An image-sensor-based optical receiver fabricated in a standard 0.35-μm CMOS technology for mobile applications

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ABSTRACT

We present an image-sensor-based optical receiver for mobile applications. In our scheme, each pixel has a function of an optical receiver as well as an image sensor. The functional mode can be selected pixel by pixel. The position of a communication target is detected from the image captured in the image sensor mode. Then, functional mode of the pixel receiving optical signals is changed to the optical receiver mode to start communication. We designed and fabricated test pixel circuits and a 50x50-pixel image sensor in a standard 0.35 -μm CMOS technology, and fundamental operations were successfully verified.

INTRODUCTION

We study a new CMOS image sensor working as an optical receiver in local infrared communication for mobile applications. Recently, IrDA[1] attracts great attention in the application filed of local communication between mobile appliances such as mobile phones and personal data assistants (Fig. 1). To aim at post-IrDA with data bandwidth of more than 100-Mbps, capability with concurrent communication between multiple appliances, and intelligent communication, we have proposed a new scheme of infrared communication based on a special CMOS image sensor realizing intelligent and high-speed communication[2]. In this paper, we show some results of the CMOS image sensor fabricated in a 0.35-μm CMOS technology.

ARCHITECTURE OF IMAGE SENSOR

In our scheme, an image sensor, which is composed of a large number of micro photodiodes, is utilized as a photoreceiver as well as a position-sensing device, although a single photodiode is used in the conventional IrDA scheme. The use of image sensor has promising potentialities; because it can capture the scene around the communication node or hub at once like ordinary image sensors, it is easy to implement detection and tracing of the communication nodes or hub without any mechanical devices to search them. Figure 2 shows light detection scheme using an image sensor and the block diagram of the proposed image sensor. The proposed image sensor can select two functional modes pixel by pixel: image sensor and communication modes. In the image sensor mode, it woks as an ordinary CMOS image sensor, and the positions of the other appliances are detected from the captured image. Instead in the communication mode, optical signals are directly readout from the pixels receiving it without integrating photocurrents. By making best use of advantages of the image sensor, communication area can be widened without reducing communication bandwidth, and concurrent communication between multiple appliances will be possible. Figure 3 shows a setup for transmitting and receiving optical signals, and capturing images. To realize high-speed communication, a directional light beam with high power density is utilized. The light beam is deflected toward the communication target by a MEMS (Micro-Electro-Mechanical Systems) mirror. Thanks to recent progress in MEMS technologies, it is possible to fabricate a very compact transceiver module.

EXPERIMENTS

We have fabricated a pixel TEG and a 50x50-pixel image sensor in a standard 0.35-μm CMOS technology. Figure 4 shows a pixel TEG that can switch the functional modes. Specifications is summarized in Table 1. The circuit is composed of a photodiode, a source follower, and a transimpedance photocurrent amplifier[3]. From the experimental results shown in Fig. 5, we have confirmed that two functional modes can be switched correctly. Data rate of 40 Mbps with estimated bit error rate of 2.2×10^{-8} was confirmed. Photosensitivity and trasimpedance gain were 0.06 A/W@ λ=830nm and 6.8 kΩ, respectively. Based on the pixel TEG, 50x50-pixel image sensor shown in Table 2 and Fig. 6 was fabricated. Each pixel has a digital memory to store functional mode and a decoder of the functional mode. The block diagram of the image sensor is almost identical to Fig. 2(a), however, column amplifiers for communication mode is omitted. We have successfully captured images in the image sensor mode and read out optical signals from the specified pixel in the communication mode.

CONCLUSIONS

CMOS-image-sensor-based optical receiver for local infrared communication between mobile appliances was proposed. We fabricated a test pixel circuit. From the experimental results, fundamental operations of the test pixel circuit and the 50x50-pixel image sensor in the image sensor and communication modes were confirmed.

ACKNOWLEDGEMENTS

This study is carried out as a part of "R&D promotion scheme for supporting university-industry tie-ups and younger researchers with priority" promoted by TAO.

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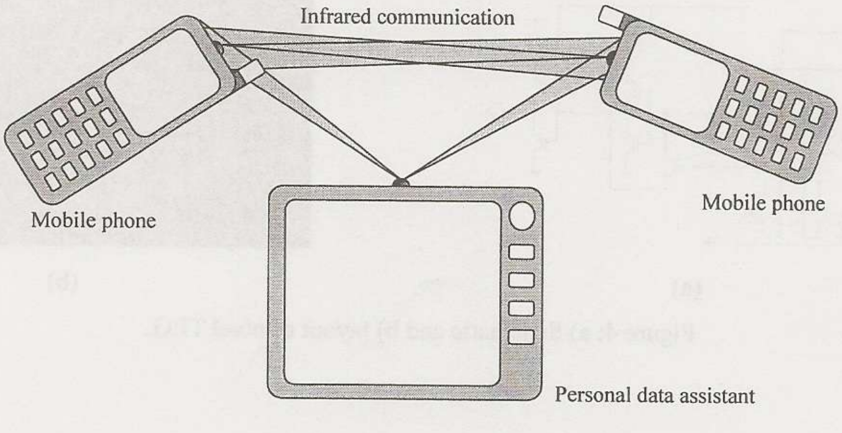
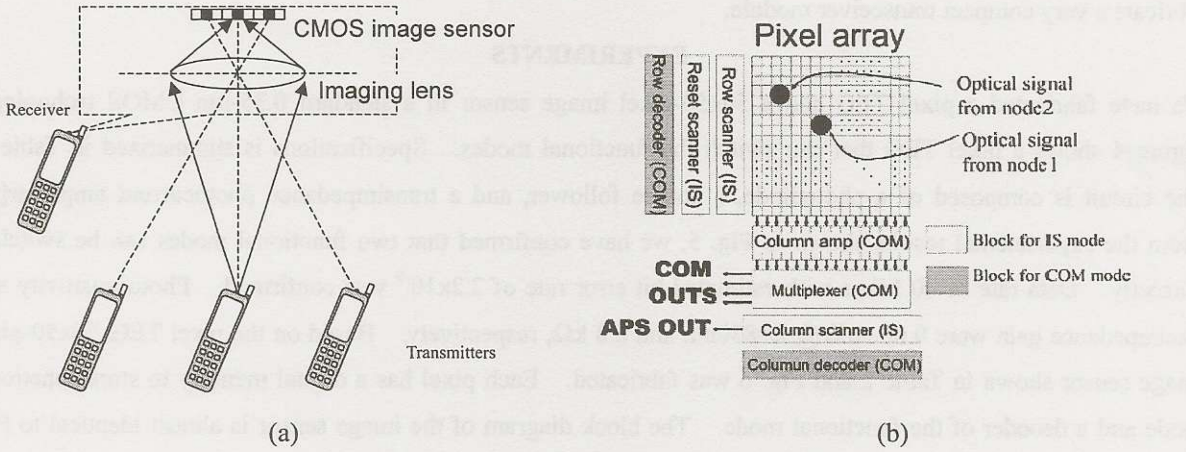


Figure 1: Free-space local optical communication between mobile appliances.



(a) (b)

Figure 2: a) Light detection scheme using an image sensor and b) block diagram of the proposed image sensor.

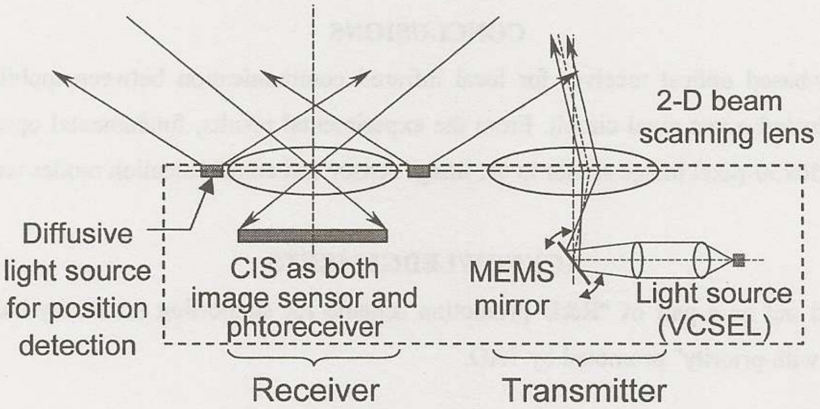
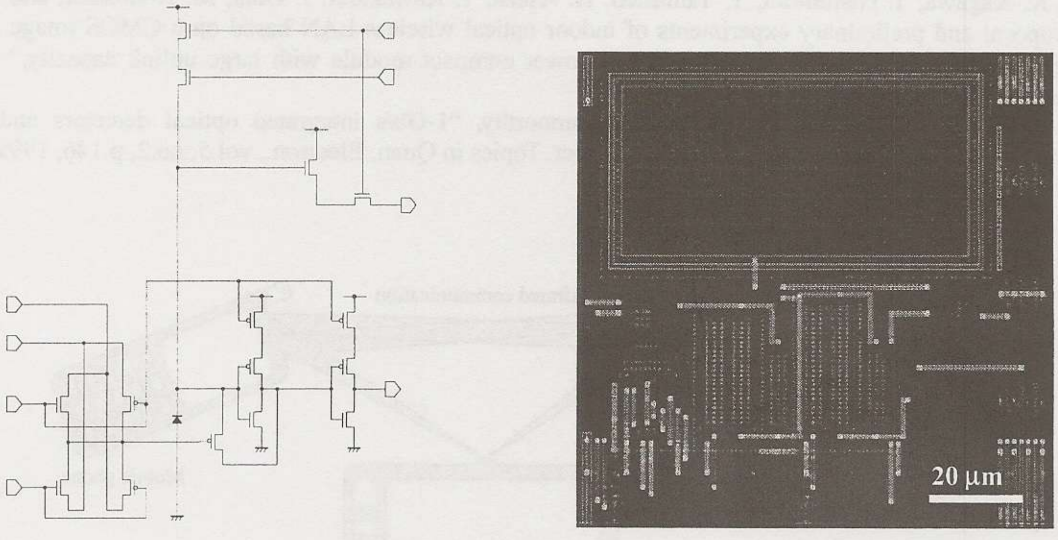


Figure 3) Setup for transmitting and receiving optical signals.

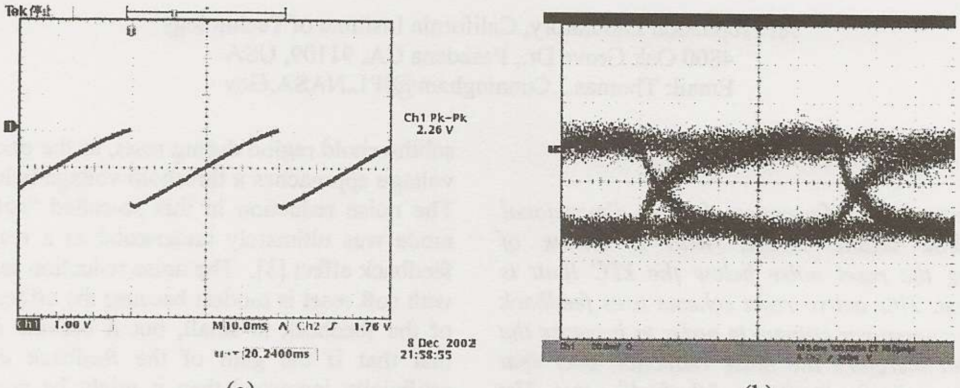


(a) (b)

Figure 4: a) Schematic and b) layout of pixel TEG..

Table 1: Specifications of pixel TEG

Technology	0.35μm CMOS (2-poly 3metal)
Pixel size	100 μm x 100 μm
Photodiode	N-well/ P-substrate junction
Fill factor	28%

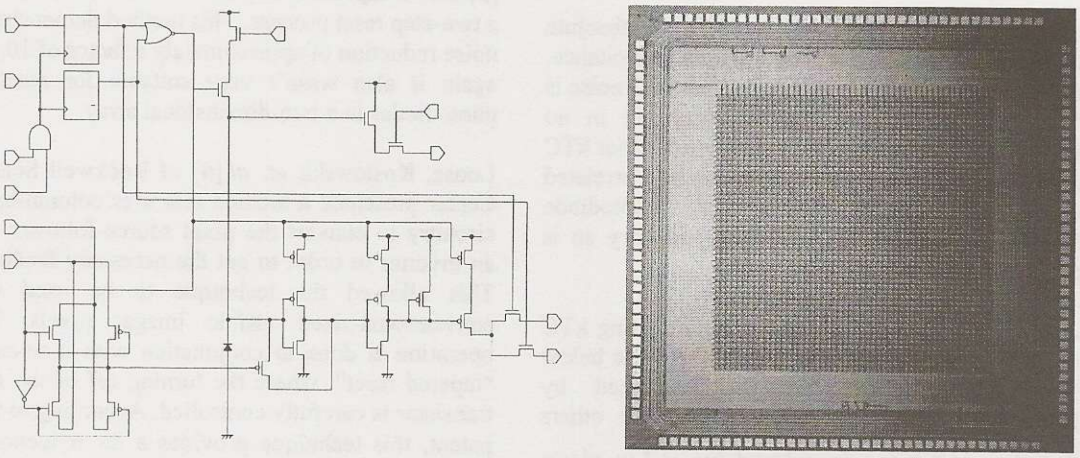


(a) (b)

Figure 5: Experimental results: a) APS behavior under illumination of 1.4 nW @ λ=830nm and b) eye pattern at data rate of 40 Mbps for incident power of 98 μW.

Table 2: Specifications of 50x50-pixel image sensor.

Technology	0.35μm CMOS (2-poly 3-metal)
Chip area	4.9 mm x 4.9 mm
Pixel number	50 x 50
Pixel size	60 μm x 60 μm
Photodiode	N-well/ P-substrate junction
Fill factor	16%



(a) (b)

Figure 6: a) Schematic of pixel and b) microphotograph of 50x50-pixel image sensor.