

An Adaptive Embedded Readout System for Resistive Sensor Arrays

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Summary: Resistive sensor arrays are extensively used for spatially distributed sensing and acquiring multiparametric data. However, a major challenge is the need of bulky measurement instruments for precise array readout. Here, we report an embedded and adaptive resistance readout system for sensor arrays. The readout yields low errors $\pm 0.5\%$ in 1 k Ω – 33 M Ω resistance range with a high SNR of 70–92 dB. End-to-end operation of the developed readout is demonstrated by utilizing a packaged 4 $\times$ 4 ZnO photodetector-array and accurate monitoring the photocurrents in real-time.

Keywords: resistive sensor arrays, embedded readouts, multiplexed arrays, PCB sensor instrumentation, UV photodetectors

Background and Motivation

Resistive photodetectors based on wide-bandgap semiconductors attractive for solar-blind UV sensing, environmental ozone and flame detection. When constructed as microdimensional sensing elements, these devices generate photocurrents ranging from picoamperes to microamperes, spanning several orders of magnitude in sensor resistance depending on optical intensity, device geometry, and applied bias. Capturing this dynamic range in a single multiplexed measurement without forfeiting accuracy or portability is challenging. Source measure units can deliver the required precision but at a cost and footprint incompatible with embedded deployment [1]. PCB-level alternatives each trade off a different dimension: voltage-divider readouts with adaptive reference tuning [2] cover only $\sim$ three decades and scale poorly with array size; diode-steered op-amp interfaces [3] multiplex many pixels but over a narrow resistance range; precision transimpedance amplifiers [4] achieve pA-level sensitivity but only as single-channel instruments. The 2D networked-array literature addresses inter-channel crosstalk at the algorithmic level [5, 6], leaving the analogue front-end untouched. Thus, developing an embedded readout system adaptive to the use-case base requirements would be highly beneficial.

System Description

We report development of an embedded readout that is multiplexed, wide-range, and pA-capable, with end-to-end demonstration of current reading from a 4 $\times$ 4 ZnO-based photodetector array. Fig. 1a shows the Block diagram of the multiplexed readout signal chain. The active sensor pixel is selected by a 32:1 analogue multiplexer and routed to a single OPA380

precision transimpedance amplifier (TIA), configured as a bias-offset non-inverting stage. A bias voltage $V_{bias} = 0.56$ V is applied across the sensor through a passive divider; the TIA output follows the closed-form transfer function in (1), where R_f is a selectable feedback resistor giving overlapping decade coverage from 1 k Ω to 33 M Ω .

$$V_{out} = V_{bias} \left(1 + \frac{R_f}{R_{pixel}} \right) \quad (1)$$

The output is buffered, anti-alias filtered, and digitised by a 24-bit $\Delta\Sigma$ ADC (ADS124S08) whose internal reference is 2.5 V, setting the full-scale output limit of the chain. An STM32 microcontroller (Nucleo platform) handles channel switching, ADC configuration, and serial transfer. The 16-pixel prototype uses a DIP-packaged ZnO photodetector array (Fig. 1b,c).

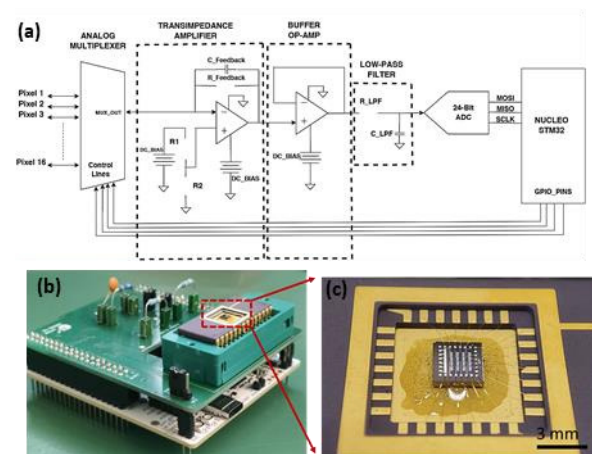


Fig. 1. a) Block diagram of the multiplexed readout signal chain: 4 $\times$ 4 sensor array $\rightarrow$ 32:1 analogue multiplexer $\rightarrow$ OPA380 TIA (bias-offset non-inverting) $\rightarrow$ unity buffer $\rightarrow$ passive anti-alias filter $\rightarrow$ 24-bit $\Delta\Sigma$ ADC $\rightarrow$ STM32 Nucleo microcontroller. b) Image of the developed embedded readout system. c) Image of the 4 $\times$ 4 sensor array.

Characterisation Methodology

The readout is characterised primarily by sweeping the pixel resistance: R_{pixel} from 1 k Ω to 33 M Ω at three representative feedback values ($R_f = 33$ k Ω , 1 M Ω , 10 M Ω), each chosen to span one decade of the operating range. For every (R_{pixel} , R_f) point, the mean of 100 ADC samples at 4 kSPS is compared against closed-form theory (1) and against an independent PSpice simulation of the full analogue chain. The measurement error is computed via (2), and the signal-to-noise ratio via (3). A representative linearity check is performed by fixing R_{pixel} at 1 M Ω and sweeping R_f to confirm gain linearity and locate the saturation boundary.

$$\text{Error (\%)} = \frac{V_{\text{measured}} - V_{\text{theory}}}{V_{\text{theory}}} \times 100 \quad (2)$$

$$\text{SNR (dB)} = 20 \log_{10} \frac{V_{\text{out}}}{\sigma} \quad (3)$$

Results

Fig. 2 shows the V_{out} measured at three R_f values. Hardware, PSpice simulation, and closed-form theory overlap across the full 1 k Ω – 33 M Ω range, with each curve saturating at 2.5 V once V_{out} approaches the ADC's internal reference. The asymptotic approach to $V_{\text{bias}} = 0.56$ V at high R_{pixel} confirms correct operation of the bias-offset topology.

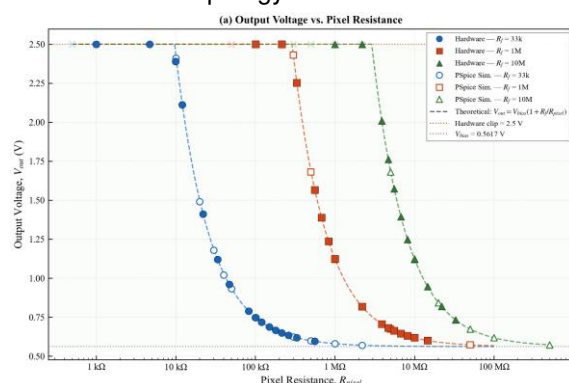


Fig. 2. V_{out} vs R_{pixel} at $R_f = 33$ k Ω , 1 M Ω , 10 M Ω . Hardware (filled), PSpice simulation (open), and closed-form theory (dashed) overlap across the full 1 k Ω – 33 M Ω range; saturation at 2.5 V is set by the ADC internal reference.

Measurement error is shown in Fig. 3a. Across most of the operating range, error stays within $\pm 0.5\%$, and within the middle decade of each gain setting it remains within $\pm 0.1\%$. The worst-case -2.1% excursion appears at $R_{\text{pixel}} = 10$ k Ω with $R_f = 33$ k Ω , where the closed-loop gain (~ 4.3) drives V_{out} into the 2.5 V saturation ceiling; this is an input-range limit imposed by the ADC reference, not an amplifier non-linearity.

Fig. 3b shows the signal-to-noise ratio across the pixel-resistance range. SNR exceeds 80 dB over the central operating region of each gain setting, reaching 92 dB at the peak, and remains above 70 dB at the extremes of the sweep.

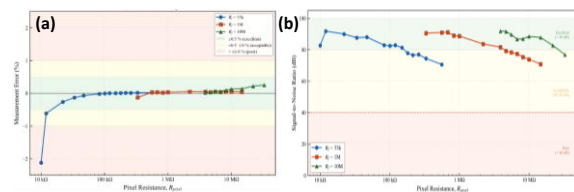


Fig. 3. a) Measurement error (%) vs. R_{pixel} at $R_f = 33$ k Ω , 1 M Ω , 10 M Ω . b) Signal-to-noise ratio (SNR) vs. R_{pixel} .

Demonstration on ZnO Photodetector Array

To verify end-to-end operation, the 16-pixel microsensor array chip was wire-bonded into a DIP package (Fig. 1c), thereafter ZnO nanoparticles (diameter ~ 100 nm) were dropcoated on top of the microelectrodes. The packaged chip was connected directly to the readout PCB (Fig. 1b). Fig. 4 shows the acquired output current from one of the pixels; first kept at dark and then illuminated with a 365 nm UV LED for 100 s and thereafter kept in dark. The current transitions from a dark baseline of 0.8 nA to 7.385 μ A upon UV illumination, and returns to baseline when the source is removed, resolved in real time at $R_f = 33$ k Ω .

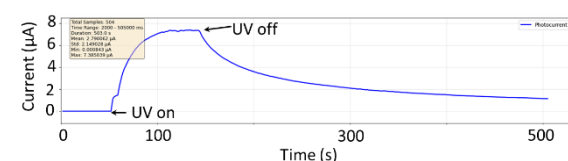


Fig. 4. Current vs. time plot for a ZnO-coated microsensor pixel under dark-UV (365 nm) illumination-dark condition. The data was acquired at $R_f = 33$ k Ω .

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