Isolight Color Light Meter

User Manual

Rev 1.3

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1 Introduction

Congratulations on your purchase of the Isolight Color light meter system. Your Isolight Color light meter is designed to be the ideal companion for all kinds of image quality testing, analysis and demonstrations. The Isolight Color features four color sensors, light level status LED indicator rings, a 100 LED chaser display, audio output, a 4x40 LCD display, and may other useful features.

1.1 Features

The system includes the following features:

- Four color sensors simultaneously measure incident illumination and color at each corner
  - Color sensors closely match the CIE XYZ curves for accurate color and luminance readings under most light sources. Color can be reported on the build-in display as:
    - Correlated color temperature (CCT) in Kelvin
    - Yxy format, with Y in lux and x and y in normalized CIEXYZ coordinates
    - Color can also be reported over the USB port in Yuv format, with Y in lux and u and v in CIELUV coordinates
- All color sensors are cosine-corrected
- Sensors are auto-ranging from 1 lux to 1Mlux. No manual range setting is required
- User selectable reading update rates from 0.25 s to 2 s let the user balance responsiveness with display stability
- LED indicators around each light sensor show when the light levels are too low, too high, or within the user-programmable range
- A 100 LED chaser display enables time-related measurements such as integration time, frame rate, and frame rate jitter, and integration time gaps
  - Every 5th, 10th, or 33rd LED can be made brighter as a visual mark to make counting easier
- Audio output synchronized to the LED chaser allows audio/video synchronization measurement
- A large backlit 4x40 character LCD display shows measurements and system state in a range of easy to read, user-selectable numerical and graphic formats
- Four programmable preset buttons make saving and recalling setting quick and easy
- A USB port enables remote operation for automated control and data acquisition
- Two retractable chart-holder clips and a lipped shelf securely keep standard-sized test charts in position
  - Chart holder clips retract flush into the body surface to prevent interference with large charts
- Multiple mounting options
  - two ¼”-20 tripod mounting threads, one on the bottom, and one on the back
  - folding legs for table-top use
  - integral magnets (optional) for mounting to magnetic surfaces, such as light booth walls or white boards
  - Keyhole slots for mounting on walls
- The case is 18% gray with a matte finish to avoid disturbing auto exposure and auto white balance algorithms
- All displays (LCD, keypad backlight, LED indicators, and LED chaser) feature manual brightness level settings including an “auto” brightness mode
- Flexible power – standard USB, DC adapter, or 6 AAA batteries
- Dimensions: 13.6in x 11.6in x 0.8in (345mm x 295mm x 21mm)

2 System Description

2.1 Front

Figure 1 shows the front view of the device.

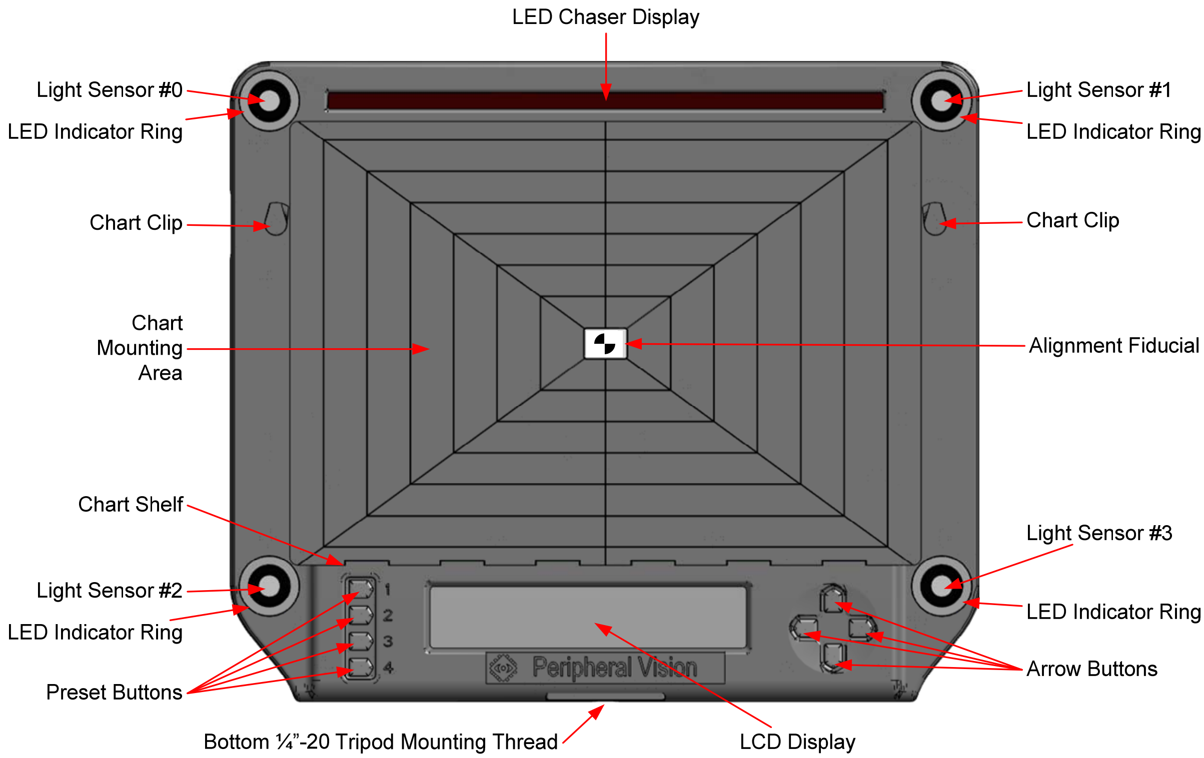


Figure 1. Front view

2.2 Rear View

Figure 2 shows the device rear view.

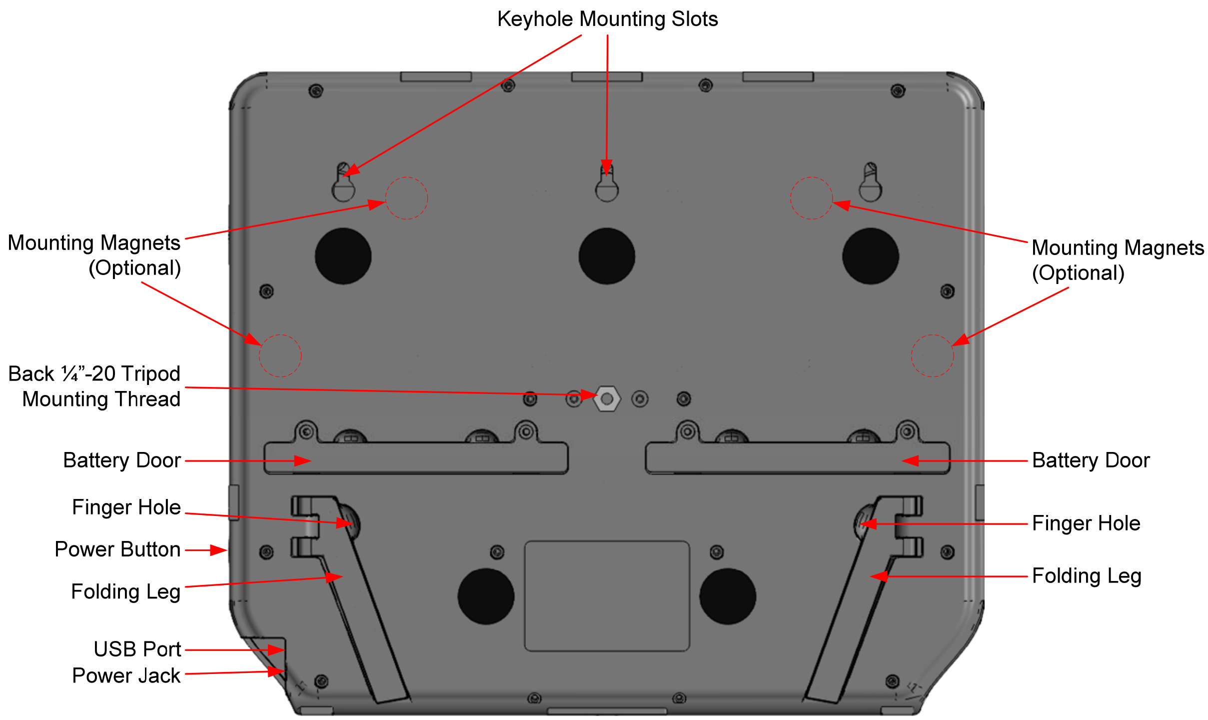


Figure 2. Rear view

2.3 Side View

Figure 3 shows the device right side.

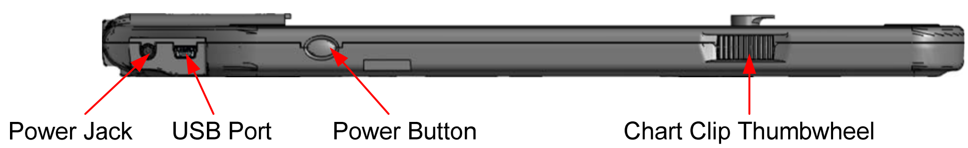


Figure 3. Right side view

3 Setting Up

3.1 Powering the Meter

The Isolight Color light meter can be powered either by 6 AAA batteries, the supplied DC power adapter, or from USB power. An internal circuit automatically selects the best power source from those available to minimize battery use (either the internal batteries or the battery of a notebook computer powering over USB). The power source priority order is:

1. DC power adapter (preferred supply)
2. USB power
3. Battery power (lowest priority)

The system will automatically switch between power sources without interrupting operation.

3.1.1 Battery Installation

The light meter uses six AAA (LR03, UM4) 1.5V batteries. To install the batteries, first turn off the light meter. Remove the two screws on each battery door with a Philips #0 screwdriver. Insert the batteries with polarities as shown in Figure 4.

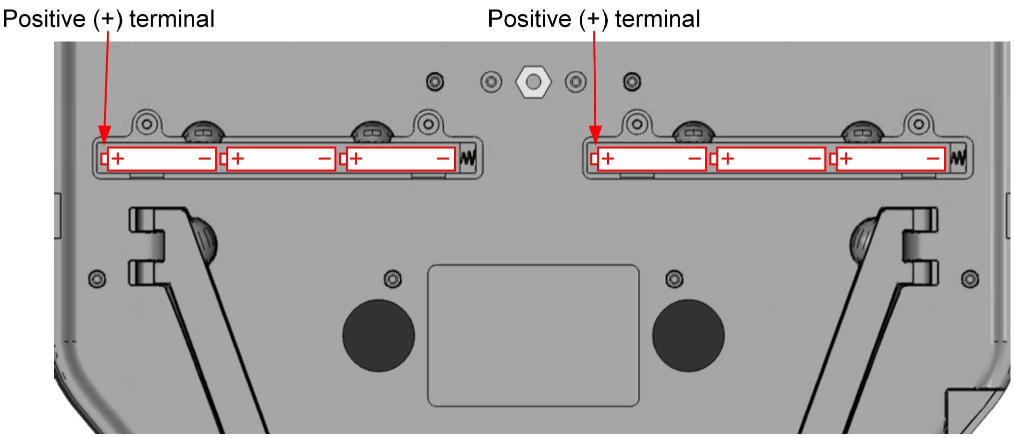


Figure 4. Correct battery orientation

For maximum battery life and safety please observe the following cautions:

- Always use new batteries
- Never mix different battery types (NiCd, NiHM, alkaline, etc.)
- Never mix batteries from different manufacturers
- Never mix new and old batteries
- Remove batteries of the unit will not be used for an extended period

3.1.2 Using the Power Adapter

To use DC power, plug the supplied wall adapter into the power jack. The power adapter is compatible with 90VAC to 240VAC, 50Hz to 60Hz power mains.

3.1.3 USB power

The device may be successfully powered from some USB ports, depending on the power level the port can provide.

3.1.4 Turning Power On and Off

To turn on power, briefly press the power button. The light meter will boot, briefly display an power-on information screen, and then enter the default data display mode (see section 4.1 for more information on display modes). To turn off the meter, press the power button again.

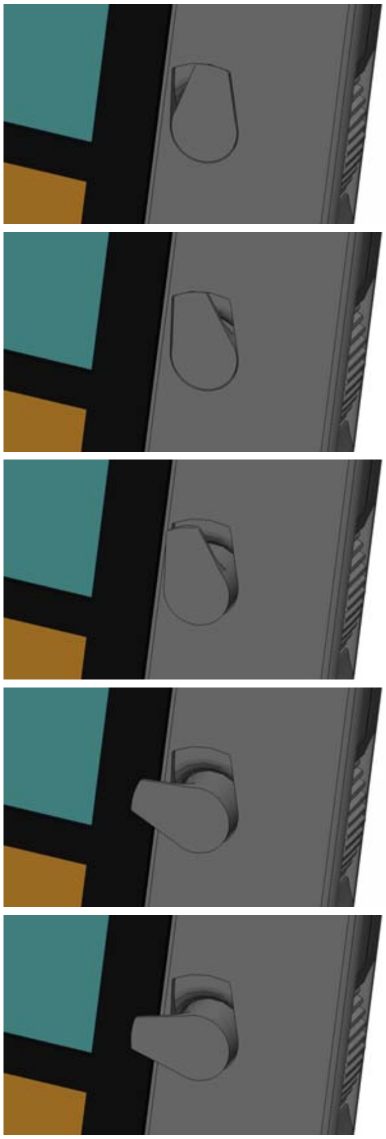
The light meter can be set to power off automatically after a period of inactivity. See section 8.2 for more information on the auto-power off feature and settings.

3.2 Installing Charts

The Isolight Color light meter is designed for use with both standard-sized test charts, as well as larger and smaller charts. To keep test charts securely mounted and flat, the light meter features a small shelf with a raised lip as well as two retractable, thumb-operated chart clips. All charts will rest and be held in place on the shelf. If using a standard-sized chart, the chart clips provide additional support and maintain chart flatness.

3.2.1 Using the Chart Clips

Two chart clips securely mount test charts in the chart area. The clips have five positions. The clip will rest in four of the five positions. In the fifth position (clip in but unlocked), a spring forces the clip out of the light meter surface. Figure 5 shows the five chart positions.



a) Clip in and locked

b) Clip in but unlocked.
Note: an internal spring forces the clip to pop out to position I

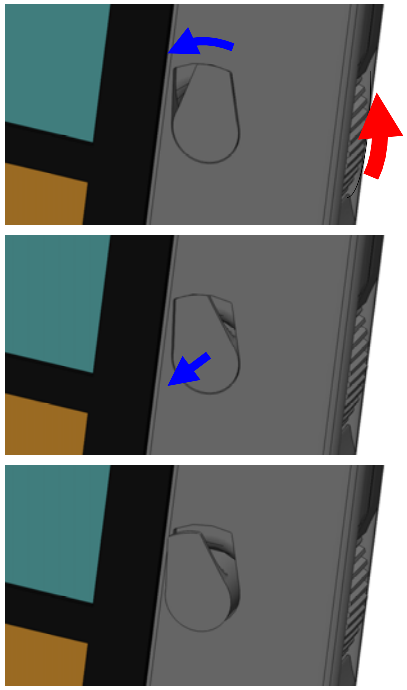
c) Clip out and up

d) Clip out and down, but unlocked

e) Clip down and locked

Figure 5. Chart clip positions

When the chart clips are retracted into the light meter surface, follow the sequence in Figure 6 to extend them. Note that in step (1) a locking detent may require that a little extra force be applied to unlock the chart clip.



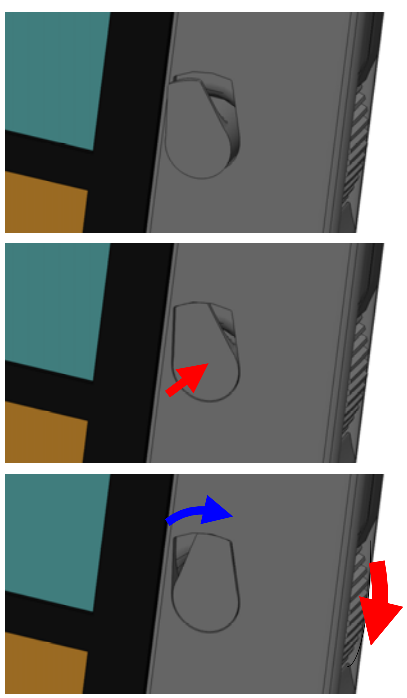
1) Rotate thumb wheel counterclockwise. The chart clip is locked in this position by a detent, so firm pressure may be required to unlock it

2) An internal spring will force the chart clip to pop out

3) The chart clip is out and pointing up

Figure 6. Extending the chart clip. Red arrows denote user actions. Blue arrows denote spring-driven movements.

To retract the chart clip back into the light meter surface, follow the sequence in Figure 7. Remember to press and hold the chart clip down in step (2). Step (3) may require extra force to lock the chart clip into position.

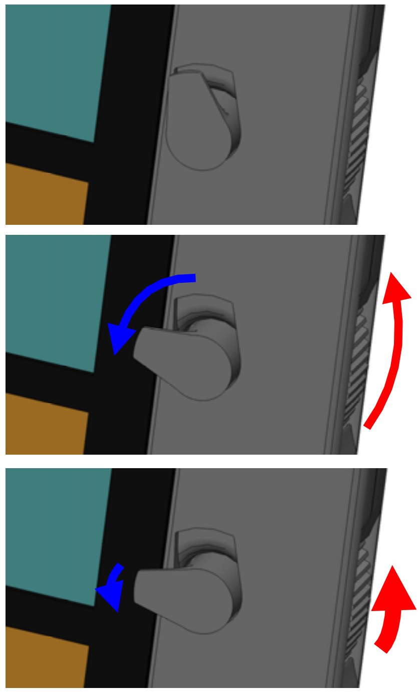


1) Start with the chart clip in the up position

2) Press <u>and hold</u> the clip into the chart surface

3) While holding the chart clip down, firmly rotate the thumb wheel clockwise until the chart clip locks into place. A click sound will confirm the clips are locked in position

Figure 7. Retracting the chart clip into the chart surface. Red arrows denote user actions. Blue arrows denote spring-driven movements.



1) Start with the chart clip out and up

2) Rotate the thumb wheel counter clockwise to lock the chart into position

3) If desired, apply extra force to lock the clip into position. The clips will make a “click” sound to confirm they are locked in position

Figure 8. Locking a chart in place. Red arrows denote user actions. Blue arrows denote spring-driven movements.

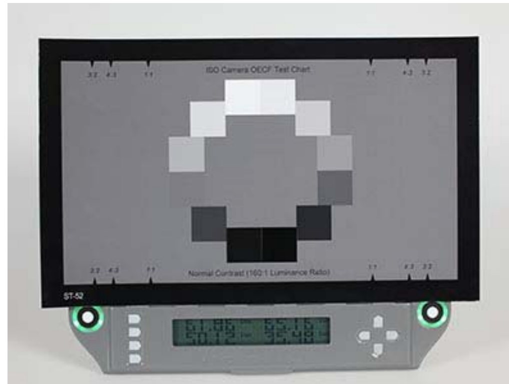
3.2.2 Using Standard Sized Charts

The Isolight Color light meter is designed for standard test charts sized 290mm x 204mm. To install a standard test chart:

1. Set both clips in the “up” position by rotating the thumbwheels. Refer to Figure 6.
2. Place the test chart onto the chart shelf
   - Ensure that the chart bottom edge is captured securely between the shelf edge and the light meter chart area
3. Rotate the clips into the “down” position or “down and locked”. Refer to Figure 8.
   - Rotate the thumbwheels firmly until a “click” sound is heard and the clips lock into the down position

3.2.3 Using Other Chart Sizes

It is possible to use test charts which are larger or smaller than the standard size. Two examples are shown in Figure 9. Note that some charts may block the upper light sensors (sensors 0 and 1). If this occurs, the average and uniformity readings will not be correct and should be ignored.



Q-14 chart ISO12232 OECF chart

Figure 9. Examples of using non-standard sized charts

1. Set both clips in the “up” position.
2. Follow the sequence in Figure 7. Push each clip down, towards the light meter surface, and hold there. At the same time, rotate the thumbwheel (counter-clockwise for the left clip, clockwise for the right clip) until a “click” is heard and felt. The result should look like Figure 5a.
    - This locks the clips flush with the chart area, preventing the clips from interfering with the test chart
3. Place the test chart onto the chart shelf
    - Ensure that the chart bottom edge is captured securely between the shelf edge and the light meter chart area
    - Be careful that the test chart does not bend forward or tip out of the shelf edge. If possible, recline the light meter backwards or use the fold-out legs to lean the light meter and chart backwards at a slight angle

3.3 Mounting the Light Meter

The Isolight Color light meter can be mounted in test scenes many different ways:

- on a tripod
- against a steel surface
- on the built-in folding legs
- on hooks or a nail in a vertical surface such as a wall

3.3.1 Tripod Mounting

There are two ¼”-20 tripod mounting threads: one on the back, and one on the bottom of the instrument.

Be careful not to tilt the device more than fifteen (15) degrees from the vertical position when using the bottom tripod mount. At large tilt angles, the tripod mount experiences very high stresses and may break or be damaged. In these situations, use the back tripod mount instead.

3.3.2 Mounting Magnets

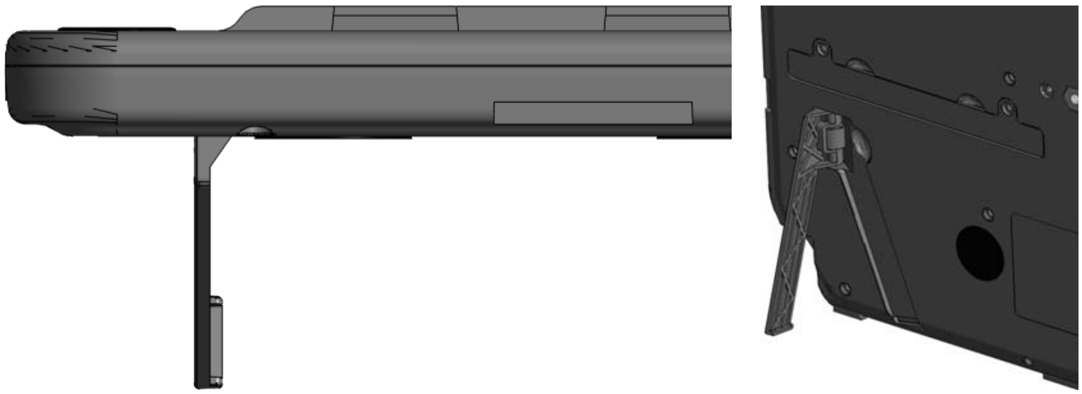
Your Isolight Color may come equipped with powerful rare-earth magnets mounted inside the back surface. These magnets allow the instrument to be mounted on iron and steel surfaces, such as light booth walls and white boards. Rubber pads on the back surface prevent the instrument from sliding or shifting during use.

The internal magnets may corrupt magnetic storage media such as credit cards, desktop and notebook computer hard drives, and floppy disks. Please keep the light meter away from any susceptible devices.

3.3.3   Table-Top Use

The Isolight Color is equipped with two fold-out legs for table-top use. The legs are also ideal for use with plastic-walled light booths or other small test scenes.

To open the legs, place a finger in each recessed finger hole and unfold the legs until they are at right angles to the back surface. Figure 10 shows how the legs should look when completely open.



Top View   Back View

Figure 10. Proper leg open position

3.3.4   Mounting on a Wall

There are three keyhole slots on the back for hanging the instrument on a wall via hooks or nails. Use the middle slot for mounting by a single nail. Note that the instrument may tilt if bumped or pulled by either the USB or power cable. To alleviate the problem, use the two outer keyhole slots instead.

4 Display Modes and Menus

The LCD display has two modes: data display mode and menu mode. In the data display mode, light sensor readings and other parameters are displayed and continuously updated. In menu mode, the user can quickly navigate, view and adjust all device functions, mode settings, and parameters. Table 1 details the functions of each arrow key in both display mode and menu mode.

Key	Action in display mode	Action in menu mode
UP	Previous menu item	Previous menu item
DOWN	Next menu item	Next menu item
LEFT	None	Return to previous level. If at top the level, return to Display mode
RIGHT	Enter Menu mode	Select item or enter submenu

Table 1. Arrow key functions in each mode

4.1 Data Display Modes

The twelve data display modes are shown in Figure 11. On power up, the system defaults to the average brightness mode (top mode).

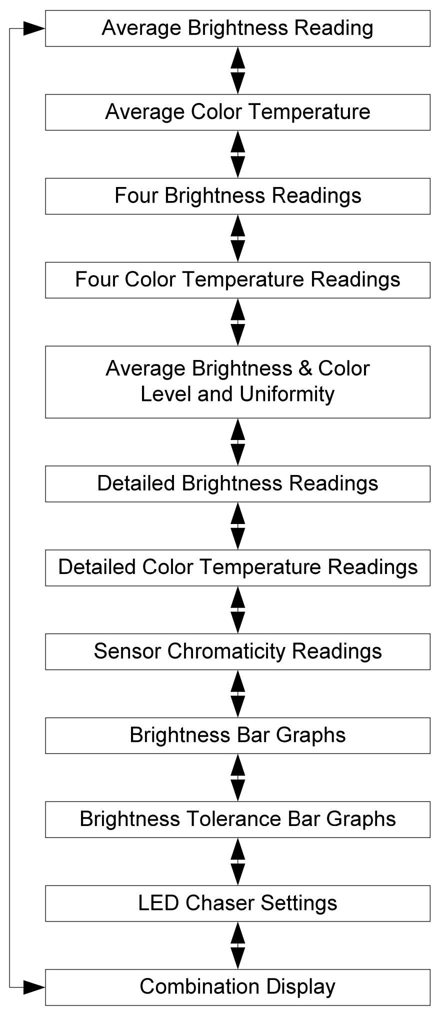


Figure 11. Data display modes and cycle order

4.1.1 Average Brightness Reading

The average brightness reading mode displays the average of the four sensor readings in Lux in a large 4x sized font. This mode is legible even at large distances and in low resolution images.

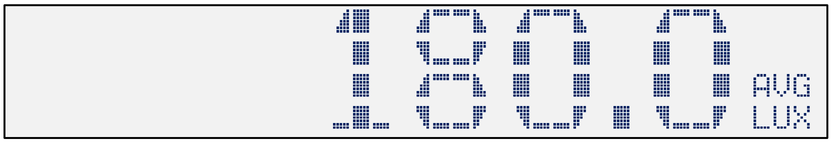


Figure 12. Average reading display mode

4.1.2 Average Color Temperature

The average color temperature mode displays the average of the four sensor color temperature readings in Kelvin in a large 4x sized font. This mode is legible even at large distances and in low resolution images.

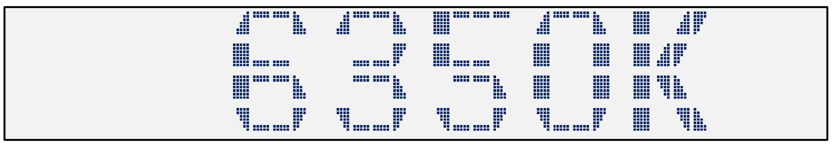


Figure 13. Average color temperature reading display mode

If any of the sensor color temperatures are invalid, the average reading is also invalid. Invalid readings are displayed as shown in Figure 14.

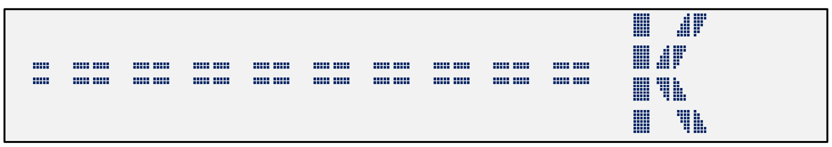


Figure 14. Example of an invalid color temperature display

4.1.3 Four Brightness Readings

The four brightness readings mode displays each sensor's light level in lux in a double-sized font. This mode works well for high to medium resolution images and for verifying the light level at all four corners simultaneously.

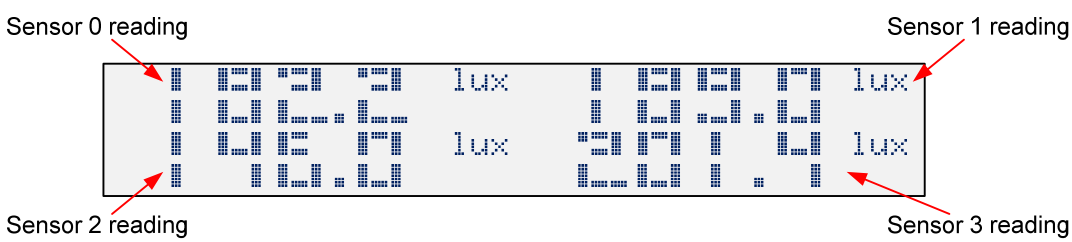


Figure 15. Four sensor readings display mode

4.1.4 Four Color Temperature Readings

The four color temperature readings mode displays each sensor's color temperature in Kelvin in a double-sized font. This mode works well for high to medium resolution images and for verifying the color temperature at all four corners simultaneously.

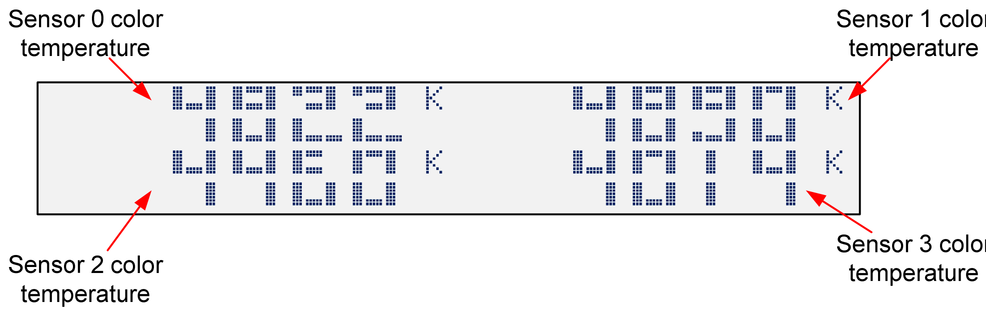


Figure 16. Four color temperature readings display mode

If any color temperature readings are invalid, they are displayed as shown in Figure 17.

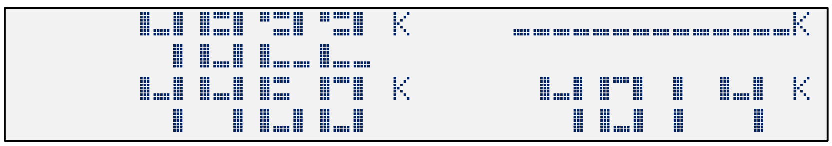


Figure 17. Example of an invalid color temperature reading

4.1.5 Average Brightness and Color Level and Uniformity

This mode displays the average brightness in lux, the average color temperature in Kelvin, and the percentage nonuniformity each. This mode is useful for quickly evaluating or recording the overall lighting conditions.

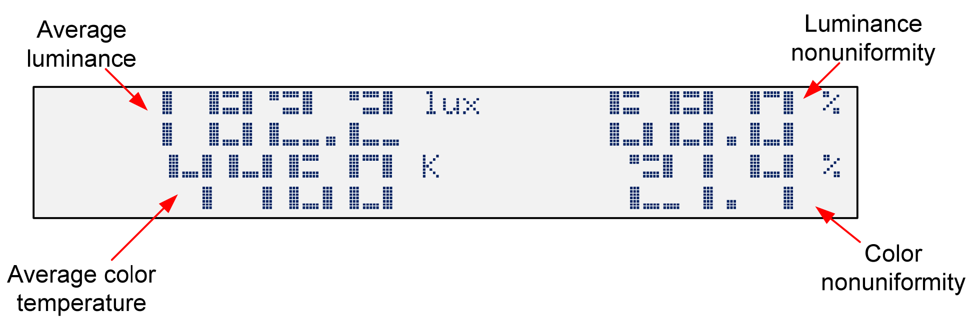


Figure 18. Average brightness and color levels and nonuniformity display mode

4.1.6 Detailed Brightness Readings

The detailed brightness readings mode displays many useful parameters in a single screen:

- The average light level in Lux
- Luminance nonuniformity in percent
- The current target minimum and maximum luminance values in Lux
- The readings of all four sensors in Lux

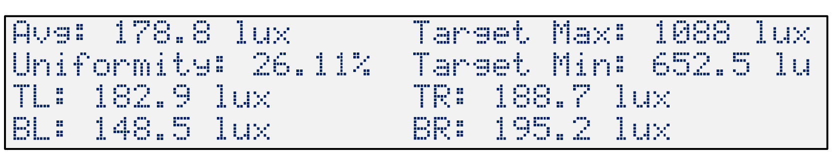


Figure 19. Detailed brightness readings display mode

The target minimum and maximum values reflect the current target values. Target values are set by the user in level-and-tolerance mode, and determined automatically in tolerance-only mode.

Due to the small font, the Detailed Readings mode is usually visible only in high-resolution images.

4.1.7 Detailed Color Temperature Readings

The detailed color temperature readings mode displays many useful parameters in a single screen:

- The average color temperature in Kelvin
- Color nonuniformity in percent
- The current color target minimum and maximum values in Kelvin
- The color temperature readings of all four sensors in Kelvin

```
Y: 3103 K                    Target Max: 5100 K
Uniformity: 26.11%           Target Min: 4900 K
TL: 3017 K                   TR: 3058 K
BL: 3238 K                   BR: 3068 K
```

Figure 20. Detailed color temperature readings display mode

The target minimum and maximum values reflect the current target values. Target values are set by the user in level-and-tolerance mode, and determined automatically in tolerance-only mode.

Due to the small font, this mode is usually visible only in high-resolution images.

4.1.8 Sensor Chromaticity Readings

The sensor chromaticity readings mode provides the most detailed color readings of all. For each sensor, four values are displayed:

- Light level in Lux
- Color temperature in Kelvin
- Normalized CIE XYZ chromaticity coordinates (x and y)

```
  74.08 lx   x:0.428 Y:67.96 lx   x:0.423
CCT:2977 K   y:0.390 CCT:3147 K   y:0.412
  65.74 lx   x:0.418 Y:60.44 lx   x:0.436
CCT:3242 K   y:0.394 CCT:3028 K   y:0.411
```

Figure 21. Four sensor readings display mode

The chromaticity values are especially useful when working with light sources whose color isn't accurately described as a correlated color temperature. Examples include fluorescent and LED light sources.

Due to the small font, this mode is usually visible only in high-resolution images.

4.1.9 Sensor Bars

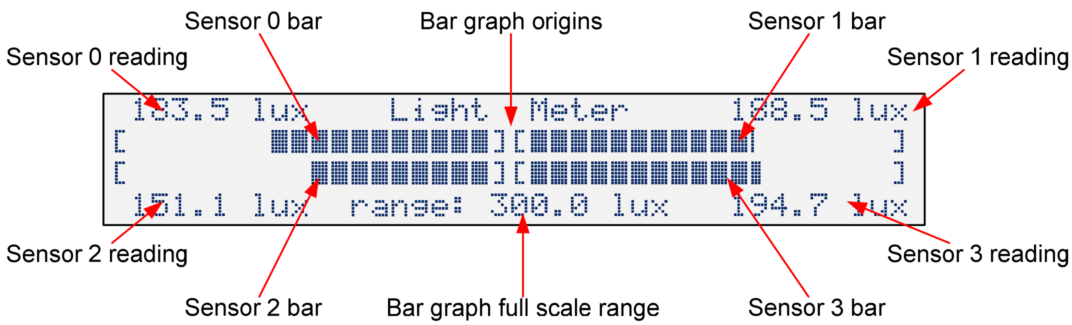


Figure 22. Sensor bars display mode

The sensor bars mode displays the current light levels in both numerical and graphical form. The display is divided into four quadrants, with each quadrant displaying the light level both numerically and as a bar graph. The bar graphs extend from the center of the screen outwards to the left and right. All bars share the same scale. The current maximum scale range is displayed at the bottom center of the screen. Sensor levels are also displayed numerically in the four corners.

4.1.10 Tolerance Bars

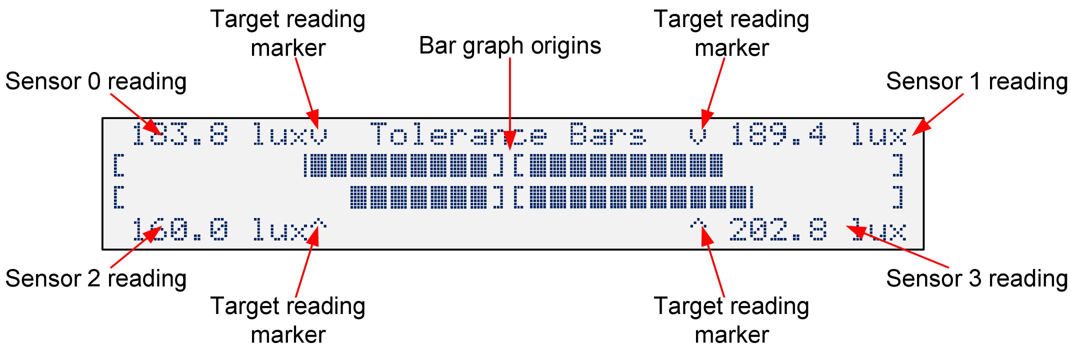


Figure 23. Tolerance bars display mode

Four bar graphs show how close each sensor is to the target level. Arrows above and below each bar at the half-way mark show the target brightness levels. The current brightness levels are also displayed numerically in the four corners. The large bars are clearly visible, and convenient for adjusting lighting at distance.

4.1.11 LED Chaser Settings

The LED chaser display mode displays the LED chaser's current state including LED step and total duration, emphasis mode, and Beep mode. This mode is useful for capturing the LED chaser state during video-audio synchronization testing.

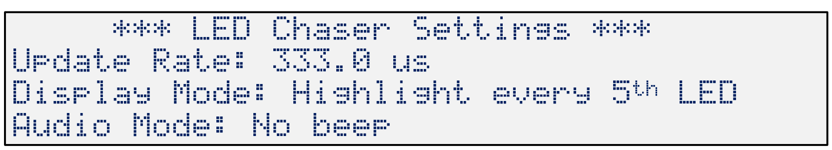


Figure 24. LED chaser display mode

4.1.12 Combination Display

This mode displays the current light levels (average and individual sensors), current target level ranges, LED chaser mode, and battery voltage. It is useful when monitoring both light levels and using LED chaser.

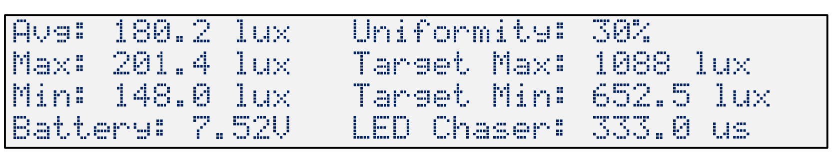


Figure 25. Combination display mode

4.2 Menu Mode

All system settings are accessed through menus and submenus. Figure 26 shows a sample menu screen. On start-up, the device enters the data display mode. To access the menus, press the right arrow key. To exit the menus and return to the data display mode, repeatedly press the left arrow key.

Menu options are selected with the four arrow keys. The up and down keys scroll though the available menu options. A scroll bar on the left side of the screen shows the currently selected menu item, as well as showing how many menu items are above and below the current selection. To select a menu option, press the right arrow key. To exit any menu and return to the previous menu level, press the left arrow key. The menu structure is shown in Figure 27.

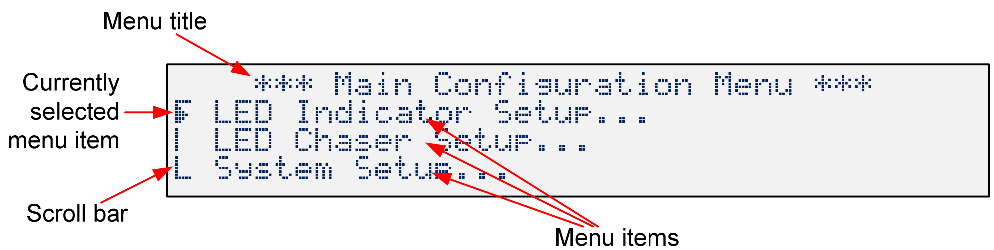


Figure 26. Sample menu screen

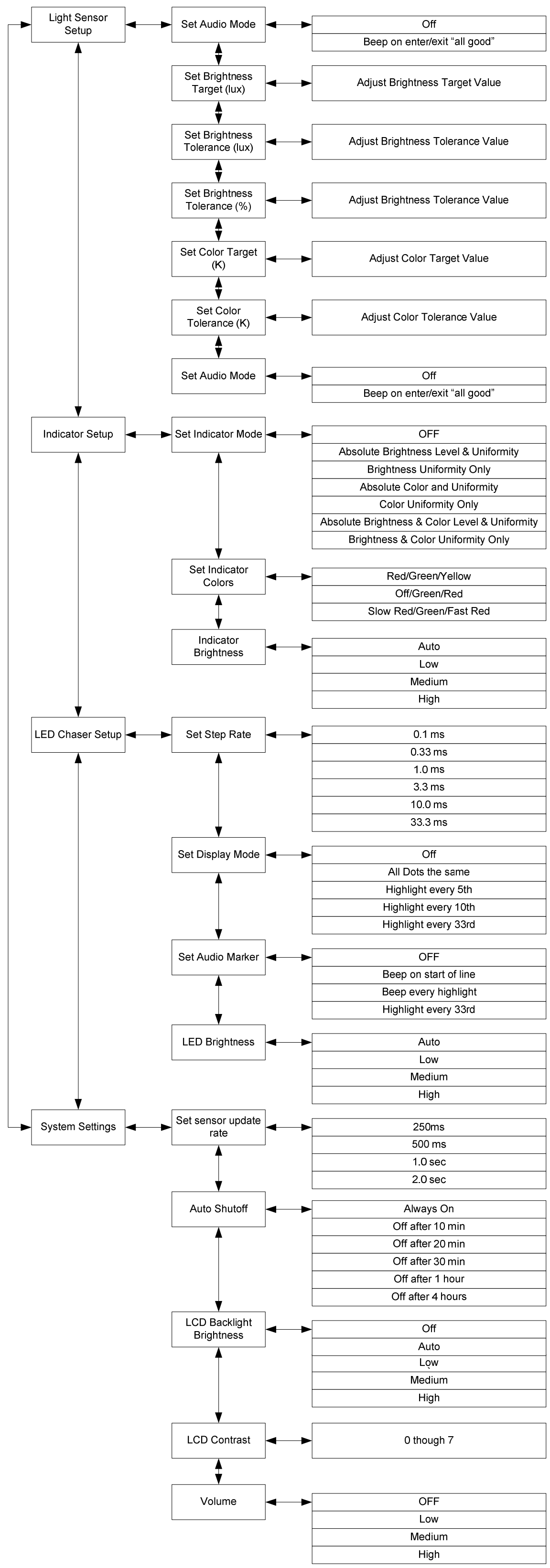


Figure 27. Menu structure

4.3 Preset Buttons

Four preset buttons are provided for saving and restoring commonly used settings. Preset settings are stored in non-volatile memory and are retained even if power is lost.

Not all system settings are saved. Table 2 shows which settings are saved by the presets.

System Parameter	Saved with Presets
Target brightness and color level and tolerance	Yes
LED indicator mode settings	Yes
LED chaser settings	Yes
LCD backlight brightness mode and contrast	No
System volume	No

Table 2. System parameters saved by presets

4.3.1 Saving and Recalling Preset Settings

To save the current settings, press and hold the desired preset button for two seconds. The device will play a “success” beep and the current system settings will be stored.

To recall saved settings, press and quickly release the desired preset button. If the preset contains previously saved settings, the device will play a “success” beep and the saved settings will be immediately loaded and applied. If no settings have been saved, a “warning” beep will sound and the current settings will not change.

5 Measuring Brightness and Color

Having the correct lighting brightness, color, and uniformity is critical to obtaining the most accurate image quality test results. Your Isolight Color light meter is designed to make setting up and verifying scene lighting quick, accurate, and simple.

The two most common goals for lighting are; (1) achieve a specific lighting brightness, and (2) to achieve uniform lighting across the test chart. Many image quality tests require specific lighting levels and color, such as low light tests or tests that mimic ambient room lighting. Uneven lighting or color across a test chart can introduce significant measurement errors. In fact, lighting errors can be much larger than errors from the equipment under test.

5.1 Measuring Scene Brightness

The easiest way to measure the overall scene brightness level is to use the average brightness reading display mode (section 4.1.1).

1. Make sure the Isolight Color is in the display mode. If it is in menu mode, press the left arrow key repeatedly to return to display mode
2. Press the up or down arrow keys until the average brightness reading is displayed
3. Place the Isolight in the scene and install the desired test chart
4. Adjust the scene lighting to achieve the desired light level. When adjusting the lighting, be sure not to obstruct the lighting by standing in front of the lights.

Note that the lighting will likely not yet be uniform.

5.1.1 Measuring Scene Lighting Uniformity

To measure the uniformity of the scene lighting, the four brightness readings (section 4.1.2) and sensor bars (section 4.1.7) display modes are most useful.

The four readings display mode is most useful for verifying that each corner of the test chart is receiving the correct amount of light. Since the readings are displayed in a larger font, this mode is most useful when the lights are some distance away from the test chart.

The sensor bars mode is most useful for verifying that each chart corner is receiving the same level of light, but is harder to use to achieve a specific light level since the light level readings are in a small font.

1. Make sure you are in the display mode. If you are in menu mode, press the left arrow key repeatedly to return to display mode
2. Press the up or down arrow keys until the average reading is displayed

Using the LED indicators (section 6) makes the job of setting the correct lighting levels and uniformity much easier at any distance from the chart.

5.2 Measuring Illumination Color

Each light sensor measures the full RGB color. This allows the Isolight Color to measure not only the average illumination color, but also color uniformity. This is especially useful when lighting a scene with multiple light sources or lights whose color is not consistent, such as LEDs.

The onboard LCD displays color information in two formats: Yxy and correlated color temperature (CCT). The USB interface can also provide color information in Yuv format.

5.2.1 Background Information on Color

Some background information on color and these formats is useful to known when each is useful or appropriate.

5.2.1.1 CIEXYZ and Yxy

The human eye has three types of color receptors. Each detects either long (red), medium (green), or short (blue) wavelengths of light. Color is thus most naturally represented as a set of three values. Though much research and international consensus, a set of standard spectral basis functions were defined to closely match average human color sensitivity. These basis functions form the CIEXYZ color standard color space.

The CIEXYZ coordinate values, denoted by the capital letters X, Y, and Z, represent the perceived optical power of red, green, and blue light. Note that the levels are weighted by the human eye response functions, and are not measured in physical units such as W. The XYZ values vary with both optical brightness and color. This is inconvenient when one wishes to compare only color and ignore brightness. To describe color independent of brightness, the XYZ values are normalized as follows:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

The lowercase x, y, and z values are brightness normalized color coordinates. The z coordinate is usually omitted, since it can be recovered using the relationship:

$$z = 1 - x - y$$

The xy values are useful for comparing colors. Any two colors with the same xy coordinates should be perceived as identical, regardless of their spectral content.

Brightness information is still often useful, so the Y, x, and y values are usually reported together. The Y value is a measure of the perceived brightness, while the x and y provide color information. The Isolight Color reports the Y value in lux, while the x and y values are dimensionless, ranging in value from 0.0 to 1.0.

5.2.1.2 $Yu'v'$ Colorspace

While CIEXYZ space defines color in terms of the human eye spectral response, it has some drawbacks. Notably, the perceived difference between any two colors varies greatly in xy space. Thus, xy space is not useful for comparing colors in a perceptual sense. In that case, the $Yu'v'$ color space is more suitable.

The Y component is the same as the Yxy space, again representing the lighting brightness in lux. The $u'v'$ coordinates can be determined from the CIEXYZ values using the following formulae:

$$u' = \frac{4X}{X + 15Y + 3Z}$$

$$v' = \frac{6Y}{X + 15Y + 3Z}$$

The transform between coordinate spaces is one-to-one and reversible.

5.2.1.3 Correlated Color Temperature

All objects emit electromagnetic radiation in a manner directly related to their temperature. The simplest theoretical object is a perfectly black, non-reflecting object held as a constant, known temperature. The entire spectrum of radiation from this “black body” is correlated to its temperature. This correlated color temperature (CCT) is usually reported in degrees Kelvin (K). Thus, a single temperature value can be used to describe the color of radiated light.

Objects and normal room temperature (approximately 300K) emit only invisible infrared radiation. But once an object is heated to about 800K, it starts to emit light in the visible spectrum. The first visible color is a deep red. As the object's temperature is increased, the emitted color changes from red to orange, yellow, white, blue, and eventually becomes invisible ultraviolet light. Figure 28 shows the approximate blackbody color at various temperatures.

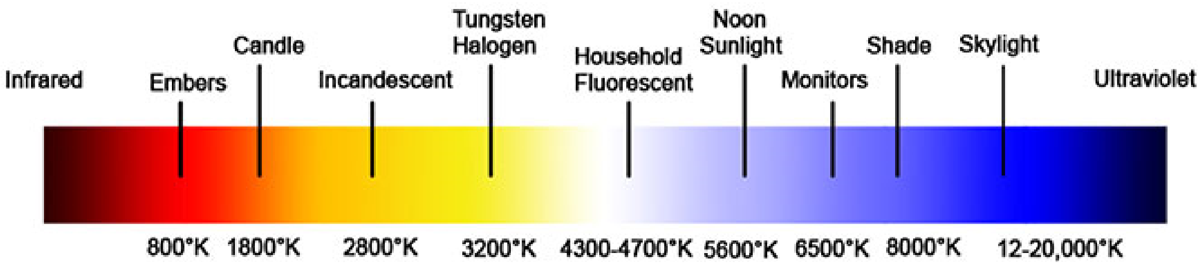


Figure 28. Approximate visible color as a function of color temperature (Color Temperature & Color Rendering Index DeMystified)

Figure 29 shows the line of CCT colors plotted on a CIEXYZ *xy* chromaticity diagram.

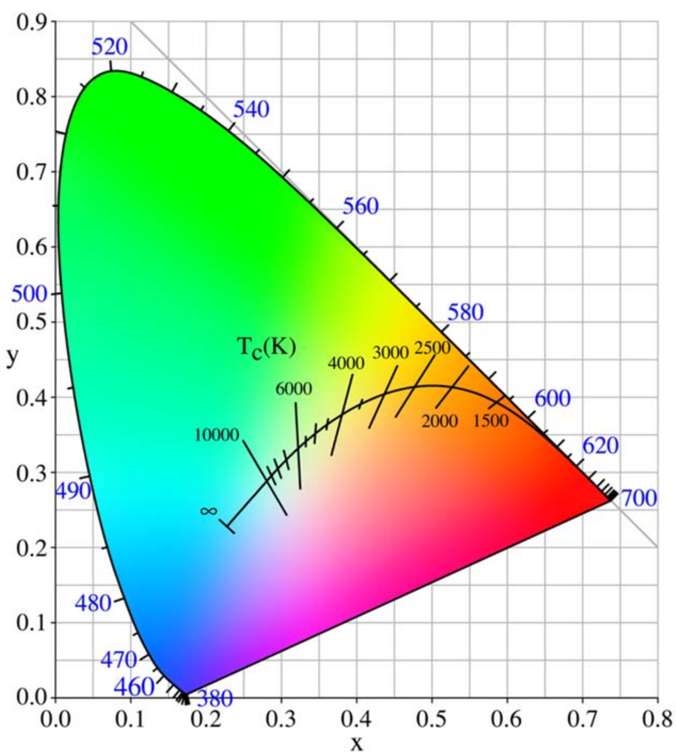


Figure 29. Plot of correlated color temperature colors in x-y chromaticity space (Chromaticity)

Many real world light sources are blackbody radiators (candles, tungsten lights, tungsten-halogen), or closely approximate the spectra of blackbody sources (daylight and shade sources). Photographers and the lighting industry have come to use CCT as a convenient way to describe the color of various light sources.

The color coordinates of many lights, such LED and fluorescent lighting, do not lie exactly on the black-body line shown in Figure 29. If the distance to the line isn't too large[1], such lights can still be assigned an approximate color temperature by finding the point on the blackbody curve closest to their actual chromaticity.

5.2.2 Isolight Color Display Modes

Section 4.1 describes the Isolight Color display modes, many of which include color information. Under most light sources, the CCT and xy coordinate readings are displayed normally. However, if the lighting has a very strong color cast, e.g. bright red, yellow, green, blue or if the lighting is very dim, it may not be possible to accurately report xy color readings. As described in section 5.2.1.3, the color temperature is also invalid for many bright colors. In these cases the color information is not reported and a series of dashes is displayed instead. See Figure 14 and Figure 17 for examples.

5.3 Setting Update Rate

When adjusting scene lighting, the display and readouts should update as quickly as possible, for maximum responsiveness. However, a rapidly changing display is difficult to photograph. This is especially true under low light, where long exposures are often required. Table 3 shows a comparison of the advantages and disadvantages of fast and slow update rates.

	Advantages	**Disadvantages**
Slow update rate	Easy to photograph in low light and with long exposure times	Takes longer to see effects of lighting changes – less responsive
Fast update rate	Lighting changes are quickly reported, making it easier to quickly adjust lighting to the desired level	Rapidly changing displays can appear blurring and difficult to read in low light scenes or images with long exposure times

Table 3. Comparison of sensor update rates

Your Isolight allows you to select update rates from 250 ms to 2.0 seconds to achieve the optimal balance between responsiveness and display stability. To adjust the sensor update rate, go to the `Menu→System Setup→Sensor Update Rate` menu item and select the desired rate:

- 250 ms
- 500 ms
- 1.0 seconds
- 2.0 seconds

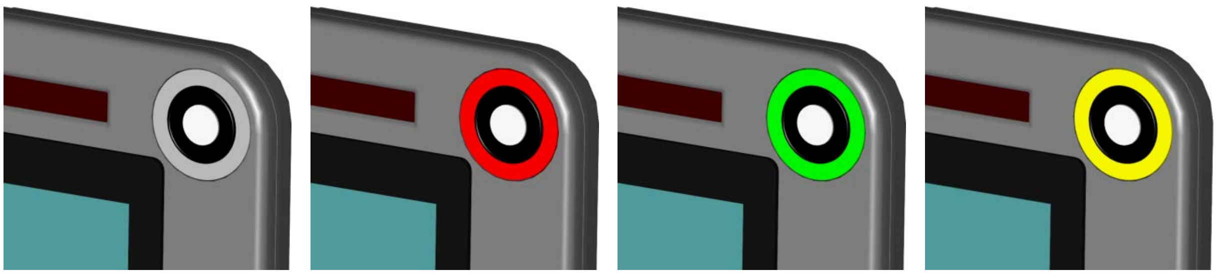
Note that under low-light conditions, the light meter may slow the update rate to less than the desired setting. This feature ensures that a reasonable signal-to-noise ratio and signal resolution is maintained.

[1] The color error distance to the blackbody line must be less than 0.05 in CIELUV uv coordinate space.

6 LED Indicator Rings

The LED indicator rings make it particularly easy to achieve and verify the correct scene lighting. There are four LED indicator rings, one around each light sensor. Depending on the selected mode, the LED indicator rings can monitor lighting brightness, color, or both. The LED color and/or flash pattern indicates whether the light falling on each sensor is too high, too low, or within the target property range(s).

Figure 30 shows the four possible LED indicator states. The meanings of each state vary with the display scheme and mode. Red generally means "too dark" or "color temperature too low". Green means "just right" or within the target range. Yellow means "too bright" or "color temperature is too high". See section 6.8.2 for more information on choosing and setting the display scheme.



Off	Red – Light level too low	Green – Light level within correct range	Yellow– Light level too bright

Figure 30. LED indicator display colors

The LED indicator ring brightness can be manually adjusted or set automatically. In the "auto" mode the brightness is set so that the indicators are clearly visible in ambient light, but not so bright as to create light pollution or alter the behavior of the device under test. See section 6.8.1 for information on adjusting the indicator ring brightness.

6.1 Computing Illumination Uniformity

The Isolight Color computes illumination nonuniformity with the following formula:

$$\%\ Nonuniformity = \frac{\max(\ Sensor\ Reading) - \min(Sensor\ Reading)}{\mathrm{mean}(\ Sensor\ Reading)} \times 100\%$$

Perfectly uniform lighting will have 0.0% nonuniformity. By definition, nonuniformity values will always be between 0% and 400%. The current nonuniformity is displayed in the detailed sensor readings (section 4.1.4) and (section 0) combination display modes.

6.2 Choosing and Setting the Indicator Mode

When setting up a test scene, there are two types of lighting criteria:

1. Make the lighting both uniform and a predetermined brightness. E.g. 1000 lux, +/- 100 lux.
2. Make the lighting uniform, but the actual lighting brightness is not important.

Lighting uniformity is always important goal. Achieving a specific light level may or may not be important. The Isolight Color LED indicators provide modes for achieving either uniformity only or achieving both absolute level and uniformity requirements. The seven indicator modes are shown in Table 4.

Indicator Mode	Brightness Target Level	Brightness Uniformity Tolerance	Color Target Level	Color Uniformity Tolerance
OFF				
Brightness level and tolerance	X	X		
Brightness tolerance only		X		
Color level and tolerance			X	X
Color tolerance only				X
Brightness and color level and tolerance	X	X	X	X
Brightness and color tolerance only		X		X

Table 4. LED indicator modes

In modes where the target brightness/color levels are used, the tolerance levels are constant. I.e. the min and max tolerance levels are determined purely from the user-supplied values. In modes where only uniformity is measured, i.e. the absolute target level is ignored. The min/max tolerance levels are dynamically computed from the user-supplied tolerance range and the average brightness/color readings. Table 5 shows which how the target level and tolerance are determined in each mode.

Indicator Mode	Target Level	Tolerance
OFF	None	None
Level and tolerance	User-selected	User-selected
Tolerance only	Current average light level	User-selected

Table 5. How indicator target level and tolerance are determined

6.3 Setting the Target Brightness Level

To set the target brightness level, go to the `Menu`→`Set Brightness Target Levels`→`Set Target Brightness Level (lux)` menu item. The LCD display should appear similar to Figure 31. The current target level is shown on the left side of the screen. For reference, the upper and lower tolerance levels are shown on the right side. If the target brightness level is changed, the tolerance levels are immediately updated.

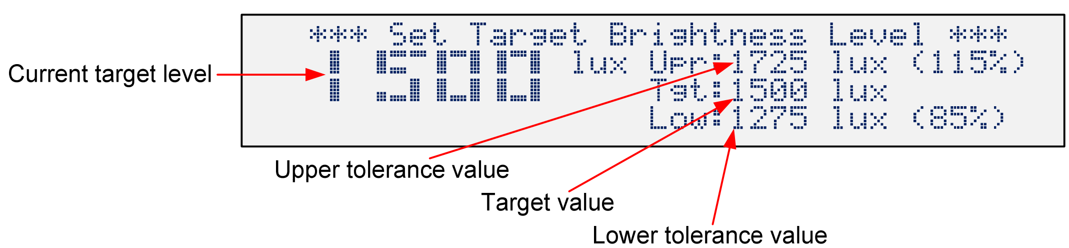


Figure 31. Target light level setting screen

To change the current brightness target level, use the up arrow to increase the target level and the down arrow to decrease it. Pressing and holding either button causes the button to repeat, with the repeat rate becoming faster the longer the button is held. The size of the step increments scales with the target level. I.e. when the target brightness level is small, the steps are also small. As the brightness target level increases, the step size also increases.

6.4 Setting Brightness Tolerance

There are two brightness tolerance modes: the lux-controlled mode and the percentage-controlled mode. The actual upper and lower target levels will be computed differently, depending on whether the tolerance was most recently set in lux or percent.

By setting the brightness tolerance level in lux, the upper and lower target levels will be computed by adding or subtracting the brightness tolerance level to the brightness target level. This sets the lux-controlled tolerance mode. If the brightness target level is subsequently changed, the upper/lower target levels will maintain the same offset in absolute lux terms. If the lower level would become negative as a result, it is clipped to zero.

Conversely, if the brightness tolerance level is set in percent, the tolerance mode changes to the percentage-controlled mode. The upper and lower brightness target levels will be computed by scaling the brightness target level, rather than by adding/subtracting. If the brightness target level is changed, the upper and lower values will maintain the same ratios relative to the brightness target level.

6.4.1 Setting Brightness Tolerance In Lux

To set the brightness target level in lux, go to the `Menu`→`Set Brightness Target Levels`→`Set Brightness Target Level (lux)` menu item. The LCD display should appear similar to Figure 32. Notice that the current tolerance is set as the offset (+/-) from the brightness target level, so that the actual tolerance range is twice the width reported. E.g. if the tolerance level is set to 100 lux, the actual target range is 200 lux wide.

Figure 32. Setting the brightness tolerance in lux screen

Entering the tolerance-in-lux screen only displays the current settings. It does not immediately change to the lux-controlled mode. As soon as either the up or down keys are pressed, new brightness target levels are computed using the lux-controlled mode.

To save the current setting and exit, press the left arrow key.

6.4.2 Setting Brightness Tolerance In Percent

To set the brightness tolerance level in percent, go to the `Menu`→`Set Brightness Target Levels`→`Set Brightness Target Level (%)` menu item. The LCD display should appear similar to Figure 33. Notice that the current tolerance is set as the offset (+/-) from the brightness target level, so that the actual tolerance range is twice the width reported. E.g. if the brightness tolerance level is set to 10%, the actual target range is 20% wide.

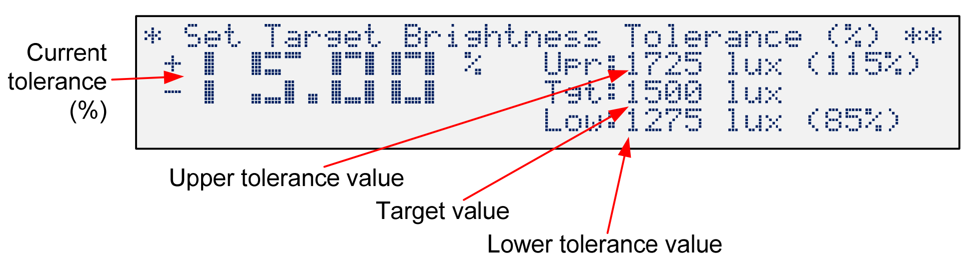


Figure 33. Setting the brightness tolerance in percent screen

As with the lux setting, entering the tolerance-in-percent screen only displays the current settings. It does not change to the percent-controlled mode until either the up or down keys are pressed. The upper and lower target values automatically update as the brightness tolerance level is changed.

Note that if the tolerance-only indicator mode is selected, the brightness target level is computed dynamically from the average brightness level. The upper and lower target levels will also change dynamically, always updating as the average brightness level reading changes.

To save the current setting and exit, press the left arrow key.

6.5 Settings Color Temperature Target

To set the target color temperature level, go to the `Menu`→`Set Color Target Levels`→`Set Target Color (K)` menu item. The LCD display should appear similar to Figure 31. The current target color temperature is shown on the left side of the screen. For reference, the upper and lower tolerance levels are shown on the right side. If the target color temperature is changed, the tolerance levels are immediately updated.

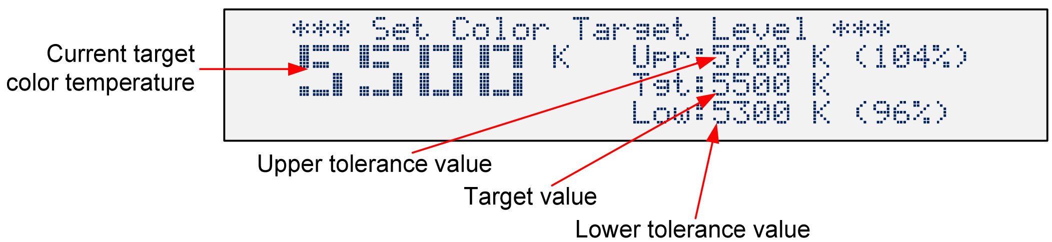


Figure 34. Color temperature target level setting screen

To change the current color temperature, use the up arrow to increase the target temperature and the down arrow to decrease it. Pressing and holding either button causes the button to repeat, with the repeat rate becoming faster the longer the button is held. The step size is constant.

6.6 Settings Color Temperature Tolerance

To set the color temperature in Kelvin (K), go to the `Menu`→`Set Color Target Levels`→`Set Color Tolerance (K)` menu item. The LCD display should appear similar to Figure 32. Notice that the color temperature tolerance is set as the offset (+/-) from the color temperature target level, so that the actual tolerance range is twice the width reported. E.g. if the tolerance level is set to 100 K, the actual target range is 200 K wide.

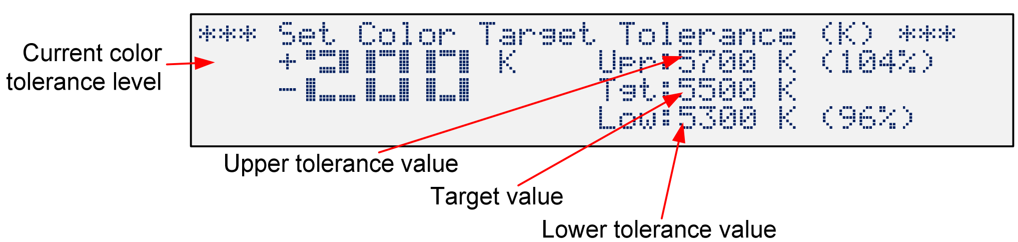


Figure 35. Color temperature tolerance setting screen

To save the current setting and exit, press the left arrow key.

6.7 Using Presets

Remember that the Preset buttons can be used to save and recall brightness and color target and tolerance level settings. Presets are especially useful when testing requires switching between several specific lighting conditions. E.g. 10 Lux, 300 Lux, and 1000 Lux.

6.8 LED Indicator Options

6.8.1 Indicator Brightness

The LED indicator brightness has for settings: three manual levels (low, medium, and high), and automatic. The automatic setting adjusts the LED indicator brightness based on the average lighting brightness level. The LED brightness is set so that the indicators are clearly visible[2], but not so bright as to cause significant light pollution. Naturally, there are limits to how dim and bright the LEDs can be set. It may be difficult to see the indicators in very bright light. To set the indicator brightness mode, go to the `Menu`→`LED Indicator Setup`→`Indicator Brightness` menu item.

6.8.2 Indicator Color Schemes

There are three display schemes for indicating the current light level status. From the `Menu`→`LED Indicator Setup`→`Color Scheme` menu item, you can choose from:

- Red/Green/Yellow
- Red/Off/Yellow
- Slow Red Flash/Green/Fast Red Flash

Table 6 shows how each scheme displays the current lighting state.

Indicator Scheme	Brightness or CCT too low	Within Range	Brightness or CCT too high	Comments
Red/Green/Yellow	**Red**	**Green**	**Yellow**	Good for general work. Verifies that the indicators are working, since LEDs are always on
Red/Off/Yellow	**Red**	OFF	**Yellow**	Good for production testing, since LEDs only turn on when the measured light level is out of range
Slow Red/ Green/ Fast Red	**Slowly flashes red**	**Green**	**Rapidly flashes red**	Good for video, monochrome imaging, or machine vision detection, since a dynamic display can be easier to detect than static colors

Table 6. LED indicator display schemes

6.8.3 Audio Indicators

In addition to the LED indicators, the Isolight can generate a brief audible tone either when:

- all sensors become "within range". A "happy" tone will play.
- all sensors are within range, and then one or more fall "out of range". A "sad" tone will play.

To enable or disable the Audio Indicator, go to the `Menu`→`LED Indicator Setup`→`Audio Mode` menu item.

[2] LEDs are set to the equivalent brightness of an approximately 50% reflective object.

7 LED Chaser Display

The LED chaser display is very useful for making a wide range of time-related measurements. Some of the possible measurements include integration time, video frame rate, and shot-to-shot delay. When used with the synchronized audio beep, the LED chase can be used to measure audio-video frame synchronization. Table 7 lists some of the parameters that can be measured in still and video modes.

Parameter	Still	Video
Integration time	✓	✓
Shot-to-shot duration	✓	✓ (Frame-to-frame jitter)
Frame rate	n/a	✓
Dropped frames	n/a	✓
Audio-video synchronization	n/a	✓
Auto exposure behavior	✓	✓

Table 7. Parameters that can be measured with the LED chaser

7.1 Description

The LED chaser display consists of 100 LEDs in a horizontal row. Each LED is turned on one at a time, in sequence from left to right. Each LED remains on for the same preset duration. When the sequence reaches the rightmost LED, the sequence restarts again with the leftmost LED. Since each LED is lit for a known time period, they serve as stable time markers in captured images.

7.1.1 LED Step Rate

The LED step time is adjustable from 0.1ms/LED to 1.0sec/LED in half-decade steps. To adjust the LED step rate, go to the `Menu`→`LED Chaser Settings`→`LED Step Rate` menu item and select the desired step rate. Table 8 lists the step rate settings including the full display time for each LED step rate setting, the upper and lower integration times, and how many frames elapse at 30fps.

LED Step Rate	Full Display Period	Integration Time Resolution	Max Integration Time	Frames per display @30fps
0.1ms	10.0 ms	1/10000 sec	1/100 sec	0.33
0.33ms	33.3 ms	1/3333 sec	1/33 sec	1.1
1.0ms	100.0 ms	1/1000 sec	1/10 sec	3.3
3.3ms	333.3 ms	1/333 sec	1/3 sec	11.1
10.0ms	1.0 sec	1/100 sec	1.0 sec	33.3
33.3ms	3.3 sec	1/33 sec	3.3 sec	111
100.0ms	10.0 sec	1/10 sec	10.0 sec	333
333.3ms	33.3 sec	1/3 sec	33.3 sec	1111
1.0 sec	100 sec	1 sec	100 sec	3333

Table 8. LED step and integration time relationships

7.1.2 Display Mode and Emphasis LEDs

Many measurements require counting the number of lit LEDs in an image. Counting upwards of 100 LEDs can be tedious and error prone. To aid and simplify the process, certain LEDs can be set to be extra bright, to act as visual “markers” and to divide the lit LEDs into fixed-size groups. The extra-bright LEDs are called “emphasis LEDs”. Emphasis LEDs divide the chaser display into easily recognized groups, making counting LEDs much easier.

Figure 36 shows a sample display with emphasis LEDs enabled every fifth LED.

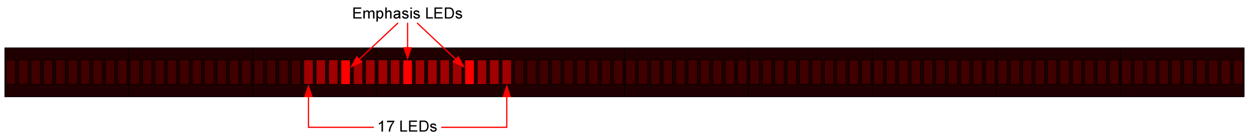


Figure 36. LED chaser display elements

Emphasis LEDs can be set to display every fifth, tenth, or 33rd LED, as shown in Figure 37. The "33rd" setting is useful for video applications where frame rates and integration times are multiples of 1/3 sec. To adjust the LED step rate, go to the `Menu`→`LED Chaser Settings`→`Chaser Mode` menu item and select the desired setting.

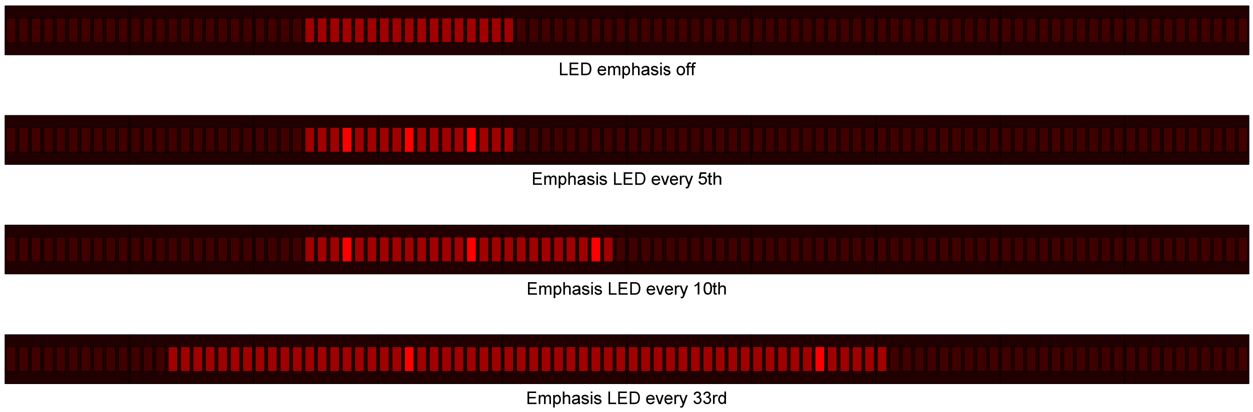


Figure 37. Sample display at various emphasis LED settings

7.1.3 Setting Chaser Brightness

The LED Chaser brightness can be set to four settings: low, medium, high, and "auto". The first three set the brightness to a fixed level. The "auto" setting uses the average ambient light level reading to automatically adjust the brightness so that the chaser is visible, but not so bright that the LEDs overpower the ambient light level (creating light pollution).

7.1.4 Setting Audio Markers

In addition to the Emphasis LEDs, the Isolight can generate audible beeps synchronized with the LED steps. These "audio markers" are used during video testing to detect and measure audio-video synchronization problems.

There are four Audio mode settings:

- OFF – no sound is produced
- Start Of Line – a beep is generated for the left most LED only
- Every Emphasis LED – a beep is generated for each emphasis LED
- Every LED – a beep is generated every time a new LED lights

To adjust the audio mode, go to the `Menu`→`LED Chaser Settings`→`Audio Mode` menu item and select the desired setting. Note that the system audio level determine the volume of the beeps. If the system volume is set to OFF, then no beeps are produced, regardless of the audio mode setting.

Depending on the chaser step rate, the duration of the actual beep tone varies. Beeps are normally 10ms long. If the step rate is long, the beep plays for only part of the LED step time.

If the step rate is too fast, the beeps blend together into an indistinct, solid tone. Table 9 shows which combinations of step rate and emphasis mode settings produce clearly identifiable beeps and which result in an indistinct audio output. A check mark "✓ " indicates clearly distinguishable beeps.

LED Step Rate	Beep at Start of Line	Beep Every Emphasis LED	Beep Every LED
0.1ms	Indistinct	Indistinct	Indistinct
0.33ms	✓	Depends on emphasis setting	Indistinct
1.0ms	✓	Depends on emphasis setting	Indistinct
3.3ms	✓	Depends on emphasis setting	Indistinct
10.0ms	✓	✓	Indistinct
33.3ms	✓	✓	✓
100.0ms	✓	✓	✓
333.3ms	✓	✓	✓
1.0 sec	✓	✓	✓

Table 9. Beep clarity vs. LED step rate and emphasis setting

7.2 LED Chaser Measurements

7.2.1 Measuring Integration Time

The most basic measurement is integration time, i.e. the length of time a camera is actually capturing an image. Since each chaser LED is ON for a known period of time, the integration time is found by capturing an image, counting the number of lit LEDs, and multiplying the number of LEDs by the LED step time.

Figure 38 illustrates the process. In the figure, the LED step time is set to 1.0ms/LED. The camera starts integrating at t=2.0ms, and stops at t=7.0ms. The captured image shows five lit LEDs, indicating a 5.0ms integration time.

The general procedure is:

1. Set the LED step time to a small fraction (less than 1%) of the estimated integration time.
    - Typical integration times are 1/30sec to 1/1000sec.
    - A 0.33msms/LED step time gives a detectable range of 1/30sec (100 LEDs) to 1/3000 sec (one LED).
2. Capture an image
3. Count the number of LEDs
4. Multiply the number of lit LEDs by the LED step time

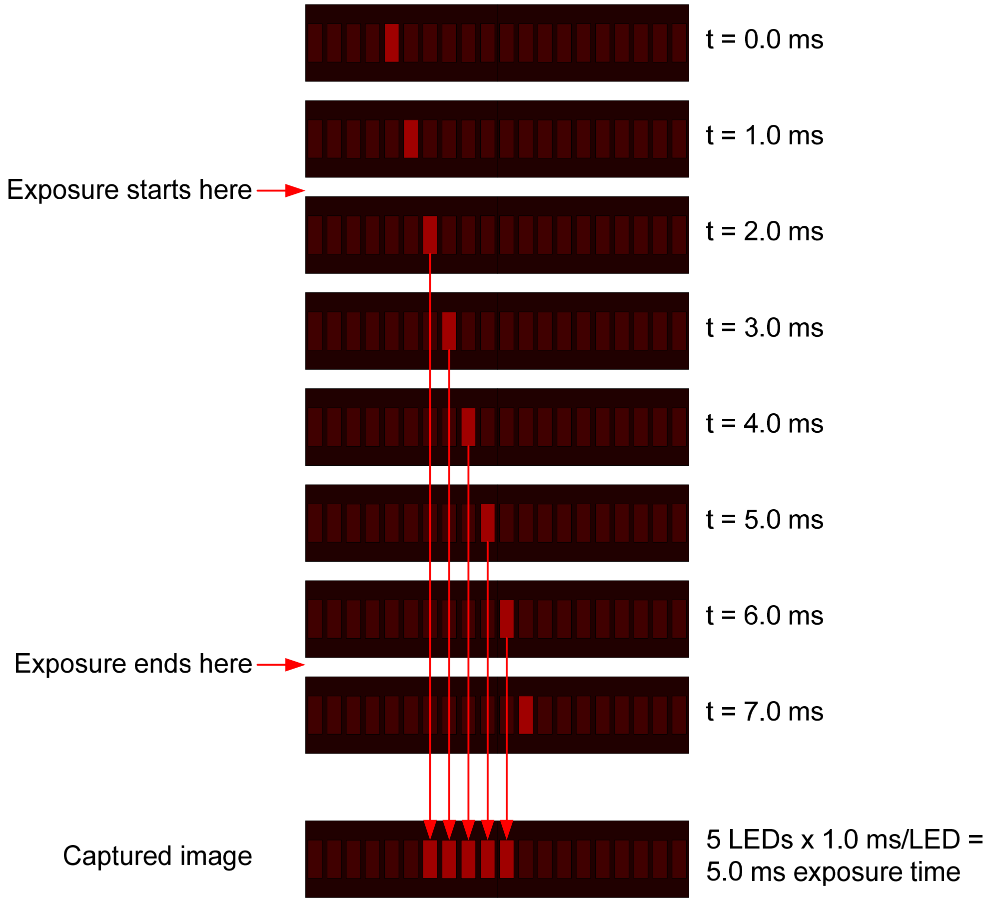


Figure 38. Example of measuring integration time with LED chaser

7.2.2 Measuring Frame Rate (Still Shot-to-Shot Lag)

To measure video frame rate (or still shot-to-shot time), use the following procedure:

1. Set the step time so that approximately 20 to 30 LEDs are visible in a single frame. For 30fps video (33ms per frame), the 1.0ms/LED setting works well. For 60fps video, the 0.33ms/LED setting is better
2. Capture several frames
3. Count the number of LEDs between the left-most LED in the first frame to the left-most LED in the second frame. See the example in Figure 39. In the figure, there are 18 LEDs between the left-most LEDs in each frame.
4. Multiple the LED spacing (18 LEDs in the example) by the LED step time. For the example, the frame rate is:

18 LEDs between frames x 1.0ms/LED = 18ms between frames

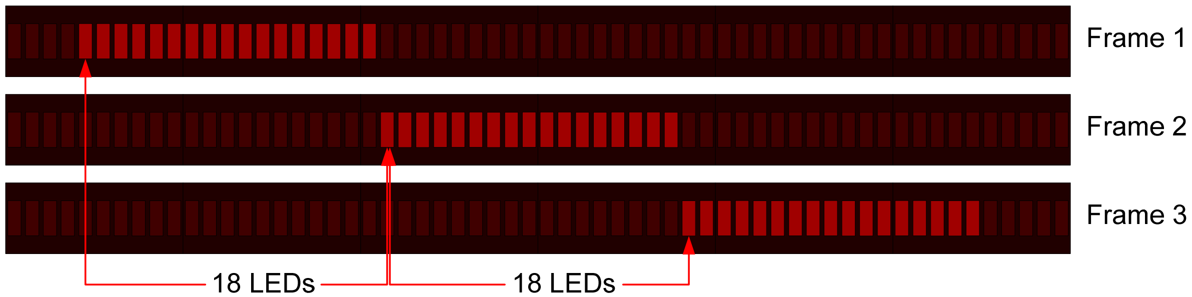


Figure 39. Measuring frame rate

7.2.3 Detecting Integration Time Gaps

It is possible to detect gaps between the end of one frame's integration time and the start of the next frame's integration time. To detect such gaps, look for missing LEDs between frames. Figure 40 shows that three LEDs were not captured by either frame, indicating a gap.

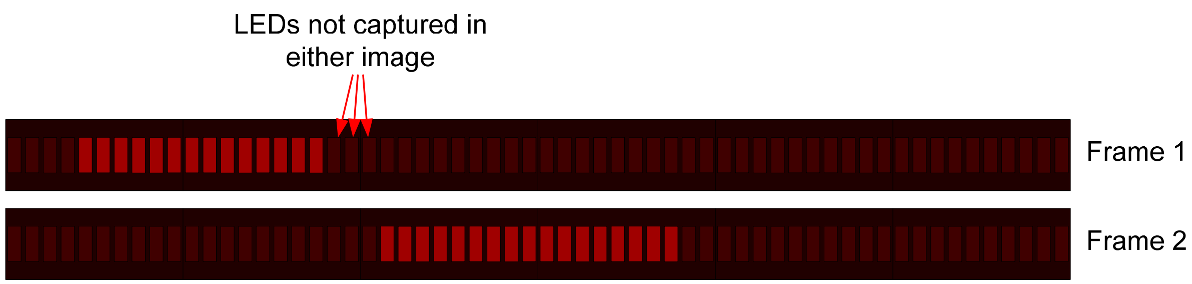


Figure 40. Detecting dropped frames

7.2.4 Measuring Frame Rate Jitter

Frame rate jitter is a variation in frame rate from one frame to the next. To detect frame rate jitter, measure the frame rates between several frames. Figure 41

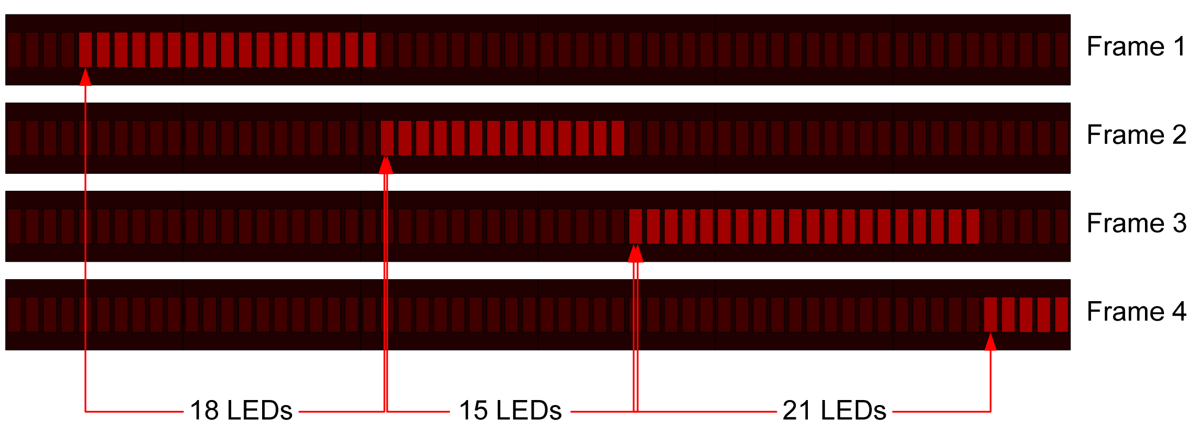


Figure 41. Measuring frame rate jitter

8 System Settings

This section describes the various system settings.

8.1 Sensor Update Rate

The sensor update rate is programmable. See Section 5.2 for information on choosing and setting the optimal update rate.

8.2 Automatic Shut-off Timer

The Isolight Color provides an automatic shut-off timer to preserve battery life. The timer is reset any time a button is pressed or a serial command is received. Once the timer expires, the light meter turns off automatically.

The automatic shut-off time can be set to the following:

- Off (never turn off)
- 10 minutes
- 20 minutes
- 30 minutes
- 60 minutes
- 4 hours

To set the shut-off timer, go to the `Menu→System Setup→Auto Shut-off` menu item and select the desired time.

8.3 LCD Brightness

The LCD backlight brightness can be adjusted through the `Menu→System Setup→LCD Brightness` menu item. The following settings are available:

- Off– backlight always off
- Auto – backlight automatically adjusts to the current average light level. In bright light, the LCD backlight turns off
- Low – the minimum brightness
- Medium
- High – the maximum brightness

8.4 LCD Contrast

The LCD contrast can be adjusted through the `Menu→System Setup→LCD Contrast` menu item. Contrast can be set from 0 to 7, with 3 being the default. Contrast should not normally need to be adjusted, except under temperature extremes or high viewing angles.

8.5 Volume

The global system volume is adjusted through the `Menu→System Setup→Volume` menu item. The following settings are available:

- Off– all audio output is disabled, regardless of other settings
- Low
- Medium
- High

Disabling the volume does not change any other system settings, such as LED Indicator or Chaser audio settings. They will resume playing when the OFF setting is no longer selected in the `Menu→System Setup→Volume` menu.

8.6 System Information

The system information screen can be displayed through the `Menu`→`System Setup`→`System Information` menu item. The firmware revision number, firmware build number, and device serial number are displayed. These are useful when reporting problems or recording which device was used during testing.

9 Remote Operation

Your Isolight Color light meter can be remotely controlled via a serial-over-USB interface. It appears as a COM port on Windows PCs and as a `/dev/ttyUSB` device on Linux systems.

The communication protocol details are:

- 115200 baud
- 8 bits, no parity, one stop bit (8N1)
- Sending a BREAK signal triggers a hard reset of the MCU
- Command strings are terminated with a line feed (LF) character (0x0A)
- The “>” symbol is used as a command prompt
- Sent characters are not remotely echoed

9.1 Command Format

All serial commands are in the form:

```
<Command> [parameter] <LF>
```

For SET commands, if successful, the device will respond with:

```
OK<LF>
```

For GET commands, if successful, the device will response with

```
<Command> [parameter] [= response]<LF>
```

If the command is unsuccessful, the system will return a brief error message.

9.2 System Commands

The following commands are for global system settings parameters.

Command	Description	Param Type	Parameter Value	Return Type	Return Value
***IDN?**	Query device ID	n/a	none	String	Device identification string
?	Displays help screen	n/a	none	String	Text help screen
GBL	Get battery level	n/a	none	Floating point	Current battery voltage
GCPS	Get current power source	n/a	none	Integer	0 – on battery power 1 – on USB power 2 – on DC adapter
GDM	Get display mode	n/a	none		Same as SDM command
GFBN	Get firmware build number	n/a	none	String	Text string identifying the current build. The build changes more frequently than the revision number
GFR	Get firmware revision number	n/a	none	Floating point	Returns the major (whole value) and minor (fractional part) revision number
GLCDBM	Get LCD backlight mode	n/a	none	Integer	Same as SLCDBM command
GLCDC	Get LCD contrast	n/a	none	Integer	Same as SLCDC command
GLE	Get local echo	n/a	none	Integer	Same as SLE command
GLSUR	Get light sensor	n/a	none	Integer	Same as SLSUR

Command	Description	Param Type	Parameter Value	Return Type	Return Value
	update rate				command
GPST	Get power shutdown time	n/a	none	Integer	Same as SPST command
GSN	Get device serial number	n/a	none	Integer	Returns device serial number
GV	Get volume	n/a	none	Integer	Same as SV command
HELP	Displays help screen	n/a	none	String	Text help screen
RESET	Perform hard reset	n/a	none	n/a	Resets device to power-on state.
RFD	Restore factory defaults	n/a	none	n/a	Restores all settings and system states to factory defaults. Erases all presets. Also performs a hard reset.
SDM <mode>	Set the display mode	Integer	0 – Average reading 1 – 4 corner readings 2 – Detailed sensor readings 3 – Sensor bars 4 – Tolerance bars 5 – LED Chaser settings 6 – Combination display	n/a	None
SLCDBM <mode>	Set LCD backlight mode	Integer	0 – Off 1 – Automatic 2 – Low 3 – Medium 4 – High	n/a	None
SLCDC <contrast>	Set LCD contrast	Integer	0 to 7: 0 – lowest contrast 7 – highest contrast	n/a	None
SLSUR <update rate>	Set light sensor update rate	Integer	0 – 250ms 1 – 500ms 2 – 1.0 sec 3 – 2.0 sec	n/a	None
SLE <enable>	Set local echo	Integer	0 – disable local echo of serial characters 1 – enable local echo	n/a	When enabled, all characters received serial characters are echoed back to the host. This is useful for interactive terminal sessions
SPST <timeout>	Set power shutdown time	Integer	0 – Always on 1 – 10 minutes 2 – 20 minutes 3 – 30 minutes 4 – 1 hour 5 – 4 hours	n/a	None
SV <volume>	Set volume	Integer	0 – Off 1 – Low 2 – Medium 3 – High	n/a	None

Table 10. System serial commands

9.3 Light Sensor Commands

The following commands for reading luminance and color data.

Command	Description	Param Type	Parameter Value	Return Type	Return value
RLSALX	Read average of all light sensor channels (lux)	n/a	n/a	Floating point	Average of all four light sensor readings (lux)
RLSAALX	Read all light sensors and average (lux)	n/a	n/a	5 Floating point values	Four light sensor readings and average (lux)
RLSACCT	Read average of all light sensor color temperatures (K)	n/a	n/a	Floating point	Average of all four light sensor color temperatures (K)
RLSAACCT	Read all light sensors color temperatures and average (K)	n/a	n/a	5 Floating point values	Four light sensor color temperatures and average color temperature (K)
RLSCCT <channel>	Read sensor correlated color temperature	Integer	Sensor ID (0 to 3)	Floating point	Sensor's current correlated color temperature
RLSLX <channel>	Read light level of a single channel (lux)	Integer	Sensor ID (0 to 3)	Floating point	Sensor's current reading in lux
RLSYUV <channel>	Read sensor color in Yuv coordinates	Integer	Sensor ID (0 to 3)	3 floating point values	Sensor's current reading in in Yuv coordinates. Y is reported in lux
RLSYXY <channel>	Read sensor color in Yxy coordinates	Integer	Sensor ID (0 to 3)	3 floating point values	Sensor's current reading in Yxy coordinates. Y is reported in lux

Table 11. Light sensor luminance and color serial commands

9.4 LED Indicator Commands

The following commands for setting the LED indicator target levels, tolerances, and operating modes.

Command	Description	Param Type	Parameter Value	Return Type	Return value
GIAM	Get indicator audio mode	n/a	none	Integer	Same as SIAM command
GIBM	Get indicator brightness mode	n/a	none	Integer	Same as SIBM command
GIM	Get indicator mode	n/a	none	Integer	Same as SIM command
GIS	Get indicator color scheme	n/a	none	Integer	Same as SIS command
GICTLV	Get indicator color target CCT level in Kelvin	n/a	None	Integer	Same as SICTLV command

Command	Description	Param Type	Parameter Value	Return Type	Return value
GICTTK	Get indicator color target CCT tolerance in Kelvin	n/a	None	Integer	Same as SICTTK command
GICCTC	Get indicator current CCT color target in Kelvin	n/a	None	Floating point	Returns the current CCT color target level in Kelvin. Depending on the indicator mode, the target level may be static (set by the user) or dynamically calculated (tolerance-only mode)
GICCTL	Get indicator current CCT color lower tolerance level in Kelvin	n/a	None	Floating point	Current lower tolerance color CCT threshold in Kelvin
GICCTU	Get indicator current CCT color upper tolerance level in Kelvin	n/a	None	Floating point	Current upper tolerance color CCT threshold in Kelvin
GILTLV	Get indicator luminance target level in Lux	n/a	None	Integer	Same as SILTLV command
GILCTC	Get indicator current target level in Lux	n/a	None	Floating point	Returns the current target level. Depending on the indicator mode, the target level may be static (set by the user) or dynamically calculated (tolerance-only mode)
GILCTL	Get indicator luminance current lower tolerance level in Lux	n/a	None	Floating point	Current lower tolerance luminance threshold in Lux
GILTTX	Get indicator luminance tolerance level in Lux	n/a	None	Integer	Same as SILTTX command
GILTTP	Get indicator luminance tolerance level in percent	n/a	None	Integer	Same as SILTTP command
GILCTU	Get indicator luminance current tolerance upper level in Lux	n/a	None	Floating point	Current upper luminance tolerance threshold in Lux

Command	Description	Param Type	Parameter Value	Return Type	Return value
SIAM <mode>	Set indicator audio mode	Integer	0 – Off 1 – Beep when all sensors are in range or when any sensor becomes out-of-range	n/a	None
SIBM <mode>	Set indicator brightness mode	Integer	0 – Auto 1 – Low 2 – Medium 3 – High	n/a	None
SIM <mode>	Set indicator mode	Integer	0 – Off 1 – Absolute luminance target level and tolerance 2 – Luminance tolerance only 3 – Absolute color target level and tolerance 4 – Color tolerance only 5 – Absolute target luminance and color level and tolerance 6 – Luminance and color tolerance only	n/a	None
SIS <mode>	Set indicator color scheme	Integer	0 – Red/Green/Yellow 1 – Red/Off/Yellow 2 – Slow red flash/Green/ Fast red flash	n/a	None
SICTLV <color temperature>	Set indicator color CCT target level in Kelvin	Floating point	Set the target color CCT (correlated color temperature) level in Kelvin	n/a	None
SICTTK <temperature tolerance>	Set indicator color CCT tolerance level in Kelvin	Floating point	Set the target color CCT (correlated color temperature) tolerance in Kelvin	n/a	None
SILTLV <level>	Set indicator luminance target level in Lux	Floating point	Set the target luminance level in Lux	n/a	None
SILTTX <tolerance>	Set indicator luminance tolerance level in Lux	Floating point	Target tolerance luminance in Lux	n/a	None
SILTTP <percent>	Set indicator luminance tolerance level in percent	Floating point	Returns the current target luminance level. Depending on the indicator mode, the target level may be static (set by the user) or dynamically calculated (tolerance-only mode)	n/a	None

Table 12. LED indicator, target level, and tolerance serial commands

9.5 LED Chaser Commands

The following commands control the LED chaser's mode, speed, and other parameters

Command	Description	Param Type	Parameter Value	Return Type	Return value

GLCAM	Get LED chaser audio mode	n/a	none	Integer	Same as SLCAM command
GLCBM	Get LED chaser brightness mode	n/a	none	Integer	Same as SLCBM command
GLCM	Get LED chaser mode	n/a	none	Integer	Same as SLCM command
GLCS	Get LED chaser speed	n/a	none	Integer	Same as SLCS command
SLCAM <mode>	Set LED chaser audio mode	Integer	0 – Audio marker off 1 – Beep at the start of the line (at LED 0) 2 – Beep every emphasized LED 3 – Beep every LED	n/a	none
SLCBM <mode>	Set LED chaser brightness mode	Integer	0 – Auto 1 – Low 2 – Medium 3 – High	n/a	none
SLCM <mode>	Set LED chaser mode	Integer	0 – Off 1 – All LEDs the same 2 – Emphasize every 5th LED 3 – Emphasize every 10th LED 4 – Emphasize every 33rd LED	n/a	none
SLCS <speed>	Set LED chaser speed	Integer	0 – 0.10 ms/LED 1 – 0.33 ms/LED 2 – 1.0 ms/LED 3 – 3.33 ms/LED 4 – 10.0 ms/LED 5 – 33.3 ms/LED 6 – 100.0 ms/LED 7 – 333.3 ms/LED 8 – 1.0 sec/LED	n/a	none

Table 13. LED chaser serial commands

9.6 Serial Command Examples

This section contains sample command sequences for reading and setting various device parameters.

9.6.1 Read light sensors

The following command sequence reads the current value of all four light sensors:

Sent command	Isolight response
`RLSLX 0<LF>`	`RLSLX 0 = 100.0<LF>`
`RLSLX 1<LF>`	`RLSLX 0 = 101.0<LF>`
`RLSLX 2<LF>`	`RLSLX 0 = 99.0<LF>`
`RLSLX 3<LF>`	`RLSLX 0 = 102.0<LF>`

9.6.2 LCD Display

Set the LCD to the “four sensor bars” mode and to “HI” brightness mode:

```
SDM 3<LF>
SLCDBM 4<LF>
```

9.6.3 LED Indicator

Set the target light level to 1000 Lux, ±10%, red/off/yellow mode, and auto brightness:

```
SITLV 1000.0<LF>
SITTOP 10.0<LF>
SIM 1<LF>
SIS 1
SIBM 0<LF>
```

9.6.4 LED Chaser

Turn on the LED chaser and emphasize every tenth LED, set step time to 1.0ms/LED, and brightness to auto:

```
SLCM 3<LF>
SLCS 2<LF>
SLCBM 0<LF>
```

10 Bibliography

Chromaticity. (n.d.). Retrieved January 10, 2014, from Wikipedia: http://en.wikipedia.org/wiki/Chromaticity

Color Temperature & Color Rendering Index DeMystified. (n.d.). Retrieved January 10, 2014, from http://lowel.tiffen.com: http://lowel.tiffen.com/edu/color_temperature_and_rendering_demystified.html

Appendix A. Specifications

General

Specification	Value	Conditions
Display	40x4 alphanumeric backlit TFT LCD	
Operating temperature	0ºC to 40ºC (32ºF to 104ºF)	
Storage temperature	-10ºC to 50ºC (14ºF to 140ºF)	
Humidity	Less than 80% RH	Non-condensing

Optical Specifications – General

Specification	Value	Conditions
Detector area	78.5 mm^2 (10mm diameter disc)	
Angular response	TBD%	Deviation from ideal cosine response
Range selection	Fully automatic	
Measurement rate	0.25 to 2.0 sec	

Optical Specifications – Luminance

Specification	Value	Conditions
Spectral response	TBD % deviation from CIE $\bar{y}$ photopic curve	f_1' method under tungsten (A) light
Luminance measurement range	0.1 Lux to 1.0Mlux	
Resolution	0.25 Lux or 1% of reading, whichever is greater	
Repeatability (single channel)	TBD	Tested under standard A (2856K tungsten) light
Channel to channel mismatch	<3.0% Typical	Tested under standard A (2856K tungsten) light
Accuracy	TBD	Tested under standard A (2856K tungsten) light

Optical Specifications – Chrominance

Specification	Value	Conditions
Detector type	Three silicon photodiodes with color filters	
Spectral response	TBD % deviation from CIE $\overline{xyz}$ photopic curves	f_1' method under tungsten (A) light
Color measurement (CCT)	2,000K to 50,000K	CCT is valid within 51pprox.. 0.05 units from the Plankian blackbody radiator curve
Resolution	0.25 Lux or 1% of reading, whichever is greater	
Repeatability (single channel)	TBD	Tested under standard A (2856K tungsten) light
Channel to channel mismatch	<3.0% Typical	Tested under standard A

		(2856K tungsten) light
Accuracy	TBD	Tested under standard A (2856K tungsten) light

Electrical Specifications

Specification	**Value**	**Conditions**
Input voltage	3.5VDC to 9.0VDC	
Power requirements	TBD W	See note 3
Battery life	TBD Hours	See note 3

Mechanical Specifications

Specification	**Value**	**Conditions**
Dimensions	346mm x 295mm x 21mm (13.6in x 11.6in x 0.83in)	
Mass (without batteries)	995 g	
Mass (with batteries)	1065 g	Includes 6 AAA alkaline batteries

[3] Varies depending on system settings

Appendix B. Mechanical Drawings

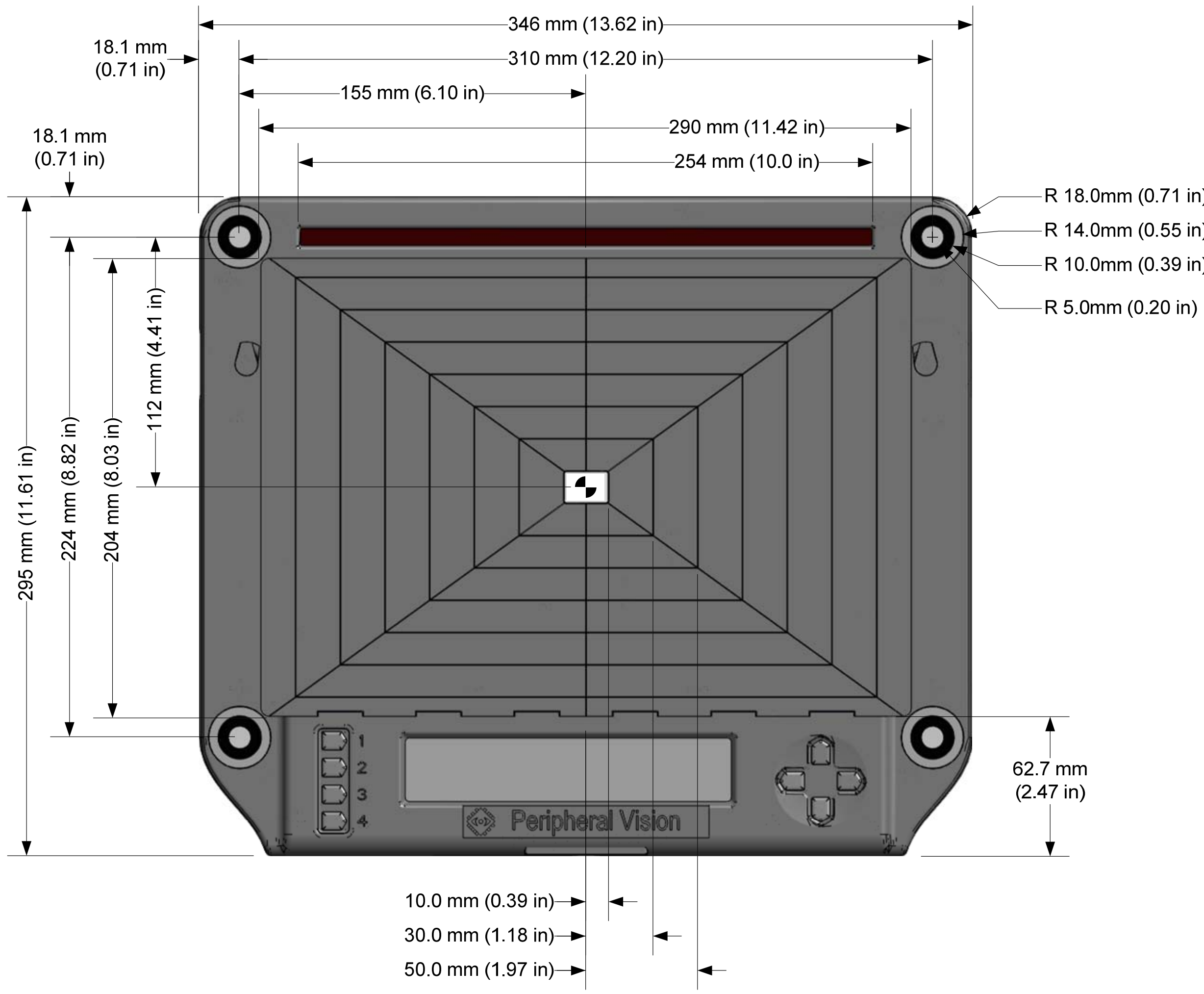


Figure 42. Front view with dimensions

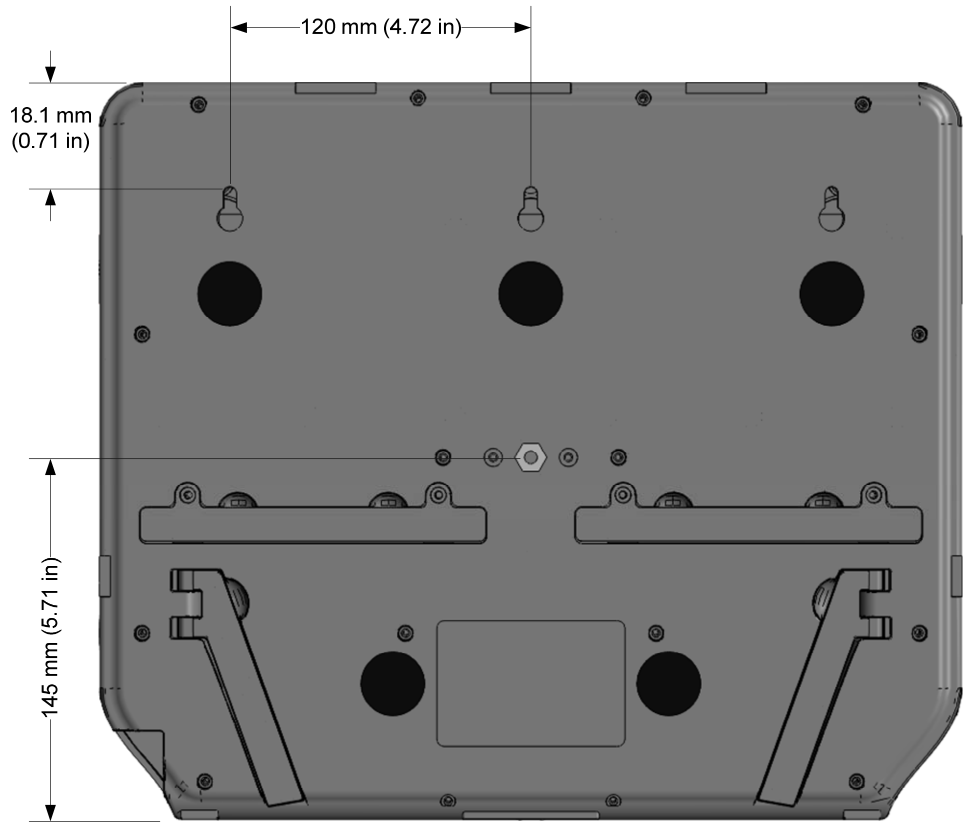


Figure 43. Rear view with dimensions

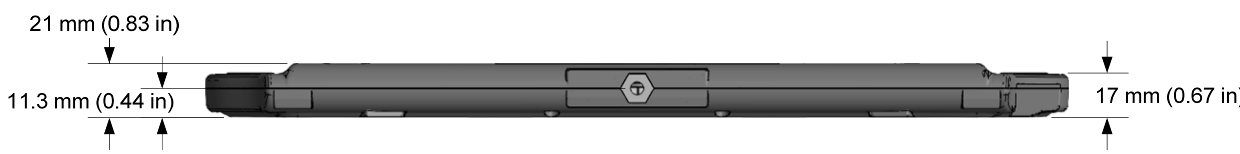


Figure 44. Bottom view with dimensions

Appendix C. Warranty

Peripheral Vision, Inc. (“PV”) warrants to the original purchaser of the Isolight Light Meter with which this **Limited Warranty** (the “Product”) is included that the Product will be free from defects in materials and workmanship under normal use (“Defects”) for a period of **one (1) year** from the date of purchase (the “Warranty Period”). During the Warranty Period, the Product will be repaired or replaced, at PV’s choice without charge to you for parts or labor.

The Limited Warranty does not apply to:

- Normal wear and tear
- Any Product opened or repaired by someone not authorized by PV
- Any Product or part thereof damaged by misuse, moisture, liquids, proximity or exposure to heat
- Accident, abuse, non-compliance with the instructions supplied with the Product, neglect or misapplication
- Physical damage to the surface of the Product
- Any software that may accompany or be installed on the Product
- Installation, removal or maintenance of the Product or any costs related thereto.

To make a claim of a Defect, the purchaser must contact PV during the Warranty Period at 408-588-1928 or via email at custsupport@pv-imaging.com to explain the Defect and to obtain a RMA number (Return Materials Authorization), if necessary. The Product must be returned during the Warranty Period, along with an explanation of the Defect, to the address provided to you by PV. If a defect arises and a valid claim under this Limited Warranty is received by PV after the first one hundred eighty (180) days of the Warranty Period, PV is entitled to charge the purchaser for reasonable shipping and handling costs made in connection with the repair or replacement of the Product. Purchaser must comply with any other return procedures stipulated by PV, if any.

This Limited Warranty gives the original purchaser specific legal rights. Additional legal rights may vary from state to state and jurisdiction to jurisdiction.

If any part of this Limited Warranty is held to be invalid or unenforceable, the remainder of the Limited Warranty shall nonetheless remain in full force and effect.

This Limited Warranty is the only express warranty made by PV and is provided in lieu of any other express warranties or similar obligations (if any) created by any advertising, documentation, packaging, or other communications.

Except for the Limited Warranty, and to the maximum extent permitted by applicable law, PV and its suppliers provide the Product “AS IS AND WITH ALL FAULTS”, and hereby disclaim all other warranties and conditions, whether express, implied or statutory, including, but not limited to, any implied warranties, duties or conditions of: merchantability, non-infringement, quiet enjoyment, system integration, satisfactory quality, fitness for a particular purpose, reliability or availability, accuracy or completeness or responses, results, workmanlike effort, lack of viruses, and reasonable care and skill, all with regard to the Product, and the provision of or failure to provide support or other services, information, software, and related content through the Product, or otherwise arising out of the use of the Product. This exclusion does not apply to (i) any implied condition as to title and (ii) any implied warranty as to conformity with description. If applicable law requires any implied warranties with respect to the Product, all such warranties are limited in duration to ninety (90) days. Some states and/or jurisdictions do not allow limitation on how long an implied warranty lasts, so the above may not apply to you.

This Limited Warranty may not be transferred to any other person.

Limitation Of Warranty

Neither Peripheral Vision, Inc. ("PV") nor its suppliers shall be liable to Purchaser or to any third party for any indirect, incidental, consequential, special or exemplary damages (including in each case, but not limited to, damages for the inability to use the equipment or access data, loss of data, loss of business, loss of profits, business interruption or the like) arising out of the use or inability to use the Product, even in PV has been advised of the possibility of such damages.

Notwithstanding any damages that Purchaser or any third party might incur for any reason whatsoever, including without limitation, all damages referenced herein and all direct or general damages in contract, or anything else, the entire liability of PV and any of its suppliers shall be limited to the amount actually paid by the Purchaser for the Product.

The above exclusions or limitations of incidental or consequential damages are applicable only to the extent permitted by applicable law.

Notwithstanding the above, neither PV's nor any of its suppliers' liability for death or personal injury resulting from its own negligence shall be limited.

Appendix D. Document Revision History

Revision	Date	Changes
1.0	January 21, 2014	Initial release.
1.1	August 1, 2014	Various minor corrections and formatting changes.
1.2	Oct 1, 2014	Adding new commands to match firmware rev 1.5.
1.3	May 22, 2016	Adding new commands to match firmware rev 1.7.