TOTAL CURRENT MEASUREMENT INTERRUPTS DETECTION METHOD IN AUTOMOTIVE BULBS CIRCUITS

Zbigniew Sobczyk

Military University of Technology, Faculty of Mechanical Engineering
Institute of Motor Vehicles and Transport
Gen. S. Kaliskiego Street 2, 00-908 Warsaw, Poland
tel.+48 22 6837744, fax: +48 22 6837370
e-mail: zsobczyk@wat.edu.pl

Abstract

Identification of interruption in automotive bulbs circuits by total current measurement method seems very attractive. This method allows on application the least length and weight wires in automotive electric network. These savings have special meaning in mass production. Due to less connections number increases reliability, too.

Basing on electrical schematic general diagram has been described total current measurement interrupts detection method in automotive bulbs circuits. It has been pointed at sensibility on supply voltage value changes range of this method. It has been described bulbs' main properties.

As an analysis example has been chosen the most exacting from the possibilities of total current measurement method indicator lamp circuit. Besides supply voltage change, there are not equal load resistances in this circuit. This causes different bulbs' electric current values.

It has been computed failure detector's electric current values at minimal and maximal voltage in vehicle network. It has been analyzed proper working circuit likewise interruptions in bulbs' 21 [W] and 5 [W] circuits. It has been found that at accepted establishments correct and univocal interruption detection in 21 [W] bulbs is possible in full range of changes supply voltage. Detection of interruption in 5 [W] bulbs is possible only in part of range of changes supply voltage.

Keywords: *transport, automotive lights, bulbs, network failures, interruptions identification method*

1. Introduction

Automotive lights fulfil important functions. Besides illumination, they have signalling, warning and inquiry functions. It has direct influence on road safety. For that reason, it is important that automotive lights should be reliable and their failure is often signalling, because luminous parts of the car lamps are not often directly visible for this car driver.

Automotive lights get out of order by reason of bulbs' lifetime and difficult service conditions, such as vibrations, temperature, humidity changes and corrosion. That also leads to other light sources development, like for example LED, but bulbs are still in common use. Such damages are probably the more so as bulbs' lifetime and so as joints damages are commonly drawback in vehicle electric network [1, 8], as shown on Fig. 1.

2. Total current measurement method electrical schematic general diagram

The total current measurement method electrical schematic diagram is shown on Fig. 2. Such solution could be the most profitable in mass production because of the shortest wire length and the least weight. On account of less connections number, such solution, in compliance with Fig. 1, is more reliable too.

The total current measurement method is the most suitable for interruptions of electric circuit signalling at constant value supply voltage circuits and at constant and equal resistance of every load. In automotive electric network with bulbs, such conditions are inaccessible. Then should be considered bulbs' properties and their work conditions under varying supply voltage. It should be noticed that threshold value uncertainty caused by real manufactured detectors and current sensors is negligible small.

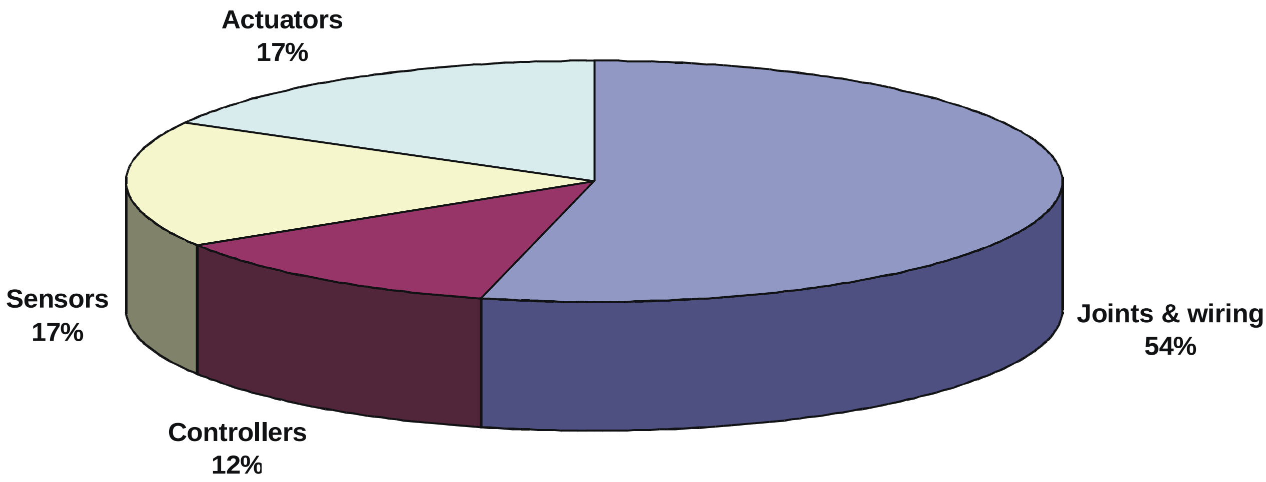


Fig. 1. Automotive electric network elements failure frequency [1, 8]

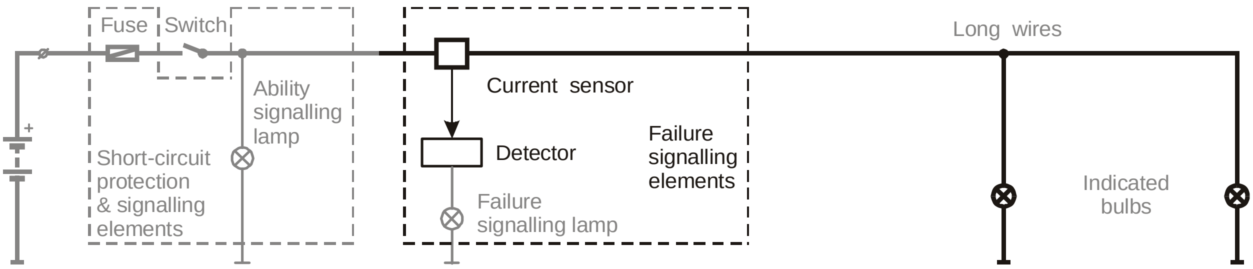


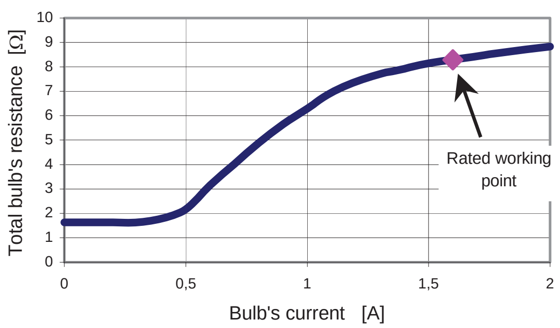
Fig. 2. Interruption's of electric circuit signalling with total current sensor

3. Automotive bulbs properties in aspect of total current measurement method

Luminous bulb's filament is heated by flowing current up to over 3000 K. Total bulb's resistance consists of filament and lead wires resistances. The filament is made of a tungsten alloy. Bulb's resistance depends on temperature. On account of heating bulb's filament to very high temperature, its resistance varies most of all. For example, tungsten has a positive temperature coefficient equals 0.0052 K^{-1} [3]. It means that turning on increases of total bulb's resistance from several to a dozen or so times and then filament resistance is a main component of total bulb resistance. Lead wire resistance usually is as small as possible in order to elimination power loss. Current-varying total resistance for automotive P21W bulb (12V rated voltage) is shown on the Fig. 3a. Similar shape characteristic is presented in [5] but bulb's parameters are different. Such resistance changes and filament's temperature inertia explains why bulb's starting current is respectively bigger than rated current.

Voltage sources are more often in practice than current sources. This is caused by obvious advantage of voltage sources. In no-load state, there is not loss of energy. Electrochemical sources are usually voltage sources. Because of low internal resistance, automotive batteries and generators are generally treated as voltage sources. In load connected to the voltage source the voltage is a cause of current is passage. Then graph shown on Fig. 3a could not be useful. Thus, better bulbs' characteristic appears current dependence on voltage, as produced on Fig. 3b.

a) *b)*



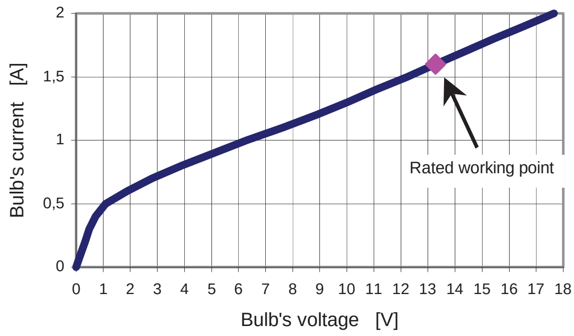


Fig. 3. Principal electric bulb's characteristics (for P21W bulb):
a) general diagram, for all sensors' types; b) diagram for sensors except resistors

Bulb's relationships are similar for a lot of them, therefore can be normalized to rated values. Because of bulbs useful features ranges that normalized relationships changes are bounded. Supply voltage changes or other can affect on boundaries values. In [2] can be found ±35% changes' of supply voltage range which exactly covers ±5% changes' range in [9].

Typical normalized relationships between main bulb parameters' are shown on Fig. 4 [2].

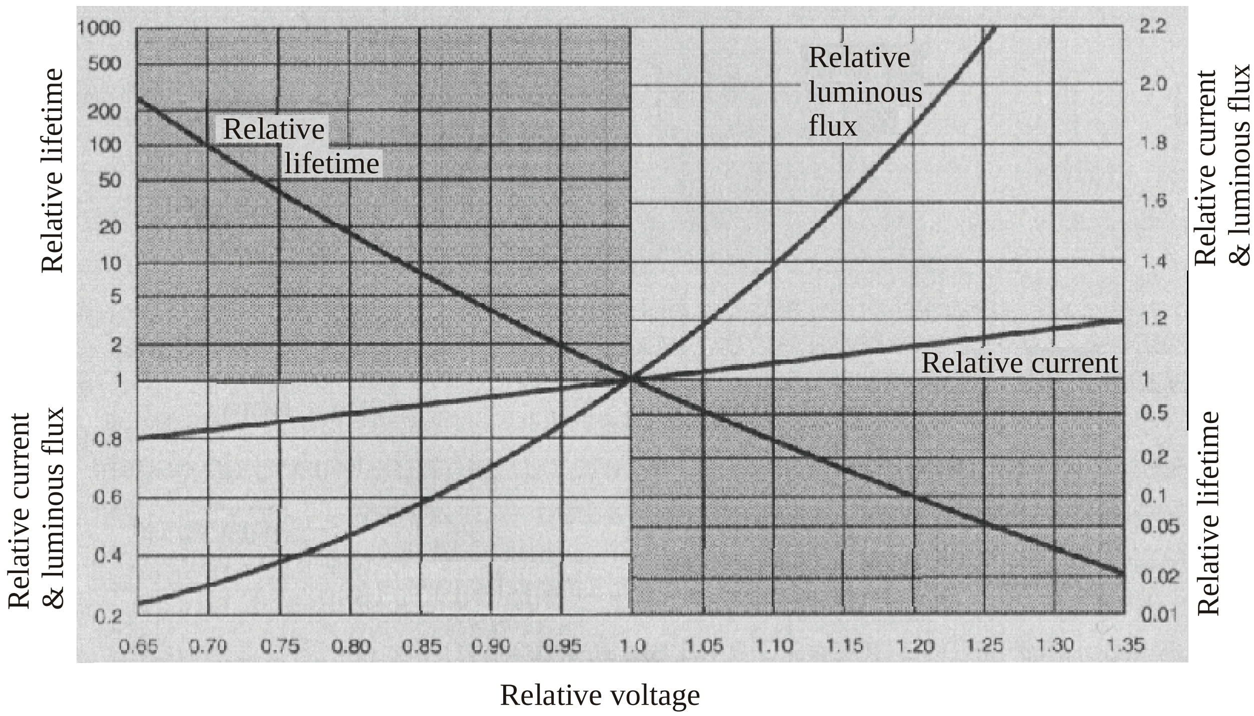


Fig. 4. Normalized to rated values relationships between main bulb parameters [2]

4. Total current measurement method failure detection possibilities example

The most interesting for bulbs failure detection possibilities in total current measurement method is the automotive indicator lamp circuit. It usually consists of three bulbs on each of both sides of the vehicle. Two of them have nominal power 21W and one 5W as shown on Fig. 5. Thus, not all this load resistances are equal. It affords examination the most complicated possibilities of failure.

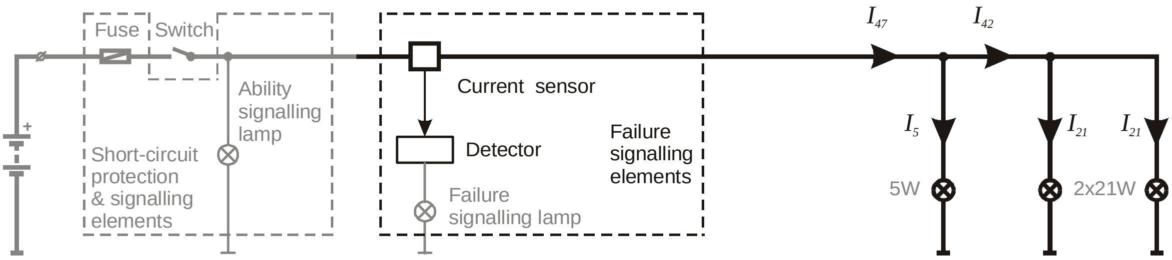


Fig. 5. Total current measurement failure detection method in indicator lamp circuit

It should be noticed that electric automotive network voltage is not constant, too. It changes [4, 6, 7] from 10,5 to 14,5 [V].

Nominal electric current value I_n drew by bulbs with nominal power P_n in steady state at nominal voltage U_n can be obtained from expression (1):

$$I_n = \frac{P_n}{U_n}, \tag{1}$$

what adequately gives nominal electric current value I_{n5} drew by bulb with nominal power P_n=5 [W] (2) and nominal electric current value I_{n21} drew by bulb with nominal power P_n=21 [W] (3):

$$I_{n5} = 5[\mathrm{W}]/12[\mathrm{V}] = 0.41(6)\ [\mathrm{A}], \tag{2}$$

$$I_{n21} = 21[\mathrm{W}]/12[\mathrm{V}] = 1.75\ [\mathrm{A}]. \tag{3}$$

Therefore total current of proper working in nominal conditions indicator lamps equals (4):

$$I_{n47} = I_{n5} + 2\mathrm{x}\ I_{n21} = 0.41(6)\ [\mathrm{A}] + 2\mathrm{x}\ 1.75\ [\mathrm{A}] = 3.91(6)\ [\mathrm{A}]. \tag{4}$$

Minimal and maximal automotive network voltage gives voltage changes coefficients k_U can be appointed (5) and (6):

$$k_{U10.5} = 10.5\ [\mathrm{V}]/12[\mathrm{V}]= 0.875, \tag{5}$$

$$k_{U14.5} = 14.5\ [\mathrm{V}]/12[\mathrm{V}]= 1.208\ (3). \tag{6}$$

For these values can be stated from fig. 4 electric current changes coefficients k_J (7) and (8).

$$k_{J10.5} = [(k_{J12}\text{-}\ k_{Jmin})/(k_{U12}\text{-}\ k_{Umin})]\mathrm{x}(k_{U10.5}\text{-}\ k_{Umin})+ k_{Jmin} =$$

$$= [(1\text{-}0{,}8)/(1\text{-}0.65)]\mathrm{x}(0.875\text{-}0.65)+0.8 = (0.2/0.35)\mathrm{x}0.225+0.8= 0.92857, \tag{7}$$

$$k_{J14,5} = [(k_{Jmax}\text{-}\ k_{J12})/(k_{Umax}\text{-}\ k_{U12})]\mathrm{x}(k_{U14,5}\text{-}\ k_{U12})+ k_{J12} =$$

$$= [(1.2\text{-}1)/(1.35\text{-}1)]\mathrm{x}(1.208(3)\text{-}1)+1 = (0.2/0.35)\mathrm{x}0.208(3)+1= 1.119. \tag{8}$$

For minimal automotive network voltage, values of electric current will be as follows, (9)-(13):

- for single 5 [W] bulb:

$$I_{min5} = I_{n5}\ \mathrm{x}\ k_{J10,5} = 0.41(6)\ [\mathrm{A}]\mathrm{x}0.92857= 0.3869\ [\mathrm{A}], \tag{9}$$

- for single 21 [W] bulb:

$$I_{min21} = I_{n21}\ \mathrm{x}\ k_{J10.5} = 1.75\ [\mathrm{A}]\mathrm{x}0.92857= 1.625\ [\mathrm{A}], \tag{10}$$

- for proper working circuit (two 21 [W] and one 5 [W] bulbs in parallel):

$$I_{min47} = I_{min5} + 2\text{x } I_{min21} = 0.3869\ [A] + 2\text{x}1.625\ [A] = 3.6369\ [A], \tag{11}$$

- while interruption in one 21 [W] bulb (one 21 [W] and one 5 [W] bulbs in parallel):

$$I_{min26} = I_{min5} + I_{min21} = 0.3869\ [A] + 1.625\ [A] = 2.0119\ [A], \tag{12}$$

- while interruption in 5 [W] bulb (only two 21 [W] in parallel):

$$I_{min42} = 2\text{x } I_{min21} = 2\text{x}1.625\ [A] = 3.25\ [A]. \tag{13}$$

For maximal automotive network voltage, values of electric current will be as follows, (14)-(18):

- for single 5 [W] bulb:

$$I_{max5} = I_{n5} \text{ x } k_{J14.5} = 0.41(6)\ [A]\text{x}1.119 = 0.4662\ [A], \tag{14}$$

- for single 21 [W] bulb:

$$I_{max21} = I_{n21} \text{ x } k_{J14.5} = 1.75\ [A]\text{x}1.119 = 1.95825\ [A], \tag{15}$$

- for proper working circuit (two 21 [W] and one 5 [W] bulbs in parallel):

$$I_{max47} = I_{max5} + 2\text{x } I_{max21} = 0.4662\ [A]+2\text{x}1.95825\ [A] = 4.3827\ [A], \tag{16}$$

- while interruption in one 21 [W] bulb (one 21 [W] and one 5 [W] bulbs in parallel):

$$I_{max26} = I_{max5} + I_{max21} = 0.4662\ [A]+1.95825\ [A] = 2.42445\ [A], \tag{17}$$

- while interruption in 5 [W] bulb (only two 21 [W] in parallel):

$$I_{max42} = 2\text{x } I_{max21} = 2\text{x}1.95825\ [A]= 3.9165\ [A]. \tag{18}$$

Thus, for extreme changes of automotive network voltage, ranges values of electric current ΔI will be as follows, (19)-(18):

- for proper working circuit (two 21 [W] and one 5 [W] bulbs in parallel):

$$\Delta I_{47} = I_{max47} - I_{min47} = (4,3827\text{-}3,6369)\ [A] = 0,7458\ [A], \tag{19}$$

- while interruption in one 21 [W] bulb (one 21 [W] and one 5 [W] bulbs in parallel):

$$\Delta I_{26} = I_{max26} - I_{min26} = (2.42445\text{-}2.0119)\ [A] = 0.41255\ [A], \tag{20}$$

- while interruption in 5 [W] bulb (only two 21 [W] in parallel):

$$\Delta I_{42} = I_{max42} - I_{min42} = (3.9165\text{-}3.25)\ [A] = 0.6665\ [A]. \tag{21}$$

These electric current ranges values are shown on Fig. 6:

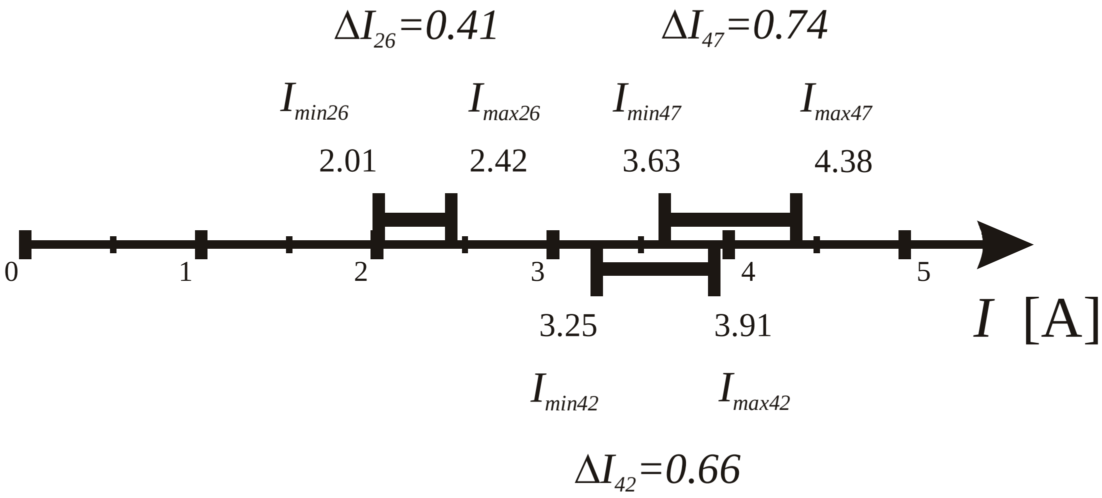


Fig. 6. Comparison of the computed indicator lamp circuit electric current values

5. Conclusions

Correct and univocal interruption detection in bulb circuit by the total current measurement method is possible only for these out of order circuits, which electric current ranges of change ΔI do not overlap with proper working circuit range.

In practice, to obtain reliable detection, these ranges of interrupted circuits should be distant from the proper working circuit range. It should be because of: bulb parameters productive spread, ambient temperature changes influence and detector's threshold tolerance.

In placed example, range of interrupted 21 [W] bulb circuits is distant from the proper working circuit range. Thus, it is possible detection of interruption in 21 [W] bulb's circuit. In order to attain that, value of electric current threshold should be chose from 2,42-3,63 [A] interval. The detection of interrupted circuit is possible for interrupts in 21 [W] bulb circuits together with any other bulb circuit interruption.

Detection of interruption in 5 [W] bulb circuits is not possible in full range of automotive network voltage. Ranges of interrupted 5 [W] bulb circuit overlaps the proper working circuit range. Interruption can be detected only if value of electric current threshold would be choosing from 3.25-3.63 [A] interval. However, there is vast interval of changes 3.63-3.91 [A] in which correct detection is not possible.

References

[1] Herner, A., Riehl, H. J. *Elektrotechnika i elektronika w pojazdach samochodowych*, WKŁ, Warszawa 2006.
[2] *Katalog ELFA 55*, ELFA Polska, sp. z o.o., Warszawa 2007.
[3] Kolbiński, K., Słowikowski, J., *Materiałoznawstwo elektrotechniczne*, Wydawnictwa Politechniki Warszawskiej, Warszawa 1975.
[4] Konopiński, M., *Elektronika w technice motoryzacyjnej*, WKŁ, Warszawa 1987.
[5] Limann, O., Pelka, H., *Radiotechnika. Poradnik*, WKŁ, Warszawa 1993.
[6] Ocioszyński, J., *Laboratorium elektrotechniki samochodowej*, WPW, Warszawa 1974.
[7] Pijanowski, B., *Akumulator*, WKŁ, Warszawa 1991.
[8] Widerski, T., *Samochodowe sieci informatyczne*, Poradnik Serwisowy Nr 5/2005, Wydawnictwo INSTALATOR POLSKI, Warszawa 2005.
[9] www.swiatla.arbiter.pl: *Wykres trwałości, światłości, mocy, ilości światła w zależności od napięcia*.