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Division of Control and Robotics

Term Design

Design and implementation of a new control system for an industrial robot IRp-6

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Subject Description

The original subject of the work was the modernization of the existing factory controller of the IRB-6 robot, so the first works focused on exploring its structure, connecting the power supply and verifying functionality. Only the correct operation of the drives could be ascertained from the factory design.

Fig. 1. Legendary IRB-6

1.1 Historical Presence

Under these conditions, the current topic of the work was born, the purpose of which is clearly defined by it. Before a detailed description of the controller construction, the history of the IRB-6 industrial robot (the prototype of the IRp-6) and the development of its design at the turn of the years at ASEA was presented. The history of the IRB-6 license in Poland was also summarized, on the basis of which the unit being the subject of the work was also created.

1.2 Control System

The next chapter presents the construction of the manipulator itself as a control object and the general concept of the construction and operation of the factory control cabinet (in contrast to the new design). The concepts of modernization of the control system for the IRB-6 robot in other academic centres in Poland were also introduced. The tools used during the project implementation were discussed, including all preliminary simulations and theoretical analyzes.

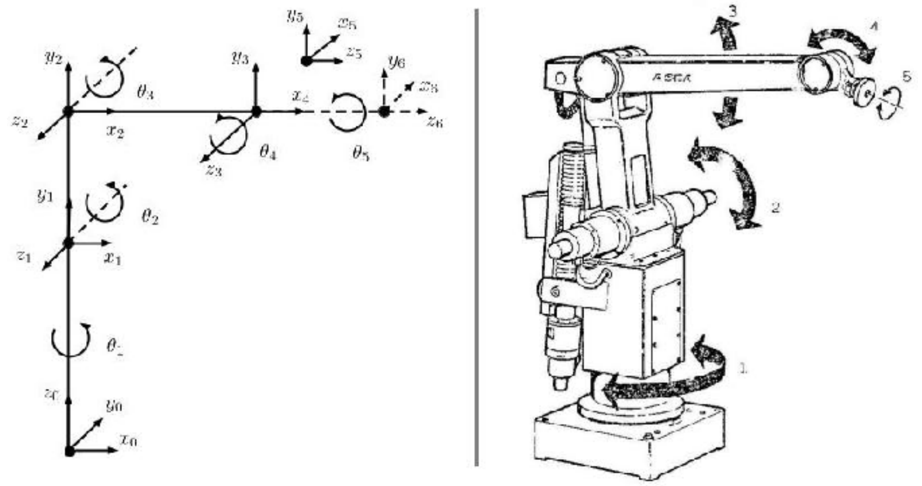


Fig. 2. Kinematic Architecture

1.3 Construction

The chapters devoted to constructing the structure are divided into two parts: implementation hardware and software. The hardware implementation phases usually consisted of the presentation of theoretical basics, initial assumptions, selection of components, construction of an electronic diagram, design of a printed circuit board, and production and assembly in properly machined housing. Before the system's final version was created, a prototype design was often carried out to check its functionality, as evidenced by its conclusions, comments and more interesting observations from the practical implementation phase.

Specifications

2.1 Approach of controlling one degree of Freedom in IRB-6

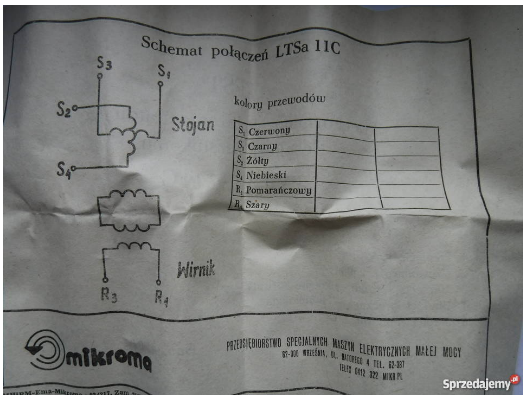
In this part, we will discuss the electronic components specification and its benefits and required circuits for the working module of our control system.

2.2 Available components to control

1 Resolver-LTSa 11C Mikroma 12/6V

This type of transformer is a converter for measuring angular positions in measuring and control devices of industrial automation and machine tools. It is used in all kinds of CNC systems to accurately measure the displacement of moving components of machine tools and other devices.
The output signal of this type of resolver has the parameters of 12/6 V - 2500 Hz in the exact measurement class. The voltages of individual windings, connection method and other parameters are given.

(a) Resolver-LTSa 11C Mikroma 12/6V



(b) Wiring diagram for LTSa 11C Mikroma 12/6V

2 Motor Specification

Fig. 4. Motor Specification and its requirements

Required Hardware and its importance

3.1 Resolver to Digital Conversion

Resolvers, electromechanical sensors that measure precise angular position, operate as variable coupling transformers, with the amount of magnetic coupling between the primary winding and two secondary windings varying according to the position of the rotating element (rotor), which is typically mounted on the motor shaft. Employed in industrial motor controls, servos, robotics, power-train units in hybrid- and full-electric vehicles, and many other applications that require precise shaft rotation, resolvers can withstand severe conditions for a very long time, making them the perfect choice for military systems in harsh environments.

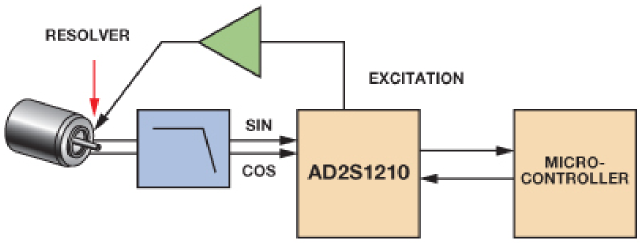


Fig. 5. Visual Implementation of R2DC

The two output signals are modulated by the sine and cosine of the shaft angle. A graphical representation of the excitation signal and the sine and cosine output signals is shown in Figure 2. The sine signal has a maximum amplitude at 90° and 270° and the cosine signal has a maximum amplitude at 0° and 180°.

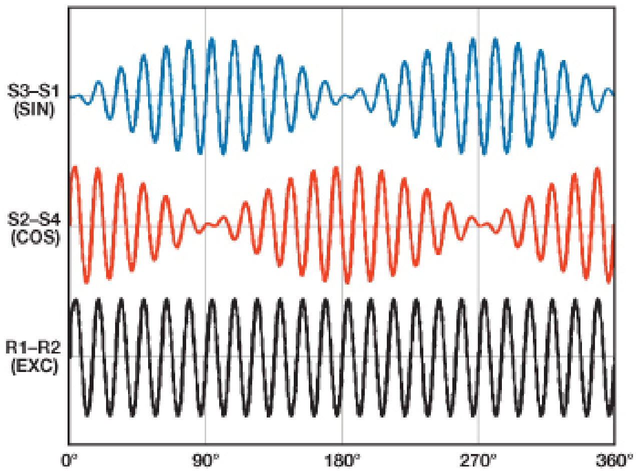


Fig. 6. Resolver electrical signal representation

Control system Visual Implementation of the circuit To measure the error, multiply the sine and cosine inputs by $\cos(\phi)$ and $\sin(\phi)$ respectively:

$$E_0 \sin \omega t \times \sin \theta \cos \phi (\text{for} S3 - S1)$$

$$E_0 \sin \omega t \times \cos \theta \sin \phi (\text{for} S2 - S4)$$

Next, take the difference between the two:

$$E_0 \sin \omega t \times (\sin \theta \cos \phi - \cos \theta \sin \phi)$$

Then, demodulate the signal using the internally generated synthetic reference:

$$E_0 (\sin \theta \cos \phi - \cos \theta \sin \phi)$$

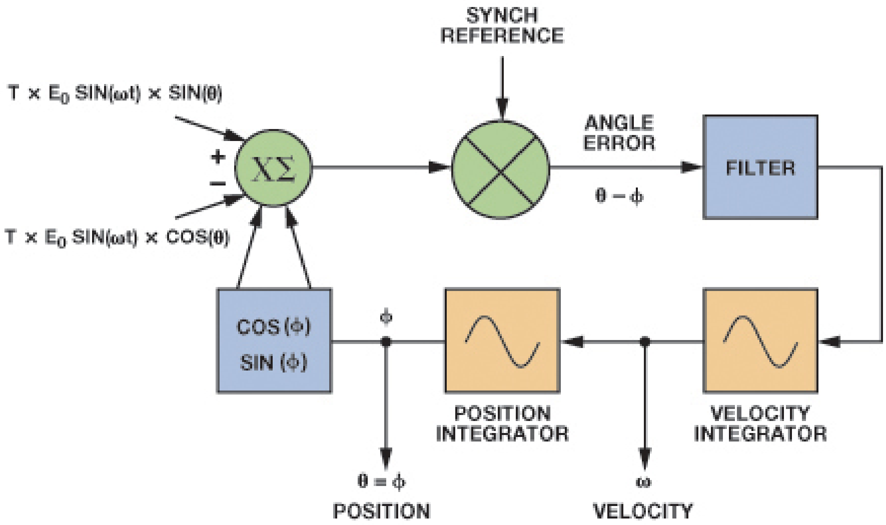


Fig. 7. Visual Implementation of Control system

1 AD2S1210-Resolver-to-digital converter

The AD2S1210 is a complete 10-bit to 16-bit resolution tracking resolver-to-digital converter, integrating an on-board programmable sinusoidal oscillator that provides sine wave excitation for resolvers. The converter accepts 3.15 V p-p 27 per cent input signals, in the range of 2 kHz to 20 kHz on the sine and cosine inputs. A Type II servo loop is employed to track the inputs and convert the input sine and cosine information into a digital representation of the input angle and velocity. The maximum tracking rate is 3125 rps.

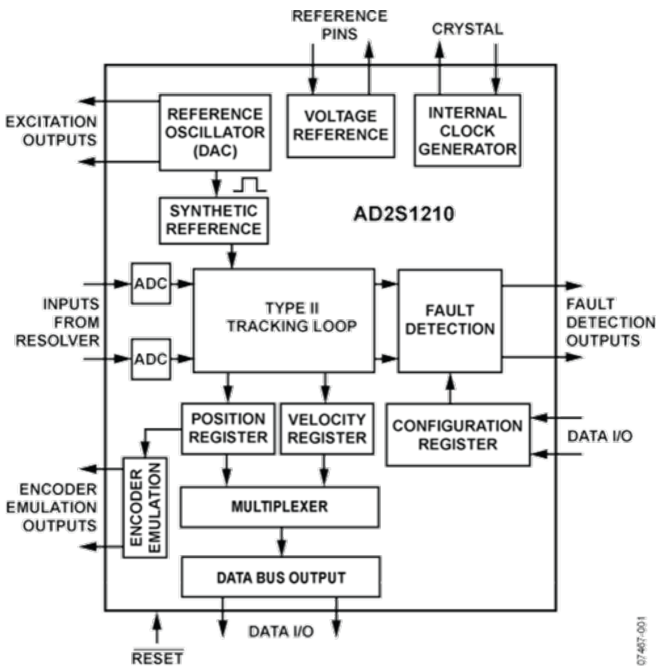


Fig. 8. AD2S1210-Resolver-to-digital converter

The application consists of DC and ac servo motor control, Encoder emulation Electric power steering, Automotive motion sensing and control

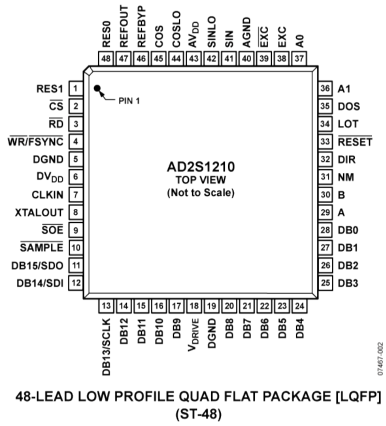
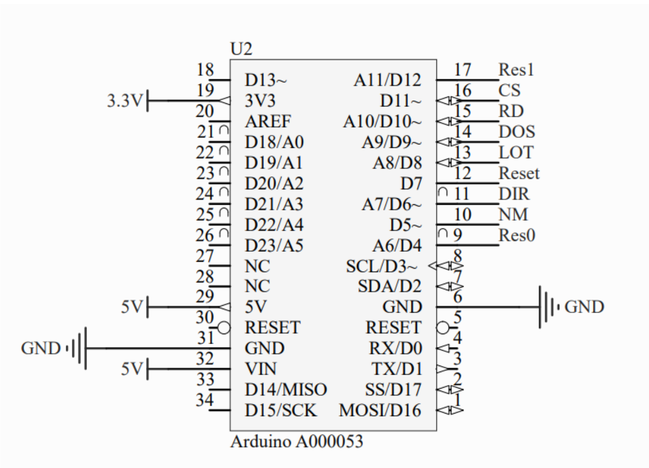


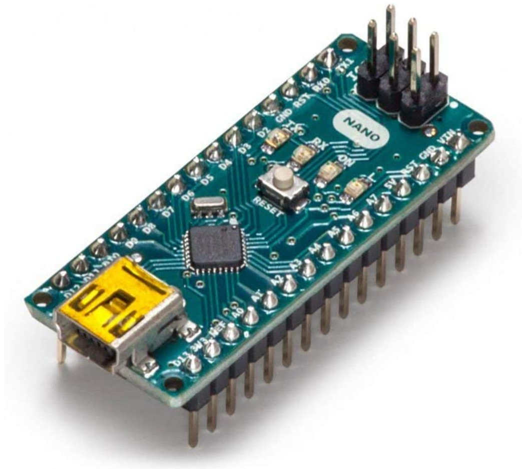
Fig. 9. AD2S1210-Pin configuration

3.2 ARDUINO MICRO

The Arduino Micro is a microcontroller board based on the ATmega32u4, developed in conjunction with Adafruit. It has 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analogue inputs), a 16 MHz crystal oscillator, a micro USB connection, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a micro USB cable to get started. It has a form factor that enables it to be easily placed on a breadboard. The Micro is similar to the Arduino Leonardo in that the ATmega32u4 has built-in USB communication, eliminating the need for a secondary processor. This allows the Micro to appear to a connected computer as a mouse and keyboard, in addition to a virtual (CDC) serial / COM port. It also has other implications for the behaviour of the board.



(a) ARDUINO MICRO-Schematic



(b) ARDUINO MICRO

3.3 H-Bridge

The two basic states of an H bridge Changing the polarity of the power supply to the DC motor is used to change the direction of rotation. Apart from changing the rotation direction, the H-bridge can provide additional operation modes, "brake" and "free run until frictional stop". The H-bridge arrangement is generally used to reverse the polarity/direction of the motor, but can also be used to 'brake' the motor, where the motor comes to a sudden stop, as the motor's terminals are shorted. In shorted case, the kinetic energy of a rotating motor is consumed rapidly in form of electrical current in the shorted circuit. The other case is to let the motor 'free run' to a stop, as the motor is effectively disconnected from the circuit. The following table summarizes the operation, with S1-S4 corresponding to the diagram above. In the table below, "1" is used to represent the "on" state of the switch, and "0" to represent the "off" state

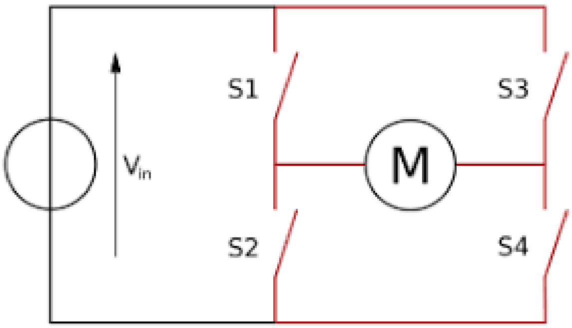


Fig. 11. Simple H-Bridge conceptualization

S1	S2	S3	s4	Result
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
0	0	0	0	
1	0	0	0	
0	1	0	0	Motor coasts
0	0	1	0	
0	0	0	1	
0	1	0	1	Motor brakes
1	0	1	0	
x	x	1	1	Short circuit
1	1	x	x	

3.4 Motor Controller

Motor controllers are devices which regulate the operation of an electric motor. In artificial lift applications, motor controllers generally refer to those devices used in conjunction with switchboards or VFDs to control the operation of the prime mover. Motor controllers often include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, speeding up or slowing down, and controlling other operational parameters. In addition, motor controllers can provide protection for the artificial lift system by regulating or limiting the torque, and protecting against overloads and faults. Many motor controllers contain additional capabilities such as data collection and data logging as well as application-specific control logic.

Implementation

The Motor and the resolver will be paired so that they work co-dependently. The resolver gives the output in an analogue sin/cos signal, which will be converted into a digital signal, which makes it easier for the microcontroller to measure the position and speed of the motor. The microcontroller calculates the speed/position parameter in order to control the Motor using the Motor controller, which was built by Dr mgr inż. Bogdan Fabiański, which consists of an H-bridge which assists in the speed and direction of motor rotation.
The below images show the design and the construction of the used Motor control.

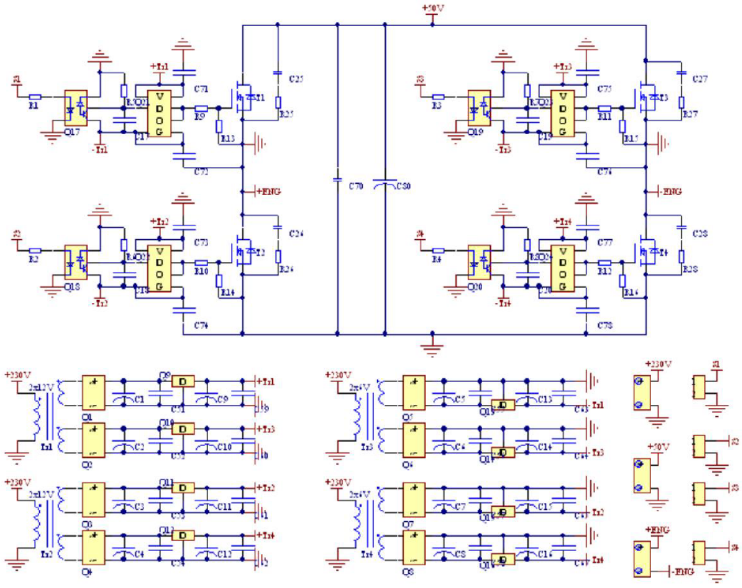


Fig. 12. Design scheme of Motor controller

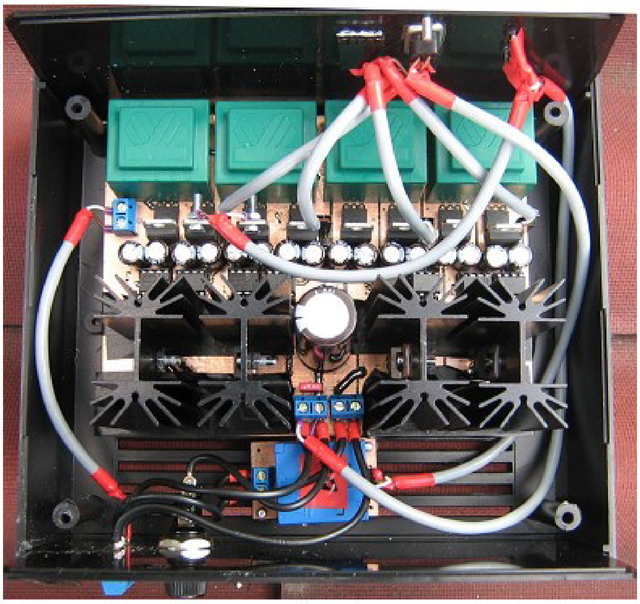


Fig. 13. Motor Controller

The below image implementation of the Resolver to Digital signal converter circuitry.

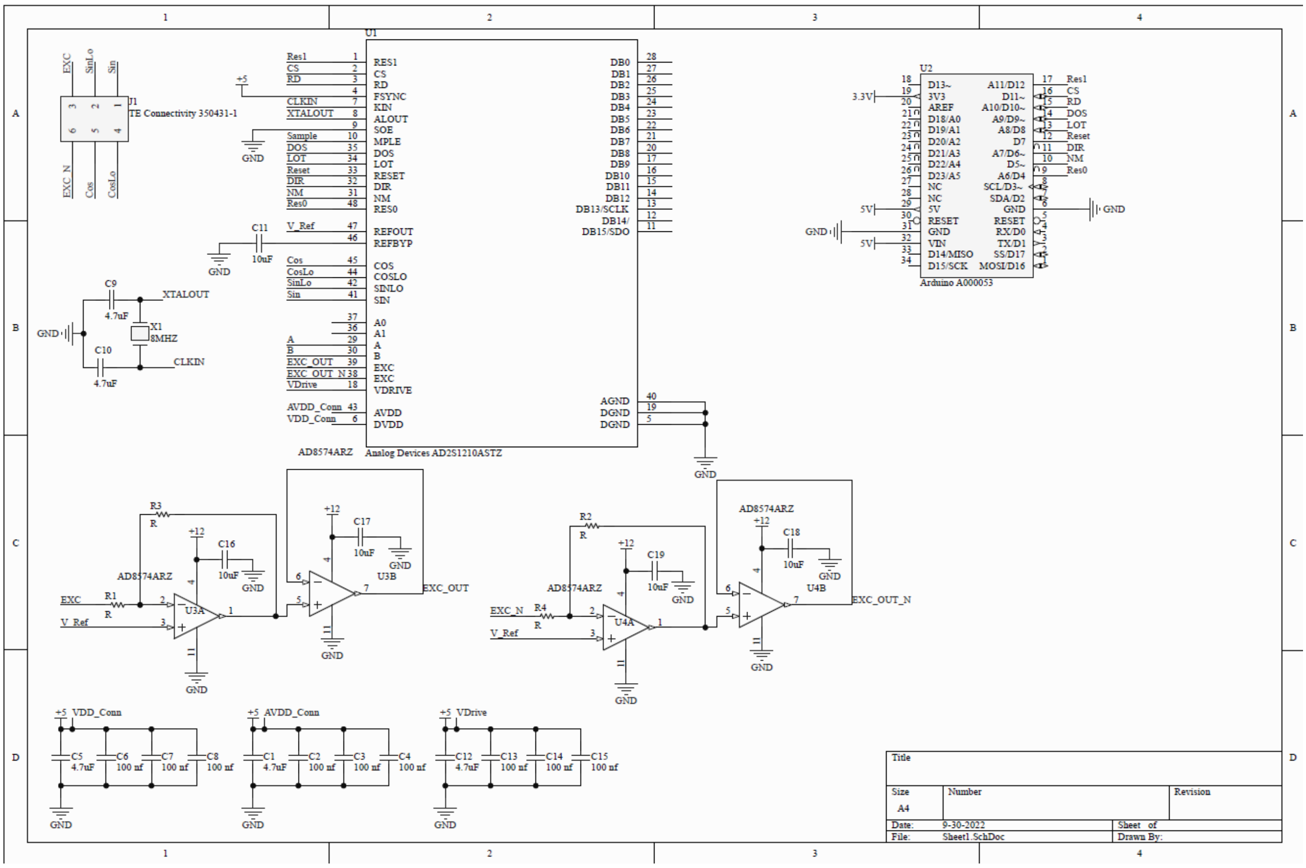


Fig. 14. Resolver to Digital signal converter circuitry

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