An extensive survey of microelectronic implants

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ABSTRACT

In recent years, biomedical engineering has seen phenomenal technological achievements. A particular subfield - biomedical, microelectronic implants - has emerged and, in time, gained much momentum. Starting with the implantable pacemaker some 50 years ago, such devices have been increasingly investigated over the last two decades, resulting in a plethora of actual systems of diverse capabilities and for various biomedical applications. However, the special nature of the implant application environment, i.e. the inside of the human body, poses many stringent design constraints, the two most important being low power consumption and small implant size. These have traditionally limited the design space of implant researchers and developers. Nonetheless, over the last few years, phenomenal advances in microelectronic technology, featuring ultra-low-power transistors of miniature size, have somewhat relaxed these two constraints, and have redefined what is "feasible" and what is not in implant design. Thus, new design approaches can now be investigated for developing new generations of powerful, multi-featured, tiny implants.

To this end, a clear view of the current state of the art is in order. The microelectronic technology being the vehicle, such an (unprecedented) study will be the basis for any future implementations. In this work we have assumed two tasks. Firstly, we performed a broad and scrutinous survey of existing implantable systems over a period of, approximately, 20 years. In this survey we have collected, organized and reported on each studied system. As a second task and based on the findings of the survey, an exhaustive classification of the studied systems was presented and complemented with an in-depth annotation of the findings.

Selected such findings are the following: i) there are two major categories of implants, ones used for stimulation of paralyzed nerves and muscles and ones used for in-vivo measurement (monitoring) of various physiological parameters such as blood glucose concentration and pressure. ii) Implants based on commercial, off-the-shelf components are increasingly favored over full-custom designs. iii) Increasing amounts of data processing are performed in new generations of implants. In-system memory sizes increase respectively. iv) Implant cores are increasing based on microprocessors and microcontrollers over FSMs (Finite-State Machines). Design for system-level reliability is seriously absent in past and present implantable devices.

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