



Environmental Test Manual of the Danish Public Transport Authorities

Part 2 - Noise measurement

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ON BEHALF OF:

TiD (the Danish Public Transport Authorities)
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1 Introduction

The Danish Public Transport Authorities focus on keeping emissions from busses as low as possible for health and environmental reasons and to protect passengers and the surroundings.

For the purpose of limiting the emission of soot particles (particle mass (PM) and particle number (PN)), NO_x gases (NO and NO₂) and noise from vehicles, the buses used by the bus operators running bus services on the routes of the Danish Public Transport Authorities are subject to routine testing. The routine testing forms part of the environmental testing of in-service buses.

The Environmental Test Manual of the Danish Public Transport Authorities is used to determine whether the busses tested are well-maintained and whether their emissions are reduced to the greatest extent possible. Also, the environmental test ensures that the bus operators comply with the guidelines of the relevant Transport Authority. The Environmental Test Manual is divided into two parts:

Part 1: Measuring emissions from buses:

- Nitrogen and nitrogen oxide, NO_x (sum of NO and NO₂)
- Carbon dioxide, CO₂
- Soot particles, including particle mass (PM) and particle number (PN)

Part 2: Measuring noise from buses:

- Exterior vehicle noise
- Interior vehicle noise

This Environmental Test Manual is Part 2 and contains a description of the requirements for measuring noise from buses in connection with environmental tests. The measurement method is representative of the actual bus passenger experience – both inside the bus and outside the bus, for instance at bus stops. The measurement method takes into account that noise emitted from, for instance, hybrid and electric buses differs from noise from conventional diesel-powered buses.

Part 1 is a separate manual which describes the requirements for measuring emissions from buses.

The Environmental Test Manual has been prepared by FORCE Technology at the request of Movia.

2 Measuring noise from buses

The noise measurement method described is considered representative of the noise experienced by passengers. The measurement method has been prepared so that it is suitable for characterising the noise from both electric and hybrid buses on equal terms with diesel-powered buses.

The measurement method includes:

- Measurements of vehicle exterior and interior noise
- Partial identification of unnecessary noise from the vehicle.

The measurements thus include the noisiest and most significant incidents while the bus is driving.

The AVAS¹ must be switched off during noise measurements.

¹From 1 July 2019, all electric and hybrid vehicles must be fitted with an AVAS (Acoustic Vehicle Alert System) which is activated at speeds up to approximately 20 km/h or during reversing. According to Regulation No 138, the AVAS must be equipped with a mode switch which is easily accessible to the driver of the vehicle and which engages and disengages the AVAS. However, the AVAS is not obligatory until as of 1 July 2021.

2.1 Measuring equipment requirements

The sound pressure level meter must meet the requirements contained in the IEC 61672-1:2002 class 1 standard and be traceably calibrated within the past year.

The sound pressure level meter must be calibrated using an acoustic calibrator before and after each series of measurements. The acoustic calibrator must meet the requirements contained in the IEC 61672-1:2002 class 1 standard and be traceably calibrated within the past year. In case of any deviations between pre- and post-calibration levels by more than 0.5 dB, the measurements are invalid and must be repeated. It is necessary to calibrate the measuring device before and after each new bus so as to make data from each single bus traceable.

2.2 Requirements for measuring technician

It must be possible to show that the measuring technician has the relevant qualifications to make sound measurements and experience from comparable tasks and the necessary knowledge of acoustic diffusion and measuring technology in general, including calibration of the equipment used, quality assurance and reproducibility of measurements.

The measuring technician must be familiar with Report from The Reference Laboratory, RL 20/96 Quality requirements for "Environmental testing – exterior noise" and "Environmental testing – traffic noise". This means that the technician must, as a minimum, complete practical training in noise measurements, etc. and know the general guidelines for exterior noise measurements issued by the Danish Environmental Protection Agency.

As a general rule, the technician is considered qualified if he is certified or accredited for "environmental testing - exterior noise" in accordance with the certification scheme of the Danish Environmental Protection Agency. This scheme is described at www.referencelaboratoriet.dk (in Danish only).

2.3 Handling measuring equipment

2.3.1 Exterior noise measurements

Place the microphone/sound pressure level meter on a stand to keep the prescribed measuring height and distance stable. Alternatively, you can hold the sound pressure level meter at arm's length from your body in the prescribed measuring position.

It may, however, be an advantage to place the microphone on a stand and with a cord to the sound pressure level meter to be able to start and stop the measurement while you are on the stop line. (See more under Description of test procedure)

It is a requirement that a wind screen is used for the microphone during all measurements.

2.3.2 Interior noise measurements

It is recommended that interior noise measurements are performed using hand-held devices to avoid distortion of the microphone from bus floor vibrations in the stand.

It is a requirement that a windshield is used for the microphone during all measurements.

2.4 Measured values

All measured values are stated to one decimal place, whereas results are rounded off and stated in whole dB(A) re 20 μ Pa.

Report vehicle exterior noise measurements as maximum values of the registered A-weighted sound pressure level L_{pAmax} , measured using the sound pressure level meter in FIXED position.

Vehicle interior noise measurements must be reported as the energy-equivalent, A-weighted sound pressure level L_{Aeq} mean over the period it takes for the bus to cover the measurement distance (from A to B in Figure 1). You must also report background noise as the L_{Aeq} level mean over at least ten seconds.

State indications of time in seconds to one decimal place.

2.5 Background noise

For the result of a measurement to be valid, the background noise in vehicle exterior noise measurements must be at least 10 dB lower than the result of the measurement. Measure the background noise in the same measuring position as the measurement itself without irrelevant vehicles passing or other distracting events. It is a good idea to measure background noise while the bus is on the starting line with its engine turned off before the first measurement. Measurements of background noise is not required in vehicle interior noise measurements.

2.6 Measurement conditions

The place of measurement must be an even, well-maintained road of asphalt without significant damage or repairs such as holes, loose stone or gravel. This means that there may not be any "bumps" from driving over manhole covers or holes in the road surface. The driving lane must be dry.

2.6.1 Measurement position (vehicle exterior noise measurements)

Place the microphone in an undisturbed place 1.5 m above ground, and make sure that nothing is blocking the area between the bus and the microphone during the measurements.

Take measurements by first measuring on the right side of the bus and thereafter on the left side of the bus, and keep the microphone in the same position while the bus is driving in the opposite direction past the microphone. (After that, the bus must drive in both directions through the measuring area from A to B and then from B to A).

It is recommended to conduct the measurements without directly reflective screens or buildings in a distance of 20 metres from the middle of the baseline (see Figure 1). It is recommended to keep at least 10 meters from the middle of the baseline to any reflective surfaces on the opposite side of the driving distance. If this is not possible, the result may be corrected according to the below table:

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Table 1: Correction of measured value for reflections.

Distance to reflective surfaces	4 m behind the microphone	5 m behind the microphone	6 m behind the microphone	7 m behind the microphone	>8 m behind the microphone
Correction of measured value	-0.9 dB	-0.8 dB	-0.6	-0.5 dB	No correction

Measurements conducted with reflective surfaces closer than 4m from the microphone will not be accepted because of the result and thus the measurement uncertainty.

A reflective surface means a surface behind the microphone of the same size as the front of a bus. If the reflective surface is greater, the measuring area must be moved further away from the reflective surface. If in doubt, find another location for the measurement.

2.6.2 Measurement position (vehicle interior noise measurements)

The microphone must be placed in an undisturbed place 1.2 metre above the floor in the middle of the bus. Measure noise over both the front and rear axles.

2.6.3 Weather conditions

When conducting vehicle exterior noise measurements, the weather must be calm with a wind speed of less than 5 m/s at the measurement position and without rain. The driving lane must be dry. The cloud ceiling is of minor importance.

2.6.4 Unnecessary noise

Unnecessary noise from the bus is not acceptable and may not be present at any time – neither before nor after the measurement. Unnecessary noise includes shrieking brakes, squealing bearings, rattling noise from the bodywork and interior decoration, etc. For the bus to pass the environmental test, any unnecessary noise from the bus must be eliminated. This applies to both vehicle interior and exterior noise measurements. The supplier must be informed of the existence of the unnecessary noise, and the measurement may not be conducted. Tick off the check box in the measuring table, and describe the unnecessary noise, and if possible, its source.

2.7 Description of test procedure

Measurements of interior and exterior noise must be conducted as acceleration measurements. Before conducting the measurements, you should draw up the four lines: the starting line (A), the stop line (B) and the two traffic lines which place the bus in a 3m wide driving lane centred on the baseline (see Figure 1).

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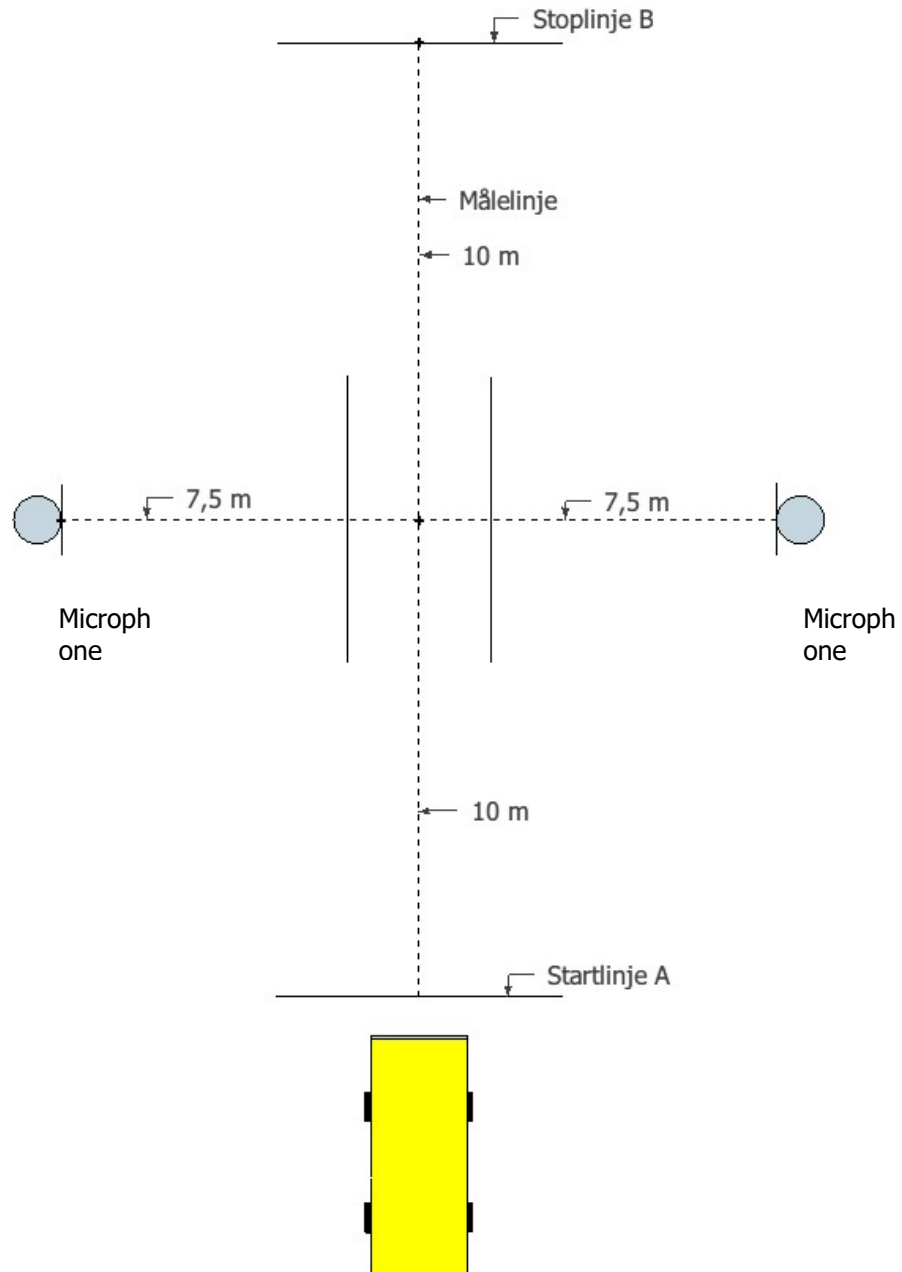


Figure 1: Sketch of measurement range. Distances are measured from the centre of the traffic line (baseline) to microphone positions on the side, starting line A and stop line B.

Conduct an acceleration measurement where the bus is standing on the starting line (A) and accelerates most powerfully. Tell the driver to accelerate up to the place where the rear end of the bus passes the stop line (B), but to continue driving approx. 10 meters before making an emergency stop manoeuvre.

As mentioned, the bus must accelerate until the rear end passes the stop line (B). Measure noise from accelerations on both sides of the bus.

During the measurements, the engine must be running at normal operating temperature, and the air-conditioning system at full capacity.

2.7.1 Exterior noise measurements

The exterior noise measurements must be conducted 7.5 metres from the baseline at a height of 1.5 above ground (see Figure 1). Start the sound measurement when the driver is given signal to start accelerating and just before the front end of the bus passes the starting line (A) and stop and read the measurement when the rear end of the bus passes the stop line (B).

During these measurements, you should be aware of any other noise sources that may affect the measurement.

To ensure that the accelerations are representative, measure the time it takes from the front end of the bus passes the starting line (A) until the front end of the bus passes the stop line (B). The method is to start the stop watch when the bus "takes off" from the starting line (A) and stop the time when the front end of the bus passes the stop line (B). It will be an advantage for the measuring technician to stand at the stop line (B) to be able to determine the passing time more accurately. Record the values measured in the measuring table.

Conduct measurements at least three times on each side of the bus. If measurements differ by more than 2 dB on the same side (maximum minus minimum), then conduct another two measurements on that side of the bus. Record the measured values from each passing in the measuring table to one decimal place. Include overruns of more than 2 dB which are not caused by outside circumstances, but by the bus air-conditioning system or otherwise by the bus as a valid measurement.

In case of three passings with a difference of 2 dB or less, calculate the average values measured on each side of the bus before including correction for reflective surfaces. In case of five passings, record all five, but record the average of the four lowest values before including correction for reflective surfaces, and comment on the reason(s) for any increase in the individual passing omitted.

Report the highest noise level from the two bus sides as the result of the acceleration measurement.

The exterior noise measurements are expected to take no more than 15 minutes.

2.7.2 Interior noise measurements

Perform the interior noise measurements inside the bus above the front and rear axles at a height of 1.2 metre above the floor. In case of overdrive distortion of the measuring equipment due to powerful impulse-like vibrations during driving, it is recommended to conduct the interior noise measurement using a hand-held microphone at arm's length from the body.

You should conduct noise measurements in the bus without passengers. The bus must stand idle at the starting line (A). Begin the sound measurement exactly when the bus passes the starting line (A), and stop the measurement when the bus has just passed the stop line (B). Use the same range of measurement as for the exterior noise measurements.

Conduct measurements with the air-conditioning system at full capacity.

Measurements must be conducted over one simultaneous run or two separate runs – above the front and rear axles.

The measured values from both measurement positions (front and rear axles) should be measured as the energy-equivalent, A-weighted sound pressure levels, the L_{Aeq} , mean over the period the acceleration from A to B takes. Record the values measured in the measuring table. Record the highest value as the final result of the measurement in the table.

The interior noise measurements are expected to take no more than 10 minutes.

3 Reporting and documentation

3.1 Reporting

Enter the measurement results in the form (Appendix A). The completed form must be available electronically in a database accessible by the Transport Authority.

The electronic version of the measurements must contain a time and date code. In addition, all information from Appendix A must be included. File naming and data layout in the file (e.g. the order of the individual columns with data) must be agreed separately with the Transport Authority.

The relevant measurement body must also create a folder with the following documentation:

- Results from continuous calibration/adjustment of the measuring equipment.
- Information on defects in and repair of the measuring equipment.
- Results of ring calibration.

The results of the environmental measurements are the property of the Transport Authority and may not be published or used by operators or the measurement body in another context without permission from the Transport Authority.

3.2 Measurement uncertainties and questions of doubt

3.2.1 Measurement uncertainties

To eliminate any doubt in case limit values are exceeded, it is deemed acceptable if the limit value is exceeded by up to 2.0 dB relative to the noise value/contractual limit value stated by the operator. This applies to both vehicle interior and exterior noise measurements. The instrument and measurement uncertainty in independent measurements will be in that area. The uncertainty will not be used when there is no limit value to meet.

3.2.2 Questions of doubt

In case of reasoned disagreement between the bus operator and the measurement services provider, the Transport Authority is the supreme authority. The Transport Authority may demand documentation for calibration interval and calibration records from the firm making the measurements.

Annex A - Test Report

Date/start time (yyyy-mm-dd tt:mm):	
Date/start time (yyyy-mm-dd tt:mm):	
Point of measurement:	
Weather conditions and wind speed (m/s):	
Make of bus:	
Type:	
Bus number	
Registration number:	
Operator:	
Infrastructure:	
Test method (Environmental Test Manual, version):	
Environmental test ordered by:	
Executed by:	

Exterior noise measurement - All values are quoted in dB								
Side of the bus	Measured L_{pAmax}					Average	Correction for reflective object	Contribution
	1	2	3	4	5			
Right								
Time (sec.)								
Left								
Time (sec.)								
Background noise, L_{Aeq}						Maximum contribution, L_{pAmax}		
						Maximum contribution, minus an uncertainty of 2 dB		
						Limit value		
						Passed / not passed (if limit value is stated)		

Interior noise measurement - All values are quoted in dB	
Measurement position	Measured L_{Aeq}
Front axle	
Rear axle	
	Highest measured value
	Highest measured value, minus an uncertainty of 2 dB
	Limit value
	Passed / not passed (if limit value is stated)

Unnecessary noise

Measured unnecessary noise , Comment: _____

Passed/not passed:

Conclusion

Passed/not passed:

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Measuring equipment used

No.	Measuring equipment	Make	Type	Calibration	
				Most recent	Next