Chapter 5. General Guidelines for Electronic Visual Displays

In this chapter are general guidelines intended to be used for all the electronic visual displays included in the handbook. Guidelines specific to each electronic display, and for nonelectronic displays, are in chapter 6. Table 21 shows to which displays the general guidelines in the present chapter apply.

Table 21. Display types to which general guidelines for electronic visual displays apply.

	Do the General Guidelines in Chapter 5 Apply?	
	Yes	No
Analog/Mechanical		3
Cathode Ray Tube	3	
Counter/Mechanical		3
Electroluminescent	3	
Head-Up Display	3	
Light-Emitting Diode, Matrix Addressed -	3	
Liquid Crystal Display.		
• Transflective, Segmented Characters	3	
• Transflective, Matrix Addressed.	3	
• Transmissive, Matrix Addressed.	3	
Plasma, Matrix Addressed.	3	
Speech		3
Simple Tone		3
Vacuum Fluorescent Display:		
l Segmented Characters.	3	
l Matrix Addressed.	3	
Simple Indicators:		
l Incandescent.		3
l Light-Emitting Diode		3

118. WHEN TO USE:

Electronic visual displays should be used generally where presentation of dynamic information and flexible display formats are more important than power consumption and sunlight visibility.

119. LUMINANCE ADJUSTMENT:

The user should have the capability to adjust luminance level manually. (Based on reference 38.)

120. AIR FROM DISPLAY COMPONENTS:

The exhausting of air from display components should be accomplished so as to avoid discomfort to users of the display or to other users in the vicinity of the equipment.[39]

121. IMMEDIATE DISPLAY SURROUND:

The area immediately surrounding a display screen should be matte black to avoid specular reflections.[40]

Comment: Color may be less important than the matte finish, although black will reduce reflections better than other colors.

122. CONTRAST RATIO:

The minimum required monochrome contrast ratio (defined as $luminance_{higher}/luminance_{lower}$) is 1.5 for acceptable legibility and 2.5 for comfortable reading.[40]

Comment: There is no reason to specify a maximum, since visual performance improves with increases in luminance contrast ratio. If two or more people in the vehicle must use the display simultaneously, or if the display must be usable from multiple positions in the vehicle, the contrast requirement should be met for each viewing position.

123. MAXIMUM LUMINANCE:

Maximum display luminance should be at least 70 to 140 cd/m2 (20.4 to 40.9 fl), measured after any optical effects such as neutral density filters or touch screens which tend to reduce display luminance. (Based on reference 40.)

Comment: A lower display luminance will likely be desirable for night viewing (see guideline 124).

124. LUMINANCE RANGE:

Display luminance should be adjustable over a range of **at least 50:l (highest to lowest), with a preferred range of 100:l.** (Based on reference 40.)

Comment: The preferred range of 100:l assumes that the preferred display luminance level at night will be approximately two orders of magnitude below that required for daylight driving, to avoid uncomfortable display glare and misadaptation of the eyes to the outside visual scene.

125. CONTRAST ENHANCEMENT FILTER:

When a contrast enhancement filter is used on an electronic display, a neutral density filter is preferred to a narrow band filter. (Based on reference 40.)

Comment: Although luminance contrast may be improved by using a narrow-band contrast enhancement filter, a neutral density filter may improve color contrast.

126. LUMINANCE HALF-LIFE:

The luminance half-life of a display (i.e., the total number of operating hours until the display luminance is reduced to 50 percent or less of its original maximum luminance) should be at least 5000 h. (Based on reference 40.)

Comment: Under some circumstances, display luminance may fail catastrophically. However, a gradual loss of display luminance over the life of the display is typical. Operating conditions such as extreme temperatures may cause display half-life to be reduced.[41]

127. VISIBILITY ENVELOPE:

An electronic display must be visible (i.e., retain its required luminance contrast as well as not be physically or optically obstructed) within an envelope defined as:

- **At least ±30° to 40° laterally from the design eye reference point.**
- **At least 30° above and 5° below the design eye reference point.** (Based on reference 40.)

Comment: If two or more people in the vehicle must use the display simultaneously, or if the display must be usable from multiple positions, the visibility envelope requirements should be met for each design eye reference point.[41]

128. SURFACE TEMPERATURES:

External surfaces that can be touched during operation should have a surface temperature that does not exceed 50 °C (122 °F). Surfaces that are intended to be touched during normal operation should not exceed 35 °C **(95 °F).[39]**

129. AVOIDING GLARE:

Displays should be positioned in the vehicle to avoid glare, including both glare from the outside environment and glare from other vehicle lights, displays, and reflective surfaces, to the extent possible. Glare at the display screen should be reduced by using a diffusing (etched)

surface, antireflection coating, or a mesh, or by shielding the display from glare sources. (Based on reference 39.)

Comment: Interior illumination sources include lights and other displays. In general, glare increases with the luminance, size, angle of incidence, and proximity of the source to the line of sight. It may require shielding or filtering to prevent glare from illumination coming from outside the vehicle. Care should be exercised in choosing a glare reduction technique, since some techniques may have the undesirable side effect of reducing the sharpness of the displayed image.

130. COLOR AS A STAND-ALONE CUE:

Make color coding redundant with some other display feature such as symbology; do not code by color alone.[42]

Comment: Redundancy permits people with color vision deficiencies to interpret color coded displays correctly. And, in situations such as high ambient lighting conditions, redundancy can help to ensure the accurate transmission of information where colors alone may be difficult to distinguish even for persons with normal color vision.

131. COLOR CODING QUANTITATIVE INFORMATION:

In general, color should not be used to code quantitative information unless that information can be divided into a small number of distinct categories, such as has been done for color coded weather radar map displays.[43]

Comment: Color has been shown to be effective as a coding scheme, particularly for qualitative information. Where more than a small number of coding categories exist, other coding schemes, such as alphanumerics, are more efficient for the transmission of the information. However, the use of color may still enhance information transmission if the separate categories can be logically divided into several major divisions.[43]

132. NUMBER OF COLORS TO USE:

In general, no more than six symbol colors should be used on displays. These include white, red, green, yellow (or amber), magenta (or purple), and cyan (or aqua). These six colors plus black, gray, brown, and blue for background shading can be used effectively.[43]

Comment: The use of more than six symbol colors may degrade performance on search, identification, and coding tasks due both to poorer discriminability (especially under high ambient light) and a loss of organizational value.[43]

133. ACCENTUATING COLOR DIFFERENCES:

To accentuate differences among colors, differences in the brightness of display colors should be used wherever possible.[43]

Comment: Although the terms luminance and brightness are often used interchangeably, they really refer to separate concepts. Luminance is a physical measure of the amount of light and can be measured by instrumentation. Brightness, however, is a person's perception of luminance and cannot be directly measured by instrumentation. An increase in luminance will normally lead to an increase in brightness, but the increase in brightness will not be a linear function of the luminance increase. In addition, objects displayed at equal luminances but in different colors may appear to vary in brightness.

134. RELATIVE BRIGHTNESS AND CHROMATICITY OF COLORS:

Since brightness differences are a source of information, the relative brightnesses of colors should remain the same over the total luminance range of the screen. Also, chromaticity (color quality) should track over the luminance range of the display.[43]

Comment: In addition to relative brightness changes, the hue (dominant wavelength) and saturation of colors may appear to change as luminance is varied. Hue changes may cause viewers to misname colors (e.g., red vs. orange), while saturation changes will cause confusion among colors that vary primarily in the amount of gray.[41]

135. COLOR CONVENTIONS:

Traditional warning and caution colors (red and amber or yellow) should be reserved solely for those purposes, as the use of these colors for other functions will degrade their alerting value. Color conventions include the following:

a. Red is used to indicate an alarm condition.

b. Flashing red is used to indicate an emergency condition requiring immediate user action.

c. Yellow is used to indicate a caution condition.

d. Green is used to indicate a normal, in-tolerance condition.

e. White is used as a neutral color.[14,42,43]

Comment: The handbook editors believe this guideline applies to cases where the simple colors are used to convey information by themselves, as opposed to when they are used as parts of complex graphics (e.g., a red fire engine).

136. USE OF PURE BLUE:

Pure blue on a dark background should be avoided for text, for thin lines, and for high resolution information.[39]

Comment: The normal eye is blue-blind in the central fovea.

137. USE OF PURE RED AND PURE BLUE TOGETHER:

Simultaneous presentation of both pure red and pure blue (or to a lesser extent red and green, or blue and green) on a dark background may result in chromostereopsis (a three-dimensional effect) and should, therefore, be avoided unless chromostereopsis is acceptable or intentional.[39]

Comment: Chromostereopsis (the color-induced illusion of three dimensionality) is generally uncomfortable to view and should be avoided if the primary purpose of the display is to convey information rather than to entertain.

138. CHARACTER HEIGHTS AND COLOR DISCRIMINATION:

Table 22 shows minimum character heights below which color discrimination is expected to deteriorate. (Based on reference 43.)

Table 22. Minimum character sizes for some color discriminations.[1]

	Blue vs. Yellow	Red vs. Green
Minimum size on the retina	30 arcmin	15 arcmin
Minimum height, centimeters	Viewing distance/l 14.59, where distance is in centimeters	Viewing distance/229 18, where distance is in centimeters

[1] The formula for determining character height (h) upon which the table is based is as follows:

$$h = 2\left(\tan\left(\frac{\text{character size on the retina}}{2}\right)\right)(\text{viewing distance})$$, where h and viewing distance are in centimeters, and character size on the retina is in degrees. [41]

Retinal character size is used because it is independent of viewing distance. Thus, one can tell whether a character that subtends 30 arcmin (its retinal size) can be read without knowing the distance at which it is viewed, but one could not tell whether a 0.3-cm- (0.12-in-) high character could be read without knowing the viewing distance.

Example of determining character height (in centimeters) using the formula shown in the table: what character height is needed if a user must discriminate between red and green at a viewing distance of 76.2 cm (30 in)? Character height = 76.2/229.18 = 0.33 cm (0.13 in). So, at a distance of 76.2 cm (30 in), a character height of not less than 0.33 cm (0.13 in) is recommended if the user must discriminate between red and green.

139. POLARITY:

Either display polarity-dark characters on a light background or light characters on a dark background- i s acceptable provided it meets the other display requirements.[39]

Comment: The presentation of dark characters on a light background may reduce the effects of distracting reflections from the surface of the display. The effects, however, of disability glare (the loss of character contrast, for example) caused by superimposed reflections are the same for displays of either polarity. Cathode ray tube displays on which dark characters are presented on a light background appear to minimize the effect of reflections on the user's screen, but such displays may require a higher refresh rate in order not to appear to flicker.[39]

140. BRIGHTNESS/CONTRAST COMPENSATION:

An automatic brightness/contrast compensation system should be used. This permits the maintenance of acceptable image brightness and chromatic (color) differentiation under all ambient light conditions without the user having to manually make the adjustments.[43,44]

Comment: In general, three types of brightness control are needed to provide a satisfactory automatic compensation system: (1) a manual brightness control to accommodate individual differences in the visual sensitivity of users as well as the use of sunglasses or sun visors, (2) an automatic brightness/contrast compensation system that changes the display luminance as a function of the changing ambient light levels incident on the display (as detected by an internal light sensor integral to each display), and (3) an automatic brightness/contrast compensation system that changes the display symbol-to-background contrast as a function of changing luminance levels in the user's forward field of view (as detected by a remote, forward facing light sensor). [43]

141. LUMINANCE UNIFORMITY:

Luminance uniformity, the variation from the center to the edge of the active area of the display, should not vary by more than 50 percent of the center luminance.[39]

Comment: Luminance variations that occur gradually over the display surface may be quite large without being bothersome or even detectable, while much smaller luminance variations that occur in adjacent screen areas will be noticeable.[41]

142. RELATIVE DISCRIMINATION AND LUMINANCE DIFFERENCES:

For relative discrimination, adjacent areas on the display (e.g., sections of a pie chart) should have a luminance difference of at least 7 percent. Nonadjacent areas (e.g., in highlighted text) should have a luminance difference of at least 20 percent.[39]

143. FLASHING SYMBOLS:

Flashing may be used to draw attention to critical information or for danger conditions. No more than two different flash rates should be used. If a single flash rate is used, it should be 3 to 5 Hz. If two flash rates are used, the slow rate should be not less than 0.8 Hz and the fast rate should not be more than 5 Hz; the difference between the two rates should be at least 2 Hz. In any case, the percentage of time that the image is on (i.e., the duty cycle) should be greater than or equal to the time that it is off; a 50 percent duty cycle is preferred.[14,39]

Comment: Flashing symbols may become annoying and become a distraction. Users should be provided with a means to acknowledge the message and terminate the flashing.[41]

144. CHARACTER HEIGHT-TO-WIDTH RATIO:

The height-to-width ratio of a given character is the ratio of the vertical distance between the top and bottom edges (height), and the horizontal distance between the left and right edges (width) of a nonaccented capital letter. For fixed (as opposed to proportionally spaced) column presentations, the character height-to-width ratio should be between 1:0.7 and 1:0.9. For display formats requiring more than 80 characters on a line, ratios as low as 1:0.5 are permitted. For proportionally spaced presentations, a height-to-width ratio closer to 1:1 is permitted for some characters, for example, the capital letters M and W.[39]

145. MATRIX SIZE FOR SPECIAL CHARACTERS:

A 4 by 5 (width by height) character matrix should be the minimum matrix used for superscripts and for numerators and denominators of fractions that are to be displayed in a single character position. The 4 by 5 matrix may also be used for alphanumeric information not related to the user's task, such as copyright identification.[39]

Comment: References to matrix size and number of pixels do not apply to segmented-character liquid crystal and vacuum fluorescent displays.[41]

146. MATRIX SIZE FOR NUMERIC AND UPPER CASE CHARACTERS:

A 5 by 7 (width by height) character matrix should be the minimum matrix used for numeric and upper-case-only presentations. The vertical height should be increased upward by two pixel positions if diacritical marks are used.[39]

Comment: References to matrix size and number of pixels do not apply to segmented-character liquid crystal and vacuum fluorescent displays.[41]

147. MATRIX SIZE FOR READING OR LEGIBILITY:

Legibility is the rapid identification of single characters that may be presented in a noncontextual format. A 7 by 9 (width by height) character matrix should be the minimum matrix for tasks that require continuous reading for context, or when individual alphabetic character legibility is important. The vertical height should be increased upward by two pixel positions if diacritical marks are used. If lower case is used, the vertical height should be increased downward by at least one pixel position, preferably two or more, to accommodate descenders of lower case letters.[39]

Comment: References to matrix size and number of pixels do not apply to segmented-character liquid crystal and vacuum fluorescent displays.[41]

148. MATRIX SIZE FOR SYMBOL ROTATION:

When symbol rotation is required, a minimum character matrix of 8 by 11 (width by height) is required, with 15 by 21 preferred.[13,45]

Comment: Symbol rotation requires greater character addressability to counteract reduced legibility as a function of aliasing (jagged lines) introduced at irregular character positions. Also, references to matrix size and number of pixels do not apply to segmented-character liquid crystal and vacuum fluorescent displays.[41]

149. BETWEEN-CHARACTERS SPACING:

Between-characters spacing should be a minimum of 10 percent of character height. A two-pixel space between characters may enhance readability in some cases.[39]

Comment: References to matrix size and number of pixels do not apply to segmented-character liquid crystal and vacuum fluorescent displays.[41]

150. BETWEEN-LINES SPACING:

A minimum of two stroke widths or 15 percent of character height, whichever is greater, should be used for spacing between lines of text. The space between lines of text should not be used for upper case accent marks or for lower case descenders of characters.[39]

151. BETWEEN-WORDS SPACING:

A minimum of one character width (capital N for proportional spacing) should be used between words.[39]

152. FONT TYPE:

Script and other highly stylized fonts (e.g., shadow, calligraphy) should be avoided. Preference should be given to simple styles with straight lines and clear differences between 0 and 0 (zero) and between S and 5. Lincoln/Mitre and Leroy are preferred fonts.[38,46]

153. CHARACTER HEIGHT FOR LEGIBILITY:

Legibility is the rapid identification of single characters that may be presented in a noncontextual format. For a task in which legibility is important, character height should conform to the recommendations in table 23. (Based on reference 39.)

154. CHARACTER HEIGHT FOR READABILITY:

Readability is the ability to recognize the form of a word or group of words for contextual purposes. For a task in which readability is important, character height should conform to the recommendations in table 23. (Based on reference 39.)

155. CHARACTER HEIGHT FOR NONTIME-CRITICAL READING:

For a reading task in which identification of individual characters is not time-critical, character height should conform to the recommendation in table 23. (Based on reference 39.)

Table 23. Minimum character sizes for legibility and readability.

	For Legibility	For Readability	For a Reading Task in Which Identification of Individual Characters is Not Time Critical
	CHARACTER SIZE ON THE RETINA, ARCMINUTES		
Minimum	16	16	10
Preferred	20 to 22	20 to 22	-
Maximum	45	24	-

(Table continued on next page.)

Table 23. Minimum character sizes for legibility and readability (continued).

	For Legibility	For Readability	For a Reading Task in Which Identification of Individual Characters is Not Time Critical
	CHARACTER HEIGHT, CENTIMETERS[a]		
Minimum	Viewing distance/214.86[b]	Viewing distance/214.86[b]	Viewing distance/343.77[b]
Preferred	Viewing distance/l71 .89[b] Viewing distance/156.26[b]	Viewing distance/l71 .89[b] to Viewing distance/156.26[b]	-
Maximum	Viewing distance/76.39[b]	Viewing distance/143.24[b]	-

[a] The formula for determining character height (h) upon which the table is based is as follows:

$$h = 2\left(\tan\left(\frac{\text{character size on the retina}}{2}\right)\right)(\text{viewing distance})$$

where h and viewing distance are in centimeters, and character size on the retina is in degrees.[41]

Retinal character size is used because it is independent of viewing distance. Thus, one can tell whether a character that subtends 30 arcmin (its retinal size) can be read without knowing the distance at which it is viewed, but one could not tell whether a 0.3-cm- (0.12-in-) high character could be read without knowing the viewing distance.

Example of determining character height (in centimeters) using the formula shown in the table: If readability is important, what is the minimum character height needed at a viewing distance of 101.6 cm (40 in)? Character height = 101.6/214.86 = 0.47 cm (0.19 in).

[b] Viewing distance is in centimeters.

156. MINIMUM VIEWING DISTANCE:

The minimum design viewing distance should be 30.5 cm (12 in).[39]

Comment: Shorter viewing distances pose a problem for older users, who typically have difficulty focusing on close objects due to presbyopia. Shorter viewing distances to in-vehicle displays may also increase the risk of physical injury to the user and to the display. And, shorter viewing distances to in-vehicle displays may increase the time required for users to visually transition from the display to the outside world (provided the accommodation distance of the display is not greater than the viewing distance).[41]

157. SYMBOL/IMAGE MOTION:

When moving symbols or images are displayed, motion should be smooth and without any unintended ratcheting or jerked motion. (Based on reference 47.)