

Implementation of a Wireless Power Transfer and Communications System for an Implantable Drug Delivery System

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The use of magnetic fields in implantable drug delivery systems (IDDS) was first demonstrated by Edelman¹. The rate of drug release was controlled by exciting magnetic beads within a polymer which also encapsulated the drug. Recent progress in MEMS technology has made reservoir IDDS possible. Such systems offer, an advantage over polymeric IDDS, in that it is possible to separate formulation which controls drug stability from the mechanism which controls release². At present, these reservoir IDDS need some on-board control mechanism and power supply in the form of a chemical battery to release drug³⁻⁴. Despite advances in miniaturisation, batteries are relatively large and occupy a considerable volume of the implant and also pose a hazard if the battery leaks. A wireless power transfer system offers a route to further miniaturize the implant, and eliminate the health risk due to battery leaks.

A radio frequency (RF) system, based on inductive coupling, to transfer power to and communicate wirelessly with a twelve-reservoir drug delivery chip has been designed, implemented and tested. Figure 1 illustrates the block diagram of the system. Each reservoir can be individually-addressed for drug release purposes and control is implemented with a Dual-Tone Multiple Frequency (DTMF) encoder/decoder. The encoder modulates two frequencies which are unique in combination for each reservoir, onto a radio frequency carrier while the decoder demodulates the signal. The inductively coupled circuits for power and communication consist of a pair of resonant LC tanks. The primary has 8 turns of 1mm copper wire wound on a 48mm diameter former resonated with an air-spaced capacitor. The secondary consists of a surface-mount-device (SMD) inductor with ferrite-core resonated with a SMD capacitor. The resonant frequency is 7.1MHz. While a much lower frequency can provide less signal attenuation (due to body fluid) over distance, the secondary coil has to be physically larger. On the other hand, a much higher frequency than 7.1MHz requires a smaller receiving coil but suffers from more signal attenuation. Thus, resonating at 7.1MHz provides a good compromise for this system. In the receiver block, we have implemented a 500Hz oscillator with 66% duty cycle to generate a digital pulse stream which is used as the activation signal for drug release. The pulse stream provides sufficient potential difference between the anode and the cathode of each reservoir/cell to corrode the gold membrane which seals the reservoir. Figure 2a is a micrograph of our drug delivery chip⁵ and Figure 2b is an image of a cell which comprises an anode, a cathode and a reservoir. Each reservoir can store up to 50nl of drug. Experimentation has shown that the receiver is able to pick up 1.24mW when the transmitter coil is excited with 1W of power. This is with the on-board electronics located 20mm from the transmitter. When the inductive coupling system is connected to the drug delivery chip filled with ink, the seal of the targeted reservoir can be removed and the ink released within 5s.

In conclusion, this work has demonstrated the practical application of a microsystem based device which uses inductive coupling to release drugs wirelessly in a controlled manner.

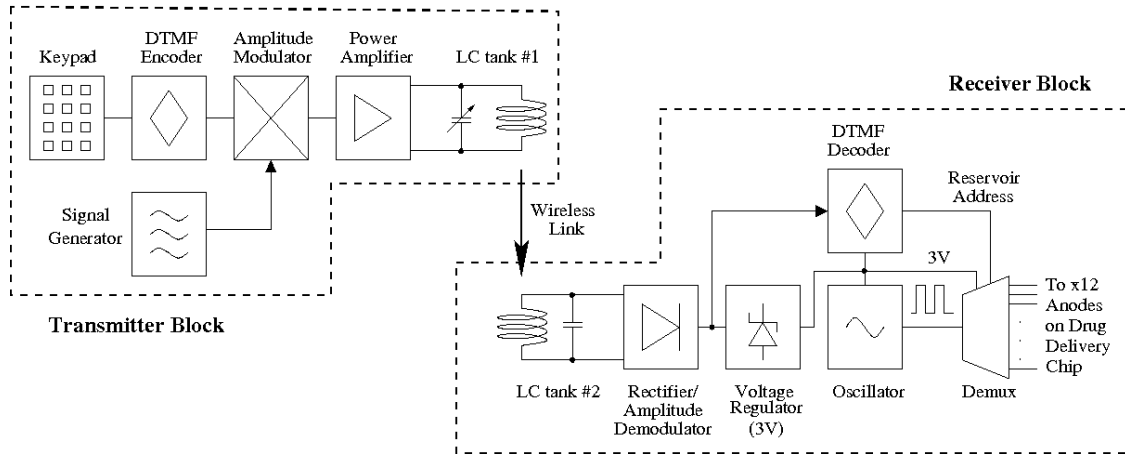


Figure 1: Block diagram of the inductive coupling system. The data communication and the power transfer are achieved via a wireless link (7.1 MHz). The induced 3V power at the receiver is used to run a DTMF decoder, an oscillator (pulse waveform generator) and a demultiplexer (DEMUX).

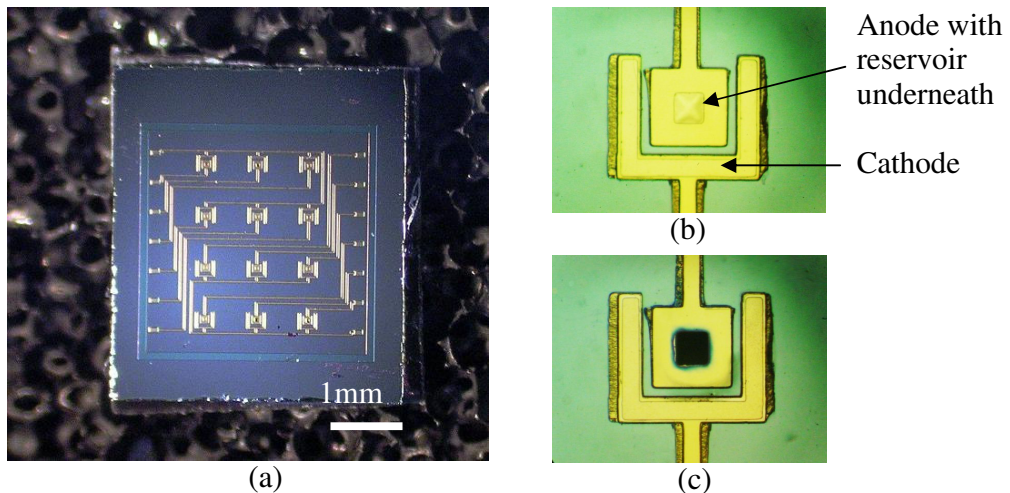


Figure 2: (a) A micrograph of a twelve-reservoir drug delivery chip. Top view of a cell under microscope: (b) before activation and (c) after 10s of activation with a stream of 3V pulses showing where an area of $50\mu\text{m} \times 50\mu\text{m}$ has been removed and left an opening for the release of the ink.

References

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