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Two New Commercial Haptic Rotary Controllers

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Abstract. Two new commercial haptic rotary controllers are presented: a Low Cost Rotary Controller (LCRC) and a High Performance Rotary Controller (HPRC). The LCRC was developed in order to explicitly address the cost constraints of commercial devices while maintaining the haptic fidelity required to render quality detents, and barriers. It consumes a fraction of the power of standard rotary controllers, and is quite compact (13 mm x 23 mm dia.). The High Performance Rotary Controller (HPRC) was developed to improve the haptic quality over standard rotary controllers, especially in rendering detents and barriers. Combined with compatible and relevant software tools like Immersion® Studio for Automotive, designers can easily create a wide range of useful, intuitive haptic effects. These tools present an opportunity for haptic research laboratories to quickly acquire the necessary infrastructure critical to performing research studies in haptics, or other Human-Computer Interaction (HCI) tasks.

1 Introduction

Immersion Corporation has been actively developing programmable haptic rotary controllers for a number of years. The introduction of haptics to the user interface provides designers with new paradigms, where a single input controller can be used to provide varying tactile feedback to a number of different input functions. For example, the number and type of detents can be varied depending on the operating task, whether it consists of adjusting the radio or controlling the seat adjustment.

Several major automotive manufacturers have endorsed this technology, making haptic rotary controllers a part of their flagship products. Haptic Rotary controls are featured in such cars as the BMW 7 series [1], the BMW 5 series and Rolls-Royce Phantom. These first generation rotary controllers [2] will be referred to in this paper as Standard Haptic Rotary Controllers (SHRC). Other examples of uses of haptic rotary controllers are given in Badescu et al. [3], for vehicular controls, and in MacLean and Roderick [5], in the description of a haptic doorknob.

In order to produce quality haptic sensations, the rendering device must meet stringent specifications, including low control latency, high-resolution sensing and high peak output actuator authority. When considering commercial devices, cost and

power consumption must also be considered. Commercial haptic devices must meet the standard of quality of real mechanical rotary switches, provide the flexibility of programmability and configurability, and satisfy manufacturer's cost concerns.
This paper presents two new haptic rotary controllers that can maintain the desired quality of haptic experience while minimizing the costs to produce the device.

2 New Commercial Haptic Rotary Controllers

Two of the primary uses of rotary controllers are in rendering detents and creating barriers. Detents are used to indicate preferred locations of the device, and are useful when navigating lists. Barriers are used to restrict or limit the user's motion, and are useful as in, for example, indicating the last item in a list.

One of the major engineering challenges in creating commercial haptic rotary controls consists in satisfying the widely varying specifications required for generating diverse haptic effect types. The requirements of the device to render both high quality detents and high quality barriers are quite different. The required barrier peak force is often four to five times that of the required detent peak force. In order to reconcile these conflicting requirements and ensure a more satisfying user experience, two new haptic rotary controllers have been developed: a Low Cost Rotary Controller and a High Performance Rotary Controller.

2.1 Low Cost Rotary Controller (LCRC)

The Low Cost Rotary Controller (LCRC) was developed in order to explicitly address the cost constraints of commercial devices while maintaining the haptic fidelity required to satisfy end users. The LCRC is shown in figure 1 with a table of relevant specifications. The LCRC is powerful enough to produce adjustable, stiff barriers, while preserving a level of quality essential for rendering satisfying detents. There are several different detent types that can be created resulting in a rich variety of distinct haptic experiences. For each type of detent, width and peak magnitude are adjustable.

Parameter	Value
Maximum Torque	100 mN-m
Maximum Free-Running Torque	5 mN-m
Maximum Power Consumption	1.75 Watts
Push-To-Select Switch	Yes
Height (enclosure)	13 mm
Diameter (enclosure)	28 mm

Fig. 1. Low Cost Rotary Controller (LCRC)

The LCRC is also a low power device using less than 10 % of the power consumed by a standard haptic rotary controller. This is a critical aspect when considering handheld devices such as remote controls. Other advantages of the LCRC include its compact size, and its reduced part complexity versus standard rotary controllers.

2.2 High Performance Rotary Controller (HPRC)

The High Performance Rotary Controller (HPRC) was developed to improve the haptic quality over standard haptic rotary controllers. While maintaining a similar base cost as the standard controller, the HPRC is able to render detents of improved quality. The detents feel crisp, and can be equal to the haptic experience of physical mechanical rotary switches. There are also a greater variety of different types of detents resulting in a richer palette of haptic experiences. Similar to the LCRC, the HPRC is able to produce stiff barriers that are difficult to penetrate during normal use (up to 120 mNm).

Parameter	Value
Maximum Torque	120 mN-m
Maximum Free-Running Torque	7 mN-m
Maximum Power Consumption	18 Watts
Push-To-Select Switch	Yes
Height (actuator assembly)	80 mm
Diameter (actuator assembly)	57 mm

Fig. 2. High Performance Rotary Controller (HPRC)

2.3 Immersion Studio® for Automotive

In order to fully take advantage of the programmability of these devices, both the HPRC and the LCRC are compatible with a software application that enables creation, iteration and real-time evaluation of haptic effects. The application is Immersion Studio® for Automotive ("Immersion Studio software"). Refer to [4] for a more detailed description of Immersion Studio software and its benefits in the auto industry.

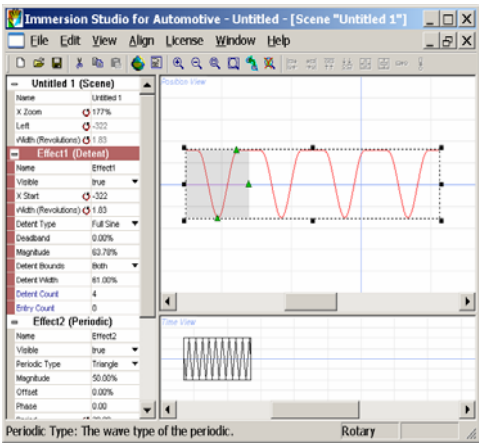

Fig. 3. Immersion Studio® for Automotive software sample screen

Immersion Studio software is a user-friendly software application allowing designers to graphically create haptic sensations, define effect parameters and experience the result in real time. Figure 3 is a sample screen from Immersion Studio software, and shows a typical haptic "scene" with two haptic effects: a time based effect at the bottom of the right hand window and four equally spaced detents in the top right-hand window. The interface is divided into several parts: main toolbar, scene window, spatial effects window, temporal effects window. The scene property window on the left allows users to change all haptic parameters including the amplitude, origin of the effect, width or duration of the effect, type of the force profile, etc. Code generation features are also available.

3 Conclusions

The HPRC and the LCRC offer new opportunities for the placement of haptic controllers in commercial user interfaces. Combined with compatible and relevant software tools like Immersion® Studio for Automotive, designers can easily create a wide range of useful, intuitive haptic effects. These technologies represent a significant improvement over standard haptic rotary controllers, with respect to the quality of the detents and barriers, the power consumption and the cost. Table 1 summarizes these benefits in a scale relative to the standard rotary controller.

These tools also present an opportunity for haptic research laboratories to quickly acquire the necessary infrastructure critical to performing research studies in haptics or other Human-Computer Interaction (HCI) tasks.

Table 1. Summary of Advantages

	Detent Quality	Barrier Quality	Power Consumption	Cost
Standard Haptic Rotary Controller	Medium	Medium	Medium	Medium
Low cost Rotary Controller (LCRC)	Medium	High	Low	Low
High Performance Rotary Controller (HPRC)	High	High	Med - Low	Medium

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