A Study for Medical Precision Control Machine Using AX-12

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Abstract— **Control devices perform various works for us in many areas. The device is being utilized for precision movement of certain object. In as much as control devices are activated by means of motors, motor control is important.[1][2] Generally, servo motors capable of precision control are more frequently used than DC motors. Use of 3 motors allows 3- way movement. Medical controllers for surgical operation require high precision. [3][4][5][6] AX-12, a servo motor can realize various types of movement. AX-12 can be easily manufactured in the form of a robotic arm and has features that MCU and its peripheral circuits are simple. For precision movement, 3 motors can be controlled by use of a single joystick and 2 buttons, with movement angles being adjusted by having preset values in the program changed.[7][8]**

By virtue of this study, we have realized small precision robotic arm system utilizing single joystick and 2 buttons. This system can control the robotic arm in the direction desired by the user. The system has been designed such that a joystick controls 2 motors with the remaining motor being controlled by a button. Single MCU is tasked with both control and movement.[9] We have shown precision robotic arm system in the Figure contained in the conclusion part and made reference to results of analysis in there. It has also been demonstrated that the system can be utilized in the industry.[8]

Index Terms— **Precision Arm, AX-12, Stick Controller**

I. INTRODUCTION

With the era of ubiquitous coming on, people have largely been developing and manufacturing systems of low power consumption, the smallest in size, convenience, speediness and guaranteeing easy use with little regard to their location. Precision controller for medical use being a mini-version of robotic arm can be activated by 3 servo motors.[2] As a servo motor has an advantage that it can control with precision RPM and rotating angle, it can be adequately used in a system configured in the form of a robotic arm. A controller like this uses a joystick and 2 buttons, which can respectively control each of 3 servo motors. For servo motor, we have adopted AX-12 motor which is easy to manufacture and control by Atmega 128.[9]

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II. CONTROLLER H/W

2.1 AX-12 Composition

AX-12 is a module type smart actuator integrating all of the reducer, driver, control unit and network into a single system. Though compact in size, it can produce big torque and is built with special material which withstands strong external force. It is also capable of self-recognition and control of internal conditions including changes in internal temperature and/or voltage of power supply.[7][8] Its operation angle is 300˚ and its input operating voltage is 7V or 10V. ID value can be assigned to each motor which means 254 values ranging from 0 to 253 can be respectively assigned to each of 254 motors. Pin assignment for AX-12 motor is as shown in Figure 1.

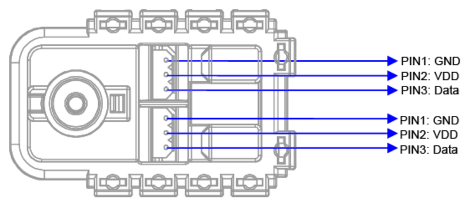

Fig. 1. AX-12 Pin Assignment

The controller for activation of AX-12 is required to support half Duplex UART of TTL level. Accordingly, Atmega 128 has been used as main controller with transmission speed of 9600 bps.[7][8]

2-2. Main Controller Interface

For control of AX-12, main controller UART signal should be converted into half duplex type meaning a serial transmission method whereby TXD and RXT cannot be performed simultaneously. This is generally used for a single BUS which accommodates multiple communication devices.[7][8] With multiple devices connected to a single BUS, all the other devices should remain in input state while one transmits. Data signal direction of TXD and RXD of TTL level is determined according to the level of DIRECTION-PORT as follows. With use of half duplex UART, multi-drop link type whereby multiple AX-12 is connected to a single node can be used. For this reason, protocol is required to operate in such a way that data should not be transmitted simultaneously from several sources when AX-12 is under control.

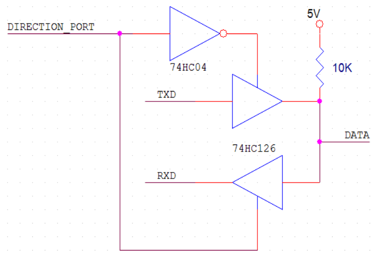

Fig. 2 Half Duplex UART Circuit

Figure 2 shows a conversion circuit. The main controller controlling AX-12 sets transmission direction in input mode but in output mode while transmitting instruction packet. 74HC04 is a chip performing the function of an inverter and is tasked with signaling for control of AX-12. 74HC126 chip has 4 buffers and outputs "high" when 2 inputs are "high" When DIRECTION-PORT is "high" therefore; AX-12 is activated following TXD signal.[7][8]

2. 3. Stick Controller

Stick controller is user's control device used to control AX-12. This device can be rotated 360˚ and is featured to turn back to the middle position when user takes its hands off the stick controller in Figure 3.

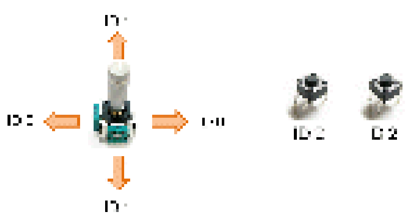

Fig. 3 Direction with ID Nr. in AX12 Control device

The stick controller is fitted with variable resistors showing voltage changes caused respectively by movement to the horizontal and the vertical axes. Position of the stick under control by user can be found by means of the voltage coming through variable resistors. 2 AX-12's used for the current system can be controlled by the stick controller in such manner that the horizontal and the vertical axes respectively controls AX-12 of ID "0" and AX-12 of ID "1" AX-12 of ID "3" can be controlled by 2 buttons.[7][8]

Ⅲ. CONTROLLER OF S/W

3. 1. Communication Protocol

Main controller and AX-12 communicate with each other transmitting packets back and forth. Type of packets includes instruction packet being transmitted from the main controller to AX-12 and status packet being transmitted the other way around. Instruction packet lets the main controller instruct AX-12 to move.[6][9]

In the event an instruction packet with its MCU set in "ID=N" is transmitted from the system having multiple AX-12's connected to single MCU, among multiple AX-12's only that one whose ID is N returns status packet and carries out instruction. AX-12's protocol transmits, through asynchronous serial communication, 8 bit, 1 stop bit and none parity. Status packet is a packet returned by AX-12 to MCU in response to an instruction packet it has received.

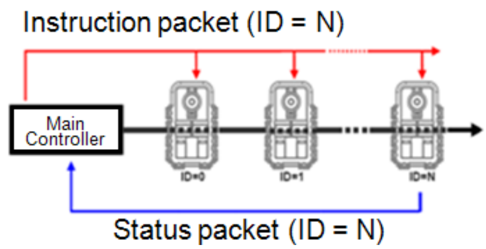

Fig. 4 Communication between AX-12 and MCU

In case the main controller transmits an instruction packet with its ID set in "ID=N" from the system connected as shown in Figure 4, among multiple AX-12's only that motor whose ID is N returns status packet and carries out the instruction.

3. 2. Initial of System

In Table 1 initialization function to activate AX-12 includes "MCU_ initialize" function and "AX-12_initialize" function as Table 1. "MCU_ initialize" function required to set up TXD and RXD pins connected to 74HC126 is used to set multiple pins connected to MCU. "AX-12 _ initialize" function is used for control set up by means of USRT and such control set up covers Baud rate of USART, RX-TX activation, data size and parity mode.

TABLE 1.
INITIAL PROGRAM FO CPU

```
void AX_12_initialize(void)
{
PORTE = 0X01;
DDRE= 0X01;
/* USART BaudRate 1Mbps (Double Speed Mode) */
UCSR1A = 0x02;
/* Double the USART TX Speed */
UCSR1B = 0x08;
/* TX Enable Set */
UCSR1C = 0x06;
UBRR1H = 0x00;
UBRR1L = 0x01;
/* USART Character Size : 8 bit Set */
Delay_ms(200);
/* Waiting AX-12 Power ON Initialization */}
```

Functions used for actual activation of AX-12 include "Set Position" for controlling AX-12 position and "Set Speed" for control of AX-12 Speed. Factors of "Set Position" function include motor ID values and position values; the latter can be set up in the range of 0 to the maximum of 1023.

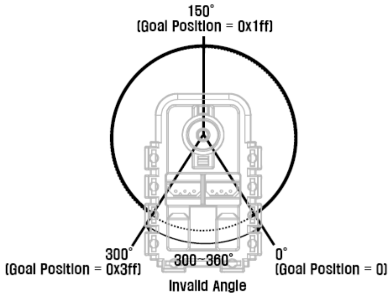

Fig. 5. AX-12 Position Table

Figure 5 is the range of AX-12 movements and it shows that AX-12 moves by about 1° when its position value is approximately 3.

Factors of "Set Speed" function include motor ID value and speed value. Speed values range from -1023 to 1023. With speed value set up in the maximum of 1023, AX-12 can move at a speed of 114RPM, if power is sufficient. If speed is set to be 1, it is the minimum speed. If it is set to be 0, AX-12 moves at the maximum speed which can be attained under current working voltage.[8]

3-3 ADC(Analog to Digital Convertor)

An analog digital convertor (ADC) is required to show variable resistor's voltage of the stick controller. Atmega 128 has 8 channels of A/D convertor with 10 bit resolution power.[6][8] Analog data are input through port F and then connected to A/D converter via multiplexer. It is capable of 10 bit resolution and takes 13-260us in conversion time. AD conversion results are aligned at either left or right side of AD converter data register for storage. Among registers related to A/D converter, ADMU X selects analog input channel on A/D converter, reference voltage source for A/D conversion and designates save format for conversion results. ADCH and ADCL registers are to save A/D conversion results and have different save format depending on whether ADLAR bit value of ADMUX register is '0' or '1' in Table 2.

TABLE 2.
ADMUX REGISTER

7	6	5	4	3	2	1	0
REFS 1	REFS 0	ADLA R	MUX 4	MUX 3	MUX 2	MUX 1	MUX 0

TABLE 3.
SUBROUTINE FOR SETPOSITION AND SETSPEED

```
void SetPosition(unsigned char ID, unsigned int Pos)
{unsigned char i, TxData[9];
TxData[0] = 0xff;
TxData[1] = 0xff;
TxData[2] = ID;
// ID
TxData[3] = 5;
// Parameter Length
TxData[4] = 0x03;
// Write Instruction
TxData[5] = 0x1e;
//WriteAddress
(P_GOAL_POSITION_L)
TxData[6] = (unsigned char)(Pos & 0xff);
TxData[7] = (unsigned char)(Pos >> 8);
```

Ⅳ. EXPERIMENT AND PERFORMANCE

Table 3 shows position and speed in server routines. A small robotic arm has been configured by use of 3 AX-12 motors. Stick controller controls 2 AX-12's while the button switch does one AX-12. Once each motor has been activated by means of "Set Speed" or "Set Position" functions, delayed time should be compensated by a certain amount of 20millisecond. This has caused difficulties to smooth movement but precision movement has been achieved anyway. We have attempted to control 3 AX-12's with a stick controller but been able to control only 2 AX-12 motors to the horizontal and the vertical axes as each motor needs to move 2-ways. 2 button switches have been used for up and down position control of the remaining AX-12 motor. In figure 6 it shows the example of up-down movement ID2 using 1 button. Figure 7 is the experiment device for control arm.

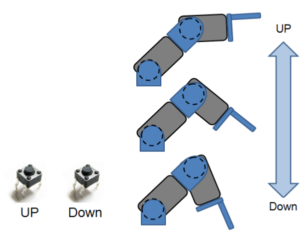

Fig. 6 The Example movement of ID 2 with AX12

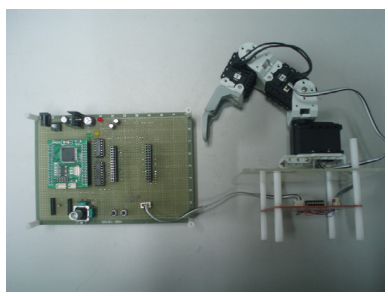

Fig. 7 Control Arm experiment device

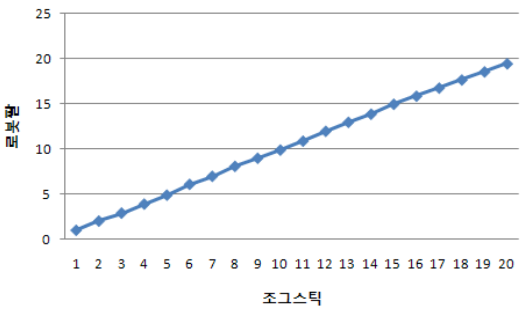

Fig. 8 Comparison of movement between Jog-Stick and Arm

Results of performance analysis are shown in Figure 8. For measurement of precision movement, an instruction bar has been attached to a jog stick and movement of the robotic arm coupled with joy stick movement has been measured. Movement was in error by less than 1% and we could observe precision movement. Error occurred against maximum movement of the jog stick due to change of internal resistance in the jog stick. With the use of precision jog stick, we could be able to realize a system virtually free from error.

Ⅴ. CONCLUSIONS

When we are unable to make precision movement in medical practices, support of precision control devices is indispensable. For precision control, we ordinarily need drive motors and high performance microcomputers to activate such motors.

In this study, we have realized a control device in the shape of a robotic arm using AX-12 motors having characteristics of servo motors. Precision control of the device was made possible within less than 1% in error. The possibility of application of the device to medical operation equipment has been ascertained. With remote data transmission to the stick controller of the control section, precision remote control can be achieved. We have found out that it is possible to apply such technology to remote medical system and remote operation control.

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