

DESIGNING INTERIOR AUDIO CUES FOR HYBRID AND ELECTRIC VEHICLES

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The advent of new propulsion technologies (e.g., hybrid, plug-in hybrid, fuel cell, and electric) changes the vehicle noise signature dramatically. Traditional powertrain sounds disappear and new sounds become audible, including those from alternative propulsion systems, power converters, and from the car's structure itself due to road noise, tire sounds, and vibration from the body frame. In the face of such developments, feedback to the driver regarding vehicle state is greatly changed, which may cause confusion and frustration. Our work explores the addition of sound cues to a vehicle's interior environment to increase drivers' aural feedback for states such as "ready to go", "systems off", and "alert". We discuss the design and evaluation of such cues for an electric vehicle, and relate this to background research in the areas of psychoacoustics, sonic branding, and auditory interfaces.

INTRODUCTION

Sound is an important part of the driving experience. Sounds from the mechanics and onboard systems inform the driver of the vehicle's state, and also provide entertainment. Sounds from outside the vehicle can be important for helping the driver safely navigate to the desired destination.

The development of new vehicles with alternative propulsion systems, such as (hydrogen) fuel cells, hybrids, and electric motors, means that audio information once available from internal combustion engines will no longer be present. Already, vehicles with quieter engines are causing concern: drivers may think they've turned off a vehicle at night only to return in the morning to find a dead battery or an empty gas tank. This project focuses on the re-introduction of sound to a vehicle's interior to avoid such problems. Specifically, we address issues related to the communication of vehicle on, vehicle off, ignition, and alert situations.

This project included background study into vehicle sounds, psychoacoustics, and user types and personalities. This research helped guide the sound designs that support the assumptions made during the entire process. The sound design itself followed an iterative process, and relied heavily on user feedback. This report describes the background research, sound development, and iterative design to create the sounds delivered at the end of the project.

1 BACKGROUND RESEARCH

A key framing question for this project was: "what kinds of sounds do we want children and video

games to emulate in the future?" The internal combustion engine (ICE) has been around for over 100 years, and its sound is extremely recognizable. We would like to keep at least some essence of this familiar sound as we move to alternative vehicle propulsion, but how much? Now that powertrains are growing more silent, the opportunity to create new start-up and ignition sounds is intriguing and thought-provoking.

1.1 Propulsion Technologies

Feedback from the engine is an important aspect of the driving experience. The sound produced by the engine and other vehicle systems in an ICE vehicle are artifacts of the technologies used, and (especially to an experienced driver) can give some indication as to how the systems are functioning (or not functioning). The engine sound, in particular, is comprised of "airborne noises such as intake noise, exhaust noise, and combustion noise, and the solid propagation noise from the engine mounting." [10] Sound is created from the movement of gas and air in the exhaust, engine, and combustion systems. The engine sounds are experienced both aurally and haptically. [1]

An electric vehicle (EV), on the other hand, produces a sound comparable to that from an electric power plant as it comes online, especially during ignition and acceleration states. The soft, high-frequency sounds that emanate from an electric motor include mechanical sounds from the spinning of the motor rotor next to a stationary starter in the presence of air. Additional sounds can emanate from a transformer coil wound around a ferro-magnetic core. The magnetic forces cause the coil to vibrate with respect to the core, causing additional sounds. The resulting sound is futuristic, and reminiscent of "The Jetsons" cartoon and the sound effects of their flying cars.

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Electric Vehicles (EVs), including Extended Range Electric Vehicles (EREVs) such as the *Chevrolet Volt*, have an electric motor as well as an ICE to provide extended range and to help decrease both emissions and noise pollution problems. The sounds present in EVs stem largely from the ICE on board. [6]

1.2 Non-propulsion Sounds

Drivers use all appropriate sensory cues to get from one destination to another as safely as possible. This includes auditory feedback of road noise, the smell of hot rubber or oil, and visual feedback of nearby vehicles. Sound from the external environment bleeds through the vehicle cabin; such sound originates from other cars and trucks, car horns, emergency vehicles, animal calls, and voices. Using audio cues in addition to visual cues is extremely helpful when determining where other vehicles, pedestrians, animals, or objects are located: for example, auditory crosswalk signals give an indication that pedestrians may be crossing a particular street.

Some other non-propulsion noises available to the driver are road noise, interior cabin noise (including HVAC systems, the sound of a door closing, and air and wind noises), and alerts designed to meet human factors requirements (such as reminders that the seatbelt needs to be properly fastened, the headlights are on, or the keys are still in the ignition when the driver's door is open). These sounds form the context for any new sounds to be created for or added to an electric, hybrid, or extended range vehicle.

1.3 Adding Feedback to Quiet Vehicles

The aforementioned quiet vehicles are remarkable for reducing both emissions and noise pollution. However, as Don Norman points out, "quiet is good; silence may not be." [9] Auditory feedback provides an important channel of information about the vehicle and its journey. Norman explains:

"feedback provides informative clues about what is happening, clues about what we should do. Without it, many simple operations fail, even one as simple as [starting a car]. Proper feedback can make the difference between a pleasurable, successful system and one that frustrates and confuses." [9]

These vehicles can be so silent that the driver might be unaware the vehicle is running. Therefore, auditory feedback of critical events could be reintroduced to increase driver confidence that everything is working normally.

When we created sounds for this project, we considered events that were important for the driver, but for which there was currently insufficient auditory feedback. Notification that the engine is on (or not) has been a concern for hybrid and electric vehicle users. If the vehicle is inadvertently left on, batteries can drain. Since there is no sound from the engine, and the center display

does not turn off until the driver opens the car door, it can be difficult for the driver to determine whether the car has been turned off when leaving the vehicle. A "goodbye" sound could indicate to the driver that, yes, the vehicle has turned off properly. Similarly, an ignition sound would be helpful when the car is started to inform the driver that the car is indeed ready to go.² [9]

1.4 Sonic Branding

Sounds can be a very powerful component for building a brand. One goal of this project was to create sounds that would contribute to a unique vehicle branding. Research into psychoacoustics and related fields gave us insight as to what functional sounds would be appropriate. We began by investigating sounds created for computers (such as Macintosh^{3,4}, Intel⁵, and Microsoft Windows^{6,7}), mobile phones and service providers (such as Nokia⁸ and T-Mobile⁹), and other brands with iconic sounds (such as the NBC Chimes¹⁰ and the THX "Deep Note"¹¹). Most of these sounds can be found at the U.S. Patent and Trademark Office.¹²

The companies we studied all utilized the concept of sonic branding. Sonic branding is becoming increasingly important for conveying a memorable message. Managing Partner Bill Nygren of Boom Sonic Branding identifies a sonic brand as "the aural equivalent of the graphic logo."¹³ The objective of sonic branding is to create a "memory trigger, intrinsically linking a product name, service or benefit with a pleasant

² As of October 2008:

<http://www.greenhybrid.com/discuss/f58/design-flaw-i-just-left-our-car-running-all-night-15692/>

³ As of October 2008: <http://scopeweb.mit.edu>

⁴ As of October 2008:

<http://musicthing.blogspot.com/2005/05/tiny-music-makers-pt-4-mac-startup.html>

⁵ As of October 2008:

<http://musicthing.blogspot.com/2005/05/tiny-music-makers-pt-1-intel-inside.html>

⁶ As of October 2008: <http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/1996/06/02/PK70006.DTL>

⁷ As of October 2008:

<http://windowsvistablog.com/blogs/windowsvista/archive/2008/06/13/behind-the-scenes-of-the-windows-vista-sound-schemes.aspx>

⁸ As of October 2008: http://en.wikipedia.org/wiki/Nokia_tune

⁹ As of October 2008: <http://www.sonicsista.com/sonic.html>

¹⁰ As of October 2008: <http://www.nbcchimes.info>

¹¹ As of October 2008:

<http://musicthing.blogspot.com/2005/05/tiny-music-makers-pt-3-thx-sound.html>

¹² As of October 2008:

<http://www.uspto.gov/go/kids/kidsound.html>

¹³ As of October 2008, BrandChannel:

http://www.brandchannel.com/features_effect.asp?pf_id=63

memory.”¹⁴ In other words, sonic brands are sound identities that attract the emotional and logical mind to a memory: “a hybrid of voice, sound design and original music, the sonic brand works by harnessing the power of music to trigger an emotional response.”¹⁵

Most companies take one of two approaches to building an audio identity. The first is promotional audio branding, which uses a sonic logo or brand-identifier everywhere the company communicates. The second approach is actionable audio branding, which makes the most of psychoacoustics (discussed further in the next section) to affect our emotions and change our behaviors. Well-designed, behavior-based audio branding is a critical part of the experience that we have with everyday products and environments, and is an extremely effective marketing technique.¹⁶

1.5 Considerations for Sound Creation

Sounds can trigger vivid recollections of past experiences, helping us remember intricate details associated with the event, including emotions. Sound has an immediate, direct link to both the rational and emotional parts of our brain which transcends language and cultural barriers, much like the beauty of music, allowing delivery and reception of the message.^{17,18} For this reason, sound designers focus much of their efforts on the creation of pleasing feelings through their sounds.

The goal of the sounds produced in this project was to allow customers to identify a set of sound cues appropriate for an EV. In much the same way that “You’ve Got Mail!” is associated with AOL’s e-mail alert, our goal was to create sounds that would be immediately identifiable with our product.

1.5.1 Mapping Sounds to Functions

The design of appropriate sounds requires consideration of the mapping between the sound and the state it is meant to represent. Previous research by one of the authors indicates that recognizability is a critical aspect in the design of appropriate sounds for auditory interfaces. Many different features of a sound can be recognizable, including the sound’s (source) identity, its pitch contour, and its cultural meaning. [7] A strong mapping between any of these aspects and an interface component can be used to create a successful audio cue.

¹⁴ BrandChannel, op.cit.

¹⁵ BrandChannel, op.cit.

¹⁶ As of October 2008, AIGA Article:

<http://www.aiga.org/content.cfm/building-brand-value-through-sound>

¹⁷ BrandChannel, op.cit.

¹⁸ AIGA Article, op.cit.

1.5.2 Perceived Urgency

The sounds designed for this project are meant to alert drivers to a set of key states during the use of their vehicles. Auditory signals have an inherently high capacity to alert, due to the omnidirectionality of sound. This can be used as an advantage to draw attention to important events without requiring the listener to be oriented in a particular direction. It can, however, also be a disadvantage, such as when the alert becomes distracting or annoying.

Some sounds are inherently more strident and abrasive than others, such as those used in smoke alarms and other emergency signals. The acoustic features of these sounds create a high *perceived urgency* for the listener. [5] When the perceived urgency matches the actual urgency of the situation, the use of such sounds is appropriate and helps the listener to make the decision to act on the signal.

A problem arises when perceived urgency and actual urgency do *not* match well. [3] Unnecessarily loud or shrill alarms that are used to signal non-urgent events (e.g., the space heater that emits a loud buzz every time it is bumped) quickly trigger annoyance. It is also possible to choose sounds with too high of a perceived urgency when signaling even a critical event. Edworthy and Stanton cite a case from an airplane pilot who was signaled to a critical event (wing stall) by such a loud sound that he was startled into non-action. [4] In the case of piloting an aircraft or driving a car, startle responses and distraction inhibit the pilot or driver’s ability to operate the vehicle safely, sometimes with tragic results. In these circumstances especially, alerts should be designed to attract the proper amount of attention without causing a dangerous level of distraction. Although sounds with low perceived urgency may seem less annoying or distracting in general, these can also cause annoyance if they are used to signal urgent situations, since they may be easily missed.

1.5.3 Length

Sound length must also be carefully managed, as longer sounds can cause annoyance. This is especially true if the listener must wait for the sound to finish playing before an action can be taken. Automated phone systems and voice recognition systems that force users to wait until the end of a prompt to speak or make a selection quickly become annoying. To mitigate this problem, sounds should be kept short, and should allow the listener to interrupt and stop the sound. This maximizes the amount of information conveyed to the shortest possible time.

1.5.4 Number of Sounds and Repetition

Sounds can quickly become extraneous clutter if not carefully orchestrated. Therefore, the number of

sounds, noises, or musical pieces available in a given context should be kept to a minimum. In the driving context, listening to the radio adds sound to the already-present noises from the engine, road, and tires. Other passengers, conversations, and handheld cell phones can each add more distraction. Creating multiple alerts for the car itself could easily inundate the driver with an overabundance of sounds. If there are too many sounds, the listener can become frustrated and be unable to react properly. Our job was to create simplistic sounds which would be informative but not overwhelming.

In a related study from one of the authors, it was determined that “keeping the total number of sounds in an ... interface small reduces distraction.... By using many sounds in an interface, the cognitive load placed on the user is high, since there are many signs that have to be remembered.” [8] However, it should be noted that repeating any particular sound could cause “audio fatigue,” especially when using musical sounds. [2]

Concern for the factors outlined above (perceived urgency, number of sounds, length, and repetition) suggested guidelines for the design of the sounds in this project. In general, the sounds we are designing are not meant to signal critical situations, but rather to provide feedback. The fact that the vehicle has turned on successfully, is ready to go, or has shut down successfully is useful information to the driver, but these states do not qualify as emergencies. Sounds for these situations should not convey a strong sense of urgency, but, on the other hand, should be audible. Since the driver has to wait for the sounds to play when entering or exiting the vehicle, the sound should not be exceedingly lengthy. Since drivers often make more than one vehicle trip per day suggests that sounds should not be too musical, as they will be repeated each time a trip is made. An alert sound may be played multiple times during a vehicle trip, so it is critically important that this sound is kept short, and it should convey proper urgency without the startle effect.

2 DESIGNING FOR USER TYPES

Four customer themes were identified by the design team. Through focus groups and research, potential customers were separated into four categories, here identified as *A*, *B*, *C*, and *D*.

The *A* driver is the classic “early adopter”, and would buy an EREV to showcase his or her status. This driver wants to say, “Hey, look at me! Check this out!”

The *B* driver is a Gen-X or Gen-Y consumer who has grown up during the technology revolution and is accustomed to obtaining the very latest and greatest in technological achievements. *B* is also an early adopter like *A*, but is less focused on status and more focused on following the cutting edge of technology. It is a theme for someone who would say, “I want the next, *next* generation electronics.”

The *C* driver is an environmentalist who is concerned with how humans interact with and impact on the planet. This driver might say, “I want to be good to the environment by driving a fuel-efficient, low emissions car.”

The *D* buyer recognizes the need for new technologies, but prefers tried and true designs, and products that are familiar. This buyer is looking for a simple, reasonably priced car that gets safely and efficiently from one destination to another.

These user themes were initially mapped to music genres as a guide for the design process. Although it is not necessarily appropriate to generalize, our initial impressions were that *A* would be familiar and comfortable with the overlap (if one could be agreed upon) of rock, R&B, pop, and hip hop – something with a beat; *B* with video games, computer music and electronica; *C* with New Age chants, nature sounds, and ambient vocals; and the *D* user type would identify with classical and jazz – something simple.

3 DESIGNING FOR AN ELECTRIC VEHICLE

The creative process for developing audio cues stems from the previously discussed background research and targeted marketing schemes. During the research and discovery process, the first author created sounds based on interesting concepts and ideas. Only a handful of sounds were required as deliverables for the project; however, over a hundred sounds were created throughout the process.

3.1 Functional Sounds

Letting sound follow function limits a designer from adding too much complexity. The sounds for this project are not random sounds, but rather are meant to convey a specific message. To increase the consumer experience, the functional sounds for this project were determined through hypothetical usage scenarios, as follows:

- A welcome sound greets the driver who walks up to the car, opens the door, and sits down. This lets the driver know the system is starting up.
- The driver is ready to put the car into motion, and presses the ignition button. While the button is being depressed, a sound plays indicating that the car is ready to go.
- An auditory cue signals that the state of the vehicle’s propulsion system has changed, depending on the state of charge of the battery.
- The driver has reached his or her destination and presses the ignition button to turn off the car. A goodbye sound signifies that all systems have indeed shut down properly.

The remainder of this section describes the design considerations and process used to determine the best sounds for each function.

3.2 Technology and Methodology

The computer applications used for this work were *Max/MSP* by Cycling 74, *GarageBand* by Apple, and the open source audio editor *Audacity*. *Max/MSP* was used for FM synthesis and convolution. *GarageBand* was utilized for its “musical typing” interface, as well as for its synthetic instruments. *Audacity* was used as the digital audio workstation for tracking, editing, and finalizing the sounds. The produced sounds use effects such as phasers, panning, and reverberation to create non-conventional, “computer music” sounds. Synthetic sounds are generally considered more “futuristic”, which is more in keeping with the intended branding. Conventional instruments and sounds (such as a recorded ICE) were considered undesirable by the team.

3.3 Sound Parameters

The sounds designed for this project followed a number of parameters and guidelines that stemmed from our background research. These were inspired both from music, such as the use of specific keys and rhythms, and non-musical sounds, such as nature sounds.

3.3.1 Motifs

The innovative nature of electric vehicles produced the idea of “going somewhere” and “moving forward”, and suggested the concept of using rhythm and beats. Making the rhythm and beats have meaning seemed ideal. One idea, which stemmed from syllabic concepts used by both Microsoft Windows (“Win-dows-Vis-ta”) and Intel (“In-tel-In-side”), was to use Morse code. The letters “GM” could be presented in the desired time frame. “GM” in Morse Code is dah-dah-dit, dah-dah”. The extra perk of having a syncopated palindrome added to the enjoyment. Another coincidental subtlety was that, in Morse code, GM is shorthand for good morning, a “welcome” phrase.

Another motif we explored was the use of a specific key: G Major. The abbreviation for G Major is GM, which, again, seemed ideal for our purposes. Although few people have perfect pitch and would immediately recognize this particular motif, it makes for a nice double entendre in the vehicle. Most of the pitched sounds created for this project were centered on G Major or its consonant relative, C Major.

3.3.2 Fast versus Slow Melody

The concept of fast versus slow was also taken into consideration during the design process. Fast melodies are indicative of something moving forward. Slow melodies signify gentle repose. EVs are marketed as efficient and forward-moving, so faster melodies seemed more preferable and appropriate.

3.3.3 Major and Minor Keys

Major keys were quickly selected for this project. Major keys are equated with happy and cheerful emotions, whereas minor keys are associated with dark, sad, and depressing feelings. In addition to the “happy sounding” major keys, chords that were very open (covered a wide range of frequencies, rather than all being condensed) were considered necessary.

3.3.4 Upwards versus Downwards Motion

Upwards motion conveys a feeling of “booting up”, coming towards someone, or initiating something. This seemed proper for a welcome sound motif. The downwards motion conveys more of a powering down, “going away”, or a leaving feeling, which fit for “goodbye”.

3.3.5 Abstract and Natural Sounds

Although many of our sound choices revolved around musical considerations, there were instances where musical sounds were not entirely appropriate. The most difficult sound to create was the ignition sound. Preconceptions about ICE sounds weighed heavily on the final design. Furthermore, it was determined, through trial, error, user surveys, and advice, that only two sounds should be available. Since ignition was the most critical (and potentially most “brand-able”) sound, having many variations (even across different user types) seemed undesirable. Choices were narrowed down to a modified ICE and an abstract sound effect, to go along with the cluster themes of “Analog” and “Digital”. This was the most reasonable way to convey the vital information that the vehicle has started and is ready to go, while still allowing some customization.

3.3.6 Other Ideas

Other sounds and effects considered during the creation process included nature sounds such as wind, water and waves, pure sine waves, low-frequency bells, reverb and reverse reverb, sweep filters, and drones. For this eco-friendly vehicle, wind and water seemed appropriate, but only in the context of being mixed with other sounds, so as not to be confused with external weather sounds while driving. Wind and water can each give very powerful forward-moving feelings, especially using frequency sweeps on the sounds, which would emphasize the concept of this car. Along with nature sounds, reverb is a huge selling point to most sounds. It gives a feeling of space and surrounding, and is an effect used throughout the designs. Another thought was to keep the sounds within an audible, but non-annoying mid-frequency range. The frequency spectrum of about 300Hz to 3.4kHz is reasonable here. All of these concepts and effects are meant to convey “fresh eco-friendly” or

“futuristic power” concepts, which fit well to the EV’s image.

3.4 Design Process

The design process involved several steps. Initially, we started with some settings on the FM Synthesis patch (setting the modulator and the carrier frequencies), and then tuned by ear. As the settings were randomly changed, the timbre would change. Preferable timbres would be captured, and then manipulated to make a string of sounds, or a melody. Sometimes the sounds were too extreme or harsh; sometimes the sounds were bland and pointless. Zeroing in on good timbres was the tricky part. After the proper timbres were gathered for the different user types, those sounds were manipulated to fit a melody or motif. Integrating the Morse code into each of the welcome sounds was seen as necessity from a product branding standpoint. The last step, which was the most time consuming, was shaping these sounds to be appropriate length, and using effects to convey the proper message. Each of the clips was engineered using wave format, and mixed to be as clean and clear as possible, ready to go in the car as is.

4 EVALUATION

The sounds created for this project underwent many design iterations, based on feedback from stakeholders and other evaluators. Evaluations included polling coworkers to gather feedback on whether the intended goals of the project were being met.

One way of getting direct feedback almost immediately was through email, wiki, and weblog postings. An internal wiki was utilized to share sounds and ideas, as well as to gather feedback. Listeners provided insight, opinions, and suggestions at their own convenience, rather than requiring synchronous feedback through meetings, which was more difficult to schedule across time zones and personal schedules. A user survey was also created to gather informal feedback.

4.1 Survey Design

Asking people to listen to clips and evaluate them is an important aspect of the sound design process. However, it is important to not fatigue the listeners who are generously donating their time and ears. In our surveys, we evaluated only a handful of the sounds at a time (twenty or less, all approximately three seconds in length). The feedback form was also designed to be as succinct as possible.

A survey was designed for employees directly involved with or very knowledgeable about this project. These individuals already knew a great deal about the platform’s research and development. They each had preconceived ideas as to what they might want for sound effects, so the survey was designed to elicit quantitative

(“Does this sound fit as is?” : yes / no) and qualitative (“Please explain why”) feedback.

Participants also volunteered into which theme (of the four discussed above) they thought each sound best fit. This proved to be useful data for characterizing the information received from each participant.

4.2 Gathering Data

Several different groups participated in the survey. In the first organized trial, eighteen sounds were presented to the design team. Each sound was played multiple times, and each person completed the survey individually. At the end of the session, the listeners had the opportunity to give the authors feedback as a group. The listeners provided their feedback forms to the authors, and were encouraged to provide additional thoughts and ideas. The individual feedback portion of this procedure was also performed locally, where coworkers were provided with sounds to rate and a questionnaire to fill out at their convenience.

4.3 Analysis and Results

The goal in our survey was to reach a consensus about the sounds to be used from those that were tested in the focus groups. Complicated statistical analysis was not required, as the evaluations were meant to be formative in nature rather than summative. Instead, the focus was on tallying results from the feedback forms to determine the most and least popular options (as well as reasons for these choices, if given), and to choose the sounds with the most positive feedback. Care was taken to account for users’ opinions based on their defined (or self-admitted) user types. The advice of an *A* person about the *D* theme was not considered with nearly as much weight as a *D* person’s advice on *D*. However, we did find a general consensus as to what kinds of sounds were appealing or not.

From the original mandate of twelve sounds (Welcome, Ignition, and Goodbye for four themes), which then changed to sixteen sounds (an added Alert sound), the final result was fourteen sounds: four Welcome, four Alert, four Goodbye, and two Ignition.

All of the sounds included the most important effect: reverb. The tables below give a brief description of the sounds produced for this project.

	<i>Analog</i>	<i>Digital</i>
Ignition	Rising frequency of “bubbly” pitch over a metallic GM chord without the third	Flutter with an echo

<i>A</i>	
Welcome	Electronic G2 with ramping amplitude

	over G1'ed Morse Code
Alert	Electronic G1 note, short, ending with a pop
Goodbye	Quick ramp up of pitched white noise ending with an electronic G1 pitch fading out

<i>B</i>	
Welcome	Electronic G2 with swirling EQ ending in a "pop" over G1'ed Morse Code
Alert	Electronic "horn" quick melody G1 followed by twice repeated octave C's (C3 C2)
Goodbye	Electronic synth melody G2 D2 E2 G1 with EQ swirl

<i>C</i>	
Welcome	Electronic reverbed synth melody G2 C3 E3 D3 G3 over G1'ed Morse Code
Alert	Electronic synth quick melody C2 G2 repeated three times
Goodbye	Electronic reverbed swirled synth melody G3 C3 D3 G2

<i>D</i>	
Welcome	Piano arpeggiating up C2 G2 C3 D3 E3 over C2'ed Morse Code
Alert	Electronic "horn" quick melody B1 A1 A1 B1 A1
Goodbye	Piano arpeggiating down C3 G2 F2 E2 C2

5 CONCLUSIONS AND FUTURE WORK

This project was intended to produce useful and unique interior audio cues for a future GM electric vehicle, in a short amount of time and at a reasonable cost. Four vehicle states were addressed by the audio cues, which are the states most likely to be of interest to the driver: the vehicle has started (or stopped) properly, the engine is ready, and the battery's state of charge. The sounds designed for this project considered various aspects of psychoacoustics and sonic branding in an attempt to create sounds that would be pleasing and useful to the driver, and create a positive brand image.

This project raised many unique challenges, not the least of which was designing to match the context of a vehicle that is not yet in production. We also needed to make sure to develop sounds that would appeal to a wide range of potential buyers, who may come from very different backgrounds and have differing reasons for their

attraction to the vehicle. Therefore, we created four sets of sounds, mapped to four major buyer categories for the vehicle. Another factor behind this decision was to convey the promise of customizability or personalization. The vision for future iterations of this vehicle is to allow personalized sounds, much like ringtones for cell phones. In this way, buyers have the option to personalize their vehicles as parts of their lives, giving a stronger sense of ownership and satisfaction with their car.

As a result of this project, fourteen sounds were produced which will be used to guide interior sound design for the *Volt* interior. These sounds have been delivered to the production team, who will make final decisions regarding necessary modifications and potential inclusion into early generations of the vehicle.

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