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SIGNAL CONVERTER FOR ORGANIC PHOTODIODE STRUCTURES

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Organic photodiode structures (Organic Photodiodes, OPD) are widely used in flexible, energy-efficient, and integrated sensor systems due to their technological simplicity, tunable spectral sensitivity, and compatibility with flexible substrates [1–3]. At the same time, OPDs exhibit complex photoconversion mechanisms, including the coexistence of photodiode and photoresistive components, which complicates informative signal interpretation and long-term stability control during operation [1, 2]. Particular attention in recent research has been focused on improving detectivity and operational stability of organic photodetectors [1, 5].

The objective of this work is to further develop the transimpedance conversion method for forming informative signals of organic photodiode structures with the possibility of separating photodiode and photoresistive components and enabling in-situ monitoring of their parameters.

The organic photosensitive structure is represented by a SPICE macromodel that takes into account the photocurrent, the photoresistive component, and the parasitic capacitance C_P.

The signal processing path is based on a transimpedance amplifier (TIA) implemented using an operational amplifier with a resistive-capacitive feedback network (Fig. 1).

In the first approximation, the feedback current I_{FB} is assumed to be equal to the photocurrent I_{PH}, and the output voltage is defined as:

$$V_{out} = -I_{PH}R_{FB} \tag{1}$$

However, a detailed analysis of dynamic operating modes reveals a significant influence of the photodetector parasitic capacitance and operational amplifier parameters (unity-gain bandwidth, phase margin, slew rate, input bias currents) on conversion stability and transient response characteristics.

It has been established that the interaction between C_P and the feedback network may cause self-oscillation effects during transient processes. To ensure stability, frequency compensation is implemented by introducing a capacitor C_{FB} into the feedback loop. Variation of C_{FB} enables controlled modification of transient behavior and frequency characteristics of the converter.

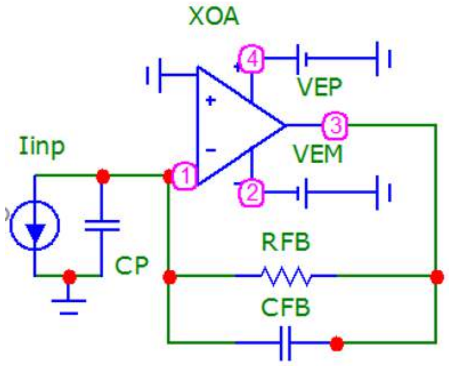

Fig. 1. Transimpedance converter circuit for an organic photodiode structure

Parametric analysis was performed using Nyquist diagram construction (Fig. 2), enabling investigation of the complex impedance characteristics of the signal path.

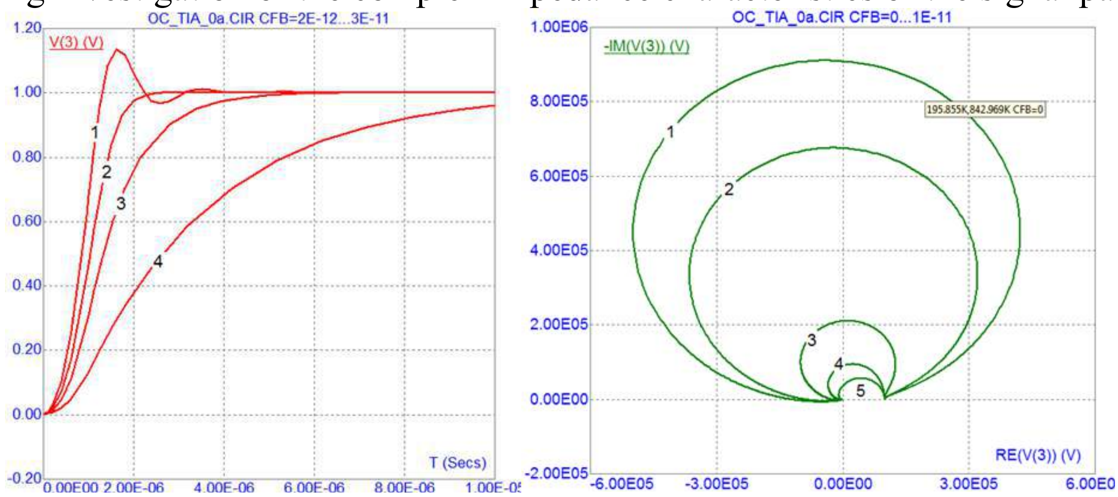

Fig. 2. Output characteristics of the transimpedance amplifier: (a) transient responses for C_{FB} 2E-12 (1), 1E-11 (2), 2E-11 (3), 3E-11 (4); (b) influence of C_{FB} on the impedance characteristics of the circuit

The obtained results demonstrate transitions between capacitive and inductive conversion mechanisms depending on frequency correction parameters. The identified regularities provide a basis for separating photodiode and photoresistive components of organic structures and can be applied to evaluate stability and degradation processes of OPDs in sensor systems [4, 5].

The proposed signal converter architecture significantly enhances the informative capabilities of organic photodiode-based sensors and forms the foundation for implementing in-situ monitoring functions of their operational parameters.

In addition to transient analysis, AC small-signal simulations were performed to evaluate the frequency response of the transimpedance stage over a wide frequency range. The dependence of gain magnitude and phase shift on the feedback capacitance value was investigated, allowing determination of stability margins under various operating conditions. The performed simulations confirmed that an improper ratio between R_{FB}, C_{FB}, and the photodetector parasitic capacitance C_P leads to phase degradation and amplification peaking, which may result in oscillatory behavior and distortion of the informative signal.

Special attention was given to the sensitivity of the converter parameters to variations in the photocurrent level, which corresponds to changes in optical illumination intensity. It was shown that under low-light conditions, the influence of bias currents and noise components becomes more significant, requiring optimized selection of operational amplifier characteristics. Therefore, proper coordination between OPD parameters and TIA dynamic characteristics is a key factor in ensuring stable and reliable operation of the sensor channel.

From a methodological perspective, the proposed approach combines time-domain and frequency-domain analysis, enabling a comprehensive evaluation of both transient stability and impedance behavior. Such combined analysis provides additional informative criteria for distinguishing between photodiode-dominated and photoresistive-dominated operating regimes of organic structures.

The scientific novelty of the work lies in establishing the relationship between frequency compensation parameters of the transimpedance converter and the impedance transformation mechanisms of organic photodiode structures. Unlike conventional TIA optimization focused solely on stability improvement, the proposed approach utilizes impedance behavior as an informative diagnostic feature.

From an engineering standpoint, the developed signal converter architecture can be applied in flexible optical sensing systems, wearable electronics, and low-power embedded devices, where continuous monitoring of photodetector stability and degradation processes is required.

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SOFTWARE-BASED MODELING OF SPECTRAL INTERACTION IN COLOR SENSOR SYSTEMS

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The formation of informative signals in optical sensor systems is fundamentally determined by the spectral interaction between three key components: the radiation source (actuator), the optical medium, and the photosensitive element [1–3]. From a physical standpoint, the measured electrical response is not governed by any single component separately, but rather by the spectral overlap of their characteristics within a common wavelength domain. Variations in LED emission spectra, medium absorption or scattering properties, and photodiode responsivity functions significantly affect measurement accuracy, calibration stability, and long-term reproducibility of sensor systems.

In practical applications, even minor spectral shifts caused by temperature drift, aging effects, or manufacturing tolerances may lead to measurable deviations of the output signal. Therefore, the ability to quantitatively evaluate the spectral overlap between system components becomes a critical aspect of sensor design and optimization.

To systematize the study of such interactions, a mathematical model and a dedicated software environment, Color Sensor, were developed. The proposed approach enables parametric spectral synthesis of each system component using Gaussian function decomposition and provides numerical evaluation of the resulting informative signal under various configurable conditions. Gaussian representation was