Benefits of LEDs for Instrument Cluster Lighting

Application Brief A02

Introduction

LED technology provides a number of benefits over incandescent bulbs for instrument cluster lighting. For purposes of comparison, a MY92 Ford Thunderbird instrument cluster was retrofitted with 100% LED lighting. A number of measurements were made between the original incandescent bulb design and the LED prototype. A summary of the key findings is listed below:

Benefits of LEDs for Instrument Cluster Lighting

1. LEDs Have Lower Power Consumption

In this design, the LED instrument cluster uses 1/5 of the electrical current of the incandescent instrument cluster.

2. LEDs Have Less Heat Generation

Interior thermal measurements within the instrument cluster case indicate that the LED design operates 10-15°C cooler than the incandescent design.

Interior thermal measurements within the telltale cavity airspace indicate that the LED design operates 25-50°C cooler than the incandescent design.

3. LEDs Provide Equivalent or Better Lighting

This design used two LED lamps per telltale. The lighting performance (luminous sterance) was measured. The comparative performance is as follows:

Red LEDs are 3X brighter

Amber LEDs are 2X brighter

Green LEDs are equivalent or slightly dimmer than incandescent bulbs

Blue LEDs are equivalent

This design used from 4 to 16 LED lamps per gauge, depending on size and number of colors. LED lighting varied from equivalent to 3X brighter, depending on color. LEDs cannot provide the deep blue green color, so yellow-green (570 nm) LEDs were used. LEDs could reproduce the other colors — red, amber, and blue.

4. LEDs Provide Better Reliability

- LED reliability is on the order of 10 million hours MTBF. This compares to 5000 - 20,000 for bulbs.
- LED lifetimes (as measured to a 70% reduction in light output) are typically in excess of 50,000 hours of continuous operation.
- LEDs are capable of withstanding high degrees of mechanical shock and vibration without failure.
- LEDs are capable of withstanding over 1000 temperature cycles -40/100°C, non-operating, without failure.

5. LEDs Allow for Smaller Telltales

The socketed T3-1/4 incandescent bulb (#194) limits the telltale's spacing to 0.60 - 0.75 inches. Since LEDs are available in sizes less than 1/8" in diameter, LED telltales can be placed on spacings of 0.25 - 0.30 inches, if desired.

6. LEDs Are Dimmable with Potentiometer

LEDs are normally wired in series with a current limiting resistor. Multiple LEDs (i.e. 2, 3, 4, 5) can be driven with a single resistor. In general, LEDs can be dimmed with a single potentiometer, as long as all series strings use the same number of LEDs.

LEDs can also be dimmed through pulse width modulation. In this case, the number of lamps in each series string is not critical.

7. LEDs Provide Direct Cost Savings

- LED telltales have the same cost as socketed incandescent bulbs when using two $0.12 LEDs per telltale.
- LED gauge lighting is more expensive than incandescent bulbs. It takes 6 to 18 $0.12 LEDs to replace each bulb. However, the use of LEDs allows for simpler graphics.
- Since LEDs are colored light sources, colored silkscreen graphics are not needed. In this design, we were able to eliminate 5 of the 12 silkscreen layers on the appliqué. This is estimated to save $5.00 per instrument cluster.

- Potentially, LEDs allow for less expensive drive circuits. LEDs operate at lower currents (20 mA instead of 255 mA). Also, LEDs do not have a high inrush current when first turned on.

Lower Power Consumption

The MY92 T-Bird Super Coupe Instrument Cluster uses five #194 bulbs for gauge and pointer lighting and fourteen #194 bulbs for the telltales. These bulbs operate at 255 mA each for a 12.8 Volt input. This means that the gauges run at 1.28 A at maximum brightness. All 14 telltales ON consume 3.57 A.

The LED concept T-Bird Super Coupe Instrument Cluster uses 54 LEDs, arranged as 18 strings of 3 in series, for the equivalent gauge and pointer lighting. The telltales use 28 LEDs, arranged as 14 strings of 2 in series. The cluster was designed so that all strings operate at 20 mA from 12.8 Volts. Thus, the gauges run at 360 mA at maximum brightness and all 14 telltales ON consume 280 mA.

Less Heat Generation

Several thermocouples were mounted inside the T-Bird Super Coupe Instrument Cluster. Four thermocouples measured the interior of the case around the gauges. Two thermocouples measured the interior of the telltale cavities. After one hour with the five gauge bulbs ON, the interior of the case had an average temperature rise of 18°C around the gauges (varying from 14 to 26°C). After one hour with the five gauge bulbs ON and one telltale ON, the interior of the case had an average temperature rise of 20°C around the gauges and 32°C temperature rise inside the telltale cavity. As a last experiment, we turned ON three adjacent telltales. After one hour, we could smell burning plastic and the interior of the center telltale cavity had a temperature rise of 61°C! Needless to say, we did not want to turn all 14 telltale bulbs ON!

Under the exact conditions, when all 54 LEDs were turned ON, the interior of the case had an average temperature rise of 7°C after one hour. Even with the 54 LEDs ON, and 8 LEDs ON (4 telltales), the worst case temperature rise was only 8°C.

Equivalent or Better Lighting

A number of luminous sterance measurements were made on both clusters. Both clusters were driven at 12.8 Vdc. The results are summarized in the tables shown on the following page. It should be noted that the most cost-effective LEDs were chosen for each lighting color. For example, for red telltale lighting, AS AlGaAs LED technology was chosen instead of the premium TS AlGaAs LED Technology. All gauge lighting used GaP LED materials technology, instead of the more expensive AlGaAs and AlInGaP LED materials technology. AlInGaP was used for the amber telltales, although amber GaP could have been used. SiC Blue LEDs were used for the high beam telltale and temperature gauge.

In general, LEDs outperformed the incandescents for all gauge colors. The challenge would seem to be to reduce the number of LEDs while still maintaining uniformity.

LEDs outperform incandescents for the red and amber telltales. For red and amber, a single T1 undiffused lamp could have been used. For green and blue telltales, the performance of the LEDs was equivalent to or somewhat less than the incandescent bulbs.

Direct Cost Savings

For the telltale function, there is a direct correspondence between the number of incandescent bulbs and LEDs. The LED T-Bird instrument cluster used two T1 ultrabright lamps for each #194 bulb. Assuming that each LED sells for $0.12, then it competes directly with a $0.25 bulb. (The bulb pricing needs further clarification because the standard Ford design approach is to use a #194 or #37 bulb that plugs into a quarter-turn socket.) Using smaller telltales, it may be possible to use a single LED for each one. This would be a clear, direct cost savings.

Comparing the costs of the incandescent T-Bird instrument cluster to the LED T-Bird instrument cluster is difficult because there is not a one to one correspondence between the number of incandescent bulbs and LEDs. The incandescent version of the T-Bird cluster uses five #194 bulbs for the combined gauge and pointer lighting function. The equivalent lighting on the LED concept cluster used 54 LEDs. At first glance, the LED solution would seem to be cost prohibitive. (As a note, the number of LEDs can probably be reduced to 45, by tolerating some sterance variation.) However, the costs become comparable when the appliqué, pcb, and case costs are included.

The incandescent T-Bird instrument cluster appliqués (the graphics on top of the gauges and telltales) have 12 silkscreen ink layers. We have been told by several automotive customers that the production cost of the appliqué set is about $1.00 per silkscreen layer. The appliqués used in the LED concept cluster had 7 silkscreen layers. The LED concept cluster uses fewer layers because colored inks are no longer needed to define the colors of the telltales and gauges (4 layers). Because a single bulb is used to backlight each gauge, the brightness of the gauge graphics varies substantially. To eliminate these luminous sterance variations, a special "half-tone" pattern is silkscreened on the back of the appliqué. This "half-tone" pattern is designed to reduce the luminous sterance in the brighter areas of the graphics. Because several LEDs are used to backlight

Table 1. Gauge Lighting

Color	Incandescent	LED	
Green Color	3.18 cd/m^2	LPE Green (HLMP-1540)	8.91 cd/m^2
Red Color (Max. RPM, on Tach)	4.82 cd/m^2	HER (HLMP-1340)	6.88 cd/m^2
Amber Color (KPH, on Speedo)	6.49 cd/m^2	Orange GaP (QLMP-K477)	6.21 cd/m^2
Red Spots (Water Temp, Oil, Gas)	2.43 cd/m^2	HER (HLMP-1320)	4.86 cd/m^2
Blue Spot (Water Temp.)	2.35 cd/m^2	SiC Blue (HLMP-DB25)	3.73 cd/m^2

Table 2. Telltales

Color	Incandescent	LED	
Red	35 cd/m^2	AS AlGaAs (HLMP-K105)	110 cd/m^2
Amber	106 cd/m^2	AlInGaP (HLMA-KL00)	240 cd/m^2
Green	63 - 404 cd/m^2	LPE Green (HLMP-1540)	65 cd/m^2
Blue	18 cd/m^2	SiC Blue (HLMP-DB25)	15 cd/m^2

each gauge, the gauge appliqué no longer needs this "half-tone compensation" silkscreen layer. Thus, the use of LEDs in an instrument cluster saves about $5.00 in the cost of the appliqué set.

The down-side of using "colored" LED light sources, as opposed to "white" bulbs, is that light baffles need to be molded into the case to separate the different colors. The need for light baffles will tend to complicate the case design, which may add cost. Further, the pointer light pipes need to be redesigned to prevent mixing of the pointer and gauge colors.

Many current production instrument clusters, including the T-Bird, use a flexible polyester pcb to connect the telltale bulbs, gauge lighting bulbs, and meter electronics to the wiring harness connector. Polyester flexible pcb material has been used primarily due to its low cost, and the availability of low cost wiring harness connectors, and plug-in bulbs. The disadvantages of polyester pcb material are its inability to withstand wave soldering, most SMT processes, and lack of dimensional stability in moisture and temperature extremes. Flexible pcb material using a polymid base material can withstand wavesolder and SMT processes. However, it is substantially more expensive. Rigid pcb material could also be used. The local representative of Sheldahl, the largest manufacturer of polyester flex pcb, has stated that the cost of rigid FR4 pcb material is equal to or less expensive than their polyester flex pcb (for the same number of copper layers). Sheldahl also has the ability to make hybrid pcbs using half polyester flex and half rigid FR4. In this process, the LEDs would be wavesoldered to the rigid pcb. Then, the rigid pcb would be attached to the flex pcb using a special adhesive. The overall conclusion is that an LED instrument cluster using a rigid pcb or hybrid (half rigid and half flex) would be less expensive than the current polyester flex pcb. In addition, the use of one large rigid pcb in the T-Bird instrument cluster might also eliminate two small rigid pcbs that are used for the speedometer and tachometer electronics.

Another indirect cost factor is the instrument cluster housing. The T-Bird cluster housing is made of white ABS plastic. However, the telltales use two additional plastic inserts to define the telltale walls. These inserts are needed because of the tight tolerances dictated by closely packed telltales, deep cavities, and large incandescent bulbs. They may also be needed to withstand the high internal temperatures generated by the bulbs. If LEDs were used for telltales, the telltale cavities could be molded into the plastic case. This would eliminate the need for these inserts. In addition, the rear of the plastic case could be eliminated by using a large rigid pcb. Finally, the depth of the case could be reduced by over a factor of 2 by using LED lighting.

A final indirect cost factor is the cost of the associated drive circuitry. The #194 bulb used in the T-Bird instrument cluster draws about 250 mA. However, these bulbs have an inrush current of about 3A when they are first turned on. This means that the drivers either need to be discrete transistors or a high current monolithic IC. Each LED telltale operates at 20 mA. This allows the use of less expensive IC circuitry.

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