I^{2}C-Enabled Batteryless Sensors on Double-Layered Conductive Fabric

Akihito Noda, *Member, IEEE,* and Hiroyuki Shinoda, *Member, IEEE*

***Abstract*— We present detachable, batteryless, and Inter-Integrated Circuit (I^{2}C)-enabled sensor nodes that operate on clothes for wearable sensor systems. A double-layered conductive fabric is used as a signal/power bus. The clock and data signals of I^{2}C protocol individually modulate two carriers. The two modulated radio-frequency (RF) signals and dc power are simultaneously transferred via the fabric bus, in the manner of frequency division multiplexing. A modulation and demodulation circuit is designed to enable using off-the-shelf I^{2}C-interfaced sensor ICs. The proposed scheme enables flexible implementation of wearable sensor systems in which large number of tiny sensors are distributed all over a cloth.**

I. INTRODUCTION

Embedding sensors in clothing is a promising approach for body sensor network technologies. Sensor-embedded smart fabrics will enable various applications including acquisition of rich vital signs information for healthcare [1].

We present detachable, batteryless, and Inter-Integrated Circuit (I^{2}C) [2]-enabled sensor nodes for such wearable sensing systems. The proposed scheme enables embedding a large number of sensor nodes on clothes, while eliminating a number of individual wires. We have previously reported frequency division multiplexing multi-channel power transfer to tiny devices distributed all over a cloth [3].

In this work, the I^{2}C clock and data signals are tansferred via a single tranmission line, by individually modulating two carriers. The transmission line is a double-layered conductive fabric, essentially the same configuration as some related works [4], [5]. Voltage can be applied between the two conductive layers insulated from each other, and signal/power can be transferred across the fabric.

II. I^{2}C-ENABLED BATTERYLESS SENSOR NODES

As shown in Fig. 1, the proposed sensor node is composed of an off-the-shelf I^{2}C-interfaced IC, an amplitude shift keying (ASK) demodulation block, and a special filter circuit that converts the two-level logic output of the IC into two different RF impedances at each carrier frequency. Carriers generated by an external oscillator are applied to the bus and shared by all the nodes on the bus. 20- and 50-MHz carriers are used in our prototype shown in Fig. 2. When one of the nodes ouputs logic low level, its filter impedance becomes low and the carrier amplitude drops all over the bus. Thus, the digital ouputs are converted into ASK signals. DC voltage is also applied to the bus for powering the batteryless sensors.

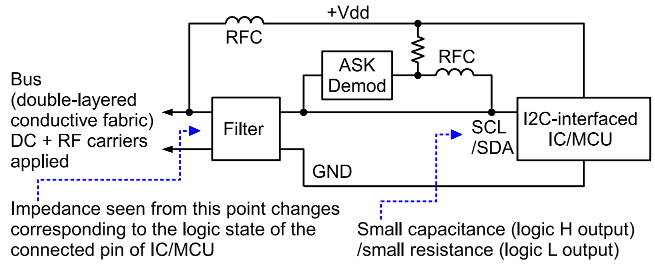

Fig. 1: Circuitry for modulating/demodulating an RF carriers with the SCL/SDA signals of I^{2}C.

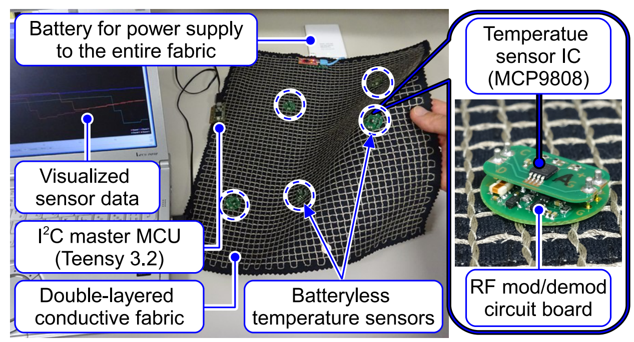

Fig. 2: Prototype system with distributed temperature sensors on a double-layered conductive fabric.

III. CONCLUSIONS

A batteryless, I^{2}C-enabled sensor for wearable sensor systems was presented. The proposed scheme is compatible with off-the-shelf I^{2}C-interfaced sensor ICs. Since I^{2}C is the defact standard of serial communication between sensor ICs and microcontrollers (MCUs), the proposed scheme can be widely used for wearable systems.

REFERENCES

[1] S. Patel, H. Park, P. Bonato, L. Chan, and M. Rodgers, "A review of wearable sensors and systems with application in rehabilitation," *J. Neuroeng. Rehabil.*, vol. 9, no. 1, pp. 1–17, 2012.

[2] N. Semiconductors, "UM10204: I2C-bus specification and user manual, Rev. 6," p. 11, 2014.

[3] A. Noda and H. Shinoda, "Frequency-division-multiplexed signal and power transfer for wearable devices networked via conductive embroideries on a cloth," in *2017 IEEE IMS Proc.*, June 2017, pp. 1–4, TUIF1.

[4] E. Wade and H. H. Asada, "Cable-free wearable sensor system using a DC powerline body network in a conductive fabric vest," in *IEEE EMBC 2004*, vol. 2, Sept. 2004, pp. 5376–5379.

[5] J. Akita, T. Shinmura, and M. Toda, "Flexible network infrastructure for wearable computing using conductive fabric and its evaluation," in *IEEE ICDCSW'06*, Jul., 2006, p. 65.

This work was supported in part by JSPS KAKENHI Grant Number 17H04685, JST ACCEL Grant Number JPMJAC1404, and Nanzan University Pache Research Subsidy I-A-2 for the 2017 academic year. Double-layered conductive fabric was provided by Teijin Limited, Tokyo, Japan.

A. Noda is with the Department of Mechatronics, Nanzan University, 18 Yamazato-cho, Showa-ku, Nagoya, Japan (e-mail: anoda@nanzan-u.ac.jp).

H. Shinoda is with the Department of Complexity Science and Engineering, The University of Tokoyo, 5-1-5 Kashiwanoha, Kashiwa-shi, Chiba, Japan (e-mail: hiroyuki_shinoda@k.u-tokyo.ac.jp).