Proceedings in MANUFACTURING SYSTEMS

Proceedings in Manufacturing Systems, Volume 14, Issue 1, 2019, 21-26 ISSN 2067-9238

A BASIC PLATFORM AND ELECTRONICS INTERFACES BOARD FOR FAMILY THERAPEUTICS TOOLS TO SURGICAL ROBOTS

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Abstract: *Robotic technologies are advancing in the field of minimally invasive surgery. The last decade, more than 1.5 million laparoscopic surgical procedures, including gynecologic, cardiac, urology, thoracic, and general surgery, have been performed by popular robotic and mechatronic systems for minimally invasive surgery. In contrast to big popular robot systems, which are designed for manipulation and video observation, this paper describes a novel instrument for therapy. The purpose of the paper is to present the design of a compact, convenient, simplified, better, and affordable priced device, so that small hospitals can access and benefit from these systems. The ultimate goal is to radically improve the quality and efficiency of healthcare.*

Key words: *robot system; therapeutics tasks; surgery, therapeutics tools, laparoscopic surgery.*

1. INTRODUCTION

Robotic technologies are advancing in the field of minimally invasive surgery. The last decade, more than 1.5 million laparoscopic surgical procedures, including gynecologic, cardiac, urology, thoracic, and general surgery, have been performed by *DaVinch*i (Intuitive Surgical Incorporation) [1]. In contrast to *DaVinchi* by Intuitive Surgical Incorporation and Zeus by Computer Motion [2], instruments that are designed for manipulation and video observation, this paper describes novel instrument for therapy with minimally invasive surgery application. The aim of the work is design of a compact, convenient, simplified, better possibilities and suitable price devices thereby the small hospitals to have accesses to this systems and patient benefit-The ultimate aim is radical improvements to the quality and efficiency of public health.

Major gallbladder diseases are stones and carcinoma. Tumors are rare diseases of the biliary tract. Correctly gallbladder function is essential to the digestive process. When gallbladder cancer is caught early, removing a gallbladder or part of the bile duct may eliminate all the cancerous cells. Gallbladder cancer does not have any proven prevention methods. The causes of the disease, such as gallstones, cannot be prevented from forming in the gallbladder. Two main types of gallbladder cancer tumors are typical-adenocarcinoma and non-adenocarcinoma. There is a lot of methods for diagnostics of gallblader carcinoma: blood tests, Ultrasound Computerized Tomography (CT) scan, Magnetic Resonance Imaging (MRI). Endoscopic Retrograde Cholangio-Pancreatography (ERCP) Biopsy, Laparoscopy, etc. Tumors tend to be harder than the surrounding tissue, and not possible indicate their presence, size and exact location without tactile sense when diagnostics is performed by laparoscopic procedure. Many gallbladder cancers are discovered after a laboratory examination of a gallbladder that has been removed for other reasons. Several researchers have also incorporated a direct sensing method for tissue characterization through pressure measurement normal to the surface of the jaws [3] or have incorporated the sensors into the handle of the robot instrument [4, 5]. Family instruments for therapeutic task are described in the following section.

2. AN INSTRUMENT FOR THERAPEUTICS TASKS

In Fig. 1, a basic structure of the instrument for therapy in laparoscopy is shown. A construction and principle of the work are described at [6].

The main elements of the instrument are a step motor by PrimoPall [7], an incremental contactless encoder, force sensors by Honeywell [8] and therapy module on the top of the slider.

The linear actuator is built on the basis of a bipolar stepper motor with a built-in encoder and a specialized driver under the control of a microcontroller and

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provides the generation of steps in the range of 8 to 48 micrometers.

The actuator executes a translation movement of the manipulator by performing a step. To ensure that the movement is executed, an incremental encoder is coupled to the bipolar stepper motor. Each step is initiated by the microcontroller, which sends a narrow pulse to the motor driver and processes the encoder data to monitor the completion of the step. Then, it starts the second macro stimulation phase. During the second phase, the microcontroller performs successive measurements of the built-in tactile sensor readings. During this period, the bipolar stepper motor is in retention mode, which is ensured by maintaining a constant current through its windings without initiating a new step (the driver always works in active state). There is hold mode which ensures correct reading of the tactile sensor response force and processing of this data from the micro controller. After that the process of therapy can began.

2.1. An instrument for mechanical therapy

An instrument for a therapy (Fig. 2) is a sophisticated module that incorporates motor sensors for positioning and control of encoders and mechanical structures that perform manipulation on tissues (laparoscopic interventions). It is coupled on the top of the Basic platform slider, having three degrees of freedom: translation, rotation, and jabbing between the jaws and been controlled by Controller.

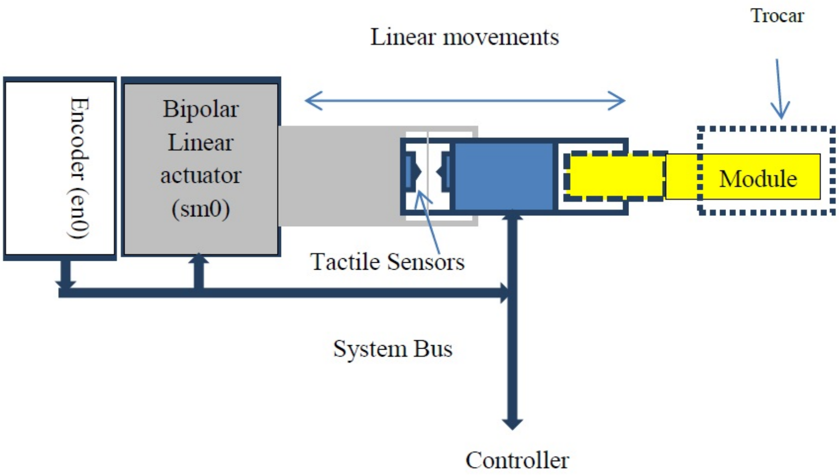

Fig. 1. A basic platform of instrument for therapy.

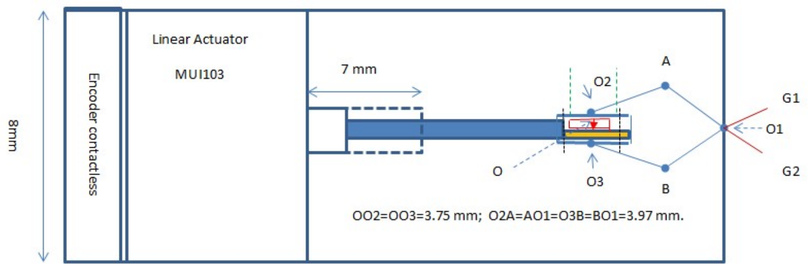

Fig. 2. An instrument for mechanical therapy.

2.2. An instrument for RF therapy

An instrument is designed for programmable tissue exposure in the frequency range from 0 Hz to 500MHz or 40 MHz to 8 GHz. The irradiation is local. A programmed change in the intensity and frequency of the radio signal is a function of time. A basic idea is to transport the end of the tool where is embedded UFR emitter and therapy to be executed locally.

The instrument uses an UHF Generator that generates a programmed frequency, forms the required radio signal through the output stage, and outputs it to an emitter to perform radiotherapy via a wired channel. The linear displacement of the module and its positioning at a set point is provided by the main step motor, taking into account force sensors readings to confirm the contact with the object of the therapy.

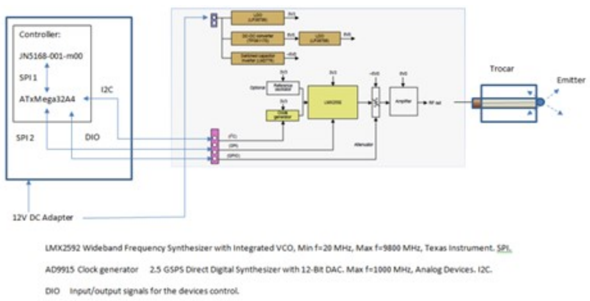

Fig. 3. Controller, UHF generator, and emitting device.

The UHF Generator shown in Fig. 3 is external device, controlled by Controller and generates the signal to the UFR emitter.The RF generator is built on the base of programmable PLL generator LMX 2592, using programmable frequency reference source AD9915. Odd of them are being controlled by SPI and I2C from microcontroller ATxMega32A4, embedded in the main controller. The formed radio- signal is transmitted through wave channel placed into the slider to the emitting block.

3. ELECTRONICS INTERFACES BOARD

The electronic interfaces board is a two-processors system, including wireless JN5168-001-M00 and industrial ATxMega32A4. The microcontroller JN5168-001-M00 works as a network device in local wireless network and simultaneously as a processor for control of different incorporated electronic modules.

ATxMega32A4 works as slave coprocessor and is responsible for the encoder's data processing and radio-therapy controlling. Figure 5 shows the block diagram of the Controller. Odd microcontrollers are connected with SPI bus, JN5168-001-m00 functions as a master.

The block diagram of JN5168-001-M00 architecture is shown in Fig. 6.

The control module includes as coprocessor microcontroller ATxMega32A4. Its architecture is shown on Fig 7. This microcontroller is responsible for the encoders' data processing and radio- therapy controlling. JN5168-001-M00 and ATxMega32A4 [9] connected between using on board SPI bus (primary). ATxMega32A4 is controlling the frequency generator module using embedded secondary SPI and I2C busses.

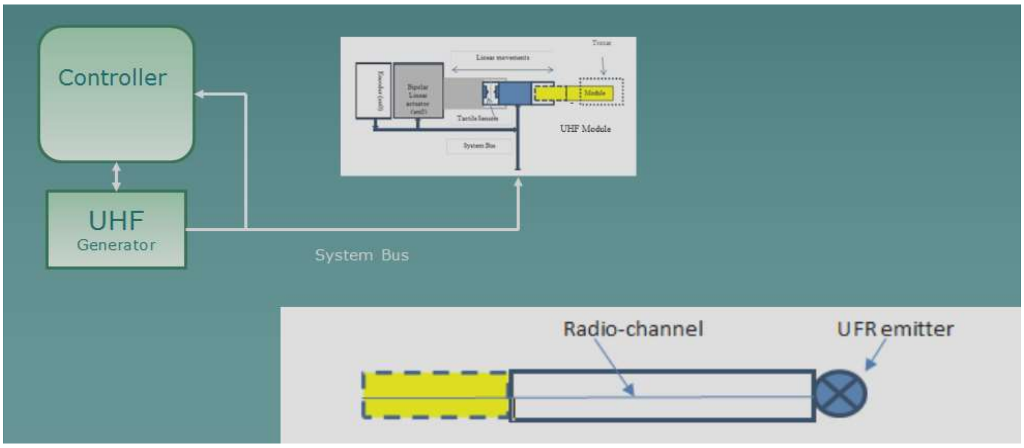

Fig. 4. RF therapy action.

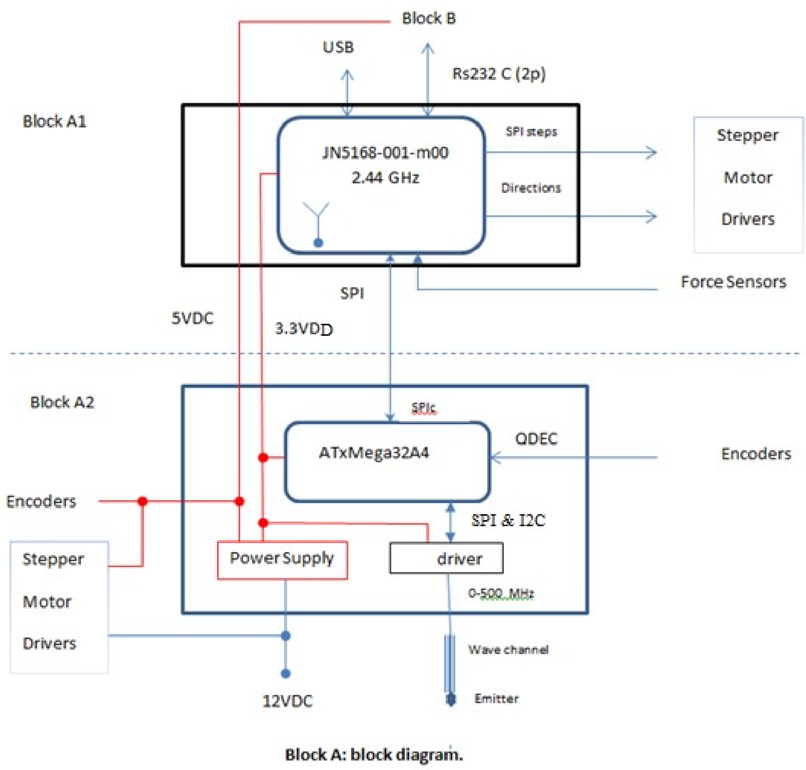

Fig. 5. Block diagram of Controlle

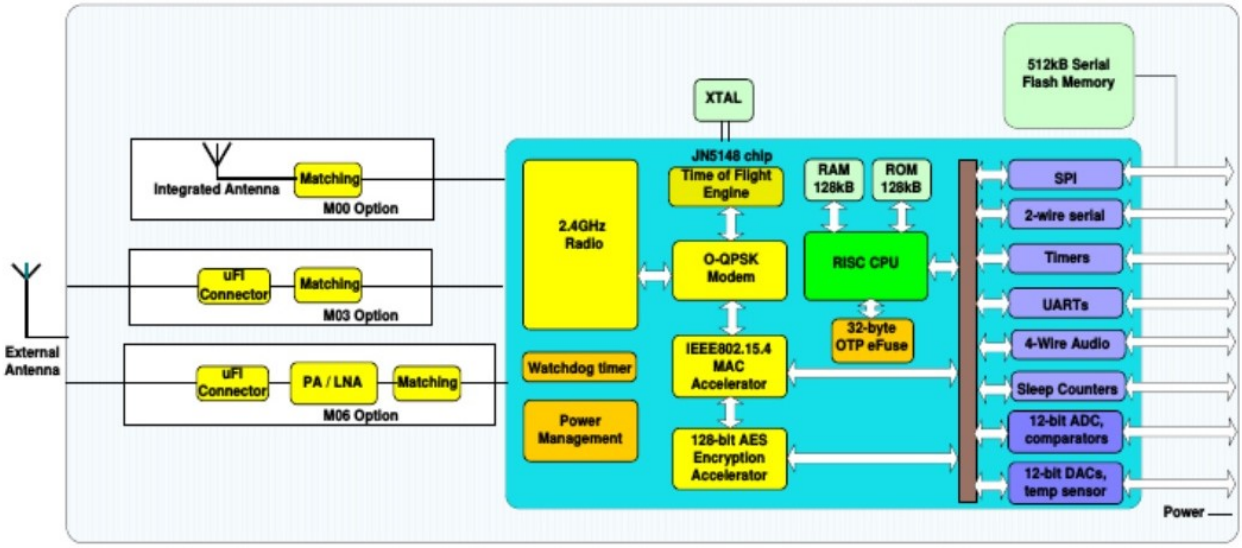

Fig. 6. Block diagram of microcontroller JN5148-01-M00.

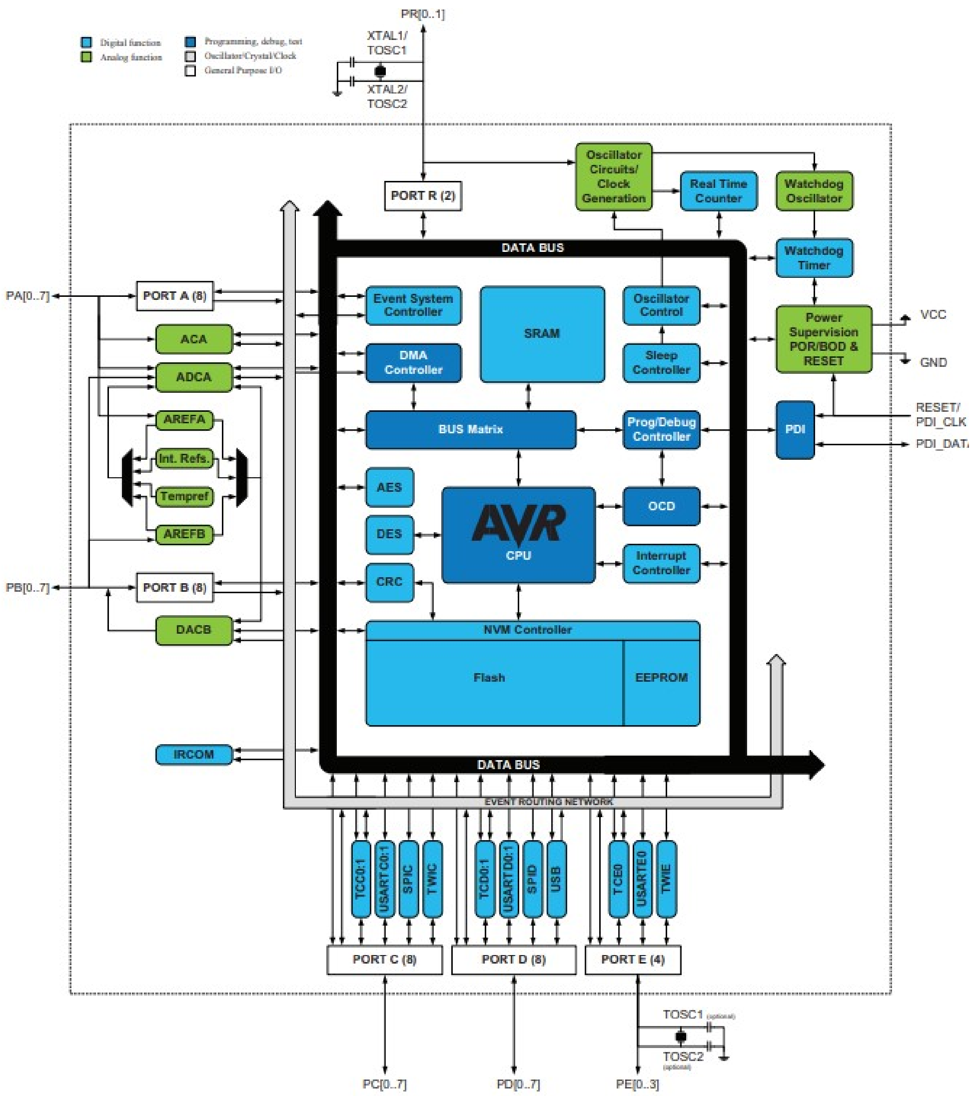

Fig. 7. Block diagram of microcontroller ATxMega32A4

4. QUANTITATIVE ASSESSMENT OF GALLBLADDER CARCINOMA BY IMAGE PROCESSING

4.1. Image processing:

Tumors tend to be harder than the surrounding tissue. Initially, image processing is performed to get some idea of presence, size and exact location of different [10]. For example, it using the laparoscopic image in a 65-year-old man. The procedure of image processing involves the following steps:

1. Preliminary image processing;
2. Image segmentation;
3. Defining and measuring the features of an image;
4. Classification of objects.

Preliminary image processing includes procedures which increase the image quality and prepare suitable images for the next steps. Image segmentation as a procedure for separating the image objects from one other and background –10. There are different approaches for the image segmentation: color-based segmentation, texture segmentation, contour segmentation, etc. [15, 16]. Defining the features of the image is a basic step in image processing. Be the features image is classified in groups.

Looking at the image can be noted that the tumor has a darker (lighter) color. This shows that must choose a feature of segmentation of the image intensity threshold. After image segmentation with different thresholds can calculated the size (area) of whole gall and size of healthy part. It can be calculated the size by expression:

$$S = \sum_{i=1}^{n-1}(x_i - x_{i+1})(y_i + y_{i+1}) + (x_n - x_1)(y_n + y_1)\,, \quad (1)$$

where (x_i, y_i) the contour's coordinate points and n is the number of contour's points on the segmented object.

The picture of gallbladder is shown in Fig 8. After segmentation with threshold 150 the following image (Fig. 9) is obtained. The size of the segmented image is of 42692 pixels. In our case, the treshold is the feature of the image. From this features, the image object (gallbladder) after contour segmentation is separated in health and ill tissues.

Fig. 8. Laparoscopic image of gallbladder.

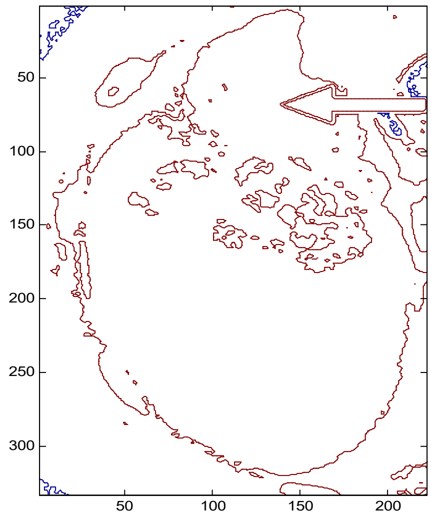

Fig. 9. Segmentation of an image.

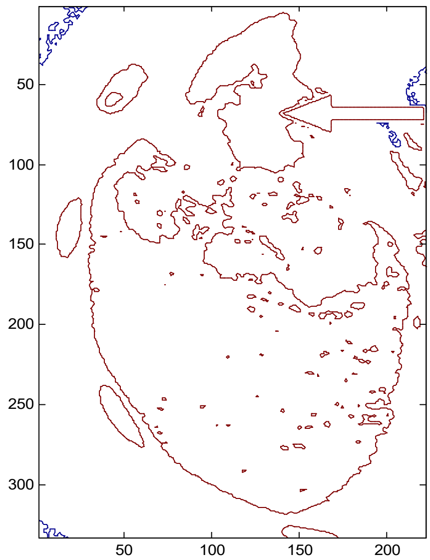

Fig. 10. Image processing.

After segmentation with threshold 190 the following segmented image is obtained (Fig. 10). The size of tumor possesses contours coordinate points (3823 pixels, 16162 pixels). The ratio of the ill part to the whole one possesses contours coordinate points (3823/42692, 16162/42692.

In this case the treshold is the feature of the image. From this features the image object (gallbladder) after contour segmentation is separated in health and ill parts.

5. EXPERIMENTS AND ANALYSES

After image processing was performed experiments and analyses. The purposes of carried out experiments are to verify the functionality and working capacity of the tools, to evaluate practically whether the error introduced by the proposed module during its normal operation is the required target within , to demonstrate the operation of the tools.

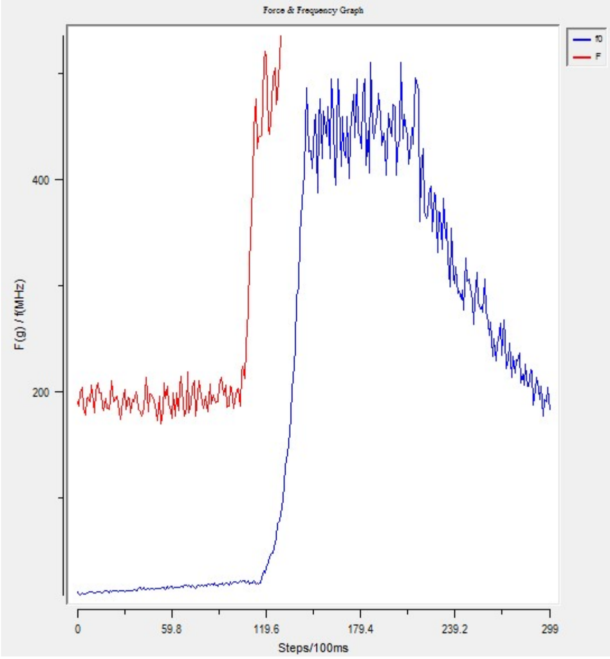

Fig. 11. Graphical presentation of the experiment.

The experiment includes a search in the work area for an aberration from a normal tissue with a set force value. It is shown in the red graphic. The blue graph shows the frequency of the generated RF signal used to irradiate the subject.

When the aberration is detected, the formation of the micro steps is terminated and the generator starts operating in accordance with the set program. Upon reaching the set frequency, in the case of 434 MHz, radiation is maintained at the set frequency and intensity for the time defined by the therapy program – in this case 10 seconds. After that, the generator turns off and the frequency drops to the minimum.

For the red graphic the number of the micro steps is located along the *X* axis.Along the *Y* axis is shown the search for the set Force value.

For the blue graph along *X* axis is shown the micro steps of the device and the frequency of the irradiation signal in MHz is shown along *Y* axis.

6. CONCLUSIONS AND INTENTIONS FOR FUTURE WORK

Robotic technologies are advancing in the field of minimally invasive surgery. The last decade, more than 1.5 million laparoscopic surgical procedures, including gynecologic, cardiac, urology, thoracic, and general surgery, have been performed with robots. In contrast to big popular robot systems which instruments are designed for manipulation and video observation offers a novel instrument for local therapy of tumor. The aim of the work is a design of a compact, convenient, simplified, better possibilities and suitable price devices and the small hospitals to have accesses to this systems and patient benefit from it. This paper discussed a basis platform and an electronics interface board for family therapeutics instruments with application of minimally invasive surgery. The proposed electronics interfaces board includes a block diagram of Controller, a block diagram of microcontroller JN5148-01-M00 and a block diagram of microcontroller ATxMega32A4. In this paper an image processing is performed to get some idea of presence, size and exact location of aberrations from a normal tissue. An image processing was performed, and experiments and analyses too. The purposes of carried out experiments are to verify the functionality and working capacity of the tools, to evaluate practically whether the error, introduced by the proposed module during its normal operation, is well within the required target, and to demonstrate the operation of the tool.

The intention for future work includes some experiments, which have to be made with various frequency and intensity, in order to the results to be compared with results obtained from irradiation of different materials.

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