Abstract

Electrical wiring crossing over the robotic device up to 180 deg joints is difficult mechanical task. Number of the crossing wires must be reduced to minimum. Possible solution - data transmission must be provided over power AC or DC line (2 wires). There are many solutions on the market today [1] (internet, radio, TV). Described below solution is an attempt to design less costly and more suitable for mentioned task - to transfer data over power line based on CAN bus and CAN bus IC.

Keywords

CAN bus, robots, snake-like movement, control via power lines

Introduction

Electrical wiring crossing over the robotic device up to 180 deg joints is difficult mechanical task. Special means typically are used – wiring conductors, flexible connections etc. Such parts always is a point of the special attention due to great possibility of wiring destroying and connection loss.

Snake-like robotic device consist of many similar controlled electrical drives. Design here must be as compact as possible. Regardless of offered several systems, there are not so many suitable for mentioned task - to big, to expensive or haven’t AD converters etc.

There are a lot of IC (Integrated Circuits) on the market to design well known CAN bus (Controller Area Network bus) networking. In this article is described how some of these IC can be implemented in to robotic snake-like movement device control as well as in to other solutions where reduction of necessary wiring is important. Necessary control signals are send from central microprocessor to corresponding drives via power supply wires - only 2 wires are used to control all drives. Basic information and diagrams are provided to describe solution in general.

Robotic snake-like movement device [2] as well as similar equipment with many DOF (Degrees Of Freedom) is based on several motor drives - typical is one electrical motor per 2 DOF (fig.1).

Fig. 1. Robotic snake-like movement device elements

Controlling all DOF by PLC (Programmable Logic Controller) require 2 wires per motor and 2 wires per sensor (fig. 2).

CAN bus is a type of serial communication (like USB, RS-232 etc) and use 3 or 4 wires for all drives and sensors (fig. 3).

Fig. 2. Typical PLC - IN/OUT circuit: 2 wires per element.

Fig. 3. CAN bus connection circuit
CAN bus electrical data are set by ISO standards [3].

Today CAN bus have wide application in modern cars, light commercial vehicles and trucks as well as in industry. More than 10 well known manufacturers (Analog Devices, Atmel, Microchip, Intel, Bosch etc.) offer different CAN IC for different tasks.

Below are described possible application of the Microchip MCP250XX CAN input/output expander as the main programmable unit for each motor control as well as common power and control signal wires.

This can be achieved by sending/receiving data packets from/to CAN device.

The CAN bus is a broadcast type of bus. This means that all nodes can "hear" all transmissions. The CAN hardware provides local filtering so that each node may react only on the interesting messages. This allow to use the same media (wires) to control all drives and receive data from all sensors.

CAN message are built from several parts (fig.4)

1 CAN Input/Output expander

It is necessary to know:
- motor (or load) address (number),
- motor rotation direction and speed,
- rotation speed, tilt (if applicable) or turn angle sensor data (servo drive),
- motor overload data (if applicable),

to control several drives.

- SOF-start of frame bit;
- the Arbitration Field (12 bits), which determines the priority of the message when two or more nodes are contending for the bus, 11-bit Identifier and the RTR bit (CAN 2.0A);
- the Data Field (1 - 64 bit or up to 8 bytes);
- the CRC Field, which contains a 15-bit checksum for error detection;
- an Acknowledgement Slot (2 bits). Any CAN controller that has been able to correctly receive the message sends an Acknowledgement bit at the end of each message. The transmitter checks for the presence of the Acknowledge bit and retransmits the message if no acknowledge was detected;
- EOF-end of frame bit.

- Microchip MCP250XX block diagram [4] (is shown on fig. 5 and pinout description on tab.1.

CAN bus data transfer rate is between 10 kbps (kilobits per second) at distance 1000 m and 1 Mbps at distance 40 m. All modules must support 20 kbps.

In robotics and mechatronics distance between CAN modules typically is less than 40 meters so here CAN bus can be driven on full speed - 1 Mbps.

Full CAN 2.0 A data package contain 32 - 95 bits and package transfer time is 32 - 95 microseconds at 1 Mbps. In a lot of cases in similar devices 2 data bytes are maximum - one Node module address byte and one information request byte. Data transfer double time (Node module information request and date receiving) is 0,094 milliseconds at 1 Mbps data rate.
Table 1. IC MCP250XX pinout description

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Standard Function</th>
<th>Alternate Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP0/AN0</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>Analog input channel</td>
</tr>
<tr>
<td>GP1/AN1</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>Analog input channel</td>
</tr>
<tr>
<td>GP2/AN2/PW M2</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>Analog input/PWM output</td>
</tr>
<tr>
<td>GP3/AN3/PW M3</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>Analog input/PWM output</td>
</tr>
<tr>
<td>GP4/VREF-</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>External VREF-</td>
</tr>
<tr>
<td>GP5/VREF+</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>External VREF</td>
</tr>
<tr>
<td>OSC1/CLKIN</td>
<td>External oscillator input</td>
<td>External clock input</td>
</tr>
<tr>
<td>OSC2</td>
<td>External oscillator input</td>
<td></td>
</tr>
<tr>
<td>GP6/CLKOUT</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>CLKOUT output</td>
</tr>
<tr>
<td>GP7/RST/VPP</td>
<td>Bidirectional I/O pin, TTL input buffer</td>
<td>External Reset input</td>
</tr>
<tr>
<td>RXCAN</td>
<td>CAN data receive input</td>
<td></td>
</tr>
<tr>
<td>TXCAN/TXR CAN</td>
<td>CAN data transmit output</td>
<td>1-wire operation</td>
</tr>
</tbody>
</table>

2 Theory of operation

Simplified electrical circuit containing one Master module and one Node module are is shown on fig. 6. Practically there are one Master module and up to 256 Node modules (vs. 16 nodes mentioned in reference [5]). The whole data sending - receiving time is $256 \times 0.094 = 24.064$ ms. 256 elements snake-like movement device control frequency therefore is up to 41.5 Hz.

Master module send to Node module necessary information and information requests. After information request Node module send information to Master module. Master Module can be connected to other computer.

Node module receive data and instructions from Master module, receive analog information from sensors, provide A/D converting, data filtering and comparing, PWM (Pulse-Width Modulation) motor drive and send data to Master module after request.

To send data from Master module to Node modules over power wires switch T1 is used. Switch T1 is controlled by CAN IC MCP250XX (2-wires operation mode- separate pins for Rx and Tx signals)

Switch T1 is closed during receiving data from Node modules.

Fig. 6. Data transfer over power line simplified electrical circuit – 2 motors per node

Fig. 7. Data transfer over power line simplified electrical circuit – motor per node
Necessary energy to power Node modules during sending data between modules is accumulated in capacitor C on each Node module. Open switch T1 allow to charge capacitor C via switch T1 and diode D.

Node module use MCP25055 IC in mode to organize 1-wire operation (the same pin for Rx and Tx signals)

Comparators, H-bridge and motors in general are shown for illustration purposes. Comparators are used to detect and determine motor rotation direction. If average PWM voltage (capacitor C2 voltage) is:

- \(< +V/3\) - rotation clockwise,
- \(> +V/3\) and \(< (+V \times 2)/3\) - no rotation,
- \(> (+V \times 2)/3\) - rotation counterclockwise.

Rotation direction is relative here - just for explanation. PWM values are set be sending corresponding code to Node module IC.

Schematics is different to control one motor per Node module (fig. 7.). Amp1 and Amp2 can have different schematics - for example half-bridge. Difference between schematics shown on fig. 6 and fig. 7 is doubled number of IC and half of possible number of Node modules to be controlled (up to 128 Node modules instead of 256 in the first description). Advantage is more simple motor power circuit - half-bridge instead of the full H-bridge.

Other - CAN bus - is the same for both circuits.

3. Practical design remarks

Practical design schematic drawing is shown on Fig. 8.

According to robotic snake-like movement device design:

- power supply voltage 5 V;
- electrical motor 3 V, 40 mA (no load), gearbox with worm gear output;
- drive wires are used as power wires (fig. 8), pulleys are used as contacting surface.

Conclusion

CAN I/O expander IC allow to design simple and reliable electric circuits to achieve simple and robust data transmission over power lines to reduce possible wiring damage over up to 180 deg bending joints.

References