Fuel Efficient Daytime Running Lights.

An Interactive Qualifying Project Report

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by

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Executive Summary:

In 2002 there were approximately 11 million vehicles involved in accidents in the United States. 90% of those vehicles (approximately 9.9 million) were passenger cars or light trucks. As the number of drivers on the roads increase there is an increase in the need to make driving conditions safer. Also in the past year gasoline prices have hit a 23 year high, so there has also been a growing interest in making automobiles more fuel efficient. In the name of safety Lobbyists for years have been trying to get Daytime Running Lights made mandatory on all passenger vehicles. This project examines the efficiency, usefulness, and economical impact of Daytime Running Lights.

If current Daytime Running lights were made standard on all cars in the United States there would be a lot of gas used just to power the lights. We would burn an extra 385 million gallons of gas each year. That's only a couple gallons for each vehicle, but in total it is more than all of the vehicles in the country burn in a day. At $1.90 a gallon, that's $732 million per year. In terms of barrels of oil it would be an extra 19.25 million barrels of oil to accommodate Daytime Running Lights on every car in the US resulting in an extra $866 million dollars.

The two main problems that current Daytime Running Lights face are glare and cost. Glare is an issue because cars and trucks come in all shapes and sizes larger cars and trucks sometimes blind smaller ones because their lights are pointed directly into their windshield. The problem of cost isn't really an individual concern; it is when you add up all the wasted gas that is used just to power the Daytime Running Lights that cost becomes apparent. Crude oil is a precious commodity and should be saved anywhere it is able to be saved.

To find an alternative to incandescent lighting a design was implemented and to determine whether or not LED's could actually be used as Daytime Running Lights. In order to test the validity of this LED design as possible alternatives to incandescent lights they were designed to be similar to the currently used design instead of a new lighting scheme all together. So the design was two circular "lamps" of LED's and to test them they were mounted them where the fog lights of a 97 Ford Contour would go.

Using this design it was calculated that the US would only burn an extra 25 million gallons of gas a year as apposed to 385 million gallons of gas each year with

incandescent bulbs. At $1.90 a gallon, that's $47.5 million per year as apposed to $732 million per year with incandescent lights. The total amount of savings is $684 million a year. In terms of barrels of oil the LED Daytime Running Lights would constitute an extra 1.25 million barrels as apposed to Incandescent lights which would burn 19.25 million, and at $40 a barrel the total would be $50 million a year as apposed to $866 million a year, a total savings of $816 million a year.

Unfortunately the design was flawed and when there is shade these are very visible and make the car show up, but as can be seen from these next pictures they are not as bright in direct sunlight, thus failing what they were designed to do. Although the LED Daytime Running Light design did not quite live up to expectation it does show that with slightly brighter LED's it could work. The LED's that were used were also not the brightest available on the market, they were just cheaper and easier to obtain.

Recommendations to take this project further would be to keep an eye out on up and coming LED technology, a better brighter LED is on the way. Also there should be more work done to thoroughly test the utility of Daytime Running Lights as an actual useful life saving device, all of the literature out there is split half say that Daytime Running Lights help save lives, while the other half says they are useless. It should be determined concretely first whether or not Daytime Running Lights are totally effective before making them mandatory or putting a lot of money into redesigning them.

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Abstract:

In 2002 there were approximately 11 million vehicles involved in accidents in the United States. 90% of those vehicles (approximately 9.9 million) were passenger cars or light trucks. As the number of drivers on the roads increase there is an increase in the need to make driving conditions safer. Also in the past year gasoline prices have hit a 23 year high, so there has also been a growing interest in making automobiles more fuel efficient. In the name of safety Lobbyists for years have been trying to get Daytime Running Lights made mandatory on all passenger vehicles. This project examines the efficiency, usefulness, and economical impact of Daytime Running Lights.

Introduction:

Within the past few months' gasoline prices hit a 23 year high, the national average was about $2.10[1], this coupled with an increasing trend in environmentalism has produced a growing interest in making automobiles more fuel efficient.

In 2002 there were approximately 11 million vehicles involved in accidents in the United States. 90% of those vehicles (approximately 9.9 million) were passenger cars or light trucks. As the number of drivers on the roads increase there is an increase in the need to make driving conditions safer[2].

In an attempt to make driving conditions safer Lobbyists for years have been trying to get Daytime Running Lights made mandatory on all passenger vehicles. There is a lot of debate on the utility of Daytime Running Lights, and very few studies exist on the economical impacts that they represent.

This paper first presents a brief history and then explains how current Daytime Running Lights work, and what kinds of accidents they were designed to take care of. Next the fuel cost of current Daytime Running Lights will be examined, followed by a survey of studies that have been made that address the actual usefulness of Daytime Running lights in crashes that they were designed to stop. Finally alternatives to the current design of Daytime Running Lights will be examined, and suggestions will be made for use in future work on the subject.

Background:

Some studies have shown that driving with headlights on during daylight hours will reduce your chances of being involved in an accident. These studies have been conducted in the United States, Canada, Sweden, Norway, and Finland. In all cases the studies have shown a positive reduction in daytime multiple collisions. A 1964 study of 181 US companies, showed a reduction in daytime accidents up to 38%. In addition the US Insurance Institute for Highway Safety has conducted their own preliminary studies that indicate a 20% reduction in daytime accidents[3].

The purpose of daytime Running Lights (DRL) is to increase the conspicuity of the vehicle to all traffic and to do it more efficiently than the vehicle's own headlight

system. It is estimated that up to 45% of all accidents occur because of perception and recognition errors. This involves improperly, judging a vehicle's speed or not seeing the other vehicle soon enough. The theory is if your vehicle was equipped with DRL's other vehicles would see you sooner and better.

In some countries, Daytime Running Lights have been mandatory or in use since the 1970s, and some have noticed a decrease in a few types of motor vehicle accidents. The countries that currently use and have used Daytime Running Lights for many years are very different from the United States in latitude and climate which are the two main factors that affect the overall usefulness of Daytime Running Lights.

Scandinavian countries were the first to impose Daytime Running Lights regulations on manufacturers and on consumers. Scandinavia, though, is located in the far northern latitudes, and has much less ambient lighting than the United States, especially in the winter. This causes Daytime Running Lights to have a different impact on motorists and on highway safety. Sweden enacted mandatory Daytime Running Light laws in 1977. Norway followed in 1986, Iceland in 1988, Denmark in 1990. Canada has required Daytime Running Lights on new cars since 1989. All of these countries are located far from the equator, and thus have harsher conditions than the United States more suited for the use of Daytime Running Lights.[4]

Initially, the National Highway Traffic Safety Administration (NHSTA) said safety experiences in northern countries had no direct application to the United States. But later the NHTSA began accepting regulatory proposals at the request of petitions from General Motors. Many have seen this as just another way for the auto industry to make more money by marketing towards the fears of the consumer.

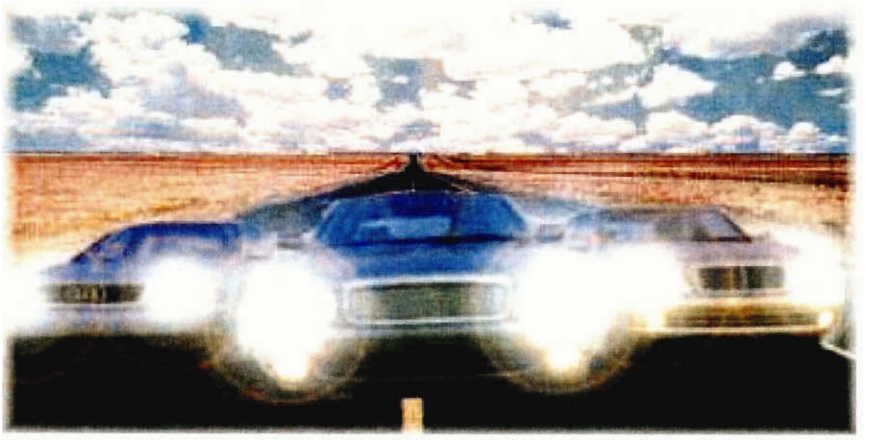
In 1987, the Insurance Institute for Highway Safety proposed that NHTSA permit Daytime Running Lights. NHTSA rejected the idea, but the Insurance Institute proposed the concept again a year later. Still, it was rejected, and NHTSA said that Daytime Running Lights do not improve highway safety and may, in fact, increase highway hazards. One of their conclusions were if most vehicles have Daytime Running Lights, it's harder to spot those who do not. NHTSA also said glare from the Daytime Running Lights of oncoming vehicles could bother some drivers.[5]

In 1990, General Motors (GM) pushed NHTSA again, asking for a national standard permitting an optional Daytime Running Light system. NHTSA complied two years later, and NHTSA regulations take precedence over any and all state laws, so now Daytime Running Lights are legal in all states, even though two-thirds of the states had previously banned Daytime Running Lights altogether. NHTSA permitted Daytime Running Lights to be implemented on high beam headlamps at up to 7000 candela. This is well above the threshold for discomfort glare. The reason that this intensity was chosen was so GM could make Daytime Running lights cheaply and GM began installing Daytime Running Lights immediately on some models in 1993. By 1997, all GM vehicles had Daytime Running Lights installed. [6]

In 1998, after receiving several hundred complaints about the excessive glare and the overall effectiveness of Daytime Running Lights, NHTSA proposed reductions in Daytime Running Light intensities and in 2001 low beam Daytime Running Lights would be allowed if they were no stronger than 1500cd above the horizontal. Due to vehicles operating at a higher voltage in the real world than in the lab, this figure would approach 2000cd when the car hit the road. In addition, there was no limit placed on the intensity below the horizontal. Because of the differences in heights between the different types of passenger vehicles glare is still an issue.

According to GM, since 1995, 37,000 crashes have been prevented due to Daytime Running lights. A study done by the NHTSA in June 2000 credits Daytime Running Lights with a 7% reduction in non-fatal crashes and a 28% cut in pedestrian fatalities.

The conclusions from the studies on Daytime Running Lights are mixed results, some say that they represent a dramatic increase of safety, while other studies say that they represent a negligible increase of safety if not hinder safety all together. Because of these results and because the United States does have more ambient lighting than countries where Daytime Running Light regulations are used, Daytime Running lights are not currently required in America.



Cost of Daytime Running Lights:

If current Daytime Running lights were made standard on all cars in the United States there would be a lot of gas used just to power the lights. To understand just how much of an impact that there will be this section steps through reasoning and calculation of how much gas will be used and how much money this will cost the American people.

The first piece of data needed to calculate how much Daytime Running Lights cost per year is the amount of miles driven in the United States. According to the National Bureau of Transportation Statistics in 2001 vehicles in the US drove 2,777 billion miles.[7]

Next we need the average speed that people drove per hour. In most rural areas the speed limit is usually between 30 and 40 mph. On most highways the speed limit is usually between 50 and 65 mph. If the assumption is made that people drive the speed limit, and we take the average of the low and high speeds then we obtain an average of about 45 mph. At 45 mph it takes a minute and forty five seconds to go a mile. So at one minute and forty five seconds per mile and 2,777 billion miles driven, the total amount of time driving would be 4,859 billion minutes or 81 billion hours in 2001. Because an assumption could be made that half of the total time driving is at night the total amount of time that the Daytime Running Lights would be on was 40.5 billion hours.

A bulb from a headlight on a car uses about 55 watts[8], one of the techniques used to realize Daytime Running Lights is to run the normal head lights at less power, and most dedicated Daytime Running Lights use slightly less wattage so they use less power. A good approximation is around 50 watts. Since there are two bulbs Daytime Running

Lights use about 100 watts. By multiplying the amount of hours by the amount of watts consumed by the lights we get the total amount of power used, 4,050 billion watt-hours or 4.05 billion kilowatt-hours.

A gallon of gas contains about 60 kilowatt-hours of chemical energy, but this energy has to go through two conversion processes before it can be used to light the bulb. First the chemical energy must be turned into mechanical power by the engine of the car, which isn't very efficient, only about 25% of the chemical energy can be turned into mechanical power, and the rest is wasted as heat. After the engine gets done with the gallon of gas there is 15 kilowatt-hours left.[9] The second conversion is done from mechanical energy to electrical energy; this is done by the alternator. The alternator is about 70% efficient.[10] Therefore the total amount of electrical energy from one gallon of gas is about 10.5 kilowatt-hours.

To calculate how many gallons of gas this is, you can divide the 4.05 billion kilowatt hours of energy that the daytime running lights consume each year by the 10.5 kilowatt-hours of energy each gallon of gas yields. If daytime running lights were on all the vehicles in the U.S., we would burn an extra 385 million gallons of gas each year. That's only a couple gallons for each vehicle, but in total it is more than all of the vehicles in the country burn in a day. At $1.90 a gallon, that's $732 million per year.

For every 42 gallon barrel of oil 20 gallons of gas are made, therefore it would take an extra 19.25 million barrels of oil to accommodate Daytime Running Lights on every car in the US. Currently the price of oil per barrel is $45 per barrel, so the total added cost in terms of cost of barrels of oil would be an extra $866 million dollars.[11]

Problems with Current Daytime Running Lights:

There are a few problems that are associated with Daytime Running Lights that cause motorists grief, this section explains the major drawbacks and makes some suggestions on how to they could be fixed.

Glare:

As can be seen from the previous sections there are two main problems with current Daytime Running lights, they are glare and cost. This section explains these problems and examines ways that could be used to fix each problem.

Glare is an issue because cars and trucks come in all shapes and sizes larger cars and trucks sometimes blind smaller ones because their lights are pointed directly into their windshield. There are a few different ways to combat this problem.

The first that I will discuss is the idea of dedicated daytime running lights. Dedicated daytime running lights are secondary lights that use lower wattage bulbs and are mounted lower on the vehicle, many SUV's and trucks come standard with holes in their grill already for fog lights so replacing these with Daytime running lights wouldn't prove much of a problem. To help combat the glare not only could these lights be lower power, but they could also be angled down slightly so that on smaller vehicles they wouldn't be pointed right at eye level, and since the point of Daytime Running Lights is to be able to see another person and not the use of the lights for navigation this is a feasible solution. The problem would arise from automobiles that don't have specialized holes in the grill, and on these automobiles mounting a secondary set of lights would be costly. The following picture is of a 97 ford probe that is equipped with secondary lighting.

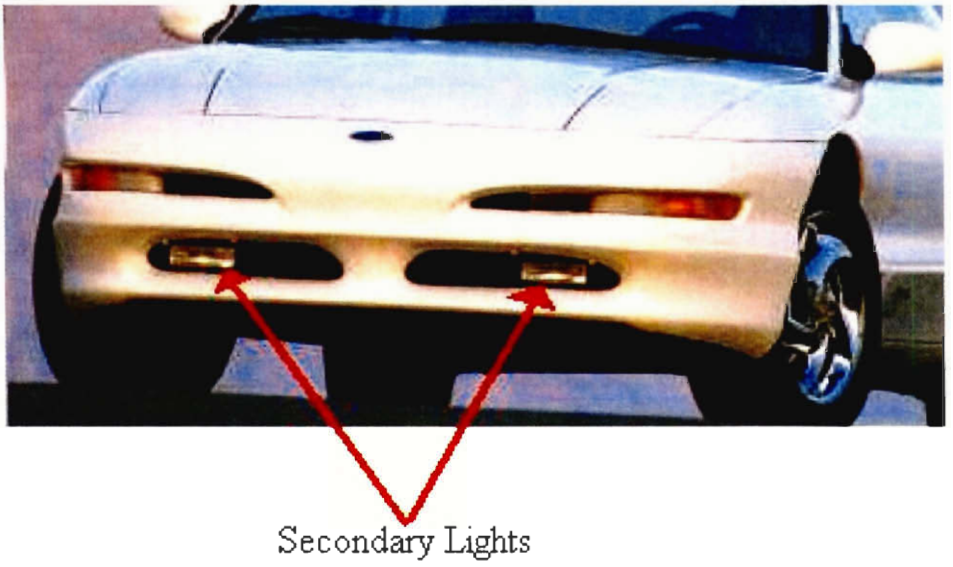


Figure 1

Another possibility is through the use of low power high output LED's which could be set for different levels of intensity depending on lighting conditions outside. Because of the way an LED disperses light the effect is softer and more pleasing to the eye, and an array of LED's could be used to create the same effect as current Daytime

Running Lights were designed for without the problem of glare. Like the previous alternative this method would require secondary lights, unless the brightness of the LED's could swing from low during daytime usage to the intensity of normal high beams. These could then take the place of normal headlights in cars that don't have the option of secondary lights.

A third option available is to use sensors to detect the height of an on coming vehicle and use a motor to angle the lights down so that the size of each individual vehicle could be accounted for. The problem with this option is that a space would be needed behind the current lights to accommodate for the motor and circuitry needed to realize this idea, and even if some vehicles had the space chances are not all do. Another problem created by this option is that there become more parts that may need replacing so the overall complexity of this idea may out way its utility.

The fourth and final option that I will discuss is a completely different lighting scheme all together. Instead of having headlight type lights, an LED light strip of high intensity could be used placed strategically on the front of the car so that the car still stands out during the day, but without pointing lights at cars. The following are LED light tubes which could be used, but a higher intensity would be needed.

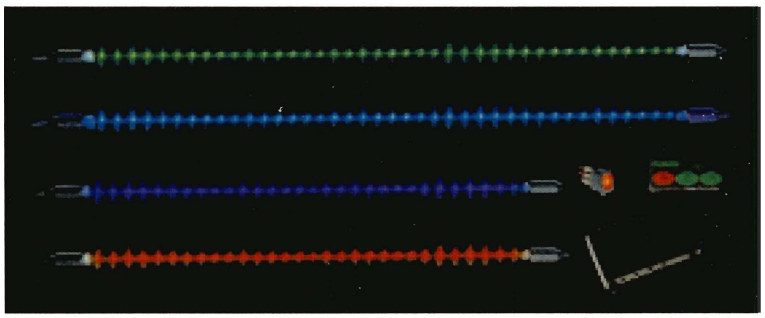


Figure 2

Cost:

The problem of cost isn't really an individual concern; it is when you add up all the wasted gas that is used just to power the Daytime Running Lights that cost becomes apparent. Crude oil is a precious commodity and should be saved anywhere it is able to be saved. Unfortunately there is only two real ways to cut the cost of Daytime Running

Lights, and that is to either use a lower powered/different type of bulb, or use a different lighting scheme all together.

By using a lower power incandescent bulb, we would in fact decrease the amount of wattage and thus decrease the amount of fuel needed to power them, but the bulbs that are actually available for use is limited and the gain would be miniscule. If instead an LED based light was used, it would use only a fraction of the power of an incandescent bulb and could be adjusted easier to account for weather conditions and location.

Alternative to the Current Daytime Running Lights:

In the previous sections some of the downfalls of the current design of the Daytime Running Light were discussed, and a few alternatives were suggested that could be used. Within this section a simple LED based design will be discussed which I implemented to test whether or not LED's could actually be used as Daytime Running Lights. I chose to try out LED's over other methods for three reasons; first as an Electrical Engineering student I find LED's are quite easy to work with, second also they are very low power so they are perfect for cutting down the cost of energy required, and third the LED technology is continually getting brighter, so even if it proved that LED's were not bright enough yet, they definitely soon will be.

I decided that in order to test the validity of LED's as possible alternatives to incandescent lights it would be best to use a design similar to the currently used design instead of either a light bar design or such. So the design is two circular "lamps" of LED's and to test them I mounted them where the fog lights of my car would go on my car, a picture can be seen at the end of the section.

Design:

The first task in the design of an LED based Daytime Running Light is to choose an LED, and the LED I chose was the LUMEX Ultra Bright Clear White LED, which can be seen in Appendix A. This LED has output of 11000 mcd, and requires 20 mA to be properly turned on. The reason I chose this LED was because it had the brightest rating that I could find outside of specially ordering them from an optoelectronics manufacturer, there are many available at a much higher price and at a much higher. Eighteen of these LED's would be used for each light.

In order to drive the LED's National Semiconductors LM3916 Dot/Bar display Driver was used. According to the specs this driver, which can be seen in Appendix B, can drive up to ten LED's of a rating up to twenty five volts, and from one to thirty milliamps. The circuit which was used is pictured below. In the original design I was going to use two drivers per headlight, but after a misfortunate accident with one of the purchased drivers, I found out that the chip had no problems driving all eighteen without any problem.

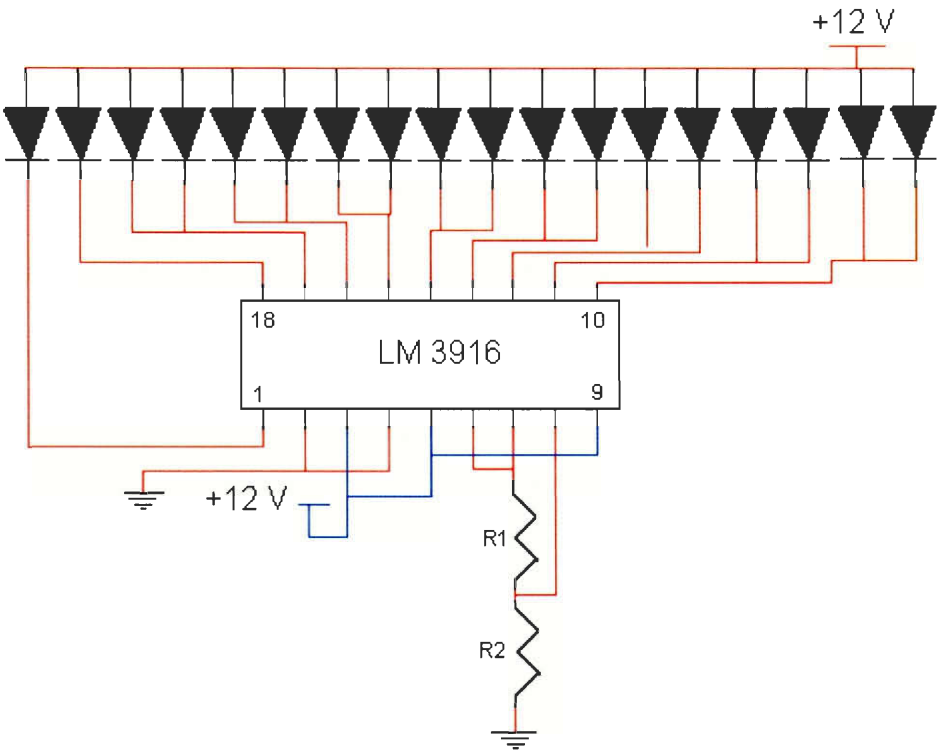


Figure 3

The case for each light was made out of a PVC cap, the metal top of a folders coffee can, and the plastic cap from a folders coffee can which fit the PVC cap perfectly. The metal top was used to keep the LED's secure and in the correct orientation, and the plastic top was used to keep the metal top in place. Finally for extra security electrical tape was used to seal the top. The final product is pictured below.

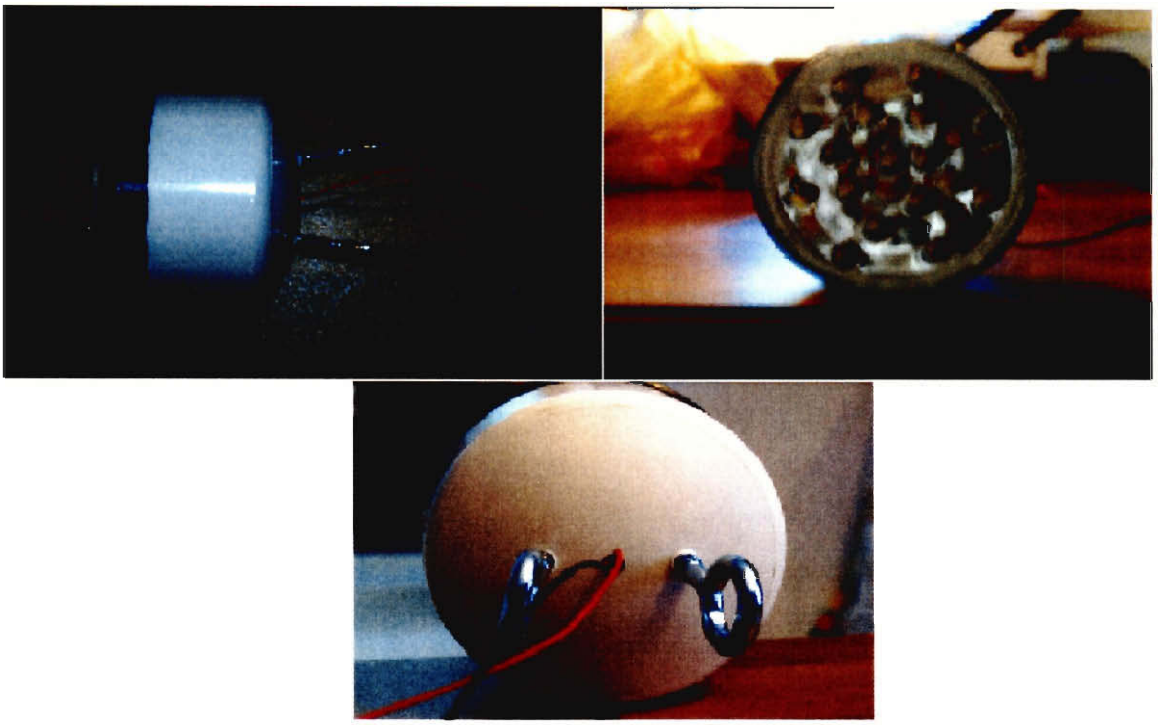


Figure 4

Theoretical Savings with LED Daytime Running Lights:

To find the cost of the LED Daytime Running Light the same method can be used that was used to find the cost of the Incandescent Daytime Running Lights.

In 2001 vehicles in the US drove 2,777 billion and at an average speed of 45 mph the total amount of driving time would be 4,859 billion minutes or 81 billion hours. Half of that can be assumed to be at night so the Daytime Running Lights would be off so that the Daytime Running Lights would be on 40.5 billion hours.

Each LED dissipates 105 milliwatts of energy, and since I used eighteen in each light, the total amount of energy dissipated by the LED's is 1.89 watts. The driver dissipates 1.37 watts, so the total amount of power dissipated by each light is 3.26 watts. The total amount of energy dissipates by both would therefore be 6.52 watts. By multiplying the amount of hours by the amount of watts consumed by the lights we get the total amount of power used, 264 billion watt-hours or 264 million kilowatt-hours.

From our previous calculation the amount of electrical energy from one gallon of gas is about 10.5 kilowatt-hours, and to calculate how many gallons of gas this is, you can divide the 264 million kilowatt hours of energy that the daytime running lights

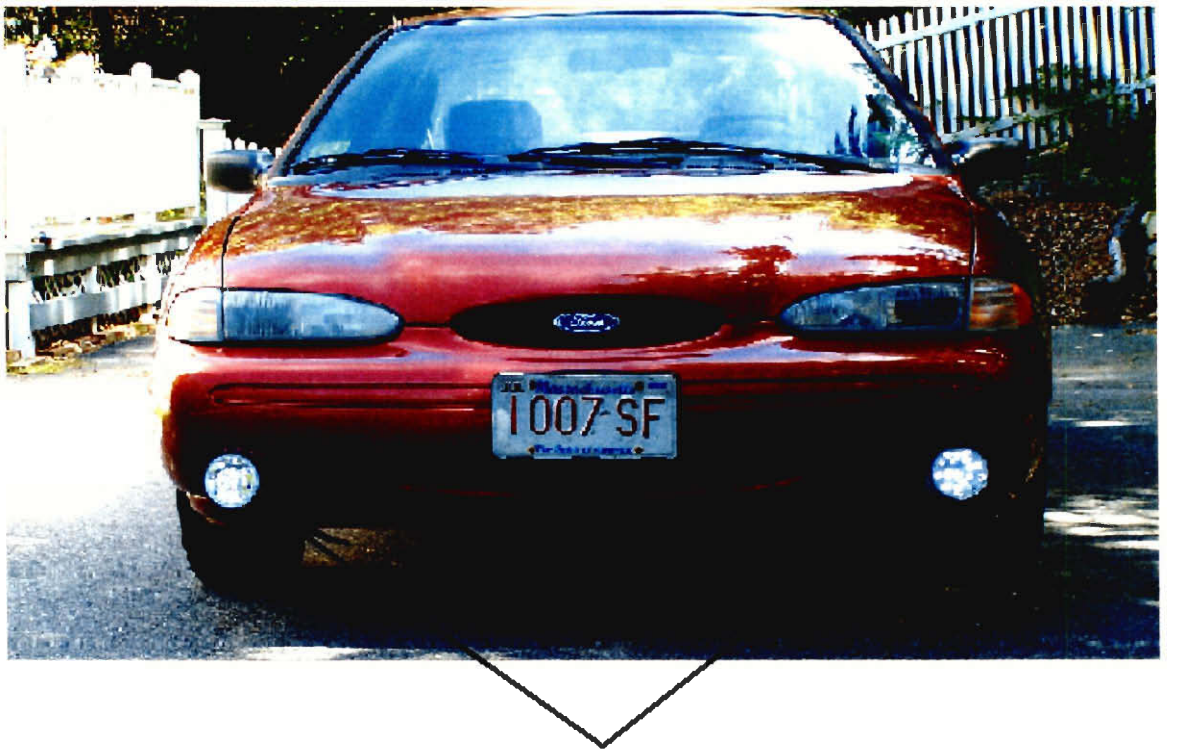
consume each year by the 10.5 kilowatt-hours of energy each gallon of gas yields. If LED daytime running lights were on all the vehicles in the U.S., we would only burn an extra 25 million gallons of gas a year as apposed to 385 million gallons of gas each year with incandescent bulbs. At $1.90 a gallon, that's $47.5 million per year as apposed to $732 million per year with incandescent lights. The total amount of savings is $684 million a year.

In terms of barrels of oil the LED Daytime Running Lights would constitute an extra 1.25 million barrels as apposed to Incandescent lights which would burn 19.25 million, and at $40 a barrel the total would be $50 million a year as apposed to $866 million a year, a total savings of $816 million a year.

So as can be seen from the above calculation, switching to LED's would be quite cost affective. The real question now is can LED's work feasibly as Daytime Running Lights? The next section discusses this question by using the implementation of the design explained in the previous section.

Results:

The following is a picture of my car with the newly designed LED Daytime Running Lights.



LED Based Daytime Running Lights

Figure 5

As can be seen from the photo, when there is shade these are very visible and make the car show up, but as can be seen from these next pictures they are not as bright in direct sunlight, thus failing what they were designed to do.

Figure 6

There are a few reasons that the lights did not meet expectations. The first reason is that the metal coffee can top that was used to mount the LED's was slightly warped due to the pressure from drilling the holes, this created a problem when trying to get the LED's in the proper alignment. It is hard to see from the above pictures but another problem was that the LED's would have worked better had the viewing angle been slightly wider, these lights have a 30 degree viewing angle I think that a 35 or 40 degree viewing angle would work better, due to the fact that it would have spread the light out more. Although the LED Daytime Running Light design did not quite live up to expectation it does show that with slightly brighter LED's it could work. The LED's that were used were also not the brightest available on the market, they were just cheaper and easier to obtain.

Conclusions and Recommendations:

From this project it is plain to see that if Daytime Running Lights were made mandatory on all cars there would be a lot of wasted money, gas, and oil just to run the current incandescent lights. Even though my particular design did not fully work the way that it was intended it shows that very cheaply a more efficient light can be made to take the place of the current design.

My recommendations to take this project further would be to keep an eye out on up and coming LED technology, a better brighter LED is on the way. Also there should be more work done to thoroughly test the utility of Daytime Running Lights as an actual useful life saving device, all of the literature out there is split half say that Daytime Running Lights help save lives, while the other half says they are useless. It should be determined concretely first whether or not Daytime Running Lights are totally effective before making them mandatory or putting a lot of money into redesigning them.

References:

1. The current price of gas was obtained from the MSNBC news site; www.msnbc.com

2. Vehicle accident statistics were obtained from the National Transportation Safety Board; www.ntsb.gov

3. Studies about Daytime Running Lights were obtained from Ibiblio the publics library and digital archive; www.ibiblio.org

4. The rest of the History about Daytime Running Lights was compiled from the following web sites; The Association Against Daytime Running Lights www.lightsout.org; www.howstuffworks.com; and the department of highway safety www.highwaysafety.org

5. The National Highway Traffic Safety Association Studies were obtained from their website; www.nhtsa.gov

6. The publications of General Motors can be found at www.gm.com

7. The statistics about the number of cars on the road were obtained from the Bureau of Transportation Statistics; www.bts.gov

8. The wattage from a incandescent light used in a daytime running light was obtained from the auto parts dealer Autozone; www.autozone.com

9. The conversion from chemical to electrical energy of a car battery can be found on the Physics Central website www.physicscentral.com

10. The efficiency of a car alternator was obtained from www.autoeducator.com