Motorcycle Headlamp with Dynamic Light Beam Position Adjuster in the Course of Turning

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Abstract

This paper is devoted to elimination of negative consequences arising in the course of turnings performed by two-wheeled vehicles, that is elimination of increase in glare of oncoming drivers and of decrease in visibility range.

A motorcycle lighting system has been proposed which is noted for improved lighting performance in law beam and high beam modes and provides dynamic light beam position adjustment in the course of turning by stabilization of position of rotating optical fiber image converter around optical axis of the headlamp.

Motivation

For the 120 years past from the moment of occurrence of the first motorcycle, despite of the apparent similarity, a New Verner of 1901 and a modern motorcycle differ a lot. Nevertheless, despite of substantial changes in design, there is a problem having a considerable impact on traffic safety, though all the attempts of which resolving have remained unsuccessful since the 20th of the last century.

This problem is connected to the position of headlamp mounted on a fork or a mud cover of a motorcycle so that at turning its inclination angle is practically the same as of the motorcycle itself. Depending on direction of the turn (right-hand, left-hand) this circumstance results to different, but in both cases sad consequences: both at the right-hand, and the left-hand turn driver loses visibility in the direction of movement, that is already dangerous to all participants of traffic including pedestrians, and at right-hand turn there might also be glare impact on the oncoming drivers as it is shown in fig. 1.

Figure 1 Visibility and passing track with oncoming vehicle when using headlamp without adjusting gadget

At first sight, it is clear how to solve this problem: light beam position is to be stabilized depending on the dynamic impacts arising during performance of the turn, as it is shown in fig. 2.

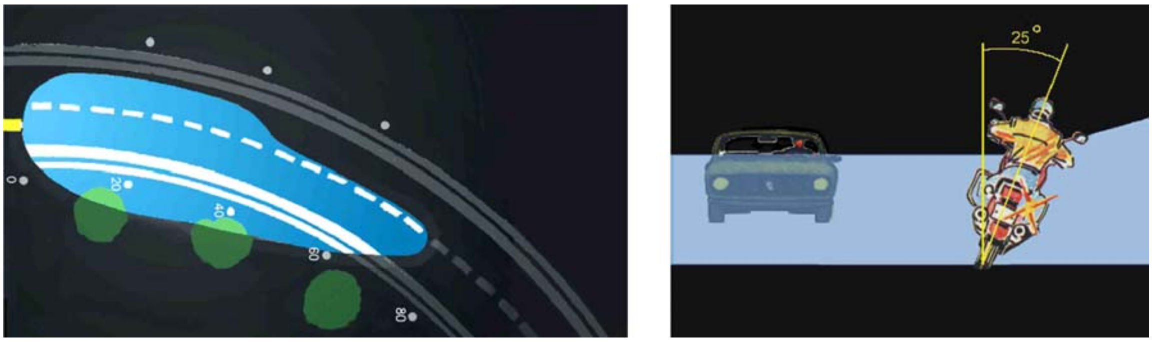


Figure 2 Visibility and passing track with oncoming vehicle when using headlamp with the adjusting gadget

However, as the analysis shows, this problem cannot be solved effectively when using conventional headlight designs both with parabolic and elliptic reflector, as the light beam in these designs can be turned to the angle necessary for its stabilization in the following ways:

-Either turning the headlight as an assembly that requires a drive of relatively high power to move against inertial mass;

-Or turning screen forming cut-off-line in elliptic headlamp, that makes it necessary to use axially symmetric ellipsoid having low lighting performance and an additional lens.

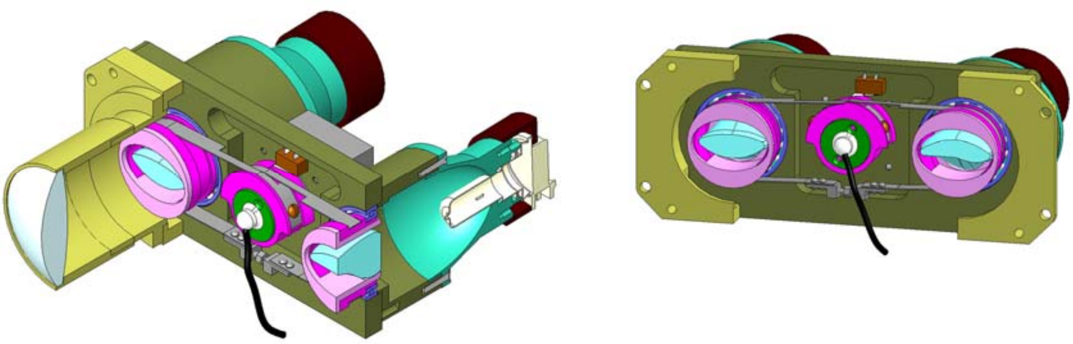
As a variant it is also possible to turn the screen in multielliptic headlight but it will not be either effective because in this case turning of screen relative to asymmetrically concentrated in the area of the second focus light beam results in essential change of both geometry and lighting performance in the resulting lighting pattern.

Therewith it is necessary to note that though motorcycles and scoters usually ride at rather high speed their power supply is limited so they use light sources of low power. As a result their headlights are relatively inferior to automobile headlights in the respect of lighting performance as use of effective and low-power discharge light sources appears to be too expensive for this class of vehicles.

Thus to solve the outlined problem it was necessary to develop such a lighting design that could ensure turning of the light beam round the basic design members (reflector, light source, lens) on retention of its geometrical and lighting performance as also of its high efficiency.

Modular Headlamp Design

The design of modular headlamp presented in this paper (see fig. 3) allows having both low beam and high beam. In this design two optical fiber image converters are used to form low beam and high beam. Each of them is located between the second focus of the associated axially symmetric ellipsoid and the focal plane of the associated condenser lens and can be rotated around the optical axis of the headlamp. Such converter [1] represents an optical fiber component comprising focon which inlet end face has form and size of the bulb filament image generated by reflector in the second focal plane (in this case it is the form of a circle). The outlet end face of the component has the form corresponding to the lighting pattern configuration of the headlamp in mirror.

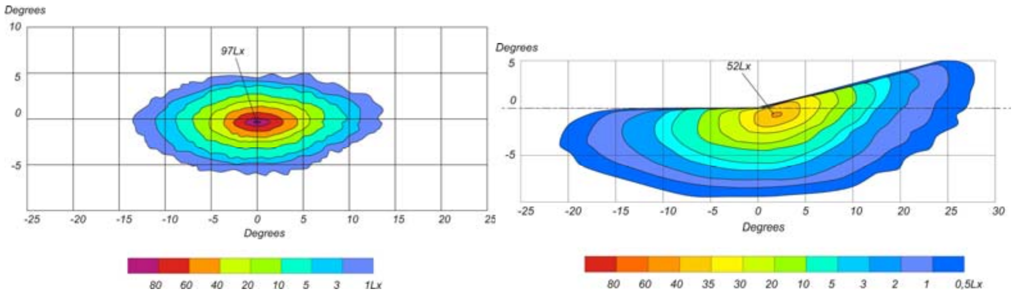


a) *b)*

Figure 3 a) Appearance of the headlamp in section

b) View of the actuating mechanism of the converter drive

Such performance of the optical fiber image converter allows at minimal power losses to transform the concentrated conic light beam to the beam form of which is set by the outlet end face that in result provides preservation of lighting characteristics at radial turning of the converter relative to (about) the fixed reflector and lens. In doing so the necessary lighting pattern (zone coordinates with the maximal illuminance value) is provided with [1] position of the second focal point of the reflector on the inlet end face. Lighting characteristics of the low beam and high beam modes are shown in fig. 4 with the lenses of Ø70 mm and H7.



a) b)

Figure 4 a)High beam light pattern with H7 bulbs

b) Low beam light pattern with H7 bulbs

Synchronous turning of the both optical fiber image converters is carried out by a drive with the actuating mechanism made in the form of three pulleys (see fig. 3b), one of which is mounted on a shaft of the step electric motor and rigidly connected by two elastic tapes to the pulleys being a holder of the converters. Free ends of the tapes are closed by the tightening mechanism. On the pulley of the drive there fixed a cam of the reference point sensor and a spring ensuring the system resetting in the initial position in case of the drive failure.

Design of Adjusting Module

The adjusting module was developed to control angular position of the headlamp light beams in horizontal plane.

Use of the familiar mathematic models in order to define dynamic effects arising in the course of turning cannot solve all the problems that appears in the process of simulation of the headlamp light beam control system. That is why we had to develop an instrument (a stand) allowing getting the necessary data directly in motion, when the motorcycle is moving along the fixed trajectory.

The stand comprises the modular headlamp with an adjustment system additionally equipped with the inertial module having 6 degrees of freedom and connected with a Pocket PC. The mounting of the stand made it possible to execute some test rounds using a method with moving along different trajectories at different speeds.

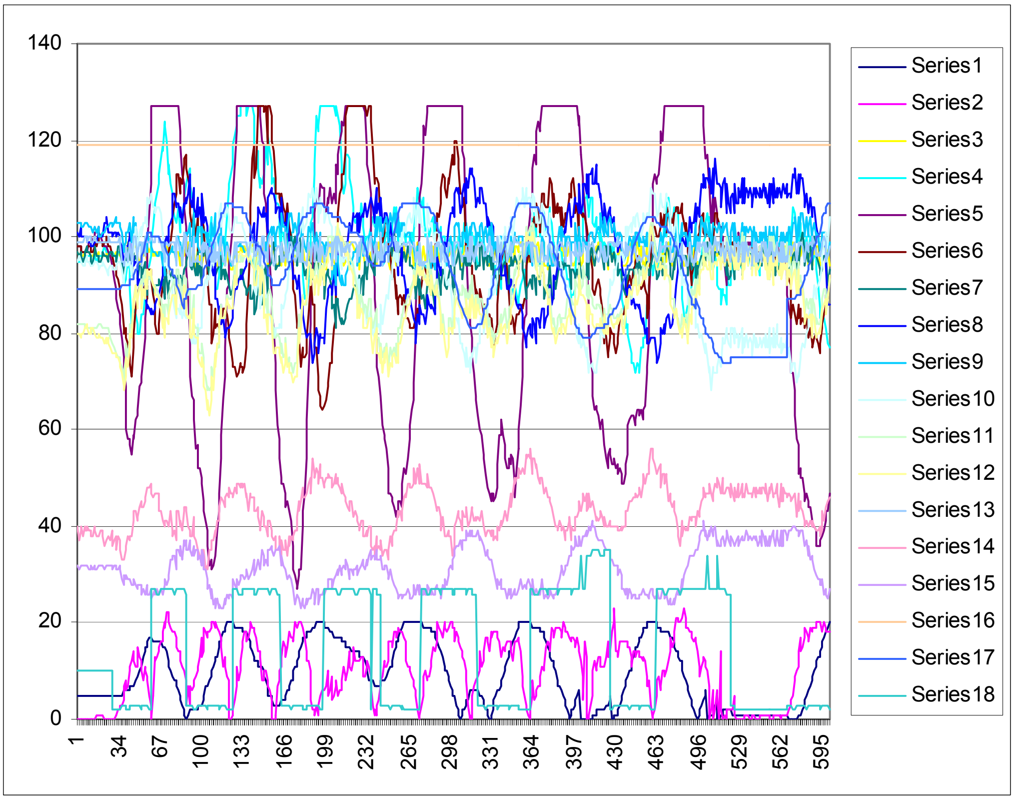


Figure 5. Telemeter data

*Series 1 - φ - deviation angle (relative units); Series 2 - **ω** - angular speed (operating value, obtained from a sensor mounted on the platform);*

*Series 3 – $\mathbf{a_{1x}}$; Series 4 – $\mathbf{a_{1y}}$; Series 5 – $\mathbf{a_{1z}}$; Series **6** – a_{2x}; Series 7 – $\mathbf{a_{2y}}$; Series 8 – $\mathbf{a_{2z}}$; Series 9 – correction angle; Series 10 – $\boldsymbol{\omega_x}$ (the initial data);*

Series 11 - $\boldsymbol{\omega_y}$ (the initial data); Series 12 - $\boldsymbol{\omega_z}$ (the initial data);

Series 13 - $\boldsymbol{\omega_x}$ (after rate setting); Series 14 - $\boldsymbol{\omega_y}$ (after rate setting);

Series 15 - $\boldsymbol{\omega_z}$ (after rate setting); Series 16 – $\mathbf{U_{ref}}$ – (reference voltage};

*Series 17 - **ω** (operating value); Series 18 - Data on the algorithm performance*

As a result different data on a number of characteristics have been obtained; namely, the data on motorcycle linear acceleration factors ($\mathbf{a_x}$, $\mathbf{a_y}$, $\mathbf{a_z}$,) along **X, Y, Z** axes, on angular speeds of rotation ($\boldsymbol{\omega_x}$, $\boldsymbol{\omega_y}$, $\boldsymbol{\omega_z}$) about **X, Y, Z** axes; on the temperature **T** on crystal of the angular speed data transmitters and on the reference voltage **U**. The example of the received data is shown in figure 5. The data received in the experimental road testing have been used while elaborating the stabilization module.

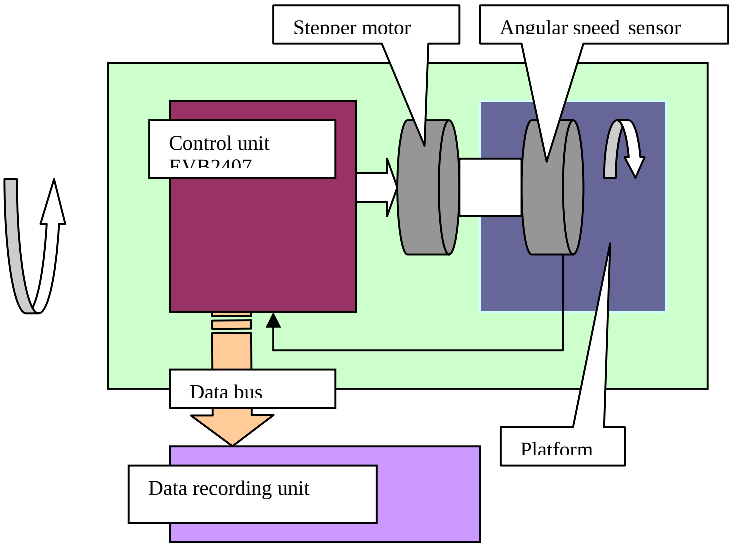


Fig. 6. The block diagram of the adjusting module

In contrast to some known design patterns [2,3], which would constitute one-circuit automatic control system, ensuring light beam position stabilization only on practically flat roads (with small slopes), this module design is now constructed on the basis of DSP processor of Texas Instruments Co. and represents two-circuit automatic control system, block diagram of which is shown in figure 6, and the diagram of the system operation on a motorcycle - in figure 7. The control system additionally is used to take signal measurement of the temperature-sensitive element located directly on the gyroscope crystal with the purpose of additional compensation of error signal caused by the change of temperature inside the headlamp housing.

The adjusting system carries out compensation of external influences on the following key parameters:

- α - turning angle of the platform (the platform is a system of the optical fiber image converters with the actuating mechanism), which compensates the angle of turning of the motorcycle;
- β -angle of the platform shift while it stays at the stable position for a long time- (arises due to accumulation of mistakes);

- Mechanical fluctuations arising because of repeated stabilization procedures
- Angle of the platform shift when the angular speed sensor is exposed to temperature changes

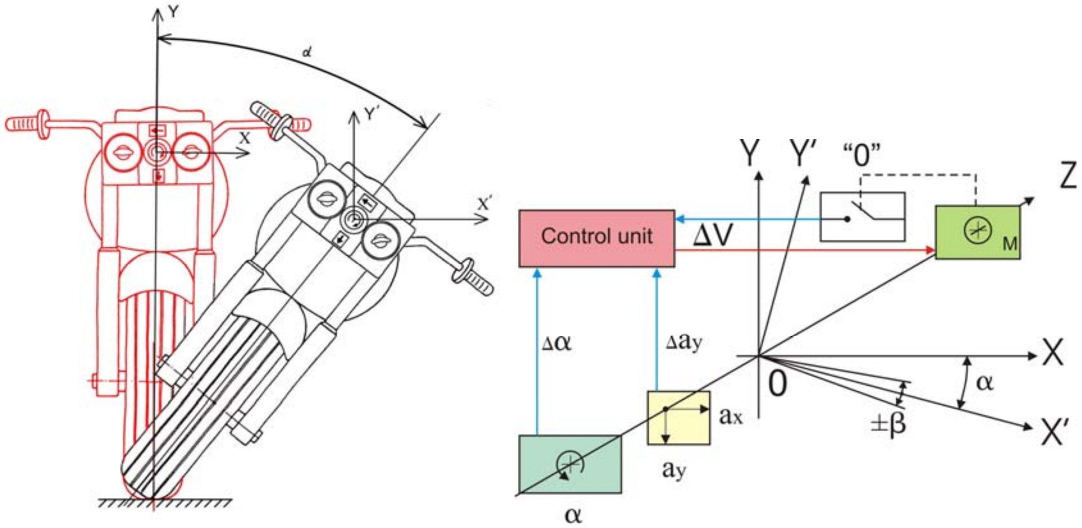


Fig. 7. Diagram of operation of the adjusting system

X, Y, Z – *global coordinate system;*

Y', X', Z' - *local coordinate system tied to the platform;*

α - angle of the platform relative turning, is defined as a result of integrating of the values for the platform angular speed;

β -angle of the platform shift in the local coordinate system;

ay *– factor of linear acceleration along Y axis which is to be measured, is used to tie the local coordinate system to the global one.*

When moving along the roads having slopes, there can arise additional force in the vertical plane along Y-axis, which is taken, into account by analyzing **a**y and **a**x acceleration values. The instantaneous values of ay and ax are compared to their values when moving on an even road.

Basic Control Circuit

Basic control circuit, the block diagram of which is shown in figure 8, is made on the basis of the gyroscope transmitter measuring angular speed of the platform turning in the vertical plane. The main result of its operation is the absence of vibrations of the platform drive caused by the repeated regulation procedures. The basic control circuit also carries out the platform drive control.

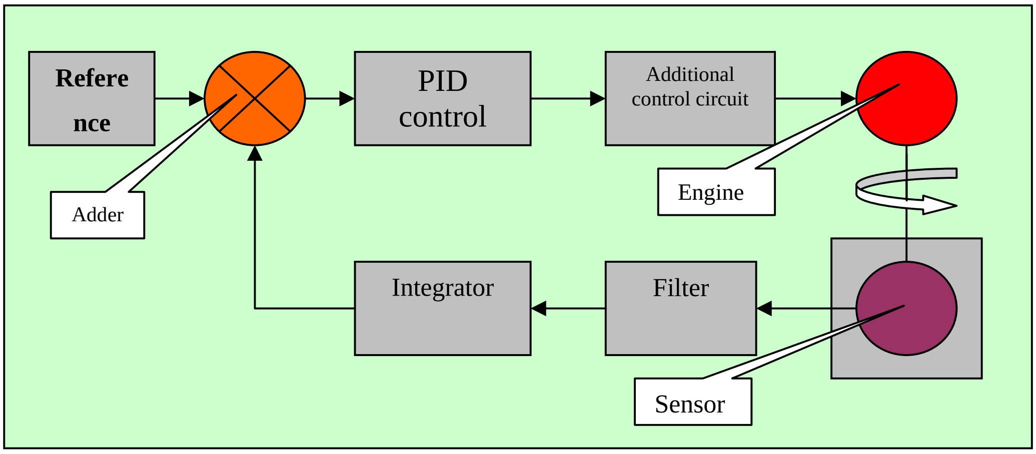


Figure 8. Basic control circuit

Algorithm of Operation of Basic Control Circuit

The algorithm is modelled on the principle of measurement of the mobile platform angular speed with the subsequent calculation of the angle of the platform deviation out of horizontal plane to form the error signal with the purpose of the platform stabilization.

As a sensor of angular speed there used an ADXRS300 of Analog Devices make, which is a gyroscopic sensor [4]. The voltage signal formed at the output of the transmitter is linearly proportional to its angular speed.

A signal from the transmitter is sent to processing controller where it is subjected to filtration and then to valuation. To calculate a current value of the platform angle of deviation out of the horizontal position the inlet signal, which is proportional to angular speed of the platform turning, is being integrated. For the integration the compound formula of trapezes is applied [6] (the necessary accuracy is achieved by having 7 members in the formula of trapezes). After integration the received current value of the angle of deviation is compared to its reference value to form the error signal. Then after processing the error signal in the PID control unit and allowing for the correction signal produced in the additional control unit, the signal is transmitted to the control driver of the step-by-step engine.

Additional Control Circuit

The additional control circuit is intended for current correction of the local coordinate system, correction of the platform position in horizontal plane in response to error signal and the platform turn to the defined angle, containment of the platform in the preset position for a long time, and also correction of the accumulated integration error while the system is kept in the stable position. The last point is important in those cases when temporal error correction does not allow gaining the given accuracy of the platform position.

To run this circuit two mutually perpendicular linear accelerometers are used. They are located in vertical and horizontal planes coaxially with the transmitter measuring angular speed of the platform turning. Such design allows to measure inertial properties of the motorcycle and to compensate centrifugal acceleration when moving irregularly. The block diagram of the additional control circuit is given in figure 9.

At regular motion the additional control circuit is only used for correction of the platform slope (measured by the angular speed transmitter after integrating), as the use of the accelerometers allow the angle of the platform position relative to the vertical to be measured without integrating. The slope error correction is carried out within the limits of a step of the engine. In this mode of motion the correction of inertial properties of the motorcycle is not carried out.

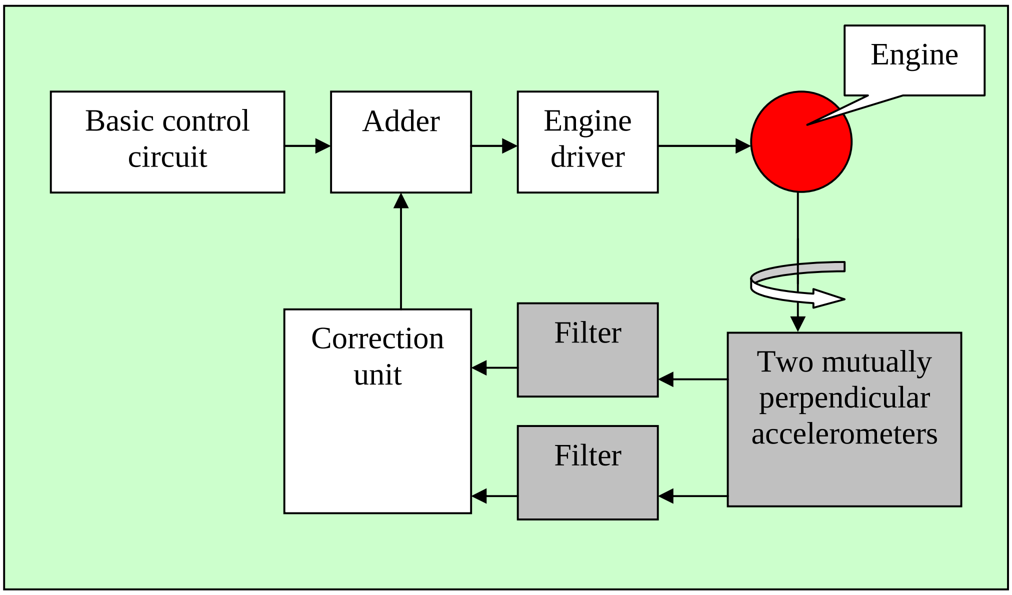


Fig. 9 Additional control circuit

Algorithm of Operation of Additional Control Circuit

In design of the slope value transmitter it is used ADXL202 accelerometer of Analog Devices make. This microcircuit incorporates two identical acceleration transducers (along **X** and **Y** axes) and the built-in processing controller where analog signals are transformed into DCC (Duty Cycle Change) oscillations.

Each of the two acceleration transducers represents a set of differential capacitors each of which is built of a stationary base and a mobile part fixed on this base by the use of a polysilicone spring. If an external force is applied, the mobile part moves relative to the motionless base, and values of capacitance of the differential capacitors vary accordingly. A signal from the transmitter is sent to processing controller where it is transformed into a DCC signal. **T1/T2** ratio varies directly as the acceleration acting on the system. DCC signals from the both transducers are passed to inputs of the controller, which calculates their ratio. Expression is applied to define the value of acceleration it is used the following expression:

$$\mathbf{A = (T1/T2 - T\ off)/S,} \qquad \text{where}$$

T off = T1/T2 at zero slope (zero acceleration),

S - scale factor (on the average S = 12.5 %).

Definitions

T1 - Length of the “on” portion of the cycle.

T2 - Length of the total cycle.

Duty Cycle - Ratio of the “on” time (T1) of the cycle to the total cycle (T2), defined as T1/T2 for the ADXL202E.

Pulse width Time period of the “on” pulse. Defined as T1 for the ADXL202E.

A low-frequency filter is applied to decrease noise level in ADXL202E. Frequency band of the filter at the level of 3 dB is determined by capacitance value of the external capacitors.

The slope value of the sensor varies proportionally to the acceleration acting on its mobile part, and is calculated according to the following formula:

$$\mathbf{ß = ASIN\ (A).}$$

To perform this algorithm and calculate the slope value, a Taylor series expansion of the **ASIN (A)** function is taken [6,7,8]. It can be shown that to calculate the slope value to an accuracy of 0.5 °, the series can be truncated to first four members. To eliminate errors connected to internal data representation in the controller, arithmetic of repeated accuracy with the fixed point is used.

In the correction unit the obtained value of slope is compared to zero slope to form the error signal. The unit is equipped with the additional detector of zero position in the horizontal plane, which comes into action when the platform is in horizontal position. In this case zero position of the local coordinate system is adjusted and both of the accelerometers are calibrated. To carry out the calibration at the moment when the detector of zero position in the horizontal plane comes into action, the value of the ratio **T off = T1/T2** at zero slope and the value of scale factor S are calculated **(S = (X1-X2)/2g**; where **X1** - the detector reading at 1g; **X2** – the accepted value of 1g.).

The detector readings, upon averaged by sliding mean method [8], are sent to the basic control circuit.

The block diagrams of the basic and additional control circuits, presented above, only reflect the major points of operation procedure of the stabilization unit. Therefore, for operation in any extraordinary conditions, like errors; failures in operation or in an emergency, in the control unit a hardware-software module are provided to operate on an emergency basis.

In the control unit the generalized alarm signal is provided with the subsequent switching-off of the control and power circuits and mechanical resetting the platform through the use of the centering spring in the fixed position

The basic parameters of the adjusting module are given in table 1.

Table 1.

Parameter	Value	Note
Maximal turning angle of the platform from the central position	35°	
Engine step	1.5°	depends on the choice of the engine
Control step	3.0°	
Range of operating temperatures	-20°C to +50°C	
Angle of the platform shift engine	1.5°Arches	1 step of the the engine

Thus, as a result of the research and design work the lighting system for motorcycles has been developed, this system having high lighting efficiency and providing dynamic light beam position adjustment in the course of turning to sufficient accuracy for road safety, without regard to vertical alignment and trajectory of a road.

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