

MICRO-ELECTRONIC PILL FOR MINIATURIZES AND LOW POWER BIOMEDICAL APPLICATIONS WITH BI-DIRECTIONAL COMMUNICATION SYSTEMS*

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ABSTRACT

With the help of advancement of microtechnology, a new and efficient invention of Micro Electronic Pills consisting of a multi-channel sensor has been made. This paper looked out the vital existing electronic pills within the showcase and models in research centers. The main objective of the research conducted was to create an advanced pill which had all the necessary qualities and make a pill which has all the important aspects needed in a capsule. The outline telemetry unit uses a non-stop stage DQPSK of 115kHz of a very low frequency which allows a synchronous bidirectional communication between the transmitter and the receiver, this allowed inductive information transmission which was suited for the vitality exchange within the human body. Through this accurate exchange of information through the pill transmitter and the receiver, efficient drug delivery can take place as well as the pH and temperature of the body can be measured. The pill has a 32bit processor, external peripheries, location facility and a memory. The pill has been designed and fabricated in such a way that it would fulfil all the requirements in a small-sized framework with low power consumption and a size of just 7X25mm along with an integrated circuit.

KEYWORDS

Ingestible Pill, Wireless Communication, Bidirectional Communication.

1.INTRODUCTION

Advancement of innovation in later a long time has helped us to get more and more advanced in the applications of microelectronic systems within the medicinal faculty and diagnostic. With the increasing application of technology in the medical field, there is a rising market for the smart pills, intelligent microsystems and electronic digestible capsules. This rises in the field of

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microtechnology helps to enhance the procedure of treating several disorders like diabetes, cancer etc. and also contribute significantly in the biomedical analysis of the Gastro Intestinal Tract. On an average, nearly 70 million people are diagnosed and treated for several GI diseases summing the costs at €10 Billion Euro annually. The invention of the first radio telemetry capsule is tracked four decades back in 1957 which was made by Mackay and in 1972 the first pH sensor capsule was successfully build, after these inventions, there was no looking back for enhancing and advancing technologies in the field.

2.ELECTRONIC CAPSULES

The capsules are named by the Lab-on-Chip, Pharmacy-on-Chip which has the state-of-the-art. The recent modern capsules which describe the modern advancements and perform the sophisticated biomedical analysis and treatments are Biochips and

BioMEMS. Functioning of these two capsules has been categorized in to two categories:

-Actuators as sedate conveyance frameworks

-Sensors as temperature, pH, picture, motility and others

Capsules			Frequency (in MHz)	Size (in mm)	Localization	Power supply	Company/Institute	Remarks
Actuators	Drug Delivery	IntelSite	6.78	35x10	Scintigraphy	External	Glaxo, US	Pulsed release
		ChipRx	N.A.	N.A.	No	Battery	Uni. Irvine, US	Continue release
		Telemetric	108	39x11	Cogwheel	Battery	Strasbourg, Fr	Radioactive freePulse released
		Gastrotarget	N.A	N.A.	Yes	Battery	Uni. NY, US	Dummy Unit Localizer
		Enterion	1.8.	32x12	Scintigraphy	External	Phaeton, UK	Pulse released
		HF Capsule	4	28x12	X-Ray	External	Battelle, DE	Pulse released
Sensors	pH, Temperature, Pressure	Temperature Pill	1	35x9	No	Battery	NASA, US	NASA pill
		IDEAS	38	36x12	No	Battery	Uni. Glasgow, UK	Multi-sensors

	SmartPill	N.A.	N.A.	In Progress	Battery	Diagnostics, US	Multi-sensors
	Tohoku pH	N.A.	2x2	N.A.	Battery	Uni. Tohoku, JP	In Progress
	BRAVO	433	25x6	No	Battery	Medtronic, US	Attached to Esophagus
	Microcapsule	433	23x10	Ultrasonic	Battery	Uni. Shanghai	MEMS Tech.
	Radio Pill	0.35	22x9	No	Battery	Mackay, US	1st radio pill (1957)
	Heidelberg pH	1.9	18x8	Polarization	Battery	Heidelberg, DE	-

Image	PillCam/ M2A	N.A.	27x11	Image	Battery	Given Imaging, IL	Pioneer
	IVP	900/ 1	23x11	Image	External	IMS, DE	High PowerTransmis
	Norika	2400	23x9	Image	External	Rf SystemLab, JP	State-of-the-Art
	Endoscope	433/ 315	30x11	Image	Battery	Uni. Kyungpook, Kr	-

Table 1- List of capsules along with their specifications

2.1.CAPSULES AS ACTUATORS

When usually drug release takes place, it is absorbed by the upper part of the small intestine which comes right after the stomach which makes it a lot difficult to release the drug when it is required at the lower end of the intestine. The GI tract is structured in such a way that it is really difficult for the drug to be absorbed in the lower ends, for the same, the procedure of intubation is one of the procedure which can help but it is uncomfortable for the patients at times. To solve this problem of drug action at an earlier stage, engineers were working on a capsule which will release the drug at the targeted place only and not anywhere else. After two decades of hard work, they were successful in creating a pill which will release the drug at the desired location and time. Some of the capsules which were designed in the initial times were HF, IntelliSite, and Telemetric Capsules. These pills had a very basic working system, they were set off by the

Radio Frequency (RF) pulse which was sent from the generator which was placed outside the body. The drug was released when the needle which was fixed inside the capsule, pierces it due to the heat which melts the thread to which it is attached. The most popular state-of-the-art capsules which one can look up to are Enterion and ChipRx.

Release of drug in the Enterion capsule takes place when the filament which is made of fiber burn due to the trigger signal received by the capsule and the drug holder.

The capsules mentioned above have been fabricated in such a way that they have a location specific release of the drug, the drug is discharged at once it is in the specified area.

A continuous drug discharge is portrayed by ChipRx, using MEMS innovation a few holes throughout the container which will help in continuous release of the drug, this drug release is facilitated by the biological stimuli. So as to sum up how much drug is to be released, a biosensor has also been fabricated which will understanding the patients drug requirement (pharmacy-on-chip).

One of the major issues faced previously was the release of drug at a particular time and a fixed location. So as to locate the capsule once it has entered the body, X-Ray, Scintigraphy and radioactive compounds were used. It is a really difficult task to figure out the exact location of the capsule due to the complexity of the GI tract.

For the same, the patient first has to go through a few gammas checks to identify the area. Telemetric capsule employs a cogwheel for localization. To achieve a more practical arrangement for position assurance, localization is one of the most important area of interest.

2.2 CAPSULES AS SENSORS

With the modifications, the pills are getting more advanced and this has led to accurate measurements of pH, temperature, motility and many other aspects which are important in a capsule. These advancements have also made the procedure a lot easier and comfortable for the patients. Most of the sensors which are present, don't provide the accurate location of interest which is needed to collect the necessary biomedical information from the patient's body. Prior pills designed and structured in this field are the Radio Pill, BRAVO, Heidelberg and Temperature capsules. Nearly all the pills which have been fabricated and designed utilize power from the batteries fitted inside them.

Some of the new capsules in this field are Thoughts, Smart Pill and Tohoku capsules. IDEAS and Smart Pill give multi-sensors a microsystem for genuine time investigation.

One of the major breakthroughs of the 2000s was the retrieving of images and video clips of the insides of GI tract through wireless endoscopy. The very first to develop this imaging was M2A and after that RF

Framework Lab from Japan came up with the invention of Norika pill which was considered as the state-of-the-art in this field.

One more capsule which has been newly invented was from IMS Stuttgart and it is the IVP (Intracorporeal Video Probe).

There is a difference between the power sources for both the pills, M2A/PillCam are fueled by batteries whereas Norika and IVP are fueled by an external magnetic field. An exchange takes place between the battery within the interiors and the body which has a limited supply of control which uncovers the body with RF signal so as to gain access over the LEDs and camera.

3. "ePill" SYSTEM DESIGN

The communication channels of the capsule are designed in such a way that they have a bi-directional communication which go to and from the body.

Helping to set off the actual delivery of the drug and record the pH esteem and body temperature or chemical sensor.

One of the advancements which could be observed was the localization utilizing a near field attractive acceptance strategy inside a 20 cm circular range and having a resolution of ± 1 cm.

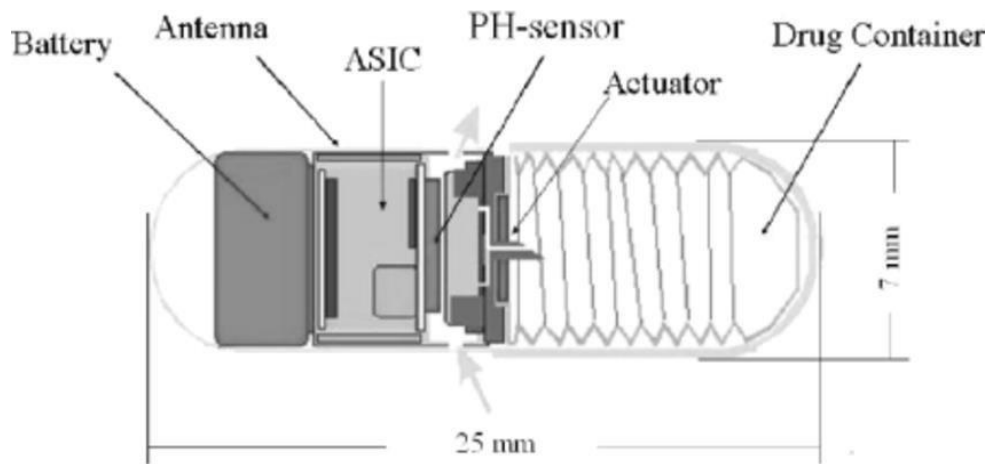


Fig. 1. Electronic pill comprising sensors, control chip (ASIC), radio transmitter and batteries. The unit is encapsulated in bulk-machined PEEK. The rear cap is removed for clarity.

3.1. SIRIUS PROCESSOR

The SIRIUS core (acronym for Small Imprint RISC for Ubiquitous Systems) stands in execution somewhere between the exceptionally fruitful performances and architectures of the ATMEL AVR (AT mega 8 bit), the TI MSP 430, the Pico Blaze - and well underneath the ARM 7/9-course of 32-bit machines, the LEON (SPARC), Motorola 68xxx and other 32bit models (NIOS II, Micro Blaze). Fig. 2. Depicts the core of SIRIUS through a block diagram.

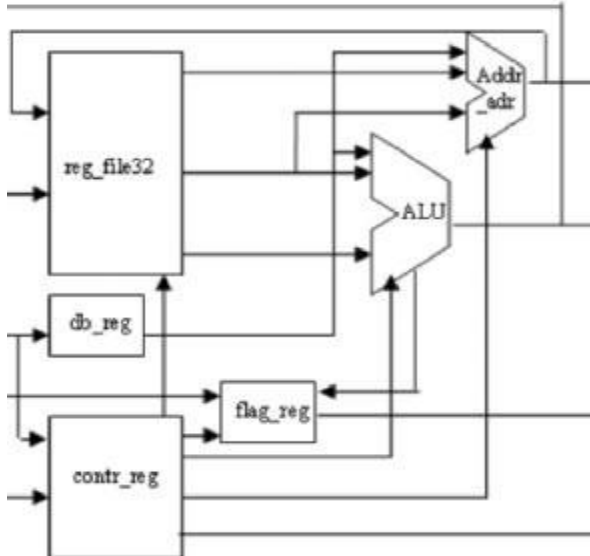


Fig. 2. Block diagram of the SIRIUS core

The following are the specifications of the processor:

- Load-Store design with 16 bit external database bus.
- RISC design with 3 stage pipelines and 1 Instruction/clock cycle and a normal execution of 0.8 MIPS/MHz
- 16 bits/32-bit internal transport structure with 32-bit ALU and 16x16 MPY.
- 16 registers set of orthogonal registers, 12 x 16-bit, 4 x 32 bit, the 16-bit all-inclusive registers may be combined to twofold registers and dealt with as 6 x 32-bit registers.
- Instruction pointer 32 bit and stack pointer 32 bit are portions of the enroll set.
- Stack arranged engineering with boundless nesting levels.
- Pointers 16 bit as well as 32 bits upheld.
- Multiplex transport framework, isolated 8- bit IO transport and fast memory transport, all IO is associated through a separate 8-bit transport with claim address space.
- Address space 64k or 4G depending on pointer addressing.
- Vectored equipment hinders and program interrupt (exception).
- Compact 16-bit instruction arranged with just three modes.
- Instruction set design with 56 informational optimized for compact C-Compilation
- Netlist form made from entryway primitives, able to be mapped on each existing innovation without using macros.
- Execution around 100 MIPS in 0.35 μ m CMOS and 50 MIPS in genuine FPGA- technologies.
- Completely inactive, extraordinary low control plan, all registers made from flip- flops.

-Comes with Program IDE, C-Compiler and Simulator and essential BIOS.

3.2 COMMUNICATION BLOCK

The DQPSK asynchronous carried a frequency of 115kHz frequency which was suited in the communication block, counting an advanced PLL at the collector/receiver's side. The rate of data is 9600 Baud.

This balancing method was used for a non-stop stage of utilization of Gaussian channels for the soft shift keying. The Gaussian channels helped in the smooth phase transition for one stage to the next. About 255 bytes of data could be carried in the information bundle along with an attachment of 16-bit CRC. For the 4B/5B coding there is the 1- and 1- bit error location which is there within the framework. The bust errors for the outline of the capsule is less than 16 bits.

All the serial information which is shared with the database is prepared with the help of modulator by converting the two parallel bits for the quadrature frame.

There is a separate encoding which is modulated so as to differentiate between the transmitter and the receiver. Based on the phase shift, a frequency of about 107-123kHz is generated by the signal sent from the Numerically Controlled Oscillator (NCO). All the steps which are followed in the modulator, exact opposite steps are processed in the demodulator. In the demodulator, there is a Schmitt- trigger which is used for the digitizing of the analog signals which were obtained. So as to lock the received shift, an advanced PLL is used. Other than this there is a choice circuit with will help to access the image, a parallel-serial converter and a decoder to recuperate the first information.

4.HARDWARE VERIFICATION AND LAYOUT

The FPGA Tornado II was the basic idea behind the SIRIUS Processor and communication piece; this has also helped to design the emulation test board which tests the system's usefulness.

For the transmission and receiving a single coil was used. Different capsules have different combination of the combination, for the transmission mode, the capacitor, coil and resistor were placed in a serial combination and for the receiving mode, there was a parallel combination of capacitor, coil and resistor. The Q factor calculated is 7 and the transfer speed is 16 kHz with center recurrence of 115 kHz.

The first thing which was done was that a computerized circuit was steered. With the help of the 0.35 μ m AIMS technology, the SRAM processor was framed with an external fringe and a communication square. The basic primary routings have been clearly reflected in the region of 11mm² as also portrayed in the Fig 3.

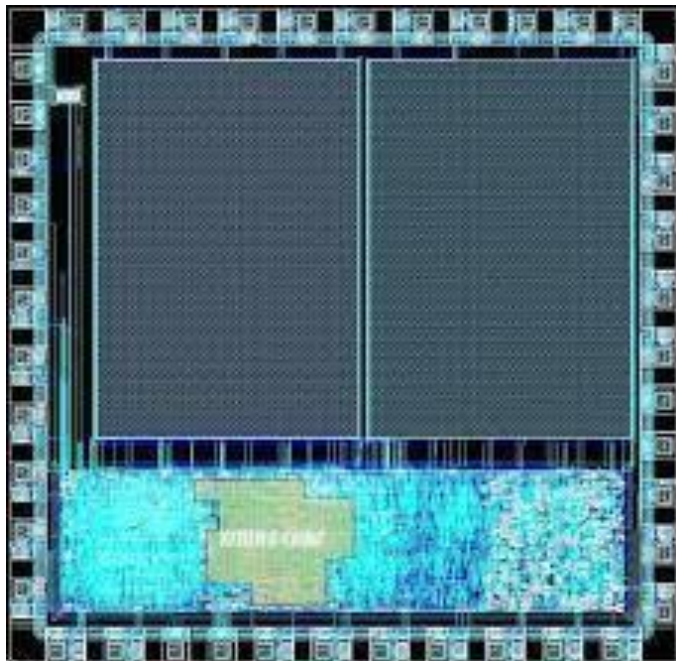


Fig. 3. Initial prototype layout of 0.35 μ m AMI technique of 11mm² measurement

Block	Number of primitives (ASIC)	Logic Elements (Cyclone II)
SIRIUS core	4197	2870
ROM	392	106
Bus controller	92	335
PIO	52	20
SIO	388	132
SPI	241	123
I2C	343	191
Interrupt controller (12 Intr)	773	346
ISO-14443 Interface	1407	617
QPSK Interface	3186	1252
Timer	214	88

Table 2: Synthesizing results for 0.35 ASIC Library and for ALTERA Cyclone II

The above Table 2 summarizes the results obtained in the synthesis of a 0.35 μ m AMI library along with the low entry FPGA Cyclone II device.

5.CONCLUSION

Based on the FPGA, a system was fabricated which was bidirectional, emulated and simulated. To begin with, the steering prototype for the digitally advanced portion was done utilizing 0.35 μ m AMIS innovation. The last format with total peripheries and analog components is still beneath advancements. The framework contains a wake-up director unit for a reduction of control utilization. An extraneous signal will be sent either to wake the framework up or transit it to sleep mode. The framework was able to demodulate the accepting signal, CRC checks the entirety and spares the information within the memory. A transparent mode to resend the information was accomplished. The framework seems to trigger an actuator through a transmitted command.

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