

Automating the Screening of Microphonic Defects in Automotive Radio Receivers

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This article describes a test setup for radio testing in the high vibration of an automotive environment

As a vehicle travels over uneven roads with many potholes, bumps, etc., its chassis couples mechanical shocks to the dash-

mounted radio receiver. Due to the phenomenon of *microphonic*, this mechanical energy is translated into electrical noise within the radio. The end result is a jarring noise affecting the listener's enjoyment of the radio program. A microphonic-prone radio can affect the customer's perception of the product quality, so manufacturers actively seek to eliminate radios with the worst manifestation of this defect during production testing.

Background

A. Definition and Cause

Microphonic noise is defined as unwanted electro-acoustic effects that can be produced as a result of mechanical vibration of components [1]. The term *microphonic* arose because some components behave like little microphones. A car radio has several hundreds of electronic and electro-mechanical components, and the more sensitive ones convert mechanical displacement into electric current. These initially tiny noises are amplified by the RF and audio gain stages in the modern super-heterodyne receiver. (FM receivers have >100 dB of cumulative gain between aerial and loudspeaker.)

B. Susceptible Components in Receivers

Certain components are more sensitive than others. In the early 20th century, aircraft receivers suffered from microphonic because the filaments and grids in vacuum tubes could

vibrate [2, 3]. In the modern semiconductor-based superheterodyne receiver, the local oscillator (LO) and the phase locked loop (PLL) are often involved. Sudden movement can either shift the LO resonator's frequency [4] or momentarily unlock the PLL [6] and the resultant frequency changes are translated to noise by the FM demodulator. The quartz crystal, which serves as the PLL frequency reference, has also been implicated [6]. The alternate architecture of direct conversion is also prone to microphonic due to its very high gain at audio/baseband [7, 8].

Microphonic noise also occurs due to intermittent contact, such as when a vertically standing daughterboard is joined to the motherboard through a mechanically inadequate connector. When the assembly is subjected to vibration, the movement of the daughterboard can cause the connector's spring-loaded contacts to break and reconnect, creating tiny electrical transients [9].

C. Existing Screening Process Limitations

Current production screening relies on trained workers to perform a standardized listening test in order to screen for this defect. Following the IEC 315-4 measurement setup for unwanted acoustic feedback [1], an unmodulated RF signal is connected to the radio's aerial input connector through an attenuator network that is intended to simulate a vehicle-mounted aerial [10]. With the radio tuned to the carrier, the volume control is adjusted to 75% of its maximum range. The radio top surface is then tapped repeatedly with either a small mallet or the hand while listening for the signature ringing noise [11]. Because microphonic evaluation relies on the

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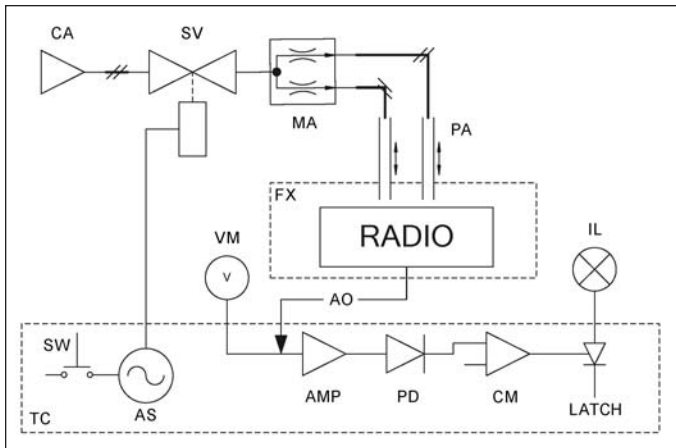


Figure 2 · Block diagram of the microphonic tester.

listener’s subjective judgement, no quantitative measure exists to define the defect [12]. Another factor is the variation in the tapping force by different individuals.

The present form of microphonic screening can be highly fatiguing to the operator due to the unpleasant noises. Moreover, the test must be conducted inside a sound-proof enclosure to prevent background noises from clouding the operator’s judgment. These enclosures occupy precious space along the assembly line.

Proposed Automatic Screening Tool

A. Mechanical Stimulus

Figure 1 is a block diagram of the proposed system. As the dimensions of the car radio receiver are DIN standardized [13], one fixture (FX) can fit all models. FX is made of clear plastic and holds the radio in place, also providing a mounting surface for a 3 × 3 array of pneumatic actuators (PA). When activated, these pencil-type pneumatic cylinders plunge downward to strike the radio top surface, to mimic a human operator tapping at various spots (Fig. 2).

When switch (SW) is closed to initiate the test, the astable multivibrator circuit of Figure 3 (AS), built around an NE555 IC, drives the actuators at a 2 Hz rate via a solenoid valve (SV). This repetition rate was chosen to as a balance between the time needed for the actuators to return to rest and getting a stable reading of the microphonic noise voltage on an audio voltmeter (VM). Although the audio voltmeter has a damped meter movement, it cannot “hold” the reading steady if the repetition rate of the evaluated signal drops below this value. Conversely, a higher repetition rate than this value would have resulted in the actuators being unable to return to their fully retracted position, lowering the striking force. A manifold (MA) splits the compressed air coming out from the solenoid valve to the 9 actuators.

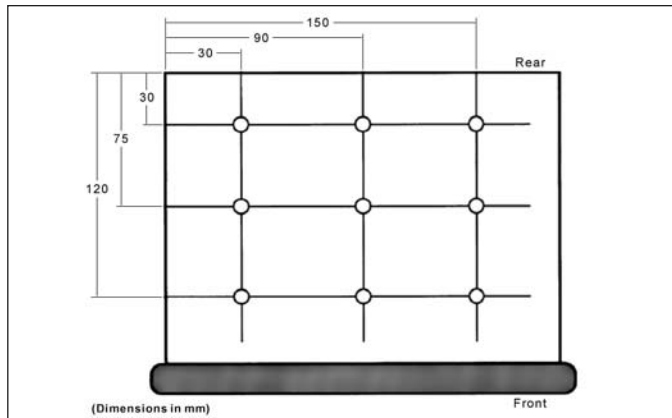


Figure 1 · Positions on the radio top surface (marked by circles) where the pneumatic actuators (PA) strike.

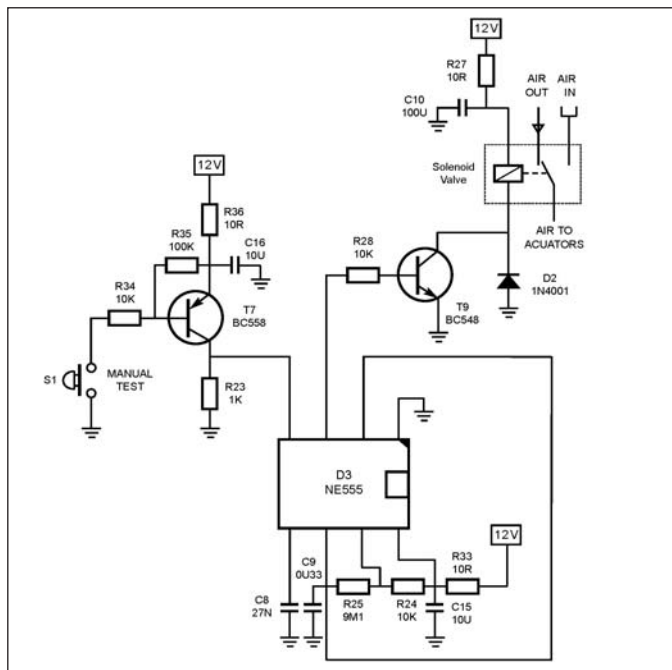


Figure 3 · Circuit for driving the solenoid valve (SV).

A standardized mechanical stimulus is presented to different models as the actuator position is referenced to the radio housing via the fixture. The impact force is fixed by regulating the compressed air (CA) source pressure at 2 Bar and the distance of actuator travel to 12 mm (this is the distance between the tip of the fully retracted actuators and the impact surface).

Prior efforts at creating repeatable mechanical stimuli for microphonic testing relied on a shake table [5, 14, 15]. However, the pneumatic actuators proposed in this work are significantly cheaper and smaller than the shake table. Additionally, it is easier to integrate with the control electronics because the solenoid valve uses low DC voltage whereas the shake table is mains powered.

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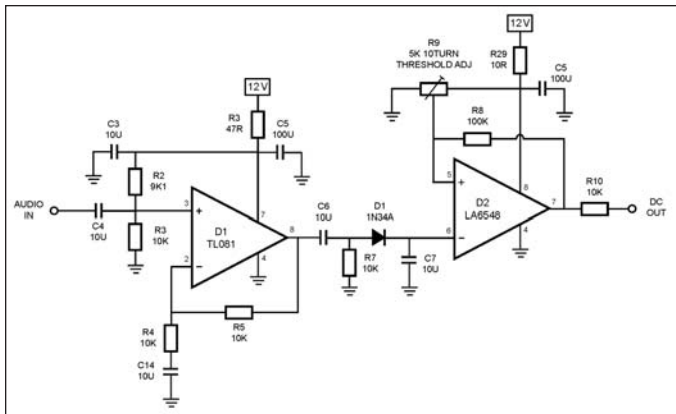


Figure 4 . Circuit of the microphonic noise detector consisting of buffer amplifier (AMP), peak detector (PD) and threshold comparator (CM).

B. Microphonic Noise Detector

During the test, the radio audio output (AO) is simultaneously evaluated by an audio voltmeter (VM) in peak detection mode and a microphonic noise detector (Fig. 4) consisting of TL-081 operation amp (AMP), 1N34A germanium diode peak detector (PD) [16], LA6548 op-amp comparator (CM) and a cross-coupled bipolar transistor pair latch (Fig. 5) [17]. The detection sensitivity can be adjusted through a 10-turn potentiometer (R9) connected to the comparator reference input. When the comparator preset threshold is exceeded, the comparator output momentarily changes state. The latch (T2 and T4 in Fig. 5) holds the comparator output state change and an indicator light provides visual feedback to the human operator. The latch is reset before the next sample is tested.

Both the actuator driver and the noise detector were hand-assembled on a printed circuit board designated as the test controller (TC) in Figure 6.

Test Method and Result

The microphonic tester was initially correlated with human perception by evaluating radio samples that have been previously ascertained as “good” and “bad.” These are production units kept as reference samples by the quality department for operator training.

For repeatability between samples, it was necessary to standardize their volume control settings prior to commencing the microphonic test. With a reference RF signal ($f = 98 \text{ MHz}$, $E' = 40 \text{ dBuV}$, $m = 22.5 \text{ kHz FM}$ and $AF = 1 \text{ kHz}$) connected to the radio’s aerial input and the audio output (AO) terminals monitored by the audio voltmeter (VM), the volume control was adjusted to give a voltage of $1.41V_{\text{RMS}}$ into a 4Ω load (equivalent to $0.5 W_{\text{RMS}}$)—this value was chosen because it reflected the typical listening level in a passenger car. Upon completing the volume control adjustment, the modulation on the RF signal was

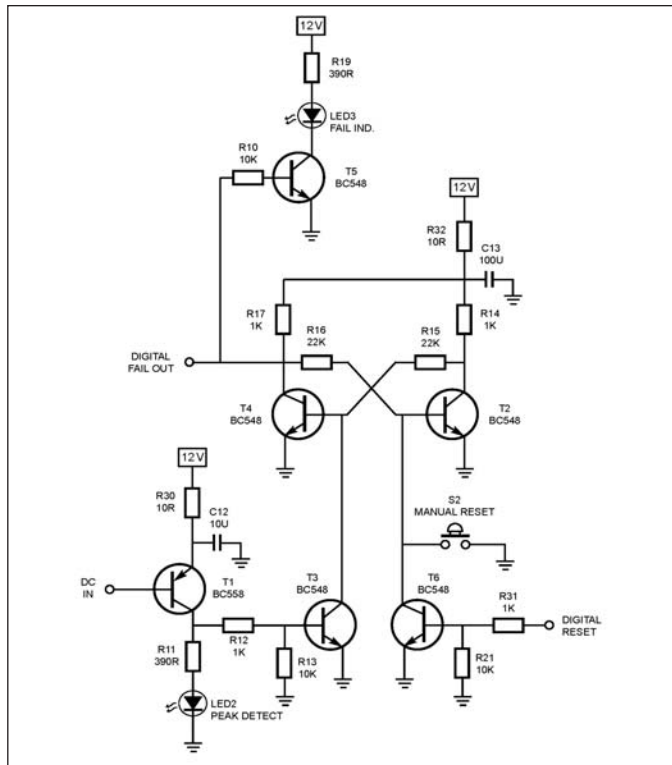


Figure 5 . Latch and indicator (IL) driver circuit.

turned off ($m = 0$). With an unmodulated carrier as the source, the voltage at the audio output terminals dropped to almost zero. Subsequently, the pneumatic actuators were then activated to initiate the microphonic test and the noise voltage at the audio terminals was recorded.

It was observed that the audio output voltage of the “good” samples ($n = 2$) did not exceed 220 mV , whereas the “bad” units ($n = 2$) consistently exceeded this value. Therefore, the pass/fail threshold on the comparator was tentatively adjusted this value. It is anticipated that the comparator threshold voltage will have to be further fine-tuned using a larger sample size prior to the tester being adopted by manufacturing. Due to the limited number of test samples, it was not possible to collect meaningful data on the tester reproducibility.

Conclusion

An automatic screening tool for microphonic defect has been described and proposed as replacement for the subjective listening test which is currently performed by trained operators. Besides being low cost and easy-to-build, this screening tool removes the human decision-making process by visually alerting the operator when a preset threshold for microphonic is exceeded. Additionally, it presents a consistently reproducible mechanical stimulus to the test sample and enables the defect to be quantified by a measurable value. As the measurement medium is elec-

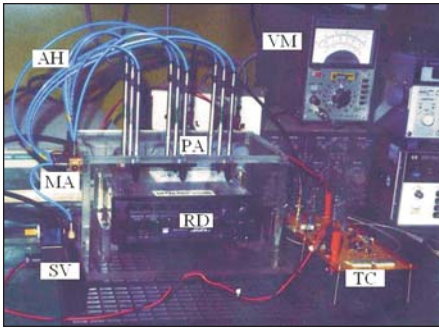


Figure 6 · Photo of the microphonic tester in preliminary operation.

trical rather acoustic, considerable saving in floor space is achieved by eliminating the sound enclosure.

Acknowledgment

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