**Design Issues**

MSP430 Motor Control Card

Michigan State University – ECE480 – Design Team 4

Roy Dong
Micajah Worden
Mark Barnhill
Andrew Kleeves
Dave Seaton

**Introduction**

Our sponsor, Texas Instruments, is planning on introducing a new revision (rev. F) of the DRV8412 motor driver card. The DRV8412 provides a large amount of functionality for the purposes of driving a motor. The DRV8412 has on-board DACs, which calculate the equivalent DC voltage of Pulse-Width Modulated (PWM) signals, PWM amplifiers, which amplify supplied signals to levels sufficient to drive motors, and current sensors, for advanced motor control utilizing feedback. However, the DRV8412 does not have any on-board control capability.

Texas Instruments wants the DRV8412 to be released with several motor control cards using a variety of microcontrollers to increase demand for the DRV8412. The new revision of the DRV8412 will utilize a 100-pin Dual In-line Memory Module (DIMM100) interface for communication between the DRV8412 and a motor control card. These motor control cards should both be able to provide simple driving signals to the motor as well as implement robust control of motor speed and torque in the presence of dynamic loads.

In the design of this project, it is important to consider several issues related to product design. First, we discuss the entire product lifecycle, from design to disposal. Then, we discuss issues of safety already accounted for, as well as potential ideas for improved safety prior to production. Finally, we propose several design changes that would allow the product to be utilized by a more universal consumer base.
Product Lifecycle Management

Product lifecycle management, or PLM, is an important plan of action regarding the lifecycle of a product. This follows the entire lifecycle of a product including design, production, distribution, consumption, and the disposal of the product.

When designing the MSP430 control card many things were taken into account. Our product has to be representative of the quality that Texas Instruments has demonstrated in past products. This was done through extensive research of the C2000 control card and its functionality, as well as research into the MSP430F5435 processor, which we use to replace the Piccolo C2000F28035 used in the previously designed C2000 control card. This also accounted for our customer need, because Texas Instruments requested that we make the MSP430 control card function exactly the same as the C2000 control card. Timing is also a major issue. Given 15 weeks to design and produce the control card, strict deadlines had to be met, and milestones achieved. To do this, we produced a Gantt chart to track progress and ensure that the project was advancing as planned. Energy efficiency is accounted for through the use of an extremely low power MSP430 microprocessor, as well as emulating the peripheral circuitry on the C2000 control card. This should produce efficiency roughly equivalent to that of the C2000 control card. To provide testability of the MSP430 control card, test points were designed into the PCB board to test the ground and the power layers of the four-layer board, as well as placing LEDs on the board to visually show that the board is powered. In order to ensure the product remains up-to-date, continued software support would be recommended.

The next step in realizing the MSP430 control card design is to produce a prototype. Manufacturing costs were a big issue, because of the $500 dollar budget, and the quantity of surface mounted components designed into the MSP430 control card. Total cost of production included $150 dollars for discrete components, and $1154 for fabrication and assembly of the control card. The budget had to be renegotiated, to account for the high cost of surface mounting and fabrication. Production time also became a huge issue. The company we had initially contacted, Hughes Circuits, to produce the control card gave us an estimated time of delivery of 20 days, putting us far past our deadline. After contacting many companies, Sunstone Circuits provided us with
a much quicker option of 3 days for fabrication and 2 days for assembly through another company, Screaming Circuits. The per-unit costs would be expected to go down with large scale production of this product. To ensure quality control, each board undergoes electrical testing to check layer isolation, and the validity of traces. Environmental concerns associated with the caustic chemicals used in PCB production, would be encompassed by Texas Instruments’ current disposal methods, most likely recycled, or properly disposed of when they have outlived their usefulness.

Texas Instruments is a very large company, and has many resources available in the distribution of products. Many products can be ordered through Texas Instruments’ website, or a third party distributor with expedited or regular shipping. Shipping costs depend on the time frame the end user desires the product be shipped in. Since this product is associated with the upcoming release of the DRV8412 motor driver, Texas Instruments would advertise the MSP430 control card as an option for controlling the motor along with the C2000 control card. Texas Instruments has large warehouses in which this product would be stored until it was shipped to a customer. More units would be made according to the amount of products in the warehouses as well as demand for the product.

How the customer will learn to use this product is another major concern for the success of this product. Texas Instruments is well known for their customer support, data sheets and application notes. Texas Instruments is aware that availability of resources to operate their products is essential to the eventual success of a product, and takes care in providing many resources to facilitate ease of use by the consumer. Data sheets and application notes would be available through their website. Trained customer service people would be easy to contact through Texas Instruments’ support lines. For repairs, the user would send the card to Texas Instruments to check for solutions to their problems. Continued software support would be a vital part of continually improving the performance of this product, keeping it current and keeping it functioning. Hardware upgrades would, most likely, not be in the plans for this product once it has been shipped, but possible revisions to the card could occur.

With an increasing awareness of environmental issues, and hard evidence of the impact of humanity on our surrounding world, many companies are taking an active role
in providing environmentally friendly ways to dispose of their products. Though this is a relatively new thought process in our consumerist nation, we can look to Europe for some examples of how to minimize the impact of products and preserve the environment for future generations. In the future, products will most likely have some sort of deposit associated with them. When the product has reached the end of its lifecycle either a customer would drop off the part to the distributor, where they would receive a refund of their deposit, or the device would be shipped back to Texas Instruments, with return shipping included in the original price of the product. This would provide customer incentive to return the product, and Texas Instruments could salvage what they could for recycling, remove heavy metals from the board, and properly dispose of what no longer has a use in an environmentally conscious manner.

**Product Safety**

Due to the nature of motor control, it can be dangerous if not properly handled. Like all electrical circuitry, there is power involved and improper wiring can shock the individual using the device. Also, there are moving parts that are associated with the operation of the device. If misused, these moving parts could potentially damage the equipment or cause injury. The motor control system our product uses, the MSP430 motor control card, can be decomposed into distinct parts, each with different safety issues: the control card, the driver board, the power supplies, and the motors.

Although the control card is a small, low-power device, proper use is still necessary to ensure safety. If the card is not properly handled, it is possible that the user may damage the control card or attached equipment. Also, there is a small chance that misuse can result in an electrical shock. Another issue is the control card is fully user-programmable. The user is responsible for the ultimate signal outputted from the card; if software is not properly designed, the motor could draw large spikes of current that are highly dangerous to equipment and personnel. When the MSP430 control card comes into production, it is highly recommended that Texas Instruments include fail-safe software modules. These modules must limit the control card’s output to a safe range, as well as provide ease of access, understanding, and utilization, without hampering
functionality significantly. Such fail-safe implementations would protect the safety of users and equipment.

Unlike the control card, the motor driver board draws significantly more power. The driver board has dual 12V inputs and can pull large amounts of current. The large current is necessary to drive a motor, but also presents significant safety issues. Without proper safety measures, the user can potentially shock themselves with enough current to cause death. It is recommended that the driver board implement an adjustable current-limiter in the hardware. Many uses of the driver board need not draw as much current as the board, and this safety-oriented hardware could greatly decrease the risk of fatal injury without any adverse effects to functionality.

The power supplies used to provide power to the motor driver board are not specified; the user is free to choose any power supply based on their application. It is highly advised that the user read the instruction manuals for their respective power supplies, as well as understand the safety risks of power supplies before using any of Texas Instruments’ motor operating hardware or software. Also, great care should be exercised in the wiring of power supplies; these supplies are capable of providing large amounts of current, which may prove fatal in misuse. In terms of Texas Instruments’ technology, “High Voltage” warnings are readily visible on the driver board, and the proposed current limiter on the driver board would decrease the chance of injury or damage.

Motors come in many different types with different capabilities, so the user is responsible for understanding the characteristics and behaviors of the motor for safe operation. A motor, by nature, generates motion and this introduces the possibility of injury or equipment damage in misuse. It is difficult to enforce safety measures on motors, because the motor itself is beyond the scope of the equipment provided by Texas Instruments. However, easily visible warnings and safety instructions would greatly reduce the risk of dangerous outcomes due to motor misuse.
Universal Design Principles
One of the most important features of all operator-based products is design elements that allow a broad range of people to use the product. This can involve facilitating accessibility for persons with disabilities, to automating entire processes, to simplifying product use for inexperienced operators. Some of these features, regardless of their original intended purposes, can also be used to improve the overall user experience and the speed of operation. In some cases, designing this into the system may come to be required by law or industry standard. This section of our paper will discuss some potential solutions for universal design in our MSP430 control card project.

Systems based on graphical programming languages are often more intuitive for many people who find textual programming difficult. Whether it involves making a Simulink model or LabVIEW virtual instrument, providing a visual interface allows a non-technical user to grasp how a certain software module works and allows a technical user to interpret and begin advancing software more quickly. Since our software is composed of different functional blocks of code such as the Ramp Control or Speed Measurement modules, written code can easily be encapsulated in a visual representation. Once the tasks are summarized, it can be easily taught to less experienced programmers. The premade blocks would have inputs or a properties dialogue to change certain attributes. This would allow for a more diverse set of users of our final product. At the more advanced level, the blocks can be disassembled into C code and developed further or modified for more advanced programmers.

Another possible general usability idea that can double as an accessibility feature is a text-to-speech assistant that will improve the overall operator experience. It would also provide individuals with sight limitations an easier way to program. This system would involve creating a premade library of words and commonly used programming structures in the form of audio files. These audio clips could be included with the general help structure and include longer lessons dedicated to a programming concept or short summaries of statements. For instance, consider the following statement:

\[ \text{pwmdac1.PwmDacInPointer0} = \&\text{PwmDacCh1}; \]

This statement could have a 2-3 sentence audio description that uses the text-to-speech software to make it unique to that certain statement. It would play audio clips that explain
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what type of statement it is, what variables change, the arguments the statement accepts, and other useful attributes. This would be beneficial to the general user as well as the visually-challenged. First, it provides an unintimidating way in which any user can begin to learn the functionality of code; second, for users with poor visual field or eyesight, it is very difficult to decipher lines and lines of code. An audio-based summary of code functionality and layout would alleviate such concerns, and facilitate future code generation by both the visually handicapped and users unfamiliar with programming.

Closing Remarks

In designing the MSP430 motor control card, it is crucial to consider the entire product lifecycle. The design aspects should not only account for design and production, but also use and disposal. Environmental concerns found us using a low-power microprocessor and taking care to reduce the amount of non-recycled waste that is produced by our product. Additionally, there are safety concerns which must be considered to reduce product liability and increase customer satisfaction. Although many aspects of a motor control system are not part of our design, fail-safe software mechanisms as well as readily visible warning symbols can increase user safety and reduce the chance of equipment damage. Finally, we propose a graphical interface as well as an audio interface to expand the user base of the motor control card. The graphical interface will allow for non-technical users to learn how to program in a fashion more intuitive to them, and the audio interface will help non-technical users begin to learn the intricacies of code in a non-intimidating manner, as well as help users with visual field issues to interpret code more quickly to begin their own code generation.