# Efficient Optical Radiation Supply System for Electronic Devices

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***Abstract*** — *This article covers the construction option of the optical radiation supply system for electronic devices with automatic adjustment of radiation power to ensure the photovoltaic converter operation in the maximum power point with alternating electric load and wide-range changing temperature.*

**Keywords** — *photovoltaic converter, maximum power voltage, supervisor, feedback channel.*

## I. INTRODUCTION

The optical radiation supply systems (ORSS) for electronic devices for commercial use are characterized by significant change in the electric load parameters and operation modes of the photovoltaic converters (PVC) within a wide temperature range [1]. In view of this, the continuous adjustment of optical radiation power is necessary for efficient operation of the ORSS to ensure the PVC operation with maximum efficiency. This predetermines the presence of an optical feedback channel [2], [3] in the ORSS via which the information about the current operation mode of the PVC is transmitted to the supply radiation power regulator. Generally, to measure the actual voltage of the PVC and the temperature, the analog-to-digital converters are used, and encoding of their output signals into a format acceptable for transmittance via the fiber optical channel requires certain energy costs, which additionally reduces the ORSS performance.

## II. METHODS

This work offers the ORSS with minimum energy consumption of the feedback channel and adjustment of the optical radiation power for the PVC operation in the maximum power point with changing electric load and temperature parameters.

This point is determined by the voltage $U_{MPP}$ that can be found on the basis of semi-empiric ratio ensuring the practical accuracy for the unijunction GaAs/AlGaAs PVC:

$$U_{MPP} \approx (0{,}99625 - 2{,}5 \cdot 10^{-4} T) \cdot (U_{oc}(T) - I_{sc} R_s) \quad (1)$$

where the open voltage linearly depends on the temperature $U_{oc}(T) = 1.599 - 1.16 \cdot 10^{-3} T$ (Kelvin temperature) and slightly depends on radiation power. Generally, for the high quality PVC, the equivalent series resistance $R_S$ is rather small and the criterion for the adjustment of radiation power can be the PVC voltage hold-up value of about $U_{MPP} \approx 1.593 - 1.55 \cdot 10^{-3} T$. In case of significant deviation of $U_{MPP}$ from this dependence, the actual dependence $U_{MPP}(T, P)$ can be entered into the memory of the microprocessor-based supply laser power regulation module in the form of table. The flow chart of the supply system implementing the above principle is shown in Fig. 1.

The device comprises a microprocessor-based module 1 linked to a controlled current source 2 for laser 3 supply. In practice, the microprocessor-based module 1 and the current source 2 are designed as a microcircuit, for example, iC-HTP [4]. The laser 3 radiation flows via the light conductor 4 to the photovoltaic converter 5 input where it converts into the electric voltage. The converter output is connected to the step-up converter 6 input, as well as to the voltage meter 7 input. The output signal of the voltage meter should be in a format allowing its transmittance via the optical channel without additional encoding. The simplest way to implement it is to use the voltage-frequency converters or supervisors with the adjustable reset threshold input as the basis.

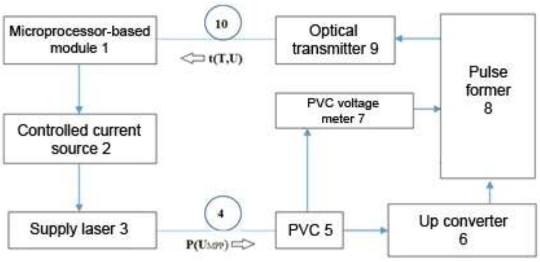

Fig 1: Flow chart of the optical supply system

## III. RESULTS

The simplest option for the PVC voltage control with simultaneous temperature compensation is to use the MAX6838 supervisor with the KTY82/222 Silicon temperature sensors [5] in the input external resistive-divider network to set the reset threshold voltage. This supervisor operates at low supply voltage (from 0.8 V), has low consumption current (max 10 µA) and accuracy of at least 2,5% within the temperature range of --40–+85°C. The supervisor forms a pulse with duration of 70 µs when the measured voltage achieves the threshold value determined by the external resistant divider. The parameters of this divider are easy to estimate on the basis of the parameters of the supervisor and the temperature of the silicon temperature sensors with the positive temperature coefficient of resistance according to the equation to determine the voltage of the maximum power point. The resistance of the KTY82/222 heat resistor varies from 960 Ohm at -55 °C to 2,623 Ohm at +60°C, the connection diagram of the supervisor and heat compensated input divider is shown in Fig. 2.

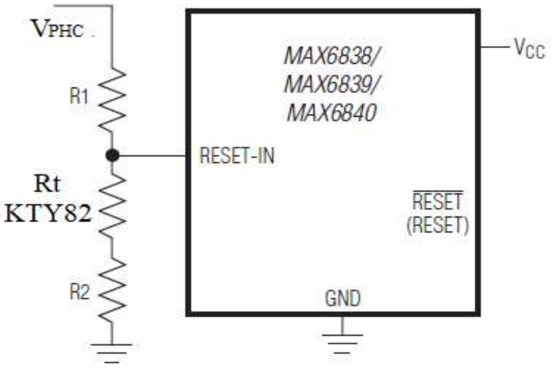

Fig 2: Connection of the MAX6838 supervisor for voltage control of the maximum power point

For the unijunction PVC with the idle voltage of 1.23-1.25 V and the maximum power voltage and temperature dependence being described by the above expression ( $U_{MPP} \approx 1.593 - 1.55 \cdot 10^{-3} T$ ), the resistances of the resistors $R1$ and $R2$ can be determined using the following system of equations:

$$\begin{aligned} (R2+2623)/(R2+R1+2623) &= K(60) \\ (R2+990)/(R2+R1+990) &= K(-55) \quad (2) \end{aligned}$$

where $K(60) = 444/U_{MPP}(333)$ – the division factor at +60 °C,

$K(-55) = 444/U_{MPP}(218)$ – the division factor at -55 °C, 444 – the reference voltage of the supervisor.

Solving the system (2) gives the following values of the resistors $R1$and $R2$ at the room temperature: $R1 = 10579$ Ohm and $R2 = 4744$ Ohm. With such nominal values of the resistors, the supervisor tracks not only the maximum power voltage but also its temperature dependence. The dependence on the maximum power voltage temperature and tripping limit of the supervisor is shown in Fig. 3. The figure illustrates that this option of the maximum power voltage control system makes it possible to generate the feedback signal for the supply laser's power regulation quite accurately.

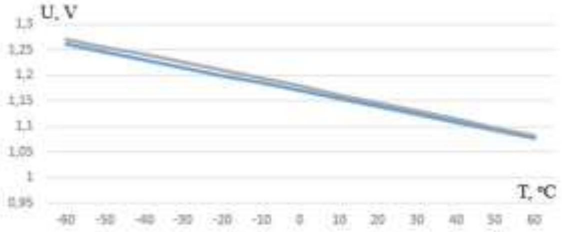

Fig 3: Projected dependence of the supervisor with the heat compensated input voltage divider on the maximum power voltage temperature and tripping limit

When the supply system is on, the pumping current is set so that the converter 6 starts reliably at load, and then, in several seconds (depending on the capacity at the PVC output), it begins reducing with the conductance of 1-10 mA/sec. When the maximum power point is achieved, the supervisor generates a pulse with duration of 70 µs that enters the optical transmitter 9 input designed, for example, on the basis of the HFBR1414 LED. The optical pulses via the LED 10 enter the photodetector input (for example, AFBR-2418) connected to the microprocessor-based module 1 input where they are used in the laser 3 current regulation system. At the time of arrival of the pulse, the laser pumping current is stored and recorded as the operating current. Periodically, for example, each second (the temperature and load do not change quicker), the supply current increases by 3-5% and then it starts decreasing to record a new value of the maximum power point. Therefore, the relative pulse duration exceeds $10^4$ that, with the pulse current of 50 mA via the HFBR1414 LED, will correspond to the average consumed current of 5 µA. As a result, the average energy consumption of the feedback channel will not exceed 100 µW, among which 90 µW is consumed by the input divider of the supervisor. The connection diagram of the HFBR1414 optical transmitter differs from the standard one [5] and is shown in Fig. 4.

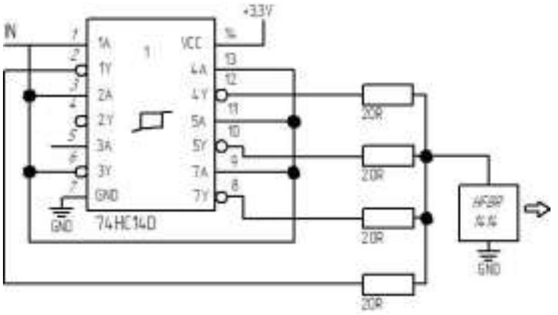

Fig 4: Control diagram of the optical transmitter of the feedback channel of the HFBR1414 based ORSS

The most universal option for the voltage control of the PVC of different types, including those with non-linear dependence of the voltage in the maximum power point and the temperature, is the use of a micropower voltage-frequency converter. Unfortunately, the converters of such type produced by the leading companies consume significant power and cannot be used in the relevant optical supply system. The low-voltage micropower voltage-frequency converter can be designed according to the diagram shown in Fig. 5 [6], [7].

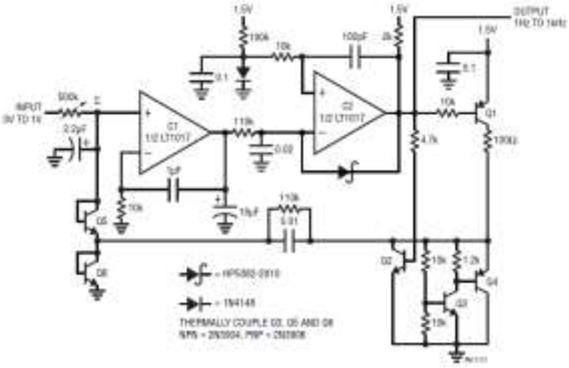

Fig 5: Diagram of the low-voltage micropower voltage-frequency converter [6]

Better energy consumption characteristics can be obtained by replacing the micropower dual comparator LT1017 for TLV7022 with own consumption current by more than 4 times less. At the converter output, a series of pulses is formed with the frequency directly proportional to the PVC voltage. These pulses enter the former 8 input that, by the rising edge of the input pulse, forms a pulse with the temperature-dependent duration. This pulse shaper can be designed on the SN74LVC1G123 microcircuit with the silicon-based heat resistor of type KTY82/222 in the time-setting circuit that, with the time-setting capacity of 0.01 uF of NPO type, will correspond to the duration of the output pulse from 10 to 25 µs at the changing temperature from -60 to +60 $^{o}$C. With the changing duration of this pulse with the enable of 0.1 µs, the accuracy of temperature measurement will be at least 2-3 degree. The pulses with the frequency containing the PVC voltage information and the duration containing the temperature information are also transmitted via the optical communication channel from the former output to laser current control unit. The relative pulse duration will make about 100, that corresponds to the average consumed power of 500-600 µW.

## IV. CONCLUSIONS

In this option, the offered optical radiation supply system (Fig. 1) operates as follows. Initially, the microprocessor-based module 1 generates a control signal for the current source 2 so that the radiation power is sufficient to start the converter 6 with the load connected to the output, then the feedback channel starts working for the radiation power adjustment so that the PVC output voltage corresponds to the maximum power voltage at the current temperature that is stored in the microprocessor's memory or is calculated.

Therefore, the offered construction option of the optical radiation supply system will ensure the PVC operation in the maximum power point with the minimum power consumption of the feedback channel, with the changing load-consumed current and changing temperature.

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