Haptic Feedback Technology

ECE480: Design Team 4

Application Note

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Abstract:

With the daily interactions between humans and their surrounding technology growing exponentially, the development of new and innovative ways to provide operator feedback is becoming a necessity. With visual feedback being the first and most popular means of providing this user feedback, touch response is an increasingly popular choice as a secondary form of notification for many electronic devices. It is a simple, yet effective, way to alert the user that a specific action has occurred in instances where visual or auditory feedback may not be an option. Haptic technology is the leading field for creating this touch-based system interaction between humans and their electronics.

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Key Words: Microcontroller, Haptic Driver, Linear Resonant Actuator, Eccentric Rotating Mass, Piezo Actuator.

Introduction:

Haptic technology, or haptics, is a method of assigning a tactile feedback response to a designated input. It is used in electronic devices to recreate the sense of touch, through vibrations or forces, to the user. The necessary components for producing and regulating haptic feedback are a microcontroller, a mechanical driver, and an actuator. A simplified diagram how these components work together is show in figure 1 below. The haptic vibrations are initially created and regulated through the motor and actuator. These sensations are then controlled through the external microcontroller with imbedded software. More detail about each of these components and their importance to the overall system will be discussed in the following section. As the haptic technology becomes more advance and the response becomes realistic, it will inevitably become an increasingly popular option for consumer applications that involve two-way interactions between humans and technology.

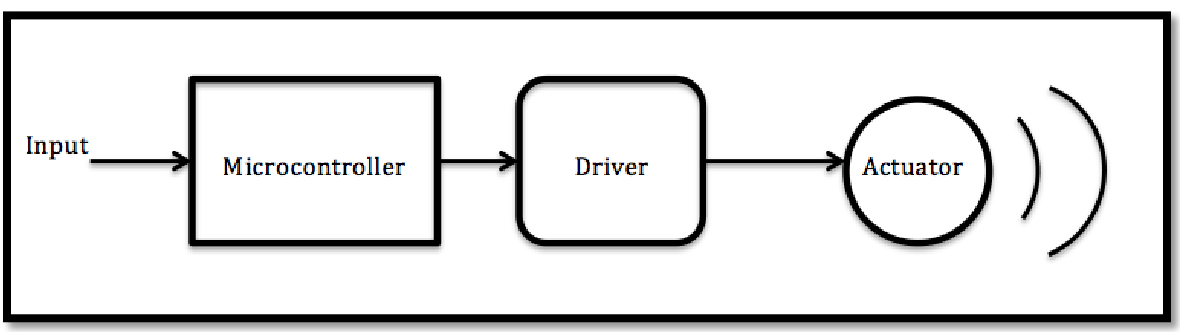

Figure 1: Haptic System Overview

Components:

- <u>Actuator</u>: As detailed above, the actuator is the mechanical provider of when and how much vibration is felt by the user. Currently, there are three main types of actuators on the market: linear resonant actuator, eccentric rotating mass, and piezo actuator.

  Linear Resonant Actuator: Of the motor-based actuators, the linear resonant actuator, or LRA, is the most popular due to its quick response time and long life span. The LRA is created through a moving magnetic mass connected to spring. This is detailed further in figure 2 below. An incoming current produces an electromagnetic field within the voice coil of the LRA that drives the magnetic mass and spring up and down, causing it to vibrate in a single direction at a fixed resonant frequency. It must be noted that the LRA requires an alternating current to produce this magnetic field, so the associated haptic drivers IC must be capable of outputting an AC signal.

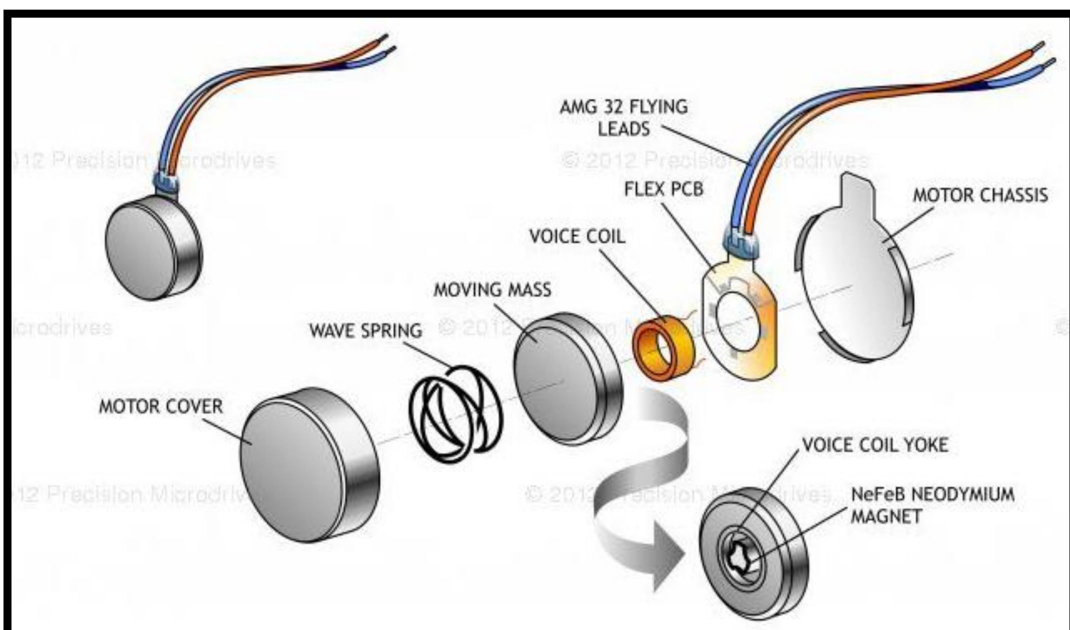

Figure 2: LRA Internal Components

Eccentric Rotating Mass: The eccentric rotating mass is the simplest and cheapest of the actuator units. It consists of a basic DC motor attached to an off-center mass. Figure 3 below features this internal configuration. When activated by the DC voltage produced by the driver, the motor spins the off center mass and the centripetal force produced causes the bidirectional vibration throughout the unit. However, since the ERM actuator is so basic in design, it is very difficult to accurately control the amplitude and duration of the voltages. Despite its low cost, this inconsistency and lack of precision makes the ERM an ineffective option for most feedback response systems where fine detail is required.

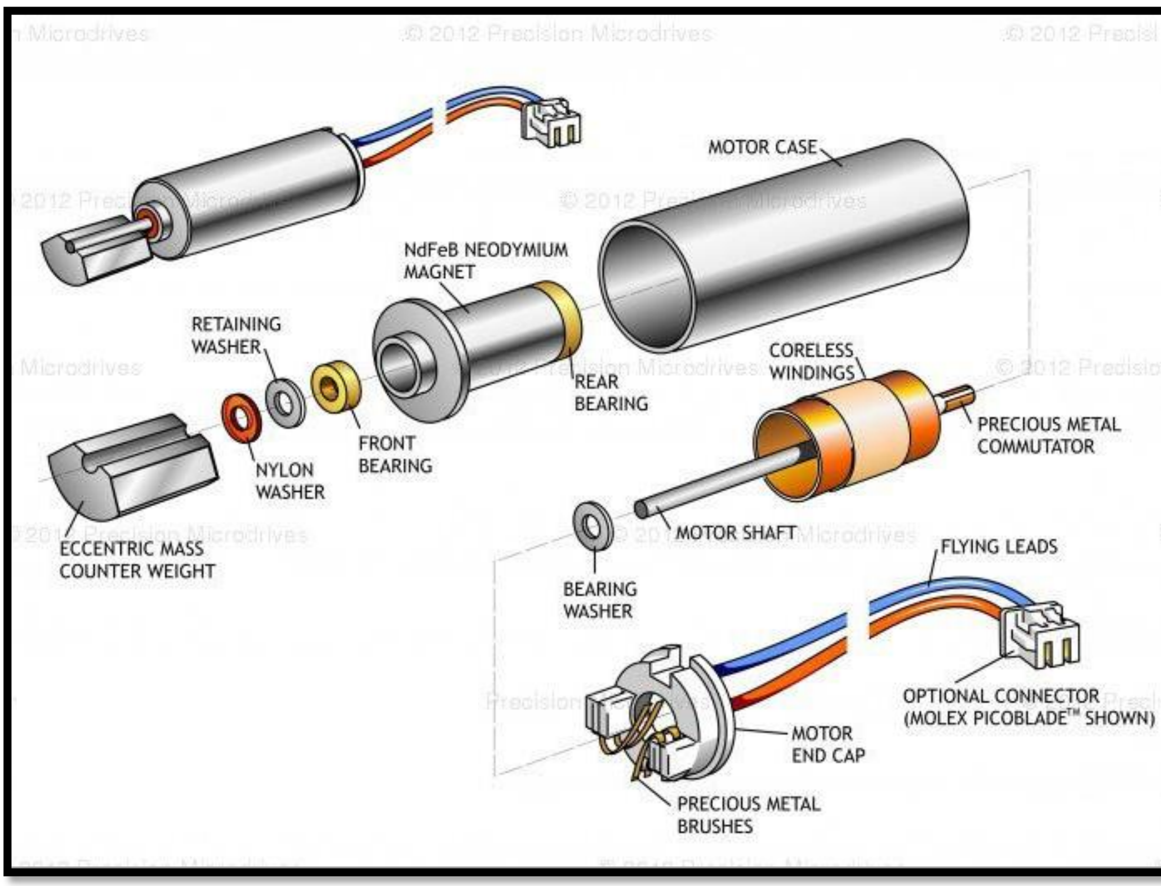

Figure 3: ERM Internal Components

Piezo Actuators: The most recent and increasingly popular innovation in the haptics community is the piezo actuator. As shown in figure 4 below, piezo actuators consist of thin layers of piezoelectric materials that bend back and forth quickly when a voltage is applied, causing vibration. To produce this bending, piezo actuators require a relatively high voltage input from the driver, usually between 50 and 150 volts. To provide this high voltage, a piezo specific haptic driver must be used in the system. Piezo actuators have many advantages over the motor-based LRA and ERM actuators. The main advantage for this actuator type is size, as the piezo layers don't require any internal components to drive the vibrations. This lack of internal mechanics also helps to reduce the start up and breaking time of the actuator, as well as eliminate any audible mechanical noise during periods of vibrations. Lastly, due to their piezoelectric material properties, piezo actuators are able to achieve stronger vibrations at lower bandwidth than the other actuator models. However, these advantages come with a price. The main disadvantages for piezo actuators are low durability of the piezoelectric material, giving then a shorter lifespan than the motor-based actuators, and high power consumption.

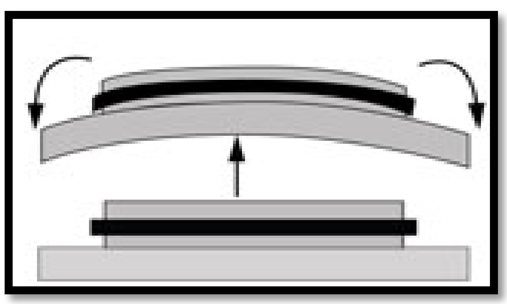

Figure 4: Peizo Actuator Operation

- <u>Haptic Driver:</u> The intermediate step between the control source (microcontroller) and the vibrating unit (actuator) is a haptic driver. The driver is required to provide a complete motorized control of the actuator, as the microprocessor is unable to deliver enough power for the actuator to begin its initial vibrations. There are two main methods used by the driver to insure that the actuator starts and stops its vibrations as quickly as possible, making the overall haptic response smooth and crisp. The first is overdrive, where the motor produces more power then necessary to reduce the time it takes for the actuator to begin vibrations. The second is active breaking, in which the driver produces a reverse voltage of a certain amount to quickly end the actuators vibrations. The driver is also capable of smart loop architecture, which allows it to constantly monitor the actuators performance. Figure 5 below details the general inner workings of a haptic driver. When choosing a driver the type of associated actuator being used must be taking into account, as each actuator requires a unique set of inputs from the driver. Texas Instruments provides an extensive collection of LRA, ERM, and piezo haptic drivers.

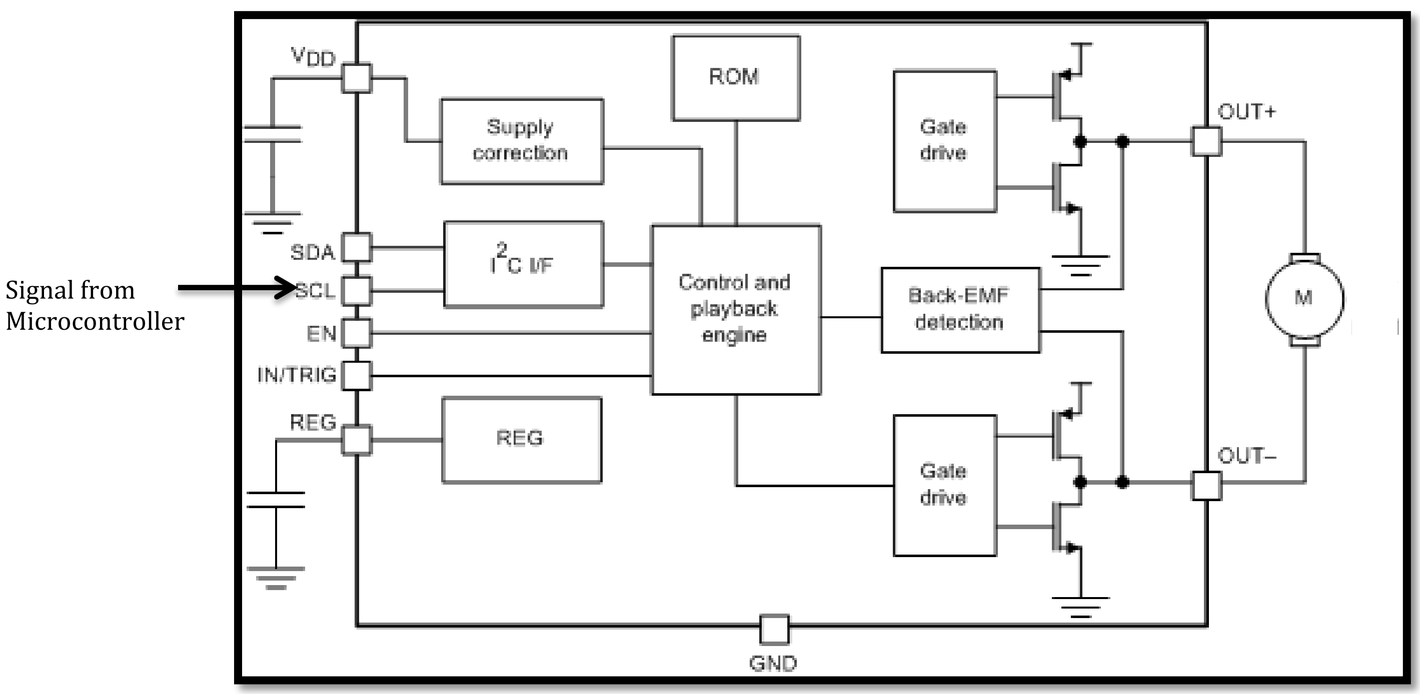

Figure 5: Haptic Driver Diagram

- Microcontroller: The role of the microcontroller is to make all logic decisions regarding when and how the haptic technology responds to a designated input. When a desired input, such as a capacitive change from a touch screen, is registered by the microcontroller, it sends a pulse width modulated signal to the haptic driver. The driver will then control the actuator's vibration levels and duration based on the duty cycle of this pulse width modulated signal. Today many processors can be purchased with a fully integrated library of haptic waveform effects that can simplify the programing aspect and make haptic integration a convenient option for any application.

System Integration:

The schematic in figure 6 below details the hardware setup for a simple haptic feedback system. This particular system includes a MSP430 microcontroller (TI), a DRV2605 haptic driver (TI), and a 10 mm LRA (Precision Motordrives). Time permitting; this is the system that will be incorporated into the Blind User Accessible Insulin Pump. The MSP430 registers an incoming signal through capacitive touch sensors connected to the input pins (2.0, 2.1, and more if necessary). By comparing this input signal with a user-designated reference signal, the MSP430 will output a specific PWM square wave to the DRV2605 driver. The driver will then take this PWM signal and, using an internal association library, produce a related AC source to vibrate the LRA. The driver operates at 5 volts and is also the sole power supply the entire system. Therefore, the TPS73633 is a linear voltage regulator used for converting the 5V produced by driver to the 3.3V required for operating the microcontroller.

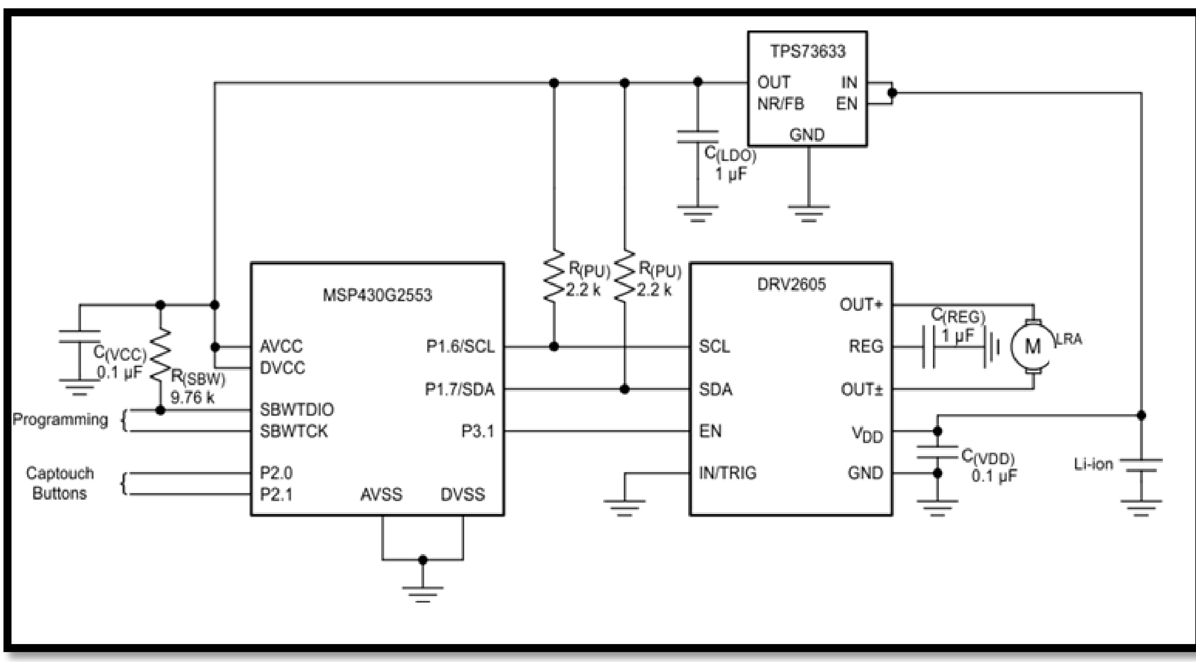

Figure 6: Complete Haptic System

Conclusion:

Haptic technology is undoubtedly a valuable addition for providing additional user-friendliness and guidance to any device. However, before integrating haptic feedback response into a technological application, one should deeply consider what components would work best for their particular system. They should take into account which actuator design, and associated driver, will provide the ideal feedback performance under their system constraints. They should also investigate how they need to effectively integrate the controller aspect into their overall design. This may take some additional time and effort, but the use of haptic feedback will provide a significant convince to the device's human interaction capabilities.

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