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METHODS AND INSTRUMENTS FOR NONCONTACT DIAGNOSTICS OF THE TCAS SYSTEM

This article is devoted to an investigation of the TCAS (Traffic Collision Avoidance System) diagnostics and self-diagnostics problems. The aim of the current research is to prepare the TCAS system built-in diagnostics aid and to build a model of a device for non-contact monitoring of the TCAS unit operational status. The tasks of the research are the following: to conduct analysis of the features and capabilities of the TCAS diagnostic techniques and aids; to develop a model which can detect the spurious actuation of the system and false decision-making; to prepare techniques which can detect such behavior of the system during a flight; to construct a model of a device for built-in diagnostics based on an non-contact monitoring of the TCAS states. The applied techniques of the researches are the following: application of signs, facts, and heuristic information about faults, implementation of an instrumental approach and diagnostic techniques based on an estimation of measured and monitored parameters. The system state monitoring method was proposed to carry out non-contact diagnostics of the system and to monitor the operating modes. This method is based on operating current variations by means of current measure using non-contact meters. It was proposed to apply the Hall sensor and the Rogowski coil to carry out such diagnostics. The schematic model to monitor the operation of the TCAS receiving and computing unit is developed considering Hall sensors' capabilities to measure both direct and alternating currents. It was proposed the method and schematics to monitor TCAS system transmitter operating modes due to the fact that Rogowski coil is capable to measure both pulse and HF currents. This promotes to carry out diagnostics of the system proper operation. Several model versions of Rogowski coil are developed. Researches were carried out applying self-contained testing device (АКИП – 3407/2A) and Tektronics TSB digital oscilloscope.

Conclusions. The novelty of the carried researches is follows: it is proposed a method for monitoring the variations of operating currents applied by the TCAS basic units for providing the self-contained diagnostics system; it is proposed a method for monitoring the system state according to the operating current variations, based on current measurements applying the Hall sensor and the Rogowski coil to provide the TCAS non-contact diagnostics. The research includes analysis of the laboratory measurements which were performed applying several versions of the Rogowski coil. Functional diagrams of the coil connections to the circuit are developed applying MultiSim14. The logical unit of the TCAS electrical modes built-in monitoring device is developed applying MatLab and MultiSim14.

Keywords: *TCAS; false decisions; operating current; non-contact diagnostics; Hall sensor; Rogowski coil*

Actuality of the problem

Diagnostic of the TCAS system is particularly important as the TCAS system on all aircraft is designed to prevent mid-air collisions. Thus, considering the possibility of errors and the possibility of problems occurring within the TCAS system, development of an autonomous diagnostic method for this system is one of the reasonable solutions. Design of an autonomous diagnostic device based on this method is important for the implementation of the proposed autonomous diagnostic method. As a result of considering false decisions and fault cases that could present in the TCAS system, we can prevent these possible problems using autonomous diagnostic unit, having prepared operational algorithm of this project and its functional schematic, which is formed by the established measurement methods.

Solutions of the problem

As you know, the TCAS system works in super high-frequency range and consists of several parts such as transmitter-receiver and computing unit which provides data exchange. In accordance with the secondary radar principle, the system performs operations such as observation and communication using existing equipment and software. The TCAS system makes certain decisions to ensure the operational safety of the flight. Thus, it is possible that correct decision in particular situation depends on TCAS system's operating parameters and can be controlled. It is necessary to determine whether the TCAS system operates properly to provide safety when the aircraft is in flight and for this purpose, the solution of the problem can be performed by controlling the situational change in the TCAS system operating electrical parameters' certain values.

Technical diagnosis is known to be a process of estimating the state of any system by its indirect symptoms. The purpose of TCAS built-in diagnostics development and designing of the device for non-contact monitoring of the system state is to define the reliability and validity degree of the information received via TCAS.

To solve this problem, the tasks are set to analyze the features and capabilities of the TCAS diagnostic techniques and aids, to develop a model for detecting the system false actuation and false decision-making, to develop techniques to detect such states of the system during the flight, and to construct a model of a device for independent (built-in) diagnostics based on a non-contact monitoring of the TCAS state.

For this purpose, the suggested technique provides the early detection of the TCAS false actuation and the following decision-making, enabling to predict or to eliminate their progress and thereby to exclude actions and maneuvers resulting from the system false responses which can result in harmful consequences.

Typically, the diagnostics of a technical state consists of two procedures: fault detection and diagnosis. Each of them is based on certain techniques and approaches to carry out a diagnosis versus system behavior and the following conditions. The diagnosis procedures of a technical state are based on the analysis of the analytical and heuristic symptoms. In most cases, diagnostics is based on an estimation of the parameters measured and monitored by a human operator [12].

In the case of automated diagnosis, analytical knowledge of the process is required; to estimate the values observed, the human operator's expert knowledge, called heuristic knowledge, is required.

In simple cases, troubleshooting is based on single measurement of a signal and is carried out by limit testing or testing against trend; or, in more complex cases, by operating with the signal specific model, via extraction of the signal's features and by varying the detection techniques.

When checking the limits of absolute values, as a rule, two preset values (maximum and minimum), called thresholds, are used. The process is in a normal state if the variable remains within the specified limits. Exceeding one of the thresholds indicates a fault (a trouble) in the process.

Testing against trend includes calculating the first derivative of the monitored signal and checking whether it is within acceptable limits. If small limits are selected, a trouble signal can be received much earlier than in case of limit testing.

Applying the special mathematical models for the signal measured, we obtain the required properties such as amplitude and phase, frequency spectrum and correlation function to define the signal bandwidth. Then, the properties obtained are compared with the normal values of the process to detect any changes.

Different approaches to fault detection (troubleshooting) with the process models have been developed over the past few decades. Their task is to carry out detection of faults in processes, actuators, and meters, using dependencies between measured signals. These dependencies are expressed in the process of mathematical models. Methods based on the process model require knowledge on the process dynamic model, on the model's mathematical form and parameters.

For some technical processes, the basic relations between faults and their symptoms can be partially known. Then the knowledge is represented in the form of cause-and-effect relations: fault – event – symptom. The advent of these cause-and-effect relations results from analysis of fault tree which starts from a fault and extends via supporting events to the symptoms, or, based on the analysis of the fault tree which starts from the symptoms and extends to a fault [11].

In the classical version, the analysis of a tree of faults, symptoms, and events is considered as binary variables, and conditions as a part of rules can be obtained with logical equations for a parallel-series connection. However, this procedure didn't succeed due to the continuous and gradual behavior of a fault.

Geometric methods are based on the analysis of the graphical representation of fault symptoms (in numeric terms) with the values of the analyzed variable. The difference between statistical or geometrical methods is in applying the probability function.

Neural networks used in performing diagnostics enable to approximate the non-linear equations and to define wide regions of solutions in a continuous or digital form [5].

In most cases, the process control charts are used, which represent the graphical aids of analysis using statistical data. This does not require the deterministic model of the process. However, assumptions, with respect to statistics of variables which are to be monitored, are required.

In the course of the research conducted, the following methods were chosen: 1) application of fault symptoms, facts and heuristic data; 2) instrument approach, and 3) diagnostics based on an estimation of parameters under measurement and monitoring.

To implement the system non-contact diagnostics and to monitor the operation modes, the 3rd method, the method of the system state monitoring, was chosen. This method is based on monitoring one of the basic operating parameters for operating current variation by means of current metering with non-contact meters.

It is possible that this system proper operation, true and exact decision-making for aircraft's maneuver is based on controlling operating current of TCAS system. This problem can be solved with application of the Rogowski coil and Hall sensor [8].

In this article it was intended to control the values variability of the actual electrical parameters of the system such as evaluation criteria, to determine whether the TCAS system is functioning properly or not during the flight.

It is possible to check the system's operating performance by controlling its operating current. For this reason, when TCAS is in standby mode, the operating currents of its receiver and the computing units have the minimum values of $I_{\text{receiver min.}}$ and $I_{\text{computing min.}}$, and the operating current of the TCAS transmitter is $I_{\text{transmitter}} \approx 0$. Operating currents of the active TCAS system during the flight, which is intended to be monitored, is much higher than the values in the standby mode due to the interaction with other TCAS systems [4, 7]. It is possible to provide autonomous diagnostic based on contactless control of these currents operating parameters change. The Hall sensor, the Rogowski coil and other types of current sensors can provide such control [1, 6]. The main purpose of this work is to check the real performance and decision-making of the TCAS system by contactless control of the current rate increase or decrease.

Hall current sensors differ from other sensors due to the absence of conductivity loss and ability to measure both direct current and alternate current. The Hall sensor is isolated from the measured current circuit which automatically provides galvanic separation. Disadvantage is a necessity of an external energy source. When measuring high currents (10-2000A), the Hall sensor can be placed closely to the cable without using additional magnetic core. Linear Hall sensors also allow to measure high frequency currents and when located near to the current conducting cable, the output voltage of the sensor is proportional to the arisen magnetic field induction and eventually the current [1, 13].

The simplest Hall current sensor implementation is when the Hall sensor is located near to the measured current conducting cable. The induction of the magnetic field generated by the current conducting cable can be defined by the following formula [1]:

$$B \approx \mu_0 (I / 4\pi r), \tag{1}$$

r, is the distance between the centers of the Hall sensor and the cable. When selecting the linear Hall sensor's position relative to the cable, it is important to notice that the highest sensitivity is achieved when the magnetic field lines cut the sensor's plane at the straight angle. The main disadvantage of this sensor is that any external magnetic field source affects the order of the sensor. Therefore, in order to increase sensitivity and reduce external influences, precision sensor based on an integrated circuit is placed in the intermediate part of the magnetic core and the current conducting cable is transmitted from inside the toroid as in the transformer sensor [1].

In addition, during the research, measurements of the current in the range of 0.1 - 10A were performed via transistor, operational amplifier and optocoupler based amplifiers to achieve the required amplification to reduce generated extra noise in the Hall sensor, to provide measurement of the smaller currents and to avoid the use of special magnetic cores and microelectronic circuits. According to this, the current control was carried out by placing the Hall sensor near to current conducting cable. The Hall sensor allows measuring the currents up to 100 kHz. It is impossible to use Hall sensor to measure the transmitting current of TCAS system due to transmitting frequency being very high - 1030 MHz. Therefore, Rogowski coil may be considered as the most applicable sensor to control transmitting current of TCAS system. The main feature of this sensor is that electromotive force in its signal winding is directly proportional to the derivative of the measured current and allows to measure high frequency currents [1, 2, 3, and 10].

Due to above mentioned characteristics Rogowski coil is widely used as current sensor in variable current circuits. Known Rogowski coil contains toroid which is made of dielectric material that has winding with equal turn. Electromotive force occurs when closing the loop in the surrounded coil with the measured current conducting cable. According to the Ampere's law, the linear integral voltage of the magnetic field is equal to the total current on the restricted surface within this closed loop [9, 14].

$$\varnothing H \cdot \cos\alpha \cdot dl = I. \tag{2}$$

Here, H – is the magnetic field vector and α – is the angle between the normal direction and turn's surface of the elementary section with length dl.

The correlation between magnetic flux (Φ) and magnetic field voltage (H) is determined by the following expression [9]:

$$\Phi = \iint \mu_0 \cdot H dS = \mu_0 \cdot A \cdot n \varnothing H \cdot dl. \tag{3}$$

Where, dS = A×n×dl (A – is the width area of the elementary section; n – is the amount coils, dl – length of the single coil in the section.

Electromotive force occurs according to the induced electric field during the magnetic field change in the closed loop [9]:

$$\varepsilon = -\frac{d\Phi}{dt} = -\mu_0 xAxn\frac{d\lambda}{dt} = -Md\lambda / dt. \qquad (4)$$

Here, M = μ_0×A×n – is the mutual inductance between the coil and the cable. This sensor cannot be used to measure the direct current, because electromotive force is induced during the magnetic field change. Evermore, is the most important case being to follow equal distribution of turns along length during wrapping of the winding.

The Rogowski coil is highly susceptible to the external magnetic fields and in order to reduce the impact of this harmful factor, equal wrapping of the windings in the circular toroidal core is to be performed which will balance influence of the external equal magnetic field inside the coil.

In addition, Rogowski coil is placed inside an electrostatic screen and in the result external electromagnetic fields effects are removed. Furthermore, one of the effective methods is to use an opposite winding which eliminates the effects of external variable magnetic fields.

The main advantages of the Rogowski coil:

- the current change is the linear function, which in turn enables expansion of the measured current range;
- it allows measurement without interrupting the current line and it has a disassembled design;
- winding inductive is low and so on [9].

Under laboratory conditions, we practiced several measurements based on Rogowski coil with *АКИП - 3407/2A*mark signal generator and *Tektronix, TSB*mark digital oscilloscope and obtained necessary parameters. During the measurements, three different types of Rogowski coil were examined and the results of the obtained measurements were analyzed with both MS Excel and MATLAB.

Firstly, measurements were performed in sinusoidal signal modes. In order to avoid the use of additional amplifier units, the operating frequency range was selected relatively high scaled and considering that EMF is proportional to the frequency in low frequency range, it was determined via calculation.

During the measurement the effective value of the operating current was taken at I = 50 mA.

Based on obtained parameters from measurement results and obtained the graphs through the MATLAB program, it seems that,

1) When using ordinary Rogowski coil:

When using Rogowski coil wrapped on the toroidal plastic frame (current conducting cable passes through winding), signal amplitude appropriate to signal frequency 400 kHz (Figure 1) is U_m= 18 mV.

Frequency, kHz	100	200	300	400	500	600	700
Voltage, mV	4.8	9	13.5	18	20	24	28

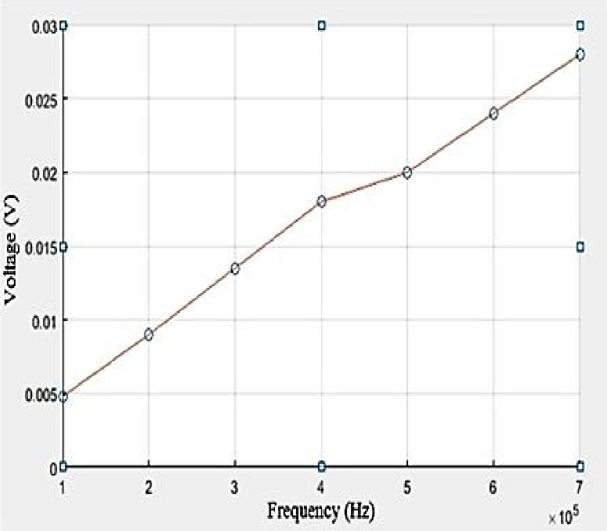


Figure 1. Plot of results obtained using MATLAB (when using wrapped Rogowski coil on the toroidal plastic frame - current conducting cable passes through winding) in the first case

2) When using ordinary Rogowski coil, but current conducting cable is in different position:

When we use wrapped Rogowski coil on the toroidal plastic frame (current conducting cable is wrapped on the coil, approximately 10 windings), signal amplitude appropriate to signal frequency 400 kHz is U_m = 190 mV (as shown in Figure 2). In this case, signal amplitude increases according to amount of wrapped current conducting cable's windings on the Rogowski coil (according to the transformer principle) and is 10 times more: 19 mV x 10 = 190 mV.

3) When using Rogowski coil with an unordinary design (a form is made by us):

In the third case – Wrapped Rogowski coil with non-standard form gives the 54 mV amplitude in response to 400 kHz signal, so that in this case it is 3 times more when comparing to first case samples (Figure 3).

In the first and the third cases, we can do measurements without breaking the current conducting cable. Thereby, we make it possible to evaluate the current flowing in circuit bringing the Rogowski coil closer to the current conducting cable. It is possible to increase the sensitivity n times by wrapped current conducting cable’s winding on the Rogowski coil (current conducting cable is wrapped as n times of windings on the coil) in the second case.

Frequency, kHz	100	200	300	400	500	600	700
Voltage, mV	58	100	145	190	210	250	290

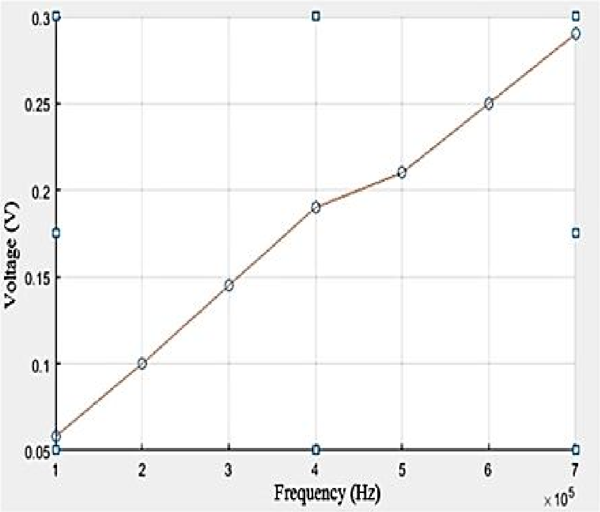


Figure 2. Plot of results obtained using MATLAB (when using wrapped Rogowski coil on the toroidal plastic frame - current conducting cable is wrapped on the coil) in the second case

Frequency, kHz	100	200	300	400	500	600	700
Voltage, mV	15	30	40	54	62	75	90

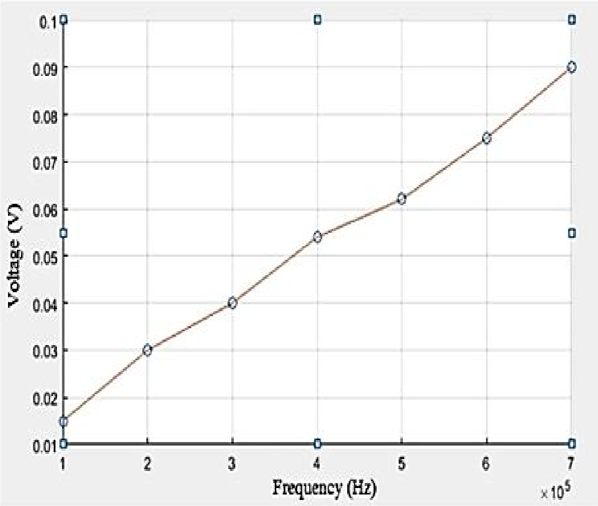


Figure 3. Plot of results obtained using MATLAB (wrapped Rogowski coil with non-standard form) in the third case

However, in this case the circuit of the current conducting cable should be broken and the wrapped current conducting cable's n times windings on the Rogowski coil should be made using wires that are appropriate to the operating current. For example, if the current in the circuit is 100A, thus this winding's cable should be calculated for this current, so that it should have diameter relevant to 5-10 mm^2 surface. Consequently, this causes extra weight and complex construction.

When the operating current is 50 mA (100 mA) and 400 kHz in the current line, the obtained signal amplitude is 18 mV (in the first case), 190 mV (in the second case), and 54mV (in the third case) with the Rogowski coil. This means that, we can obtain values appropriate to the same cases when the operating current is 50 A (100 A) and frequency is 400 Hz as in modern aircraft AC circuits, so that the operating current is 1000 times more than values we used and the operating frequency is 1000 times less than values used during the experiment.

We can develop current sensor with the implementation of the Rogowski coil and the sensor based on Hall Effect to control an operating mode according to the current. System's diagnostics and its' model synthesis is possible in this way.

It is possible to build circuit of an autonomous control unit based on new types of current sensor which are Hall sensor and Rogowski coil.

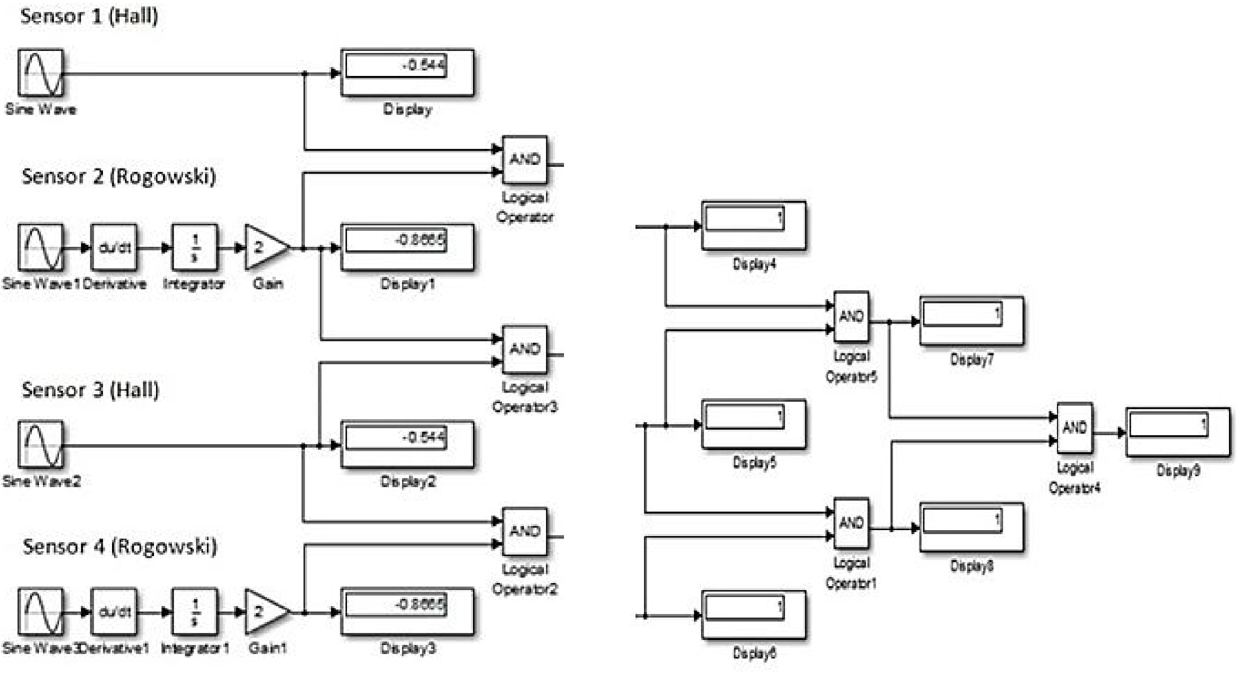
The logical block-diagram of an autonomous diagnostics unit was built using MATLAB Simulink to provide autonomous control of the TCAS system operating process implementing the Rogowski and Hall sensors based on the accomplished analysis and research. Following the circuit, if there is a failure, false launch and false decision cases within the TCAS system during the flight, it is possible to obtain the information about it and this block-diagram is shown in Figure 4.

In some cases, it is also important that both the medium value of the current and its shape are known. Therefore, integrator must be used for turn the current to initial shape, because obtained electromotive force with Rogowski coil is appropriate to the derivative of current.

To simulate Rogowski coil current sensor's operation in Multisim 14, the coil was substituted with RC differentiating circuit, the current converter unit's circuits were formed using integrator on the basis of ordinary RC circuit and operational amplifier as integrated circuit.

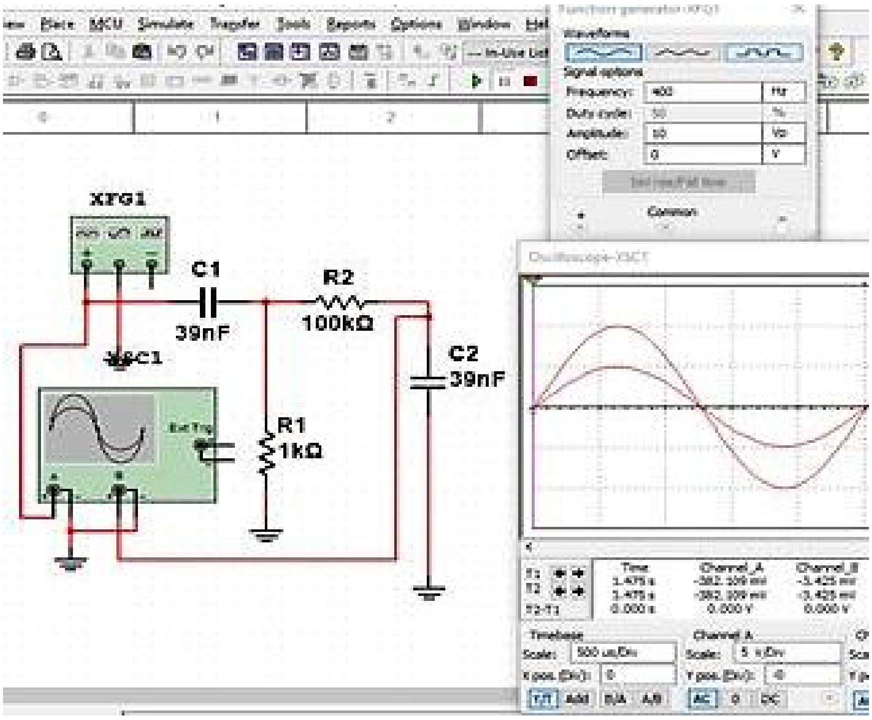
Continuation of the Figure 4.1 is shown Figure 4.2.

The simplest RC integrator's circuit and its operating modes' simulation for the Rogowski coil using MultiSim is shown in Figure 5. Here, R_1C_1 is the differentiating circuit (substitute circuit for Rogowski coil) and R_2C_2 is the ordinary integrator circuit.



(4.1) (4.2)

Figure 4. Logic block-diagram of autonomous diagnostics unit based on Hall and Rogowski sensors developed using Matlab Simulink (4.1, 4.2)



Frequency: 400 Hz
Duty cycle: 50 %
Amplitude: 10 Vp
Offset: 0 V

	Time	Channel_A	Channel_B
T1	1.475 s	-382.109 mV	-3.425 mV
T2	1.475 s	-382.109 mV	-3.425 mV
T2-T1	0.000 s	0.000 V	0.000 V

Timebase Scale: 500 us/Div
X pos.(Div): 0
Channel A Scale: 5 V/Div
Y pos.(Div): 0

Figure 5. The simplest RC integrator's simulation in MultiSim for Rogowski coil

Simulation of the integrator based on operational amplifier for the Rogowski coil was performed using MultiSim as shown in Figure 6.

According to the limit value of current, amplifier-comparator block's circuit in MultiSim 14 provides "0" and "1" logical levels to evaluate ranges of the current appropriately to the TCAS system's false decision cases. This unit's block diagram is shown in Figure 7.

This circuit can be used separately to amplify the signals obtained by both of the Hall sensor and Rogowski coil and to compare with comparator based on the standard level (level of warning).

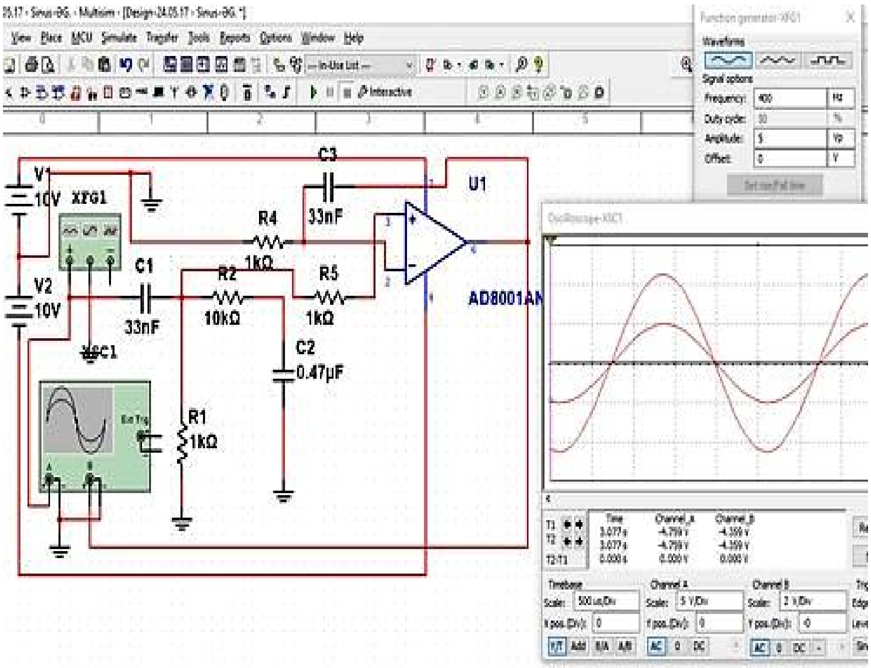

Frequency: 400 Hz
Duty cycle: 50 %
Amplitude: 5 Vp
Offset: 0 V
Timebase Scale: 500 us/Div
Channel A Scale: 5 V/Div
Channel B Scale: 2 V/Div

Figure 6. Simulation of the integrator based on operational amplifier for the Rogowski coil in MultiSim

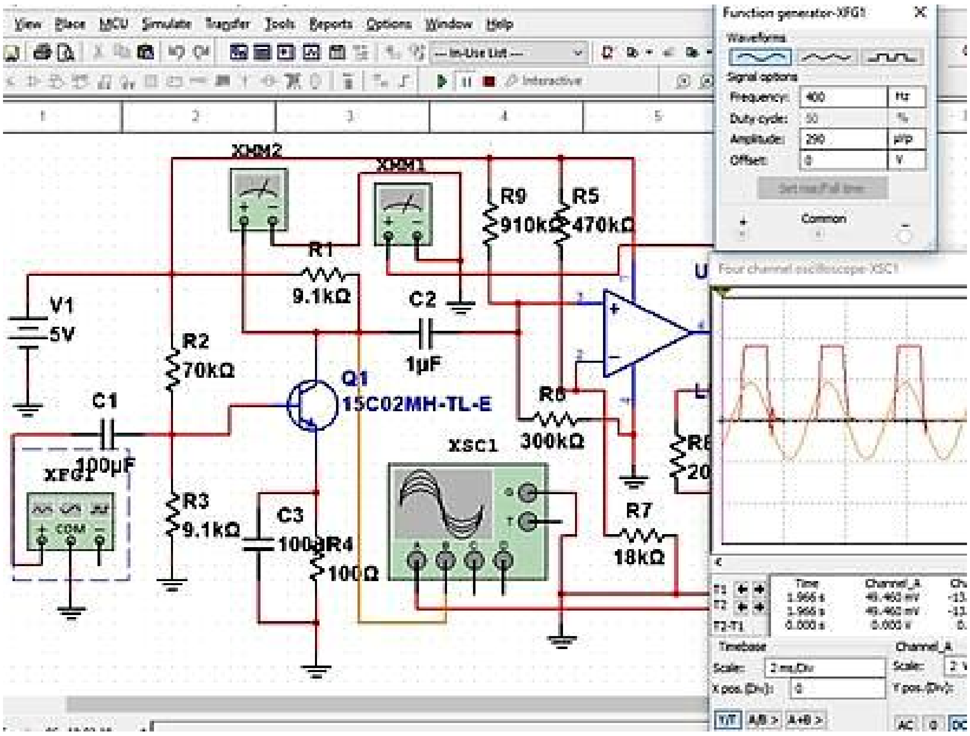

Frequency: 400 Hz
Duty cycle: 50 %
Amplitude: 290
Offset: 0 V
Timebase Scale: 2 ms/Div

Figure 7. Amplifier and comparator unit's diagram

Conclusion

The main results of the accomplished work are as follows:

1. Control method to operating currents change of TCAS system's main units was proposed to provide the autonomous control of the TCAS system.
2. TCAS system operating current control methods were investigated.
3. Considering the necessity of the proposed autonomous diagnostic method, measurements with Rogowski coil were performed under laboratory conditions for TCAS system.
4. The results obtained during measurements were analyzed using MatLab and were compared for various conditions.
5. The main functional block diagrams of autonomous diagnostic unit were developed using MultiSim 14 according to the intended method to solve design issues of autonomous diagnostic unit for TCAS system.

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МЕТОДЫ И СРЕДСТВА ДЛЯ БЕСКОНТАКТНОЙ ДИАГНОСТИКИ СИСТЕМЫ TCAS

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Данная работа **посвящена** исследованию проблем диагностики и самодиагностики системы TCAS (Traffic Collusion and Avoidance System) и разработке модели устройства автономной диагностики данной системы. **Целью данной работы** является разработка методов автономной диагностики системы TCAS и модели устройства бесконтактного контроля состояния системы. **Задачи,** поставленные в работе: анализ особенностей и возможностей методов и средств диагностики TCAS; разработка модели обнаружения ложного срабатывания и ложного решения в системе; разработка методов обнаружения таких состояний системы в полете; построение модели устройства автономной диагностики на основе метода бесконтактного контроля состояний системы TCAS. Используемыми **методами** для исследований являются: методы использования признаков, фактов и эвристических данных о неисправностях; инструментальный метод; методы диагностики, основанные на оценке измеряемых и контролируемых параметров. Для реализации бесконтактной диагностики системы и контроля режимов работы предложен метод контроля состояния системы по изменению рабочего тока путем измерения токов с помощью бесконтактных датчиков. Предложены схемы реализации такой диагностики применением датчика Холла и катушки Роговского. Разработана модель схемы контроля приемника и вычислительного блока TCAS с учетом возможностей датчика Холла измерить как постоянный, так и переменный ток. С учетом особенностей катушки Роговского измерить импульсный, а также высокочастотный токи предложена методика и схема контроля режимов работы передатчика системы, тем самим диагностики правильной работы системы. Разработаны несколько макетных вариантов катушки Роговского и проведены исследования с использованием генератора сигналов *АКИП - 3407/2А* и цифрового осциллографа *Tektronix, TSB.* **Выводы.** Научная новизна работы состоит в следующем: предложен метод контроля изменения рабочих токов основных блоков системы TCAS для обеспечения автономной диагностики системы; для обеспечения бесконтактной диагностики системы TCAS предложен метод контроля состояния системы по изменению рабочего тока, путем измерения токов с помощью датчика Холла и катушки Роговского. Проведен анализ результатов лабораторных измерений с использованием нескольких вариантов катушки Роговского и сформированы в среде MultiSim14 функциональные схемы включения катушки. Разработан логический блок автономного устройства контроля электрических режимов системы TCAS, который сформирован на MatLab и MultiSim14.

Ключевые слова: TCAS; ложные решения; рабочий ток; бесконтактная диагностика; датчик Холла; катушка Роговского.

МЕТОДИ ТА ЗАСОБИ ДЛЯ БЕЗКОНТАКТНОЇ ДІАГНОСТИКИ СИСТЕМИ TCAS

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Дана робота присвячена дослідженню проблем діагностики та самодіагностики системи TCAS (Traffic Collusion and Avoidance System) і розробці моделі пристрою автономної діагностики даної системи. Метою даної роботи є розробка методів автономної діагностики системи TCAS і моделі пристрою безконтактного контролю стану системи. Завдання, поставлені в роботі: аналіз особливостей і можливостей методів і засобів діагностики TCAS; розробка моделі виявлення помилкового спрацьовування і помилкового рішення в системі; розробка методів виявлення таких станів системи в польоті; побудова моделі пристрою автономної діагностики на основі методу безконтактного контролю станів системи TCAS. Використовуваними методами для досліджень є: методи використання ознак, фактів і евристичних даних про несправності; інструментальний метод; методи діагностики, засновані на оцінці вимірюваних і контрольованих параметрів. Для реалізації безконтактної діагностики системи і контролю режимів роботи запропонований метод контролю стану системи зі зміни робочого струму шляхом вимірювання струмів за допомогою безконтактних датчиків. Запропоновано схеми реалізації такої діагностики застосуванням датчика Холла і котушки Роговського. Розроблено модель схеми контролю приймача і обчислювального блоку TCAS з урахуванням можливостей датчика Холла виміряти як постійний, так і змінний струм. З урахуванням особливостей котушки Роговського виміряти імпульсний, а також високочастотний струм запропонована методика і схема контролю режимів роботи передавача системи, тим самим діагностики правильної роботи системи. Розроблено кілька макетних варіантів котушки Роговського і проведені дослідження з використанням генератора сигналів АКИП - 3407/2А і цифрового осцилографа Tektronix, TSB. Висновки. Наукова новизна роботи полягає в наступному: запропонований метод контролю зміни робочих струмів основних блоків системи TCAS для забезпечення автономної діагностики системи; для забезпечення безконтактної діагностики системи TCAS запропонований метод контролю стану системи зі зміни робочого струму, шляхом вимірювання струмів за допомогою датчика Холла і котушки Роговського. Проведено аналіз результатів лабораторних вимірювань з використанням декількох варіантів котушки Роговского і сформовані в середовищі MultiSim14 функціональні схеми включення котушки. Розроблено логічний блок автономного устрою контролю електричних режимів системи TCAS, який сформований на MatLab і MultiSim14.

Ключові слова: TCAS; помилкові рішення; робочий струм; безконтактна діагностика; датчик Холла; котушка Роговського.

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