Design of autonomous endoscopic video system

O V Filipovich*, M M Maistrishin and M I Garmatyuk
Sevastopol State University, Sevastopol, Russia

*ophisl@yandex.ru

Abstract. The use of video endoscopic systems for medical purposes and possible directions associated with the improvement of their designs are considered. Within the framework of the design of a universal autonomous endoscopic video system, the solution of the problems of synthesizing a structural diagram, developing a structure and analyzing its elements is described. The block diagram of a block-modular system and a model of its assembly are presented. The keypad design process is described in detail. The areas of possible application of the video system and its differences from analogues are given.

1. Introduction
Endoscopic surgery is one of the promising areas in modern medicine, the development of which requires the development and application of modern visual control and observation systems. Endoscopes are a group of complex optical-mechanical and optical-electronic devices that perform various functions and tasks [1-3]. These devices are divided into two classes: technical and medical. Technical endoscopes are used to inspect hard-to-reach elements of machinery and equipment during their maintenance and performance assessment, as well as in security systems for examining hidden cavities. A medical endoscope is understood to mean a device introduced into the internal cavities and organs of a person through natural channels or surgically. Medical endoscopes are used for examining and treating internal human organs as well as abdominal and other body cavities [4-9].

Performing endosurgical operations requires special, rather complex and expensive equipment and instruments, one of the main elements of which is a video system, consisting of a video camera and a monitor. In modern minimally invasive surgery, a key role is played by the ability to integrate modern surgical equipment with the latest methods of visualization of the operating field [10]. The use of modern means of visual control during the operation can significantly reduce the errors of the human factor, guarantee the accuracy of movements. In addition, video endoscopy tools can become part of an integrated multifunctional operating room, which allows performing surgical tissue dissection at the highest level of visual control, having access to all the necessary clinical information about the patient at any time during the entire operation and the ability to remotely monitor the course of the intervention, for example, to ensuring control of the surgical intervention by experts who are outside the operating room.

The use of minimally invasive and endosurgical methods of treatment is the basis of the modern concept in medicine "One-day surgery": the provision of the highest quality medical services with minimal time costs. At the same time, the time spent by the patient for the examination is reduced to one hour, and the time for the operation and rehabilitation is reduced to one day.
The vast majority of integrated endosurgical operating rooms in Russia are equipped with imported equipment. Thus, the development of an autonomous video endoscope is an urgent task in the framework of import substitution, i.e. equivalent replacement of imported equipment with domestic equipment with an adequate pricing policy and unchanged requirements for quality and safety.

Some of the possible directions associated with improving the designs of endovideo systems for medical purposes are:
- development of an autonomous universal module that can be integrated with equipment already installed in operating units;
- use in the module of a block capable of wireless transmission of information to an external display device.

2. Video system structure and model

This work is devoted to the design of a universal autonomous endoscopic medical video system. In this case, it is supposed to solve a number of interrelated tasks:
1) synthesis of a structural diagram, taking into account the specifics of functioning and application;
2) design development and element analysis;
3) manufacturing and purchase of components;
4) assembly and configuration of the video system;
5) software deployment.

Let’s dwell on the first two. The block diagram of the video system is shown in Figure 1.

![Figure 1. The block diagram of the video system.](image)

The developed video system can be functionally divided into two independent units: a backlight unit, a video signal processing and output unit.

The backlight unit allows you to illuminate the workplace with a powerful LED, which is controlled by an LED driver. The LED driver controls the power of the LED, and also provides cooling by controlling the fan activation depending on the temperature sensor reading. For convenience, the set backlight power value can be displayed on the LED indicator. The luminous flux is transmitted to the working area through an optical fiber.
The video signal processing and output unit outputs the image received from the camera to the monitor. It allows you to adjust the image quality (color shades, brightness, magnification, etc.) for more convenient observation, as well as save photos and videos while working with the device. To obtain an image, a digital camera is used, which has four control buttons ("freeze" the image, brightness control, AWB). The camera is controlled via an RS232 serial interface. The video signal is transmitted and processed by the motherboard, implemented on a high-speed ARM controller. It supports digital and analog video interface for video signal output: HDMIx2, VGA, DVI, CVBS, SDI, video input for the camera. The motherboard has a port for connecting a button keyboard. To save images and videos, a USB interface is used, to which an external data carrier is connected.

A display controller and a backlight controller are used to display the image on the matrix. The display controller is connected to the motherboard with an adapter to the HDMI connector. The display controller connects to the matrix via an LVDS interface. A backlight controller is used to generate the required supply voltages for the matrix.

For wireless signal transmission from the autonomous module to the monitor, wireless HDMI is used, which allows the transmission of a high-definition multimedia signal over a radio channel (Wi-Fi). The transmission range without amplification can reach up to 200 meters.

Control buttons are separate module that connects the flat cable to the motherboard. A fan is used to remove warm air from the device case. The device is powered by a 12V 200W power supply.

The assembly model of the autonomous module, made in the Autodesk Inventor environment, is shown in Figure 2.

![Figure 2. The assembly model of the module.](image)

3. Development of a keypad

For the production of printed circuit boards (PCBs), the most widely used services are JLCPCB (jlcpcb.com) and PCBWay (pcbway.com). The former also has its own online board development environment EasyEDA, in which you can create a circuit, lay out a printed circuit board and send it to production. Here you can also order PCB components and their installation on the PCB. The service has the largest PCB prototyping enterprise in China and own production with huge capacity.

Gerber RS-274X and Excellon N/C Drill files are used to order printed circuit boards in production. Gerber is a file format that describes a PCB project for the production of photomasks on a wide variety of equipment. Almost all modern electronic CAD systems support output to this format. On the other hand, almost any modern equipment can read data in this format. The N/C Drill file describes the parameters of all holes on the board.

Let’s consider the process of creating Gerber files for a keypad board, developed in DipTrace 4. The PCB scheme is developed (Figure 3), the top and bottom sides of the PCB are wired (Figure 4) and a 3D model of the PCB (Figure 5) for further design is made in Autodesk Inventor. All files are created in PCB Layout program from DipTrace packages.
Figure 3. Electrical schematic diagram.

Figure 4. Layout of the upper and lower PCB layers (designation of elements is disabled).
The format assumes that each layer of the board is placed in a separate file. Most services adhere to the following file naming convention (Table 1).

Table 1. File naming.

| File name            | Alternative         | Note                  |
|----------------------|---------------------|-----------------------|
| Top.GBR              | <boardname>.GTL     | Top copper layer      |
| Bottom.GBR           | <boardname>.GBL     | Bottom copper layer   |
| Topmask.GBR          | <boardname>.GTS     | Top layer of the mask |
| Bottommask.GBR       | <boardname>.GBS     | Bottom layer of the mask |
| Topsilk.GBR          | <boardname>.GTO     | Top marking layer     |
| Bottomsilk.GBR       | <boardname>.GBO     | Bottom marking layer  |
| BoardOutline.GBR     | <boardname>.GKO     | Board outline         |
| Through.drl          | <boardname>.TXT     | Board holes           |

The specified layers are sufficient for making the board. Layers Toppaste and Bottompaste - the upper and lower layers of the stencil for applying solder paste, used for automatic soldering of parts (in our case, we do not use it).

Next, the board is checked for errors. If there are no errors, then the placement and layout of the elements is checked according to the technical specifications and only then the Gerber files are exported.

4. Conclusions
Based on the developed design documentation, it is planned to manufacture and order components, assemble a prototype video system. It differs from foreign analogues in its compactness and the ability to use various methods of video signal transmission.

Such a system is optimally suited for both inpatient use as part of an operating endoscopic complex, and for use on the go or for quick movement among several reception rooms.

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