System-on-chip for Nanometric-range, High-speed Optical Positioning Measurement

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A nanometric-range, high-speed optical positioning measurement system-on-chip was integrated in 0.18 µm CMOS image sensor technology to implement high-precision absolute optical encoders for metrological, automotive and harsh environment applications.

The spaceCoder technology [1] consists in computing the spatial position of a moving reference object from the position of the shadow image of a specific code pattern, which is projected on a sensor. Depending on the application constraints, this technology can be implemented with various hardware configurations: off-the-shelf components (sensor, optic, code pattern and lighting) or custom solutions. The shadow position measurement is done in two steps:

- A phase measurement of the shadow position for high-resolution position measurement
- Decoding of the absolute code interleaved with the phase pattern to extend the measurement range

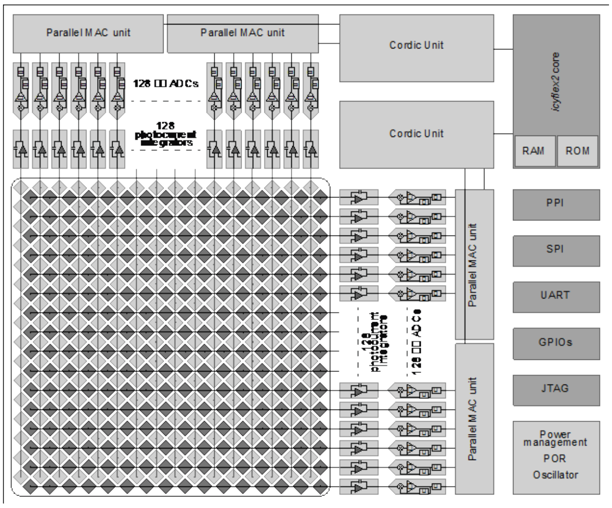

Figure 1: Block schematic of the spaceCoder system-on-chip.

A custom system-on-chip has been realized to fulfil the speed and temperature specifications of demanding applications that cannot be reached by assembling existing components. The block schematic of this ASIC is depicted in Figure 1. To achieve the high-speed requirement, a specific frontend composed of interleaved vertical and horizontal photodiodes was designed. The photocurrent of each photodiode is integrated and converted in parallel by row and column integrators, as well as ADCs placed at the edges of the photodiode array. A dedicated hardware unit (DHU) performs the phase computation in both the vertical and horizontal directions simultaneously by parallel multiply-and-accumulate operations, and two Cordic operators. With this optimized architecture, it is possible, under optimal illumination conditions, to compute the 2D phase position of the shadow in 5 µs, allowing a sampling rate of 200 kHz. The high-level application dependent algorithm is computed by an *icyflex2* processor and associated peripherals. For more demanding applications, a customized system-on-chip embedding a hardwired high-level algorithm could be developed. The micro-photograph of the ASIC is shown in Figure 2 and its main specifications are summarized in Table 1.

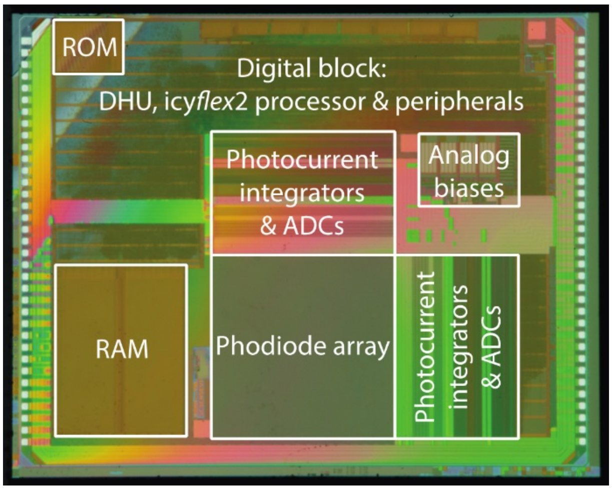

Figure 2: Micro-photograph of the spaceCoder system-on-chip.

Table 1: Summary of the system-on-chip characteristics.

Technology	**0.18 µm CMOS Image Sensor**
Size	20 mm^2 (5 × 4 mm^2)
Power consumption	120 mW (full speed)
Temperature	140°C maximum operating temperature
Clock frequency	48 MHz
Number of pixels	128 + 128 interleaved horizontal and vertical pixels
ADC resolution	12 bit ΣΔ (1 ADC per pixel)
Integration time	Typically 1-5 µs (depending on lighting)
Sampling rate	Maximum 200 kHz , with 1 µs integration
Position resolution	10 nm (2D shadow position on the sensor)

For each targeted application, the spaceCoder system-on-chip is a core component that is implemented in a custom configuration including a dedicated lighting, optic and code pattern. Possible applications include:

- Metrological applications: linear, rotary, multi-dimensional high-speed, high precision encoders
- High-temperature automotive applications
- Harsh environment applications

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[1] E. Grenet, P. Masa, E. Franzi, P.-A. Beuchat, "spaceCoder: a nanometric 3D position sensing device", CSEM Scientific and Technical Report (2011) 89