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THE DESIGN OF THE ENGINE CONTROL UNIT OF THE SMALL AIRCRAFT ENGINE

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Summary. Article deals with a design of the Engine Control Unit of the small aircraft engine, focusing on the measurement of engine operating variables, transmission and recording of data and setting of required operating mode with throttle control of the engine. The author deals with the issue of characteristics measurement of small aircraft engine and design of the engine control unit software solution for the purpose of creating a control part for a small auxiliary power unit. Adjustment of control variables is realized using a touchscreen, which also serves as a display unit of operating and controlling variables. Engine control and signal processing are provided by the microcontroller.

Keywords: control unit, small aircraft engine touchscreen, measurement of operating variables

1. INTRODUCTION

This article deals with a design of a small aircraft engine control unit that is capable of measuring engine operating variables, displaying them together with control variables and recording them for further processing and analysis needs. The reason for the implementation of the small engine control unit is the creation of a small auxiliary power unit and the engine control unit is one of its components. When designing a small auxiliary power unit, we draw from the output power requirement of up to 1 kW of electrical energy. Such performance can be achieved by using a model aircraft engine that is sufficiently available and performance-efficient. For our purposes, we used a small model piston engine with a power output of 0.82 kW. It is a 4.58 ccm air cooled single cylinder engine. In order to achieve the main objective of the design of the control unit, it was necessary to design sensors for the measurement of operating engine variables 00. The article summarizes the work done during bachelor and engineering studies.

2. MEASUREMENT OF ENGINE OPERATING VARIABLES

The engine operating variables must be known to monitor and ensure proper engine operation. The basic operating variables to be sensed include engine speed, engine temperature and throttle position. The throttle is controlled by the actuator, it is not necessary to read its position. The additional measure we have chosen is vibration of the engine. Using vibration sensing, we can replace engine speed measurement if necessary. Engine vibrations can also provide information about engine condition and its operating load. According to these variables, correct engine operation and engine performance are assessed 00.

2.1. Engine speed measurement

The speed measurement of the piston engine is performed by the optical method. The principle of this method is to illuminate an infrared light sensitive phototransistor by means of an infrared diode. The system responds to a change in phototransistor light that is caused by reflection of infrared light from the engine propeller. The essence is that the emitter passage of the phototransistor opens when it is illuminated. The speedometer is located behind the engine propeller during the measurement. We have chosen this concept of sensor placement because the speedometer can be located outside of the propeller area when measured 00.

Figure 1 Speedometer position behind the propeller blades

In order for the signal from the speedometer to be measurable, it was necessary to design an additional electrical circuit for signal processing. The circuit consists of a voltage monitor, comparator and passive element (resistors, capacitors) that are used to smooth the supply voltage. The voltage monitor is made up of the integrated circuit OPA37. The output from the tracker is then fed to the comparator. This compares the voltage at the inputs of the operational amplifier. As a comparator, we used the integrated circuit OPA177. This operational amplifier fulfills the function of a differential amplifier. The signal is further directed through the rectifying diode and is resiliently adapted for further processing in the microcontroller 0.

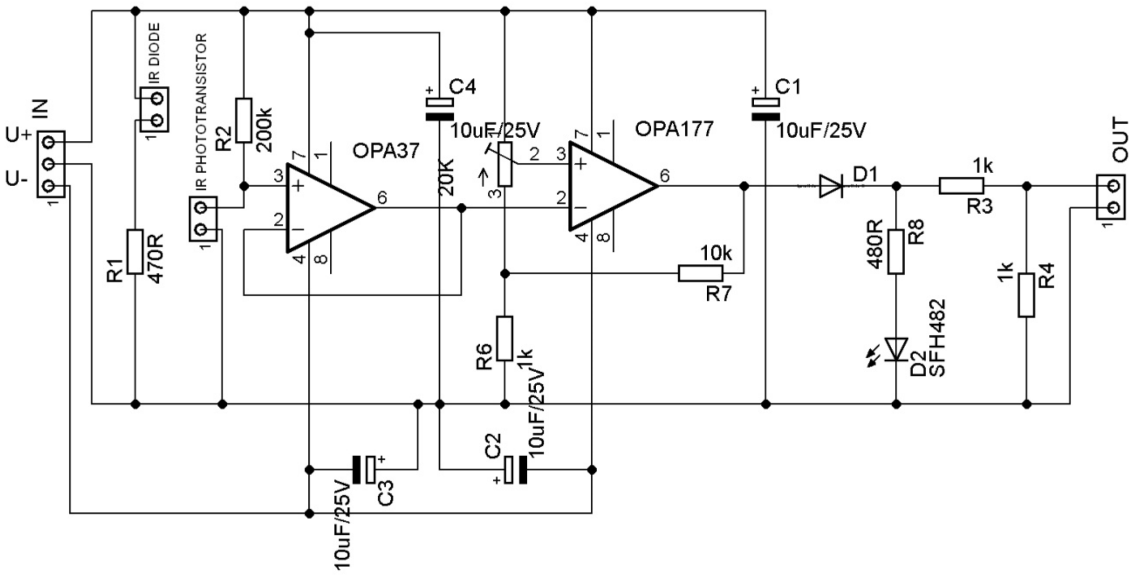

Figure 2 Electrical curcuit diagram of speedometer

Using an optical speedometer, we measured the engine speed dependence on the throttle angle. With full throttle, the engine reaches maximum operating speed. By gradually closing the throttle, the speed decreases. During the measurement, the engine speed reached a maximum of 10,065 rpm. The manufacturer gives a maximum speed of 14,000 rpm. However, this value is considered using a 9x6 or

10x5 propeller. The deviation between the manufacturer given the maximum speed and our maximum measured value could be due to the use of a 10x6 propeller 0.

Figure 3 Measured speed dependence on throttle position

2.2. Engine temperature measurement

Engine temperature measurement is performed using a thermocouple. The advantage of using a thermocouple is in a simple construction and high reliability. The thermocouple is placed on the engine cylinder when measured 0. However, when measuring, the cold end compensation must also be taken into account. For this purpose, we used the DS18B20 Digital Temperature Sensor, which is located outside of the engine compartment and can operate from -55 °C to +125 °C, with a range of -10 °C to +85 °C with a 9-bit resolution guaranteed an accuracy of ±0.5 °C and an accuracy of ±0.0625 °C can be achieved with a resolution of 12 bits 0.

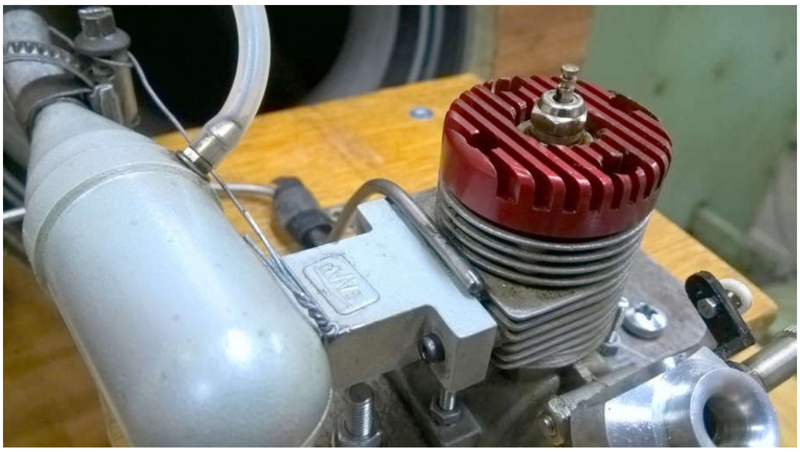

Figure 4 Place the thermocouple on the engine

Measurement using a thermocouple is simple as the output thermoelectric voltage is proportional to the measured temperature. However, this voltage is low and therefore needs to be amplified. To amplify this voltage we designed a simple amplifier 0.

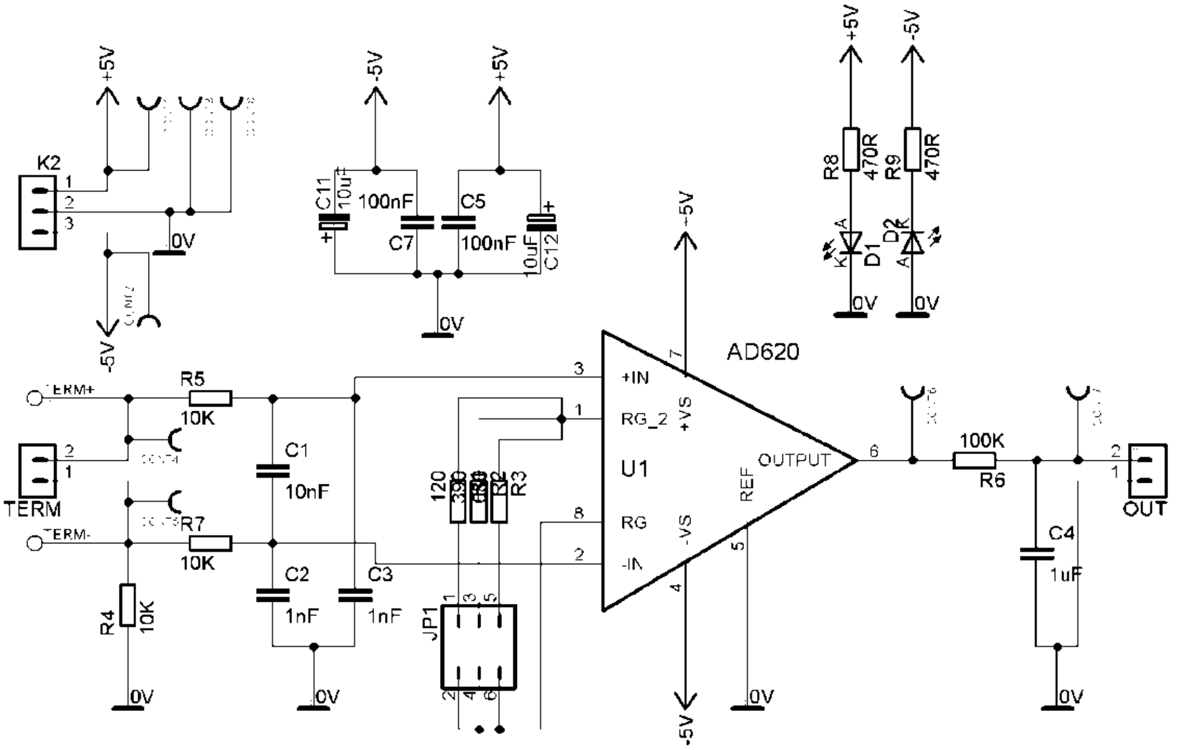

Figure 5 Electrical curcuit diagram for the thermocouple amplifier

Engine temperature was measured in dependence on engine speed. The maximum temperature during the measurement was 154 °C. This temperature was reached at a speed of 4,500 rpm. The throttle was set at 45°. Gradually changing the throttle position, that is, increasing engine power, the temperature began to drop. At maximum engine speed when the flap was fully open, the temperature reached 96.5 °C. The decrease in temperature was due mainly to the cooling of the engine by the air flow from the propeller 0.

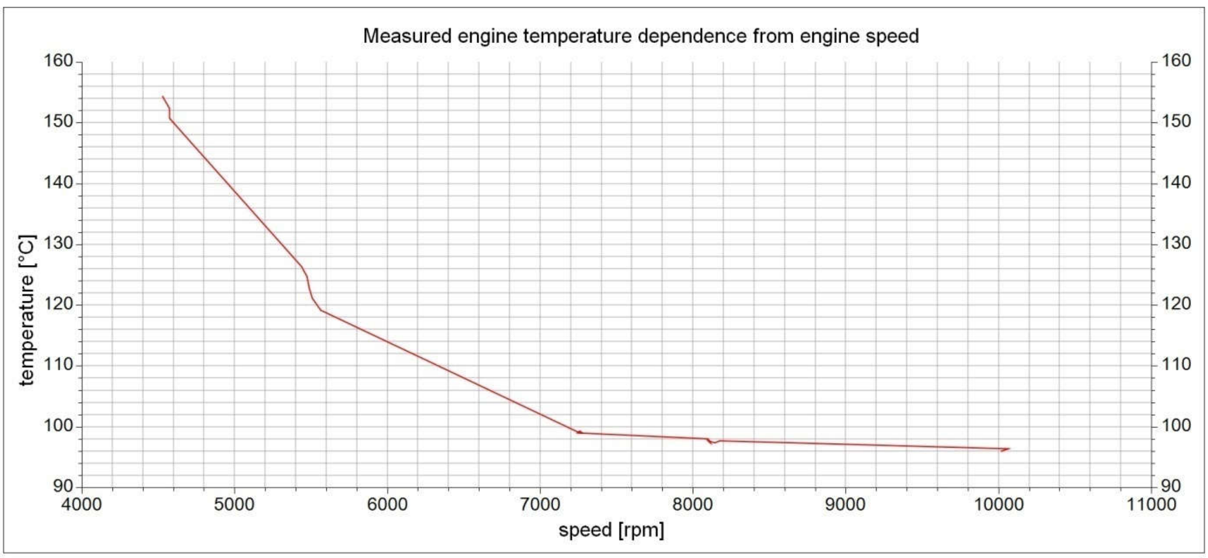

Figure 6 Measured engine temperature dependence from engine speed

2.3. Measure vibration of the engine

The basic rated parameter is the amplitude of vibrations that control the engine's further operation. Vibration measurement is performed using a piezoelectric accelerometer KD-37. Piezoelectric accelerometers are very often used for vibration measurement and offer several advantages over other technologies, such as small sensor dimensions, large bandwidth and high dynamic range. The accelerometer generates an electrical charge at its output in microvolts or millivolts. Since the value of this charge is very low, it needs to be further amplified. In most applications, it is possible to achieve the best performance using a charge amplifier which had to be designed. When designing the amplifier, we used the parameters and frequency characteristics of the accelerometer 0.

Table 1 Parameters of piezoelectric accelerometer KD-37

Parameter	Value	Unit
Voltage sensitivity	6,19	mV/ms-2
Sensor capacity with 1.5m cable	0,76	nF
Capacity of 1.5m cable	0,15	nF
Capacity of 5m cable	0,50	nF
Transverse sensitivity	1,8	%
Insulation resistance	>1000	MΩ

The values of the individual elements must be determined based on the accelerometer characteristics KD-37. The accelerometer used together with a 1.5 m cable has a capacity of 0.76 nF (C2). Capacitance of the C1 capacitor found in the feedback of the amplifier is set to 0.76 nF to obtain a charge amplifier gain of 1 mV/pC 0. The design was based on the following curcuit diagram:

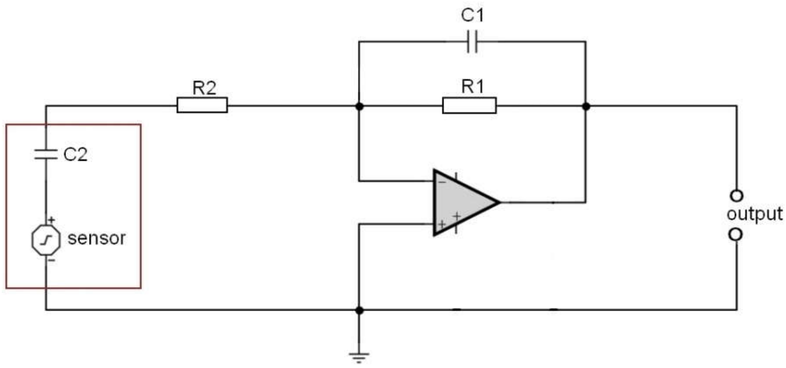

Figure 7 Basic curcuit diagram of a charge amplifier

Resistor R1, connected in parallel to capacitor C1, affects the lower limit frequency 0. Using a resistor with a value of 20.1 MΩ, we get a lower limit of 10 Hz resulting from the equation:

$$f_d = \frac{1}{2.\pi.C1.R1} \tag{1}$$

The upper limit of 8 kHz was deduced from the frequency response of the sensor indicated by the manufacturer. At this frequency, the accelerometer characteristic is linear. The upper limit frequency is given by the resistor R2, connected in series to the accelerometer 0. For the calculation, we used the equation:

$$f_h = \frac{1}{2.\pi.C2.R2} \tag{2}$$

After expressing the R2 value, we get the resulting definition for calculating the resistor value R2:

$$R2 = \frac{1}{2.\pi.C2.f} \tag{3}$$

where R2 = 26.17 kΩ, corresponding to the nearest output value of 26.1 kΩ. The resulting frequency characteristic of the proposed charge amplifier is shown in the following chart:

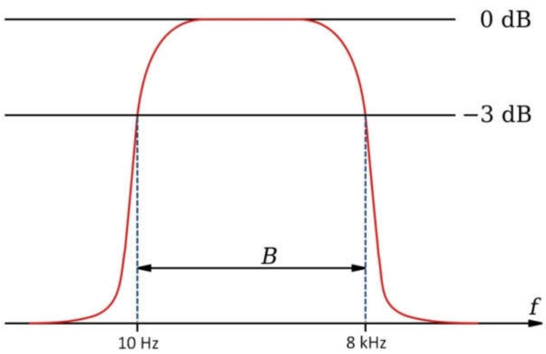

Figure 8 Frequency characteristic of the designed charge amplifier

3. MEASUREMENT AND CONTROL PLATFORM

As a measurement and control platform, we chose the Arduino Mega 2560 microcontroller, for which we also created our own software. This is a development board that includes 54 digital I/O outputs and 16 analogue outputs. Communication between the microcontroller and other devices is via the serial line. Arduino MEGA 2560 also supports communication via I2C and SPI. The microcontroller can be powered in two ways, either via a USB port or external power supply 0. Connecting the sensors to the microcontroller shows the following picture:

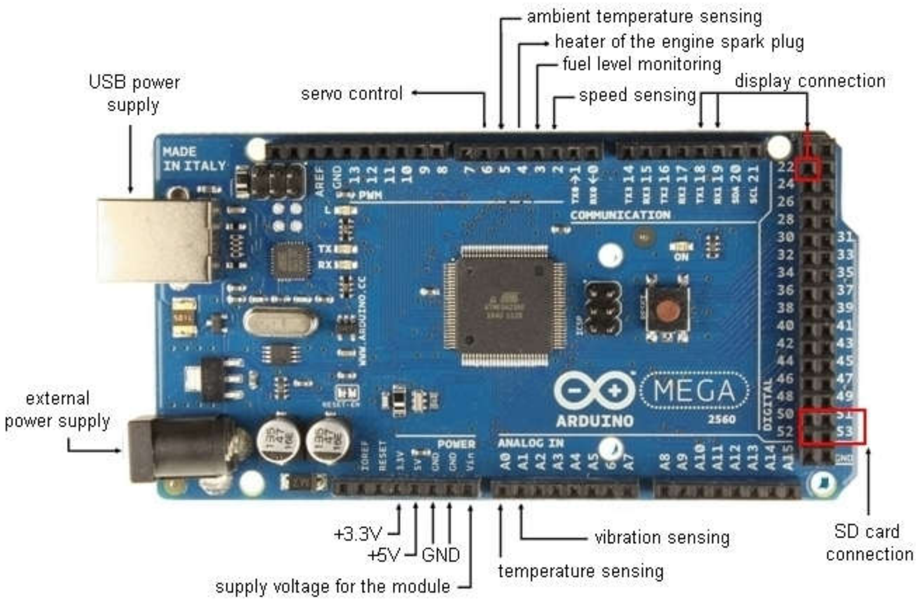

Figure 9 Description of used microcontroller input/output terminals

4. THE DESIGN OF THE ENGINE CONTROL UNIT

The engine control unit consists of a microcontroller, a touchscreen LCD and a module that includes power circuits, a spark plug heater circuit, a speedometer circuit, a temperature measurement circuit and a vibration measurement circuit.

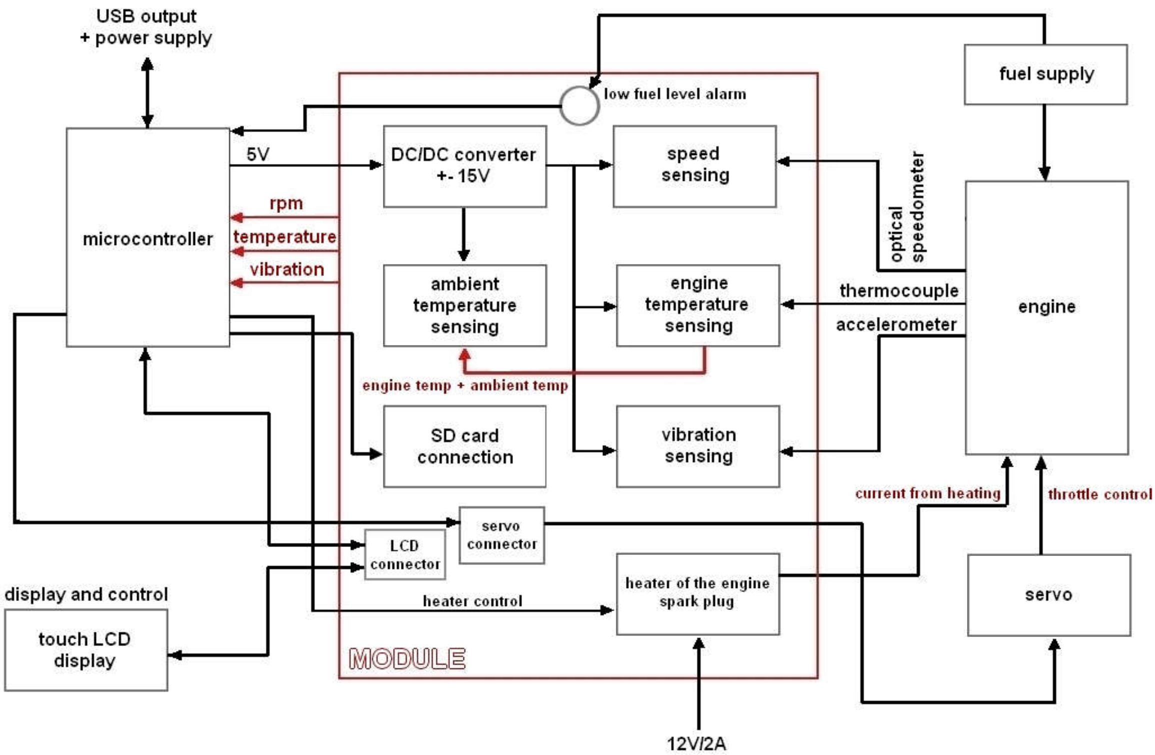

Figure 10 Block diagram of the engine control unit

The inputs to the measuring circuits located on the module are output signals from the speed sensor, thermocouple and accelerometer. The supply voltage for each measuring circuit is provided by the DC/DC converter. The module board also includes additional connectors for additional fuel capability and connectors for connecting a microSD memory card, an LCD display, and an actuator with a microcontroller. The output of the module is the speed, temperature and vibration signals. These signals are fed to the inputs of a microcontroller that processes them using the software. The output from the microcontroller is the speed, temperature and vibration values. Measured variables are displayed using the touchscreen. All variables are also recorded on a micro-SD card. In addition to the processing, the microcontroller also provides power to the DC/DC converter and generates a signal to control the heater's engine. Heat of the engine spark plug is realized using a MOSFET transistor and a MOSFET driver. The driver is controlled by the signal from a microcontroller. After setting the signal to 5V, the gate of the transistor turns on to start the heater of the engine. By setting the signal to 0V, the spark plug heater stops 0.

The operation of the control unit provides the designed software. The control of the engine is realized by setting the throttle. Throttle control is provided by a servo that opens, closes or stops the flap. Depending on the speed set by the user. The desired speed can be entered using the sliding graphic element on the touchscreen. From this value, the current speed obtained from the speedometer is then deducted. The result is the deviation between the required and the actual speed. If this deviation is greater than 0, servo will open the throttle, resulting in an increase in engine speed. If the deviation is less than 0, the throttle will close to reduce the engine speed. This process will be performed until the engine has reached the required speed. When the required speed is reached, servo stops and maintains the throttle position 0.

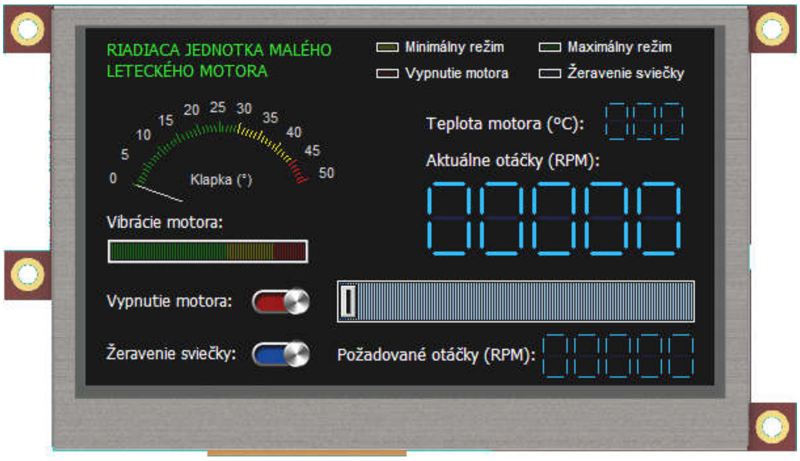

Figure 11 Graphics interface of the engine control unit

To create a compact unit, we used a plastic case adapted to own requirements. The case has openings with connectors for connecting power, sensors and other peripherals.

Figure 12 Engine control unit stored in the case

CONCLUSION

The article describes the design of a small aircraft engine control unit. To measure the engine speed, we chose the optical method. The principle of this method is to change the phototransistor illumination caused by the reflection of the infrared light from the propeller. Engine temperature measurement ensures a thermocouple placed on the engine cylinder and vibration measurement is solved using a piezoelectric accelerometer and a charge amplifier. The maximum speed measured using a 10x6 inch propeller was 10,065 rpm. Measured temperature values ranged from 96 °C to 154 °C, according to the engine mode set. After the realization and verification of the individual circuits to measure the operating variables, a module was designed that combines these circuits into one unit. The module is complemented by a spark plug heater circuit and a DC/DC converter that provides power to the measuring circuits. The module also includes additional connectors for additional fuel supply sensing and connectors for connecting the micro-SD card, touchscreen LCD, and servo with microcontroller. The module, microcontroller and touchscreen LCD therefore constitute a small aircraft engine control unit that allows measurement of engine operating variables, data logging, display of operating and controlling engine variables and adjusting the engine speed using the engine throttle. The operation of the control unit is provided by the microcontroller with the designed software.

ACKNOWLEDGEMENT

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