Author: Essa Jafer, Thesis title: Investigation into the Design of a Capsule Prototype for use in a Telemetry Gastro-Intestinal (GI) Measurement System

Abstract

Capsule telemetry can be used for the investigation of functional intestinal disorders (FID), such as irritable bowel syndrome. This affects up to 20 % of the population in the United States alone and when direct and indirect costs are taken into account, it is estimated that this was 1.7 billion dollars in 2000.

The main aim of this research was to investigate possible techniques to model and develop an efficient pressure telemetry pill prototype that can be used mainly to monitor GI pressure and also other physiological conditions, such as pH and temperature. First a system-level model for a multi-channel capsule system was developed using SIMULINK® software. A suitable source encoding scheme based on the nature of the biomedical signals was carefully investigated at this stage. In addition data compression, RF channel effects, transceiver architectures and signal decoding were studied to extract useful and relevant information.

In order to provide a platform for future application-specific integrated circuit (ASIC) designs, the high level digital part of the capsule was re-modelled using a hardware description language (HDL). Two different designs for the digital controller were developed and tested. Verilog-HDL was used to code all the controller units. In order to speed up project implementation and verification phases, a field programmable gate array (FPGA) device was used to test the developed HDL units. Hardware debugging was performed using an on-chip programmable tool. Both top level and HDL final models were co-simulated to assess their performance in the same environment and also to evaluate the overall system operation under different conditions.

The first prototype to be developed measured 60×63 mm^2 and is designed for future wireless sensor systems. This prototype uses two different types of sensor; resistive and capacitive, whose signals can be remotely monitored by a wireless system. The sensor signals are transmitted back to a single centralized station for further analysis using the 433.92 MHz, industrial, scientific and medical (ISM) band. Two types of highly sensitive pressure sensor were used with this prototype; these are polyvinylidene difluoride (PVDF) and polyethylene (PE). The pressure sensors work in the region of 0 – 17 kilopascals (kPa) with a resolution not less than 0.67 kPa.

The final prototype was developed based on an RF microcontroller unit (MCU) and a capacitance to digital conversion device. In total it measures 10×26.5 mm^2 and can be configured in different low power operating modes. Both pressure and temperature can be measured and the measurements sent to a base station through a 433.92MHz RF link. A long functional life of two weeks can be achieved with this capsule prototype using different power management techniques. PVDF and also silicon-germanium-boron (SiGeB) miniaturized pressure sensors were tested with this prototype. A test bench was built to simulate a GI pressure environment and assess the RF module performance.

This project succeeded in building a GI capsule telemetry micro-system with a considerably longer working life than previous systems and also provided a platform for further developments in such a system.