

Michigan State University
ECE 480 – Senior Design
Design Team 6
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MSP430-F1612 AND THE STELLARIS-LM3S9B95
STEPPER MOTOR CONTROL CARDS FOR THE DRV8824
MOTOR DRIVER

EXECUTIVE SUMMARY

Texas Instruments has developed an evaluation module for their newest motor driver the DRV8824. This evaluation module comes with a MSP430F1612 on board to control the motor driver. The MSP430 uses two pulse-width modulation (PWM) signals to control the motors speed.

The problem that faces Texas Instruments here is that the customers can only use this brand new motor driver with code written for just the microcontroller that is on the DRV8824 evaluation module. Texas Instruments would ideally like to have an evaluation module that could drive motors and be compatible with many different microcontrollers.

To solve this problem the board will be partitioned into two parts, a motor driving board and a controller card. The motor driving board will have a DIMM slot that will be able to accept multiple controller cards that can all have different microcontrollers onboard.

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INTRODUCTION

The electric motor has been around since the early 1800's, and it is still a very important piece of equipment today. Electric motors are used in many devices today, including cars, air conditioners and microwaves. There are also many types of electric motors, including brushed, brushless and stepper DC motors. Each type of motor can be used in many different applications, and each motor must be controlled to fulfill the requirement of the applications.

Texas Instruments (TI) is a company that offers many ways to control electric motors. The DRV8824 is one such control device. The DRV8824 is a pulse width modulation (PWM) microstepping motor driver. TI would like to make this card modular, by allowing different microcontrollers to be connected to DRV8824 with minimal effort. This will allow TI's customers to use their preferred microcontroller, and also TI will not have to create a separate DRV for each microcontroller. TI plans to have each type of microcontroller on a dual in-line memory module (DIMM) card, and then the DIMM card will interface to the DRV board.

Last semester's design team integrated an MSP430 on to a DIMM card. The MSP430 is a 16-bit microcontroller. They also programmed and created an interface to control the electric motor. Design Team 6 (DT6) will expand on this project. DT6 is tasked with both software and hardware designs. On the hardware side DT6 will remove the MSP430 from the DRV8824 and integrate it on a DIMM card. They also plan to attach a DIMM card slot to the DRV8824 board. On the software side, DT6 needs to write code for controlling the stepper motor. TI has also provided a DIMM card with a Cortex M3 already in place. Hence, DT6 must port the code from the MSP430 DIMM card to the M3.

Upon completion of these tasks TI will have 2 DIMM cards. One will contain the MSP430 that was removed from the DRV8824, and the other will contain the Cortex M3 microcontroller. These cards will both be able to control the electric stepper motor by interfacing with the DRV8824 through the DIMM card slot.

BACKGROUND

Texas Instruments has developed a DRV8824 Motor Drive EVM to demonstrate motor control to potential customers. The motor drivers have potential applications in printers, scanners Automatic Teller Machines, robotics, gaming systems and other automated systems. The board is equipped with two H-bridge motor control drivers and can be used to drive a bipolar stepper motor or two DC motors. The H Bridges structure is used extensively in motor control and allows a voltage to be applied across a load in two directions. This allows DC motors to run forwards and backwards.

The DRV board also provides internal shutdown functions for over-current protection, short circuit protection, under voltage lockout and thermal protection. The current through the motor is regulated by pulse width modulation (PWM). When an H-bridge is enabled, current through the motor increases until it reaches a defined threshold. Once the current reaches this threshold, the bridge then disables the current until the beginning of the next PWM cycle.

FAST DIAGRAM

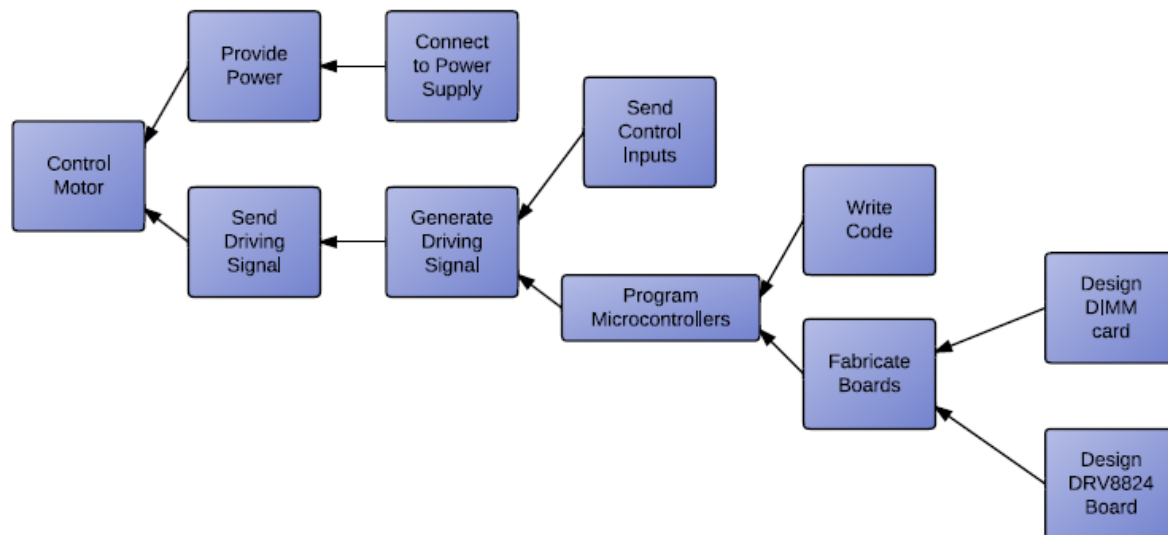


Figure 1. This is the fast diagram showing all of the steps that need to be taken in order to control the motor. First, the DRV8824 board and DIMM card must be designed and fabricated. Then the microcontrollers need to be programmed. Then finally the control inputs can be sent from the PC to the DRV8824 to control the motor.

CONCEPTUAL DESIGN DESCRIPTIONS

As shown in Figure 2, the design consists of five parts: the PC, the DIMM card with the MSP430, the DIMM card with the Cortex M3, the EVM board which has the DRV8824 and the stepper motor. The PC will communicate with the DIMM cards by a USB connection. It will also use the connection to program the microcontrollers. The PC also has a GUI that sends signals to the microcontrollers on the DIMM cards. Each DIMM card is connected to the DRV8824 through the DIMM100 slot that will be installed on the EVM board. The microcontrollers will process the signals from the PC and then send the signals to the DRV8824 which will drive the motor. The DRV8824 will then receive feedback from the motor. This data will be then sent back through the microcontroller to the PC.

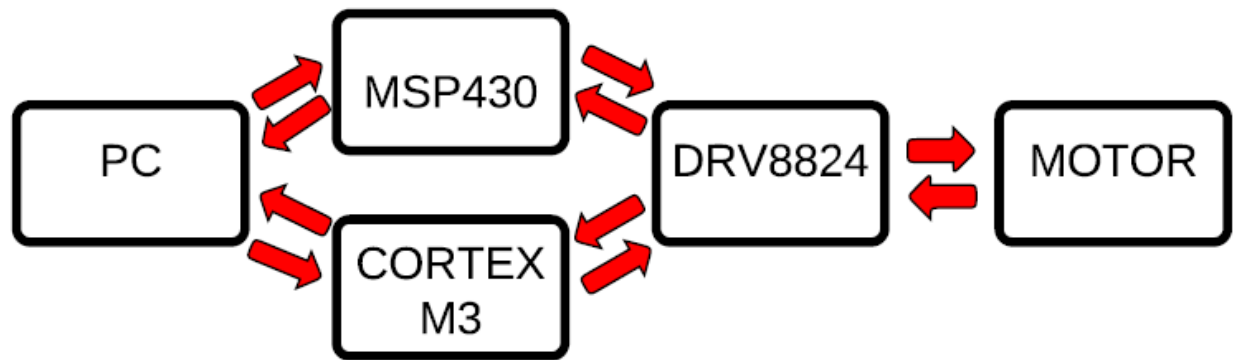


Figure 2. The diagram above depicts how each component of the entire system, when finished, will communicate with each other.

RANKING OF CONCEPTUAL DESIGNS

As shown in Table 1, the components of the design and the design criterion were compared. Each design criterion was given an importance value (1 being least important, 5 being most). Then each component is compared to each of the design criteria and assigned a value of 9, 3, or 1. Then by multiplying the importance value with the correlation value and adding up each column, the resulting numbers at the bottom of the table are calculated. The values highlighted green are the most vital parts of the design. Whereas the values highlighted red do not have much to do with the design portion of the project.

Design Criterion	Importance	Stepper Motor	DRV8824	MSP430	Cortex M3	PC GUI	Microcontroller Code	PC
Motor Control	5	△	●	●	●	△	●	△
Communication with Motor	5	△	●	○	○	△	△	○
Cost	3	△	○	○	○	△	△	△
Power	3	●	○	○	○	△	△	△
Aesthetics	2	△	△	△	△	●	○	△
Safety	4	○	○	○	○	△	△	△
Revisable Software	4	△	△	△	△	○	●	△
		58	126	96	96	50	102	36

● Strong (9)
○ Moderate (3)
△ Weak (1)

Table 1. The table above compares the components of the project with the design criteria. The DRV8823, MSP430, Cortex M3, and the microcontroller code are the most important aspects of the design.

DESIGN SPECIFICATIONS

Texas Instruments has provided several design specifications for a modular approach to control of a stepper motor evaluation module. The modularity of the design will originate from the ability to interchangeably use multiple microcontrollers, the MSP430 and the Stellaris M3 Cortex, to control a stepper motor. To provide the modularity required for this design, DIMM100 interface cards will contain the circuitry for the microcontrollers. These DIMM cards will mount onto the DRV8824 circuit board to interface with the motor driver.

The MSP430 family of microcontrollers is as low cost, low power microcontroller designed for embedded applications. It is a 16-bit microcontroller with a maximum clock speed of 8 MHz. However the clock speed may be reduced to provide lower power modes. The MSP 430 provides 16 16-bit registers, with a very simple instruction set of only 27 instructions.

The Stellaris M3 Cortex is another microcontroller that provides low power solutions for embedded applications. The Stellaris is an ARM architecture which provides the ability to use both 16-bit and 32-bit instructions while it is a 32-bit processor. It can operate at a maximum clock rate of 80 MHz while providing 16 32-bit registers.

The microcontrollers are required to operate and control the stepper motor in the same fashion. The same software will be used between the microcontrollers. This allows for the same functionality, however creates the requirement to port the current code from one microcontroller to the next. Inputs in the software for one microcontroller must be translated to the correct inputs on the next microcontroller. Alongside the software for controlling the microcontrollers, the Windows application currently provided must contain a form to control each new microcontroller. The application will allow for control of stepping speed, acceleration rate, direction, and switching frequency.

The final design will contain the following:

- Schematic and PCB design for the modified DRV8824 evaluation module.
- A Fabricated DRV8824 EVM with a DIMM100 socket.
- Schematic and PCB design for a DIMM100 card containing the MSP430 F1612 microcontroller containing USB interface.
- A fabricated DIMM100 card redesigned with the MSP430 F1612 microcontroller and USB interface.
- A fabricated DIMM100 card supplied by Texas Instruments containing the Stellaris M3 Cortex microcontroller.
- Software to control the MSP430 microcontroller and the M3 Cortex microcontrollers.
- A Windows application containing sections to control each of the available microcontroller DIMM100 cards.

PROPOSED DESIGN

The proposed solution encompasses the hardware redesign of the DRV8824 evaluation board, and the design of the MSP430F1612 DIMM control card. In addition, software to control the motor will need to be ported to the Stellaris M3 DIMM cards. The hardware redesign consists of removing the digital section of the DRV8824EVM and replacing it with a DIMM slot. To achieve this, the pin outs of the M3 Cortex card will be carefully studied in order to design a functional MSP430F1612 control card.

There are three major steps for accomplishing our project.

- Removal of the MSP430F1612 and definition of DIMM ports

The DRV8824EVM has a MSP430 microcontroller on board that will be removed. There will then be input and output wires that need to be connected to the DIMM slot. The DIMM ports will be ported based on the pins that the Stellaris control cards can both control the motor driver.

- Design of MSP430F1612 Control Card

Once the definition of the DIMM ports is selected then the design of the MSP430F1612 control card can take place. The code will be the same as that the DRV8824EVM comes stock with, but the control card will be a removable extension of the DRV8824EVM.

- Coding of the Stellaris Control Card

Since the Stellaris has never been programmed to work with the DRV8824 motor driver before, the code from the MSP430F1612 will be ported to the Stellaris control card. This will require much porting of 16-bit registers to 32-bit registers. The reason this will work is because ARM's architecture allows for 32-bit micro-controllers to still run 16-bit instructions.

RISK ANALYSIS

Risk	Effect	Level of Impact (1, 3, 6)	Likelihood (1, 3, 6)	Score
Delayed PCB layout Design	Delayed PCB Fabrication	3	3	9
Delayed PCB Fabrication	Delayed code Debugging and Testing	6	1	6
Incorrect DRV8824 Design	Inability to control motor	6	3	18
Incorrect MSP430 DIMM Design	MSP430 DIMM rendered useless. Stellaris still valid.	3	3	9

Table 2. The table above shows the risks and likeliness of their occurrence during the design process. An incorrect DRV8824 design would greatly affect DT6's ability to finish the project on schedule.

PROJECT MANAGEMENT

Our team is tasked with designing a DIMM100 card using the MSP430-F1612, redesigning the DRV8824EVM, and coding the Stellaris-LM3S9B95. Our team consists of Leslie Thomas, Patrick O'Hara, Thomas Volinski, and Kole Reece. The following tables break down both the technical and non-technical roles performed by each team member:

Team Member	Technical Role	Focus
Leslie Thomas	Software/hardware development	STELLARIS
Patrick O'Hara	hardware development	DRV8824EVM
Thomas Volinski	Software/hardware development	MSP430-F1612
Kole Reece	hardware development	MSP430DIMM

Team Member	Non-technical Role
Leslie Thomas	Manager
Patrick O'Hara	Document Prep
Thomas Volinski	Presentation Prep
Kole Reece	Website

BUDGET

Each design team is given \$500 for parts budget. There is an estimated 100 parts to complete the project. All the parts have been ordered and the total as \$55, which was reduced by \$30 because TI allows students to order samples of their products. Estimates for PCB fabrication and assembly from the service provider TI uses were \$140 and \$350, respectively. These estimates were done by taking the original unedited PCB and requesting a professional quote, which allows for an accurate estimation of the fabrication and assembly costs. Once this project is finished a load will be needed on the motors for demonstration on Design Day.

Expenses	Cost
Surface Mount Parts	\$55.97
PCB Fabrication	\$140
PCB Assembly	\$350
Total	\$470.97

Table 3. The table above shows the estimated worst case expenses of the entire project. The total expense comes in just under the allotted \$500.

PCB assembly as it stands right now is at its absolute maximum. The team plans to use the ECE shop in the engineering for assembly of the new DRV8824. This will allow the ability to have multiple boards assembled for free. On the other hand the MSP430 DIMM cards components are too small and will require the PCB assembly companies to do this.

References

<http://www.onestopassembly.com/>

<http://www.4pcb.com/>

<http://www.ti.com/>