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Department of Industrial and Medical Electronics

Master Thesis

Title
X-ray machine table-tripod control system *Система управления столом-штативом рентгеновского аппарата*

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Objective

Document

Master Thesis

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Title

X-ray machine table-tripod control system	
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Content	1. *Introduction and literature review;* 2. *Overview of XG501A;* 3. *Overview of XG510;* 4. *Experiment on studying psychological effects;* 5. *Results;* 6. *Financial Management and resource efficiency;* 7. *Social responsibilities*
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ABSTRACT

Today, there are more than 10,000 types of medical devices available. The nature of medical treatment requires that to provide complete care, you must be in possession of complete equipment. To allow a hospital to comprehensively treat patients, there is a standard set of medical equipment that all hospitals should always have on-hand both for diagnosis and monitoring or treatment.

We can classify the diagnosis equipment in to four major divisions as follows,

1.Ultrasonography- Diagnosis is based on ultrasound waves.

2.MRI machines- Based on magnetic resonance, radio waves.

3.PET- Based on positron emitting technique.

4.CT Scan- Based on computer combination of many X-ray images.

5.X-ray – Based on X-Ray machines

Since, X-ray is the most relied-upon imaging modality, accounting for approximately 60% of imaging procedures in hospitals. There is an important need to optimize the entire process both in imaging and operations as well.

To enhance optimization nowadays medical equipment manufactures adapts new techniques in X-ray machine such as automated table movements with increased degree of freedom. Allowing both the patients and hospital to reach certain level of ease and convenient.

Specifically, in this thesis, we will be looking in to designing of automated control systems of X-ray machine SMEW_XG-510 and SMEW_XG501A. In addition, with the study of psychological effects of patients during the period of diagnosis in X-ray machine and recommendations to control the effects.

ACKOWNLEDGMENTS

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CHAPTER 1
INTRODUCTION & LITERATURE REVIEW

1.1 What is an X-ray?

An X-ray is a common imaging test that's been used for decades. It can help your doctor view the inside of your body without having to make an incision. This can help them diagnose, monitor, and treat many medical conditions.

Different types of X-rays are used for different purposes. For example, your doctor may order a mammogram to examine your breasts. Or they may order an X-ray with a barium enema to get a closer look at your gastrointestinal tract.

1.2 Why is an X-ray performed?

Your doctor may order an X-ray to:

- examine an area where you're experiencing pain or discomfort
- monitor the progression of a diagnosed disease, such as osteoporosis
- check how well a prescribed treatment is working

Conditions that may call for an X-ray include:

- bone cancer
- breast tumors
- enlarged heart
- blocked blood vessels
- conditions affecting your lungs
- digestive problems
- fractures
- infections
- tooth decay
- needing to retrieve swallowed items

1.3 What are the benefits of having an x-ray?

Using x-rays for diagnosis can bring very real benefits to patients. The overriding concern of your doctor and the hospital radiology department is to ensure that when x-rays are used, the benefits from making the right diagnosis, and consequently giving you the right treatment, outweigh any small risk involved.

If treatment decisions depend on the findings, then the risk to your health from not having the examination is likely to be much greater than that from the radiation itself.

1.4 What are the different types of x-ray?

Radiography: This is the familiar X-ray which most of us will have at some time during our lives, usually for looking at broken bones or at the chest or teeth. A machine directs a beam of X-rays through the part of your body that is being examined and on to a special film. A picture is produced on the film of the structures the X-rays have passed through in your body. Simple x-rays such as these involve extremely low amounts of radiation.

Fluoroscopy: This is sometimes called 'screening'. After passing through your body, the X-ray beam is viewed by a special camera which produces a moving picture on a TV screen. The radiologist or radiographer performing the examination can take snapshots of any important findings, or record and store the whole thing. Fluoroscopy is often used to look at the gut. For example, in a 'barium meal' you will be asked to swallow a drink of barium, which is shown up well by X-rays, to give moving pictures of your stomach and intestine. Fluoroscopic examinations usually involve higher radiation doses than simple radiography.

1.5 X-Ray Table Types

There are various types of X-Ray machines depending on their applications, different types of X-Ray machines are as follows:

- Fixed
- Floating
- Rotary

Fixed tables are a traditional x-ray tables where there are no movements made. It is oldest x-ray table with many limitations such as able to image only in certain positions and parts of bodies. Moreover, patient is highly disturbed and lots of inconvenience is made through the entire diagnosis.

Floating tables are a more comfortable than compared to fixed tables. These table enables you to accurately and simply get perfect positioning every time. The radiolucent x-ray table offers movement in every horizontal direction possible. After positioning, release the foot operated lock and the top locks noiselessly into position. There is also now no need to disturb the patient when the cassette is changed or a grid is used, as both are held in trays underneath the table top.

Rotary are latest available technology which makes patients and doctors to complete the diagnosis of x-ray machine easily and feasibly. This type of machine delete the limitations of another machine. It is designed in such a way that X-ray tube and diagnostic able to make linear movements horizontally and vertically. Adding to this diagnostic tables can make radial movements within the limited radians. This provide opportunity to diagnosis the patients in different position and obtain complex medical images in a simpler way. XG501A and XG510 are rotary type x-ray tables.

1.6 Why to study psychological effect?

Medical product design has a lot to do with embodying devices with characteristics that make them easy to understand and to use. To do this effectively, designers must understand perception and cognition: how we sense the world, how those sensations are interpreted by our brains and how we think about what it is we perceive.

Cognitive psychology is an area that few designers are trained. That's unfortunate, because much of the design process is spent considering how users will interact with the device that is being designed. By knowing how we sense and interpret information in the world around us, medical product designers can be deliberate in providing cues that enable devices to be operated intuitively, confidently and safely.

1.7 Discussion

Patients often suffer from cognitive deficits such as difficulty concentrating, being in a 'brain fog' or being more tired. Psychological or Psychiatric Symptoms The chronic disequilibrium as well as difficulty performing routine daily activities because of BVH can have a psychological impact.

Some patients also complained mainly of oscillopsia (a sensation that the visual environment is moving when it is not) and of imbalance. Symptoms such as dizziness, headache, nausea, double vision, photophobia, and light-headedness.

Cognitive Deficits BVH patients often suffer from cognitive deficits such as difficulty concentrating, being in a 'brain fog' or being more tired. Psychological or Psychiatric Symptoms The chronic disequilibrium as well as difficulty performing routine daily activities because of BVH can have a psychological impact. Besides those, psychiatric conditions such as depression could play a confounding role in the reported health status of patients. In the chronic phase, it is mainly the psychiatric disorders which worsen the clinical picture along a more disabling and debilitating course, not the vertigo symptoms.

Patients with BV complain mainly of oscillopsia (a sensation that the visual environment is moving when it is not) and of imbalance. Symptoms related to vestibular function impairment, such as vertigo, dizziness, headache, nausea, double vision, photophobia, ataxia, and light-headedness, have also been reported in BV patients.

Thus, it is necessary to understand the psychological effects and optimize the diagnosis process to comfort the patients and doctors for further development.

CHAPTER 2

OVERVIEW OF XG501

2.1 GENERAL VIEW ON XG501

XG501A is a medical diagnostic X-ray unit. It is configurated with diagnostic table which can be remote controlled, either put in and out the cassette in sideway; Bucky table with 4-way movement and convenient for radiography, x-ray tube support movement transversely turning around the arm. It also can be radiography with chest stand and so on. And it also has the characteristic as follow:

- The main technical requirement adopts the equivalent international standard.
- The unit is double tables and double tubes medical diagnostic X-ray unit with the excellent feature and full function.
- The main console operation integrated with the table control, easily to use.
- The diagnostic table is remote controlled with rotation foot panel, and control board on the table, it can be remote controlled and controlled near the table as well. It is convenient with side cassette device for stomach and intestines radiography.
- This unit can be controlled in bright room, and protect the patients and doctors from the x-ray thanks to the image intensifier system, the images of fluoro will be clear and bright.

It is easy to move the patient during the radiography due to the table is four-way movement. The unit can be used as X-ray fluoroscopy, stomach and intestine radiography, normal radiography, sternum radiography and other non-ravage X-ray examination.

Fig.2.1 XG501

2.1.1 Components

- **X450F control board:**

The key-board control diagnostic table electrical device.

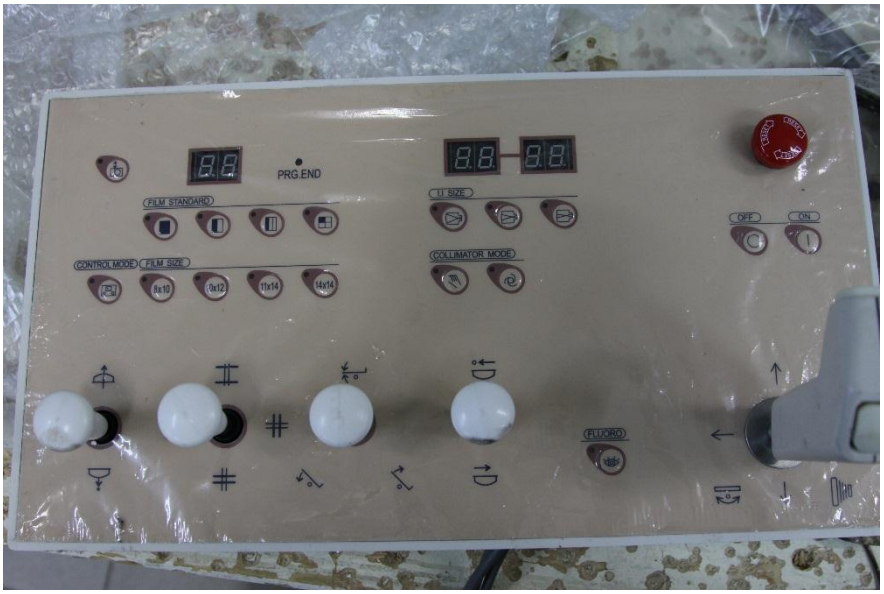


Fig.2.2. X450F Control board.

- **X708C diagnostic table:**

The diagnostic table is controlled by “diagnostic table electrical device”, through the push knob (or the optional handle), the table moves smoothly with the transducer when the table is rotate, the tabletop moving or trail moving.

Fig.2.3. X708C Diagnostic Table

Degrees of Freedom of X708C diagnostic table	
Rotation	+90°～0°～ -15° Rotation speed 90°/20 s
Movement	Movement 600 mm Tabletop size 2000 mm x 765 mm Speed 40 mm/s

Table.2.1. X708C Technical Specifications

Movements of all moving parts of X708C electric diagnostic table can be operated by way of button switches and handle switches, with each correspondent part driven by the motor and speed-reducing device. The rotating range of the bed boy of electric diagnostic table is large, able to rotate randomly with the scope of -15° upside down ~ horizontally 0° ~ vertically +90°. Vertical movement and vertical pulley bracket of the bed surface have a large movement scope (if the movement scope of bed surface is moved 600mm to the head, the vertical pulley bracket shall have a range equal to or above 600 mm), to satisfy clinic needs by sciascopy check and photography of digestive system.

The board of bed surface is plane, with a huge application area, convenient for installation of accessories on the bed surface, such as pedal and handle, and easy for operation and cleaning. If placed upright, the rotating pedal with a rotating wheel can rotate the patient examined by way of operational switch, so to make it easy for sciascopy check of digestive organs.

2.1.2 Technical parameters

- **Bed surface**
  - ✓ *Space of the bed surface:* 765×2000 mm
  - ✓ *Distance off the ground:* 840 mm
  - ✓ *Vertically movement distance:*640 mm (to the head)
  - ✓ *Vertically movement speed :*40mm/sec

- **Rotation of the bed body**
  - ✓ *Rotating angle:* -15°～0°～90°
  - ✓ *Rotating speed:* 90°/20 s

- **Vertical pulley bracket movement**
  - ✓ *Movement distance:*600 mm
  - ✓ *Movement speed:*40 mm/s

- **Horizontal pulley bracket movement**
  - ✓ *Movement distance:* ± 90 mm
  - ✓ *Movement speed:* 35 mm/s

2.2 CONTROL SYSTEM OF XG501

X708C electric diagnostic table uses 3-phase AC power supply, with a cable voltage of 380V, a power frequency of 50Hz, and a power volume of 3 kVA. The power is connected from the distribution board in the machine room to the electric control cabinet of the bed by use of special cable equipped. Major components used in control system of XG501 are as follows:

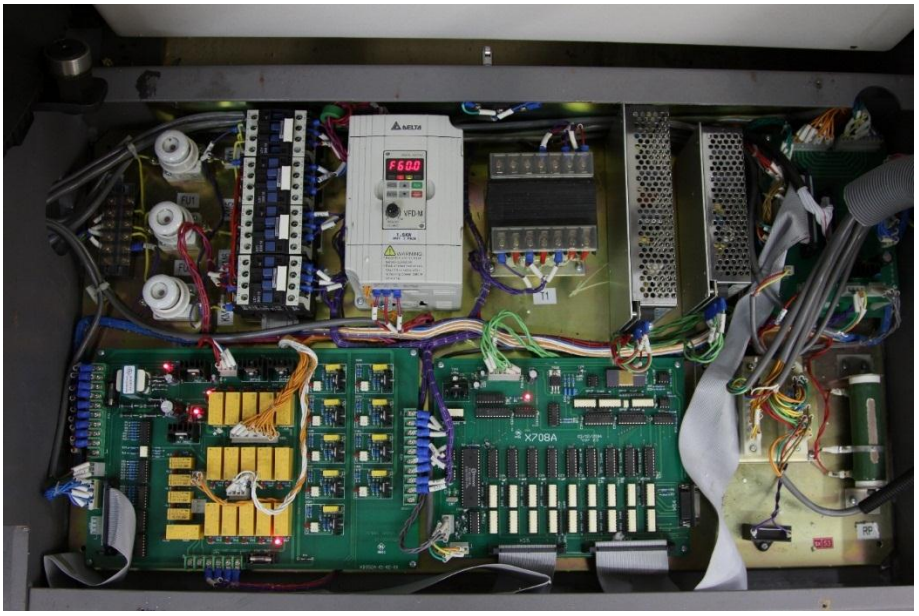


Fig.2.4. Control System of XG501

1. **DC Power supply (5V & 12V & 24V):**
   - ✓ 5VDC power supply is for microcontrollers and digital circuits.
   - ✓ 12VDC power supply is for all switches mounted in the machine.
   - ✓ 24VDC power supply is for DC Actuators which includes motors.
2. **3 phase contactors:**
   - ✓ Acts as a switch controlled by microcontrollers through driver circuits(relay) for 3phase AC motors.
3. **Variable Frequency drive (VFD):**
   - ✓ Major role of this frequency convertor is to change the frequencies to control the speed of AC motors.
   - ✓ Phase Changing is also done by this to change the direction of AC motors.

4. Relay board (Motor Diver circuit):

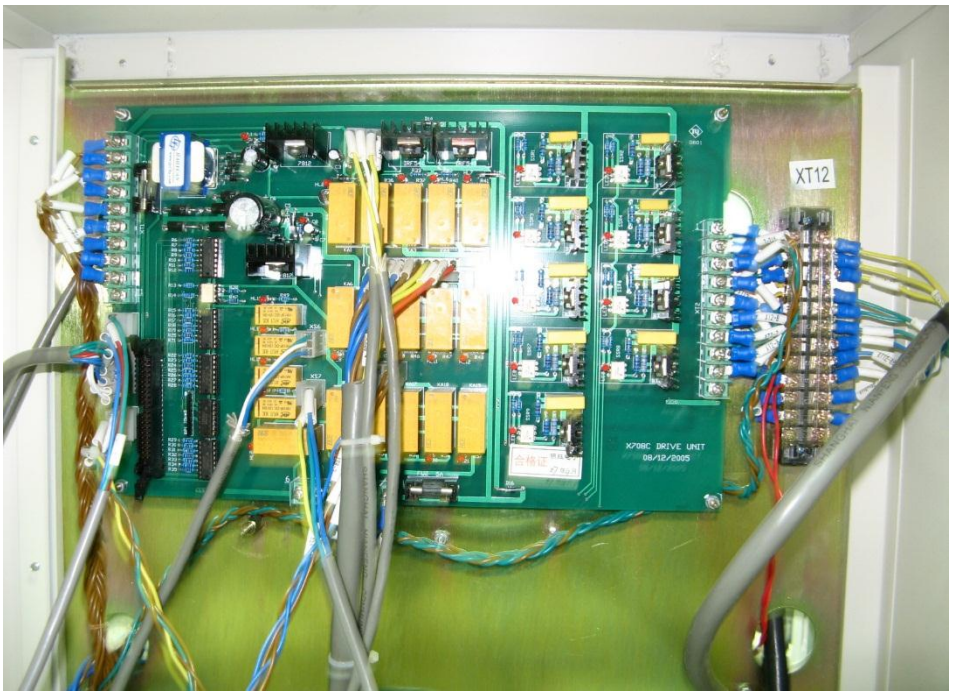


Fig.2.5. Relay board of XG501

Generally, relay board acts as motor driver circuits as the output supply from microcontroller circuit is not enough to drive the actuators. Hence this board is connected in between the microcontroller unit to the motors and contactors.

Components mounted in the circuit are:

1.***Transistors***-acts as switch between output of the microcontroller and input of the relay coil as the output current from the microcontroller is not enough to switch the relay.
2.***Capacitors*** are connected in parallel to the DC supply to stabilize the input supply.
3.***LEDS*** are connected in parallel to relay coil to indicate the state of relay.
4. Various ***connectors*** to connect all inputs and outputs of the relay.

5. Microcontroller board (Logic Gates included):

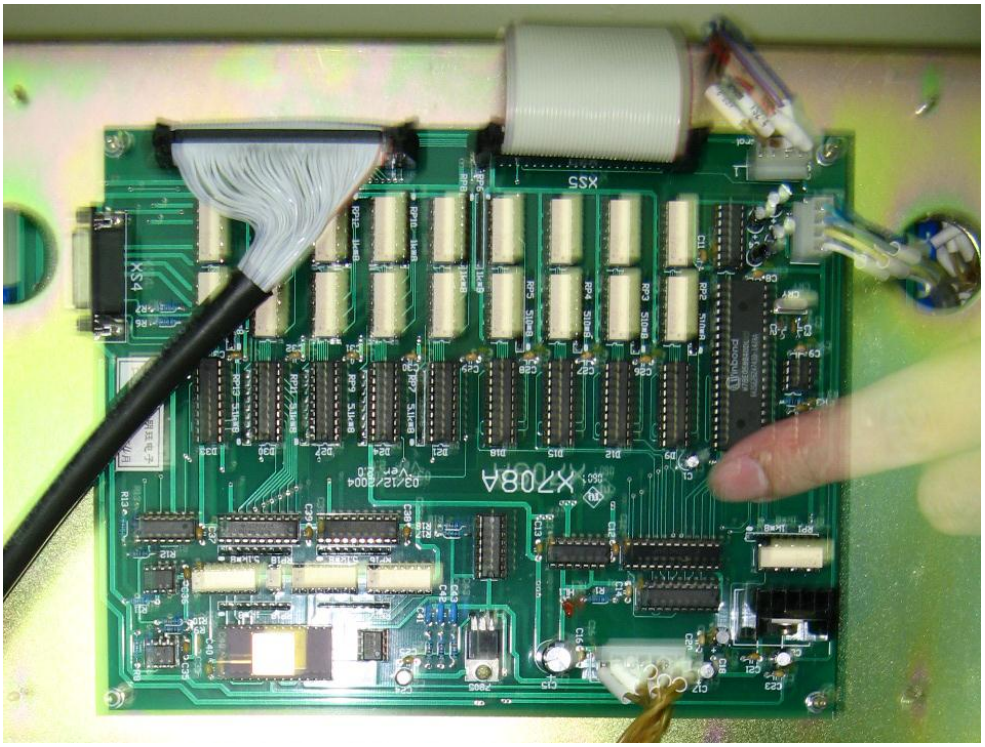


Fig.2.6. Relay board of XG501

- ✓ Brain of whole automatic control system.
- ✓ This circuit board generally consists of logic gates, multiplexer and demultiplex to circulate input and output signals.
- ✓ All commands are sent from this board to the entire system per the specified program.

6. Limit Switches

Heavy-duty Limit Switches are mounted in several positions of the machine to indicate the maximum limit of the X-ray column. Summing up to total 6 heavy duty switches are used.

7. Motors (AC & DC):

AC Motor mounted and engaged with mechanical belt drive and further into the gear box to transmit more power efficiently. This motor is used to rotated the diagnostic table within the given limit of freedom i.e. -15°～0°～90° and the speed determined by the VFD (90°/20 s).

Fig.2.7. AC motor and Mechanical systems for Bed rotation

This motor is used to move the diagnostic bed linearly within the given limit of freedom i.e. 640 mm and the speed determined by the VFD (40mm/sec).

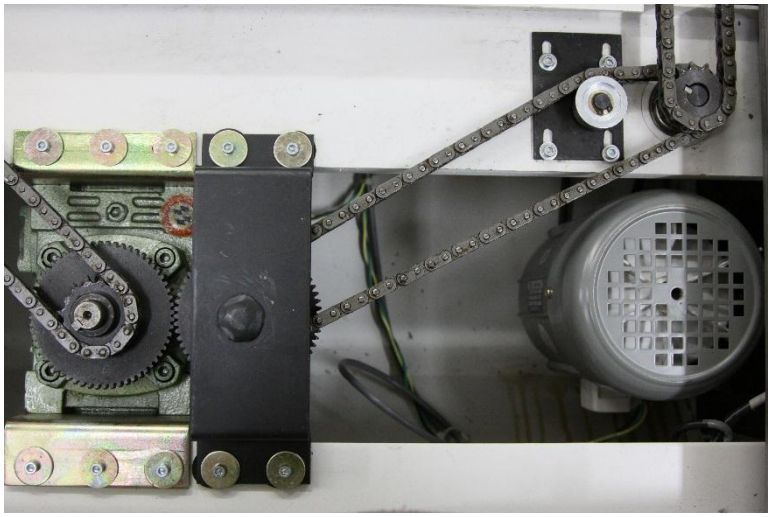


Fig.2.7. AC motor and Mechanical systems for Table

DC Motors are mounted and engaged with mechanical system for low transmission of power i.e. X-Ray Films, Diaphragm of X-ray tubes etc.

2.3 CONTROL PANELS

X708C electric diagnostic table is totally driven by motor. All components on the bed, such as rotation of the bed bracket, movement of the bed surface, can be operated by the bed control keyboard on the console or the short-distance control panel on the gastrointestinal check and photography device.

When carrying out remote operation in the operation room, the communication system provided together with the machine can be used to conduct double way communication between the operator and the patient examined so that the operator can guide the patient examined in time and the patient can send feedback of his or her conditions to the operator to avoid the happening of any hurt to the patient examined.

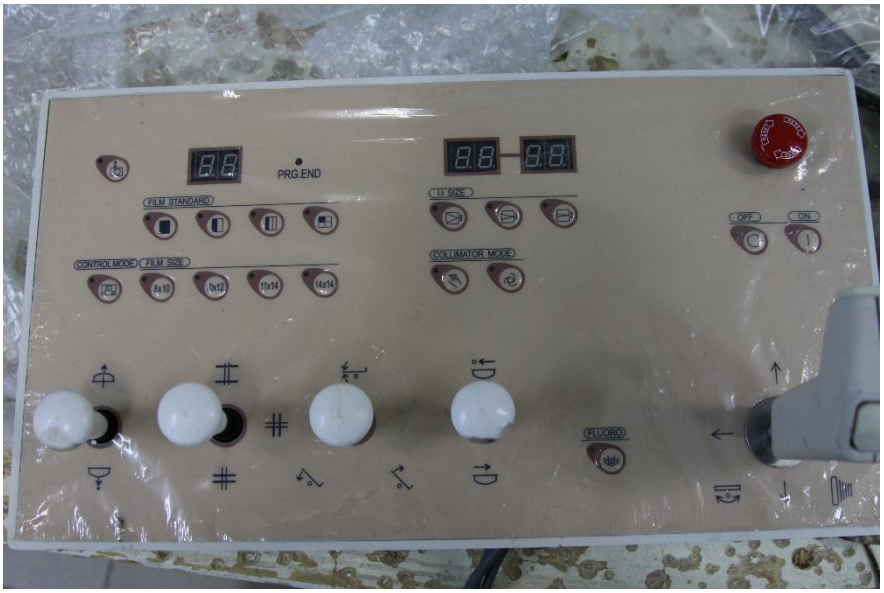


Fig.2.8. X450F Control board.

2.3.1 Functions of all buttons:

(1)  Power On/Off buttons

(2)  Switch button between short-distance control and remote control

.

(3)  Compressor Forward/Back buttons

(4)  Compressor Up Movement Button

(5)  Compressor Down Movement Button

(6)  Bed body Up/Down buttons

2.3.2 Use of short-distance control panel

Operation and control of all actions and functions of the electric diagnostic table can similarly be realized by the short-distance control panel. Its use is basically like the functions of bed control keyboard as described.

Functions of all buttons:

(1)  Vertical pulley Up Button

(2)  Vertical pulley Down Button

(3)  Bed surface Up Button

(4)  Bed surface Down Button

(5)  Horizontal pulley Left Button

(6)  Horizontal pulley Right Button

(7)  Rotating pedal right button

(8)  Rotating pedal left button

CHAPTER 3

OVERVIEW OF XG510A

3.1 General Purpose of XG510

XG510A is a medical diagnostic X-ray unit. It is configurated with diagnostic table which can be remote controlled, Bucky table with 4-way movement and convenient for radiography, x-ray tube support movement transversely turning around the arm. It also can be radiography with chest stand and so on. Mostly like the previous machine XG501 in operations and control systems and all other aspects with only few differences.

Fig.3.1 XG510A.

3.2 Difference between XG501A and XG510A

XG501A	XG510A
1.) Linear movement of pulley bracket (X-Ray tube) is done by DC motors with chain drives due to less load.	**1.)** Linear movement of pulley bracket (X-Ray tube) is done by AC motors with chain drives due to heavy load.
2.) Linear bed movement is vertical (Up/down) up to the limit of 600mm.	**2.)** Linear bed movement is horizontal (Left/Right) up to the limit of 200mm.
3.) Rotation angle of diagnostic table is from (+90°～ 0°～ -15°)	**3.)** Rotation angle of diagnostic table is from (-30°～0°～15°).
4.) Control circuit is inbuilt to the machine.	**4.)** Control circuit is not built to the machine. Separate cabinet is placed next to the machine.

Table.3.1. Difference between XG510A and XG501A.

3.3 Control system for XG510A

3.3.1 Overall concept explanation:

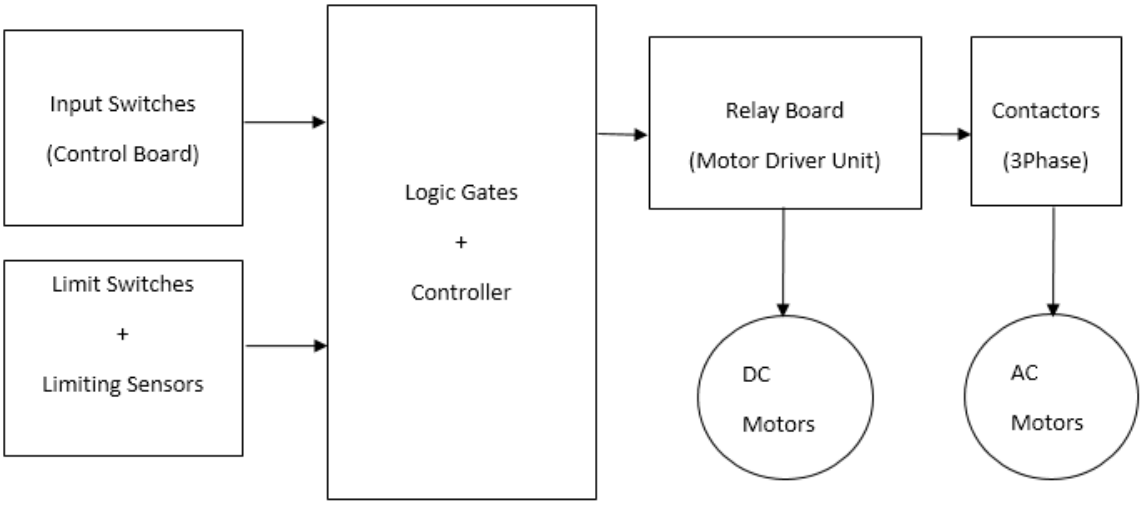


Fig.3.2. Block diagram of XG510 control system.

1. All commands are given by the user through control panel to control unit.
2. Signals from the limit switches and sensors are also directed to the control unit.
3. As of the received commands, the microcontroller instructs as specified in the program.
4. Output port of the microcontrollers are connected to the driver boards i.e. relay board.
5. As per the designed logics the relay switches accordingly and provide proper supply to actuators.

3.3.2 Components used:

1. **Input Switches/Control panel:**

Simple push button is used to control the machine operation. Referring to the previous control system similar input commands are designed to this machine also. It includes 10 input commands for various operations and 1 emergency stop button.

Fig.3.3. Short distance control panel.

Fig3.3. Long distance control panel.

2. Limit Switches and Limiting Sensors:

Limiting Sensors:

1mm aperture opto-electric single channel slotted interrupter switches with transistor sensors.

Description:

The ISTS100, ISTS200 opaque photo interrupters are single channel switches consisting of a Gallium Arsenide infrared emitting diode and a NPN silicon photo transistor mounted in a polycarbonate housing. Operating on the principle that objects opaque to infrared will interrupt the transmission of light between an infrared emitting diode and a photo sensor switching the output from an "ON" state to an "OFF" state. In total 3 limiting sensors are used to understand the position of bed.

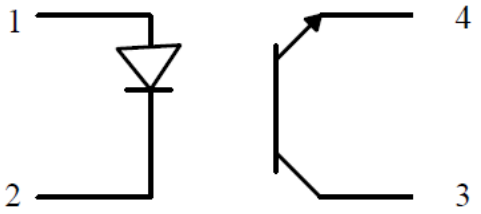


Fig.3.4. Schemactic circuit of limiting sensors.

INPUT DIODE

Forward Current	50mA
Reverse Voltage	5V
Power Dissipation	75mW

OUTPUT TRANSISTOR

Collector-emitter Voltage BV_{CEO}	30V
Emitter-collector Voltage BV_{ECO}	5V
Collector Current I_C	20mA
Power Dissipation	75mW

Limit Switches:

Heavy-duty Limit Switches are mounted in several positions of the machine to indicate the maximum limit of the X-ray column. Summing up to total 6 heavy duty switches are used.

3. DC Actuator:

Linear actuator is used to move X-ray tube vertically in the X-ray column. Technical specifications of Linear actuator are as follows:

Manufacturer	Runyes
Model	RY400-PL-2000N
Maximum Load	2000N
Power rating	24VDC 3.8Amp
Duty Cycle	Max.6min./hour

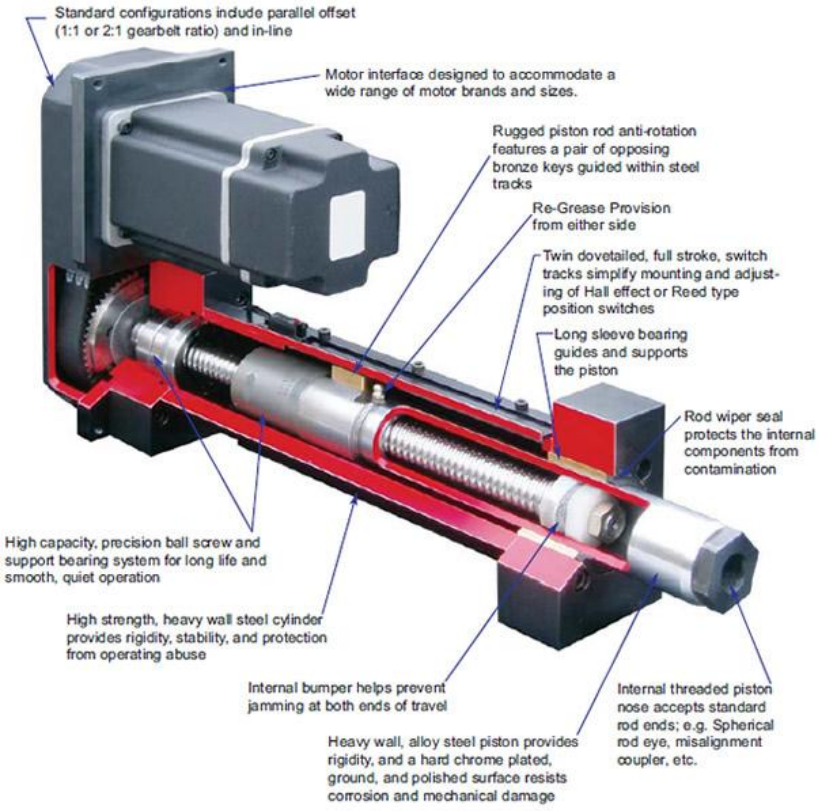


Fig.3.5 Linear actuator RY400-PL-2000N.

4. AC Motors:

Two AC Motors are mounted in the machine to perform two major mechanism of the machine i.e.

1. Rotating the bed from -30°～0°～15°.
2. Linear movement of X-Ray column front and back.

Specifications of Motor are as follows:

Serial No.	3phase	Freq.	R/min	KW	Cos	A
Bed Motor	380-420V	50	1400	1.1	0.75	2.72
Column Motor	380-420V	50	931	0.55	0.74	2.72

Fig.3.6. AC Drives

5. Contactors:

Contactors are circuited to this control system to switch 3 phase supply to AC motors under the instruction of microcontroller through relay board and contactor are used to change the phase to change the direction of motor.

Specification of Contactors are as follows:

LC1-D09-01-U6

US Breaker- Brand Part #	Telemecanique Contactor Cross Ref Direct	Direct	Control Coil Voltage	Auxiliaries NO	NC	Price Each
NC1 D09 01 - V24	LC1D0901 - B7	LC1-D09-01 - B7	24V B7	0	1	$12.98
NC1 D09 01 - V120	LC1D0901 - G6	LC1-D09-01 - G6	120V G6	0	1	$12.98
NC1 D09 01 - V240	LC1D0901 - U6	LC1-D09-01 - U6	240V U6	0	1	$12.98

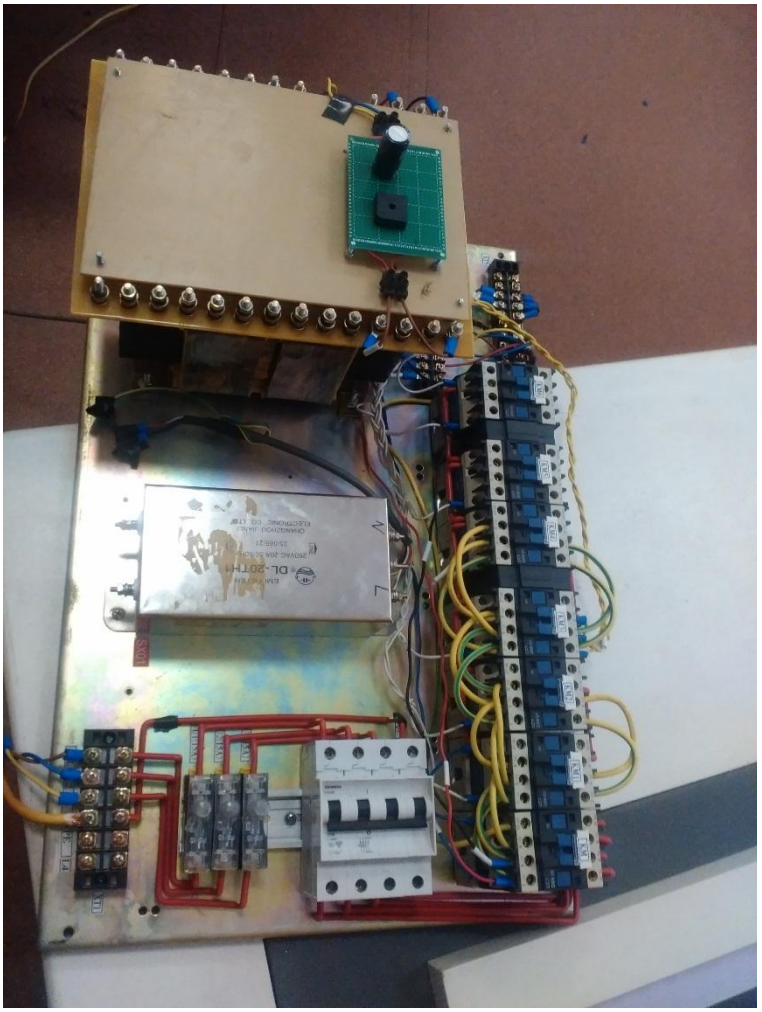


Fig.3.7. Contactor Unit

3.3.3 Relay board schematic circuit:

Relay board is designed as a motor driver circuit board. The main purpose to design relay board is that the output from the controller board is not enough to drive any actuators.

Components used in relay board:

1.Relay- all relay used in this board are double contactor relay so that number of relay would be minimized. The model used is 845h-2c-c.

2.Transistors – NPN transistors are used to switch on the relay coil because the current from microcontroller is not sufficient to switch on the relay coil. The model used is 2SC9013.

3.Capacitors – Both polar and non-polar capacitors are used for reducing and smoothing ripple factor of rectified DC supply. Types of capacitors are as follows.

- KM-63; V-220
- RD-100; V-470
- K73-9-100;

4.Diode – IN4007 is used to eliminate the spike of relay coil. Hence it is placed across the relay coil. Additionally, LED is connected parallel to the coil indicating the ON/OFF state of relay.

5.Resistors – appropriate resistors are used across the circuit.

PCB Design of Relay board:

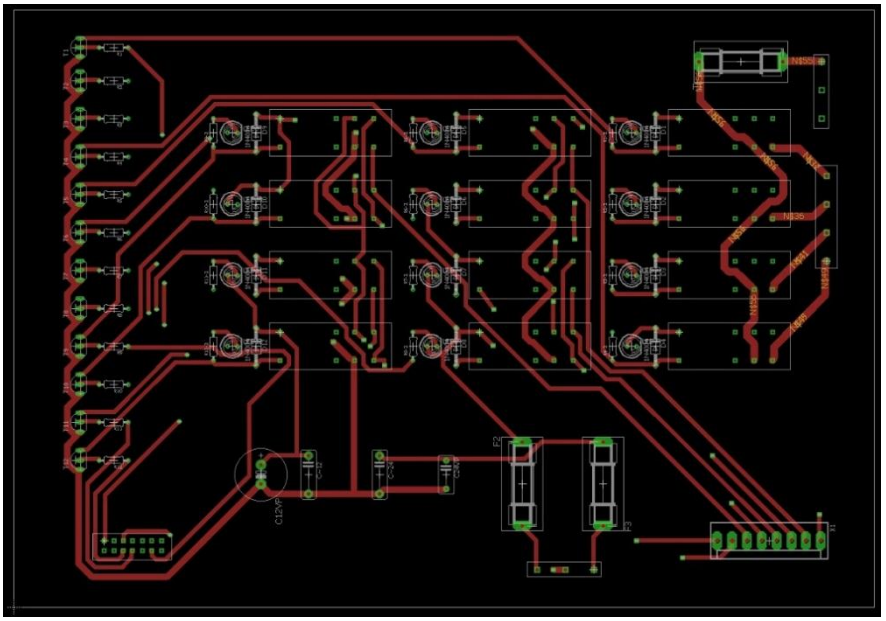


Fig.3.8. Top layer of the plate.

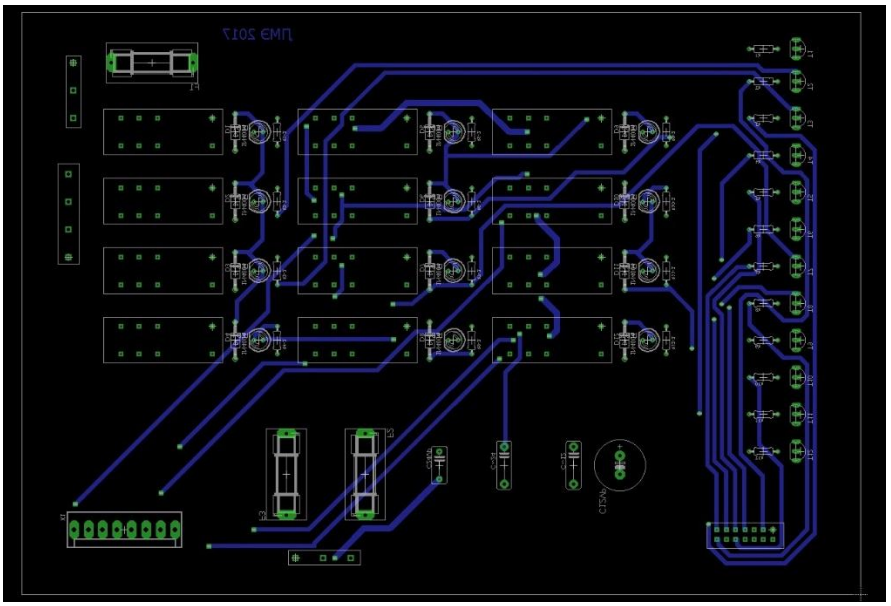


Fig.3.9. Bottom layer of the plate.

Relay board:

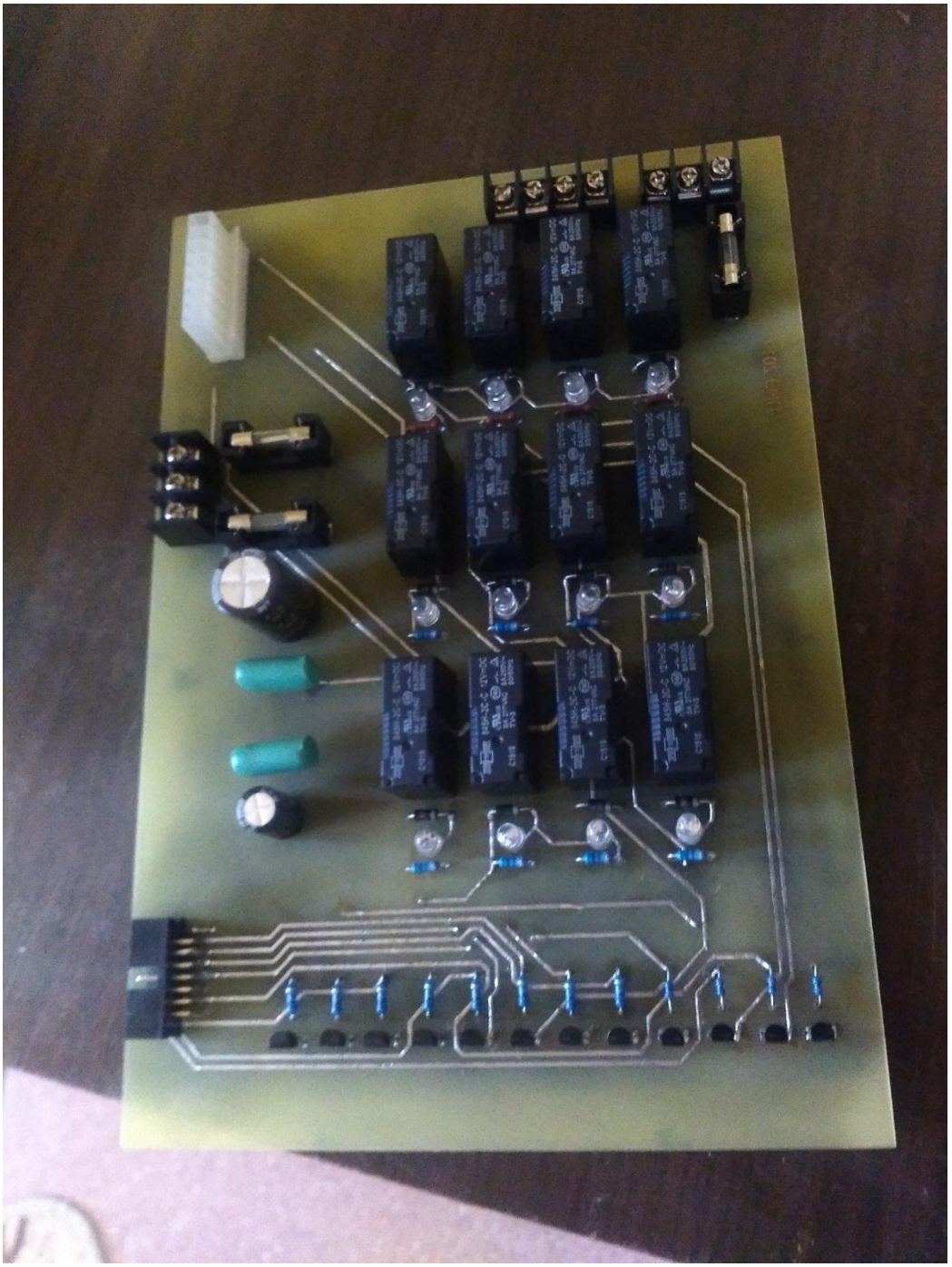


Fig.3.10. Bottom layer of the plate.

TASK FOR THE CHAPTER
"FINANCIAL MANAGEMENT AND RESOURCE EFFICIENCY"

Student

Group	Name
1AM5I	AHILARAJAN JAYASANKAR

Institute	Department	Specialization	Level of education
Institute of Non-Destructive Testing	Department of Industrial and Medical Electronics	Electronics and Nanoelectronics	Graduate

Background of the "Financial management, resource efficiency":	
1. The cost of research: logistics, resources, and labor	225529.62rub
2. Regulations and standards for resource consumption	Federal Law No. 212-FZ of 24.07.2009
The list of subjects of the study, design and development:	
1. Assessment of potential commercial value, prospects and alternatives based on the idea of resource efficiency and conservation.	X-Ray machines with higher degree of freedom are designed to overcome the diagnosis process and achieve detailed medical imaging in an easier way which impacts the field dramatically.
2. Research of planning and budgeting	As Per the law and regulations.
3. Implement the resource (resource-saving), financial, budgetary, social and economic efficiency study	Apply the plan in practice
List of requirements (with a precise indication of mandatory drawings):	
1. Evaluation of competitiveness of technical solutions. 2. Alternatives of Science research. 3. Plan of budget of science research. 4. Evaluation of the resource, financial and economic efficiency of science research.	

Consultant

Position	Name	Education	Signature	Date
Assistant	Valentin S. Nikolaenko	Graduate		

Student

Group	Name	Signature	Date
1AM5I	AHILARAJAN JAYASANKAR		

Tomsk 2017

CHAPTER 5
FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY

5.1 Plan of research project

5.1.1 The structure of the work within the framework of scientific research

Planning complex proposed works in the following order:

- Definition of work within the structure of scientific research;
- Defining members of each work;
- The duration of the work to establish;
- Plot research.

The research is performed by a group which includes researchers, teachers, engineers, technicians and laboratory assistants, the number of groups may differ. For each type of planned works is defined corresponding to the position of performers. An exemplary procedure for drawing up the steps and work distribution of the performers per type of work is given in Table.

Main stages	**№ work**	**The content of the work**	**Executive Position**
Development of R&D jobs	1	Drawing up and approval of the research tasks	Scientific adviser
Conducting research			
The direction of research	2	The study of the problem and the search for materials	Scientific adviser, Graduate student,
	3	Selection of methods and models	Scientific adviser
	4	Schedule works	Scientific adviser,
Theoretical and experimental	5	Development of models for research	Scientific adviser, Graduate student
Research	6	Search methods for solving	Graduate student, Scientific adviser

	7	The implementation models	Graduate student, Scientific adviser
Synthesis and assessment Results	8	Analysis of the results	Graduate student, Scientific adviser
	9	Evaluation effectiveness	Scientific adviser, Graduate student
Documentation work for research	10	Making explanatory notes	Graduate student

Table.5.1. Structure of work

5.1.2 Determination of the complexity of work

Majorly labor costs contribute the fund in drastic manner, therefore it is necessary to determine the work load and it's pay of every participant included in research.

The complexity of the implementation of scientific research is evaluated by experts relating to man and days, though it depends on many factors and it is difficult to determine the expected (mean) value of the complexity. The formula gives us an approximate estimation.

$$t_{\text{ощ}i} = \frac{3.t_{min\ i}+2.t_{max\ i}}{5}$$

Where,

$t_{\text{ощ}i}$ - the expected complexity of labor of *(i)* number in terms of person-day;

$t_{min\ i}$ - the minimum possible complexity of implementation of a given number *(i)* operation (an optimistic estimate: assuming the most favorable circumstances);

$t_{max\ i}$ – the maximum possible the complexity of performing of a given number *(i)* operation (pessimistic estimate: assuming the most unfavorable combination of circumstances).

Based on the expected volume of work which is determined by the duration of each job in working days, considering the parallel performance of works by several performers. This calculation is necessary for reasonable payroll, as the share of salaries in the total estimated cost of the research is about 65 %.

$$T_{P_i} = \frac{t_{\text{ощ}i}}{\text{Ч}_i}$$

Where,

T_{P_i} - duration of a work;

Ч_i - the number of performers performing at the same time the same job on the same stage;

5.1.3 The development of schedule of scientific research

For the convenience of plotting, the duration of each stage of the work of working days should be transferred to the calendar days. To do this, use the following formula:

$$T_{K_i} = T_{P_i} \cdot k_{cal}$$

Where,

T_{K_i} - working days in calendar;

k_{cal}- calendar factor;

Calendar ratio is calculated by the following formula:

$$k_{cal} = \frac{T_{cal}}{T_{cal} - T_{\text{вых}} - T_{np}}$$

Where,

T_{cal}- number of calendar days (365);

$T_{\text{вых}}$- number of holidays in a year (52);

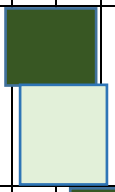
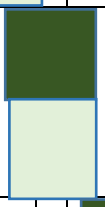
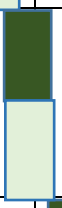
T_{np}- number of work holidays in a year (15);

$$k_{cal} = \frac{365}{365 - 52 - 15} = 1.22$$

No	Performers	Duration of work						
		t_{min}	t_{max}	$t_{ощ}$	T_P	T_k	y_i, %	г$_i$, %
1	scientific adviser	7,00	14,00	9,80	10	12	11,32	11,32
2	Scientific adviser, graduate student,	14,00	21,00	16,80	9	11	10,38	21,70
3	scientific adviser	3,00	7,00	4,60	5	6	5,66	27,36
4	scientific adviser	4,00	7,00	5,20	5	7	6,60	33,96
5	Scientific adviser, graduate student	21,00	28,00	23,80	12	15	14,15	48,11
6	Graduate students, scientific adviser	14,00	21,00	16,80	9	11	10,38	58,49
7	Graduate students, scientific adviser	8,00	11,00	9,20	5	6	5,66	64,15
8	Graduate students, scientific adviser	14,00	21,00	16,80	9	11	10,38	74,53
9	Graduate students, scientific adviser	7,00	14,00	9,80	5	6	5,66	80,19
10	Graduate students	14,00	21,00	16,80	17	21	19,81	100,00

Table.5.2. Duration of work

As per above table, we construct a line graph of the R & D which will show the sequence of the operations and timing of steps. Calendar schedule is at the first performance, as it takes less time and is optimal for performing the thesis.

Stage	Work	Performers	T_k	February	March	April	May	June
1	Drawing up and approval of the research tasks	Scientific adviser	11					
2	The study of the problem and the search for materials	Scientific adviser, Graduate student	13					
3	Selection of methods and models	Scientific adviser,	7					
4	Schedule of work	Scientific adviser,	8					
5	Development of models for research	Scientific adviser, Graduate student	5					
6	Search methods for solution	Scientific adviser, Graduate student	12					
7	The implementation models	Scientific adviser, Graduate student	14					
8	Analysis of the results, conclusions	Scientific adviser, Graduate student	9					
9	Evaluating the effectiveness of the results	Scientific adviser, Graduate student	2					

10	Documentation work for research	Graduate student	15																				

Tab.5.3. Duration of work

 - Scientific Advisor  - Graduate student

5.2 The budget of the scientific and technical research (STI)

This item includes the cost of all materials used in the development of the project:

- Purchase from the raw material
- Purchase materials
- Purchase components and semi-finished products

5.2.1 Calculation of material costs STI

Material costs are calculated by the following formula:

$$З_м = (1 + k_m) \cdot \sum_{i=1}^{Q} Ц_i \cdot N_{расхi}$$

Where,

Q – Total number of different materials bought during the master work;
$Npacxi$ – The amount of material sources planned to use during the master thesis;
$Ц_i$ – purchase price of the unit;
k_m- coefficient for transportation and procurement costs; Transportation expenses are within 15-20% of material costs.

Name	Unit	Price per. quantity (rubles)	Cost of materials (rubles)
Relay	12	190.00	2280.00
Transistor	12	3.50	42.00
Diode	12	1.00	12
Capacitor	4	35.00	140.00
Resistor	30	0.50	15.00
3 phase switch	1	455.00	455.00
Fuse	10	10.00	100.00
Cables	Mixed size	-	324.00
Ferric Acid	3kilogram	740.00	2220.00

Solder	1	50.00	55.00
Socket	5	32.00	160.00
		Total	5803.00

Table.5.4. Calculations of material

5.2.2 The calculation of the cost of special equipment for scientific (experimental) work

This portion includes all price associated with the acquisition of special equipment (instruments, test equipment, test benches, devices and tools) which is in need. Design of automatic control systems are implemented using various parts (DC power supply, relay boards, microcontrollers, actuators). Costs of each component are also considered.

5.2.3 The basic salary

The initial regulations wages of these categories of workers is salary, which determines the level of monthly salary, depending on the volume of work and responsibility. The structure of the basic salary includes premiums paid monthly from the salary fund in the amount of 20 to 30% of the rate or salary.

It is believed:

The salary of the head: 1.4 thousand rubles / day;

Wage of Student: 0.3 thousand rubles / day;

Payroll of Consultant: 1 thousand rubles / day;

№	Designation of stages	Person	The complexity Per person per day		Wages per person per day. thousand Rub.		Total wages at the rate (salary), thousand Rub	
			Исп.1	Исп.2	Исп.1	Исп.2	Исп.1	Исп.2 Исп.3
1	Drawing up and approval of the research tasks	Scientific adviser	10	12	1,4		16,8	20,16
2	The study of the problem and the search for materials	Scientific adviser, Graduate student	9	12	1,7		18,36	24,48
3	Selection of assay methods and models	Scientific adviser, Graduate student	5	5	1,4		8,4	8,4
4	Schedule of work	Scientific adviser	5	4	1,4		8,4	6,72

5	Development of models for research	Graduate student	12	12	1,7	24,48	24,48
6	Search methods for solution	Scientific adviser, Graduate student	9	15	1,7	18,36	30,6
7	The implementation models	Scientific adviser, Graduate student	5	11	1,7	10,2	22,44
8	Analysis of the results, conclusions	Scientific adviser, Graduate student	9	5	1,7	18,36	10,2
9	Evaluating the effectiveness of the results	Scientific adviser, Graduate student	5	5	1,7	10,2	10,2
10	Explanatory notes	Graduate student	17	17	0,3	6,12	6,12
Total						139.68	163.8

Table.5.5. Cost of performers

$$З_{зп} = З_{осн} + З_{доп},$$

Where,

$З_{осн}$ – Basic wages;

$З_{доп}$ – Additional wages (12-20 % of $З_{осн}$)

5.2.4 Contributions to non – budgetary funds (insurance deductions)

The value of contributions to extra-budgetary funds is determined based on the following formula:

$$З_{внеб} = К_{внеб} \cdot (З_{осн} + З_{доп})$$

Where,

$К_{внеб}$ – rate deductions for the payment of extra-budgetary funds (pension fund of obligatory medical insurance and so forth)

In 2016, in accordance with the Federal Law №212-FZ of 24.07.2009 set the size of insurance premiums of 30%. Based on paragraph 1 of article 58 of the Law №212-FZ of institutions engaged in educational and scientific activity is found a reduced rate in 2016 - 30%.

Executor	The basic wage, Rub		Additional monthly board, rub	
	Исп.1	Исп.2	Исп.1	Исп.2
Project Manager	52000	53000	6240	6360
Graduate students	9000	12000	1080	1440
Factor of payments to non-budgetary funds	0,3			
Total				
execution 1	88816			
execution 2	94640			

Table.5.6. Contributions to non-budgetary funds

5.2.5 Overheads

Overheads –the costs of organizing, management and maintenance of the production process of goods, provision of services are complex, that is, they include a variety of economic cost elements.

Overhead costs are 16% of the basic, additional wages and on insurance premiums, workers directly involved in the execution of threads. Calculation of overhead is conducted per the following formula:

$$З_{накл} = (\text{сумма статей } 1 \div 7) \cdot k_{нр},$$

Where $k_{нр}$ – coefficient considering overheads

5.2.6 Estimated development costs

These costs are included in the estimate.

Name of article	Amount rubles.		Note
	Исп.1	Исп.2	
1. Material costs of STI	3342	3342	Paragraph 5.2.1
2. The cost of special equipment for research papers	-	-	no cost
3. Costs of basic salary threads performers	61000	65000	Paragraph 5.2.3
4. The costs of the additional wages threads performers	7320	7800	Paragraph 5.2.3
5. Contributions to non-budgetary funds	20496	21840	Paragraph 5.2.4
6. Expenses for research and production missions	-	-	no cost
7. Counterparty costs	-	-	no cost
8. Overheads	14528,48	15460,32	Paragraph 5.2.5
9. Budget of STI	105331,5	112087,3	Sum of art. 1-8

Table.5.7 Calculation of the budget cost of STI

5.3 Study of resource (resource-saving), financial, budgetary, social and economic efficiency

Determination of the effectiveness occurs based on the calculation of the integral index of the effectiveness of scientific research. Its presence is associated with the determination of weighted average of the two values: cost-effectiveness and resource efficiency.

Integrated financial measure defined as development:

$$I_{\text{финр}}^{\text{исп.}i} = \frac{\Phi_{\text{p}i}}{\Phi_{\max}},$$

Where,

$I_{\text{финр}}^{\text{исп. i}}$ –integrated financial indicator development;

$\Phi_{\text{p}i}$ – value of the No. i embodiment;

$\Phi_{\max}$ –maximum cost of implementation research project (including analogs).

An integral component of resource efficiency research object variants can be determined as follows:

$$\text{I}_{\text{pi}} = \sum a_i \cdot b_i,$$

Where,

I_{pi} – an integral component of resource efficiency for the No. *i* embodiment of the development;

a –weight ratio No. *i* embodiment of the design;

b –a score of the No. *i* embodiment of the development is set by an expert selected by the scale of assessment;

n –the number of comparison parameters

Object of study / Criteria	The weighting factor setting	Исп. 1	Исп. 2
1. It helps increase user productivity	0,1	5	3
2. Ease of use (complies with the requirements of consumers)	0,15	4	3
3. Immunity	0,15	3	4
4. Energy savings	0,20	4	3
5. Reliability	0,25	5	3
6. Consumption of materials	0,15	4	4
TOTAL	1	4.2	3.3

Table.5.8. Comparative evaluation of the characteristics of the project variants

№	Indicators	Исп.1	Исп.2
1	Integrated financial indicator development	0.9	1
2	An integral component of resource efficiency development	4.2	3.3
3	The integral efficiency index	4.7	3.3
4	Comparative effectiveness of variants	1	0.7

Table.5.9. Comparative effectiveness of development

Compared with integral indicator of the effectiveness of the execution of development options, it is possible to determine the relative effectiveness of the project most suitable embodiment.

Publications

1. Ahilarajan Jayasankar, Khaleev A.A, Automated control system for X-ray machine table top, Instrument making and information technology program, IX-Student scientific-practical conference devoted to the day of education 2016.