School of Electrical Engineering & Telecommunications

ELEC1111 Tutorial 1

Design of the rear lights of a vehicle

Conspicuity for the rear of a vehicle is provided by rear position lamps (also called tail lamps or tail lights). These are required to produce only red light and to be wired such that they are lit whenever the front position lamps are illuminated, including when the headlamps are on. Rear position lamps may be combined with the vehicle's stop lamps or separate from them. In combined-function installations (as the one you will explore today), the lamps produce brighter red light for the stop lamp function and dimmer red light for the rear position lamp function. Regulations worldwide stipulate minimum intensity ratios between the bright (stop) and dim (rear position) modes, so that a vehicle displaying rear position lamps will not be mistakenly interpreted as showing stop lamps, and vice versa.

Light Emitting Diodes (LEDs) are gradually coming to be preferred over filament bulbs as the light sources for vehicle rear lamps.

In this tutorial, you will be given a set of specifications, and an opportunity to design the rear lights of a hybrid vehicle.

Specifications:

The combined stop-rear lights circuit design is to conform to the following specifications:

1. Needs to illuminate 12 LEDs distributed in a grid pattern (i.e. X rows × Y columns).
2. The intensity ratio between the bright (stop) and dim (rear position) modes is 100/30 (i.e. 100% intensity in stop mode, and 30% intensity in rear position mode).
3. All LEDs are to have equal current flowing through them (equal brightness).
4. Current through each LED is to be no greater than 75 mA.
5. The circuit is to be powered using a 12 V car battery.

Consider issues of cost, robustness, number of components and any other factors in making a good design.

Notes:

- LEDs used for our tail-lights (CP42B-RKS) drop about 2.5 V across terminals for currents around 70 mA.
- We will model the LED as a 2.5 V voltage source.
- You may use any number of switches.
- You may use any number of resistors. Resistors to be used are rated at 0.5 W. If possible, use standard resistor values (see list of standard resistor values on last page).

1. Hybrid vehicle battery analysis

A specific brand of a hybrid vehicle features a high voltage Hybrid Vehicle (HV) battery pack and a 12 V auxiliary battery. High voltage electricity powers the electric motor, generator, air conditioning, compressor, and inverter/converter. All other automotive electrical devices such as the rear lights, horn and radio are powered from a separate 12 V battery.

The HV battery pack is a Nickel Metal Hydride (NiMH) battery pack consisting of 34 low voltage (7.2 V) modules connected in series. The capacity of the battery is 6.5 Ah.

Q1. How much total energy is available from the HV battery pack? Express your answer in joules and KWh.

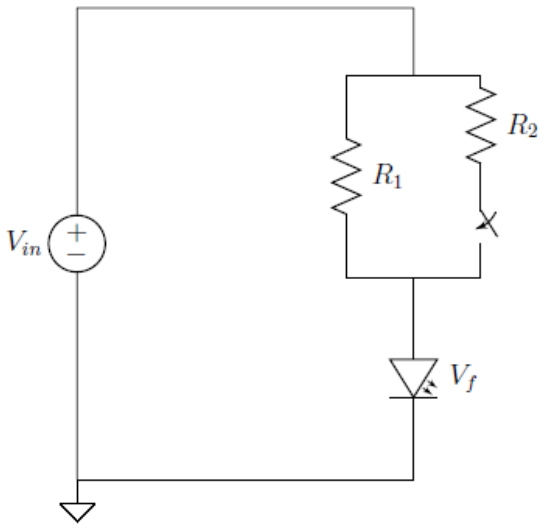
Answer: w = 1.591 KWh or w= 5728320 J = 5.728 MJ.

Q2. If the vehicle drives for 15 minutes as an all-electric vehicle using only the energy available in the fully charged HV battery pack, what is the average current used when driving? And the average power?

Answer: i = 26 A, p = 6364.8 W

2. Circuit to illuminate a single LED

To help you with the design task, you will start analysing a circuit that illuminates a single LED functioning as stop-rear light.



In the previous circuit, the stop mode occurs when the switch is closed, since the value of the resistance will decrease ($R_1 \| R_2 < R_1$) and the current and brightness of the LEDs will increase.

Q3. Calculate the current in stop mode (i_{stop}) and rear position mode (i_{rear}) if V_{in} = 12V, R_1 = 442 Ω, R_2 = 196 Ω, and V_f = 2.5 V. Check whether these currents conform to the specifications.

Answer: i_{stop} = 69.95 mA; i_{rear} = 21.5 mA. They conform to the specifications.

Q4. Check whether the resistors meet the power specifications (resistors to be used are rated at 0.5 W).

Answer: p_{R1} = 0.204 W; p_{R2} = 0.46 W. They meet the power specifications.

3. Rear lights design

The values of R_1 and R_2 in the previous circuit were obtained according to the following design steps:

1. According to the specifications, the current through each LED is to be no greater than 75 mA. We can then choose:

$$i_{stop} = 70\ mA$$
$$i_{rear} = 70 \times 0.3 = 21\ mA$$

   Note that the intensity ratio between the bright (stop) and dim (rear position) modes is 100/30.

2. If the car battery provides 12V and we assume ideal behaviour of the LED (V_f = 2.5 V), R_1 can be then calculated as follows:

$$R_1 = \frac{12 - 2.5\ V}{0.021\ A} = 452.38\ \Omega$$

   We choose a standard resistor value as close as possible to 452 which meets the current limitation. E.g. R_1 = 442 Ω (from E48 series).

3. If i_{stop} = 70 mA and i_{rear} = 21 mA, then i_{R_2} = 70 – 21 = 49 mA. R_2 can be then calculated as follows:

$$R_2 = \frac{12 - 2.5\ V}{0.049\ A} = 193.88\ \Omega$$

   We choose a standard resistor value as close as possible to 194 which meets the current limitation. E.g. R_2 = 196 Ω (from E48 series).

Q5. Design the rear lights of a hybrid vehicle, conforming to the specifications listed in the first page. Use the single LED circuit functioning as stop-rear light as a starting point, and keep in mind the steps followed to design it.

Consider issues of cost, robustness, number of components and any other factors in making a good design.

Answer: There are many possible correct designs. If you have a design in mind and you want to know whether it is correct out of tutorial hours, you can simulate it using Falstad (http://www.falstad.com/circuit/) or any other simulator of electric circuits. Otherwise, please contact your lecturer to organise an appointment.

NOTE:

- CP42B-RKS price: $0.28 per unit.
- Resistor price: $0.75 per package of 5.
- Switch price (e.g. SP0720): $1.45 per unit.

Note that these are illustrative prices. They might change a bit depending on the provider. Bulk pricing would be lower.

Standard EIA Decade Values Table (100 to 1,000 Decade)

E6	E12	E24	E48	E96	E192
100					100
				100	101
			100		102
				102	104
		100			105
				105	106
			105		107
				107	109
	100				110
				110	111
			110		113
				113	114
		110			115
				115	117
			115		118
				118	120
					121
				121	123
			121		124
				124	126
		120			127
				127	129
			127		130
				130	132
	120				133
				133	135
			133		137
				137	138
		130			140
				140	142
			140		143
				143	145
					147
				147	149
			147		150
				150	152
		150			154
				154	156
			154		158
				158	160
	150				162
				162	164
			162		165
				165	167
		160			169
				169	172
			169		174
				174	176
150					178
				178	180
			178		182
				182	184
		180			187
				187	189
			187		191
				191	193
	180				196
				196	198
			196		200
				200	203
		200			205
				205	208
			205		210
				210	213

E6	E12	E24	E48	E96	E192
220					215
				215	218
			215		221
				221	223
		220			226
				226	229
			226		232
				232	234
	220				237
				237	240
			237		243
				243	246
		240			249
				249	252
			249		255
				255	258
					261
				261	264
			261		267
				267	271
		270			274
				274	277
			274		280
				280	284
	270				287
				287	291
			287		294
				294	298
		300			301
				301	305
			301		309
				309	312
					316
				316	320
			316		324
				324	328
		330			332
				332	336
			332		340
				340	344
	330				348
				348	352
			348		357
				357	361
		360			365
				365	370
			365		374
				374	379
330					383
				383	388
			383		392
				392	397
		390			402
				402	407
			402		412
				412	417
	390				422
				422	427
			422		432
				432	437
		430			442
				442	448
			442		453
				453	459

E6	E12	E24	E48	E96	E192
470					464
				464	470
			464		475
				475	481
		470			487
				487	493
			487		499
				499	505
	470				511
				511	517
			511		523
				523	530
		510			536
				536	542
			536		549
				549	556
					562
				562	569
			562		576
				576	583
		560			590
				590	597
			590		604
				604	612
	560				619
				619	626
			619		634
				634	642
		620			649
				649	657
			649		665
				665	673
					681
				681	690
			681		698
				698	706
		680			715
				715	723
			715		732
				732	741
	680				750
				750	759
			750		768
				768	777
		750			787
				787	796
			787		806
				806	816
680					825
				825	835
			825		845
				845	856
		820			866
				866	876
			866		887
				887	898
	820				909
				909	920
			909		931
				931	942
		910			953
				953	965
			953		976
				976	988

http://www.logwell.com/tech/components/resistor_values.html