Methods of Legend Fabrication

Application Note 1012

INTRODUCTION

Avago Technologies LED Light Bar Modules inscribed with fixed messages or symbols can be used to construct economical annunciators. Annunciators can be used in a variety of ways; to convey the status of a system, to indicate a selected mode of operation, or to indicate the next step in a sequence. Light bars are available in 5.08 mm x 10.16 mm (0.2 inch x 0.4 inch), 5.08 mm x 20.32 mm (0.2 inch x 0.8 inch), 10.16 mm x 10.16 mm (0.4 inch x 0.4 inch), and 10.16 mm x 20.32 mm (0.4 inch x 0.8 inch) sizes and in either single surface or multi-segmented form. Light bars can be easily installed in front panels using the Avago Technologies Panel and Legend Mount (HLMP-2598, -2599, -2898. -28991.

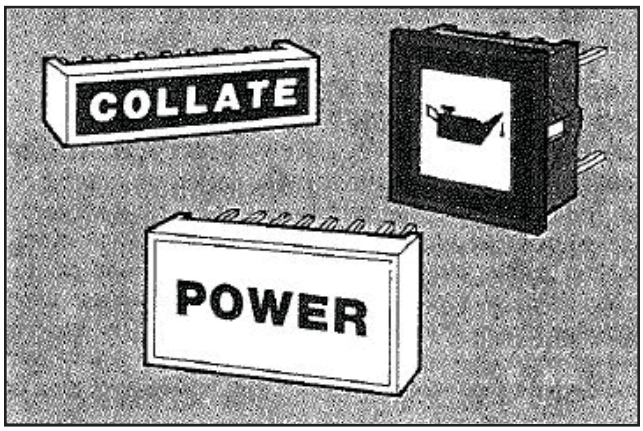
This application note discusses alternative ways the message or symbols (legends) can be designed. A selection matrix is then provided to assist in the selection of the most appropriate method of legend fabrication. Each fabrication method is explained in detail along with mounting and attachment techniques. Finally, prevention of cross-talk is discussed for legend areas of a multi-segmented light bar

LEGEND DESIGN

Format

The two basic legend formats are shown in Figure 1. Dark field format consists of a transparent message with an opaque surround. Dark field formats are typically used to display a message that conveys routine information, such as the next step in a sequence or a selected mode of operation. Light field format, the inverse, consists of an opaque message with a transparent surround. The transparent surround permits a maximum amount of emitted light to catch the eye of an observer. Light field formats are typically used to indicate critical messages, for example, when a tank nears empty and needs to be refilled.

Figure 1. The Two Basic Legend Formats



Font

Easy-to-read bold faced characters or symbols are more desirable than light faced characters or symbols (Figure 2). Suggested type faces are Helvetica, Futura Demi-Bold or Univers 65.

The size of the characters in the legends are directly related to the distance at which they are viewed. The following table, based on normal visual acuity[1], shows character height necessary to comfortably read the display from various distances.

Table 1. Viewing distance vs. character height

Viewing Distance Metres (Feet)	Min. Character Height mm (inch)
1 (3.3)	1.45 (0.06)
2 (6.6)	2.91 (0.11)
3 (9.9)	4.36 (0.17)
4 (13.2)	5.82 (0.23)

Note:
1. Character Height (mm) = Viewing Distance (m) x 1.454
   Visual activity = 5 minutes of arc for 20/20 vision
   Tangent of 5 minutes of arc = 1.454 x 10^{-3}.

Figure 2. Boldfaced Characters and Symbols Make Legends that are Easy to Read

Front Panel Appearance

If it is desirable to conceal the message when the device is OFF, a Dead Front can be employed. A Dead Front can be achieved by placing a low transmission filter over the display to reduce contrast between off segments and the background of the legend. It may also be necessary to reduce the color difference between off segments and the background by using transparent and neutral density gray areas to form the legend. In this case, the transparent portions of the legend as they reflect ambient light in the OFF condition will appear similar in color to the neutral density gray. In the ON condition, the illuminated transparent areas of the legend will contrast vividly with the neutral density gray.

In many cases it may be desirable for the observer to be aware of the message in both the ON and OFF state. This is achieved by using a higher transmission filter and/or legend areas with a large color difference, such as black and transparent areas, in the OFF state the background area will have a recognizable color difference from the transparent area and the message will be readable.

SUMMARY AND COMPARISON OF LEGEND GENERATION TECHNIQUES

Two basic methods can be used to fabricate legends for light bar modules. The first involves engraving directly on the front surface of the light bar and filling the engraved area with opaque enamel. The second method involves fabricating a thin film legend such as an exposed photographic film, silkscreened polycarbonate film, prefabricated adhesive film or instant lettering. These thin film legends are applied to the light bar with the Avago Technologies Panel and Legend Mount, with double sided transparent tape or with adhesive backing. Figure 3 shows the steps required in each fabrication method.

Durability of the legend is often an important factor to the designer. The following tests have been performed on samples of each of these legend fabrication methods, where applicable:

Temperature Cycling:	100 cycles from -40° C to +85° C 15 min. at extremes, 5 min. transfer
Temperature Storage:	+55° C 1000 hours
Humidity Test:	5 days, 90-98% RH, -10° C to +65° C non-operating
Transmission Test:	Visual inspection
Peel Strength Test:	Maximum dynamometer deflection at constant rate of peel (127 minute)
Taber Abrasion Test:	500 grams for 1,000 cycles
UV Testing:	2 years simulated UV exposure under QUV® weathering equipment
Solvent Resistance:	Freon, Methanol, Isopropanol, Alcohol, Water

Table 2 shows results of these tests and also provides information on relative costs.

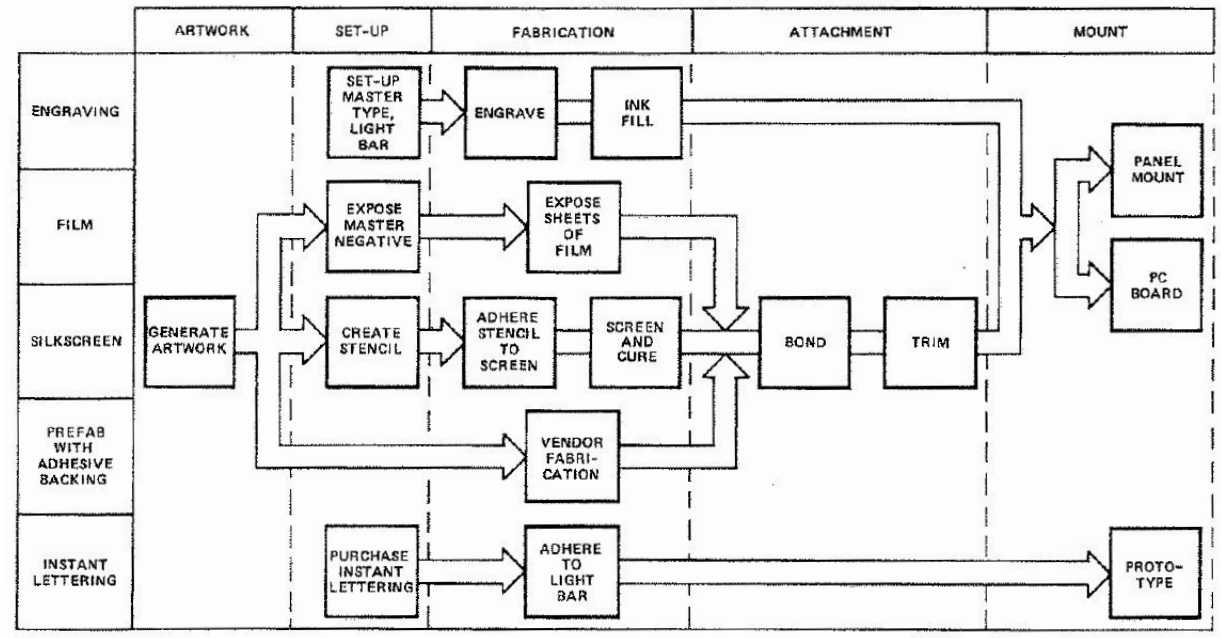


Figure 3. Legend Fabrication Methods

Table 2. Selection Matrix

	Format/Mounting				Durability				Relative Cost	
Legend Fabrication Method	Dark Field	Light Field	Dead Front	Panel and Legend Mount	Abrasion Resistance	Temp. Compat-ibility	Peel Strength	Solvent Resistance	Set-Up Cost	Manufac-turing Cost
Engraving		X		X	X	X	Excellent	Good	High	High
Photographic	X	X	X	X	X	X	Good	Good	Low	Med Low
Silkscreen[1]	X	X	X	X	[1]	X	Good	Fair	Med	Med Low
Prefab with Adhesive Backing[2]	X	X	X	X	X	X	Good	Good	Low	Low
Instant Lettering[3]		X		X			Poor	Poor	Low	Med

Set-Up Cost:
Cost of original artwork, tools, equipment necessary to begin legend fabrication.

Manufacturing Cost:
Cost of raw materials, and labor necessary to fabricate and assemble a legend on a light bar.

Notes:
1. Abrasion resistant only when backprinted.
2. For extreme ultra-violet exposure. Brady-Panel® is the recommended fabrication method.
3. Recommended for prototype applications only.

ENGRAVING

Engraving is recommended for high temperature and high humidity applications. It should be noted, however, that engraving is only appropriate for light field formats.

Since small areas are to be engraved, such factors as type font, letter height and spacing between letters is very important. For smaller letters regular master type is recommended and for larger letters condensed master type is recommended. After the master type is set the light bar must be rigidly mounted in a vice which holds three sides in place and prevents the leads from bending.

For best results a calibrated engraving machine is necessary to control depth of cut and alignment. Several manufacturers of engraving machinery and cutting tools are listed below:

New Hermes Incorporated	1711 Monarch Street Garden Grove, CA 92641 (714) 898-9265
Lars Machine Inc. Gorton	1925 Roosevelt Avenue Racine, Wisconsin 53406 (414) 554-8880
Richards Micro-Tool Inc. (*end mills only*)	100 Nicks Rock Road Plymouth, Massachusetts (617) 617 746-6900

The depth of cut should be only 0.245 mm (0.010 inch) deep. Carbide cutters are recommended because they are extremely rigid and long lasting. The tool shape can either be a tapered shank cutter with a conical point (65° ± 5° included angle) or a straight shank end mill. For visual balance smaller letters need smaller width end mills and larger letters need larger width end mills. As a guide, for letter heights greater than or equal to 3.06 mm (0.125 inch) a 0.382 mm (0.0156 inch) end mill is recommended.

The end mill, although more fragile than a tapered cutter, offers some advantages. The shape of the end mill allows the operator to be less concerned about variations in cutting depth because the width of cut is dependent only on the width of the end mill. When using the tapered cutter the operator must be careful to engrave at a constant depth because width of cut is dependent on depth of cut. Also, due to its shape, the tapered cutter may need to be resharpened more often than an end mill. If the tip of the tapered cutter becomes dulled the width of cut will increase whereas, if the tip of the end mill becomes dulled the width of cut will remain the same.

Fill the engraved area with a viscous fiat black enamel for best results. The following enamels are recommended:

Gliddens 908 Flat Black® All Purpose Enamel	SCM Corporation Gliddens Coatings and Resins Division 801 Cantebury Rd. Westlake, Ohio 44145 (216) 344-8000
Impervo-Flat Enamel® Black 23581	Benjamin Moore Co. 51 Chestnut Ridge Rd. Montvale, NJ 07645 (201) 573-9600
Rust-Oleum Matte Black® 7776 enamel-oil base	Rust-Oleum Corporation 11 Hawthorne Parkway Vernon Hills, IL 60061 (312) 367-7700
New Hermes-Engravers® Enamel Black 30-450-35	1711 Monarch St. Garden Grove, CA 92641 (714) 898-9265

Enamel is applied with a small brush (standard 2 or 3), with a lintless wipe used immediately after to clean off the excess. The excess enamel should be kept away from the edges of the module. If, however, some enamel does become lodged along the border between the epoxy encapsulant and polycarbonate package, a solvent, such as Shell Sol BT-67® manufactured by Shell Oil Company, can be applied with a lintless wipe to clean the edges. Finally, after the enamel is nearly dry, a lintless wipe dipped in methanol or isopropanol alcohol can be used to clean the module.

THIN FILM LEGENDS

Legend Artwork

All thin film methods except "instant lettering" require the generation of photo-reproducible artwork. For best results this artwork layout should be done carefully on an enlarged scale and then reduced. Since legends must be precisely placed on the face of the light bar, alignment marks should be included in the artwork. The legend artwork, shown in Figure 4a, contains alignment marks and notched corners. By making the legend 0.005 inch oversized on each edge, any slight misalignment that might occur during attachment will not be noticeable (Figure 4b).

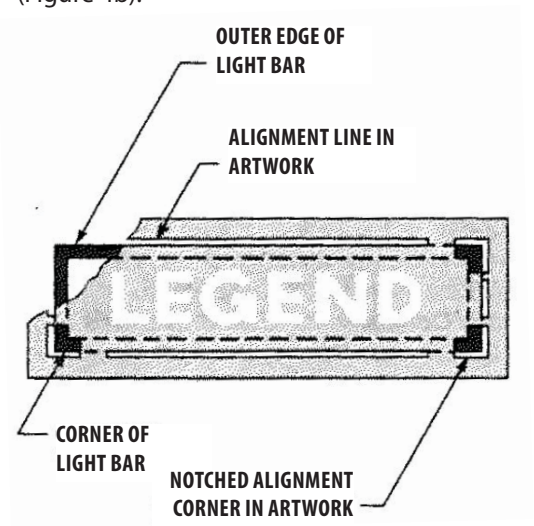


Figure 4a. Legend Artwork with Alignment Marks

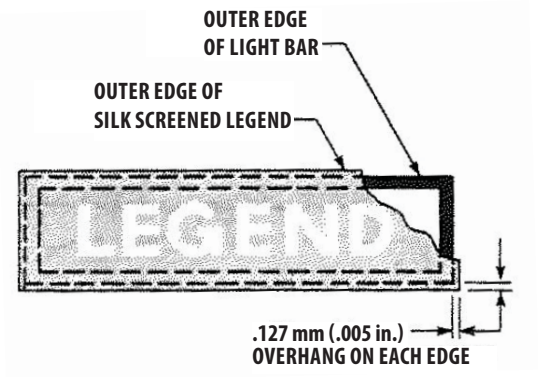


Figure 4b. Legend Artwork with Overhang to Allow for Alignment

PHOTOGRAPHIC PROCESS

The photographic process is fast and relatively inexpensive. First, the artwork is reduced, stepped and repeated to a master negative. Then, this master negative is used to expose each sheet of film in such a way that the legend is exposed through the film stock. Thus, when a legend is attached to a light bar the emulsion is in contact with the tape and epoxy encapsulant. Although the film stock protects the compile emulsion from exposure or abrasion specular reflections off the front surface is increased.

Ester based films which feature dimensional stability, contrast, maximum optical density and a very low fog level are recommended. Two polyester based films have been tested and found satisfactory – Kodak Reproduction Film 4566® and Kodalith Ortho Film type 3 4556®. Similar films can also be obtained from other manufacturers, such as Agfa Gavaert, GAF, or Dupont. Both recommended films have the same polyester base but different emulsions and development procedures. Kodak Reproduction Film, traditionally used in line work reproduction, offers greater strength and less susceptibility to pin-hoies. The Kodaiith-Ortho film is more sensitive to pin-holes or dust, and has been traditionally used in half-tone reproduction.

SILKSCREEN

The Legend Substrate

A thin untinted transparent film of polycarbonate or polyester may be used as the legend substrate. A material that exhibits very good performance is 0.102 mm (0.004 inch) thick LEXAN® Fiim No. 8010-112 manufactured by General Electric, Plastics Division, Speciality Plastics Department, 1 Plastics Avenue, Pittsfield, Massachusetts 01201. Silk-screening paints and inks adhere very well to LEXAN®. LEXAN® also exhibits very good dimensional stability with temperature variations. Polyester film, such as 0.102 mm (0.004 inch) Formula Type S MYLAR® produced by the E.I. Dupont de Nemours Company, Wilmington, Delaware 19898, may also be used as a legend substrate, although specially formulated inks are required. Epoxy inks and acrylic inks should not be used on Polyester films because the ink does not adhere well to the film.

The Silkscreening ink

Certain formulated inks, acrylic laquer type inks or epoxy inks may be used in the silkscreening process. Both polycarbonate and polyester may be screened with GF 140®, a formulated ink produced by General Formulations, 350 S. Union, Sparta, Michigan 49345. GF 140® is unusually tough and flexible, but due to its solubility characteristics special caution is required. The ink exhibits an extremely strong affinity for polyester and polycarbonate and other materials such as paper. Therefore, silkscreened film sheets should not be stacked on top of each other or stacked interleaved with paper until after the ink has been cured.

Nazdar 70-111®, a modified acrylic-lacquer type ink, may also be used to print on polycarbonates. Nazdar inks are manufactured by the Nazdar Company, 1087 N. North Branch Street, Chicago, Illinois 60622.

This ink is very easy to handle and to clean up. However, adhesion to the polycarbonate substrate is not as permanent as with the other recommended inks. One epoxy ink recommended for use only on polycarbonate films is the WORNOWINK® Series 50 with #9 catalyst produced by the Hysol Division, Dexter Corporation, 15051 E. Don Julian Road, Industry, California 91749. After screening an epoxy ink will quickly air dry to a semi-hard state that permits the legends to be sheared or cut to size without any smearing, chipping or peeling. With epoxy based ink, care must be taken to add the proper amount of catalyst. If too much catalyst is added the ink may continue to harden after the normal cure cycle. This hardening occurs over a period of several months and may cause the ink to become brittle. Thus, screened sheets may have a limited shelf life and should not be stored for a long period of time prior to light bar adhesion. When cured at elevated temperatures epoxy paints exhibit a high degree of abrasion resistance and chemical resistance.

Screen Mesh

Ink thickness is determined by the screen mesh and to a lesser degree the height of the screen above the polycarbonate sheet. The silkscreening process should produce a controlled ink thickness of 0.025 mm (0.001 inch). A thicker layer of ink may cause the legend substrate to curl or the ink to crack during temperature cycling. For each of the inks listed above the following screen mesh sizes are recommended:

50/9 WORNOWINK	200 mesh
GF140	200 mesh, 325 mesh
Nazdar70-111	325 mesh

Printing

Front printed legends are formed by screen printing the ink on the top side of the legends. When the legends are attached to the light bar the ink is exposed. Because the ink is exposed, front printed legends are not suited for abrasive environments. All the inks described above are suitable for front-printing; however, only one ink, GF 140, can be used for back printing.

A back-printed legend is formed by screening the ink on the backside of the legends. Thus, when applied to a light bar, the ink is in contact with the tape, and the polyester film serves as a protective coating. Back-printed legends with GF 140 ink exhibit abrasion resistance and slightly stronger adhesion than front printed GF 140 legends.

PREFABRICATED LEGENDS WITH ADHESIVE BACKINGS

Some manufacturers sell custom constructed polycarbonate or polyester legends backed with an industrial strength adhesive. Brady manufactures Poly-Panel®, a material constructed from second surface printed polycarbonate. Brady Poly-Panel® comes in a variety of colors and textures. A shiny clear texture materia! transmits the most light, but increases specular reflections. Therefore, this material should only be used behind a filter. A velvet texture, on the other hand, offers a diffused dead front appearance but at the cost of a greater attenuation of light. Brady Poly Panel®, thickness not to exceed 0.010 inch, can be ordered with B-196® adhesive backing, a transparent unsupported acrylic pressure sensitive adhesive backing.

The Brady Poly-Panel® has no loss of properties due to abrasion or UV exposure. Data sheets with extensive reliability testing can be obtained from the manufacturer:

W.H. Brady Co. Nameplate Division 750 West Glendale Avenue P.O. Box 571 Milwaukee, Wisconsin 53201 (414)332-7620	Poly-panel with polycarbonate substrate B-196 adhesive thickness – 0.005-0.010 inch texture – clear or velvet

INSTANT LETTERING

Instant lettering is a quick method of legend fabrication. It is usually limited to prototype applications, because under extreme temperature cycling and humidity testing noticeable bubbles may form. Also, the adhesive bond between instant lettering and the light bar is weak.

Letraset, a manufacturer of instant lettering, offers a broad line of typefaces and symbols that are easy to apply. The letters or symbols are simply transferred to the light bar with a burnishing tool. To protect Letraset a polycarbonate sheet (see silkscreening section) may be attached over the instant letters.

ATTACHING A LEGEND TO A Avago Technologies LIGHT BAR

Using the Legend in a Light Bar Panel and Legend Mount Avago Technologies Panel and Legend Mounts (HLMP-2598, -2599, -2898, -2899), are used to install light bars in frontpanels. A space has been provided for holding a 0.13 mm (0.005 inch) thin film legend over the front surface of the light bar. Legends shouid be trimmed to the size of the light bar prior to installation.

Panel and legend mounts are convenient because no adhesive or tape is required to hold the legend in place. For more specific instructions on mounting techniques refer to the Avago Technologies Panel and Legend Mount data sheet.

Tape

All thin film legends, except those with adhesive backings can be bonded to the face of a light bar with an optically transparent tape. Two tapes which have been tested and found satisfactory are M69®, produced by the Connecticut Hard Rubber Company, 407 East Street, New Haven, Connecticut 06509, and POLYKEN 126® produced by the Kendall Company, Polyken Division, 1 Federal Street, Boston, Massachusetts 02101. These optically transparent tapes consist of a polyester film carrier with acrylic adhesive on each side and a release backing. The thickness of the adhesive and carrier combination is typically 0.102 mm (0.004 inch). Both tapes can be purchased slit to desired width and of the two tapes M69® exhibits slightly stronger adhesion to the film substrate.

Bond

The steps to bond legends without adhesive backings to the face of the light bar are:

1. With release backing intact, apply the exposed adhesive side of the tape to the back side of the legend or front surface of the light bar with firm pressure.
2. Remove the release backing. Align the legend to the face of the light bar and apply with firm pressure. It is important to ensure that there are no voids in the adhesive/legend and adhesive/light bar interfaces. Voids in the adhesive interfaces, as illustrated in Figure 5, reduce light transmission through the legend due to Fresnel loss and do not permit a secure bond to take place.
3. Trim the legend to size with a pair of scissors or a small shear. (Figure 6)
4. For increased adhesion, oven cure the assembly at a temperature of 115° C (240° F) for 4 hours.

Note: For legends with adhesive backings follow steps 2 and 3 only.

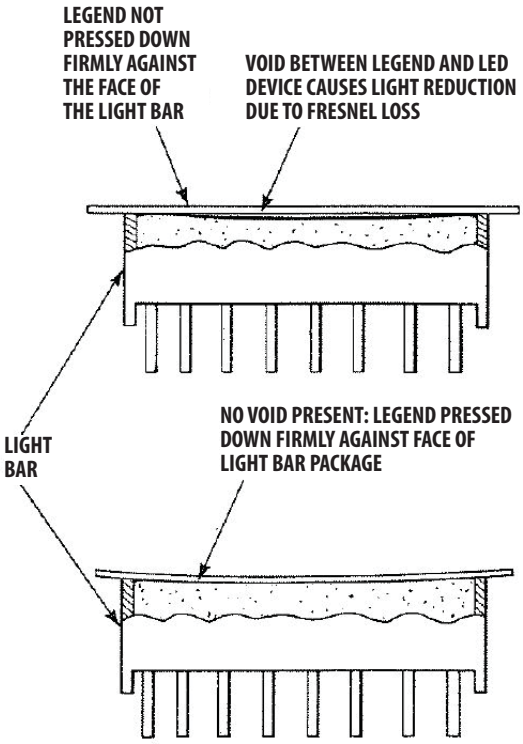


Figure 5. Securely Attached Legend Prevents Reduction of Light Due to Fresnel Loss

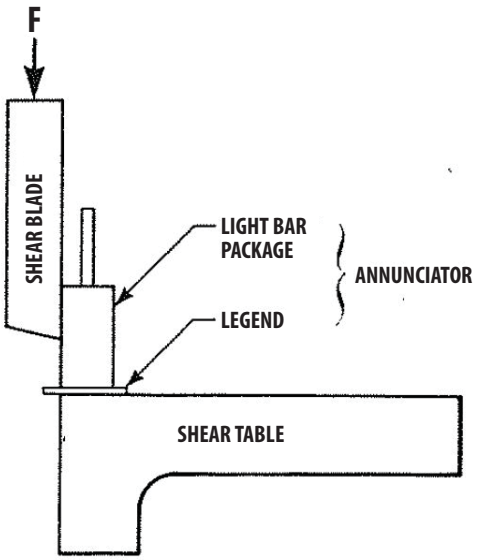


Figure 6. Shearing Legend to Size

REDUCTION OF CROSSWALK IN A MULTI-FUNCTION ANNUNCIATOR

Some Avago Technologies Light Bars provide more than one light emitting surface within the same package. Each light emitting surface may be illuminated independently. A single mufti-function legend may be applied to a multi-segmented light bar to form a small annunciator that is capable of displaying as many as four independent messages or symbols.

However, the legend substrate and the acrylic adhesive tend to act as light pipes. Some light travels from an illuminated area of the multi-function legend to adjacent non-illuminated areas, as illustrated in Figure 7. This light leakage, called cross-talk, if severe enough can cause confusion between the ON and OFF status of the adjacent functions displayed by the legend areas.

Cross-talk can be reduced by using dark field format and by printing on the back side of the legend substrate. Back side printing reduces the amount of emitted light that enters the substrate. Thus, the amount of light than can leak into adjacent legend areas is decreased.

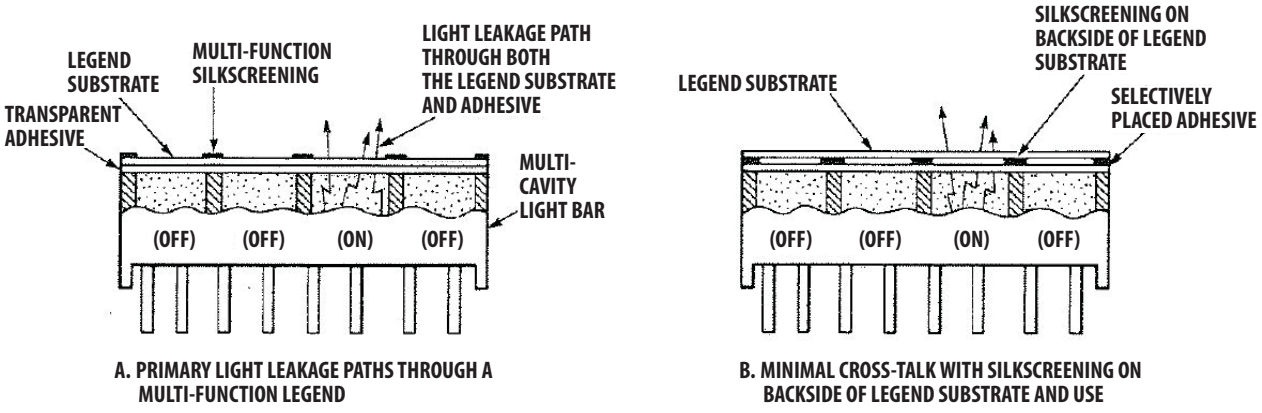


Figure 7. Light Leakage (Cross-Talk) Between Illuminated and Non-illuminated Portions of a Multi-Function Legend Bonded in a Multi-Cavity Light Bar

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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