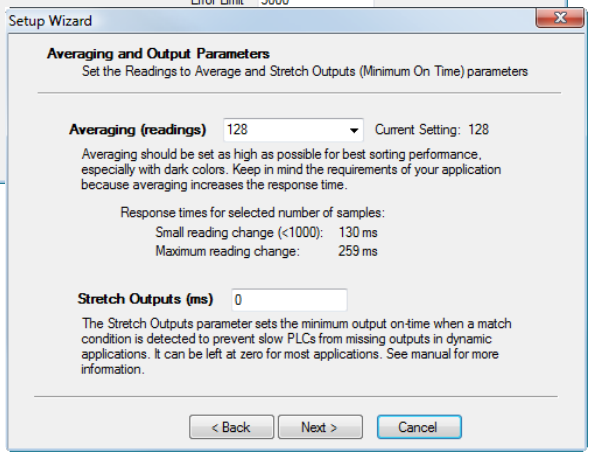
Error Limit: This parameter allows you to specify a maximum permissible error for a color to be considered a match. The default value is 5,000. See **Optimizing** for more information.

Closest Color mode can be the best mode for some sorting applications, but is rarely useful for the common color verification applications. **Closest Match** mode provides more intuitive operation for the majority of applications. **Unique Match** mode provides more flexibility in flagging colors that may be out of the normal range.

7.2 Other Parameters







Color Only is the best choice for accommodating large variations in sensor-to-target distance but it cannot be used if any of the target colors are shades of the same color (e.g. light gray and dark gray). **Color plus Intensity** handles shades of colors, and gives equal weighting to the RGB readings and the Intensity or "darkness" of the color.

The **Error Limit** parameter is also calculated for you by the optimize routine, although the default value will also probably work fine for a quick test.

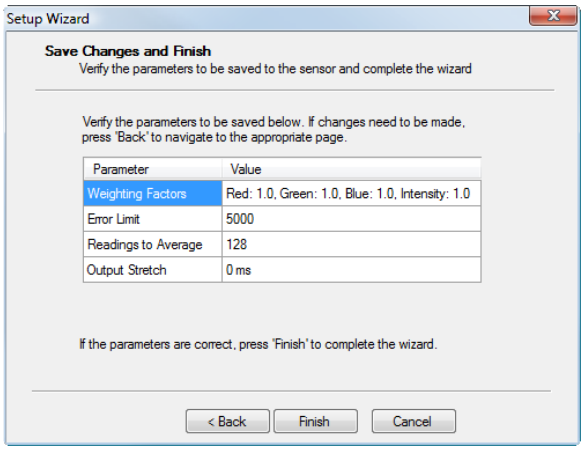
Averaging should be set high, especially with dark colors, but keep in mind how the increased response time affects your application. (See Page 25).

Stretch Outputs: This allows you to specify a minimum output on-time. This is useful in dynamic applications when interfacing the CS24D to a slow loop-time PLC. The default setting is 0 milliseconds.

When both **Hold** Input and **Stretch Outputs** are used, outputs will remain ON for the longer of the Hold time or the Stretch time. When this time expires the outputs will immediately update to the current Sort Output. If this is
No Match, the No Match will only remain until a Sort Output is found at which time the stretch output timer will began to count down. (See section 4.2 for Hold Input information). In most applications, the **Stretch Outputs** parameter can be left at zero.

7.3 Saving Parameter Changes

The last Setup Wizard screen allows you to review the parameters. Pressing the **Finish** button will download the parameters to the CS24D color sensor. Pressing Cancel will leave previous settings in place.

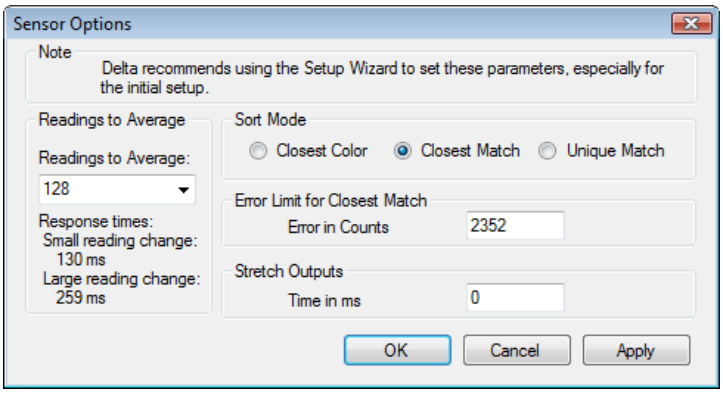


7.4 CS24D Options Summary

In addition to the Setup Wizard, options can also be viewed and changed using the **Sensor Options** screen under the **Setting**s menu.

Once parameters are set, they can be downloaded to the sensor by pressing on the **OK** or **Apply** buttons (OK also exits the screen). Pressing **Cancel** will exit with changing sensor settings.

The chart below shows the configuration parameters for the CS24D.



Configuration Parameter		Range	Default Setting
Sort Mode	Sets sorting algorithm	Closest Color, Closest Match, Unique Match	Closest Match
Error Limit	Sets error threshold limit for match	0 to 65,535	5,000
Average	Sets number of readings to be averaged by sensor (1ms/avg)	1 to 4096	64
Stretch Outputs (1)	Sets minimum output on-time when a match condition is detected	0 to 65,535 ms	0
See Optimizing Section for more information on the parameters listed below			
Optimization	Sets sorting algorithm	Color Only, Color plus Intensity, Optimized	Color plus Intensity
Weighting Factors	Sets Weighting Factors used to optimize sorting performance	(4) X 0 to 3	Red=1.0, Green=0.6, Blue=1.6, Intensity=0.8

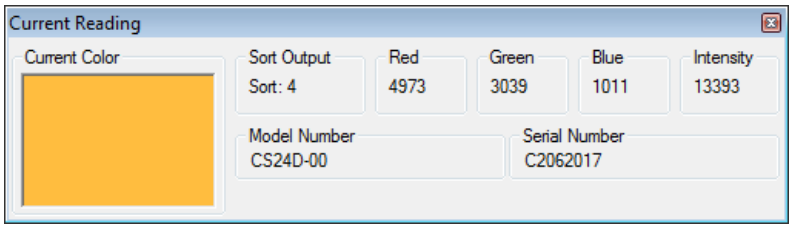
Notes:
1. When both **Hold** Input and **Stretch Output** are used, outputs will remain ON for the longer of the Hold time or the Stretch time. (See section 4.2 for Hold Input information).
2. Sensor is always in Run mode, except:
   a) when in Teach mode (Teach Mode input ON or Teach selected via ColorSense program, or
   b) when operation temporarily suspended during startup or when parameters are being downloaded and sensor is saving them to FLASH memory.

8. Optimizing Performance

The CS24D analyzes four values: red, green, blue, and intensity. The intensity value is used directly, and the blue, red, and green readings are divided by the intensity value to form ratios. The Blue, Red, and Green ratios contain the color information, while the Intensity contains the hue information. The CS24D has a unique intensity measurement that gives it a stronger and more stable signal for better performance on dark colors without the need to adjust the LED intensity.

The CS24D determines the closest match between the color currently in the sensing area and the colors previously recorded using the Teach function. It does this by comparing the differences between the sensed color and the taught color (errors) in each of the red, green, blue, and intensity values.

These squares of these errors are moderated by the standard deviation of the eight Teach samples (to help ensure that the performance is not overly affected by noisy readings) and are multiplied by the Weighting Factors (to optimize performance—more later).



The **Current Reading** screen shows the current data (for whatever is in the sensing area) and Sort Output status (1-15 or No Match). The screen also shows the Model number and Serial Number of the sensor.

The **Sort Editor** screen shows the Teach data. By clicking on the icons, you can:

- Upload Teach data from the sensor
- Download Teach data to the sensor
- Save Teach data to a file
- Read Teach data from a file.

Sort Editor

Sort	Color	Red	Green	Blue	Intensity	Red SD	Green SD	Blue SD	Intensity SD
1		1107	2351	1500	13777	23	14	23	8
2		2339	3021	1054	13827	11	6	6	4
3		3978	3329	660	14052	14	2	14	9
4		4978	3051	1021	13349	1	2	1	6
5		3975	1205	864	13999	1	7	1	12
6		3745	444	820	13600	2	4	2	10
7		3430	747	1369	13878	6	6	9	9
8		1003	1266	2161	13751	44	4	7	8
9		600	1955	3090	13642	24	15	7	8
10		691	2038	3139	13682	35	17	8	11
11		695	2093	2134	13693	31	17	20	10
12		3961	3850	3854	13909	18	9	11	11
13		3698	3779	3856	11880	4	3	3	6
14		3883	3917	3997	2644	10	13	15	50
15		3820	3680	3887	1569	10	6	15	26

Also, you can use the Arrow buttons to "move" Sort data up or down in order to change the output assigned to a taught color. The "X" button deletes the data from the selected output.

The permissible range for the displayed readings is between 0 and 16,383.
The typical range for the Intensity is from 1,000 to 15,000. The Blue, Red, and Green displayed readings are ratios with 4,096 = 1/1. The typical range for the ratios is 200 to 8,000.

8.1 Choosing a Sort Mode

The CS24D compares the current readings (from whatever is in the sensing area) to the Teach data (from previous Teaching). It determines the best match to the Sort outputs, by calculated the sum-of-errors-squared for each color for each Sort output using the current parameters. The lowest sum-of-errors-squared (Error) is the best match.

With some sorting modes, a second criterion is used to further refine the performance. A limit to the maximum Error, called the Error Limit, can be used to ensure that the colors match to within a set tolerance.

The CS24D has the following Sorting Mode choices:

- **Closest Color:** One sort output would always be turned ON as the best-fit. Does not use the Error Limit parameter or the No Match output (all outputs off). If needed, one or more "no object" conditions could be trained as sort outputs so the sensor would not try to fit a background condition into an object color output.
- **Closest Match:** The one best-fit sort output would be turned ON providing that Match Error was lower that the Error Limit parameter, otherwise the sensor would show the No Match output (all outputs off). More than one Sort output Error lower than the Error Limit parameter is permissible in this mode, and the output with the lowest error will be considered a match.
- **Unique Match:** One sort output would be turned ON providing that only that one Sort output Match Error was lower that the Error Limit parameter, otherwise the sensor would show the No Match output (all outputs off). In this mode, more than one Sort output Error lower than the Error Limit parameter would cause a No Match output.

The best choice of sort mode depends on the application. **Closest Match** is the default setting.

If Closest Match or Unique Match options are selected, the **Error Limit** parameter is used. This allows you to specify a maximum permissible error before a color is considered a No Match. The default value is 5,000 and the maximum value is 65,535. See **Analyzing Colors** below for information on how to automatically determine a starting point for this parameter for your Teach data.

8.2 Color Only or Color Plus Intensity

The choice of **Color Only** or **Color Plus Intensity** modes depends on the target colors (the colors of the objects that the CS24D will be working with). Colors such as red versus blue can be easily distinguished from the color difference from the red, blue and green ratios. However, shades of the same color (e.g. light red versus dark red) cannot be distinguished by the color information. The intensity of the received light must be used. The CS24D uses the Intensity value to handle shades of the same color.

In **Color Only** mode, differences in the Red/Intensity, Green/Intensity and Blue/Intensity ratios are used to differentiate between colors and all three are rated equally. Since the CS24D is adjusted such that the ratios track closely as the distance from the sensor to the target is varied, the ratios compensate for changes in standoff distance. Ratios also help compensate for environmental effects that reduce intensity such as dust, dirt, or scratches on the sensor window. Generally, if **Color Only** can be used to sort a given set of Teach colors, this is the preferred mode.

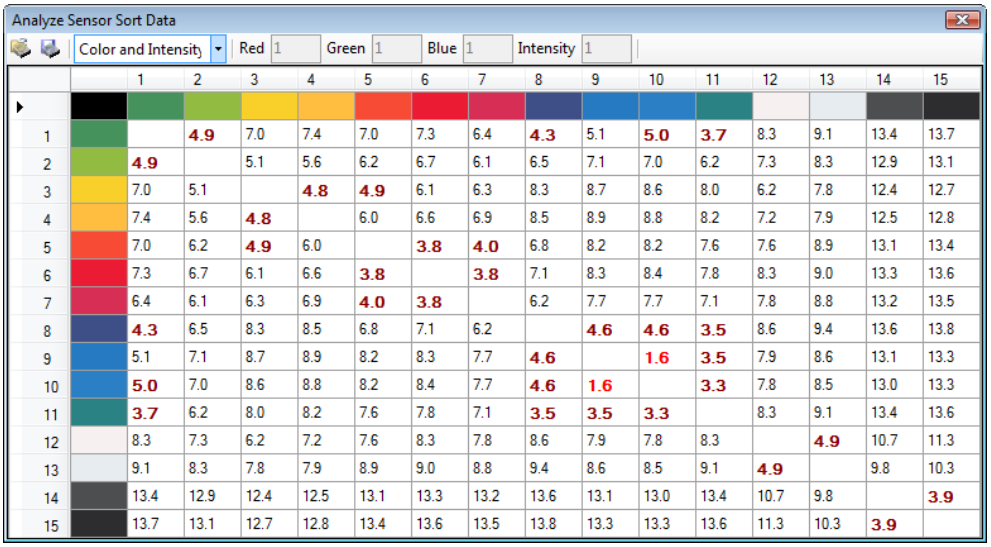
In **Color Plus Intensity** mode, differences in the Intensity values are used along with the ratios to differentiate between colors. This mode is required if any of the target colors are shades of the same color. If this mode is used, an attempt should be made to a) minimize the sensor to target distance variations, and b) prevent dust and dirt from accumulation on the sensor window.

In **Color Plus Intensity** mode, intensity is rated equally to red, green and blue. In other words, the weighting factors are all equal to one. In the **Color Only**, the red, green, and blue weighting factors are each set to 1.33 and the Intensity weighting factor is set to zero. See the next section for optimizing weighting factors.

8.3 Optimizing using the Analyze screen

The **Analyze** screen shows the predicted performance for the Teach data, which is shown as the number of standard deviations separating each Sort Output. Values less than 3 indicate that the sensor has a hard time differentiating between the target colors, and values greater than 5 indicate a high degree of confidence.
(The range of the numbers is from 0.0 to 100.0)

The pull-down box allows you to quickly compare the performance in Color Only versus Color plus Intensity modes. And by selecting **Custom** from the pull-down box, you can manually adjust the weighting factors and see the affect on performance. This unique capability allows the RGB and Intensity weightings to be optimized to the actual Teach data.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		**4.9**	7.0	7.4	7.0	7.3	6.4	**4.3**	5.1	**5.0**	**3.7**	8.3	9.1	13.4	13.7
2	**4.9**		5.1	5.6	6.2	6.7	6.1	6.5	7.1	7.0	6.2	7.3	8.3	12.9	13.1
3	7.0	5.1		**4.8**	**4.9**	6.1	6.3	8.3	8.7	8.6	8.0	6.2	7.8	12.4	12.7
4	7.4	5.6	**4.8**		6.0	6.6	6.9	8.5	8.9	8.8	8.2	7.2	7.9	12.5	12.8
5	7.0	6.2	**4.9**	6.0		**3.8**	**4.0**	6.8	8.2	8.2	7.6	7.6	8.9	13.1	13.4
6	7.3	6.7	6.1	6.6	**3.8**		**3.8**	7.1	8.3	8.4	7.8	8.3	9.0	13.3	13.6
7	6.4	6.1	6.3	6.9	**4.0**	**3.8**		6.2	7.7	7.7	7.1	7.8	8.8	13.2	13.5
8	**4.3**	6.5	8.3	8.5	6.8	7.1	6.2		**4.6**	**4.6**	**3.5**	8.6	9.4	13.6	13.8
9	5.1	7.1	8.7	8.9	8.2	8.3	7.7	**4.6**		**1.6**	**3.5**	7.9	8.6	13.1	13.3
10	**5.0**	7.0	8.6	8.8	8.2	8.4	7.7	**4.6**	**1.6**		**3.3**	7.8	8.5	13.0	13.3
11	**3.7**	6.2	8.0	8.2	7.6	7.8	7.1	**3.5**	**3.5**	**3.3**		8.3	9.1	13.4	13.6
12	8.3	7.3	6.2	7.2	7.6	8.3	7.8	8.6	7.9	7.8	8.3		**4.9**	10.7	11.3
13	9.1	8.3	7.8	7.9	8.9	9.0	8.8	9.4	8.6	8.5	9.1	**4.9**		9.8	10.3
14	13.4	12.9	12.4	12.5	13.1	13.3	13.2	13.6	13.1	13.0	13.4	10.7	9.8		**3.9**
15	13.7	13.1	12.7	12.8	13.4	13.6	13.5	13.8	13.3	13.3	13.6	11.3	10.3	**3.9**	

CAUTION: In order for the standard deviation prediction to be correct, it is essential that the Teaching be done optimally. All eight Teach readings must be taken, the eight readings must include representative samples of the range of colors that are considered permissible for that Sort Output, and the sample objects must be at the exact distance from and orientation to the sensor as they will be in actual operation. If the distance and/or orientation can vary, then the eight samples should include this variation.

The key to optimizing performance of the CS24D lies in setting Weighting Factors (WFs) to achieve the best differentiation for a given set of target colors (from previous Teach operations).

As explained above, The Intensity WF determines whether the sensor is in **Color Only** Mode (Intensity WF = 0) or **Color Plus Intensity** mode (Intensity WF greater than zero).

However, the Weighting Factors are much more powerful than that. They are used to determine how much the sensor relies on the various color values (blue, red, green, and intensity) to sort a given set of target colors. Often, performance can be enhanced by over-weighting certain values, like blue and red, and under-weighting other colors, like green and intensity.

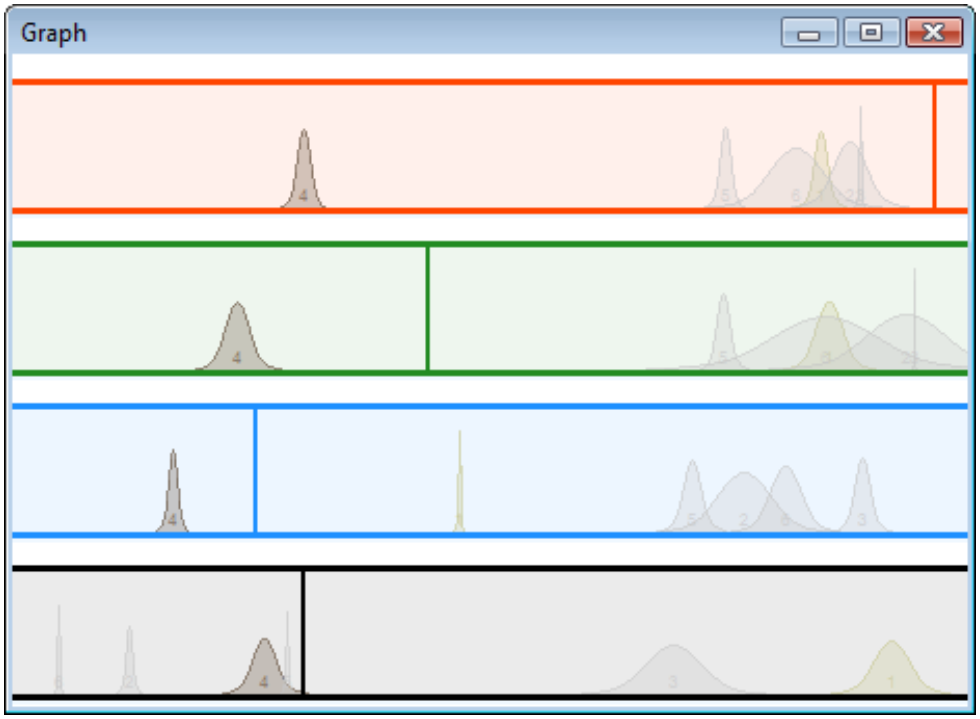
The CS24D uses four Weighting Factors, one for the Intensity, and one each for the Red/Intensity, Green/Intensity and Blue/Intensity ratios. The operation of the WFs is simple. If all four of the WFs = 1, then all four factors are weighted equally.

When adjusting WFs, the sum should always equally 4. For example, if the Intensity WF is set to zero (Color Only mode), then other three WFs should be increased to keep the sum of the WFs at four.

To use optimized Weighting Factors, press the **Save to Sensor** icon. To view the Weighting Factors currently stored in the sensor, press the **Read from Sensor** button. Changes to Sorting parameters do not change Teach data, and changing parameters does not require retraining.

8.4 Graph and Sort Error Tools

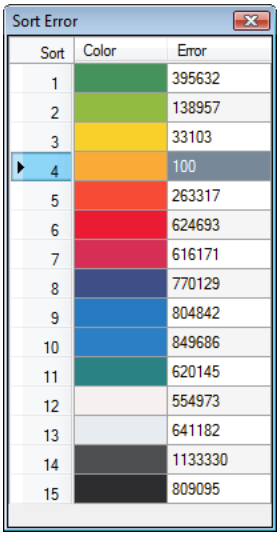
The **Graph** screen shows each color in the Teach data drawn together on a graph. This helps to visualize difficult points where taught colors overlap due to similarity or a large standard deviation.



The graph shows the sort data separated out by red, green, blue and intensity. A Sort Output taught to a color with a large standard deviation will display as a wide curve, darker colors will display to the left of the graph, and lighter colors will display on the right. The current reading for each color is displayed as vertical line.

In the example shown, Sort Output 4 is unique (no overlaps) in red, green and blue, and overlaps with just one other output (one other color) in the intensity readings. This makes the color associated with Sort Output 4 very easy to distinguish. There are no other overlaps in intensity, so the six different colors in this example can be easily separated, and will likely separate best with relatively high weighting factors for Blue and Intensity. (Note that the current reading (vertical lines) does not match with any of the taught data, indicating that the sensor was not seeing any of the taught colors at the time the screenshot was captured).

The **Sort Error** screen shows the current calculated error for each sort output. This tool can help determine how well the sample the sensor is currently reading is matched and distinguished from other colors. These numbers can also help in manually determining the error limit value.



8.5 Averaging and Response Time

Since the internal signals used by CS24D can be fairly weak (especially with dark target colors), they are subject to a variety of electrical and optical noise sources. The CS24D uses an exponential moving averaging algorithm allowing up to 4096 readings to be averaged to reduce noise. In many applications, averaging provides significant performance improvements, and we generally recommend setting the averaging as high as is practical. The limiting factor is the response time.

If a new object is suddenly placed in the CS24D sensing area, the signals will experience a step change depending on the difference in the color of the new object compared to the previous object. The time it takes for the CS24D outputs to settle to accurately represent the new color depends on four factors:

- The Averaging setting
- The magnitude of the step change in the signals (sudden change of color in the sensing area)
- The percentage of the final value needed to resolve the signal
- And, to minor extent, the number of trained channels

The chart below shows the CS24D response time for various conditions:

Averaging Setting	Change (counts)	To 10%*	Change (counts)	To 1%*	Change (counts)	To 0.25%*
None	100	2ms	1000	2ms	4000	2ms
4	100	9ms	1000	17ms	4000	22ms
8	100	18ms	1000	36ms	4000	46ms
16	100	36ms	1000	73ms	4000	92ms
32	100	72ms	1000	146ms	4000	190ms
64	100	144ms	1000	294ms	4000	382ms
128	100	296ms	1000	588ms	4000	765ms
256	100	577ms	1000	1.18sec	4000	1.53sec
512	100	1.18sec	1000	2.35sec	4000	3.06sec
1024	100	2.36sec	1000	4.71sec	4000	6.13sec
2048	100	4.71sec	1000	9.42sec	4000	12.26sec
4096	100	9.42sec	1000	18.84sec	4000	24.53sec

*Settling time with 1-4 Sort Outputs used, for 5-8 sort outputs, add 1 millisecond; for 9-15 sort outputs used, add 2 milliseconds. (Serial communications over the RS232 port can add up to 7ms to the Update and response times depending on data transfer activity. The CS24D color sensor is not intended to be operated with the RS232 Serial port in use). The CS24D reads all LED colors once per millisecond. The total response time, from when an object is placed under the sensor to the time the outputs are updated to accurately reflect the color of the object, is dominated by the Averaging parameter for settings of 4 or above. The exponential moving average can take from 1 to 6 milliseconds or more per reading averaged, depending on the difference between the readings. Thus the time to a valid output can vary from a few milliseconds to many seconds.

Note that during the time that the sensor is averaging the data from a new object, the outputs may temporarily show an incorrect value based on the average of the new color and the previous color. To prevent this, the host system should delay for a period of time at least equal to the Maximum Response time before using the CS24D outputs after a new object is placed in the sensing area.

An additional parameter that can affect response time is the Pulse Stretch parameter. This parameter causes the CS24D to make sure that any binary Output is maintained for at least the number of milliseconds specified by the Pulse Stretch parameter. For maximum response, set the Pulse Stretch parameter to 0.

9. Characteristics

9.1 Temperature

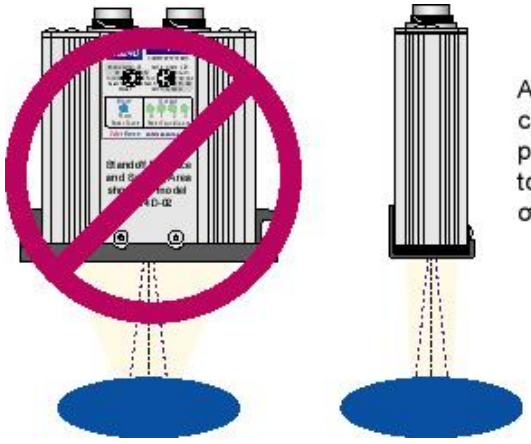
The feedback circuitry automatically compensates for the normal LED intensity variation with temperature yielding a typical stability of 0.05%/C. In the most critical applications, the CS24D should be maintained at a constant temperature since the LED color varies slightly with temperature.

9.2 Edge Effects

The CS24D series have large sensing areas. (The CS24D-02, for example, sees an area of approximately 0.5 inches square). When material is entering or leaving the sensing area, the color can appear wrong for a variety of static and dynamic conditions. For best results, read the discrete outputs only when the CS24D sees the intended material over the entire viewing area. The Hold input can be used to "capture" the data.

9.3 Convex and Concave Surfaces

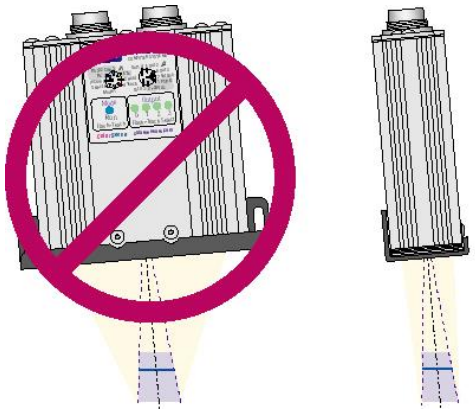
Glossy convex surfaces can reflect directly into the sensor, reducing the stability of readings. To avoid this, try to keep convex surfaces perpendicular to the narrow axis of the sensor. Concave surfaces should be avoided if possible.



Avoid shiny, convex surfaces perpendicular to the long axis of the CS24D.

9.4 Angle of CS24D to Material

Generally, the most consistent readings are obtained if the material is perpendicular to the CS24D in both planes. If angle differences cannot be avoided, it is preferable to have the angle the narrow way and the standoff at the longer end of the recommended range (2 inches for the CS24D-02). In some cases when dealing with shiny materials, angling the sensor (along the narrow axis) slightly with respect to the target may produce more consistent readings.



If the CS24D must be angled with respect to the target surface, angle along the narrow axis.

9.5 Distance Performance

The amplitudes of the readings reach the maximum value at the nominal standoff distance or slightly closer (about 1.5" for CS24D-02 and CS24D-03) and then decrease with distance. The ratios of Red/Intensity, Green/Intensity and Blue/Intensity are adjusted to be constant within the specified tolerance over the specified working range of the sensor. As the sample is moved further from the CS24D, the ratios will gradually become less consistent. This effect, along with the decrease in signal amplitude, limits the usable range of the CS24D. In applications where the differences in samples are large, the CS24D-02 and -03 may work well out to 3" or more.

9.6 General Information

The term "color" actually implies visible light--wavelengths from about 400nm (violet) to about 750nm (deep red), although in this document any wavelength that can be seen by the CS24D is referred to as a color.

With high intensity blue LEDs (450nm) and several visible wavelengths up to 700nm available, Delta's sensors can be made to see practically the entire visible color spectrum. But the capability does not stop there; the precision photodiode in the sensors can see into the near infrared up to about 1,000nm, and LEDs are readily available in this region as well.

The near-infrared (NIR) spectrum can be valuable in special applications. For example, the ratio of two different NIR colors can be used to detect certain types of glue, while ignoring visible color variations. Contact Delta for more information on these applications.

10. Maintenance

Cleaning: Under normal conditions, the CS24D requires little or no maintenance other than keeping the window and sensing area clean. Use only water and cleaning materials compatible with polycarbonate, such as isopropyl alcohol.

In dusty conditions, an automated air nozzle can be used to help keep the window clean.

The ratio calculations will compensate for signal strength degradation down to about 75% of normal signal. Beyond that, performance will start to suffer. Once the window and viewing area are cleaned, the ratio calculations will automatically readjust to the clean conditions.

Of course, if the signal amplitude is used directly (Intensity Weighting Factor greater than 0), then dust on the window (or any other condition causing a reduction in signal strength) will directly affect performance. The severity of this effect depends on the application.

If the window becomes scratched or damaged, it should be replaced. Order from Delta: Part No: CS24-Window.

11. Frequently Asked Questions

Q. How many different target colors can the CS24D sort?

A. The CS24D can be programmed to differentiate up to fifteen (15) colors simultaneously. Its four discrete outputs are binary-coded to indicate no match (all off) or 1 to 15 outputs.

Q. What if my materials are textured?

A. The CS24D successfully handles a variety of textured, grained, and other difficult surfaces where other color sensors give inconsistent readings.

Q. Can the CS24D work with patterned materials?

A. The CS24D-02 reads the average color within its sensing area of approximately 12 x 14mm (0.47 x 0.54”). If the pattern is much smaller than this area, the CS24D-02 may sort consistently. The CS24D series will not “recognize” patterns.

Q. Can the CS24D distinguish between hues of the same color (e.g. light red and dark red)?

A. Yes, in most cases. If the colors are exactly the same hue, then all of the ratios (Red/ Intensity, Blue/ Intensity, and Green/ Intensity) will be the same, however the amplitude of the signals will vary. The CS24D uses a special Intensity value to differentiate between lighter and darker versions of the same colors that makes it less susceptible to electrical and optical noise. (The Weighting Factors are used to optimize for various colors—see **Optimizing** section). Slight hue differences produce small differences in amplitudes and require consistent sensor-to-target distance and a reasonably clean environment.

Q. Is it true that the CS24D can distinguish between different materials of the same color?

A. It depends on the materials. For example, with carpet, vinyl and leather, the CS24D can separate all three colors in each material type, and also all of the material types from each other for a total of nine unique Sort outputs.

Q. What if I can’t position the sensor close to the sample?

A. The CS24A-02 handles a sensor-to-object range of 35-60mm (1.50-2.25”) standoff distance as compared to the 16-25mm (0.63-1.0”) of the CS24D-00. Delta makes other sensors with standoff distances as long as 5”.

Q. How can I verify that the CS24D will work with my samples?

A. Delta will test your samples for you and send a report showing the performance of the CS24D on your samples and recommendations for your application. There is no charge for this testing on new applications. Demonstration units are also available to qualified customers. Delta’s ColorSense software provides a utility for optimizing to your target colors and will indicate the performance as a standard deviation.

Q. What outputs are available from the CS24D?

A. The CS24D has four discrete outputs compatible with 12-24 volt discrete inputs.

Q. Does the CS24D require special lighting?

A. No additional lighting is required. The CS24D is completely self-contained with its own lighting system using high intensity light-emitting diodes (LEDs). No external light

is needed and for maximum consistency, bright ambient light (such as sunlight) should be blocked from the sensing area.

Q. What are the power requirements for the CS24D?

A. The CS24D is rated for 12-24Vdc ±20% and 50mA maximum. Typical current draw is about 30mA. The power supply must be able to provide a startup surge current of about 250mA. Although the power supply is not critical, for best noise performance a dedicated, linear supply is recommended. The power input is fully isolated.

Q. Does the CS24D require any other inputs?

A. No, except for setup and Teaching. The CS24D "free-runs" and outputs are updated periodically. An optional Hold input "freezes" the outputs allowing a simple method of ensuring data consistency. Alternately, data consistency can be ensured by taking multiple readings.

Q. Can I use the CS24D in a wash down environment?

A. The standard enclosure for the CS24D is dust-tight. Contact Delta for availability on a special sealing package for operation in wet environments.

Q. Does the CS24D have a color sensitivity specification (e.g. delta E (with CIELAB or CIEXYZ coordinates) that is common with spectrophotometers)?

A. Since on-line applications vary so widely, this specification would be of limited value. Instead, Delta will test your samples for you and send a report showing the performance of the CS24D on your samples and recommendations for your application. (No charge on new applications). Demo units are also available to qualified customers. Delta's ColorSense software shows the performance as worst case standard deviation for your target colors.

Q. How sensitive is the CS24D to changes in angle of the object?

A. The sensitivity to angles varies from very insensitive on matte surfaces to quite sensitive on gloss surfaces. This effect can be minimized with proper orientation of the sensor to the object. If possible, the varying angle should be oriented with the small dimension of the CS24D. See Section 9.4.

Q. How about curved surfaces?

A. Again, this is more critical on glossy surfaces and, if possible, the curve should be oriented with the narrow axis (small dimension) of the CS24D. Concave, glossy surfaces should be avoided if possible as they can cause direct reflections. See Section 9.3.

Q. I would like to have the sensor "look" through a slot. What materials/paints would be good to look through?

A. Ideally, the inside surface of the slot should be optically flat black. In most cases, this can be easily achieved by painting with a high quality, flat black paint such as Krylon 1602 Ultra-flat black. Some materials and finishes may provide acceptable performance without painting. They may not be obvious, however black anodized aluminum reflects in the near-infrared spectrum, for example, and should not be used without painting.

Q. What is the minimum size that I can make the slot that the CS24D looks through?

A. If space is tight, you can reduce the slot to about 5/8 x 2 inches providing the sensor is centered well. A better solution might be to angle the sides of the hole so the dimension

closest to the sensor is 3/4 by 2 1/2 inches and tapers down to about 1/2 x 1 inches. (Figures 1 and 3 show the critical sensing and light areas).

Q. Can I use the CS24D pointing up?

A. The CS24D can be mounted in any orientation. With the sensor pointing up, it is important to watch dust build-up on the sensing window. Also sunlight should not be allowed to enter directly into the sensor window.

Q. How often should the CS24D be re-taught?

A. As with all similar sensors, re-teaching is required periodically. The CS24D has compensation to greatly reduce the time and temperature drift inherent with the LEDs. The required frequency of Teaching depends on the required precision, and could be as often as once a week, or as infrequent as once a quarter or more.

Q. What are the limitations to the detection of colors?

A. The measurement consistency varies from application to application. Here is a list of some of the error sources associated with any color sensor, including the CS24D.

Sample color variations: Often colors vary from sample to sample. Dark objects tend to display the largest amount of variations. If possible, check multiple samples over time to verify consistency before setting up the thresholds. The ability to Teach the CS24D with eight readings per output can greatly improve performance with sample variations.

Presentation variations: The largest variation in multiple readings of the same object is typically differences in the orientation of the object to the sensor. Not only does the distance from the object to the sensor affect the readings, but so does the angle of the object. The least sensitive objects are those with a matte or other non-glossy finish and with a flat to slightly convex surface. The most difficult objects have a gloss finish and a concave surface. The CS24D handles these types of variation better than most color sensors, in fact spectrophotometers often require contact measurements which eliminate distance variations but also make them unsuitable for most on-line applications. Small sensor-to-object variations (~1/8") typically can be handled. The ability to Teach the CS24D with eight readings per output can significantly help performance with presentation variations.

Environment: Dust collecting on the CS24D's window reduces signal strength. Use of ratios eliminates errors from uniformly distributed dust, but eventually the loss of signal strength will impact performance.

Noise: Electrical and optical noise is typically the next largest variation from reading-to-reading of the same object. Noise is greater for green and blue since the green and blue LEDs are less intense, and less for the Intensity and red values. Optical noise is primarily caused by changing ambient light conditions. Extraneous light in the sensing area is an error signal and should be eliminated as much as possible. Moderate levels of ambient light may be tolerable, while sunlight is almost never tolerable. If response time requirements allow it, most noise can be effectively eliminated in many applications simply by increasing the averaging (using Delta's ColorSense setup program) to as high as the allowed by the application's response time requirements.

Temperature: The intensity of all LEDs diminished as temperature is increased. This effect is compensated for in the CS24D. The LED color also drifts slightly with temperature, but this is insignificant in most applications.

Time: There is a certain amount of reading variation over time, typically a few tenths of a percent per week or less. This effect is compensated for in the CS24D.

12. Troubleshooting

The CS24D's indicator LEDs provide helpful troubleshooting information. The output LEDs use binary coding to indicate which channel is active. (In Teach mode, the Output LEDs show the output being taught, not the actual output state). The chart below shows the operation of the indicator LEDs on the CS24D:

Condition	RUN LED	Output LEDs
No Power	Off	Off
Run mode, No Match	Steady Blue	ALL Off
Run mode, Match	Steady Blue	Steady Green shows Match Output
Teach mode, No Output Selected	Blinking Blue	ALL Off
Teach mode, Output Selected, No Teach commands	Blinking Blue	Blinking Green shows Selected Sort Output
Teach mode, 1 - 7 Teach commands	Off	Blinking Green shows Selected Sort Output
Teach mode, 8 Teach commands	Blinking Blue	Steady Green shows Taught Sort Output

(The blink rate of the LEDs is about 2 times per second).

If the CS24D is not operating correctly, check for:

1. Dirt buildup on the window
2. Incorrect sensor to target distance
3. Problems with power supply or wiring

Use ColorSense to view data and see how close the match is. If the CS24D seems to be operating correctly and is still misreading target colors, the sensor may need to be retrained. (See **Teaching** section).

13. Support

Delta offers extensive telephone support on all of its products, both before and after purchase. To have samples tested, send them to:

Delta Computer Systems, Inc.
1818 SE 17th Street
Battle Ground, WA 98604

Attn: Color Sample Testing

(360) 254-8688
FAX (360) 254-5435

On new applications, this testing is typically done at no charge. If required, training and field support can be provided on a time and expense basis.

14. Repairs

If a CS24D needs repair, call Delta to receive an RMA number before returning unit. Including a brief description of the problem will help to speed the repair time.

15. Warranty

Hardware products will conform to Delta's material specifications and be free of defects in material and workmanship under normal and proper use for a period of one (1) year from date of shipment to Customer by Delta or its authorized distributor. Repaired or replacement products are similarly warranted for six (6) months or the remainder of the original warranty term, whichever is longer.

Non-warranty repaired or replacement products (which may be new or reconditioned) are warranted to be free of defects in materials and workmanship for six (6) months from date of shipment from Delta.

Standard firmware and software will perform in accordance with Delta's published specifications when used with Delta-specified hardware for a period of one (1) year from date of shipment to Customer by Delta or its authorized distributor. Delta makes no representation or warranty, express or implied, that the operation of the firmware or software will be uninterrupted or error-free, or will meet or satisfy the Customer's intended use or requirements. Corrections are warranted for a period of six (6) months or the remainder of the original warranty term, whichever is longer.

Delta's sole liability under this warranty shall be, at Delta's discretion, to repair or replace product found defective or to issue Customer credit for the purchase price of defective product. Customer may obtain service under this warranty if: a) within the warranty period Customer notifies Delta of the defective product and obtains a Return Material Authorization (RMA) from Delta; b) Customer returns product to Delta, postage prepaid, in compliance with the RMA instructions, and c) Delta, upon inspection, confirms the existence of the defect, and determines that the product has not been subject to misuse, neglect, accident, or improper installation, operation, or application, or has been repaired or altered by others. Any warrantee service (consisting of time, travel and expenses relating to such services) performed other than at Delta, will be at Customer's expense.

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