THURSDAY POSTER #08

Simultaneous power transfer and bidirectional serial communication for implantable electronics

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Introduction

Al-Ajam et al. [1] investigated the use of a bone-anchored device as a hard-wired conduit for transmitting electromyography (EMG) signals from implanted epimysial electrodes towards realising EMG control of smart upper limb prostheses attached to the bone-anchor. The complexity of the implant-prosthesis connection could be further reduced by implanting the EMG recording device.

A system to both power the implant and to facilitate bidirectional serial communications through the conduit is presented.

Methods

The system (figures 1 & 2) incorporates an external power supply and two transmitter-receiver (TX-RX) modules (an external master & an internal implant module). The 1-wire signal line and a ground line are passed through the bone-anchor conduit. The 1-wire signal is a modified RS-232 communication protocol, modulated between 6-9 V. The TX module actively transfers a 0-3 V digital signal onto the 1-wire signal line, while the RX module passively monitors the 1-wire and converts all modulated signals back to the 0-3V level. Power is obtained by passing the 1-wire signal via a 22 μF smoothing capacitor to the voltage regulators on the implant.

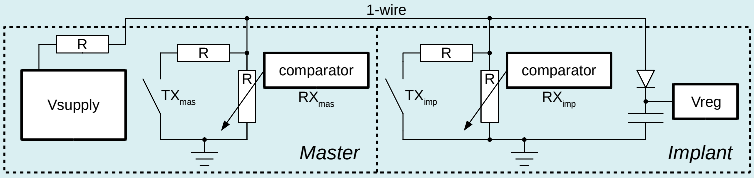

Fig. 1. Schematic representation of the system used to transfer power and data between the master and implant.

Results

A test-bench was developed (figure 3) for a prototype implantable EMG recorder [2,3]. The implantable electronics are powered by the 1-wire circuitry. Additionally the 1-wire system facilitates bidirectional communication (control signals sent to the implant and enveloped EMG data streamed from the implantable electronics).

Figure 4 shows the bidirectional serial data transmission (baudrate 38400 bps) between the master and the implant. Collision avoidance must be incorporated in the communication protocol as collisions may occur if both TX modules are active simultaneously. The RX module detects both incoming and outgoing transmissions, consequently RX interrupts within the sender should be ignored during transmission lest it be mistaken for a reply message.

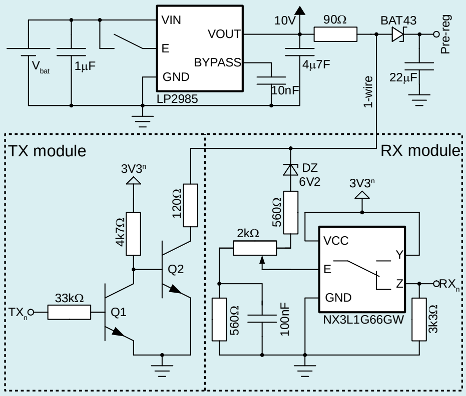

Fig. 2. Circuit diagram of the master battery supply and a single 1-wire TX-RX module.

The 2 kΩ potentiometer in the RX module voltage divider sets the threshold voltage for detecting transmitted data. The threshold is adjusted to ensure that the RX and TX module data match exactly.

Current consumption (Table I) within the TX module is determined by the DC biasing of the BJT network, while that of the RX module is determined by the analog switch (NX3L1G 66GW) and voltage divider.

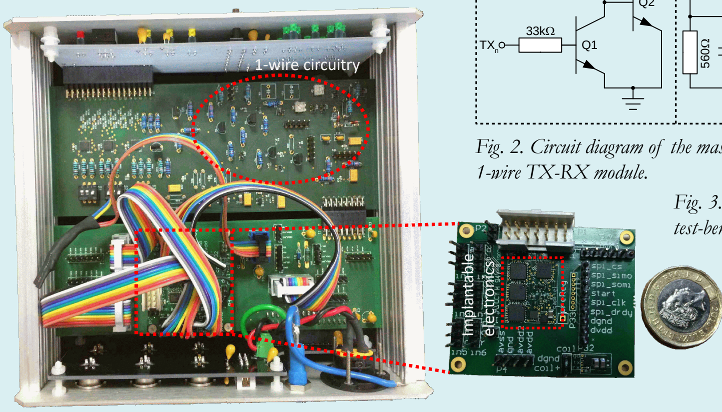

Fig. 3. Implantable EMG recorder test-bench utilising the 1-wire power and communication circuitry. At present the 1-wire system is separate from the implantable electronics. The end goal is to incorporate a TX and RX module as part of the implantable device.

Table I. Current consumption analysis.

Module/Unit	During data transmission (TX signal low)	System idle (TX signal high)
TX module[1]	42 mA	0.7 mA
RX module[2]	100 nA	100 nA
Implant[3]	12 mA	8 mA

[1]PSpice simulation; [2]Datasheet specifications; [3]Measured values

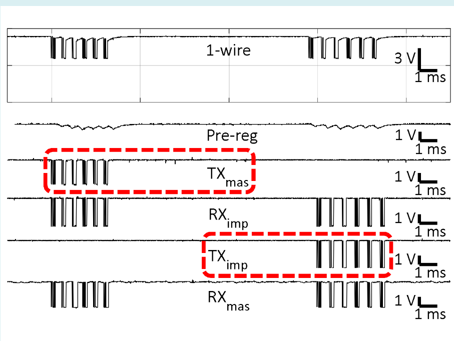

Fig. 4. Master-implant communication (2 data packets; 6 bytes). Communication drivers (TX_{mas} and TX_{imp}) are highlighted.

Discussion

A limitation of the 1-wire system is the current consumption required by the TX module during data transmission. When using a 10 V supply (figure 2), the total power consumption (1-wire + implant) is > 500 mW; power consumption of the implant on its own is 60 mW (5 V supply).

The BJT topology, chosen for robustness against ESD, may eventually be replaced by a functionally equivalent topology such as MOS (lower current usage).

Conclusion

By incorporating a MUX frontend on the EMG recorder [2,3], the 1-wire system allows for in vivo changes to electrode and implant configurations. In combination with a bone-anchor conduit, this would reduce implant-prosthesis complexity: the 1-wire system requires 2 lines (1-wire signal + reference) to connect to three 6 × electrode arrays; compared with an impractical 19 lines (3 × 6 electrodes + 1 reference).

Further benefits, as compared with wireless systems, are increased reliability and reduction of interference.

References

1. Al-Ajam Y et al. IEEE T Bio-Med Eng, 2013; 60(6):1654-1659.
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Acknowledgements

Thanks to the Restoration & Function Trust (RAFT, UK) for financial support; no conflicts of interest exist.

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