### A 110W 10Mb/s eTextiles Transceiver for Body Area Networks with Remote Batter Power

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27.6 A 110pW 10Mb/s eTextiles Transceiver for Body Area Networks with Remote Battery Power

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Emerging sensor technologies are enabling low-cost ambulatory medical devices for remote patient monitoring. In order to replace traditional bulky wired links used to communicate data around and away from the body, recent work has proposed the use of wireless body area networks (BANs) and body-coupled communication (BCC) systems [1-3]. Although such links typically communicate over short distances, the human body presents significant path loss, requiring high TX output power or large RX amplification. Additionally, these inherently single-ended systems must tolerate significant interference from external sources and nearby users.

An emerging technique for conveying information around the human body uses electronics textiles (eTextiles) as a communication medium [4-5]. Figure 27.6.1 shows the implemented eTextiles system, where the medium consists of two electrically separate grids of conductive yarn. Sensor nodes physically connect to the shared medium using metallic button-snaps, and communicate via an eTextiles transceiver chip. Using a pair of physical low-impedance connections has the distinct advantage over wireless and/or BCC systems to be able to: 1) signal differentially, permitting energy-efficient amplitude-modulation schemes that tolerate coupled interference, and 2) power sensor nodes remotely from a local basestation (BS) at extremely high efficiency, minimizing the energy storage requirements on each node. In the proposed system, each sensor node is pre-programmed with a unique 5b ID code, enabling the BS to administer medium access using a TDMA scheme. New nodes added to the eTextiles network are dynamically recognized and added to the BS queue. Additionally, energy-efficient multi-user access and encryption operations can be delegated to the BS since the wired communication link is inherently secure.

A block diagram of the proposed eTextiles transceiver SoC, used in both sensor nodes and the BS, is shown in Fig. 27.6.2. The two main inputs, \(v_+\) and \(v_-\), feed the RX front end (FE), and are the outputs of differential transmitters. Between packets, a fixed amount of time is allocated to activating transistors M1 and M2 on all sensor nodes and the BS, directly connecting \(v_+\) and \(v_-\) to the supply terminals of each chip. This permits the BS battery to remotely charge each node’s external super capacitor, which functions as each node’s energy supply.

Time-sharing of the eTextiles medium with remote charging circuitry forces the DC voltages on \(v_+\) and \(v_-\) to be at opposite rails at the beginning of packet communication. To save the energy otherwise required to completely charge and discharge the primary capacitive medium, the DC voltages are held constant by high impedance resistors, and transmitted signals are AC coupled onto the medium with supply-rail-coupled (SRC) differential transmitters (Fig. 27.6.3). This approach is advantageous, as capacitive-driving reduces output voltage swing and driver load [6,7], irrespective of the network DC potential. This approach is advantageous, as capacitive-driving reduces output voltage DC voltages on matched transistors. Time-sharing of the eTextiles medium with remote charging circuitry forces the external super capacitor, which functions as each node’s energy supply.

An incoming data packet first undergoes pre-processing and sampling, feeding the input signal into a ternary signaling scheme. The RX FE samples and digitizes the SRC differential voltage across the capacitive DACs to provide voltage swing configurability. Both TX+ and TX- are configured to have equal and opposite non-zero offsets, such that any differential samples above or below the absolute offset level convert to ‘1’ and ‘-1’, respectively; samples residing between the offset levels convert to ‘0’. The conversion is performed by an offset orientation-independent ternary encoder, permitting the comparator pair to swap roles. After calibration, this form of comparator configuration-redundancy improves the robustness of offset errors, measured as the difference between the desired and attained offset for each comparator, by 1.5-2.5X.

Each sample and conversion operation completes in two clock cycles, requiring two interleaved AQ blocks to demodulate data at full rate. Synchronization is achieved in the RX back end (BE) by correlating incoming data using two additional AQ blocks to ensure sampling occurs every half clock period (Fig. 27.6.5). A custom multiplier is implemented for the correlator ternary arithmetic, saving 2 bits in each adder stage over a traditional 2’s complement topology. If a correlator output crosses a programmable threshold, synchronization is achieved, and the two unused AQ blocks are clock gated. Alternatively, the RX BE can be configured in an auto-correlation mode for a CSMA MAC.

The transceiver is fabricated in 0.18µm CMOS, occupies a core area of 0.83mm², and operates at 0.9V. Although healthcare applications typically only require 10-100kb/s per sensor, the transceiver communicates at a raw data rate of 10Mb/s to accommodate up to 30 time-multiplexed sensor nodes on the shared medium and to provide margin for remote charging duty-cycling and coding overhead. The RX FE consumes 2pJ/bit, which is at least 20X lower than wireless and BCC systems operating at similar distances, and is comparable to wireless eTextiles systems operating over much shorter distances (Fig. 27.6.6). Over 1m, the TX FE consumes 0.7-to-18pJ/bit for output voltage swings from 6-to-290mV. At 100% receive-mode duty cycle, the chip consumes 110µW, including RX, digital baseband, and I/O power. The remote battery scheme achieves 95% power transfer efficiency from BS to sensor node, compared to 54.9% for wireless power transfer efficiency [8]. Figure 27.6.6 shows measured transmitted and received waveforms, and summarizes the chip results. A die photo is shown in Fig. 27.6.7.

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References:
Shared eTextiles communication and power delivery medium

Figure 27.6.1: Implemented eTextiles system with packet diagram shown.

Figure 27.6.2: eTextiles transceiver block diagram used for sensor nodes. The BS uses the same chip, but replaces the super capacitor with a battery.

Figure 27.6.3: Supply-rail-coupled (SRC) differential ternary transmitter.

Figure 27.6.4: RX front end (FE) consisting of four time-offset acquisition (AO) blocks.

Figure 27.6.5: RX back end (BE) used for synchronization.

Figure 27.6.6: Measured transient waveforms and table of measured results.
Figure 27.6.7: Die photograph of the eTextiles transceiver.