Bulgarian Journal of Agricultural Science, 29 (No 5) 2023, 994–998

Energy independent temperature sensor with fiber optic interface for application in agriculture

Yanka Ivanova[1*], Svetoslav Ivanov[2] and Rosen Bozhilov[3]

[1] *Trakia University, Department of Agricultural Engineering, Faculty of Agriculture, 6000 Stara Zagora, Bulgaria*
[2,3] *Technical University, Department of Electronics, Faculty of Electronics and Automation, Plovdiv branch, 4000 Plovdiv, Bulgaria*
[*]*Corresponding author:* yankakiss777@abv.bg

Abstract

Ivanova, Ya., Ivanov, S. & Bozhilov, R. (2023). Energy independent temperature sensor with fiber optic interface for application in agriculture. *Bulg. J. Agric. Sci., 29*(5), 994–998

In this paper, a sensor device for remote temperature measurement with the possibility of application in greenhouses and animal farms is proposed and investigated. The application of an intelligent sensor for measuring temperature with a digital output signal, powered by a rechargeable battery, which is charged by a photovoltaic panel, has been investigated. The main parameters of the fiber optic interface implemented with a polymer optical fiber for remote transmission of data from the sensor output have been investigated. The accuracy of the measured temperature in accordance with the received data from the optical receiver has been investigated. The effect of changing the supply voltage for the sensor and the optical receiver powered by a rechargeable battery during around the clock operation has been investigated.

Keywords: energy independent sensor; solar battery charger; fiber optic interface

Introduction

The power supply of sensors for measuring physical quantities from a rechargeable battery with a long service life, for example a Li-Ion battery, is suitable for use in greenhouses and in animal farms (Armstrong, 2008). A photovoltaic panel with a low output power of up to 24W can be used to charge the battery (Hua et al.,1998). Specialized integrated circuits have been created for charging batteries from the output electrical energy of photovoltaics (Boico et al., 2007). These circuits provide an optimal charging mode by changing the magnitude of the current consumed by the photovoltaic panel depending on the solar energy (Molina et al., 2021). Depending on the parameters of the rechargeable battery, different charging algorithms have been developed (Gupta et al., 2021). In some cases, complex DSP loading algorithms are used (Leal-Junior et al., 2019). NiMH batteries are used to power more powerful consumers of electrical energy (Agrawal, 2010). Smart sensors with digital output signal have low current consumption and can work in continuous mode, when powered by Li-Ion battery (Essiambre et al., 2010). The output signal is frequency modulated, or pulse duty cycle modulated and can also be a digital data word (White et al., 1999). In practice, sensors are also used to measure several physical quantities at the same time (A. -G. Marin et al., 2015). The use of fiber optic cables for connection enables reliable and secure transmission of information over long distances (Hassan et al., 2015). Fiber optic communications improve the electromagnetic compatibility of electronic devices and provide complete galvanic isolation between the source and receiver of signals (Athukorala et al., 2016).

The purpose of this paper is: to be investigated the possibility of continuous remote data transmission from a energy independent temperature sensor over a fiber optic interface.

Material and Methods

A Li-Ion rechargeable battery with capacity 1800 mAh is charged with the electronic converter (Figure 1). The DC-DC converter is implemented with an LT 3652 integrated circuit. The battery voltage reaches a maximum value of 4.2 V, when charging and approximately a minimum value of 3V, when discharging. The used photovoltaic panel has a maximum output power of 24 W and dimensions of 240×100×25 mm (Figure 2).

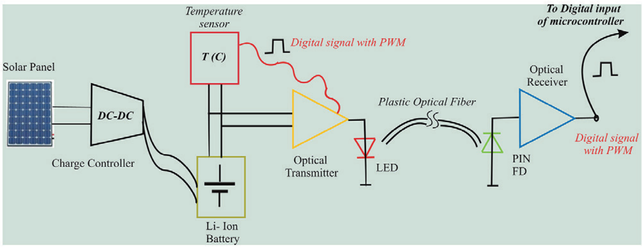

Fig. 1. Schematic diagram of the energy-independent sensor

Fig. 2. Solar panel

In the experimental studies, a 10 m long polymer optical fiber with a step profile was used with added optical connectors at the ends of the fiber (Figure 3).

Fig. 3. Plastic fiber with a length of 10 m

Polymer optical fibers have a large numerical aperture, which allows the introduction of light at a large angle about the axis of the fiber, as the source used is an LED. In this case, optical connectors are easily installed at the end of the fiber for connection with the LED and with the receiver PIN Photodiode (Figure 4).

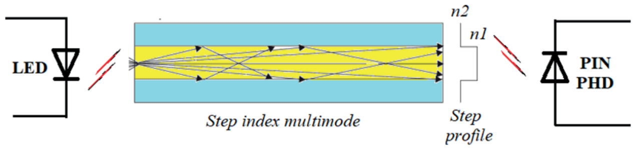

Fig. 4. Plastic fiber with step profile

The intermodal dispersion in polymer optical fibers has a high value, which limits the bandwidth of transmitted signals. For transmission of digital signals at a distance of up to 100 m, these fibers are widely used.

In the implementation made, an LED emitting light in the visible region with a red color is used as a light source. The minimum current value, when transmitting a logical „0“ is 12 mA, and when transmitting a logical „1“ is 25 mA. The average value of the current consumed by the battery is 18 mA. The schematic of the LED transmitter is shown in Figure 5. The change of the current during transmission of the logic signals is shown in Figure 6.

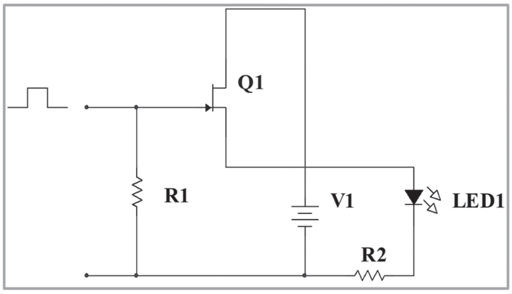

Fig. 5. Fiber optical transmitter

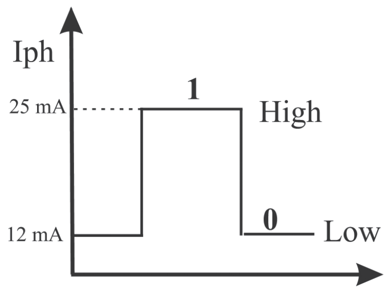

Fig. 6. Current through the LED

Passing a direct current through the LED in the „Low" level increases the fast action of the LED during the transient process when going to the „High" level.

As an optical detector, a PIN photodiode was used, which works in photodiode mode. The broadband amplifier U1 converts the current from the photodiode Iph into a voltage Uout (Figure 7). This voltage is applied to the input of the comparator U2, and digital pulses with TTL levels are obtained at the output of the comparator. The voltage V1 sets the comparison threshold of the comparator U2.

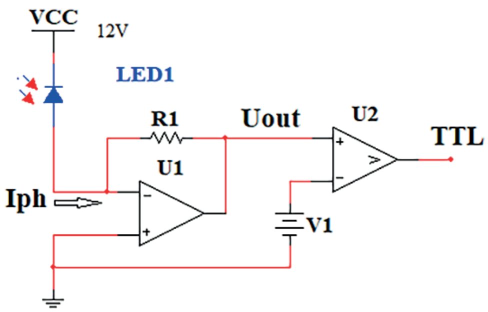

Fig. 7. Fiber optical receiver

Results and Discussion

The measured temperature value is calculated from the equation:

$$t^{\circ} = 212.77 \,.\, DC - 68.085, \tag{1}$$

where:

$$DC = \frac{t_i}{T}$$

The error in the accuracy, with which the temperature is measured using the fiber optic interface, is due to the variation in the duration of the received pulse at the output of the optical receiver. The variation of the error depends on the value of the supply voltage for the sensor, which in turn depends on the voltage of the rechargeable battery. From the obtained experimental results, an estimate of the absolute error, with which the temperature will be measured by the microprocessor system can be made. The next oscillogram shows the pulses generated by the sensor *beam 1* and the pulses received at the output of the receiver *beam 2* (Figure 9). The battery voltage is $U_{supply} = 3.7\ V$, and the frequency of the generated pulses is $F = 3.86\ kHz$.

Analysis of the obtained measurement results

A semiconductor sensor with a digital output signal SMT 172 was used to measure temperature. The sensor is powered by the voltage of a Li-Ion battery. The output signal is digital and is modulated by a duty cycle D as a function of the measured temperature (Figure 8).

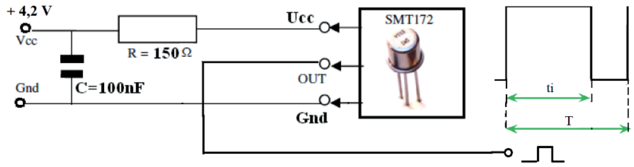

Fig. 8. Connection diagram of the sensor and shape of the output pulses

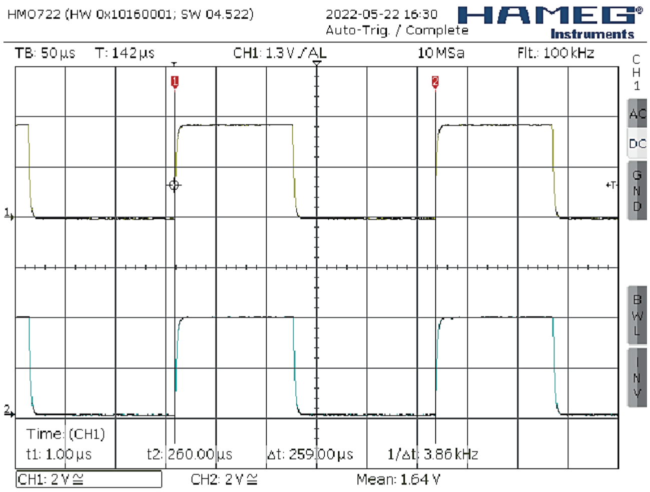

Fig. 9. Signals at the output of the sensor beam 1 and at the output of the optical receiver beam 2

The received pulses at the output of the optical receiver are delayed in time by a value (t_{delay}) and have a longer duration ($t_{extension}$) than the pulses generated by the sensor (Figure 10).

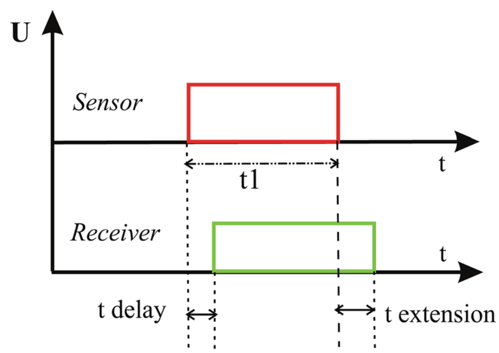

Fig. 10. Graphs of the signal generated by the sensor and the signal received by the optical receiver

The delay of the received pulses at the output of the receiver is shown in Figure 11. At this value of supply voltage it is t_{delay} = 480 ns.

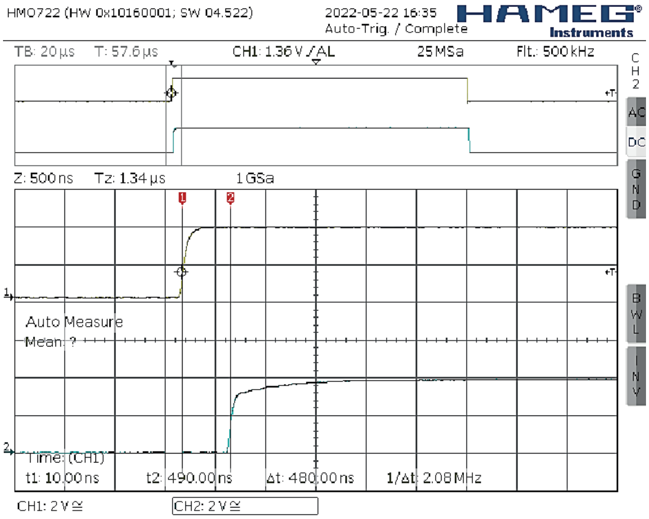

Fig. 11. Delay of the received pulse t_{delay} = 480 ns

The output pulse of the receiver is extended due to the transients in the optical transmitter and in the optical receiver. Experimental studies have reported extension with value $t_{extension}$ = 710 ns (Figure 12).

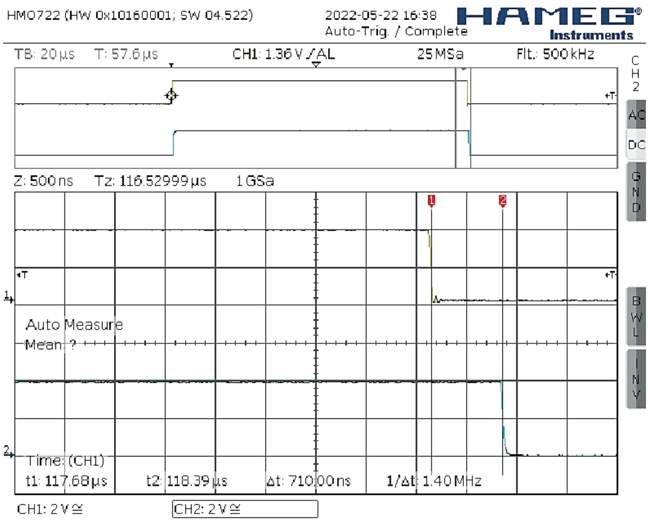

Fig. 12. Extending the received pulse $t_{extension}$ = 710 ns

The extension during the received pulse is equal to:

$$\Delta t_1 = t_{extension} - t_{delay} = 230\ ns \tag{2}$$

The frequency of the pulses generated by the sensor at a supply voltage from the battery Vcc = 3.7 V is equal to F = 3.86 kHz. The period of the generated pulses is equal to T = 259067 ns, therefore the change in the duty cycle of the pulses that the fiber optic interface introduces is equal to:

$$\Delta DC = \frac{\Delta t_1}{T} = \frac{230ns}{259067ns} = 0.887.10^{-3} \tag{3}$$

The temperature measured with the sensor during the experiment is equal to $t_{measured}$ = 28.5°C. The calculated temperature value from the output pulse of the optical receiver is equal to:

$$t^{\circ}_{calculated} = 212.77(DC + \Delta DC) - 68.085 = 28.72^{\circ}$$

The absolute error is equal to:

$$\Delta t^{\circ} = t^{\circ}_{calculated} - t^{\circ}_{measured} = 0.22^{\circ} \tag{4}$$

At the maximum value of the battery supply voltage U_{supply} = 4.2V, the frequency of the pulses generated by the sensor is f = 3.15kHz, and the period is T = 317460 ns, respectively. The absolute error in this case is equal to $\Delta t^{\circ} \cong 0.2^{\circ}$. At a minimum value of the supply voltage (with a discharged battery) U_{supply} = 3.2 V the frequency of the pulses generated by the sensor is f = 5.05 kHz with a repetition period T = 198019ns. The absolute error in this case is equal to $\Delta t^{\circ} \cong 0.3^{\circ}$.

Conclusion

The designed and investigated energy-independent temperature sensor is suitable for application in agricultural buildings for animal husbandry and in greenhouses. The fiber optic interface enables reliable measurement of temperatures over long distances, providing electrical safety and the ability to work in chemically aggressive environments. The low consumption of electrical energy by the sensor and the optical transmitter enable continuous operation even in low light conditions of the solar panel. From the experimental studies, it can be seen that regardless of the change of the battery supply voltage from 3.2V to 4.2V, as a consequence, of which the frequency of the pulses from the sensor changes from 5.05kHz to 3.15kHz, the absolute error of the measurements varies in the range from 0.2° to 0.3°C. This error is permanent and can be corrected by the microprocessor data processing system.

References

Agrawal, G. (2010). Fiber-Optic Communication Systems. 3rd ed. Hoboken, NJ: Wiley-Interscience.

Aher, M., Parbat R. & Chandre, V. (2016). A Hybrid Wired/ Wireless Infrastructure Networking For Greenhouse Management. International Conference on Automatic Control and Dynamic Optimization Techniques, 1152-1157.

Armstrong, S. & Glavinand, M. E. (2008). Comparison Of Battery Charging Algorithms For Stand Alone Photovoltaic Systems. 2008 IEEE Power Electronics Specialists Conference, 1469–1475.

Athukorala, S., Weeraratne, I. & Ragel, R. (2016). Affordable Real-Time Environment Monitoring System For Greenhouses. Proceedings of the 1st Manufacturing & Industrial Engineering Symposium, 1-5.

Boico, F., Lehmanand, B. & Shujaee, K. (2007). Solar battery chargers for NiMH Batteries. IEEE *Transactionon Power Electronics, 22*(5), 1600–1609.

Essiambre, R., Kramer, G. & Winzer, P. (2010). Capacity Limits Of Optical Fiber networks. *J. Lightw. Technol., 28,* 662–701.

Gupta, D., Hugo, V. & Albuquerque, C. De (2021). Introduction. *Smart Sensors for Industrial Internet of Things*, 1.

Hassan, M., Noor, A. & Abdullah, S. (2015). An automatic monitoring and control system inside greenhouse. *Green Energy and Technology, 1-5.*

Hua, C., Linand, J. & Shen, C. (1998). Implementation of a DSP-controlled photovoltaic system with peak power tracking. IEEE *Transaction on Industrial Electronics, 45*(1), 99-107.

Leal-Junior, A., Díaz, C. & Marques, C. (2019). 3D-Printing Techniques on the Development of Multiparameter Sensors Using One FBG. *Sensors*, *19*(16), 3514.

Marin A. G. & Tudose, **D. S.** (2015). Energy Independent Wireless Sensor Network Design. 20th International Conference on Control Systems and Computer Science, 267-272, doi: 10.1109/ CSCS.2015.94.

Molina, A., Ponce, P. & Miranda, J. (2021). Sensing, Smart and Sustainable Manufacturing Systems. *Enabling Systems for Intelligent Manufacturing in Industry 4.0*, 227.

White, W., Dueser, M. & Reed, W. (1999). Intermodal dispersion and mode coupling in perfluorinated graded-index plastic optical fiber. *IEEE Photonics Technology Letters*, *11*(8), 997-999, doi: 10.1109/68.775325.

Received: **July, 05, 2022**; *Approved*: **October, 12, 2022;** *Published:* **October, 2023**