

Automotive AC System Induced Refrigerant Hiss and Gurgle

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ABSTRACT

Traditional IC engine powered vehicles readily mask the lower amplitude transients like hiss, clicks and slight tones. However, due to the popularity and expected increase in number of hybrid and electrically driven automobiles all around the world, all the OEMs are concerned about the vehicle interior quietness and sound quality. Refrigerant system induced hiss/gurgle is quite normal phenomenon but its excessive levels and frequent occurrences can be objectionable to demanding customers. Introduction of new environmentally friendly refrigerants (HFO-1234yf), A/C compressors with built-in oil separation (reduced damping in evaporator), and use of IHX with coupled suction and liquid lines, may lead to increased refrigerant system induced hiss and gurgle.

Operation of typical A/C system generates steady-state and transient noises that consist of audible tones and high frequency hiss. A/C system usage is seasonal and operation controlled by the customer, hence the noise (if present) is readily perceived and flagged as a concern. This paper focuses on diagnostics of refrigerant system induced noise sources and spectral characteristics. A systematic approach is used to quantify and identify the paths of the refrigerant system induced hiss/gurgle propagation at the component, subsystem and vehicle levels. Also discussed are the most cost-effective counter-measures and guidelines for its suppression.

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INTRODUCTION

Automotive customers regard vehicle interior quietness quality as a major quality attribute that positively influences their vehicle purchase decisions. Introduction of electrically driven air-conditioning (A/C) compressors in the hybrid and electric drive vehicles, makes even lower amplitude noise and vibration phenomena become readily perceivable, especially when the vehicle operates in electric mode or it idles at a traffic lights. Based on the ambient and operating conditions, A/C compressors typically cycle couple of times every minute. Hence, any noise and vibration induced transients (if present) if excessive become audible and can potentially result in customer complaints/concerns. In general, automotive OEMs design their refrigerant system induced noise is readily masked by lower blower noise. However, the initial refrigerant system induced hiss can be quite severe compared to the continuous hiss following the normal A/C cycling. In addition, if the A/C is ON, and the ignition key is turned off suddenly, another transient noise referred as 'gurgle' can be perceived for 2 to 5 seconds. Due to the audibility of these unusual noises in the vehicle interior, some customer may get alarmed and suspect there is leakage of gas and/or water trickling.

Past approaches to suppress these phenomena have been to wait till the prototype vehicles are available, and thereafter develop and implement the needed design fixes to suppress them. However, the last minute design fixes that are developed are regarded as expensive band-aids that become very challenging and difficult to implement. Hence, identification of the sources and paths of propagation for these unusual phenomena at an early stage of system development is essential for understanding the inherent mechanisms and developing the needed design-fixes for their suppression.

REFRIGERANT HISS MECHANISM

Automotive air-conditioning and/or refrigerant systems are closed systems, with most of the components located in the engine compartment except for the evaporator that is located in the air-handling system under the instrument panel. When the A/C system is turned on, compressed refrigerant at high temperature and pressure gets pumped from compressor to the condenser that discharges liquid and/or gas refrigerant at high temperature and pressure to throttle through an orifice tube or a thermal expansion valve into gas and/or liquid vapor mixture through the evaporator, where it absorbs the moisture and heat from the air that cools the vehicle interior. Throttling

of the liquid refrigerant at high pressure through a tiny orifice, evaporates it to vapor with very high flow velocity causing the jet noise. However, under certain conditions, if the vehicle has been sitting or parked for 5 to 10 hours and the A/C is turned on suddenly, due to presence of high pressure gaseous refrigerant (instead of liquid) at the TXV, a loud and sometimes tonal hiss transient is induced followed by a steady hiss. The louder tonal transient and steadier hiss are also referred as initial hiss and normal cycling hiss, respectively. In general, the OEMs expect the low blower airflow induced noise to mask the refrigerant system induced hiss. However, with a sudden key OFF, A/C induced transient gurgle becomes audible due to lack of sub-cooling and the low blower masking.

Hiss Measurement Facility

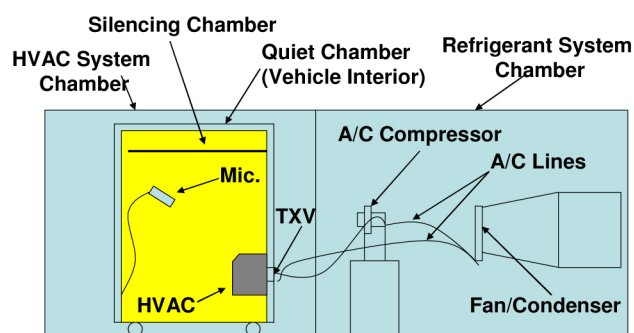


Figure 1. Refrigerant Sys. Induced Hiss Measurement Facility

A unique test-facility for refrigerant system induced noise measurement capability was designed to facilitate subsystem and component level evaluations. Figure 1 shows a schematic view of the setup with adjoined HVAC and Refrigerant system Chambers. Both the chambers were equipped with desired temperature and humidity controls. In addition, an acoustically designed quieter chamber was used in the HVAC system chamber to simulate quieter vehicle interior and isolate the A/C compressor noise from the refrigerant system chamber that simulated the engine compartment. The TXV was located in the quiet chamber wall that simulated the dash-wall in a vehicle environment. All the refrigerant system components must be production level prototypes to induce and excite the vehicle level refrigerant hiss that the customers will perceive.

Evaporator-TXV Components

Attached Figure 2 describes various components of the Evaporator TXV assembly from refrigerant IN to OUT. The evaporator is wrapped with some foam material and located in the HVAC case designed to not let any airflow leakage from its extremities thus ensuring that all blows through/ around the evaporator tubes and fins.

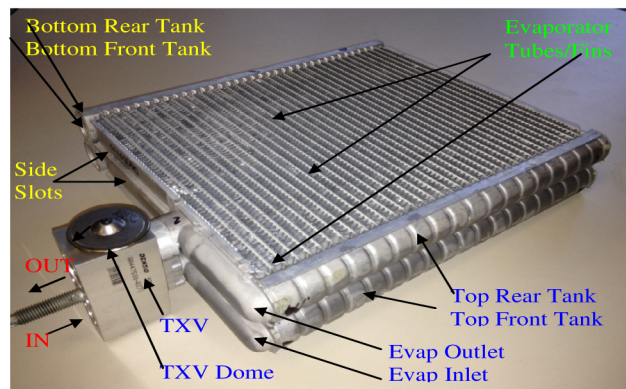


Figure 2. Component (Evaporator) Level Measurement setup

Hiss Phenomena at Evaporator Level

For a systematic noise source quantification and path identification, initial measurements were done on an instrumented evaporator alone in the quiet chamber without any airflow across the evaporator as shown in Figure 3. Two tri-axial accelerometers were mounted on the liquid line in and suction line out of the TXV (Thermal Expansion Valve) and six single-axis accelerometers were mounted on the Front and Back face of the evaporator. In addition, two microphones were located to correlate noise and vibration - one in the near-field at 2 cm, and the other one at 54 cm at 45° from the evaporator center.

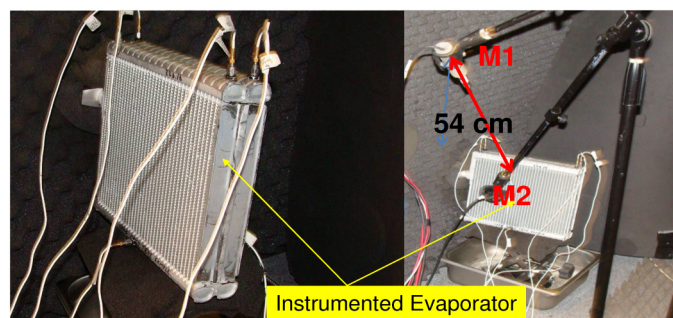


Figure 3. Component (Evaporator) Level Measurement setup

Various noise and vibration measurements revealed that there was good correlation. The near-field microphone was not as loud as the one at 54 cm, suggesting that when the hiss is induced evaporator radiates it more from the end-tanks and side-plates.

Evaporator level vibration measurements confirmed that TXV outlet going into the evaporator was the louder than the TXV inlet from the evaporator. However, due to metallic tubes upstream and downstream of the TXV, all the noise and vibration transmits to the vehicle interior via the evaporator and the HVAC case. Typical noise and vibration