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GENERAL PURPOSE SIX JOINT ROBOT CONTROLLER

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ABSTRACT: *General-purpose six-axis robot controllers was designed and build to serve as a research tool for investigation of practical and theoretical aspects of various control strategies in robotics and for industrial application. Pentium II based system was used for running AMX operation servo software. Special ISA-to-PC104 interface board was designed to handle input/output signals from the joint axis of the robot manipulator. This general-purpose controller is capable of driving robot manipulators equipped with any type of servomotors, position optical encoders and joint limit sensors (optical or mechanical). All software is written in C and assembler.*

INTRODUCTION

Design and development of new type of educational robots capable to serve both for investigation of practical and theoretical aspects of various control strategies at the university and for small industry application [3] is a new research design of the Robotics Laboratory, Mihajlo Pupin Institute in Belgrade. ROBED 03 is new type of low coast educational robots capable both for the research and industry applications.

This new design needs a low coast, general purpose Computer based robotic controller that allows the user to write programs and implement algorithm that control the robot arm form the lowest level of the closed-loop servo system to the higher level of kinematics [9] , dynamic, path planning, and robot language [8]. Easy connection to the internet and remote control is also easy to upgrade. This paper presents the design and implementation of the controller consisting of the Distribution Interface board (DB) and the operating system interface to the hardware. The standard control laws and application software are not presented here.

DESCRIPTION OF CONTROLLER

The controller presented here was designed by using a Pentium II PC [1] board running the AMX [4] (KADAK) operating system. A Distribution Interface Board was designed and constructed to provide the interface between the Pentium processor board [1] and the joint sensors (encoders, limit switches etc. The block diagram in Fig. 1 depicts the controller system.

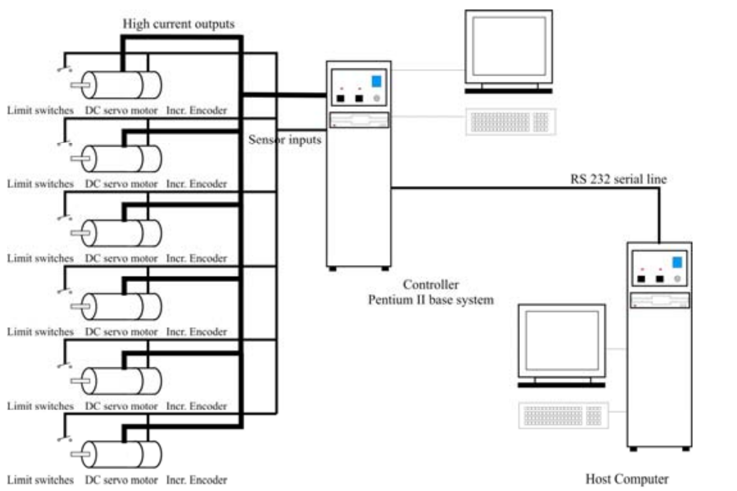

Figure 1. General purpose six-joint robot controller

Standard PC PENTIUM II board [1] running at 566 MHz is used to execute high-level control software. (Kinematics and joint servo loops) AMX operating system is used to run several tasks for control and communications between controller and user console. A multitasking environment is designed around Pentium processor and each separate task is designed for maximum processor consumption eater to control six control loops (PID or FF) either for communication between tasks, either for execution a high-level user program sends by console. It is very important to note that in case for hazardous industrial application or high lever mechanical robust application, standard PC104 processor board (Pentium I, Pentium II, or 486) or standard industrial PC board is easy to apply without any modification.

SYSTEM DESIGN REQUIREMENTS

Seven basic elements constitute the control system implementation: (1) standard PC Pentium II board [1], (2) Distribution Interface Board, (3) two pieces of ENCDA PC104 boards, (4) universal DIGIO PC104 board, (5) universal ADC PC104 board capable to read motor current for each joint, (6) High current universal AC/DC power supply, (7) six pieces of DC motor drivers [7]. PC Pentium II board performs all the control functions, from the joint motor servo control law to the higher levels of coordinated joint motion. Distribution Interface Board (DB) provides the basic link between the PC processor and the physical signals required to control the robot arm. It also provides an interconnection between a standard ISA bus [5] system to PC104 bus [6] system.

Universal ENCDA board is PC104 board especially designed to accept encoder signals form the joint and general purpose signals for each joints (joint limits, motor enable and homing signals.) Each ENCDA board is capable to serve 4 independent joints simultaneously. A general purpose DIGIO PC104 board is designed to read 16 digital general-purpose optically isolated inputs and 8 optically isolated PNP transistor outputs. In this specific situation we have to read status signals from power supply and to provide a power voltage for motor drivers. Standard ADC PC104 (ARCOM AIM104ADC16/IN8) board [2] is used to provide a current control for each joint. Because we are using standard motor drivers who have current control output, voltage signal proportional to current it is useful to measure current for each joint during the operation, especially for advanced control laws such as global feed-forward control law. For this purpose we are using ARCOM AIM104ADC 16IN8 board [2] with 16 analog channels, 10KHz-sampling rate with 12 bit ADC. Standard AC/DC power supply (WOHRLE model) that is capable to provide 40 amps current at 24 V continuous and 100 amps in peak is used for DC motors. This power supply has a control inputs for enable or disable output voltage and a control outputs for status of device. As a motor drivers it is used a devices provide by COPLEY CONTROL Corp. model 413 [7]. This DC brush motor drivers provide a drive current and voltage needed by DC servomotor. Each driver has a voltage control input to generate appropriate voltage output to the motor joint. Other control signals (inputs and outputs) are provided by Distribution Interface Board such as driver enable signals, driver status signals, direction inhibit signals, current output etc.

DC SERVO MOTOR

ROBED 03 are equipped with integral package that contain 2 basic components: (1) a DC servo motor (FOULHABER) (2) optical incremental encoder and (3) motor to joint gear. Built-in motors in the arms are not the same and depends on the force and torque needed for separate joints. The current activating the motor is the input of the system and encoder signals are the outputs. The basic function needed to operate the motor system is described subsequently.

INCREMENTAL ENCODER TREATMENT

Each manipulator joint is typically connected trough a gear train requiring a multiple number of motor revolutions to drive the joint through its operating range. This is shown in Fig. 2. Feedback element is attached directly to the motor, not the actual joint member. Joint position is inferred from the motor position and requires that absolute motor position be measured over multiple motor revolutions.

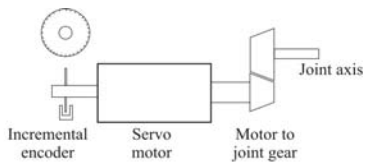

Figure 2. Typical joint motor configuration.

Once the absolute motor position has been determined from the encoder index pulse, it is continuously updated (incremented or decremented by the data from the incremental shaft encoders as long as the electronics are not interrupted (e. g. power-down). The incremental encoders have three output signals channels A and B and the index pulse. Channels A and Bare used to determine both the amount and direction of rotation in discrete steps. The index pulse produces a single short pulse each motor revolution the can be used by the system to determine the absolute zero of the joint (homing procedure). Outputs from the incremental encoders go to ENCDA board trough Distribution Interface Board. ENCDA PC104 board accept signal from incremental encoders and automatically increase or decrease hardware counter inside of the board. Processor form PC board trough ISA [5] and PC104 bus [6] read this counter to calculate absolute position of the joint. ENCDA board provides homing procedure at the beginning of the work.

During this operation automatic zeroing of the counter is provided by index pulse and homing limit sensor on the joint. This procedure ensures absolute zeroing of the joint in the working space at the same position. Each ENCDA PC104 board is capable to serve 4 encoders simultaneously.

DRIVING THE MOTOR

The drive current and voltage needed by a DC motor depend on the size and type of motor used. Standard COPLEY [7] motor driver are used. Each motor driver is possible to adjust to work in different mode (current, voltage, velocity). Current limit for each joint is adjusted separately depending of the motor joints.

For our application velocity mode is obtain. The drivers are controlled by simple analogue voltage. To generate this voltage outputs from a controller a digital to analog converter (DAC) is best to use. ENCDA PC104 board posses a BURR-BROWN 12 bit DAC-s with four different independent channels. Each joint is equipped with limit sensors. Signals form the sensors goes directly to Distribution Interface board. Reading these sensors gives the information's that limits for each separate joint are reached or not. Automatically disable of movement in desirable direction when joint limit is reached is to make possible by Distribution Interface Board. These signals are provided form the sensors to motor drivers for each separately joints.

THE OPERATING SYSTEM CHOICE

AMX 386 [4] multitasking System by KADAK is chosen as smallest and useful real time multitasking operating system of this project's implementation. AMX simplifies real-time software implementation by providing the system designer with a well-defined set or rules. AMX operates on any INTEL 80386 compatible microprocessor system and gives the system designer complete flexibility and control over the microcomputer configuration employed.

DESIGN OF CONTROLLER

This section details the design and implementation of the preceding specifications. The discussion is divided into several parts: (1) hardware design of the Distribution Interface board, (2) hardware design of ENCEDA PC104 board, (3) hardware design of DIGIO PC104 board, (4) the connection between the DB and robot manipulator, (5) software used to control the system.

DISTRIBUTION INTERFACE BOARD

A block diagram outlining the DB hardware is shown in fig 3. As seen from the processor side the DB is a small collection of I/O and bus signals. ISA to PC104 section provides a ISA to PC104 bus adaptation. Distribution

Interface Board contain 6 basic components: Bus interface logic (1), Optical encoder & limit switch logic (2), ENCDA module (3) (two pieces), ADC module (4) and DIGIO module (5) emergency chain (6).

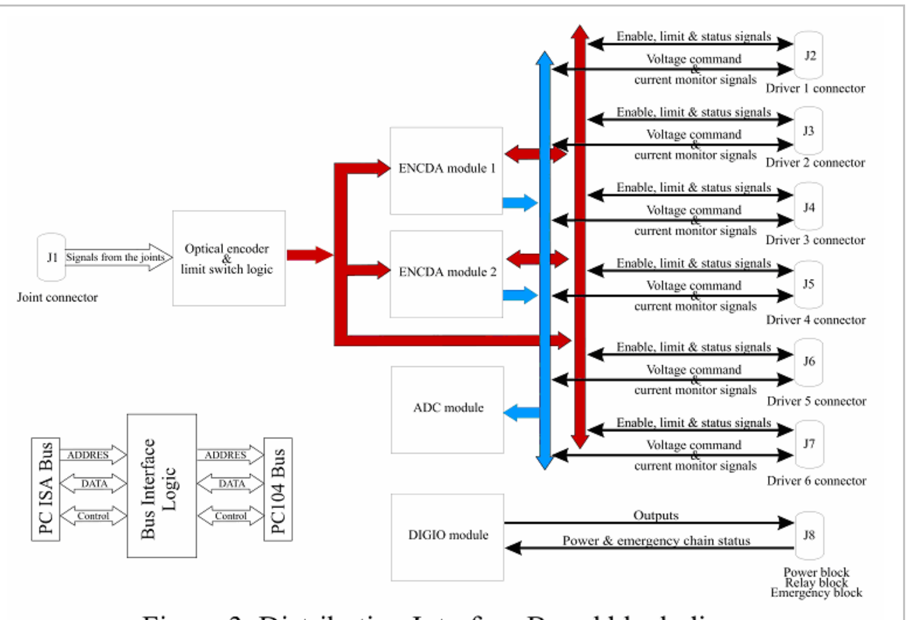

Figure 3. Distribution Interface Board block diagram

ANALOG and DIGITAL I/O

Six analog voltage outputs from ENCDA boards are transferred directly to joint servo motor drivers. From the motor drivers we have also six voltage outputs corresponding current in motor joints witch are transferred by DB to ADC board. I case of security another analog signal is produced directly on the DB. There is a need to control a level of motor power voltage, especially if battery power is used. For this purpose analogue voltage from 0 to 10 V is produced corresponding to voltage on the power source. If the user doesn't use analogue to digital conversion for power voltage monitoring there are 2 different digital signals: under voltage and over voltage. This is a control digital signals that power source voltage is under a proper level or not. DB also transfers digital signals for motor drivers. Each driver can be enabled or disabled separately. Motor driver return also a status of the subsystem to the processor (ready or fault) for each joint.

DB provides also a proper power voltage for encoders on the joints and for limit switches and home switches on the joints. Signals from limit switches from the joints inform processor that some limits are reached. This signals are also transferred to appropriated motor driver to perform automatically disable of movement in desirable direction when joint limit is reached. In this case a two level of security are formed and undesirable movement and mechanical crashing security of the robot manipulator is performed.

The processor also controls motor power supply. Working permission signal for power supply is generated by processor and transferred to the power supply. Processor also read status signal from the power supply. Third set of security signals are input signals for the processor. In case of security global emergency chain is performed. This emergency chain contains emergency STOP push-button signal and proper cable connecting between controller and robot manipulator. Two level of security in this case are also included. Improper cable connecting cause breaks of emergency chain and power voltage cannot be provided to the motor drivers.

ENCDA BOARD SUBSYSTEM

Encoder section; The main application of this module is in motion control systems where encoder position feedback and analog signal controlled motor drivers are used. For this case all necessary electronics is provided on this module to enable direct and complete control of the motor with PC/104 processor module and appropriate software. A block diagram outlining the ENCDA hardware is shown in fig 4. The encoder section on the board can be divided into tree separate sections: encoder interface logic(1), the basic up/down 16 bit counter (2) and decode logic (3). Encoder interface logic is designed to accept any standard digital outputs from an optical encoder: A (/A), B (/B) and Z (/Z). A special purpose integrated circuit is used for digital filtering, direction signal extraction, and pulse counting. 16-bit counter length is provided as standard. Special buffer-registers and appropriate electronics enable latching of the counter contents to avoid false reading if the counter value changes during read operation.

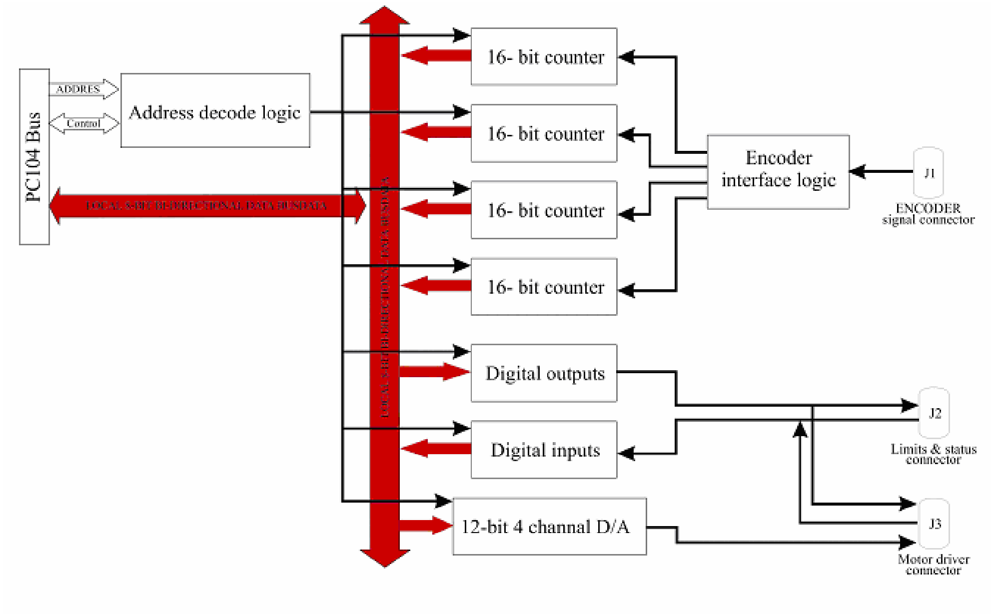

Figure 4. ENCDA Board block diagram

DA conversion section; The board has a high performance integrated solid state DA converter. There are 4 channels, each with 12-bit resolution, and +/- 0.5 LSB overall no linearity. The voltage output range is +/-10V.

General-purpose I/O section; ENCDA module has 16 TTL digital inputs and 4 digital outputs. Digital inputs are used to enable processor to get information on the status of limit switches and servo-drivers, while the digital outputs are used to enable/disable servo drivers.

DIGIO BOARD SUBSYSTEM

The main purpose for this board is reading some extra signals from the system and activates some general-purpose outputs. The block diagram for the DIGIO hardware is shown in fig 5. This board has 16 optically isolated digital inputs. For this design we are using only the few. Trough this board processor can read emergency chain status, status from the motor power supply, status of external cabling and voltage monitor digital signals: under voltage and over voltage signals. There are also 8 optically isolated digital outputs and two are used: motor power supply enabling and power on for the motor servo drivers trough some relays.

Watch Dog Timer (WDT) feature on the board provides the best way to avoid uncontrolled behaviour of the system in the case of processor module or bus breakdown, as well as when program falls. If onboard retriggerable monostable multivibrator is properly refreshed within certain time limit, outputs will be kept at the level controlled by the program in use. Otherwise outputs will
be disabled until new refresh cycle occurs.

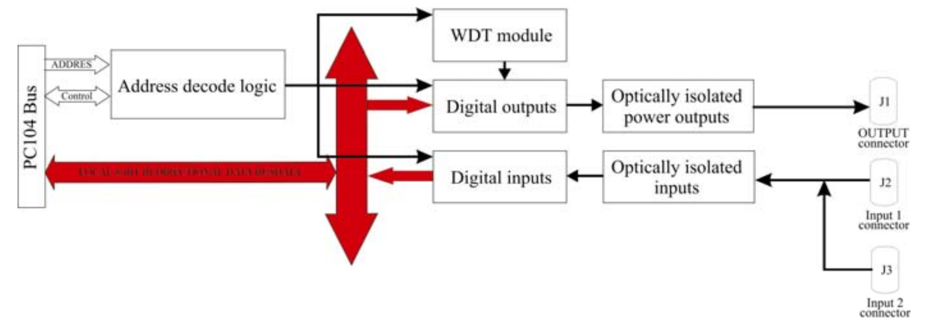

Figure 5. DIGIO Board block diagram

EMERGENCY CHAIN

In case of security a global emergency chain is implemented. The chain parts are: emergency STOP push-button, proper cable connecting and Watch Dog Timer (WDT) feature on the DIGIO board.

There is a software and hardware security control level. Software can read signal status of any part of the chain. If a problem was found emergency software procedure immediately breaks all movements and generate a message. Also physically breaking the chain (activating the push-button, in proper cabling or processor breakdown) cause loses of power for the drivers and stop of the movement.

REAL-TIME ISSUE

The AMX [4] multitasking provides a simple solution to the complexity real-time multitasking. AMX supervises the orderly execution of a set of application program modules called tasks. Each task solves a particular problem and provides a specific functional capability within the system. Each task solves a particular problem or provides a specific functional capability within the system. Each task executes independent of other tasks. Controller executes several tasks: keyboard task, receiving task, sending task, kinematics task and regulator task. AMX clock handlers and Kernel task provide timing facilities for use by tasks. Each task has a constant time of execution (1ms) and when time expired another task would be started. There is a communications between two separate tasks by messaging. AMX supports the passing of a message from one to another task.

CONCLUSION

The objective of designing and constructing a general-purpose robotic controller using a standard and low coast PC board and multitasking OS was completed successfully. The system has controlled ROBED 03 arm, demonstrating the flexibility of the design. Using standard PC platform gave a design a high flexibility in the future. Easy malfunction debugging and fixing, high modular construction are general advantage of the design. Easy connection of the system to the network, remote control and internet control made all design very profitable and useful.

Using a special industrial ISA processor boards or PC104 processor boards in extremely temperature or mechanical application is easy applicable. Distribution Interface Board (DB) served its overall design objective together with ENCDA PC104 board and DIGIO PC104 board. The general-purpose nature of the controller allows it to be used in numerous control and no control related experiments and applications.

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