Development of Automatic Evaluation System for Vehicle Alarm

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Abstract

Recently, car infotainment products include not only basic functions such as "using a car navigation" and "listening to music", but also new functions such as "display a rear camera image" and "sound a vehicle alarm", and the fucntions are more complicated. In order not to cause problems in the market, it is necessary to comprehensively evaluate these functions.

DENSO TEN combined these functions with about 100,000 kinds of power supply waveforms at the time of engine start-up, built an "automatic power supply variation test system" to perform a comprehensive evaluation, and has been operating the system. This time, we have developed an automatic judgment function of the "vehicle alarm" which is one of new functions, and developed an automatic power supply variation test system by combining the function with a power supply variation test so as to improve comprehensiveness. This paper introduces the system here.

1. Introduction

DENSO TEN develops car infotainment products such as car navigation systems, and we perform various evaluations to prevent malfunctions from occurring on the market. With in-vehicle devices, generally, each function begins operating and there is significant burden on the system when the engine starts, making it easy for malfunctions to occur. At DENSO TEN, we have constructed and been operating a power supply fluctuation test system that comprehensively and automatically applies and confirms the function of approximately 100,000 different types of power supply waveforms upon engine start-up.

In recent years, new functions that link with the vehicle ECU have been added to in-vehicle devices, such as "displaying the rear camera image" or "sounding the vehicle alarm." However, due to various reasons, these new functions cannot be handled using the automatic power supply fluctuation test system, and evaluation is performed manually. As a result, a massive amount of evaluation work hours and a long period is required for comprehensive evaluation.

Here, we have developed a vehicle alarm judgment function and combined it with the power supply fluctuation test, developing an automatic power supply fluctuation test system with improved comprehensiveness in order to reduce work hours and improve evaluation reliability.

2. What Is a Vehicle Alarm?

A vehicle alarm is a function that warns the user, such as a seatbelt unfastened alarm or a turn signal sound. For example, when the seatbelt is unfastened, a clanging alarm sounds three times from the front speaker, warning the driver. There are over 100 kinds of different alarm sounds for each such alarm event, and they are preset in the product in advance. When an event occurs, the in-vehicle device sounds the vehicle alarm due to the command from the vehicle ECU.

3. Issues and Responses in System Development

Conventionally, the automatic power supply fluctuation test system used a “sine wave” to judge if the CD or radio audio was operating properly. If it was a sine wave, a measuring instrument such as a multi-meter could be used to make a judgment.

However, vehicle alarms are preset in advance and cannot be arbitrarily changed. To judge vehicle alarms, a vehicle alarm judgment function had to be newly developed. However, if we individually created judgment functions for each of the more than 100 kinds of vehicle alarms, the program would be massive. Thus, an issue was how to determine the vehicle alarm is correctly functioning.

Here, taking advantage of the fact that vehicle alarms are comprised of four types (beeps, bells, clicks, and clacks), we proceeded with development under the policy of responding with the judging algorithm for each basic pattern, and the fluctuation in parameters (sounding count, different lengths, etc.)

The following explains the four types of vehicle alarms.

Beeps sound like “peep, peep,” and are intermittent sounds that have a sine wave with a constant frequency, like in **Fig. 1**.

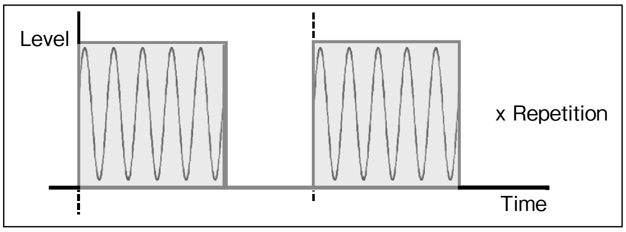


Fig. 1 Definition of a Beep

Bells sound like “clang, clang” and have a sine wave with a constant frequency similar to beeps like in **Fig. 2**, but are characterized by how the volume gradually changes and the sound ends with a resonance.

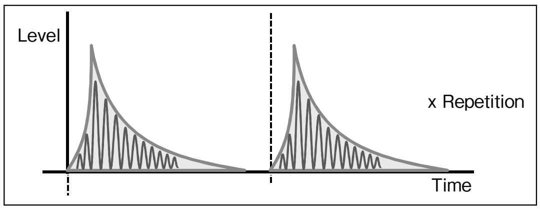


Fig. 2 Definition of a Bell

Clicks and clacks are the “tick, tock” sounds you hear when you operate your turn signal, which “tick” being a click and “tock” being a clack.

We performed investigation into how to determine that these sounds are being played.

4. Judgment Algorithm

Fig. 3 graphs four patterns of vehicle alarms we actually recorded from testsamples.

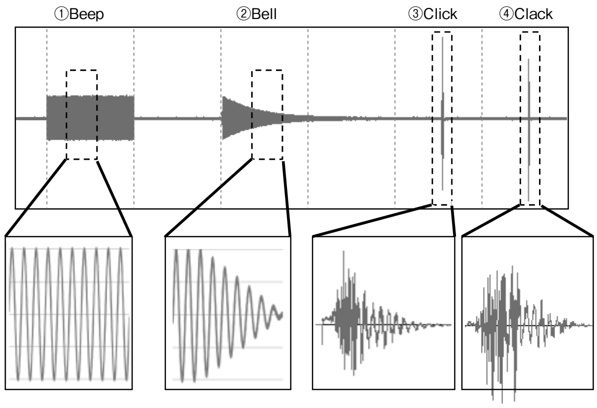


Fig. 3 Actual Vehicle Alarms

① Beep and ② bell are characterized by their continuing sine wave with a constant frequency. The difference here is, while ① has a constant level, ② has a level that gradually reduces. On the other hand, it is difficult to express the characteristics of ③ click and ④ clack using changes in the frequency and level. We need a perspective different from ① and ②.

First, for ① and ②, we divided the recorded vehicle alarms into sections at constant intervals and performed the Fourier transform for each section, calculating the peak frequency and level. Items where the frequency in all sections was constant and the level was also constant were categorized as “beeps,” while items where the level attenuated were categorized as “bells” **(Fig. 4)**.

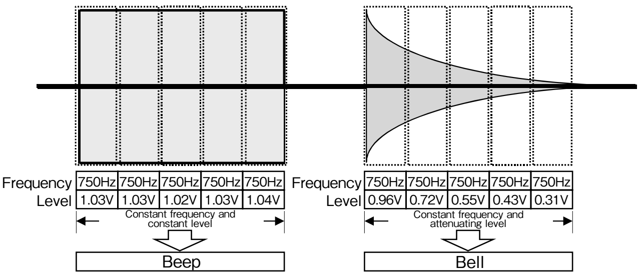
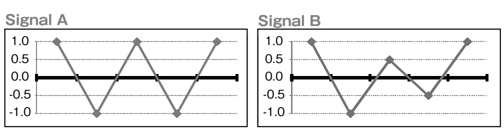


Fig. 4 Judgment Algorithm for Beeps and Bells

Regarding the calculated intervals, if they are too fine, judgment takes time, while if they are too rough, it affects the judgment result. After investigating with ① and ② of the actual vehicle alarms, we found that 1024 samples (approx. 43 milliseconds each) was the optimal amount.

Next, for ③ and ④, we applied the pattern matching method used in the field of signal processing. Pattern matching is a judgment method wherein the cross-correlation coefficient of two signals is calculated and determined to be “identical” if it meets or exceeds a certain threshold. A cross-correlation coefficient is an index used to measure the relationship of trends in the changes of two signals, and is often used in the field of image judgments. Here, we applied it to audio judgment.

For example, we have two signals, A and B, as in **Fig. 5**. The values for the two signals are a little bit different, but on the whole, they are very similar. If we calculate the cross-correlation coefficient for these signals, we find it is “0.8.”

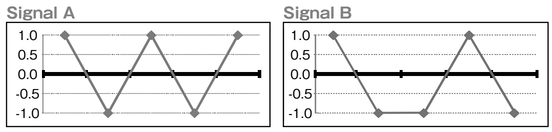


	1	2	3	4	5
Signal A	1.0	−1.0	1.0	−1.0	1.0
Signal B	1.0	−1.0	0.5	−0.5	1.0
Product of A and B	1.0	1.0	0.5	0.5	1.0

Total of product	4.0
Normalized	4.0÷5.0=0.8
Correlation coefficient	0.8

Fig. 5 Cross-correlation Coefficient (Similar)

On the other hand, the two signals in **Fig. 6** are, on the whole, not very similar. If we calculate the cross-correlation coefficient for these signals, we find it is “-0.2.”



	1	2	3	4	5
Signal A	1.0	−1.0	1.0	−1.0	1.0
Signal B	1.0	−1.0	−1.0	1.0	−1.0
Product of A and B	1.0	1.0	−1.0	−1.0	−1.0

Total of product	−1.0
Normalized	−1.0÷5.0=−0.2
Correlation coefficient	−0.2

Fig. 6 Cross-correlation Coefficient (Not Similar)

In this way, the more similar the changes of the two signals are, the larger the value of the cross-correlation coefficient is. The value is in a range of +1.0 to -1.0. Using the click-clack we acquired from test samples in advance as the expected audio, we calculated the cross-correlation coefficients for actual vehicle alarms ①, ②, ③, and ④, resulting in **Fig. 7**. We discovered that judgment could be done properly using “0.8” or higher as the threshold.

Expected audio	Alarm	Correlation coefficient
Click	①	0.303
	②	0.232
	③	**0.901**
	④	0.741

Expected audio	Alarm	Correlation coefficient
Clack	①	0.365
	②	0.351
	③	0.645
	④	**0.927**

Fig. 7 Result of Applying Cross-correlation Coefficient

5. System Application Effect

We embedded the vehicle alarm judgment function we developed into the automatic power supply fluctuation test system, linking it with existing power supply fluctuation test functions such as the power supply waveform application and operation confirmation, and added a function that creates and judges a new, arbitrary vehicle alarm **(Fig. 8, Fig. 9)**.

By doing so, we were able to construct a system that can automatically perform comprehensive evaluation combining vehicle alarms and power supply fluctuation testing for 100,000 waveforms, 24 hours a day. As a result, compared to when evaluations were performed manually, we reduced evaluation work hours from 720 hours to 8 hours, and were able to shorten the testing period from 90 days to 30 days, reducing it to 1/3.

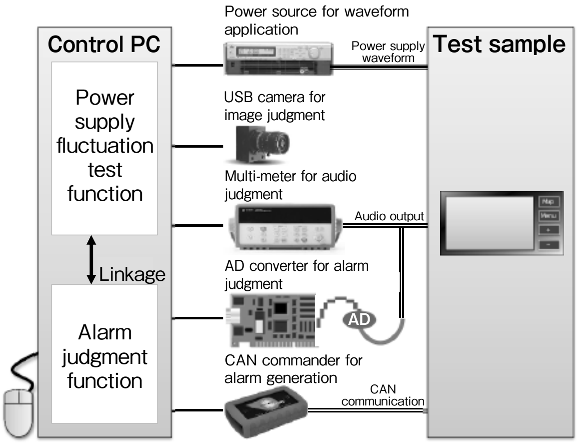


Fig. 8 System Configuration

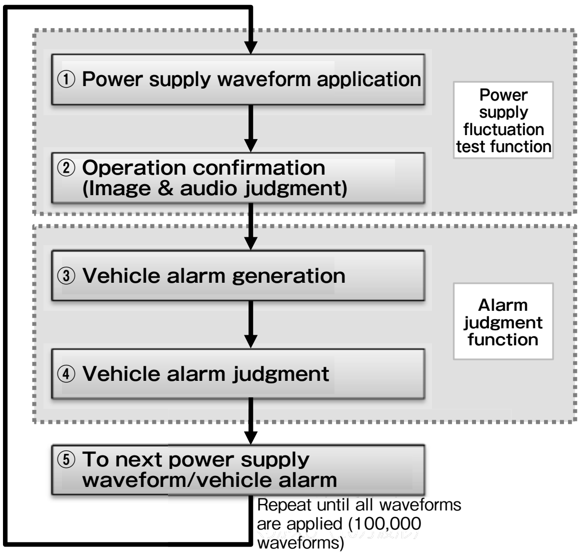


Fig. 9 Flow of Testing

6. Conclusion

We were able to embed the vehicle alarm judgment function into the automatic power supply fluctuation test system, thus improving comprehensiveness. In the future, we hope to embed new functions, such as rear camera images, into the system to improve the efficiency and comprehensiveness of evaluation.

Profiles of Writers

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