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A Pedestrian Warning System (PWS) for Electric and Hybrid Vehicles

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Abstract

The National Highway Traffic Safety Administration (NHTSA) has recognized the safety risk posed by hybrid vehicles (HVs) and electric vehicles (EVs) to unsuspecting or sight disabled pedestrians, cyclists, etc. Often, there is no audible warning of the approaching vehicle.

The Pedestrian Safety Enhancement Act of 2010 (PSEA-S.841) mandates that EVs and HVs "be equipped with a pedestrian alert sound system that would activate in certain vehicle operating conditions to aid visually impaired and other pedestrians in detecting the presence, direction, location and operation of those vehicles." Department of Transportation (DOT) Docket No. NHTSA-2011-0100.

Under one regulatory alternative, recordings of sounds produced by internal combustion engine (ICE) vehicles would be used to create the pedestrian alert sound. This paper describes a PWS that plugs into the On-Board Diagnostic (OBD-II) connector, samples data from the Engine Control Unit (ECU) of the HV or EV over the Controller Area Network (CAN) bus, and transmits the data to a dedicated programmable microprocessor where a library of sound files are stored including various ICE sounds, tire noise, wind, etc.

The microprocessor can produce the desired sound through the vehicle's audio system in synchronization with the actual engine and drive train conditions of the vehicle being driven. Additionally, audio output can be played through external speakers, wired or wireless, to allow hybrid and electric cars to be heard. The device is installed by plugging it into the OBD-II connector which is standard equipment on all vehicles manufactured after 1996.

This technology was awarded US patent 7,979,147 B1 on July 12, 2011.

Keywords: Pedestrian, Bicyclist, HEV (hybrid electric vehicle), ICE (internal combustion engine) Safety, Mandate

1 Introduction

While the rapidly growing acceptance of Electric Vehicles (EVs) and Hybrids (HVs) holds the promise of a greener future, the picture for unsuspecting pedestrians and bicyclists is not so rosy. Quiet cars, whether HVs, EVs or ICEs are particularly dangerous to the blind or unsuspecting, especially when certain vehicle maneuvers are being made such as backing up, turning the corner at an intersection, or when entering street traffic by driving across the sidewalk, such as leaving a parking lot.

The National Highway Transportation Safety Association (NHTSA) completed a 12 state study (DOT HS 811 204) to review pedestrian and bicyclist accidents involving HVs and EVs and compared the results to pedestrian and bicyclist accidents involving ICEs. The results showed a 50% greater likelihood of a pedestrian accident and a 100% greater likelihood for a bicyclist accident with EVs and HVs compared to ICEs. [1]

Weather and road conditions, speed, visibility, etc. were factors that were also considered in the study. The results definitely support the idea that a vehicle needs to be "heard" in order to be "seen" or sensed, especially by the blind.

See Tables 1-3: "Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles" taken from U.S. Department of Transportation, DOT HS 811 204.

Very Little Time for Pedestrians to React to Quiet Cars

A research project funded by the National Federation of the Blind found that HEVs are so quiet that a pedestrian may only have a few seconds to react. The study was conducted at University of California Riverside and consisted of recording a Toyota Prius (HEV) and a Honda Accord (ICE) approaching from two directions at 5 mph. Individuals listened to the recordings in an appropriate setting and were asked to say when they could first hear each vehicle and to identify the direction of approach. The tests showed that the ICE could first be heard when it was 36 ft.

Table 1: Cases included in the analysis

Cases Included in the Study	HEVs	ICE Vehicles
Total Number of Vehicles Included in analysis	8,387	559,703
Pedestrians involved in crashes	77	3,578
Bicyclists involved in crashes	48	1,862

Table 2: Vehicle maneuver prior to pedestrian crashes HEVs vs. ICE vehicles

Vehicle Maneuver	Pedestrian count - HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count - ICE vehicles	Incidence rate of pedestrian crashes - ICE vehicles
Going straight	33	0.9%	2,069	0.8%
Making a turn (*)	19	1.8%	698	1.0%
Slowing/stopping	6	0.5%	148	0.2%
Backing	7	5.3%	261	2.9%
Entering/leaving parking space/driveway	1	1.2%	55	0.9%
Starting in traffic	3	2.9%	50	1.2%
Other	6	0.3%	238	0.2%
Total	**75**	**0.9%**	**3,519**	**0.6%**
Vehicle maneuver is unknown or not reported for 2 HEVs and 59 ICE-vehicles				

Table 3: Vehicle maneuver prior to bicyclist crashes

Vehicle maneuver	Bicyclist count - HEVs	Incidence rate of bicyclist crashes - HEVs	Bicyclist count - ICE vehicles	Incidence rate of bicyclist crashes - ICE vehicles
Going straight (*)	22	0.6%	873	0.3%
Making a turn	14	1.3%	659	0.9%
Slowing/stopping	3	0.3%	101	0.1%
Backing	0	0%	21	0.2%
Entering/leaving parking space/driveway	3	3.6%	20	0.3%
Starting in traffic	1	1.0%	38	0.9%
Other	5	0.2%	129	0.1%
Total	**48**	**0.6%**	**1,841**	**0.3%**
Vehicle maneuver is unknown or not reported for 21 ICE vehicles				

away and its direction of approach could be identified when it was 28 ft. away. However, the HEV could not be heard until it was only 11 ft. away. At 5 mph, that leaves less than 2 seconds to react. [2]

When moving at speeds of around 15 to 20 mph, the tire noise and displaced air (wind) noise allow HVs and ICEs to be heard equally.

See Figure-1: Times available for pedestrians to react to HEVs compared to ICEs.

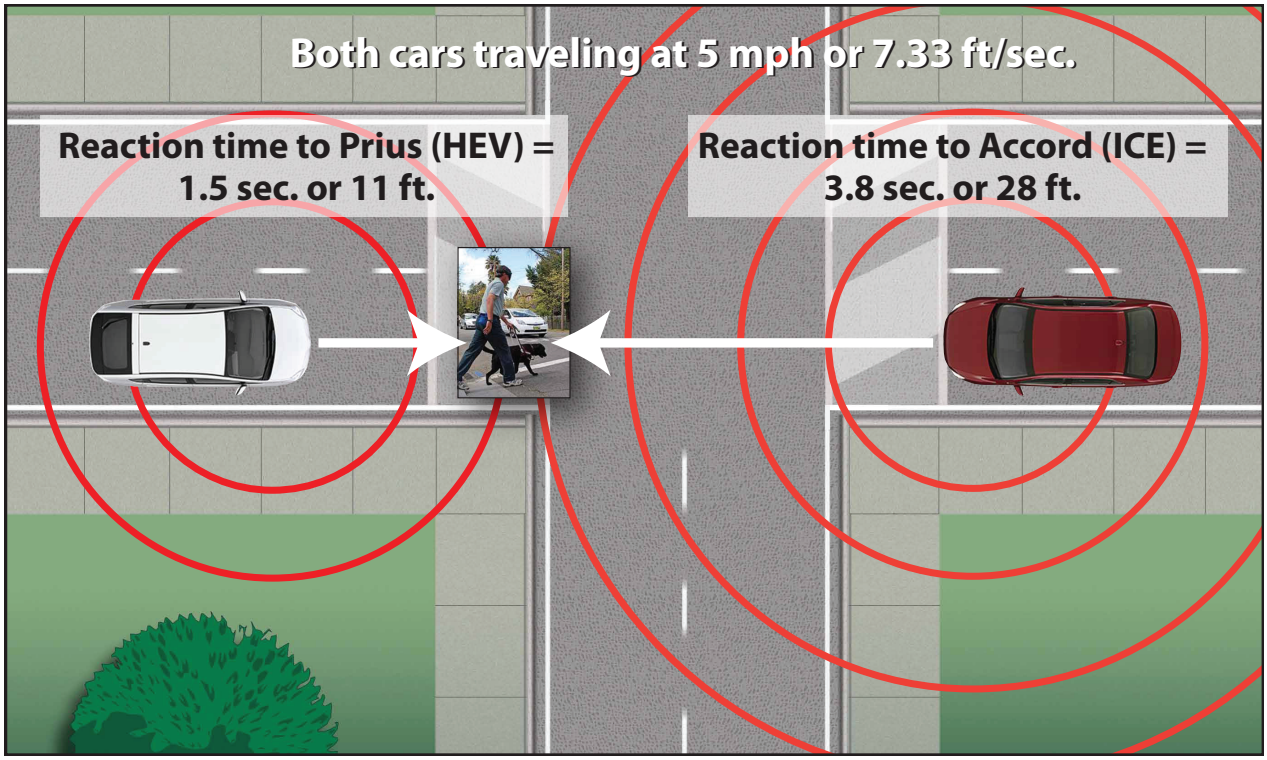

Figure 1: Times available for pedestrians to react to HEVs compared to ICEs.

What Sounds are Most Suitable?

We are conditioned to recognize the sound of an engine, of tires moving on the pavement, and the sound of the air being displaced by the moving car. These same audible cues are essential for guide dogs for the blind. Some auto manufacturers are experimenting with whistling sounds, chirps, horn beeps, swooshes, ad infinitum, but the purpose of the warning system is not to let each manufacturer "brand" their sound, it is to save lives. Pitch and frequency can also be a factor if the manufacturer uses synthetic sounds because the ability to hear higher frequencies diminishes with age. The National Federation for the Blind has suggested that intermittent sounds (beeps, chirps, etc.) are not as effective as continuous sounds, and that HEVs should emit a sound while idling as well as when moving slowly. [3]

When and How to Control the Sounds

The PSEA mandates that new EVs and HVs made after a phase-in period of approximately three year must have a warning system that cannot be disabled by the driver, and always makes a sound below a certain speed (actual on/off speeds have not been decided yet but will likely be around 15 mph or slower, where tire and wind noise no longer serve as warning).The law does not require HEVs built before that date to be fitted with a PWS. However, the device described in this paper can easily be installed in existing HEVs as well as in new HEVs as they are being manufactured.

ECTunes of Denmark collaborated with DeltaSense Lab to determine the warning sound specifications for their PWS being offered to original equipment HEV manufacturers for factory installation. [4]

See Table 4: Warning Sound Specifications

RocketAudio, Germany, is using the Texas Instruments L138 OMAP CPU/DSP to generate synthetic sounds, not only for pedestrian warning but for other car functions/warnings such as door openings, service required, etc. The product is factory installed on new HEVs and is not offered as a retrofit to existing HEVs. [5]

Proximity Sensing

Some car makers are proposing warning systems that use radar or sound waves to determine if "objects" are in proximity before making a pedestrian warning

Table 4: Warning Sound Specifications DeltaSense Lab

Sound	Driving mode	Speakers	Duration	Level	Message
Start sound	Turning power on	Front + rear	Max 2 sec	$dB_{ALICE} \cong$ 61-66 dB(A) ICE	Active car near by
Idle sound	When speeder is activated.	Front when "gear" in forward. Rear when "gear" in reverse	Speed 0-5 km/h	$dB_{ALICE} \cong$ 51 dB(A) ICE	Car beginning to drive
Drive sound	Speed above 5 km/h	Front when "gear" in forward. Rear when "gear" in reverse	Speed 5-30 km/h	See Figure 26	Driving car
Reverse sound	When speeder is activated	Rear when "gear" in reverse	Speed 0-30 km/h	See Figure 26*	Backing car

Warning sounds for the external sound generation system and their usage. dB_{ALICE} is the A-weighted sound pressure level needed for a warning sound, to give same audibility as a reference Internal Combustion Engine sound with the stated levels.
**When the reverse sound is added to the drive sound the level increase shall be less than 3 dB (A).*

sound. Much of the technology for proximity sensing is derived from existing "pre-crash" systems that use video, near and far infrared and radar. Ultrasound sensors typically used for parking aids are also being considered for sensing pedestrians. The difficulty in sorting out people from objects such as other cars could make this approach very unreliable in serving the real purpose of alerting pedestrians.

2 Pros and Cons for Warning Sounds

Some think that making hybrids louder won't solve anything. "To further expose millions of people to excessive noise pollution by making vehicles artificially loud is neither logical nor practical nor in the public interest," said Richard Tur, founder of NoiseOFF, a group that raises awareness of noise pollution. Others believe that distracted pedestrians are at greater risk than blind people from quiet cars. [6]

Those in Favor:

1) The NHTSA and the legislators who have supported the PSEA.
2) The National Federation for the Blind and other groups serving the sight disabled such as Guide Dogs for the Blind.
3) Pedestrians and cyclists who have already had a direct experience with a silent vehicle.
4) Conscientious drivers of silent vehicles who already have had an incident or "near miss" with a pedestrian or cyclist.

Those with Reservations or Doubts:

1) Some EV and HV owners are passionate about the fact that their cars are totally silent and want to keep it that way.
2) Urban planners have created ordinances to control noise pollution, banning boom boxes, loud exhausts, horn-honking, etc. Imagine the din if each HV or EV had its own signature squawk or beep and they all approached an intersection at the same time. Nancy Giora, Ford's Director for Global Electrification states: "Car companies should consider standardizing tones from future hybrids and electrics to avoid a cacophony of confusion on the streets." [7]
3) Auto manufacturers have to adapt to ever-changing laws depending on the country involved. Nissan had to remove their Vehicle Sound for Pedestrian (VSP) system on the Leaf vehicles delivered to the UK in order to conform to that country's law that requires that any hazard warning be capable of being disabled between 11:00 PM and 6:00 AM.
4) An article published July 24, 2011 in The Independent in the U K states that "Quiet electric cars 'pose no danger' to visually impaired. Warning sounds will not be added as government report deems them unnecessary." [8]

3 Overview of Solutions

The Table below shows the solutions presently offered now by various HEV manufacturers. [9]

See Table 5: Summary of Electric-Drive Cars (see next page)

Need for Customization

Since the laws that require a pedestrian warning system for HEVs are still being drafted, any solution offered now needs to be customizable. A PWS that uses a programmable micro-controller provides the flexibility required to adapt to the following areas of performance.

1) Manual on/off for aftermarket use, allows disabling.
2) Auto on/off for PSEA 2010 compliance with no disabling.
3) Stored library of sounds, ICE, tire noise, etc. upgradeable via USB, sounds of exotic cars like Ferrari, etc.
4) Set vehicle speeds at which the "alert" sound is engaged/disengaged.
5) Sense engine on, idle, forward or reverse.
6) Adjustable volume of playback for aftermarket. Factory set for PSEA compliance.

Table 5: Summary of Electric-Drive Cars

Vehicle	Powertrain type	Sound activation	Type of sound	Launch date	Markets
2012 Toyota Prius v	Hybrid electric	Automatic	Continuous	October 2011	U.S.
2012 Toyota Prius Plug-in Hybrid	Plug-in hybrid	Automatic	Continuous	2Q 2012	U.S.
2012 Toyota Prius	Hybrid electric	Automatic	Continuous	2012	U.S.
2011 Nissan Leaf	All-electric	Automatic with manual turn off	Forward: continuous Reverse: intermittent	December 2010	Japan and the U.S.
2011 Nissan Fuga Hybrid Infiniti M35	Hybrid electric	Automatic with manual turn off	Forward: continuous Reverse: intermittent	Late 2010/2011	Japan (2010) and U.S. (2011 as 2012 Infiniti M Hybrid)

PWS Installation

The PWS shown below is installed by plugging it into the OBD-II connector and following some simple calibration procedures. Each time the vehicle is subsequently started, the microcontroller completes an "auto-initialize" routine.

See Figure 2: Typical Installation of the Pedestrian Warning System (PWS) in an HEV.

The PWS described in this paper uses an ARM 32 bit micro-controller in the following manner:

See Figure 3: Pedestrian Warning System, Functional Diagram (see next page).

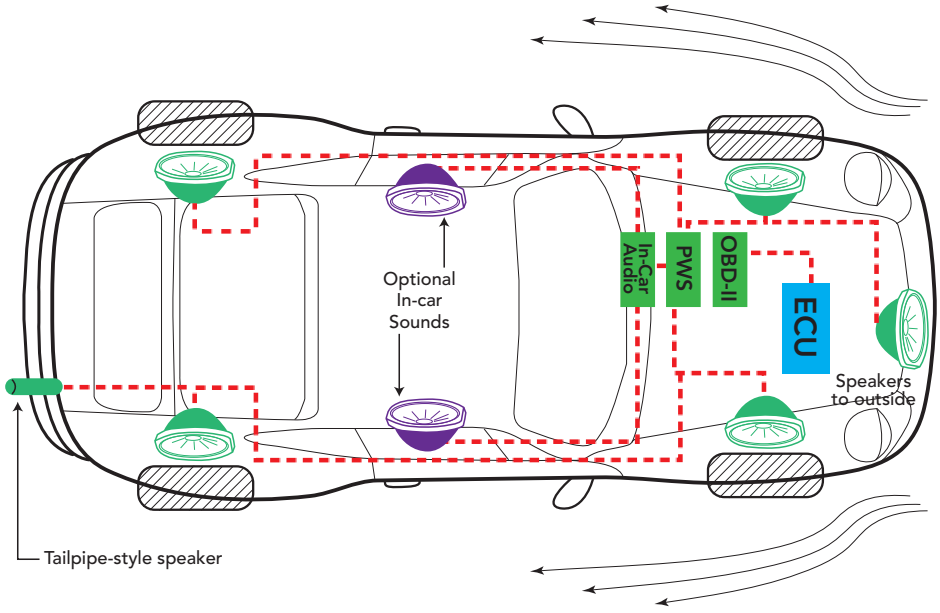

Figure 2: Typical Installation of the Pedestrian Warning System (PWS) in an HEV

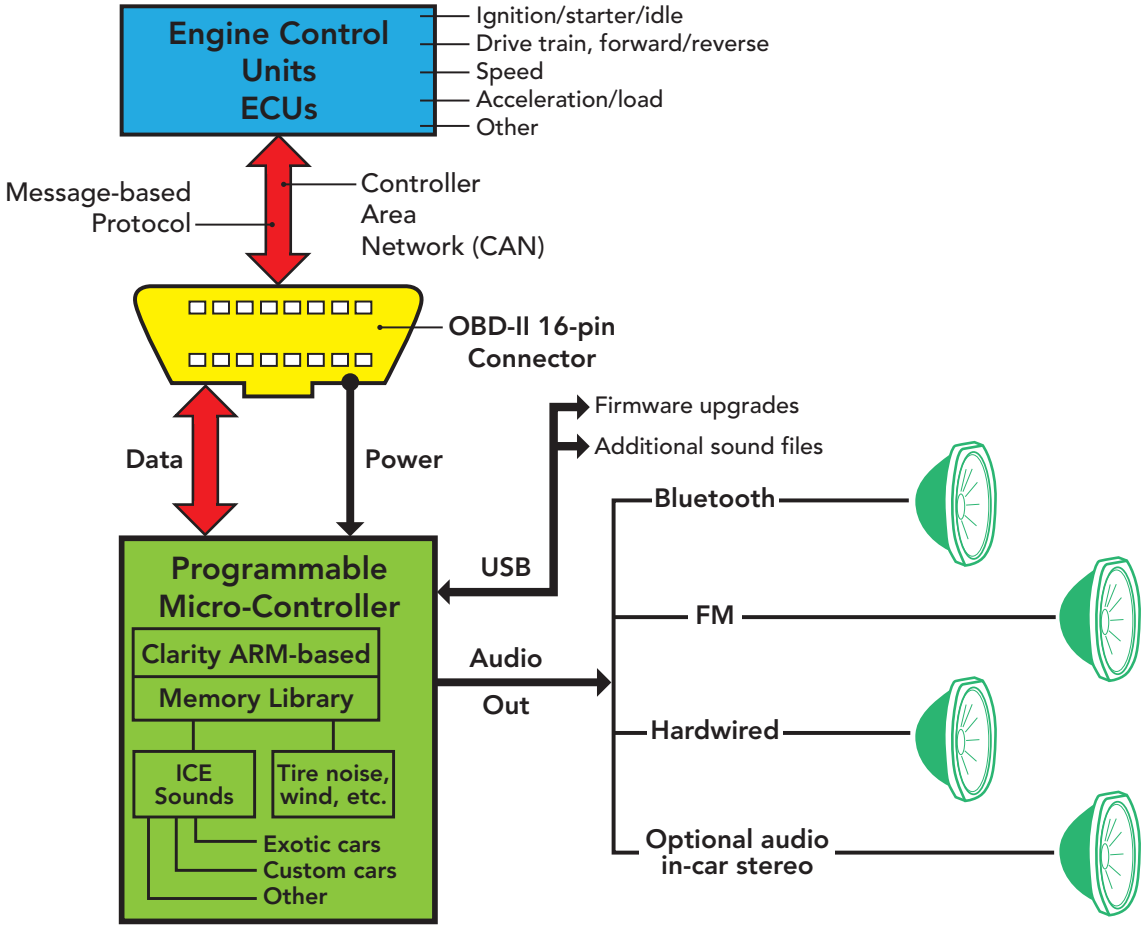

Figure 3: Pedestrian Warning System, Functional Diagram

Figure 4: PWS Warning Device

See Figure 4: PWS Warning Device

Conclusion

a) Laws being enacted in the USA and Japan will require HEVs to include a factory installed PWS.

b) The most effective PWS devices will use the sounds typical of an internal combustion engine as the audible alert.

c) Microcontroller-based designs for the PWS will allow flexibility and adaptability to change.

d) Owners of existing HEVs will most likely be exempt from these laws but might consider an aftermarket device if it were inexpensive, easy to install and reliable.

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Author

Jim Dunn is the founder of Dunn Instruments and developed the first commercially available film printers for capturing computer generated medical images. The images of Saturn that were captured by NASA's Pioneer Project were processed by the Dunn 631 Camera.

In his present role as Vice President, Business Development at Sound Vision Inc., he is responsible for developing new applications for the company's Clarity line of microprocessors.

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