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Data Acquisition and Processing Algorithm for Total and Static Pressure Measurement System †

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Abstract: In aviation measurement of static and total pressure is widely used to determine the flight conditions. Results of pressure measurements are used to monitor flight attitude, equivalent speed, Mach number, vertical velocity etc. The algorithm for data acquisition and processing for developed pressure measurement system is presented in this paper.

Keywords: pressure sensor; linear photodetector array; sensing element; centroid method

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1. Introduction

A variety of systems for monitoring of aircraft flight parameters based on different working principles exists today [1–10]. Perspective and existing systems show high measurement speed and efficiency of sensors based on optical methods of information conversion [6–8]. The working principle of optical pressure sensors is based on determination the light spots position on the surface of Photodetector Array (PA). The light spots are formed by Light Emitting Diodes (LED). The LEDs are rigidly attached to the frame of the device. The PA is attached to the pressure sensitive element such as an elastic membrane. The membrane is strained by the change of pressure which leads to a displacement of the light spot. Thus, the change of measured value is proportional to the light spot displacement relative to the initial position.

One of the disadvantages of this type of device is that the information about the current optical spot coordinate is obtained discretely with a period equal to the time interval required for polling all the PA elements. The minimum time interval between PA polls is limited by the technical capabilities of the PA. In addition, if detector is mounted to membrane there is a decrease in dynamic stability of the system.

The developed optical pressure sensor is devoid of these drawbacks. The shutters with n slots are attached to the membranes instead of detector arrays. This allows to form n optical spots on the surface of the PA. All n optical spots are displaced when the static and (or) total pressure changes. The photodetectors of the PA are polled sequentially. An electrical signal is formed at the output of PA during the polling cycle. The signal amplitude reflects the distribution of optical power along the PA. The n-th extremum in the output signal corresponds to the position of the n-th optical spot. This design allows to obtain n values of measured parameter in one polling of the array. The sensor has a higher dynamic stability as the PA is rigidly fixed to the sensor body. The dimension of the device are also reduced as the shutters are more compact than the PA.

2. Data Acquisition Algorithm

The conversion of the electrical signals (Vaut) from the PA into a digital code is performed by an analog-to-digital converter (ADC) built in the microcontroller. Acquired data is then processed by the microcontroller and the results are transmitted to a personal computer via the Universal Asynchronous Receiver-Transmitter (USART) interface. The sequence of control clock (CLK) pulses determines the appearance of a signal at the PA output (Figure 1). Therefore, the sampling rate of all pixels of the line is determined by the following condition: each subsequent control Read-Out Gate (ROG) pulse must appear after the passage of 2087 CLK pulses.

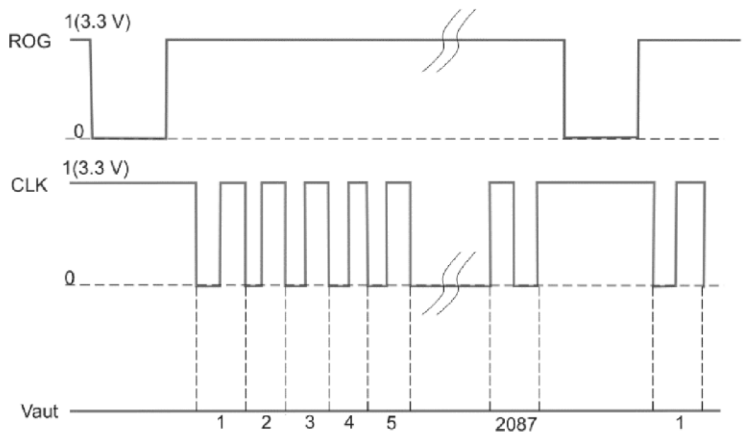

Figure 1. Diagram of control puslses.

The STM32 microcontroller algorithm of can be divided into two infinite parallel loops.

Loop No 1:

1. The Startup of the ADC channel is performed by a trigger from the timer. The data is then saved in the array with the use of the direct memory access (DMA).
2. The CLK signal is inverted by ADC interrupt handler after each conversion. (This approach to forming CLK pulses allows to obtain a data array of 4174 values for the PA consisting of 2087 pixels).
3. The flag of the completion of polling of the first half of the PD is set in the DMA interrupt handler after the half of the data array is filled.
4. The flag of the PA polling completion is set in the DMA interrupt handler and the reset signal (ROG) is formed after the whole data array is filled.

Loop No 2:

1. Tracking the status of the polling of the first half of the PA. If the corresponding flag is set data is copied to the other memory region and then processed.
2. If the averaging is not performed the results are transmitted via USART interface.
3. Tracking the status of the polling of the whole PA. If the corresponding flag is set data is copied to the other memory region and then processed.
4. If the averaging is not performed the results are transmitted via USART interface.
5. If averaging of the results is performed, then either average the data after the single poll of the PA or from several sequential polls.

3. Data Processing Algorithm

The algorithm for calculating the coordinates of the light spot uses the centroid-method and is implemented as follows. First, the numbers of n pixels N_{max_n}, are determined, the signal amplitude from which corresponds to local maxima within each of the n light spots on the photosensitive surface of the PA. Then an area of M pixels around local maxima is selected. The value of M is chosen in such a way as to include all pixels around maximum signals from which are noticeably higher than the background noise level. The coordinate of the signal maximum is then calculated according to the following formula:

$$MAX_n = \frac{\sum_{i=N_{\max\_n}-M/2}^{N_{\max\_n}+M/2} A_i i}{\sum_{i=N_{\max\_n}-M/2}^{N_{\max\_n}+M/2} A_i} \quad (1)$$

where MAX_n—coordinate of the maximum of n-th light spot expressed in the pixel number, A_i—signal amplitude from i-th pixel in vicinity of n-th optical spot, N_{max_n}—number of pixel having maximum amplitude around n-th optical spot. The elastic membrane deforms as a result of pressure change. The deformation of the membrane leads to displacement of the optical optical spots. Computation of the new coordinates of the optical spots using (1) allows to determine change of pressure relatively to some reference value according to the formula:

$$\Delta P_{stn}(t) = k_n(MAX_n(t) - MAX_n(0)) \quad (2)$$

where $\Delta P_{stn}(t)$—current value of pressure change, $MAX_n(t)$—coordinate of the n-th optical spot maximum at time t, $MAX_n(0)$—coordinate of the n-th optical spot maximum at reference pressure, k_n—calibration constant.

4. Conclusions

When using the presented algorithm for collecting and processing information, the measurement speed of the developed pressure sensor is determined by the repetition rate of the control pulses. The proposed solution provides reduced error values when calculating the altitude and speed parameters of the aircraft. Averaging of the results from one complete poll of PA (n spots) increases accuracy in $n^{1/2}$ times. On the other hand, when measurement speed is more important, the value of pressure can be obtained from the position of one optical spot.

The high speed of the measuring system in the future will make it possible to apply algorithms that provide compensation for various kinds of destabilizing factors (interference, vibrations, shock effects, etc.) that arise during the operation of aircraft.

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