A Stepper Motor and Serial Communication Interface Daughter Board for Educational Use

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Abstract

This paper presents the design and development of a daughter board consisting of stepper motor drivers and serial interfaces. The purpose of this board is to provide embedded systems students with a tool to design and develop automation applications using stepper motors and simple RS-232C serial communications. The stepper motors used is a bipolar six–wire configuration motor. Software drivers for serial communication and the stepper motors are written in the 'C' language using the High-performance Embedded Workshop (HEW) Integrated Development Environment provided with the Renesas Embedded Evaluation Board. The stepper motors are programmed to drive in full step, half step, and micro step mode. The circuit was tested on a breadboard for functionality and the PCB layout was designed and manufactured.

Key words: Serial communication, stepper motor

1. Introduction

In today's world, the need for more and more embedded engineers is increasing with the explosion of usage of microcontrollers. Embedded system make up over 90% of worldwide electronic devices and by the year 2010 there will be 10 times more embedded programmers than other types of programmers [1]. Therefore, there is a need to develop different tools to be used to train students in the embedded field. While working on various embedded systems course lab work, students often request additional instruction and hand-on experience on various interface technologies.

Stepper motors are widely used in the automation industry. Various communication techniques are employed to control these motors, including embedded systems, Personal Computer, and programmable logic controllers. The authors decided to design a daughter card that can be plugged into an instructional embedded evaluation board.

The design of the daughter board consists of Stepper motor and serial communication interface. The test board developed has a tool for students to study and implement these two functionalities in various automation applications [2]. A microcontroller-based stepper motor interface is used to energize the motor windings sequentially and control and step size precisely. Parallel port interfacing is used to give the logic signals to the windings. Stepper motors cannot be driven directly using the microcontroller signals. The microcontroller signals must be amplified to the required power to drive the motor. To give more control to the user, the microcontrollers is interfaced with Personal Computers using RS-232C serial communications. RS-232C is a standard for serial binary data interconnection between a *DTE* (Data terminal equipment) and a *DCE* (Data communication equipment). It is a commonly used computer serial port, but more important, is widely used in industry for simple, low speed communications.

After the design of the board, the circuit was tested at the breadboard level. After successful testing, a two-layered PCB layout was designed and manufactured. It consists of two DB9 connectors, one RS-232C driver IC, and four stepper driver ICs to drive two stepper motors.

Figure 1 shows the block diagram for the daughter board. UART 0 and UART 1 are used for serial communication and port P4 and P5 are used for communication with Driver IC's. The board designed attaches to the Renesas SKP30626 Evaluation Board.

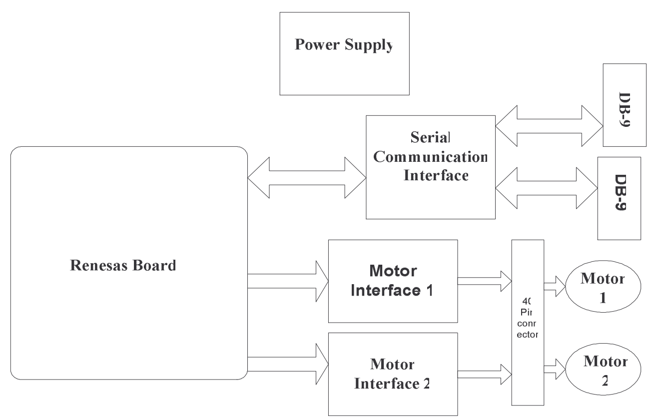

Fig. 1. Block diagram for the daughter board

The Motor Interface block represents the drive circuit for the motors. Each block consists of 2 LMD18245 T IC's. Serial Interface block consists of MAXIM 232 IC.

2. Board Interfaces

2.1 Stepper Motor

A stepper motor system is an electromechanical rotary actuator that converts electrical pulses into shaft rotations. It is a brushless dc motor whose rotor rotates in discrete angular increments when its stator windings are energized in a programmed manner [5]. Rotation occurs because of magnetic interaction between interpoles and poles of the sequentially energized stator windings. The rotor has no electrical windings, but has salient and/or magnetized poles. Hence, a stepper motor is a digital actuator, whose input is in the form of sequential energization of the stator windings and whose output is in the form of discrete angular rotations [6]. It is suited for use as an actuator in computer control systems and digital control systems.

The windings of stepper motor can be either unifilar or bifilar. Unifilar has one winding per stator pole, hence they have four lead wires. Bifilar has two identical sets of windings on each stator pole. Stepper motor includes full, half, and micro step modes. The type of step mode output of any motor is dependent on the design of the driver [6]. Full (standard) stepping motors have 200 rotor teeth, or 200 full steps per revolution of the motor shaft [6]. Dividing the 200 steps into the 360°'s rotation equals a 1.8° full step angle. Hence, in full step mode both windings are energized while alternately reversing the current. Thus one digital input from the driver is equivalent to one step. In half step mode the motor is rotating at 400 steps per revolution. In this mode, one winding is energized and then two windings are energized alternately, causing the rotor to rotate at half the distance, or 0.9. Although it provides slightly less torque, half step mode reduces the amount "jumpiness" inherent in running in a full step mode [6]. Micro stepping controls the current in the motor winding by further subdividing the number of positions between poles. It is used in accurate positioning and fine resolution applications over a wide range of speeds.

2.2 Stepper motor Interface

The LMD 18245T IC is used as a stepper motor driver. The LMD18245 T full-bridge power amplifier consists of all the circuit blocks required to drive and control current in a brushed type DC motor or one phase of a bipolar stepper motor as shown in Figure 2. The LMD18245 controls the motor current via a fixed off-time chopper technique [3]. Based on the feedback, the chopper amplifier switches the bridge power to control and limit the current in the windings of a motor. The bridge is made up of four solid-state power switches and four diodes connected in an H configuration. Figure 2 describes the flow of the system. Based on the input digital data to the DAC, it generates corresponding analog voltage that acts as a threshold. The obtained threshold is compared with the winding current Thus determines the duty cycle. It is fed to the monostable multi vibrator.

While the winding current remains less than the threshold, a source switch and a sink switch in opposite halves of the bridge force the supply voltage across the winding, causing the winding current to increase rapidly [3].

Figure 3 shows the configuration of H-bridge used in the IC. The power stage consists of four DMOS power switches and associated with diodes connected in an H-bridge configuration. While the bridge remains in this state, the winding current increases exponentially towards a limit

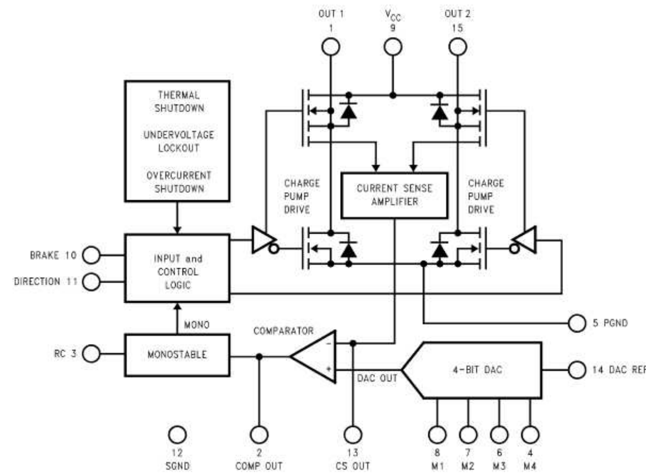

Fig. 2. Functional block diagram of the LMD 18245T [3]

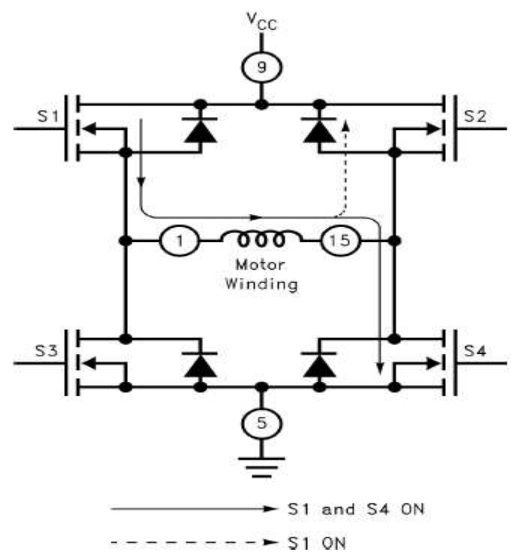

Fig. 3. H-bridge configuration in the LMD 18245T [3]

dictated by the supply voltage. Subsequently turning OFF the sink switch causes a voltage transient that forward biases the body diode of the other source switch. The diode clamps the transient at one diode drop above the supply voltage and provides an alternative current path. While the bridge remains in this state, it essentially shorts the winding and the winding current recirculates and decays exponentially towards zero. During a change in the direction of the winding current, both the switches and the body diodes provide a decay path for the initial winding current. Figure 4 shows the circuit required to drive a single motor. Note that PGND (Pin 5) and SGND (Pin 12) is isolated through out the board and shorted close to IC to reduce effect of high current in power ground over signal ground.

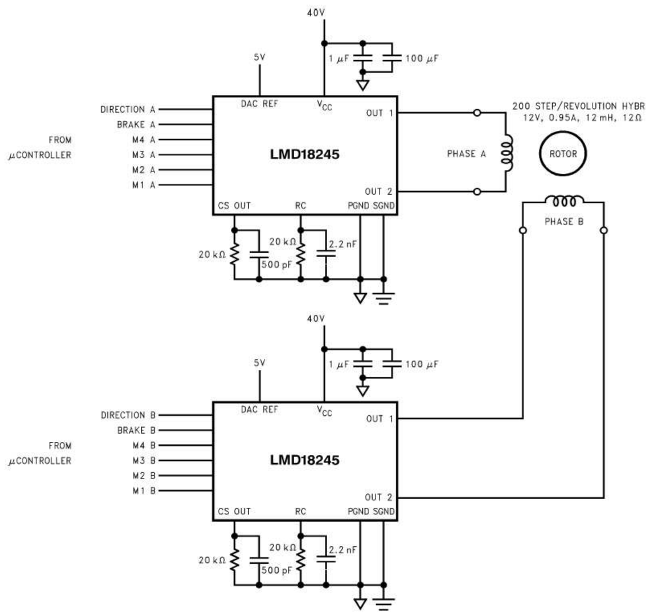

Fig. 4. Drive circuit configurations for a single motor [3]

2.3 Serial Communication for RS-232C

The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply EIA-232 voltage levels from a single 5-V supply. Each receiver converts EIA-232 inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V and a typical hysteresis of 0.5 V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into EIA-232 levels. [4]

3. Project Design

Figure 5 shows the general flow of the project. The circuit was tested with a breadboard to verify the functionality. Then the schematic was drawn to create the layout for the board in ORCAD layout plus.

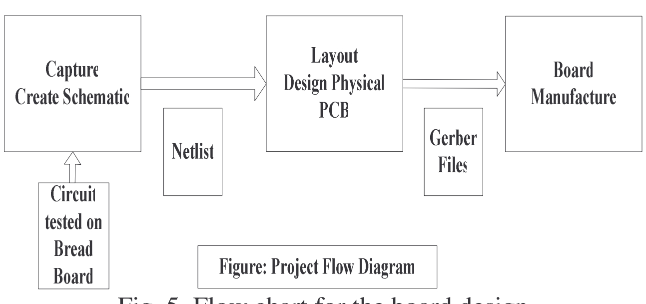

Fig. 5. Flow chart for the board design

3.1. Schematic Design

The board schematic has been designed using Cadence ORCAD Capture® tools. The schematic can be divided into two sections. First section consists of the stepper interface containing four IC's to drive two motors. The second section consists of the serial interface using one MAXIM 232 IC. Power and ground for the driver circuit and digital grounds are properly isolated throughout the board and connected only at required locations. The board is designed to plug directly into the Renesas SKP30262 board; hence the board dimensions were constraint while designing the layout. The board is designed for two layers and care is taken to isolate the H-bridge tracks carrying higher power from digital tracks. Apart from LMD 18245T (TO-220 package) all other components are surface mount allowing us to reduce the space and cost for the board. To filter out noise from the board, decoupling capacitors are used liberally. Figure 6 shows the schematic for the board.

3.2. ORCAD Design

With the help of net list generated in CIS capture, the layout was designed. The challenges faced while creating the layout was to isolate the stepper driver and serial communication tracks from each other to reduce noise in the system.

4. Testing and Implementation

The following methodology was used in the board design and manufacture process [7].

1. Theoretically calculated the power rating for the components based on the motor ratings and schematic.
2. Separately simulated the stepper circuit and serial circuit on breadboard and programmed it.
3. Ascertained that the circuit was working fine independently. Then programmed them to interface with each other.
4. Developed the PCB layout for the board.
5. Tested the manufactured board for possible shorts and continuity.
6. Soldered all the components and test the board for functionality.

The board is ready to be used for different laboratory type projects.

5. Conclusion and Future work

The daughter board can be used as the experimental test board for future students in embedded system courses. With the additions of modules such as RF communication it can become a more comprehensive student learning board. The future work in this project involves developing a front end to configure the motors in different modes and also will be able to read motor parameters. In our project RS-232C communication is used, with the addition of USB communication several new applications can be created. We believe this daughter board will work as an effective tool for students to learn and work on projects quite similar to the industry environment.

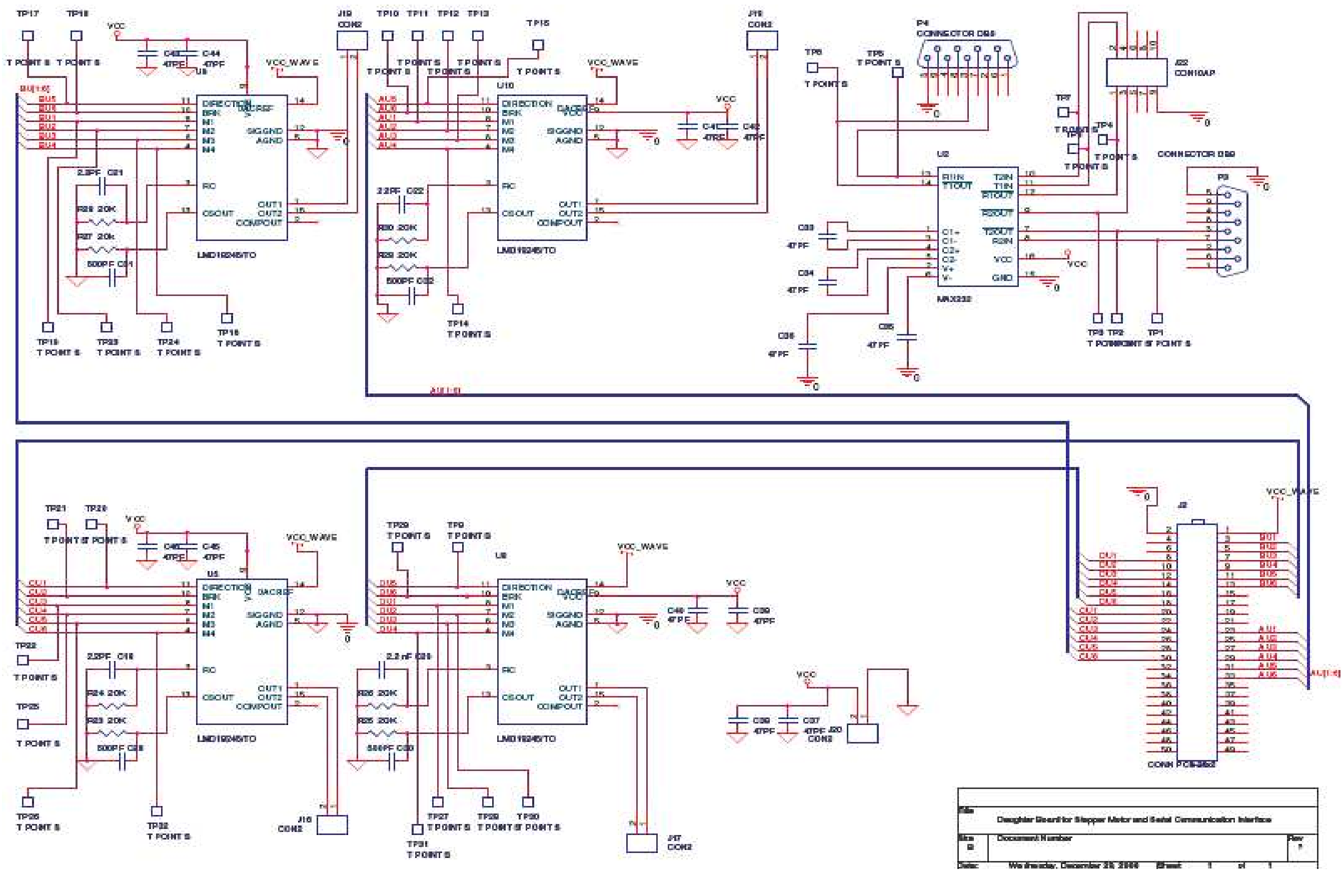

Fig. 6. Schematic for the daughter board

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