HEWLETT® PACKARD

Electrical Power Consumption Savings with LED Signal Lights

Application Note 1155-2

NOTE:
Light Emitting Diodes (LEDs) consume only one tenth the power of incandescent bulbs – Automotive LED signal lamps offer potential savings by using a smaller alternator plus slightly improved fuel economy.

Summary

LED signal lamps operate at approximately one-tenth of the electrical power consumption of incandescent signal lights. This reduced electrical power consumption provides a number of potential cost savings to the car manufacturer and benefits to the vehicle owner. The potential cost savings to car manufacturers include a potential reduction in the size of the alternator, use of lighter weight wire for the wiring harness, and Corporate Average Fuel Economy (CAFÉ) savings due to weight reduction of the alternator and wiring harness. Since the signal lights are off during the CAFÉ test, there is no direct CAFÉ savings due to the lower electrical power consumption; however, it does provide a significant benefit to the car owner. The reduction in electrical power consumption also reduces the load on the engine, which helps to reduce fuel consumption and engine heat generation. In addition, the reduction in alternator size and engine load may provide space savings in the engine compartment.

The benefits of reduced electrical power consumption of LED signal lights to the car owner include improved fuel consumption and an increased operating time for emergency flashers. Using LEDs for the front and rear turn signals increases the operating time of battery-driven emergency flashers by a factor of between two to four. This feature provides a safety improvement as well as reducing the likelihood of a dead battery.

Based on a comparison between typical incandescent and LED signal light designs, the total cost savings due to reduced electrical power consumption is shown in Table 1.

Referring to Table 1, the primary cost savings is due to the reduction in alternator size. The savings in wire harness costs and CAFÉ (corporate average fuel economy) savings due to weight reduction are much smaller. The CAFÉ cost savings comes about because the U.S. government assesses a penalty if the corporate average fuel economy falls below a defined limit (currently 27.5 MPG for passenger cars and 20.7 MPG for light trucks). The penalty is $5 per vehicle for each 0.1 MPG below the limit. Various estimates place the fuel economy savings of about 0.013 MPG per pound of vehicle weight and 0.005 MPG per watt of electrical power consumption. Thus, each pound of weight reduction corresponds to a CAFÉ penalty savings of $0.65 and each watt of average power consumption corresponds to a CAFÉ penalty savings of $0.25. Currently, the CAFÉ test is done with the signal lights turned off, so while the weight reduction results in a CAFÉ improvement, the reduction in signal light power consumption does not. Expressed in terms of cost savings divided by electrical power consumption reduction, the average savings is about $4.29/57 W, or $0.075/W

Table 1. Total cost savings per signal light due to reduced electrical power consumption.

Signal	Average night electrical power savings (W)	Cost savings due to smaller alternator ($)	Cost savings due to smaller wire harness ($)	Weight savings for smaller alternator/ harness (lb.)	Cost savings due to CAFÉ penalty ($0.65/lb.)	Total cost savings
CHMSL	8.6 to 17.6	$0.42 to $0.87	$0.00 to $0.17	0.07 to 0.24	$0.05 to $0.16	$0.47 to $1.20
Rear S/T/T	11.3 to 23.6	$0.56 to $1.16	$0.20 to $0.30	0.19 to 0.35	$0.12 to $0.23	$0.88 to $1.69
Amber rear turn	0.2 to 0.6	$0.01 to $0.03	$0.07 to $0.17	0.04 to 0.11	$0.03 to $0.07	$0.11 to $0.27
Rear side	2.5 to 5.8	$0.12 to $0.28	$0.00	0.02 to 0.05	$0.01 to $0.03	$0.13 to $0.31
Front P/T	7.1 to 14.7	$0.35 to $0.72	$0.20 to $0.30	0.16 to 0.28	$0.10 to $0.18	$0.65 to $1.20
Front side	3.5 to 7.8	$0.17 to $0.38	$0.00	0.03 to 0.06	$0.02 to $0.04	$0.19 to $0.42
Vehicle TOTAL (red rear turn)	57 to 120	$2.82 to $5.95	$0.80 to $1.37	0.87 to 1.72	$0.57 to $1.12	$4.29 to $8.44
Vehicle TOTAL (amber rear turn)	58 to 122	$2.84 to $6.01	$0.94 to $1.71	0.95 to 1.94	$0.62 to $1.26	$4.39 to $8.98

($0.96/A). Note, that if the CAFÉ test is modified to include the signal lights turned on for the test, then it would become the largest potential cost savings of $14.25 to $30.50 per vehicle and would raise the cost savings to $18.54/57 W, or $0.33/W ($4.16/A).

Detail

The automotive signal lights contribute to the overall electrical power consumption of the vehicle. During daytime operation, the use of the turn signals and brake lights increases the peak electrical load. During nighttime operation, the tail lamps and side markers are part of the average electrical load. It is fairly easy to quantify these electrical loads and to compare them to an equivalent LED signal light.

Operation of an incandescent bulb at voltages higher than the design voltage causes the forward current to increase. The forward current can be modeled by the following equation:

$$\text{Forward Current} = \text{Design Current}\left[\frac{\text{Voltage}}{\text{Design Voltage}}\right]^{m}$$

where:

forward current = forward current at applied voltage
m = exponential factor

According to bulb manufacturers, m is equal to 0.55 for small incandescent bulbs.[1]

Using this equation, it is possible to calculate the forward current of the bulbs in a signal light at any ignition voltage. Table 2 shows the forward current for the composite automotive design shown previously in Hewlett-Packard Application Note 1155-1, Tables 2 through 7.

Many automotive signal lights use multiple bulbs per signal, so the actual peak electrical power could be two times the minimum estimated electrical power shown in Table 2. For the seventeen 1998 cars and light trucks surveyed in Appendix A, the total peak electrical power for the signal lights varied from 93 to 217 W for daytime operation and from 135 to 263 W for nighttime operation.

Using the same approach described earlier, it is possible to estimate the average power consumption for the different signal lights. The driving models shown in Hewlett-Packard Application Note 1155-1 Table 1 can be modified to reflect the per cent ON time for each signal light. Note that for each driving model, the per cent ON time is simply equal to the hours ON per year for each signal divided by the ignition ON time per year. The “100% city case” might be used to estimate the “worst case” average power consumption and the “fleet distribution” might be used to estimate the “typical” average power consumption.

Table 2. Expected peak electrical power consumption for a voltage across the signal light of 12.8V.

Signal	Bulb type	Number of bulbs	Function	Design Voltage (V)	Design Current (A)	Estimated Current (A)	Signal Estimated Current (A)	Signal Estimated Power (W)
CHMSL	921	2	Stop	12.8	1.40	1.40	2.80	35.8
Combined Stop/Turn/ Tail	3057	1	Stop/Turn	12.8	2.10	2.10	2.10	26.9
			Night	14.0	0.48	0.46	0.46	5.9
Combined Stop/Tail	3057	1	Stop	12.8	2.10	2.10	2.10	26.9
			Night	14.0	0.48	0.46	0.46	5.9
Separate Rear Turn	3156	1	Turn	12.8	2.10	2.10	2.10	26.9
Rear Side	194	1	Night	14.0	0.27	0.26	0.26	3.3
Front Park/ Turn	3357NA	1	Turn	12.8	2.23	2.23	2.23	28.5
			Night	14.0	0.59	0.56	0.56	7.2
Front Side	168	1	Night	14.0	0.35	0.33	0.33	4.3
Daytime Vehicle TOTAL (red rear turn) [CHMSL, rear stop (2), and front turn (1) signals]							9.23	118.1
Daytime Vehicle TOTAL (amber rear turn) [CHMSL, rear stop (2), rear turn (1) and front turn (1) signals]							11.33	145.0
Nighttime Vehicle TOTAL (red rear turn) [CHMSL, rear stop (2), front turn (1), rear tail (2), park (2), front and rear side (2 each) signals]							12.45	159.3
Nighttime Vehicle TOTAL (amber rear turn) [CHMSL, rear stop (2), rear turn (1),front turn (1), rear tail (2), park (2), front and rear side (2 each) signals]							14.55	186.2

Table 3. Per cent ON time for the "city" and "suburban highway" driving models shown in Hewlett-Packard Application Note 1155-1, Table 1. "Fleet" distribution is shown in Hewlett-Packard Application Note 1155-1, Table 5.

Signal	100% city	80% city	50% city	30% city	20% city	10% city	100% highway	"fleet" average
CHMSL	25.0%	23.1%	19.0%	15.1%	12.5%	9.5%	5.7%	15.5%
Stop	25.0%	23.1%	19.0%	15.1%	12.5%	9.5%	5.7%	15.5%
Combined Stop/Turn	24.0%	22.1%	18.1%	14.3%	11.8%	8.9%	5.2%	14.7%
Separate Rear Turn	1.4%	1.4%	1.3%	1.2%	1.1%	1.0%	0.9%	1.2%
Tail/Side	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Front Turn	1.4%	1.4%	1.3%	1.2%	1.1%	1.0%	0.9%	1.2%
Front Side	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%

Table 3 shows the per cent ON time for each signal light for the different driving models.

Thus for our hypothetical automotive signal lamp design and daytime operation, the total average electrical power for all of the signal lights on the entire vehicle is approximately 22 W using the "100% city driving model" [CHMSL, rear stop (2), and front turn (1) signals]. For nighttime operation using the "100% city driving model", the total average electrical power for all of the signal lights is approximately 64 W [CHMSL, rear stop (2), front turn (1), rear tail (2), front park (2), and front and rear side markers (2 each)]. Using a separate rear turn signal would require approximately 23 W and 64 W average electrical power, respectively, for daytime and nighttime operation.

Many automotive signal lights use multiple bulbs per signal, so the actual average electrical power could be two times the minimum estimated average electrical power shown in Table 3. For the same seventeen 1998 cars and light trucks surveyed previously, the total average electrical power for the signal lights varied from 16 to 41 W for daytime operation and from 48 to 104 W for nighttime operation.

LED lamps provide significant power savings for automotive signal lamps. Table 4 shows a rough calculation of the minimum number of LED lamps needed to meet the SAE lighting specifications. The minimum signal lamp optical flux requirement was calculated by integrating the minimum luminous intensities shown in the appropriate SAE specification with 5° by 5° zonal constants and extrapolating missing points from adjacent points. The resulting minimum luminous flux requirement was multiplied by a guard band of 6. The guard band was estimated with the following assumptions:

- 0.85% plastic lens optical transmission
- 30% of optical flux falls outside of SAE radiation pattern
- 25% guard band on all minimum luminous intensity points
- 60 mA drive current and 450 °C/W, junction to air (factor of 0.64 on HPWx-Mx00 data sheet Figure 3. Note that this includes the 30 minute warm-up time.)
- 60% of available optical flux of LED lamp contributes to desired radiation pattern

The number of LED lamps is equal to the minimum optical flux requirement times the guard band divided by the minimum optical flux per lamp. Note that the bins selected represent typical bins (circa 6/98) and are higher than the data sheet minimums. Finally, the LED lamps are connected in series strings with four LED lamps per string. Each string is driven at 60 mA with the drive current set with an external resistor. Then the electrical signal power is equal to the total current of the LED signal times 12.8 V.

For most applications, the rear tail and front park signals can be achieved by driving the rear stop and front turn signals at reduced current, which is the reason that the number of lamps is marked "included". Since four lamps can be connected in series and driven from the ignition voltage, the possibility exists to further reduce the drive current of the side markers by using four LED lamps and reducing the drive current.

By comparing Table 4 to Table 2, it is possible to estimate the electrical power savings for LED signal lights over conventional incandescent bulb signal lights. Table 5 shows both the peak and average electrical power savings under daytime and nighttime operation. Note that each LED signal light reduces the peak electrical power consumption by 12 to 24 W and the average power consumption by 5 to 11 W. Note that these calculations assume the use of a single bulb per signal light (two for the CHMSL). Many vehicles use multiple bulbs per signal light, so the potential electrical power savings could be two times the numbers shown in Table 5.

Many automotive signal lights use multiple bulbs per signal, so the actual peak and average electrical power consumption could be two times the values shown in Table 5. In this case, if LED signal lights were used on the entire vehicle, the power consumption savings would be even higher than the values calculated in Table 5.

Table 4. Minimum number of LED lamps needed to meet US automotive signaling specifications. Guard band of 6x assumed (see text). Power calculated at 12.8 V.

Signal	SAE spec	Min flux (lm)	LED pn HPW-	Min flux (lm)	Number LEDs	Signal Estimated Current (A)	Signal Estimated Power (W)
CHMSL	J 1957	2.9	T-MH00	2.5, bin E	7, used 8	0.12	1.5
Stop	J 586	9.0	T-MH00	2.5, bin E	22, used 24	0.36	4.6
Red Turn	J 588	9.0	T-MH00	2.5, bin E	22, used 24	0.36	4.6
Amber Turn	J 588	15.1	T-ML00	1.5, bin C	60	0.90	11.5
Tail	J 585	0.23	T-MH00	2.5, bin E	Included (Stop @ 1/40 df)		
Rear Side	J 592	0.18	T-MH00	2.5, bin E	1	0.06	0.8
Front Turn	J 588	22.4	T-ML00	1.5, bin C	88	1.32	16.9
Front Park	J222	0.39	T-ML00	1.5, bin C	Included (Turn @ 1/50 df)		
Front Side	J 592	0.45	T-ML00	1.5, bin C	2	0.06	0.8
Daytime Vehicle TOTAL (red rear turn) [CHMSL, rear stop (2), and front turn (1) signals]						2.16	27.6
Daytime Vehicle TOTAL (amber rear turn) [CHMSL, rear stop (2), rear turn (1) and front turn (1) signals]						2.94	37.6
Nighttime Vehicle TOTAL (red rear turn) [CHMSL, rear stop (2), front turn (1), rear tail (2), park (2), front and rear side (2 each) signals]						2.40	30.7
Nighttime Vehicle TOTAL (amber rear turn) [CHMSL, rear stop (2), rear turn (1),front turn (1), rear tail (2), park (2), front and rear side (2 each) signals]						3.18	40.7

Table 5. Summary of peak and average electrical power consumption for the incandescent and LED signal light designs based on a voltage across the signal light of 12.8 V.

Signal	Function	Bulb peak power (W)	LED peak power (W)	Day delta peak (W)	Night delta peak (W)	Bulb avg power (W)	LED avg power (W)	Day delta avg (W)	Night delta avg (W)
CHMSL	Stop	35.8	1.5	34.3	34.3	9.0	0.4	8.6	8.6
Combined s/t/t	Stop/turn	26.9	4.6	23.1	23.1	6.4	0.9	5.5	5.5
	Night	5.9				5.9	0.1		5.8
Combined stop/tail	Stop	26.9	4.6	23.1	23.1	6.7	1.0	5.7	5.7
	Night	5.9				5.9	0.1		5.8
Separate rear turn	Turn	26.9	11.5	15.4	15.4	0.4	0.2	0.2	0.2
Rear side	Night	3.3	0.8		2.5	3.3	0.8		2.5
Front park/turn	Turn	28.5	16.9	11.6	11.6	0.4	0.2	0.2	0.2
	Night	7.2				7.2	0.3		6.9
Front side	Night	4.3	0.8		3.5	4.3	0.8		3.5
Vehicle TOTAL (red rear turn)	Day	118.1	27.6	90.5		22.3	2.8	19.5	
	Night	145.0	37.6		107.4	63.5	6.8		56.7
Vehicle TOTAL (amber rear turn)	Day	159.3	30.7	128.6		23.2	2.7	20.5	
	Night	186.2	40.7		145.5	64.4	6.6		57.8

Reduced electrical power consumption has a direct effect on the size and power rating of the alternator. An alternator is typically rated for the nominal output currents at two different rotational speeds. For example, an alternator rated at 50/140 would generate 50 A (14 V) at low speed, say 1600 rpm, and 140 A (14 V) at high speed, say 6000 rpm. Generally alternators are sized based on the total average electrical load in the vehicle. The alternator should have sufficient output to generate this average electrical load even when the engine is idling. Higher peak electrical current demands can be met with additional electrical current from the battery. At higher engine speeds, the alternator generates additional current which keeps the battery fully charged as well as providing the peak electrical needs of the vehicle.

Alternators are available in several sizes with electrical outputs varying from less than 400 W to over 1000 W under low speed operation (1600 rpm). Figure 1 shows a graph of alternator sizes and weights based on a number of Delphi alternators.[2] The power rating shown on the horizontal scale of the graph was determined by multiplying the rated electrical current at 1600 rpm times 14 V. Note that each larger alternator size is capable of supplying an additional 120 to 200 W (8 to 15 A). The linear regression on this curve shows that a 100 W reduction in low-speed alternator capacity reduces the weight of the alternator by about 0.8 pounds (assuming that the power reduction allows the use of the next size smaller alternator.

As a ballpark, alternator prices are based on the electrical output at high speeds, roughly $0.50/A.[3] Thus, an alternator rated as 50/140 A might sell in high volumes at $70. Figure 2 shows a graph of approximate alternator prices based on the same alternators shown in Figure 1. The linear regression on this curve shows that a 100 W reduction of low-speed alternator capacity reduces the alternator price by about $4.92 (assuming that the power reduction allows the use of the next size smaller alternator).

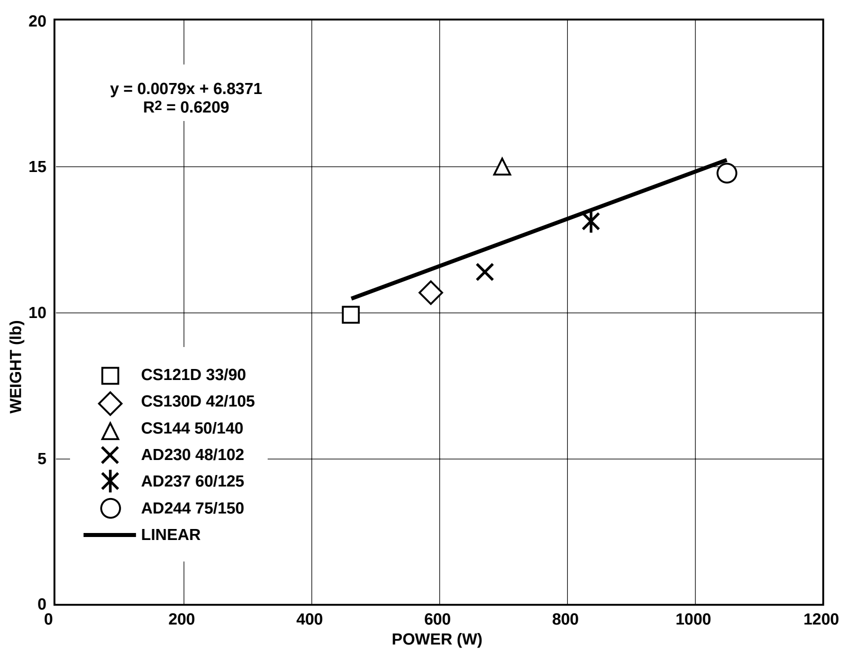

Figure 1. Alternator weight as a function of low-speed rated electrical power output in watts at 14 V

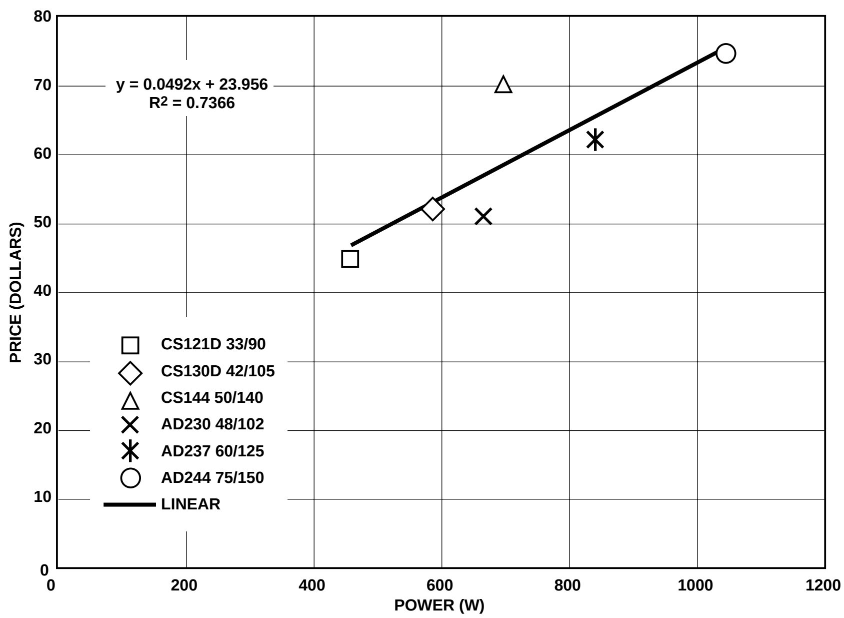

Figure 2. Approximate alternator OEM prices as a function of low-speed rated electrical power output in watts at 14 V

The total power savings for a vehicle with all-LED signal lights (57 to 120 W under nighttime conditions) may not be sufficient to justify a smaller alternator size. However, if the incremental load savings are sufficient to justify a smaller alternator, then the estimated cost and weight savings of our hypothetical signal light designs are summarized in Table 6:

Table 6. Estimated direct cost and weight savings per signal light due to use of a smaller alternator.

Signal	Average night electrical power savings (W)	Weight savings due to smaller alternator (lb.)	Cost savings due to smaller alternator ($)
CHMSL	8.6 to 17.6 W	0.07 to 0.14	$0.42 to $0.87
Rear Stop/Turn/Tail	11.3 to 23.6 W	0.09 to 0.19	$0.56 to $1.16
Amber Rear Turn	0.2 to 0.6 W	0.002 to 0.005	$0.01 to $0.03
Rear Side Marker	2.5 to 5.8 W	0.02 to 0.05	$0.12 to $0.28
Front Park/Turn	7.1 to 14.7 W	0.06 to 0.12	$0.35 to $0.72
Front Side Marker	3.5 to 7.8 W	0.03 to 0.06	$0.17 to $0.38

Reduced electrical power consumption also has direct savings in cost and weight due to the use of smaller wire sizes. Assuming that the maximum acceptable voltage drop is 1.20 V at 75°C and the total length of the wire harness is 30 feet (supply and return), then the minimum wire size as a function of peak electrical current is shown in Table 7.

Referring to Table 2, most of the present bulb-based rear stop signals, turn signals, and CHMSLs probably require a wire harness made of 20 gauge wire and dual bulb designs might even require 16 or 18 gauge wire. Referring to Table 4, the equivalent LED signal light would probably allow a wire harness made of 22 gauge wire.

Table 8 shows the approximate wire harness weight and cost calculations assuming that the average wire harness length is 15 feet (30 feet total for supply and return) and each wire would be optimally sized. This table assumes type XLP wire and doesn't include the weight or cost of any sheath surrounding the wires on any type of connectors. Based on the same seventeen 1998 cars and light trucks surveyed previously, the wire harness weight is expected to be in the range of one to two pounds and cost in the range of $3.14 to $4.57. A vehicle with all-LED signal lights would be expected to have a wire harness weight of about one pound and cost $2.34 to $2.86, resulting in a vehicle weight savings of up to one pound and a cost savings for the wire harnesses of $0.80 to $1.71.

Table 7. Minimum wire harness sizes based on 30 feet total length and 1.20 V maximum voltage drop.

Annealed copper, min. wire size (American wire gauge)	Maximum Peak Electrical Current (A)	Wire resistance for 30 feet (75°C) [4]	Type XLP wire weight, 30 feet (lb.)	Estimated price, type XLP wire, 30 feet ($) [5]
12	20.7	0.058	0.67	$1.26
14	13.0	0.092	0.42	$0.85
16	8.19	0.146	0.28	$0.58
18	5.15	0.232	0.21	$0.43
20	3.24	0.371	0.15	$0.33
22	2.04	0.589	0.11	$0.26

Table 8. Wire harness weight and cost calculations

Best Case Wire Harness Weight / Cost Calculations

Signal	Peak (A)	Wire	Weight (lb)	Units per car	Weight per car	Cost per car
CHMSL	2.2 A	#22	0.11	1	0.11	$0.26
S/T/T	2.2 A	#20	0.075	2	0.15	$0.33
	0.5 A	#22	0.055	2	0.11	$0.26
	2.7 A	#20	0.075	2	0.15	$0.33
R Side	0.3 A	#22	0.11	2	0.22	$0.52
F Pk/Turn	2.4 A	#20	0.075	2	0.15	$0.33
	0.6 A	#22	0.055	2	0.11	$0.26
	3.0 A	#20	0.075	2	0.15	$0.33
F Side	0.3 A	#22	0.11	2	0.22	$0.52
				Total	1.37 lb	$3.14
Amber Rear Turn	2.2 A	#20	0.15	2	0.30	$0.66

Worst Case Wire Harness Weight / Cost Calculations

CHMSL	4.5 A	#18	0.21	1	0.21	$0.43
S/T/T	4.5 A	#18	0.105	2	0.21	$0.43
	1.2 A	#22	0.055	2	0.11	$0.26
	5.7 A	#16	0.105	2	0.21	$0.43
R Side	0.5 A	#22	0.11	2	0.22	$0.52
F Pk/Turn	4.7 A	#18	0.105	2	0.21	$0.43
	1.2 A	#22	0.055	2	0.11	$0.26
	5.9 A	#16	0.105	2	0.21	$0.43
F Side	0.6 A	#22	0.11	2	0.22	$0.52
				Total	1.71 lb	$3.71
Amber Rear Turn	4.5 A	#18	0.21	2	0.42	$0.86

LED Signal Wire Harness Weight / Cost Calculations

CHMSL	0.1 A	#22	0.11	1	0.11	$0.26
S/T/T	0.3 A	#22	0.11	2	0.22	$0.52
R Side	0.1 A	#22	0.11	2	0.22	$0.52
F Pk/Turn	1.3 A	#22	0.11	2	0.22	$0.52
F Side	0.1 A	#22	0.11	2	0.22	$0.52
				Total	0.99 lb	$2.34
Amber Rear Turn	0.9 A	#22	0.11	2	0.22	$0.52

Reflected on a signal lamp basis, the approximate direct weight and cost savings due to the use of smaller gauge wire for the wire harness is summarized in Table 9:

Table 9. Estimated direct cost and weight savings per signal light due to the use of lighter weight wire in the wire harness.

Signal	Weight Savings	Cost Savings
CHMSL	0.00 to 0.10	$0.00 to $0.17
Rear Stop/Turn/Tail	0.10 to 0.16	$0.20 to $0.30
Amber Rear Turn	0.04 to 0.10	$0.07 to $0.17
Rear Side Marker	0.00	$0.00
Front Park/Turn	0.10 to 0.16	$0.20 to $0.30
Front Side Marker	0.00	$0.00

Reduced electrical power consumption and vehicle weight also provides an improvement in the fuel economy of the vehicle. Various sources attribute the improvement in fuel economy due to a 100 W reduction in average electrical power consumption to a fuel reduction in the range of 0.1 to 0.2 liters per 100 kilometers.[6], [7] Assuming that the fuel reduction is 0.15 liters /100 km, then at 27.5 MPG, a reduction in average electrical power by 100 W, would result in a fuel consumption savings of 0.5 MPG. These same references attribute the improvement in fuel economy to a 10 kg (22 pound) weight reduction to a fuel reduction in the range of 0.08 to 0.1 liters per 100 kilometers. Assuming that the fuel reduction is 0.09 liters/100 km for a 10 kg weight reduction, then at 27.5 MPG, a reduction in vehicle weight by 10 pounds, would result in a fuel consumption savings of 0.13 MPG.

The US government (CAFÉ) standard prescribes a maximum corporate fuel consumption rate for cars sold in the US. For MY99, the CAFÉ standard is 27.5 MPG for passenger cars and 20.7 MPG for light trucks. The US assesses a penalty of $5 for every 0.1 MPG for every vehicle that a manufacturer sells that falls below this limit. Thus a 100 W reduction in electrical power consumption can result in a CAFÉ penalty savings of $25, if it causes the vehicle to fall below the limit. A 10-pound weight reduction can result in CAFÉ penalty savings of $6.50, if it causes the vehicle to fall below the limit.

At present, when US and European fuel economy tests are conducted, only those electrical loads essential to the operation of the vehicle are active – that is, the ignition and engine electronics. Lights, air-circulating blowers for the passenger compartment, entertainment electronics, power windows, and so forth are all turned off for the tests. But this could soon change. If a typical average electrical load is required during tests, the electrical performance of the car will become much more visible.[8]

At the present, a reduction in electrical power consumption of the vehicle lighting does not directly contribute to the CAFÉ standard. However, a weight reduction due to the use of a smaller alternator and lighter wiring harnesses would contribute to the CAFÉ standard. Table 10 shows the potential CAFÉ standard savings due to the use of LED signal lights:

Table 10. Estimated potential indirect CAFÉ savings per signal light due to the potential weight reduction of a smaller alternator and lighter wiring harness.

Signal	Weight reduction due to smaller alternator (lb.)	Weight reduction due to smaller wiring harness (lb.)	CAFÉ savings ($0.65/lb.)
CHMSL	0.07 to 0.14	0.00 to 0.10	$0.05 to $0.16
Rear Stop/Turn/Tail	0.09 to 0.19	0.10 to 0.16	$0.12 to $0.23
Amber Rear Turn	0.002 to 0.005	0.04 to 0.10	$0.03 to $0.07
Rear Side Marker	0.02 to 0.05	0.00	$0.01 to $0.03
Front Park/Turn	0.06 to 0.12	0.10 to 0.16	$0.10 to $0.18
Front Side Marker	0.03 to 0.06	0.00	$0.02 to $0.04

Another benefit for LED turn signals is that their reduced electrical power consumption allows a longer operating time for the emergency flashers under battery power. Referring to Table 2, if the operation of the emergency flashers causes the front turn signals, front side markers and rear turn signals to flash at a 50% duty cycle, then the average battery load is about 4.7A. Referring to Table 4, these same signals would result in an average battery load of 1.7 A (red rear turn signals) or 2.3A (amber rear turn signals). Thus, the use of LED turn signals would increase the operating time of the emergency flashers by a factor of 2 to 3 (even higher if multiple bulb turn signals are considered).

Appendix A.

MY98 cars used in survey [9]

Car	Tail/Turn/ Brake	Tail/Brake	Amber Rear Turn	Rear Tail	CHMSL	Rear Side Marker	Front Park/Turn	Front Side Marker
Buick LeSabre	3357	—	—	194 x 2	1156 x 2	194	3357	194
Chevrolet Cavalier	3057	—	—	—	912 x 2	194	3357	194
Dodge Intrepid	-	3157 x 2	3157	—	912 x 2	168	3157NA	—
Dodge Neon	3157	—	—	—	921	916	3157NA	168
Dodge Stratus	—	3057	3057		921	3057	3157NA	—
Ford Contour	1157	—	—	—	2723 x 9	—	2357NA	—
Ford Escort	3157 x 2	—	—		921	168	3457NA x 2	194
Pontiac Grand Am	—	3357 x 2	3357	—	912 x 2	194	3357NA	—
Saturn SC2	—	2057 x 2	1156	—	921 x 3	—	3357NA	168
Saturn SL2	—	2057	1156	—	PC175 x 6	194	3357NA	168

MY98 trucks used in survey [9]

Car	Tail/Turn/ Brake	Tail/Brake	Amber Rear Turn	Rear Tail	CHMSL	Rear Side Marker	Front Park/Turn	Front Side Marker
Chevrolet S-10	3057	—	—	3057	211-2 x 2	—	3157NA	194
Chevrolet Tahoe	3057	—	—	3057	LED	—	2357NA x 2	194
Dodge Gr Caravan	—	3057	3057 (Turn/Tail)	—	921 x 3	—	3157NA	—
Dodge Ram 1500	3157	—	—	—	921 x 2	194	3157NA	—
Ford Explorer	—	3157	3156	—	LED	—	3157NA x 2	916NA
Ford F150	3157	—	—	3157	912	—	3157NA	916NA
Jeep Grand Cherokee	—	3057	3057	—	922 x 3	194	1295NA x 2	194NA

Bulbs used in survey [10], [11], [12]

Lamp	Size	Base	Fill Gas	Design Voltage	Design Current	Design mscd	Rated Life
168	T - 3 1/4	Wedge	Vacuum	14.0	0.35	3.0	1500
PC175	T - 3 1/4	PCB		14.0	0.58	5.0	1000
194	T - 3 1/4	Wedge	Vacuum	14.0	0.27	2.0	2500
194NA	T - 3 1/4	Wedge	Vacuum	14.0	0.27	1.5	2500
211-2	T-3	Double end cap	Gas	12.8	0.97	12.0	1000
912	T-5	Wedge	Gas	12.8	1.00	12.0	1000
916	T-5	Wedge	Gas	13.5	0.54	2.0	10,000
916NA	T-5	Wedge	Gas	13.5	0.54	1.5	10,000
921	T-5	Wedge	Gas	12.8	1.40	21.0	1000
922	T-5	Wedge	Gas	12.8	0.98	15.0	200
1156	S - 8	SC Bayonet	Gas	12.8	2.10	32.0	1200
1157	S - 8	DC Index	Gas	12.8	2.10	32.0	1200
				14.0	0.59	3.0	5000
1295NA	S - 8	SC Bayonet	Gas	12.5	3.00	37.0	200
2057	S - 8	DC Index	Gas	12.8	2.10	32.0	1200
				14.0	0.49	2.0	5000
2357NA	S - 8	DC Index	Gas	12.8	2.23	30.0	400
				14.0	0.59	2.25	5000
2723	T - 1 3/4	W2 x 4.6d		12.0	0.20	1.5	1100
3057	GT - 8	DC Wedge	Gas	12.8	2.10	32.0	1200
				14.0	0.48	2.0	5000
3156	GT - 8	SC Wedge	Gas	12.8	2.10	32.0	1200
3157	GT - 8	DC Wedge	Gas	12.8	2.10	32.0	1200
				14.0	0.59	3.0	5000
3157NA	GT - 8	DC Wedge	Gas	12.8	2.10	24.0	1200
				14.0	0.59	2.2	5000
3357	GT-8	DC Wedge	Gas	12.8	2.23	40.0	400
				14.0	0.59	3.0	5000
3357NA	GT - 8	DC Wedge	Gas	12.8	2.23	30.0	400
				14.0	0.59	2.2	5000
3457NA	GT - 8	DC Wedge	Gas	12.8	2.23	30.0	400
				14.0	0.59	2.2	5000

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