Noise and Vibration Final Technical Report

WOODWARD AVENUE
LIGHT RAIL TRANSIT PROJECT

Detroit, Michigan

June 2011

U.S. Department of Transportation
Federal Transit Administration

City of Detroit
Department of Transportation

WOODWARD LIGHT RAIL

Table of Contents

EXECUTIVE SUMMARY ES-1
1.0 INTRODUCTION 1-1
1.1 Project Description 1-1
1.2 Alternatives 1-1
1.2.1 No Build Alternative 1-1
1.2.2 Locally Preferred Alternative 1-2
1.2.3 LPA Variations 1-3
1.2.4 Vehicle Storage and Maintenance Facility 1-3
1.2.5 Park and Ride Lot 1-4
1.2.6 Traction Power Substations 1-4
1.2.7 Construction Staging Areas 1-4
2.0 LEGAL AND REGULATORY CONTEXT 2-1
2.1 FTA Noise Criteria 2-1
2.2 FTA Vibration Criteria 2-2
2.3 Construction Noise Regulations 2-3
2.3.1 FTA Construction Noise Regulations 2-3
2.3.2 FHWA Construction Noise Regulations 2-4
3.0 METHODOLOGY 3-1
3.1 Noise 3-1
3.1.1 Measured Existing Noise 3-1
3.1.2 Future Calculated Noise 3-1
3.2 Vibration 3-2
3.2.1 Estimated Future Vibration Levels 3-2
3.2.2 Predicted Construction-related Vibration 3-5
4.0 EXISTING CONDITIONS 4-1
4.1 Noise 4-1
4.1.1 Land Use Descriptions 4-1
4.2 Vibration 4-8
5.0 ENVIRONMENTAL CONSEQUENCES 5-1
5.1 Noise Exposures 5-1
5.1.1 Line Operations 5-1
5.1.2 Support Facilities 5-4
5.2 LRT Line Operation Vibration Impacts 5-7
5.2.1 No Build 5-8
5.2.2 Locally Preferred Alternative 5-8
5.3 Noise and Vibration Mitigation Measures 5-13
5.3.1 Noise 5-13
5.3.2 Vibration 5-14
6.0 CONSTRUCTION-PHASE NOISE AND VIBRATION 6-1
6.1 Construction Noise 6-1
6.2 Construction Vibration 6-1
6.2.1 Vibration Generated During Construction 6-1
6.2.2 Vibration Control Requirements 6-1
6.2.3 Woodward Avenue Vibration 6-2

6.3 Construction Noise and Vibration Control Measures 6-2
6.3.1 Design Considerations 6-3
6.3.2 Alternate Construction Methods 6-3
6.3.3 Source Control 6-3
6.3.4 Time and Activity Constraints 6-3
6.3.5 Community Relations 6-3
7.0 REFERENCES 7-1

List of Figures

Figure 1-1. Project Location 1-2
Figure 2-1. FTA Noise Impact Criteria 2-2
Figure 3-1. Sound Pressure and Sound Pressure Levels of Common Noise-Generating Activities 3-3
Figure 4-1. Noise and Vibration Measurement Site Locations: Mainline 4-2
Figure 4-2. Noise and Vibration Measurement Site Locations: Downtown 4-3

List of Tables

Table ES-1. Noise Impacts with Alternatives A1, B2, and B3 ..... ES-1
Table ES-2. Vibration Impacts with Alternatives A1, B2, and B3 ..... ES-3
Table 2-1. FTA Guidelines on Land Use Categories and Metrics for Transit Noise 2-1
Table 2-2. FTA Ground-borne Vibration Impact Criteria 2-3
Table 2-3. FTA Ground-Borne Vibration Impact Criteria for Special Buildings 2-3
Table 2-4. FTA Construction Noise Criteria 2-4
Table 3-1. FTA Noise Impact Criteria: Noise Levels Defining Impact for Transit Projects 3-4
Table 3-2. Source Levels for Construction Equipment Vibration 3-5
Table 4-1. Existing Conditions: Long-Term (24-hour) Noise Measurements 4-4
Table 4-2. Existing Conditions: Peak-Hour Noise Measurements 4-5
Table 4-3. Existing Conditions: Noise Levels Estimated from Nearby Long-Term (24-hour) and Peak-Hour Measurement Sites 4-6
Table 5-1. LPA Alternatives A1, B2, and B3 Mainline Noise Impacts 5-2
Table 5-2. Downtown LPA Alternative A1 Noise Impacts 5-5
Table 5-3. Downtown LPA Alternative B2 Noise Impacts 5-6
Table 5-4. Downtown LPA Alternative B3 Noise Impacts 5-7
Table 5-5. LPA Alternatives A1, B2, and B3 Mainline Vibration Impacts 5-8
Table 5-6. LPA Alternative A1 Vibration Impacts 5-11
Table 5-7. LPA Alternative B2 Vibration Impacts 5-12
Table 5-8. LPA Alternative B3 Vibration Impacts 5-13
Table 6-1. Estimated Maximum Construction Noise Levels 6-1

Table 6-2. Vibration Source Levels for Construction Equipment 6-2

List of Appendices

Appendix A. Instruments Used and Calibration Records

Appendix B. Long-term and Short-term Field Measurement Data Sheets

This page intentionally left blank

Executive Summary

This Noise and Vibration Technical Report has been prepared in support of the Woodward Avenue Light Rail Transit Project Draft Environmental Impact Statement (DEIS). This report details the noise and vibration impact analyses conducted for the DEIS. Federal Transit Administration (FTA) Noise and Vibration Impact Criteria were used to evaluate the Locally Preferred Alternative's (LPA) potential noise and vibration impacts.

Transit Noise

Alternative A1. Light Rail Transit (LRT) noise levels would exceed FTA impact thresholds for moderate impacts at five receptor sites (Table ES-1). Moderate noise impacts are predicted at Downtown residences at the Stevens Building Apartments from the building's ground floor to the seventh floor, and along the mainline at 600 Grixdale Avenue (Site LT-105), the Park Shelton Apartments (Site M1), and the Normandie Hotel (Site LT-112).

Alternative B2. LRT noise levels would exceed FTA impact thresholds for moderate impacts at six receptor sites (Table ES-1). Moderate noise impacts are predicted at the Holiday Inn Express (Site M8), the Westin Book Cadillac Detroit (Site DT-LT04), and residences along the mainline at 600 Grixdale Avenue (Site LT-105), the Park Shelton Apartments (Site M1) and the Normandie Hotel (Site LT-112). A moderate impact is also predicted at the Central United Methodist Church (Site LT-001) where noise sensitivity is limited to daytime hours.

Table ES-1. Noise Impacts with Alternatives A1, B2, and B3

Receptor Number	Site Number	FTA Land Use Category	Existing Noise Level	FTA Noise Impact Thresholds		Alternative Impact	
				Moderate	Severe	Noise Level	Noise Impact
Alternative A1							
S2	DT-ST02 GF	2	72	66	72	69	Moderate
S2	DT-ST02 7th Floor	2	63	60	66	63	Moderate
M1	M1	2	70	65	70	65	Moderate
R24	LT-112	2	65	61	67	63	Moderate
R34	LT-105	2	56	56	63	59	Moderate
Alternative B2							
M8	M8	2	75	66	74	67	Moderate
R4	DT-LT04	2	70	65	70	69	Moderate
R7	LT-001	3	66	62	68	64	Moderate
M1	M1	2	70	65	70	65	Moderate
R24	LT-112	2	65	61	67	63	Moderate
R34	LT-105	2	56	56	64	59	Moderate
Alternative B3							
R6	DT-LT06	2	73	66	72	67	Moderate
R7	LT-001	3	66	62	68	64	Moderate
M1	M1	2	70	65	70	65	Moderate
R24	LT-112	2	65	61	67	63	Moderate
R34	LT-105	2	56	56	63	59	Moderate

Source: Parsons Brinckerhoff, 2010.

Alternative B3. LRT noise levels would exceed FTA impact thresholds for moderate impacts at five receptor sites (Table ES-1). Moderate noise impacts are predicted at Downtown residences at 1450 Woodward Avenue (Site DT-LT06), and along the mainline at 600 Grixdale Avenue (Site LT-105), the Park Shelton Apartments (Site M1), and the Normandie Hotel (Site LT-112). A moderate impact is also predicted at the Central United Methodist Church (Site LT-001) where noise sensitivity is limited to daytime hours.

Transit Noise Mitigation

Noise impacts due to LRT line operations in the study area could be mitigated with placement of 3-foot tall noise barriers. However, noise-barrier acoustic effectiveness would be compromised at locations where the barrier walls would need to be segmented to provide access. A more effective abatement measure would be to use custom-designed vehicle skirts on the LRT vehicles used for the LPA. A LRT vehicle-wheel skirt, which would be specified at the time the LRT vehicles are procured from the LRT manufacturer, would provide 6 dBA of noise reduction. This would be sufficient to mitigate all noise impacts estimated with LPA Alternative A1 and most of the noise impacts estimated with Alternatives B2 and B3. Vehicle skirts that are not custom-designed for a LRT vehicle provide very limited noise abatement (i.e., approximately 2 dBA).

Vibration

Estimated vibration levels generated by LRT operations are expected to remain below FTA impact thresholds at most properties evaluated in the study area. A few properties are expected to experience vibration levels at or slightly above the minimum impact levels. However, these vibration levels represent a worst-case scenario because potential vibration-dampening effects of soil conditions are not accounted for in these vibration estimates. Soil borings would be taken during final design to determine soil conditions and any dampening effects more accurately; actual vibration impacts may ultimately be less than predicted on the basis of the DEIS analyses. No property is expected to experience vibration levels in the range that would result in structural damage to buildings.

Alternative A1. Vibration levels at the FTA impact threshold are predicted at one site, the Stevens Building Apartments (Site DT-ST02) on the ground floor. Ground-borne noise levels at or slightly above the FTA ground-borne noise impact threshold are predicted at four sites: the Fox Theater (Site M9) and at residences at the Park Shelton Apartments (Site M1), 4501 Woodward Avenue (Site LT-007), and the Stevens Building Apartments (Site DT-ST02) (Table ES-2).

Alternative B2. Vibration levels at the FTA impact threshold are predicted at two sites: the Downtown Fox Theater (Site M9) and at the Westin Book Cadillac Detroit (Site DT-LT04). Ground-borne noise levels at or slightly above the FTA impact threshold are predicted at five sites: the Downtown Fox Theater (Site M9), residences at the Park Shelton Apartments (Site M1) and 4501 Woodward Avenue (Site LT-007), the Holiday Inn Express (Site M8), and the Westin Book Cadillac Detroit (Site DT-LT04) (Table ES-2).

Alternative B3. Vibration levels at the FTA impact threshold are predicted at one site, the Downtown Fox Theater (Site M9). Ground-borne noise levels at or slightly above the FTA ground-borne noise impact threshold are predicted at four sites: the Fox Theater (Site M9), at 1450 Woodward Avenue (Site DT-LT06) and at residences at the Park Shelton Apartments (Site M1) and 4501 Woodward Avenue (Site LT-007) (Table ES-2).

Ground-borne noise (Table ES-2) would likely be inaudible as both existing and predicted airborne noise levels (Table ES-1) would exceed the noise levels caused by ground-borne vibration of the affected structures identified by the receptor numbers.

Table ES-2. Vibration Impacts with Alternatives A1, B2, and B3

Receptor Number	Site Number	FTA Land Use Category	Vibration Criteria (V dB)	Vibration Level (V dB)	Vibration Impact	Ground-borne Noise Criteria	Ground-borne Noise Level	Ground-borne Noise Impact
Alternative A1								
S2	DT-ST02 GF	2	72	72	Impact	35	37	Impact
M9	M9	3	72	70	No Impact	35	36	Impact
M1	M1 GF	2	72	70	No Impact	35	35	Impact
R12	LT-007	2	72	70	No Impact	35	35	Impact
Alternative B2								
M8	M8	2	72	71	No Impact	35	36	Impact
M9	M9	3	72	72	Impact	35	37	Impact
R4	DT-LT04 GF	2	72	72	Impact	35	37	Impact
M1	M1 GF	2	72	70	No Impact	35	35	Impact
R12	LT-007	2	72	70	No Impact	35	35	Impact
Alternative B3								
M9	M9	3	72	72	Impact	35	37	Impact
R6	DT-LT06 GF	2	72	71	No Impact	35	36	Impact
M1	M1 GF	2	72	70	No Impact	35	35	Impact
R12	LT-007	2	72	70	No Impact	35	35	Impact

Source: Parsons Brinckerhoff, 2010

This page intentionally left blank

1.0 Introduction

This Noise and Vibration Technical Report has been prepared in support of the Woodward Avenue Light Rail Transit (LRT) Project Draft Environmental Impact Statement (DEIS). It provides detailed documentation of existing noise and vibration conditions, estimated future noise and vibration levels and, on that basis, anticipated impacts with construction and operation of the Locally Preferred Alternative (LPA).

1.1 Project Description

The study area (Figure 1-1) is located in Wayne County, Michigan. It comprises the Woodward Avenue Corridor extending 9.3 miles from Downtown Detroit (Downtown), near the Detroit River, north to the State Fairground near 8 Mile Road. The majority of the study area lies within the City of Detroit, while approximately 2 miles (from Webb Street to McNichols (6 Mile) Road) is within the City of Highland Park. The study area boundary extends approximately one-half mile to the east and west of Woodward Avenue, the area within which project impacts may occur.

From south to north, the study area includes the densely developed Downtown Central Business District (CBD) and many of the City's prominent historical sites, civic buildings, sports venues and cultural attractions; medical, higher education, and additional cultural institutions north of the CBD; and residential areas and the Michigan State Fairgrounds.

1.2 Alternatives

Two alternatives are evaluated in the DEIS, the No Build Alternative and the Locally Preferred Alternative (LPA). The alternatives screening process considered alternatives that were identified through previous transit studies, a field review of the Woodward Avenue corridor, an analysis of current and projected population and employment data for the corridor, a literature review of technology modes, a rigorous alternatives screening analysis, selection of a LPA, and public and agency comments received during the formal project scoping process held to satisfy National Environmental Policy Act (NEPA) (USC 1969) requirements.

The two alternatives are described below.

1.2.1 No Build Alternative

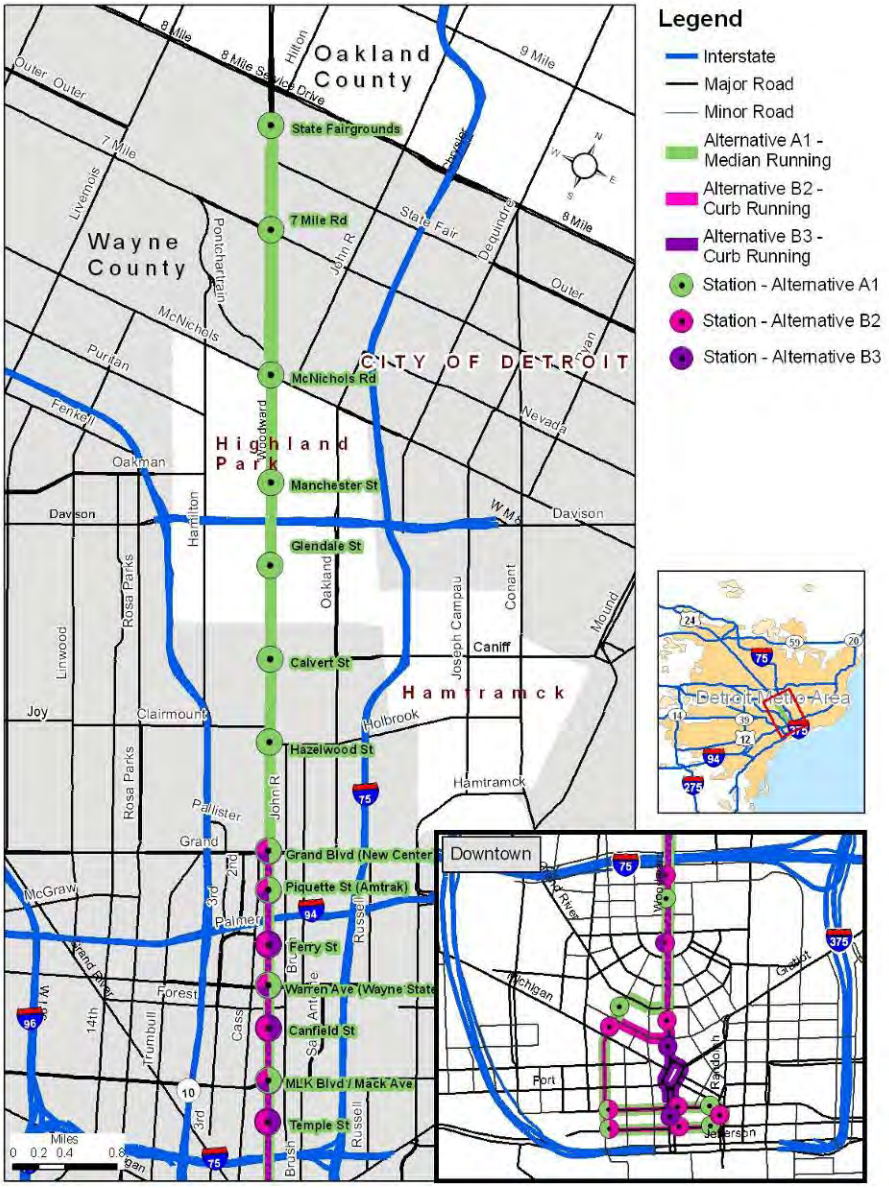
The No Build Alternative includes transit, roadway and non-motorized elements.

Transit elements include increased service frequencies on DDOT Route 53 (Woodward Avenue) and reorganization of feeder bus routes to optimize travel times. The No Build Alternative does not include any new bus routes. Also, the No Build Alternative assumes bus services on existing roads in mixed traffic; it does not assume any change in future (2030) bus travel speeds or travel times on Routes 53.

The No Build Alternative includes all capacity-related transportation system projects listed in the Southeast Michigan Council of Governments' (SEMCOG) Transportation Improvement Program (TIP) for the Detroit-Warren-Livonia Metropolitan Statistical Area (MSA) for fiscal years 2008 through 2011. In addition to the TIP projects, the No Build Alternative also includes capacity-related transportation projects in the study area that are listed in SEMCOG's financially constrained Regional Transportation Plan (RTP).

A shared-use path for pedestrians and bicycles is currently being constructed along Kirby Street on either side of Woodward Avenue. There are plans to also construct a shared-use path along

Figure 1-1. Project Location



Source: Parsons Brinckerhoff, 2010

Canfield Street on both sides of Woodward Avenue within the next few years. There are no other plans to improve or construct any other non-motorized facilities within the study area.

1.2.2 Locally Preferred Alternative

The LPA is light rail transit (LRT) on Woodward Avenue from Downtown Detroit to 8 Mile Road, with two mainline operating options and three Downtown design options still under consideration. The mainline operating options along Woodward Avenue are median-running and separated from traffic (Option A) and curb-running in mixed traffic (Option B).

LRT has been defined as an at-grade system entirely within existing rights-of-way. It would be fully functional as a stand-alone project, but would be designed to accommodate possible future extensions.

LRT uses electric rail vehicles and may operate with just one vehicle or two that are joined; if the latter, the LRT would not be expected to be longer than 180 feet. However, some City blocks in Downtown are shorter than 180 feet; therefore, LRT vehicles would be given priority at traffic signals to avoid blocking intersections and crosswalks by stopped LRT vehicles. LRT vehicles are powered via overhead electric wire (catenary); therefore, there are no safety issues as there would be with a live third rail at ground level.

Existing road rights-of-way vary considerably in the study area. In Downtown, it ranges from 78 feet along Washington Boulevard to 109 feet along Woodward Avenue south of Adams Street. North of Adams Street, the right-of-way widens along Woodward Avenue to 120 feet until reaching Grand Boulevard. The narrowest section of Woodward Avenue – at 100 feet – is found north of Grand Boulevard to Manchester Parkway, where the right-of-way then returns to 120 feet. The widest section of right-of-way is found north of McNichols Road where it widens to 204 feet.

Three Downtown design options for the LPA were identified. Their respective alignments are as follows:

- Downtown option 1: Woodward, Grand River, Washington, Larned, Randolph, Congress;
- Downtown option 2: Woodward, State, Washington, Larned, Randolph, Congress; and
- Downtown option 3: Woodward Avenue.

1.2.3 LPA Variations

The LPA alignment follows Woodward Avenue from Downtown Detroit in the south to the Michigan State Fairgrounds near 8 Mile Road in the north. Combining the two mainline alignment operating options and the three Downtown design options, three variations of the LPA were defined for evaluation in this DEIS.

- Alternative A1 – median-running with Downtown design option 1; 15 LRT stations;
- Alternative B2 – curb-running with Downtown design option 2; 21 LRT stations; and
- Alternative B3 – curb-running with Downtown design option 3; 18 LRT stations.

1.2.4 Vehicle Storage and Maintenance Facility

Additionally, three locations were identified for the vehicle storage and maintenance facility (VSMF) required to be constructed with any of the LPA variations.

The proposed VSMF would provide for indoor storage, inspection, repair and light maintenance of LRT equipment, and administrative offices. It would have its own storm water management system. The square footage of the facility is anticipated to be between 75,000 and 110,000 square feet, depending on site size, configuration and facility design. The three sites under consideration were identified on the basis of proximity to Woodward Avenue, size and configuration, zoning, land use, site ownership, and potential utility and traffic impacts. The three potential sites are as follows:

- MLK Boulevard Site (4.2 acres) – would occupy two lots north and south of West Stimson Street, just west of Woodward Avenue and south of MLK/Mack Avenue. This site would have frontage on Woodward Avenue.
- Amsterdam Street Site (4.6 acres) – would occupy two lots east and west of Cass Avenue between Amsterdam Street and the two grade-separated tracks owned by Consolidated

Rail Corporation (CR) and Canadian National Railway (CN), respectively, just south of Baltimore Avenue. This site would have frontage on Woodward Avenue and is adjacent to the Amtrak Station.

- Highland Park Ford Plant Site (19.0 acres) – would occupy one large lot east of Woodward Avenue north of Manchester Street and the former Highland Park Ford Plant. As this site is about 900 feet east of Woodward Avenue, direct access would be via the right-of-way for CR's currently abandoned rail line.

1.2.5 Park and Ride Lot

A park and ride lot, which would be provided with all LPA variations, would be located near the proposed Shoppes at Detroit's Gateway at the southeast corner of 8 Mile Road and Woodward Avenue. The lot is accessible from northbound and southbound Woodward Avenue. A pedestrian overpass would provide access from the parking lot to the median-located rail station. An existing bus stop and transfer station at the State Fairgrounds would be maintained.

1.2.6 Traction Power Substations

LRT's electric traction power system requires traction power substations (TPSS) approximately every mile, depending on the frequency and size of the vehicles. These substations, which are approximately 25 by 60 feet in dimension, require vehicular access and a relatively small site (35 by 70 feet). These facilities do not need to be immediately adjacent to the tracks. Because of this flexibility, substations can be located to minimize visual intrusions and can be visually shielded by fencing, landscaping, or walls, or can be incorporated into existing buildings. Nine TPSS sites have been preliminarily identified; eight TPSS for Alternatives A1 and B2 and seven for Alternative B3. The locations will be refined during the preliminary engineering phase of project development.

1.2.7 Construction Staging Areas

During construction of the LRT, several small sites will be required for the temporary storage of materials and equipment and will be located in the general vicinity of the LPA. Following construction of the LPA, the construction staging areas would be made available for other, more permanent development. Four construction staging areas have been initially identified. Two sites, located north of I-75 and west of Woodward Avenue, are approximately 0.9 and 1.6 acres in size, respectively. A third site, 1.6 acres in size, is proposed for the northeast corner of East Bethune Street and Woodward Avenue. A fourth site, 0.9 acre in size, is proposed in Highland Park at the southwest corner of Sears Street and Woodward Avenue. Each of these four parcels is presently undeveloped and vacant.

2.0 Legal and Regulatory Context

2.1 FTA Noise Criteria

Federal Transit Administration (FTA) noise criteria are used to assess potential noise impacts of transit projects (74 *Federal Register* 12518, March 2009). FTA guidelines assess noise impacts for various land use categories using different noise metrics (L_{eq} or L_{dn}) (Table 2-1).

Table 2-1. FTA Guidelines on Land Use Categories and Metrics for Transit Noise

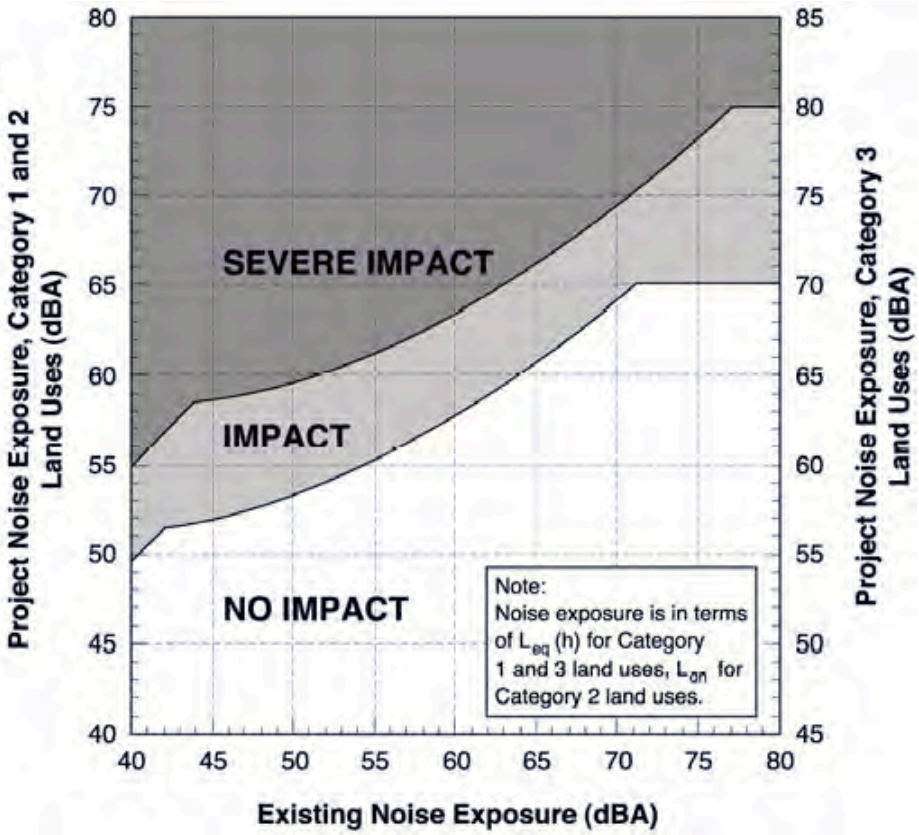
Land Use Category	Noise Metric (dBA)	Description of Land Use Category
1	Outdoor L_{eq} (h)	Tracts of land where quiet is an essential element of the land's intended purpose. This category includes lands set aside for serenity and quiet, and used as outdoor amphitheaters and concert pavilions, and National Historic Landmarks with significant outdoor use.
2	Outdoor L_{dn}	Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor L_{eq} (h)	Institutional land uses with primarily daytime and evening uses. This category includes schools, libraries, and churches where it is important to avoid interference with activities such as speech, meditation, and concentration on reading material.

Source: *Transit Noise and Vibration Impact Assessment*, FTA, May 2006.
Note: *L_{eq} for the noisiest hour of transit-related activity during hours of noise sensitivity.

The unit used in Table 2-1, A-weighted decibels (dBA), is a measure of sound loudness adjusted for the hearing range of the human ear. L_{eq} is measure of sound energy that is used to assess the impact for institutional and other land uses that do not have nighttime noise sensitivity. $L_{eq\ (h)}$ is a measure of sound energy over a one-hour period that is referred to as the equivalent noise level and is used here to designate the noise during the noisiest hour of project-related activity. L_{dn} is a 24-hour noise descriptor referred to as the day-night noise level and is used to assess noise impacts for land uses where people sleep and, as a result, there is heightened sensitivity to nighttime noise.

The land use categories in Table 2-1 are needed because the noise sensitivities of land uses with primarily daytime activity vary from those where nighttime quiet is of paramount importance, such as where people normally sleep. For each of the land use categories, FTA defines the noise impact by comparing the noise level generated by the proposed project with the existing noise level today. Figure 2-1 shows, for various levels of existing noise on the x-axis, what level of project noise (y-axis) would result in no impact at all, a moderate impact, and a severe impact. For example, at a given residential property (Category 2 land use) with an existing day-night noise level (Ldn) of 60 dBA, the predicted day-night noise level generated by the rail vehicles moving along the tracks over a 24-hour period would be a moderate impact if it is predicted to be in the range of 58 to 63 dBA, a severe impact if it is predicted to be 64 dBA or greater, and no impact at all if it is predicted to be under 58 dBA.

Figure 2-1. FTA Noise Impact Criteria



Source: *Transit Noise and Vibration Impact Assessment*, FTA, May 2006

2.2 FTA Vibration Criteria

Vibration impacts are assessed using FTA vibration prediction procedures. FTA guidelines apply to transit vehicles operating in a transit corridor, near stations and near other supporting transit facilities. FTA published its vibration impact criteria in the FTA manual *Transit Noise and Vibration Impact Assessment* (May 2006). The criteria are based on the maximum vibration level in decibels (vibration decibels [VdB]) generated by a single event. The FTA criteria for acceptable ground-borne vibration are expressed in terms of root mean square (RMS) vibration velocity. The impact thresholds are specified for three land use categories.

FTA impact criteria for ground-borne vibration and ground-borne noise from LRT operations relate to maximum vibration and ground-borne noise levels associated with a single event such as the pass-by of a LRT vehicle or train. This differs from the criteria for air-borne noise levels Section 2.1), which are associated with cumulative air-borne noise levels over a 1-hour or 24-hour period. To address the cumulative effects of multiple vibration events (i.e., the number of times a train passes by the receptor in a 24-hour period), the criteria are divided into “frequent” and “infrequent” event categories, with more stringent criteria for frequent events. As the LPA would have more than 70 vibration events per day, potential impacts were evaluated using the “frequent events” criteria.

Table 2-2 summarizes the FTA impact criteria for ground-borne vibration. These criteria are based on previous standards, criteria, and design goals, including the American National Standards Institute (ANSI) S3.29 (Acoustical Society of America 1983) and the noise and

vibration guidelines of the American Public Transit Association (APTA 1981). Some buildings such as concert halls, television and recording studios, and theaters can be very sensitive to vibration but do not fit into any of the three categories. Because of the sensitivity of these buildings, they usually warrant special attention during the environmental review of a transit project.

Table 2-2. FTA Ground-borne Vibration Impact Criteria

Land Use Category	Vibration Velocity Impact Levels		Ground-borne Noise Impact Levels	
	Frequent Events[1]	Infrequent Events[2]	Frequent Events[1]	Infrequent Events[2]
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB	65 VdB	NA	NA
Category 2: Residences and buildings where people normally sleep.	72 VdB	80 VdB	35 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime uses.	75 VdB	83 VdB	40 dBA	48 dBA

Source: *Transit Noise and Vibration Impact Assessment*, FTA, May 2006.
Notes: Vibration levels expressed in VdB are 1 micro inch/sec and ground-borne noise levels expressed in dBA.
[1]"Frequent Events" are defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.
[2]"Infrequent Events" are defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.

Table 2-3 provides criteria for acceptable levels of ground-borne vibration for various types of special buildings.

Table 2-3. FTA Ground-Borne Vibration Impact Criteria for Special Buildings

Type of Building or Room	Ground-borne Vibration Impact Levels (VdB re: 1 micro inch/sec)	
	Frequent Events[1]	Infrequent Events[2]
Concert Halls	65 VdB	65 VdB
Television Studios	65 VdB	65 VdB
Recording Studios	65 VdB	65 VdB
Auditoriums	72 VdB	80 VdB
Theaters	72 VdB	80 VdB

Source: *Transit Noise and Vibration Impact* Assessment, FTA, May 2006.
Notes: [1]"Frequent Events" is defined as more than 70 vibration events per day.
[2] "Infrequent Events" is defined as fewer than 70 vibration events per day; it includes most commuter rail systems.

2.3 Construction Noise Regulations

2.3.1 FTA Construction Noise Regulations

FTA guidelines identify a set of threshold L_{eq} and L_{dn} levels for various construction activities. In urban areas with very high ambient noise levels (L_{dn} > 65 dB), L_{dn} from construction operations should not exceed existing ambient noise levels by 10 dB or more. The noise criteria

and the descriptors used to evaluate construction noise are dependent on the type of land use near a proposed project.

Table 2-4 shows the FTA construction noise criteria for noise assessments conducted in accordance with FTA's methodology. An airborne noise impact would occur if noise levels during construction exceed the FTA recommended values shown in Table 2-4. The criteria do not identify park, recreation, museum, or church properties, which are the types of land uses that would be most affected by the LPA. The existing noise levels at sensitive receptors in the study are relatively high, reflecting their urban/commercial environment.

Table 2-4. FTA Construction Noise Criteria

Land Use	8-hour L_{eq} (dBA)		L_{dn} (dBA) 30-day Average
	Day	**Night**	
Residential	80	70	75(a)
Commercial	85	85	80(b)
Industrial	90	90	85(b)

Source: *Transit Noise and Vibration Impact* Assessment, FTA, May 2006.
Notes: (a) In urban areas with very high ambient noise levels (L_{dn} > 65 dB), L_{dn} from construction operations should not exceed existing ambient + 10 dB.
(b) 24-hour L_{eq} not $L_{dn.}$

2.3.2 FHWA Construction Noise Regulations

While noise impact and abatement criteria have been established for the operation of transit facilities in the United States, standardized criteria have not yet been established related to noise associated with the construction of such facilities. FTA's *Transit Noise and Vibration Impact Assessment Manual* presents guidelines that "can be considered reasonable criteria for assessment" of construction noise impacts. Furthermore, at properties where noise impacts have been identified the Federal Highway Administration (FHWA) have developed procedures and measures for mitigating or reducing construction impacts identified under the FTA criteria. The FHWA regulations stipulate that certain classifications of construction equipment and motor vehicles stay below specified noise emission standards; and be limited to use to weekdays between the hours of 7:00 a.m. and 6:00 p.m. Noise generated from construction activities can be determined at nearby noise-sensitive sites using the FHWA "Roadway Construction Noise Model" (RCNM) assuming the type, number, placement, and percentage of the time each equipment is in use (usage factor) are known. Thus, once preliminary design information for the selected LPA option is completed, the construction staging can be established and potential noise impacts from the construction activities can be quantified and various abatement measures can be investigated for their feasibility and acoustic effectiveness.

When working outside state-owned rights-of-way, hours of construction would be limited, as specified in local municipal ordinances.

FHWA regulates construction noise through the following process:

- Identify land uses and activities that may be affected during construction;
- Determine the measures needed to minimize or eliminate adverse construction-noise effects on the community; and
- Incorporate needed abatement measures in project plans and specifications prior to the start of construction.

3.0 Methodology

3.1 Noise

3.1.1 Measured Existing Noise

The field noise measurements were collected in accordance with procedures described in *Sound Procedures for Measuring Highway Noise* (Report Number FHWA-DP-45-1R May 1996) and in *Transit Noise and Vibration Impact Assessment* (FTA, May 2006).

Noise levels were measured at the selected locations along the proposed alignment, including proposed transit station locations and potential vehicle maintenance facility sites to establish the most sensitive existing environment. The measurements were conducted using methods consistent with ANSI S12.9-1992/Part 2 and S12.9-1993/Part 3: *Standards for Quantities and Procedures for Description and Measurement of Environmental Sound*.

Calibrated sets of Larson Davis and Norsonic noise and vibration measuring equipment were used. Norsonic 140 and Larson Davis 820 Sound Level Meters, fitted with windscreens, were used for all short-term (30-minute) peak hour noise readings.

For collecting long-term (24-hour) noise measurements, noise meter instruments suitable for 24-hour noise monitoring were used. The instruments used for all 24-hour noise measurements were Type 1 (Precision grade) Larson Davis 820 Community Noise Analyzers. Each meter was contained in a weatherproof case, which also contained a large gel cell battery to provide electrical power for an entire 24-hour period. All noise measurements were collected under acceptable weather and roadway conditions (i.e., rain-free days with dry roadway pavements and wind speed less than 12 mph). The short-term (peak-hour) and 24-hour noise measurements were collected during October 3-10, 2008, and August 25-27, 2009.

Appendix A includes a copy of the instruments used and calibration records. Appendix B contains the long-term and short-term field measurement data sheets.

3.1.2 Future Calculated Noise

Future noise exposure in the study area from the Locally Preferred Alternative (LPA) was determined in accordance with analysis procedures defined in *Transit Noise and Vibration Impact Assessment* (FTA, May 2006).

The project-generated noise level at each noise-sensitive property or "receptor" is calculated by determining four principal components:

1. noise level generated by Light Rail Transit (LRT);
2. hour-by-hour number of LRT operations over a 24-hour period;
3. hour-by-hour speed at which the LRT travels between train stations; and
4. distance between the LRT and a given receptor.

The final calculated noise level is determined after applying adjustments for shielding provided by intervening buildings, special track-work adjustments where track switches are planned, and adjustments for wheel squeal where there are curves in the tracks. For land uses where people normally sleep, a 24-hour noise descriptor (L_{dn}) is used to assess potential noise impact. For land uses involving daytime activities, noise impact is assessed using the peak-hour equivalent noise level (L_{eq}). All measured and calculated noise levels are adjusted to the "A" weighted hearing

scale, which best accounts for varying perceptions of loudness by the human ear. Figure 3-1 shows representative common noise sources and their associated decibel levels.

Table 3-1 shows the FTA impact assessment based on project noise exposure. FTA noise impact criteria determine if potential transit noise impacts would occur by comparing the existing outdoor noise levels (L_{eq} or L_{dn} depending on land use category) with the noise generated solely by the transit noise source. Project impacts are categorized as "No Impact," "Moderate Impact," or "Severe Impact," as determined from the allowable limit in project-generated noise exposure over the existing noise exposure.

The level of impact also affects potential mitigation requirements for the LPA.

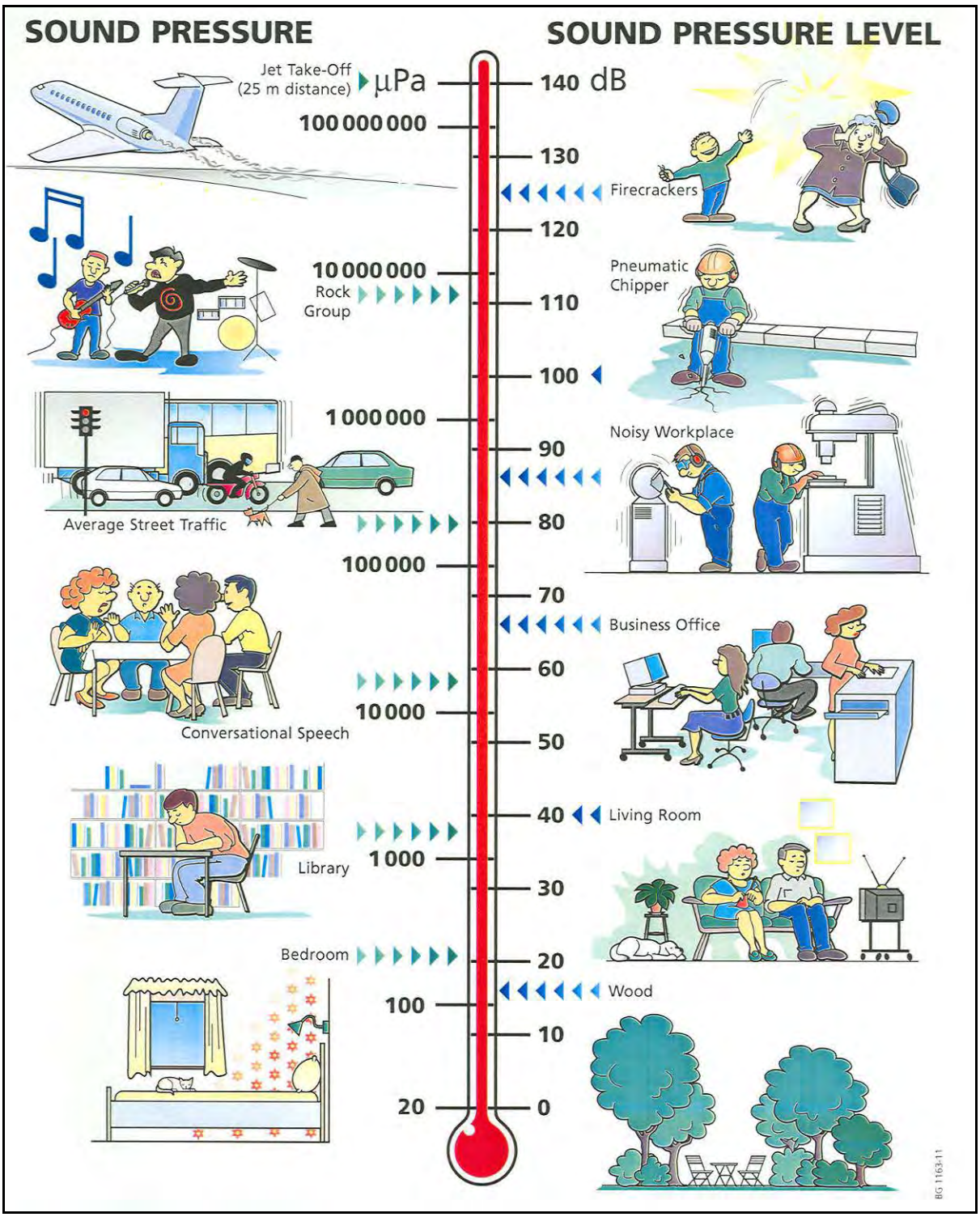
3.2 Vibration

3.2.1 Estimated Future Vibration Levels

Vibration levels were estimated in accordance with the General Vibration Assessment procedures defined in Chapter 10 of *Transit Noise and Vibration Impact Assessment* (FTA, May 2006). The method uses a generalized curve of vibration as a function of distance from the track to the building, and then adjusts the result to take into account LRT vehicle speeds, vehicle specifications, track conditions, geological transmission conditions, and interior building transmission conditions.

Vibration impacts from transit operations are generated by motions/actions at the wheel/rail interface. The smoothness of these motions/actions is influenced by wheel and rail roughness, transit vehicle suspension, train speed, track construction (including types of fixation and ballast), the locations of switches and crossovers, and the geologic strata (layers of rock and soil) underlying the track. Vibration from a passing train has the potential to move through the geologic strata, resulting in building vibration transferred through the building foundation. The principal concern related to this is annoyance to building occupants.

Figure 3-1. Sound Pressure and Sound Pressure Levels of Common Noise-Generating Activities



Source: Brüel and Kjær. Environmental Noise, Sound and Vibration Handbook , 2000

Table 3-1. FTA Noise Impact Criteria: Noise Levels Defining Impact for Transit Projects

Existing Noise Exposure $L_{eq}(h)$ or L_{dn} (dBA) *	Project Noise Impact Exposure, $L_{eq}(h)$ or L_{dn} (dBA) *					
	Category 1 or 2 Sites			Category 3 Sites		
	No Impact	Moderate Impact	Severe Impact	No Impact	Moderate Impact	Severe Impact
<43	<Ambient+10	Ambient+ 10 to 15	<Ambient+15	<Ambient+15	Ambient+ 10 to 15	>Ambient+20
43	<52	52-58	>58	<57	57-63	>63
44	<52	52-58	>58	<57	57-63	>63
45	<52	52-58	>58	<57	57-63	>63
46	<53	53-59	>59	<58	58-64	>64
47	<53	53-59	>59	<58	58-64	>64
48	<53	53-59	>59	<58	58-64	>64
49	<54	54-59	>59	<59	59-64	>64
50	<54	54-59	>59	<59	59-64	>64
51	<54	54-60	>60	<59	59-65	>65
52	<55	55-60	>60	<60	60-65	>65
53	<55	55-60	>60	<60	60-65	>65
54	<55	55-61	>61	<60	60-66	>66
55	<56	56-61	>61	<61	61-66	>66
56	<56	56-62	>62	<61	61-67	>67
57	<57	57-62	>62	<62	62-67	>67
58	<57	57-62	>62	<62	62-67	>67
59	<58	58-63	>63	<63	63-68	>68
60	<58	58-63	>63	<63	63-68	>68
61	<59	59-64	>64	<64	64-69	>69
62	<59	59-64	>64	<64	64-69	>69
63	<60	60-65	>65	<65	65-70	>70
64	<61	61-65	>65	<66	66-70	>70
65	<61	61-66	>66	<66	66-71	>71
66	<62	62-67	>67	<67	67-72	>72
67	<63	63-67	>67	<68	68-72	>72
68	<63	63-68	>68	<68	68-73	>73
69	<64	64-69	>69	<69	69-74	>74
70	<65	65-69	>69	<70	70-74	>74
71	<66	66-70	>70	<71	71-75	>75
72	<66	66-71	>71	<71	71-76	>76
73	<66	66-71	>71	<71	71-76	>76
74	<66	66-72	>72	<71	71-77	>77
75	<66	66-73	>73	<71	71-78	>78
76	<66	66-74	>74	<71	71-79	>79
77	<66	66-74	>74	<71	71-79	>79
>77	<66	66-75	>75	<71	71-80	>80

Source: *Transit Noise and Vibration Impact Assessment*, FTA, May 2006.
Notes: *L_{dn} is used for land use where nighttime sensitivity is a factor.
*L_{eq} during the hour of maximum transit noise exposure is used for land use involving only daytime activities.

3.2.2 Predicted Construction-related Vibration

The FTA guidance manual provides screening methodologies for determining where there is a significant potential for impact from construction activities. Such activities include pile driving, demolition, drilling, excavation, or blasting close to sensitive structures. The procedure includes:

- selecting the equipment and determining the vibratory levels at a reference distance of 25 feet;
- determining peak particle velocity at a receptor location using a formula that accounts for the peak particle velocity of the equipment and the distance from the receptor; and
- if consideration of annoyance or interference with vibration-sensitive activities is of concern, estimating the vibration level and applying the vibration impact.

Table 3-2 lists the vibration source levels from heavy construction equipment. These levels are average source levels under a variety of construction activities. This information can be used to predict vibration levels at various receptor distances from the operation of construction equipment. Damage and annoyance assessment follows the FTA procedures.

Table 3-2. Source Levels for Construction Equipment Vibration

Equipment	Peak Particle Velocity at 25 ft (in/sec)	Approximate L_v at 25 ft * (VdB re 10^{-6} in/sec)
Pile Driver (impact, upper range)	1.518	112
Pile Driver (impact, typical)	0.644	104
Pile Driver (sonic, upper range)	0.734	105
Pile Driver (sonic, typical)	0.170	93
Clam shovel drop (slurry wall)	0.202	94
Large bulldozer	0.089	87
Caisson drilling	0.089	87
Loaded trucks	0.076	86
Jackhammer	0.035	79
Small bulldozer	0.003	58

Source: *Guidance Manual for Transit Noise and Vibration Impact Assessment*, FTA, May 2006
Notes: *RMS Velocity in decibels (VdB).

This page intentionally left blank

4.0 Existing Conditions

4.1 Noise

Existing noise levels within the corridor were assessed based on noise measurements collected at representative sites. Noise-sensitive locations were selected for noise monitoring based on review of the Locally Preferred Alternatives' (LPA) alignments and the potential locations of the vehicle storage and maintenance facility. Selected noise-sensitive sites were principally residential dwellings, which were considered representative of typical ambient noise conditions in neighborhoods bordering the LPA alignments.

Development along the alignments is principally residential, which is within FTA Category 2, for which nighttime sensitivity to noise is assumed to be of utmost importance, and land uses within FTA Category 1, for which quiet is an essential element of the properties' intended purposes. Institutional land uses, FTA Category 3, are interspersed with Category 1 and 2 land uses, but were not differentiated from the more-sensitive residential uses. Non-sensitive commercial or industrial land uses are not represented by a FTA land-use category.

Noise measurements were performed at 70 noise-sensitive locations along the LPA mainline alignments (Figure 4-1) and the Downtown Design Options' alignments (Figure 4-2). Long-term (24-hour) noise measurements were taken at 38 sites (Table 4-1); peak-hour noise measurements during the 7:00 to 8:00 a.m. and 5:00 to 6:00 p.m. peak commuting periods were taken at 23 sites (Table 4-2).

At nine additional properties (Table 4-3), existing noise levels were derived from noise readings collected at nearby 24-hour and peak-hour measurement sites. All noise measurements were taken at exterior areas of each property.

Existing noise levels throughout the study area are typical of noise levels found in urban communities. Motor vehicles are the principal source of noise within the study area. The LPA alignments would follow existing travel routes; most communities adjacent to the LPA alignments are exposed to moderate to high ambient noise levels.

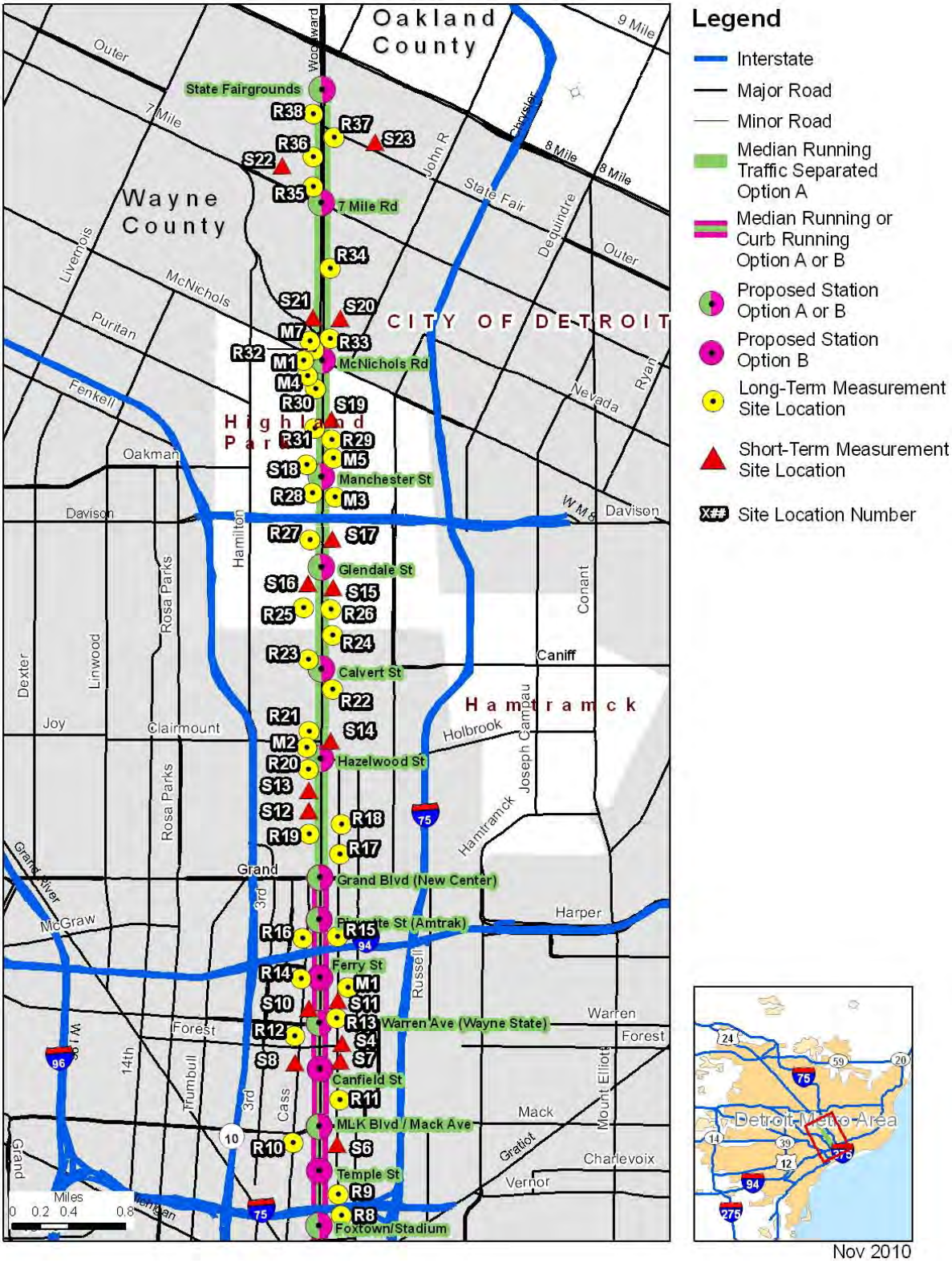
4.1.1 Land Use Descriptions

The land uses and noise-sensitive receptors that were considered in the noise analyses are briefly described below.

Larned, Randolph and Congress streets – Washington Boulevard to Randolph Street to Washington Boulevard

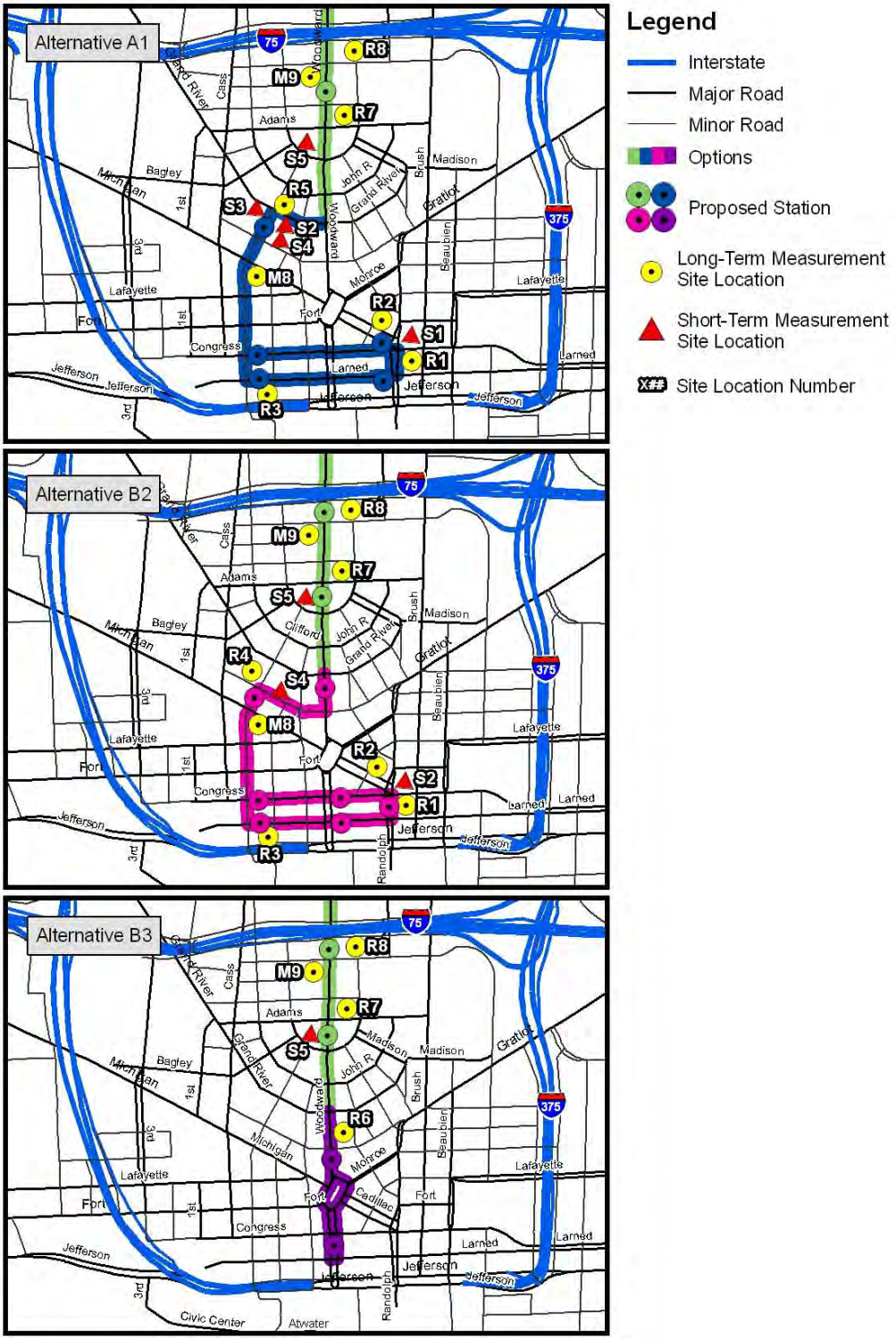
Land uses on Larned Street and Congress Street between Washington Boulevard and Randolph Street are predominantly commercial. However, four sites have noise-sensitive land uses: 1) the hotel property (Site DT-LT03) on Larned Street between Washington Boulevard and Shelby Street, 2) Millender Center Apartments (Site DT-LT01) on Randolph Street, 3) Kids Space Montessori (Site DT-ST01) at the intersection of Randolph and Congress streets, and 4) Cadillac Square Apartments (Site DT-LT02) on Cadillac Square, between Randolph and Bates streets, with a direct line of sight to Congress Street. Long-term measurement Sites DT-LT01 to DT-LT03 and DT-ST01 describe the existing noise environment in this area. Maximum-hour L_{eq} values of 65 to 71 dBA and L_{dn} values between 69 and 71 dBA were measured. The noise levels are due to local street traffic and noise from the Detroit People Mover.

Figure 4-1. Noise and Vibration Measurement Site Locations: Mainline



Source: Parsons Brinckerhoff, 2010.

Figure 4-2. Noise and Vibration Measurement Site Locations: Downtown



Source: Parsons Brinckerhoff, 2010.

Table 4-1. Existing Conditions: Long-Term (24-hour) Noise Measurements

Receptor Number	Site Number	Site Description	FTA Land Use Category	Measured Maximum-Hour L_{eq} (dBA)	Measured L_{dn} (dBA)
R1	DT-LT01	Tennis Court of Millender Center Apartments – 548 Brush Street – 5th Floor	2	69	71
R2	DT-LT02	Cadillac Square Apartments – 111 Cadillac Square – 29th Floor	2	71	69
R3	DT-LT03	Hotel at 2 Washington Boulevard – 4th Floor	2	67	70
R4	DT-LT04	The Westin Book Cadillac Detroit – 1114 Washington Boulevard – 4th Floor	2	70	70
R5	DT-LT05	Industrial Building Apartments – 232 Grand River – 4th Floor	2	72	74
R6	DT-LT06	1450 Woodward Avenue	2	74	73
R7	LT-001	Central United Methodist Church – 23 East Adams Avenue	3	65	66
R8	LT-002	Saint John's Episcopal Church – 50 East Fisher Freeway	3	67	68
R9	LT-005	2440 Woodward Avenue	2	71	73
R10	LT-014	3501 Stimson Street	2	70	70
R11	LT-003	Bi-Centennial Tower – 4 Alexandrine Street	2	67	68
R12	LT-007	4501 Woodward Avenue, Apartment 2	2	74	74
R13	LT-004	Hannah House – 4750 Woodward Avenue	2	71	72
R14	LT-010	5501 Woodward Avenue	2	67	68
R15	LT-011	Our Lady of the Rosary Parish – 5930 Woodward Avenue	3	80	82
R16	LT-008	5979 Woodward Avenue	2	69	71
R17	LT-009	Metropolitan United Methodist Church – 7730 Woodward Avenue	3	70	71
R18	LT-012	42 Chandler Street	2	60	63
R19	LT-006	8285 Woodward Avenue	2	65	68
R20	LT-013	The Family Place – 8726Woodward Avenue	1	70	70
R21	LT-115	53 Chicago Boulevard	2	60	60
R22	LT-114	Blessed Sacrament Cathedral – 9844 Woodward Avenue	2	62	63
R23	LT-116	11501 Woodward Avenue/10 Lawrence Street	2	63	62
R24	LT-112	Normandie Hotel – 11626 Woodward Avenue	2	65	65
R25	LT-117	10 Tuxedo Street	2	61	62
R26	LT-111	Massachusetts Avenue Park	1	59	61
R27	LT-113	2 Buena Vista Street	2	65	65
R28	LT-110	Labelle Towers Apartments – 33 Labelle Street	2	66	67
R29	LT-109	Charter Communications – 15120 Woodward	3	65	67
R30	LT-106	16140 Woodward Avenue	2	63	66
R31	LT-107	21 Moss Street	2	64	65
R32	LT-108	303 Covington Drive	2	62	63
R33	LT-104	324 West Montana Street	2	58	61
R34	LT-105	600 West Grixdale Avenue	2	62	56
R35	LT-103	19300 Afton Road	2	61	59
R36	LT-102	19390 Woodward Avenue	2	63	61
R37	LT-100	State Fair Apartments – 1231 West State Fair	2	60	60
R38	LT-101	Evergreen Cemetery	1	61	62

Source: Parsons Brinckerhoff, 2010.

Table 4-2. Existing Conditions: Peak-Hour Noise Measurements

Receptor Number	Site Number	Site Description	FTA Land Use Category	Measured Maximum-Hour L_{eq} (dBA)	Estimated L_{dn} (dBA)
S1	DT-ST01	Kids Space Montessori at Wayne County Building	3	65	NA
S2	DT-ST02	Stevens Building Apartments – 1260 Washington Boulevard	2	68	72
S3	DT-ST03	Washington Square Apartments – 1431 Washington Boulevard	2	69	72
S4	DT-ST04	Capitol Park	3	64	NA
S5	ST-002	Maybury Park at Corner of Woodward Avenue and Adams	1	65	NA
S6	ST-003	American Red Cross – 3510 Woodward Avenue	3	70	NA
S7	ST-004	Woodward Avenue at Canfield Street	3	68	73
S8	ST-007	Whitney House – 4421 Woodward Avenue	3	69	NA
S9	ST-008	4420 Woodward Avenue	3	70	NA
S10	ST-006	Wayne State University, Welcome Center	3	78	NA
S11	ST-005	Detroit Institute of Arts	3	68	NA
S12	ST-009	Detroit Academy – 8401 Woodward Avenue	3	78	NA
S13	ST-010	People's Community Church – 8601 Woodward Avenue	3	72	73
S14	ST-011	Northern High School	3	74	NA
S15	ST-105	Massachusetts Avenue Park	1	62	NA
S16	ST-109	Park United Presbyterian Church – 14 Cortland Street	3	74	NA
S17	ST-107	Highland Park – 2 East Buena Vista	1	65	NA
S18	ST-018	Corner of Sears Street and Woodward Avenue	3	71	NA
S19	ST-104	Highland Park Community High School – 15900 Woodward Avenue	3	61	NA
S20	ST-103	319 West Montana Street	2	57	61
S21	ST-101	Palmer Park – Tennis Courts	1	61	NA
S22	ST-102	19320 Afton Road	2	61	61
S23	ST-100	1120 West State Fair Avenue	3	58	60

Source: Parsons Brinckerhoff, 2010.
Notes: NA - These sites do not have sleep activity. L_{dn} existing noise levels are not applicable at these sites.

Table 4-3. Existing Conditions: Noise Levels Estimated from Nearby Long-Term (24-hour) and Peak-Hour Measurement Sites

Receptor Number	Site Number	Site Description	FTA Land Use Category	Measured Maximum-Hour L_{eq} (dBA)	Measured L_{dn} (dBA)
M1	M1	Park Shelton Apartments	2	65	66
M2	M2	10 Edison Street	2	74	74
M3	M3	Church – 13158 Woodward Avenue	3	65	NA
M4	M4	Apartments – 15948 Woodward Avenue	2	64	65
M5	M5	Soul Harvest Ministries – 16281 Woodward Avenue	3	64	NA
M6	M6	Apartments – 16360 Woodward Avenue	2	69	70
M7	M7	Apartments – 211 Merton Road	2	68	69
M8	M8	Holiday Inn Express – 1020 Washington Boulevard	2	74	75
M9	M9	Fox Theater – 2211 Woodward Avenue	3	67	NA

Source: Parsons Brinckerhoff, 2010.

Washington Boulevard – Larned Street to Grand River Avenue

Land use on Washington Boulevard between Larned Street and Michigan Avenue is predominantly commercial. From Michigan Avenue to Grand River Avenue, the land uses are a mix of commercial, hotels, and apartments. Long-term measurement Site DT-LT04 and peak-hour measurement Sites DT-ST02 and DT-ST03 describe the existing noise environment along this section of Washington Boulevard. Maximum-hour L_{eq} values of 68 to 69 dBA and L_{dn} values between 70 and 72 dBA were measured. The noise levels are due to local street traffic.

State Street – Washington Boulevard to Woodward Avenue

Land use on State Street between Washington Boulevard and Woodward Avenue is predominantly commercial, with the expectation of Capitol Park. Peak-hour measurement Site DT-ST04 describes the existing noise environment at the park where a maximum-hour L_{eq} of 64 dBA was measured. The noise levels are due to local street traffic.

Grand River Avenue – Washington Boulevard to Woodward Avenue

Land use on Grand River Avenue between Washington Boulevard and Woodward Avenue is predominantly commercial, with the exception of the Industrial Building Apartments and Capitol Park. Long-term measurement Site DT-LT05 and peak-hour Site DT-ST04 describe the existing noise environment along this section of Grand River Avenue. Maximum-hour L_{eq} values of 64 to 72 dBA and L_{dn} value of 74 dBA were measured. The noise levels are due to local street traffic.

Woodward Avenue – State Street to Adams Street

Land use on Woodward Avenue between State and Adams streets is a mix of ground-floor commercial and loft apartments. Long-term measurement Site DT-LT06 describes the existing noise environment along this section of Woodward Avenue. Maximum-hour L_{eq} of 74 dBA and L_{dn} value of 73 dBA were measured. The noise levels are due to local street traffic.

Adams Street to Interstate 75 (I-75)

Land use between Adams Street and I-75 is predominantly commercial. However, there are two places of worship, a homeless center, and several theaters along Woodward Avenue. Long-term measurement sites LT-001, LT-002, and ST-002 describe the existing noise environment in this area. Maximum-hour L_{eq} values of 65 to 66 dBA and L_{dn} values between 66 and 67 dBA were measured. The noise levels are due to traffic noise from I-75.

Interstate I-75 to Martin Luther King Jr. Boulevard

Land use between I-75 and Martin Luther King Jr. Boulevard is a mix of commercial and residential, and one church. Long-term measurement sites LT-005 and ST-003 describe the existing noise environment in this area. Maximum-hour L_{eq} values of 70 and 71 dBA and L_{dn} values between 71 and 73 dBA were measured. The noise levels are due to traffic noise from I-75.

Martin Luther King Jr. Boulevard to Warren Avenue

Land use between Martin Luther King Jr. Boulevard and Warren Avenue is a mix of commercial, office buildings, medical buildings, two churches, and some residential areas. Long-term measurement sites LT-003, LT-004, and LT-007 and peak-hour sites ST-004, ST-007, and ST-008 describe the existing noise environment in this area. Maximum-hour L_{eq} values between 67 and 74 dBA and L_{dn} values between 68 and 74 dBA were measured. The higher noise levels are due to the proximity of Woodward Avenue.

Warren Avenue to I-94

Land use between Warren Avenue and I-94 is a mix of commercial, office buildings, two schools, and some residential areas. Long-term measurement Site LT-010 and peak-hour Sites ST-005 and ST-006 describe the existing noise environment in this area. Maximum-hour L_{eq} values between 67 and 78 dBA and L_{dn} values between 68 and 78 dBA were measured. The higher noise levels are due to Site ST-006's location at the intersection of Woodward Avenue and Warren Avenue. Sites LT-010 and ST-005 reflect traffic noise levels from only Woodward Avenue, with maximum-hour L_{eq} values between 67 and 68 dBA and an L_{dn} of 68 dBA.

I-94 to Grand Boulevard

Land use between I-94 and Grand Boulevard is predominantly commercial with one church and some residential areas. Long-term measurement sites LT-008 and LT-011 describe the existing noise environment in this area. Maximum-hour L_{eq} values between 69 and 80 dBA and L_{dn} values between 71 and 82 dBA were measured. Traffic on I-94 accounts for the higher noise levels at Site LT-011; the noise level decreases at Site LT-008 located further north.

Grand Boulevard to State Route 8 (M 8)

Land use between Grand Boulevard and M-8 is predominantly residential, but with six churches, three schools, one hotel, and some commercial areas. Long-term measurement Sites LT-006, LT-012, LT-013, and LT-111 to LT 117 and peak-hour Sites ST-009, ST-010, ST-011, ST-105, ST-107, and ST-109 describe the existing noise environment in this area. Maximum-hour L_{eq} values between 60 and 76 dBA and L_{dn} values between 60 and 71 dBA were measured. The areas with higher noise levels are located south of Claremont Street near Grand Boulevard (Site LT-009); the area north of Claremont Street has L_{dn} values between 60 and 65 dBA.

M-8 to McNichols Road

Land use between M-8 and McNichols Road is predominantly commercial fronting residential neighborhoods. There are two schools and one church along Woodward Avenue. Long-term

measurement Sites LT-110, LT-109, LT-106, LT-107 and peak-hour Site ST-104 describe the existing noise environment in this area. Maximum-hour L_{eq} values between 61 and 71 dBA and L_{dn} values between 65 and 67 dBA were measured. The higher noise levels were measured at locations on Woodward Avenue; the lower noise levels were measured at locations removed from Woodward Avenue.

McNichols Road to 8 Mile Road

Land use between McNichols and 8 Mile roads is residential, and also includes the State Fairgrounds and Evergreen Cemetery. Long-term measurement Sites LT-100, LT-101, LT-102, and LT-103 and peak-hour Sites ST-100 and ST-102 describe the existing noise environment in this area. Maximum-hour L_{eq} values between 58 and 62 dBA and L_{dn} values between 60 and 62 dBA were measured. The higher noise levels were measured at locations on Woodward Avenue; the lower noise levels were measured at locations with some shielding from Woodward Avenue.

4.2 Vibration

The FTA impact assessment procedure does not require measurement of existing vibration levels as a baseline against which to compare vibration from the LPA. In the study area, existing vibration levels are generated principally from medium- and heavy-duty truck movements. Typical vibration levels caused by such traffic are typically in the 50 to 60 VdB range, which is below the threshold of perception of people inside adjacent buildings and below the FTA criteria for frequent events.

5.0 Environmental Consequences

5.1 Noise Exposures

5.1.1 Line Operations

Light Rail Transit (LRT) uses electric rail vehicles and may operate with just one vehicle or two that are joined; if the latter, the LRT would not be expected to be longer than 180 feet. Preliminary plans include weekday service from 5:00 a.m. to 2:00 a.m. (i.e., 21 hours of service per day). On Saturdays, Sundays and holidays, it is anticipated that service would operate from 6:00 a.m. to 2:00 a.m. (i.e., 20 hours of service per day). The longer weekday 21-hour service period was assumed in the noise analysis.

No Build Alternative

With the No Build Alternative, future noise levels would be substantially from traffic on local arterials, including Woodward Avenue, local cross streets, and the three major freeways crossed, including I-75, I-94 and the Davison Freeway. Since traffic in the study area is below roadway capacity, changes in automobile traffic are not expected to increase the 24-hour (L_{dn}) noise above existing levels at any of the noise measurement sites. Although the maximum-hour noise level could increase by one to two dBA, overall noise levels are not expected to increase. Therefore, no traffic noise impacts are projected with the No Build Alternative.

Locally Preferred Alternative

Traffic Noise

The noise from automobile traffic is not expected to change measurably with the LPA. While the LPA would divert some travel from autos to transit, resulting in some decrease in auto traffic, travel speeds for the remaining autos may be slightly reduced due to the loss of one lane of traffic in each direction for the LPA. The slightly reduced speeds may result in a very small reduction in traffic-related noise.

Transit Noise

The transit noise impact assessment findings for each of the LPA alignment alternatives are summarized below and in Tables 5-1 through 5-4.

Mainline LPA Alternatives A1, B2, and B3

Table 5-1 shows noise levels at each of the locations evaluated and identifies three potential noise impacts along the mainline, which is common to Alternatives A1, B2, and B3. LRT noise levels would exceed FTA impact thresholds for moderate impacts at the Park Shelton Apartments (Site M1), the Normandie Hotel (Site LT-112) and 600 Grixdale Avenue (Site LT-105).

Downtown LPA Alternatives

Downtown LPA Alternative A1

Downtown LRT noise levels would exceed FTA impact thresholds for moderate impacts at two receptor sites (ground floor and seventh floor) at one residential property, the Stevens Building Apartments (Site DT-ST02). Table 5-2 provides existing and future noise levels at each of the locations evaluated and identifies potential Downtown noise impacts with Alternative A1.

Table 5-1. LPA Alternatives A1, B2, and B3 Mainline Noise Impacts

Receptor Number	Site ID	Stations	FTA Land Use Category	Existing Noise Level	Noise Impact Thresholds	Noise Level	Noise Impact
R6	DT LT-06 GF	Rosa Parks Transit Center to Foxtown/Stadium	2	73	66 Moderate 72 Severe	63	No Impact
R6	DT LT-06 4th floor	Rosa Parks Transit Center to Foxtown/Stadium	2	71	66 Moderate 71 Severe	60	No Impact
R9	LT-005	Foxtown/Stadium and Temple	2	73	66 Moderate 72 Severe	60	No Impact
R10	LT-014	Temple and MLK Boulevard/Mack Avenue	2	70	65 Moderate 70 Severe	60	No Impact
S6	ST-003	Temple and MLK Boulevard/Mack Avenue	3	70	70 Moderate 75 Severe	60	No Impact
R11	LT-003	MLK Boulevard/Mack Avenue and Warren Avenue	2	68	63 Moderate 69 Severe	51	No Impact
S9	ST-008	MLK Boulevard/Mack Avenue and Warren Avenue	3	70	70 Moderate 75 Severe	58	No Impact
S8	ST-007	MLK Boulevard/Mack Avenue and Warren Avenue	3	69	69 Moderate 75 Severe	55	No Impact
S7	ST-004	MLK Boulevard/Mack Avenue and Warren Avenue	3	73	71 Moderate 77 Severe	58	No Impact
R12	LT-007	MLK Boulevard/Mack Avenue and Warren Avenue	2	74	66 Moderate 73 Severe	62	No Impact
R13	LT-004	MLK Boulevard/Mack Avenue and Warren Avenue	2	72	66 Moderate 72 Severe	60	No Impact
S10	ST-006	Warren Avenue and Piquette Street/Amtrak Station	3	78	71 Moderate 79 Severe	59	No Impact
S11	ST-005	Warren Avenue and Piquette Street/Amtrak Station	3	68	68 Moderate 74 Severe	52	No Impact
M1	M1 GF	Warren Avenue and Piquette Street/Amtrak Station	2	70	65 Moderate 70 Severe	65	**Moderate Impact**
M1	M1 10th floor	Warren Avenue and Piquette Street/Amtrak Station	2	66	62 Moderate 68 Severe	56	No Impact
R14	LT-010	Warren Avenue and Piquette Street/Amtrak Station	2	68	63 Moderate 69 Severe	60	No Impact
R15	LT-011	Warren Avenue and Piquette Street/Amtrak Station	3	80	71 Moderate 81 Severe	58	No Impact
R16	LT-008	Warren Avenue and Piquette Street/Amtrak Station	2	71	66 Moderate 71 Severe	55	No Impact
R17	LT-009	Grand Boulevard to Hazelwood Street/Holbrook Street	2	71	66 Moderate 71 Severe	62	No Impact
R18	LT-012	Grand Boulevard to Hazelwood Street/Holbrook Street	3	63	65 Moderate 71 Severe	59	No Impact
R19	LT-006	Grand Boulevard to Hazelwood Street/Holbrook Street	2	68	63 Moderate 69 Severe	54	No Impact
S12	ST-009	Grand Boulevard to Hazelwood Street/Holbrook Street	3	78	66 Moderate 76 Severe	57	No Impact
S13	ST-010	Grand Boulevard to Hazelwood Street/Holbrook Street	3	72	66 Moderate 71 Severe	60	No Impact
R20	LT-013	Grand Boulevard to Hazelwood Street/Holbrook Street	3	70	65 Moderate 70 Severe	55	No Impact
S14	ST-011	Hazelwood Street/Holbrook Street to Calvert Street	3	74	66 Moderate 73 Severe	53	No Impact
M2	M2	Hazelwood Street/Holbrook Street to Calvert Street	2	74	66 Moderate 73 Severe	60	No Impact

Table 5-1. LPA Alternatives A1, B2, and B3 Mainline Noise Impacts (continued)

Receptor Number	Site ID	Stations	FTA Land Use Category	Existing Noise Level	Noise Impact Thresholds	Noise Level	Noise Impact
R21	LT-115	Hazelwood Street/Holbrook Street to Calvert Street	2	60	58 Moderate 63 Severe	55	No Impact
R22	LT-114	Hazelwood Street/Holbrook Street to Calvert Street	3	63	65 Moderate 71 Severe	57	No Impact
R23	LT-116	Hazelwood Street/Holbrook Street to Calvert Street	2	62	59 Moderate 65 Severe	56	No Impact
R24	LT-112	Calvert Street to Glendale Street	2	65	61 Moderate 67 Severe	63	**Moderate Impact**
R25	LT-117	Calvert Street to Glendale Street	2	62	59 Moderate 65 Severe	54	No Impact
R26	LT-111	Calvert Street to Glendale Street	3	61	64 Moderate 70 Severe	52	No Impact
S15	ST-105	Calvert Street to Glendale Street	3	62	64 Moderate 70 Severe	48	No Impact
S16	ST-109	Calvert Street to Glendale Street	3	74	71 Moderate 78 Severe	56	No Impact
R27	LT-113	Glendale Street to Manchester Street	2	65	61 Moderate 67 Severe	53	No Impact
S17	ST-107	Glendale Street to Manchester Street	2	65	61 Moderate 67 Severe	54	No Impact
M3	M3	Glendale Street to Manchester Street	3	65	66 Moderate 72 Severe	57	No Impact
R28	LT-110	Glendale Street to Manchester Street	2	67	63 Moderate 68 Severe	52	No Impact
R29	LT-109	Manchester Street to McNichols Road	3	67	68 Moderate 72 Severe	56	No Impact
S19	ST-104	Manchester Street to McNichols Road	3	61	64 Moderate 70 Severe	49	No Impact
M4	M4	Manchester Street to McNichols Road	2	65	61 Moderate 67 Severe	63	No Impact
R31	LT-107	Manchester Street to McNichols Road	2	66	62 Moderate 68 Severe	53	No Impact
R30	LT-106	Manchester Street to McNichols Road	3	66	67 Moderate 73 Severe	59	No Impact
M5	M5	Manchester Street to McNichols Road	3	64	66 Moderate 71 Severe	58	No Impact
M6	M6	Manchester Street to McNichols Road	2	70	65 Moderate 70 Severe	63	No Impact
M7	M7	McNichols Road to 7 Mile Road	2	68	63 Moderate 69 Severe	60	No Impact
R32	LT-108	McNichols Road to 7 Mile Road	2	63	60 Moderate 66 Severe	52	No Impact
R33 S22	LT-104/ ST-102	McNichols Road to 7 Mile Road	2	61	59 Moderate 65 Severe	58	No Impact
S21	ST-101	McNichols Road to 7 Mile Road	3	61	64 Moderate 70 Severe	51	No Impact
R34	LT-105	McNichols Road to 7 Mile Road	2	56	56 Moderate 63 Severe	59	**Moderate Impact**
R35 S22	LT-103/ ST-102	7 Mile Road to State Fair	2	59	58 Moderate 63 Severe	54	No Impact

Table 5-1. LPA Alternatives A1, B2, and B3 Mainline Noise Impacts (continued)

Receptor Number	Site ID	Stations	FTA Land Use Category	Existing Noise Level	Noise Impact Thresholds	Noise Level	Noise Impact
R36	LT-102	7 Mile Road to State Fair	2	61	59 Moderate 65 Severe	54	No Impact
R38	LT-101	7 Mile Road to State Fair	2	62	59 Moderate 65 Severe	56	No Impact
R37	LT-100	7 Mile Road to State Fair	2	60	58 Moderate 64 Severe	54	No Impact
S23	ST-100	7 Mile Road to State Fair	3	58	62 Moderate 68 Severe	48	No Impact

Source: Parsons Brinckerhoff, 2010

Downtown LPA Alternative B2

Downtown LRT noise levels would exceed FTA impact thresholds for moderate impacts at three receptor sites: the Holiday Inn Express (Site M8), the Westin Book Cadillac Detroit (Site DT-LT04), and the Central United Methodist Church (Site LT-001). Noise sensitivity at the church is limited to daytime hours. Table 5-3 provides existing and future noise levels with the LPA at each of the locations evaluated and identifies potential Downtown noise impacts with Alternative B2.

Downtown LPA Alternative B3

Downtown LRT noise levels would exceed FTA impact thresholds for moderate impacts at two receptor sites: residences at 1450 Woodward Avenue (Site DT-LT06) and the Central United Methodist Church (Site LT-001). Noise sensitivity at the church is limited to daytime hours. Table 5-4 provides existing and future noise levels with the LPA at each of the locations evaluated and identifies potential Downtown noise impacts with Alternative B3.

Noise Exposure: Wheel Squeal

One transit-noise impact exclusive to LRT is wheel squeal. Wheel squeal occurs when trains make sharp turns; the sharper the turn, the more likely wheel squeal will occur. Railcars are supported on each end and guided through curves by a swiveling truck consisting of two pairs of wheels with parallel axles. Since the axles are held rigidly by the truck frame, they cannot take up radial positions as the car traverses a curve. Consequently, the wheels must slide sideways across the rail top as well as roll along its length. The lateral sliding of the wheel over the rail head creates rubbing forces on the wheel which, if conditions are suitable, will cause its vibration to increase until high stable amplitude is reached. The wheel vibration is radiated as squeal noise characterized by one or more intense, high-pitched tones at the natural vibration frequencies of the wheel. Wheel-squeal analysis and associated mitigation evaluation, if necessary, will be conducted for the selected LPA Alternative and documented in the FEIS.

5.1.2 Support Facilities

Park-and-Ride Lot

The park-and-ride lot is proposed to be located on the Shoppes at Gateway property at the northern end of the study area. As land use will be a mix of non-noise-sensitive uses (commercial/retail) with the proposed future development, no noise impacts are predicted to result from the proposed park-and-ride lot.

Table 5-2. Downtown LPA Alternative A1 Noise Impacts

Receptor Number	Site ID	Stations	FTA Land Use Category	Existing Noise Level	Noise Impact Thresholds	Noise Level	Noise Impact
R3	DT LT-03	Cobo Center E to Randolph	2	70	65 Moderate 70 Severe	57	No Impact
R1	DT LT-01	Randolph to Cobo Hall	3	71	71 Moderate 76 Severe	54	No Impact
R1	DT LT-01A	Randolph to Cobo Hall	2	68	63 Moderate 69 Severe	54	No Impact
S1	DT ST-01	Randolph to Cobo Hall	3	65	65 Moderate 71 Severe	53	No Impact
R2	DT LT-02 GF	Randolph to Cobo Hall	2	72	66 Moderate 71 Severe	54	No Impact
R2	DT LT-02 29th floor	Randolph to Cobo Hall	2	69	64 Moderate 70 Severe	48	No Impact
M8	M8	Cobo Hall to Rosa Parks Transit Center	2	75	66 Moderate 74 Severe	62	No Impact
M8	M8-16th floor	Cobo Hall to Rosa Parks Transit Center	2	66	62 Moderate 68 Severe	53	No Impact
R4	DT LT-04 WGF	Rosa Parks Transit Center to Foxtown/Stadium	2	71	66 Moderate 71 Severe	61	No Impact
R4	DT LT-04 4th floor	Rosa Parks Transit Center to Foxtown/Stadium	2	70	65 Moderate 69 Severe	53	No Impact
R4	DT LT-04 35th floor	Rosa Parks Transit Center to Foxtown/Stadium	2	63	60 Moderate 66 Severe	47	No Impact
S2	DT ST-02 GF	Rosa Parks Transit Center to Foxtown/Stadium	2	72	66 Moderate 72 Severe	69	**Moderate Impact**
S2	DT ST-02 7th floor	Rosa Parks Transit Center to Foxtown/Stadium	2	63	60 Moderate 66 Severe	63	**Moderate Impact**
S3	DT ST-03 GF	Rosa Parks Transit Center to Foxtown/Stadium	2	72	66 Moderate 72 Severe	58	No Impact
S3	DT-ST03 27th floor	Rosa Parks Transit Center to Foxtown/Stadium	2	67	63 Moderate 68 Severe	49	No Impact
R5	DT LT-05 GF	Rosa Parks Transit Center to Foxtown/Stadium	2	74	66 Moderate 72 Severe	65	No Impact
R5	DT LT-05 21st floor	Rosa Parks Transit Center to Foxtown/Stadium	2	65	61 Moderate 67 Severe	51	No Impact
S4	DT ST-04	Rosa Parks Transit Center to Foxtown/Stadium	3	64	66 Moderate 71 Severe	48	No Impact
S5	ST-002	Grand Circus Park and Foxtown/Stadium	3	65	65 Moderate 71 Severe	57	No Impact
R7	LT-001	Grand Circus Park and Foxtown/Stadium	2	66	62 Moderate 68 Severe	57	No Impact
M9	M9	Foxtown/Stadium and Temple	3	66	67 Moderate 73 Severe	63	No Impact
R8	LT-002	Foxtown/Stadium and Temple	3	68	68 Moderate 74 Severe	53	No Impact

Source: Parsons Brinckerhoff, 2010

Table 5-3. Downtown LPA Alternative B2 Noise Impacts

Receptor Number	Site ID	Stations	FTA Land Use Category	Existing Noise Level	Noise Impact Thresholds	Noise Level	Noise Impact
R3	DT LT-03	Cobo Center E to Randolph	2	70	65 Moderate 70 Severe	58	No Impact
R1	DT LT-01	Randolph to Cobo Hall	3	71	71 Moderate 76 Severe	56	No Impact
R1	DT LT-01A	Randolph to Cobo Hall	2	68	63 Moderate 69 Severe	55	No Impact
S1	DT ST-01	Randolph to Cobo Hall	3	65	65 Moderate 71 Severe	52	No Impact
R2	DT LT-02 GF	Randolph to Cobo Hall	2	72	66 Moderate 71 Severe	52	No Impact
R2	DT LT-02 29th floor	Randolph to Cobo Hall	2	69	64 Moderate 70 Severe	48	No Impact
M8	M8	Cobo Hall to Rosa Parks Transit Center	2	75	66 Moderate 74 Severe	67	**Moderate Impact**
M8	M8-16th floor	Cobo Hall to Rosa Parks Transit Center	2	66	62 Moderate 68 Severe	53	No Impact
R4	DT LT-04 WGF	Rosa Parks Transit Center to Grand River	2	71	66 Moderate 71 Severe	60	No Impact
R4	DT LT-04 4th floor	Rosa Parks Transit Center to Grand River	2	70	65 Moderate 69 Severe	58	No Impact
R4	DT LT-04 35th floor	Rosa Parks Transit Center to Grand River	2	63	60 Moderate 66 Severe	48	No Impact
R4	DT LT- 04 State GF	Rosa Parks Transit Center to Grand River	2	77	66 Moderate 75 Severe	69	**Moderate Impact**
R4	DT LT-04 State 4th floor	Rosa Parks Transit Center to Grand River	2	72	66 Moderate 72 Severe	64	No Impact
R4	DT LT-04 State 35th floor	Rosa Parks Transit Center to Grand River	2	63	60 Moderate 66 Severe	48	No Impact
S4	DT ST-04	Rosa Parks Transit Center to Grand River	3	64	66 Moderate 71 Severe	57	No Impact
S5	ST-002	Grand Circus Park and Foxtown/Stadium	3	65	65 Moderate 71 Severe	57	No Impact
R7	LT-001	Grand Circus Park and Foxtown/Stadium	2	66	62 Moderate 68 Severe	64	**Moderate Impact**
M9	M9	Foxtown/Stadium and Temple	3	66	67 Moderate 73 Severe	64	No Impact
R8	LT-002	Foxtown/Stadium and Temple	3	68	63 Moderate 69 Severe	59	No Impact

Source: Parsons Brinckerhoff, 2010

Table 5-4. Downtown LPA Alternative B3 Noise Impacts

Receptor Number	Site ID	Stations	FTA Land Use Category	Existing Noise Level	Noise Impact Thresholds	Noise Level	Noise Impact
R6	DT LT-06 GF	State/Gratiot and Adams/Grand Circus Park	2	73	66 Moderate 72 Severe	67	**Moderate Impact**
R6	DT LT-06 4th floor	State/Gratiot and Adams/Grand Circus Park	2	70	65 Moderate 70 Severe	61	No Impact
S5	ST-002	Grand Circus Park and Foxtown/Stadium	3	65	65 Moderate 71 Severe	57	No Impact
R7	LT-001	Grand Circus Park and Foxtown/Stadium	2	66	62 Moderate 68 Severe	64	**Moderate Impact**
M9	M9	Foxtown/Stadium and Temple	3	66	67 Moderate 73 Severe	64	No Impact
R8	LT-002	Foxtown/Stadium and Temple	3	68	63 Moderate 69 Severe	59	No Impact

Source: Parsons Brinckerhoff, 2010

Vehicle Storage and Maintenance Facility

There are three potential sites under consideration for the LPA's vehicle storage and maintenance facility:

- MLK Boulevard Site - would occupy two vacant lots north and south of West Stimson Street, just west of Woodward Avenue and south of MLK/Mack Avenue. This site would have frontage on Woodward Avenue. Site LT-014, just north of this location, has an L_{dn} of 70 dBA. Project noise exposure between 65 and 69 dBA would cause a moderate noise impact; project noise exposure above 70 dBA would cause a severe noise impact. The project noise exposure for this vehicle storage maintenance facility is predicted to be 72 dBA L_{dn} at Site LT-014. If chosen for the vehicle storage maintenance facility, a severe noise impact is predicted for Site LT-014.
- Amsterdam Street Site - would occupy two lots east and west of Cass Avenue between Amsterdam Street and the two grade-separated tracks owned by Consolidated Rail Corporation (CR) and Canadian National Railway (CN), respectively, just south of Baltimore Avenue. This site would have frontage on Woodward Avenue. No noise-sensitive receptors are located in this area. No noise impacts are predicted.
- Highland Park Ford Plant Site - would occupy one large lot east of Woodward Avenue north of Manchester Street and the former Highland Park Ford Plant. As this site is about 900 feet east of Woodward Avenue, direct access would be via the right-of-way for CR's currently abandoned rail line. No noise-sensitive receptors are located in this area. No noise impacts are predicted.

Traction Power Substations

The traction power substations would be located away from, or shielded from, noise-sensitive land uses. No noise impacts are predicted.

5.2 LRT Line Operation Vibration Impacts

The vibration levels at the nearest structures are estimated by reading values from the FTA reference vibration curve and applying adjustments to account for factors such as track support

system, vehicle speed, and track and wheel conditions. This procedure was followed while estimating vibration velocity levels for each of the LPA Alternatives.

5.2.1 No Build

As in existing conditions and without the LPA, future vibration levels would be generated principally from truck movements. Typical vibration levels caused by such traffic are typically in the 50 to 60 VdB range, which is below the threshold of perception of people inside adjacent buildings and below the FTA criteria for frequent events.

5.2.2 Locally Preferred Alternative

Estimated vibration levels at each of the representative noise- and vibration-sensitive sites for the LPA Alternatives are presented in Tables 5-5 through 5-8.

Mainline LPA Alternatives A1, B2, and B3 Vibration Impacts

Table 5-5 shows vibration levels at each of the locations and potential ground-borne noise levels and impacts for Alternatives A1, B2, and B3. There are no predicted vibration impacts on the mainline segment of the LPA Alternatives.

Table 5-5. LPA Alternatives A1, B2, and B3 Mainline Vibration Impacts

Receptor Number	Site Number	Stations	Vibration Criteria	Vibration Level	Vibration Impact	Ground-borne Noise Criteria	Ground-borne Noise Level	Ground-borne Noise Impact
R6	DT LT-06 GF	Rosa Parks Transit Center to Foxtown/Stadium	72	64	No Impact	35	29	No Impact
R6	DT LT-06 4th floor	Rosa Parks Transit Center to Foxtown/Stadium	72	62	No Impact	35	27	No Impact
R9	LT-005	Foxtown/Stadium and Temple	72	62	No Impact	35	27	No Impact
R10	LT-014	Temple and MLK Blvd/Mack Ave	72	61	No Impact	35	26	No Impact
S6	ST-003	Temple and MLK Blvd/Mack Ave	75	62	No Impact	40	27	No Impact
R11	LT-003	MLK Blvd/Mack Ave and Warren Avenue	72	56	No Impact	35	21	No Impact
S9	ST-008	MLK Blvd/Mack Ave and Warren Avenue	75	64	No Impact	40	29	No Impact
S8	ST-007	MLK Blvd/Mack Ave and Warren Avenue	75	61	No Impact	40	26	No Impact
S7	ST-004	MLK Blvd/Mack Ave and Warren Avenue	75	64	No Impact	40	29	No Impact
R12	LT-007	MLK Blvd/Mack Ave and Warren Avenue	72	64	No Impact	35	35	**Impact**
R13	LT-004	MLK Blvd/Mack Ave and Warren Avenue	72	61	No Impact	35	26	No Impact
S10	ST-006	Warren Avenue and Piquette St/Amtrak Station	75	65	No Impact	40	30	No Impact
S11	ST-005	Warren Avenue and Piquette St/Amtrak Station	75	65	No Impact	40	30	No Impact
M1	M1 GF	Warren Avenue and Piquette St/Amtrak Station	72	65	No Impact	35	35	**Impact**
M1	M1 10th floor	Warren Avenue and Piquette St/Amtrak Station	72	56	No Impact	35	21	No Impact

Table 5-5. LPA Alternatives A1, B2, and B3 Mainline Vibration Impacts (continued)

Receptor Number	Site Number	Stations	Vibration Criteria	Vibration Level	Vibration Impact	Ground-borne Noise Criteria	Ground-borne Noise Level	Ground-borne Noise Impact
R14	LT-010	Warren Avenue and Piquette St/Amtrak Station	72	61	No Impact	35	26	No Impact
R15	LT-011	Warren Avenue and Piquette St/Amtrak Station	75	65	No Impact	40	30	No Impact
R16	LT-008	Warren Avenue and Piquette St/Amtrak Station	72	55	No Impact	35	27	No Impact
R17	LT-009	Grand Blvd to Hazelwood St/Holbrook St	72	64	No Impact	35	29	No Impact
R18	LT-012	Grand Blvd to Hazelwood St/Holbrook St	75	65	No Impact	40	30	No Impact
R19	LT-006	Grand Blvd to Hazelwood St/Holbrook St	72	54	No Impact	35	19	No Impact
S12	ST-009	Grand Blvd to Hazelwood St/Holbrook St	75	63	No Impact	40	28	No Impact
S13	ST-010	Grand Blvd to Hazelwood St/Holbrook St	75	67	No Impact	40	32	No Impact
R20	LT-013	Grand Blvd to Hazelwood St/Holbrook St	75	63	No Impact	40	28	No Impact
S14	ST-011	Hazelwood Street/Holbrook Street to Calvert Street	75	58	No Impact	41	23	No Impact
M2	M2	Hazelwood Street/Holbrook Street to Calvert Street	72	31	No Impact	35	26	No Impact
R21	LT-115	Hazelwood Street/Holbrook Street to Calvert Street	72	55	No Impact	35	20	No Impact
R22	LT-114	Hazelwood Street/Holbrook Street to Calvert Street	75	62	No Impact	40	27	No Impact
R23	LT-116	Hazelwood Street/Holbrook Street to Calvert Street	72	56	No Impact	35	21	No Impact
R24	LT-112	Calvert Street to Glendale Street	72	66	No Impact	35	31	No Impact
R25	LT-117	Calvert Street to Glendale Street	72	54	No Impact	35	19	No Impact
R26	LT-111	Calvert Street to Glendale Street	75	57	No Impact	40	22	No Impact
S15	ST-105	Calvert Street to Glendale Street	75	61	No Impact	40	19	No Impact
S16	ST-109	Calvert Street to Glendale Street	75	61	No Impact	40	26	No Impact
R27	LT-113	Glendale Street to Manchester Street	72	54	No Impact	35	19	No Impact
S17	ST-107	Glendale Street to Manchester Street	72	54	No Impact	35	19	No Impact
M3	M3	Glendale Street to Manchester Street	75	63	No Impact	40	28	No Impact
R28	LT-110	Glendale Street to Manchester Street	72	54	No Impact	35	19	No Impact
R29	LT-109	Manchester Street to McNichols Road	75	61	No Impact	40	26	No Impact

Table 5-5. LPA Alternatives A1, B2, and B3 Mainline Vibration Impacts (continued)

Receptor Number	Site Number	Stations	Vibration Criteria	Vibration Level	Vibration Impact	Ground-borne Noise Criteria	Ground-borne Noise Level	Ground-borne Noise Impact
S19	ST-104	Manchester Street to McNichols Road	75	54	No Impact	40	19	No Impact
M4	M4	Manchester Street to McNichols Road	72	66	No Impact	35	31	No Impact
R31	LT-107	Manchester Street to McNichols Road	72	54	No Impact	35	19	No Impact
R30	LT-106	Manchester Street to McNichols Road	75	66	No Impact	40	31	No Impact
M5	M5	Manchester Street to McNichols Road	75	64	No Impact	40	29	No Impact
M6	M6	Manchester Street to McNichols Road	72	66	No Impact	35	31	No Impact
M7	M7	McNichols Road to 7 Mile Road	72	61	No Impact	35	26	No Impact
R32	LT-108	McNichols Road to 7 Mile Road	72	64	No Impact	35	19	No Impact
R33/S22	LT-104/ ST-102	McNichols Road to 7 Mile Road	72	60	No Impact	35	25	No Impact
S21	ST-101	McNichols Road to 7 Mile Road	75	55	No Impact	40	20	No Impact
R34	LT-105	McNichols Road to 7 Mile Road	72	60	No Impact	35	25	No Impact
R35/S22	LT-103/ ST-102	7 Mile Road to State Fair	72	54	No Impact	35	19	No Impact
R36	LT-102	7 Mile Road to State Fair	72	54	No Impact	35	19	No Impact
R38	LT-101	7 Mile Road to State Fair	72	57	No Impact	35	22	No Impact
R37	LT-100	7 Mile Road to State Fair	72	54	No Impact	35	19	No Impact
S23	ST-100	7 Mile Road to State Fair	NA	NA	NA	NA	NA	NA

Downtown Alternatives Vibration Impacts

Downtown LPA Alternative A1

Vibration levels slightly above the FTA ground-borne impact threshold are predicted at the Downtown Fox Theater (Site M9) and at the Stevens Building Apartments (Site DT-ST02). Table 5-6 shows vibration levels at each of the locations and potential vibration impacts for LPA Alternative A1.

Downtown LPA Alternative B2

Vibration levels at or slightly above the FTA impact threshold are predicted at the Downtown Fox Theater (Site M9), the Holiday Inn Express (Site M8) and the Westin Book Cadillac Detroit (Site DT-LT04). Table 5-7 shows vibration levels at each of the location and potential noise impacts for LPA Alternative B2.

Downtown LPA Alternative B3

Vibration levels at or slightly above the FTA impact threshold are predicted at the Downtown Fox Theater (Site M9) and at the ground floor level at 1450 Woodward Avenue (Site R6/DTLT-06 GF). Table 5-8 shows vibration levels at each of the location and potential noise impacts for LPA Alternative B3.

Table 5-6. Downtown LPA Alternative A1 Vibration Impacts

Receptor Number	Site Number	Stations	Vibration Criteria	Vibration Level	Vibration Impact	Ground-borne Noise Criteria	Ground-borne Noise Level	Ground-borne Noise Impact
R3	DT LT-03	Cobo Center E to Randolph	72	60	No Impact	35	25	No Impact
R1	DT LT-01	Randolph to Cobo Hall	NA	NA	NA	NA	NA	NA
R1	DT LT-01A	Randolph to Cobo Hall	72	54	No Impact	35	19	No Impact
S1	DT ST-01	Randolph to Cobo Hall	75	59	No Impact	40	24	No Impact
R2	DT LT-02 GF	Randolph to Cobo Hall	72	54	No Impact	35	19	No Impact
R2	DT LT-02 29th floor	Randolph to Cobo Hall	72	48	No Impact	35	13	No Impact
M8	M8	Cobo Hall to Rosa Parks Transit Center	72	65	No Impact	35	30	No Impact
M8	M8-16th floor	Cobo Hall to Rosa Parks Transit Center	72	54	No Impact	35	19	No Impact
R4	DT LT-04 WGF	Rosa Parks Transit Center to Foxtown/Stadium	72	64	No Impact	35	29	No Impact
R4	DT LT-04 4th floor	Rosa Parks Transit Center to Foxtown/Stadium	72	54	No Impact	35	19	No Impact
R4	DT LT-04 35th floor	Rosa Parks Transit Center to Foxtown/Stadium	72	48	No Impact	35	13	No Impact
S2	DT ST-02 GF	Rosa Parks Transit Center to Foxtown/Stadium	72	72	**Impact**	35	37	**Impact**
S2	DT ST-02 7th floor	Rosa Parks Transit Center to Foxtown/Stadium	72	60	No Impact	35	25	No Impact
S3	DT ST-03 GF	Rosa Parks Transit Center to Foxtown/Stadium	72	60	No Impact	35	25	No Impact
S3	DT-ST03 27th floor	Rosa Parks Transit Center to Foxtown/Stadium	72	48	No Impact	35	13	No Impact
R5	DT LT-05 GF	Rosa Parks Transit Center to Foxtown/Stadium	72	69	No Impact	35	34	No Impact
R5	DT LT-05 21th floor	Rosa Parks Transit Center to Foxtown/Stadium	72	48	No Impact	35	13	No Impact
S4	DT ST-04	Rosa Parks Transit Center to Foxtown/Stadium	NA	NA	NA	NA	NA	NA
S5	ST-002	Grand Circus Park and Foxtown/Stadium	NA	NA	NA	NA	NA	NA
R7	LT-001	Grand Circus Park and Foxtown/Stadium	72	64	No Impact	35	29	No Impact
M9	M9	Foxtown/Stadium and Temple	72	70	No Impact	35	35	**Impact**
R8	LT-002	Foxtown/Stadium and Temple	75	64	No Impact	40	29	No Impact

Table 5-7. Downtown LPA Alternative B2 Vibration Impacts

Receptor Number	Site Number	Stations	Vibration Criteria	Vibration Level	Vibration Impact	Ground-borne Noise Criteria	Ground-borne Noise Level	Ground-borne Noise Impact
R3	DT LT-03	Cobo Center E to Randolph	72	61	No Impact	35	26	No Impact
R1	DT LT-01	Randolph to Cobo Hall	NA	NA	NA	NA	NA	NA
R1	DT LT-01A	Randolph to Cobo Hall	72	55	No Impact	35	20	No Impact
S1	DT ST-01	Randolph to Cobo Hall	75	57	No Impact	40	22	No Impact
R2	DT LT-02 GF	Randolph to Cobo Hall	72	54	No Impact	35	19	No Impact
R2	DT LT-02 29th floor	Randolph to Cobo Hall	72	48	No Impact	35	13	No Impact
M8	M8	Cobo Hall to Rosa Parks Transit Center	72	71	No Impact	35	36	**Impact**
M8	M8-16th floor	Cobo Hall to Rosa Parks Transit Center	72	54	No Impact	35	19	No Impact
R4	DT LT-04 WGF	Rosa Parks Transit Center to Grand River	72	62	No Impact	35	27	No Impact
R4	DT LT-04 4th floor	Rosa Parks Transit Center to Grand River	72	60	No Impact	35	25	No Impact
R4	DT LT-04 35th floor	Rosa Parks Transit Center to Grand River	72	48	No Impact	35	13	No Impact
R4	DT LT-04 State GF	Rosa Parks Transit Center to Grand River	72	72	**Impact**	35	37	**Impact**
R4	DT LT-04 State 4th floor	Rosa Parks Transit Center to Grand River	72	64	No Impact	35	28	No Impact
R4	DT LT-04 State 35th floor	Rosa Parks Transit Center to Grand River	72	48	No Impact	35	29	No Impact
S4	DT ST-04	Rosa Parks Transit Center to Grand River	NA	NA	NA	NA	NA	NA
S5	ST-002	Grand Circus Park and Foxtown/Stadium	NA	NA	NA	NA	NA	NA
R7	LT-001	Grand Circus Park and Foxtown/Stadium	72	64	No Impact	35	28	No Impact
M9	M9	Foxtown/Stadium and Temple	72	72	**Impact**	35	37	**Impact**
R8	LT-002	Foxtown/Stadium and Temple	72	67	No Impact	40	32	No Impact

Table 5-8. LPA Downtown Alternative B3 Vibration Impacts

Receptor Number	Site Number	Stations	Vibration Criteria	Vibration Level	Vibration Impact	Ground-borne Noise Criteria	Ground-borne Noise Level	Ground-borne Noise Impact
R6	DT LT-06 GF	State/Gratiot and Adams/Grand Circus Park	72	71	No Impact	35	36	**Impact**
R6	DT LT-06 4th floor	State/Gratiot and Adams/Grand Circus Park	72	64	No Impact	35	29	No Impact
S5	ST-002	Grand Circus Park and Foxtown/Stadium	NA	NA	NA	NA	NA	NA
R7	LT-001	Grand Circus Park and Foxtown/Stadium	72	64	No Impact	35	28	No Impact
M9	M9	Foxtown/Stadium and Temple	72	72	**Impact**	35	37	**Impact**
R8	LT-002	Foxtown/Stadium and Temple	72	67	No Impact	40	32	No Impact

5.3 Noise and Vibration Mitigation Measures

5.3.1 Noise

Locally Preferred Alternative

Traffic Noise

No traffic noise impacts are predicted. Therefore, no mitigation is required or proposed.

Transit Noise

LPA Alternative A1

Moderate noise impacts are predicted with LPA Alternative A1. Mitigation in the form of noise barriers may not be possible for this alternative; because it would be median-running, a safe distance would need to be provided between the barrier and the travel way of the traffic. A three-foot noise barrier at the above locations would reduce noise levels by up to a maximum of five dBA and would result in no noise impacts. However, noise-barrier acoustic effectiveness would be compromised at locations where the sound walls would need to be segmented to provide access. A more effective abatement measure would be to have vehicle skirts custom designed for the specified LRT vehicle chosen for the LPA. An LRT vehicle wheel skirt, which is specified at the time the LRT vehicles are procured from the LRT manufacturer, would provide six dBA of noise reduction and eliminate all noise impacts identified along the LPA Alternative A1 alignment. Vehicle skirts that are not custom-designed for the specified LRT vehicle would provide very limited noise abatement, i.e., about two dBA.

LPA Alternative B2

Moderate noise impacts are predicted with LPA Alternative B2. Mitigation in the form of noise barriers may be possible for this alternative as the alignment would be along the curb. This would be in front of Site M8, Site DT LT-04 State GF, and Site M1 GF. A three-foot barrier at these locations would reduce noise levels by at least five dBA and would result in no impact at the sites. For Site LT-112 and Site LT-105, where the alignment would be median-running, the traffic lanes would need to be changed in these locations to provide a safe distance between the barrier and the travel way of the traffic.

A three-foot noise barrier at these two locations would reduce noise levels by up to a maximum of five dBA and would result in no noise impacts. However, noise-barrier acoustic effectiveness would be compromised at locations where the sound walls would need to be segmented to provide accessibility. A more effective abatement measure would be to have vehicle skirts custom designed for the specified LRT vehicle chosen for the LPA, as described above for LPA Alternative A1.

LPA Alternative B3

Moderate noise impacts are predicted with LPA Alternative B3. Mitigation in the form of noise barriers may be possible for this alternative as the alignment is along the curb. This would be in front of Site DT LT-06 GF and Site M1 GF. A three-foot barrier in these locations would reduce the noise levels by at least five dBA and would result in no impact for these sites. For Site LT-112 and Site LT-105, where the alignment would be median-running, the traffic lanes would need to be changed in these locations to provide a safe distance between the barrier and the travel way of the traffic. A three-foot noise barrier at these two locations would reduce noise levels by up to a maximum of five dBA and would result in no noise impacts. However, noise-barrier acoustic effectiveness would be compromised at locations where the sound walls would need to be segmented to provide accessibility. A more effective abatement measure would be to have vehicle skirts custom designed for the specified LRT vehicle chosen for the LPA, as described above for LPA Alternative A1.

5.3.2 Vibration

Locally Preferred Alternative

There are potential vibration and ground-born noise impacts predicted for each of the LPA Alternatives. In each instance, the vibration and ground-borne noise are predicted to exceed the FTA criteria by no more than two dBA. These predictions represent a worst-case scenario, and actual impacts may be less than predicted. Whichever LPA is selected for preliminary engineering design, transfer mobility tests would need to be conducted to confirm the predicted impact and the need for mitigation.

<u>LPA Alternative A1</u>

There are one vibration impact at the Stevens Building apartments (Site DR ST-02 GF) and four ground-borne noise impacts with LPA Alternative A1: the ground floor of the Stevens Building apartments (Site DT ST-02 GF), the Foxtown Theater (Site M9), apartments at 4501 Woodward Avenue (Site LT-007) and the Park Shelton Apartments (Site M1).

<u>LPA Alternative B2</u>

There are two possible vibration impacts at the ground floor of the Westin Book Cadillac (Site DT LT-04 State GF) and at the Fox Theater (Site M9) and five ground-borne noise impacts with LPA Alternative B2 at the ground floor of the Holiday Inn (Site M8), ground floor of the Westin Book Cadillac (Site DT LT-04 State GF), the Fox Theater (Site M9), Apartments at 4051 Woodward Avenue (Site LT-007), and the Park Shelton Apartments (Site M1).

<u>LPA Alternative B3</u>

There are one possible vibration impact at the Fox Theater (Site M9) and four ground-borne noise impacts with LPA Alternative B3 at the ground floor of the Woodward Loft Apartments (Site DT LT-06 GF), the Fox Theater (Site M9), apartments at 4051 Woodward Avenue (Site LT-007), and the Park Shelton Apartments (Site M1).

6.0 Construction-Phase Noise and Vibration

Noise impacts from construction activities are a function of:

- Noise generated by construction equipment used with different construction methods;
- The proximity of construction activities to sensitive land uses; and
- The duration of construction activity.

6.1 Construction Noise

Noise from construction of the LPA would be generated by heavy equipment operating as close as 50 feet from existing structures along the alignment. Table 6-1 shows estimated maximum noise levels for different stages of at-grade construction occurring 100 feet from a receptor. Construction-generated noise levels can result in elevated short-term noise levels.

Table 6-1. Estimated Maximum Construction Noise Levels

Construction Phase	Loudest Equipment	Noise Level at 100 feet L_{max}* (dBA)
Clearing and grubbing	Bulldozers, backhoes, haul trucks	86
Earthwork	Scrapers, bulldozers	88
Foundation	Backhoes, loaders	85
Structures	Cranes, loaders, haul trucks	86
Base preparation	Trucks, bulldozers	88
Paving	Pavers, pumps, haul trucks	89

Source: *Transit Noise and Vibration Impact Assessment*, FTA, May 2006.
Note: *L_{max} = Maximum Sound Level: The highest exponential-time-average sound level in decibels that occurs during a stated period.

6.2 Construction Vibration

6.2.1 Vibration Generated During Construction

Construction activities have the potential to produce high vibration levels that may be perceptible. Some construction activities have the potential to generate vibration levels that are enough to cause architectural and structural damage. Even where vibration levels are lower or imperceptible, vibration can still produce ground-borne noise. Construction activities typically producing the highest vibration and ground-borne noise levels are those involving the use of impact equipment or blasting. The effects of ground-borne vibration may include discernable rattling of windows and shaking of items on shelves or hangings on walls. In extreme cases, the vibration can cause damage to buildings. The vibration of floors and walls may cause perceptible vibration and rattling of such items as windows or dishes on shelves. The vibration of building surfaces and objects within a building can also result in a low-frequency rumble noise. The rumble is the noise radiated from the vibration of the room surfaces, even when the vibration cannot be felt; this is called ground-borne noise.

6.2.2 Vibration Control Requirements

The following vibration control measures are used to minimize, to the greatest extent feasible, vibration levels in areas outside the limits of construction:

- Use vibratory pile drivers or auguring for setting piles in lieu of impact pile drivers; and

- If impact pile drivers are used, restrict their use from 8:00 a.m. to 5:00 p.m. on weekdays in residential and semi-residential/commercial areas.

Realistic vibration limits are specified in contract documents, including:

- Development of a monitoring program during construction, and monitoring of vibrations at the nearest sensitive locations throughout the construction period; and
- Informing people living and working in the vicinity of construction activity about construction methods, possible effects, quality control measures and precautions to be used, and channels of communication available for contacting parties responsible for controlling vibration levels and enforcing such controls.

Additional vibration control plans and practices may include routing truck traffic and heavy equipment to avoid impacts to sensitive receptors, properly securing street decking over any cut-and-cover excavations, scheduling work to limit nighttime impacts in residential areas, and minimizing the duration of vibration impacts.

6.2.3 Woodward Avenue Vibration

Common vibration-producing equipment used during at-grade construction activities includes jackhammers, pavement breakers, hoe rams, augur drills, bulldozers, and backhoes. Pavement breaking and soil compaction would probably produce the highest levels of vibration. Table 6-2 shows types of construction equipment measured under a variety of construction activities, and includes an average of source levels reported in terms of velocity levels. Although the table lists one velocity level for each piece of equipment, considerable variation exists in reported ground-vibration levels from construction activities. The data provide a reasonable estimate for a wide range of soil conditions. Depending on soil conditions, activities such as pile driving can generate enough vibration to result in significant short-term noise impacts.

Table 6-2. Vibration Source Levels for Construction Equipment

Equipment		Peak Particle Velocity at 25 feet (in/sec)	Approximate L_v at 25 feet (VdB)
Pile driver (impact)	Upper range	1.518	112
	Typical	0.644	104
Pile driver (sonic)	Upper range	0.734	105
	Typical	0.170	93
Clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

Source: *Transit Noise and Vibration Impact Assessment*, FTA, May 2006.
Notes: L_v = RMS velocity in decibels (VdB) re 1 micro-inch/sec.
RMS = The square root of the mean-square value of an oscillation waveform.

6.3 Construction Noise and Vibration Control Measures

Noise control measures during construction would be required to minimize noise levels on existing noise-sensitive land uses. All construction activities would comply with City of Detroit noise regulations (Chapter 10-5 Section 36).

The noise control measures listed below are examples of those that could be used during the LPA's construction phase. They should be re-evaluated in detail during preliminary design, because impacts to residences cannot be accurately determined without detailed construction plans and schedules. The following control measures provide general guidance for reducing construction noise and can be incorporated in site-specific construction plans to minimize noise intrusion to sensitive receptors impacted by LPA construction activities. Equipment noise emission limits could also be developed and/or adopted from existing sources.

6.3.1 Design Considerations

During the early stages of construction plan development, natural and artificial barriers (e.g., ground elevation changes and existing buildings) can be considered for use as shielding against construction noise. Strategic placement of stationary equipment, such as compressors and generators, could reduce impacts at sensitive receptors.

6.3.2 Alternate Construction Methods

Certain phases of transit construction work, such as pile driving, may produce noise levels in excess of acceptable limits, even when feasible noise reduction methods are used. Using alternate methods of construction may reduce these impacts. For pile driving, vibratory or hydraulic insertion could be used, depending on a variety of factors (i.e., vibratory pile driving is not always quieter). Drilling holes for cast-in-place piles is an alternative construction method that would produce significantly lower levels of noise.

6.3.3 Source Control

The contractor must comply with standard specifications and all local sound control and noise level rules, regulations, and ordinances that apply to work performed pursuant to the construction contract. Each internal combustion engine used for any purpose for LPA construction must be equipped with a muffler of a type recommended by the manufacturer. No internal combustion engine may be operated without a muffler.

6.3.4 Time and Activity Constraints

Noisier activities involving large machinery should be limited to daytime hours, when most people normally affected are either not present or engaged in less noise-sensitive activities. Nighttime construction would require a variance. Compliance with local noise ordinances would mitigate impacts associated with construction noise. To comply with these ordinances, all construction activities adjacent to residential uses would be limited to daytime hours (7:00 a.m. to 6:00 p.m.) on Mondays through Saturdays.

6.3.5 Community Relations

Community meetings could be held to explain the construction work, the construction period and schedule, and control measures that will be taken to reduce the impact of construction noise.

This page intentionally left blank

7.0 References

ANSI — American National Standards Institute S12.9-1992/Part 2 and S12.9-1993/Part 3: *Standards for Quantities and Procedures for Description and Measurement of Environmental Sound.*

APTA 1981 — American Public Transit Association. 1981. *Guidelines for Design of Rail Transit Facilities*.

ASA 1983 — Acoustical Society of America. 1983. *American National Standard: Guide to the Evaluation of Human Exposure to Vibration in Buildings*. ANSI S3.29-1983.

B&K — Bruël and Kjaer. 2000. *Handbook of Environmental Noise. Sound and Vibration Handbook.*

FHWA — Federal Highway Administration, Office of Environment and Planning Noise and Air Quality Branch. June 1995. *Highway Traffic Noise Analysis and Abatement—Policy and Guidance*. Washington, D.C.

Federal Highway Administration. May 1996. *Sound Procedures for Measuring Highway Noise* (Report Number FHWA-DP-45-1R).

FTA 2006 — U.S. Department of Transportation, Federal Transit Administration. May 2006. *Transit Noise and Vibration Impact Assessment, Final Report*. FTA-VA-90-1003-06.

USC 1969 — United States Code. 1969. *National Environmental Policy Act of 1969*. 42 USC 4321-4345. Washington, D.C.

USDOT 1977 — U.S. Department of Transportation. 1977. *Highway Construction Noise: Measurement, Prediction, and Mitigation*.

Appendix A

Instruments Used and Calibration Records

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 107634 Description: 1/2" Free-Field Microphone

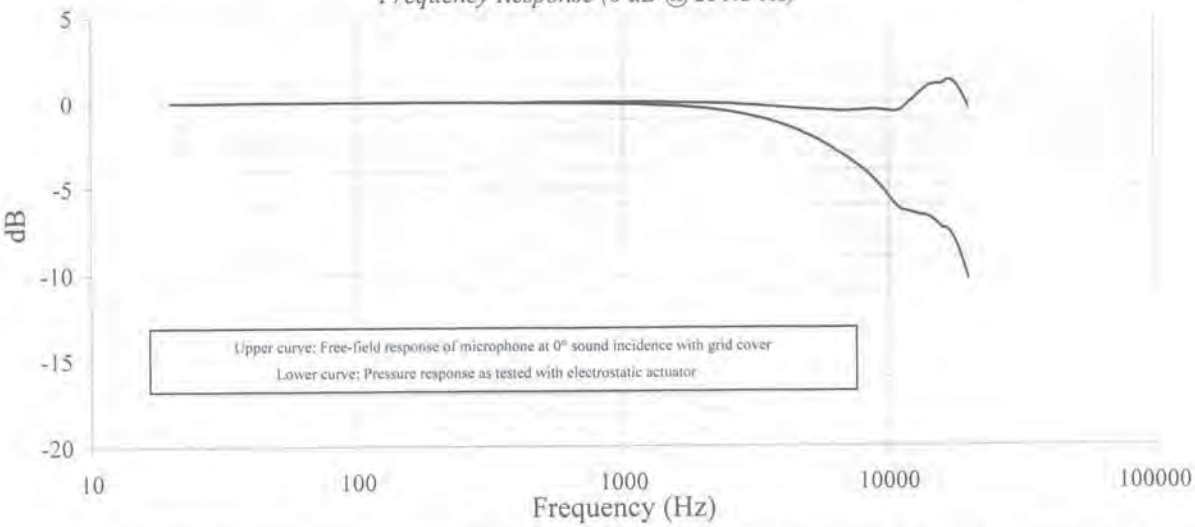
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 49.28 mV/Pa
-26.15 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.6 pF

Temperature: 73 °F (23°C) Ambient Pressure: 994 mbar Relative Humidity: 23 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	-0.01	-0.01	1584.9	-0.25	-0.04	6683.4	-3.11	-0.59	-	-	-
25.1	-0.01	-0.01	1678.8	-0.27	-0.04	7079.5	-3.35	-0.57	-	-	-
31.6	0.00	0.00	1778.3	-0.30	-0.05	7498.9	-3.63	-0.56	-	-	-
39.8	0.01	0.01	1883.7	-0.34	-0.06	7943.3	-3.93	-0.54	-	-	-
50.1	0.01	0.01	1995.3	-0.37	-0.06	8414.0	-4.24	-0.51	-	-	-
63.1	0.01	0.01	2113.5	-0.42	-0.08	8912.5	-4.61	-0.50	-	-	-
79.4	0.01	0.01	2238.7	-0.46	-0.09	9440.6	-5.06	-0.54	-	-	-
100.0	0.01	0.01	2371.4	-0.52	-0.11	10000.0	-5.53	-0.58	-	-	-
125.9	0.01	0.01	2511.9	-0.57	-0.11	10592.5	-6.02	-0.62	-	-	-
158.5	0.01	0.01	2660.7	-0.65	-0.14	11220.2	-6.35	-0.49	-	-	-
199.5	0.00	0.00	2818.4	-0.73	-0.17	11885.0	-6.45	-0.13	-	-	-
251.2	0.00	0.00	2985.4	-0.81	-0.19	12589.3	-6.56	0.21	-	-	-
316.2	-0.01	0.00	3162.3	-0.90	-0.22	13335.2	-6.64	0.55	-	-	-
398.1	-0.02	-0.02	3349.7	-0.99	-0.25	14125.4	-6.73	0.86	-	-	-
501.2	-0.03	0.01	3548.1	-1.10	-0.28	14962.4	-6.99	0.98	-	-	-
631.0	-0.04	0.00	3758.4	-1.22	-0.32	15848.9	-7.35	1.00	-	-	-
794.3	-0.07	0.02	3981.1	-1.35	-0.35	16788.0	-7.50	1.22	-	-	-
1000.0	-0.11	0.01	4217.0	-1.49	-0.38	17782.8	-8.07	1.04	-	-	-
1059.3	-0.12	0.01	4466.8	-1.64	-0.41	18836.5	-9.05	0.46	-	-	-
1122.0	-0.13	0.01	4731.5	-1.81	-0.44	19952.6	-10.28	-0.35	-	-	-
1188.5	-0.14	0.01	5011.9	-1.99	-0.46	-	-	-	-	-	-
1258.9	-0.16	0.00	5308.8	-2.18	-0.48	-	-	-	-	-	-
1333.5	-0.18	0.00	5623.4	-2.39	-0.51	-	-	-	-	-	-
1412.5	-0.20	-0.01	5956.6	-2.61	-0.54	-	-	-	-	-	-
1496.2	-0.22	-0.02	6309.6	-2.85	-0.56	-	-	-	-	-	-

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED
CALIBRATION CERT #1882.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3288823879.847

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 107634 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/21/07	3/21/08
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: N/A

As Left: New unit in tolerance

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED

CALIBRATION CERT #1962.01

PCB PIEZOTRONICS™
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3268623678.847

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 105105 Description: 1/2" Free-Field Microphone

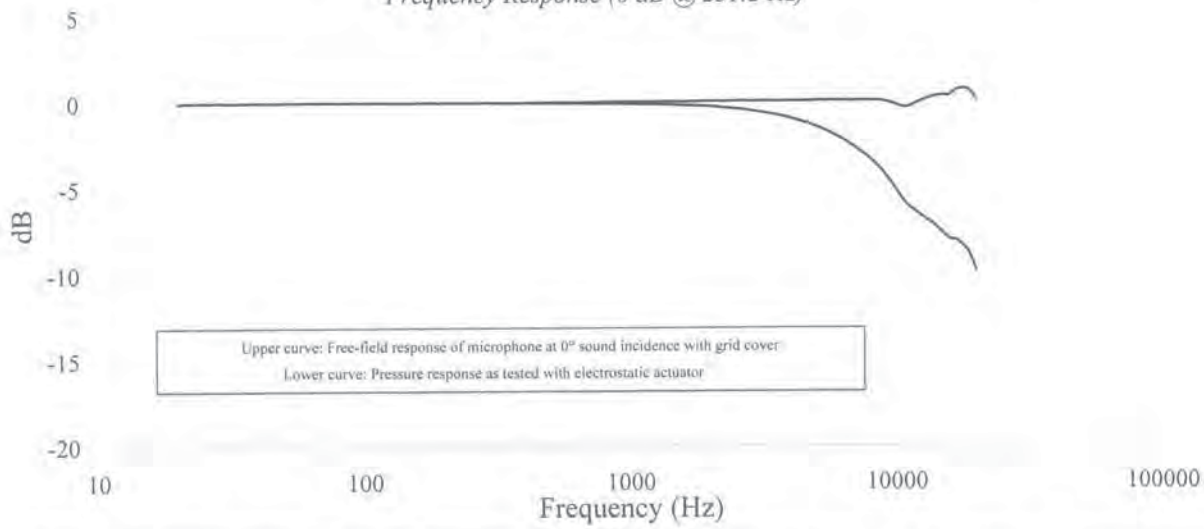
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 44.45 mV/Pa
-27.04 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.7 pF

Temperature: 73 °F (23°C) Ambient Pressure: 989 mbar Relative Humidity: 24 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	0.01	0.01	1584.9	-0.17	0.04	6683.4	-2.44	0.08	-	-	-
25.1	0.04	0.04	1678.8	-0.18	0.05	7079.5	-2.70	0.08	-	-	-
31.6	0.03	0.03	1778.3	-0.20	0.05	7498.9	-2.98	0.09	-	-	-
39.8	0.03	0.03	1883.7	-0.22	0.06	7943.3	-3.30	0.09	-	-	-
50.1	0.03	0.03	1995.3	-0.24	0.07	8414.0	-3.65	0.08	-	-	-
63.1	0.03	0.03	2113.5	-0.27	0.07	8912.5	-4.06	0.05	-	-	-
79.4	0.02	0.02	2238.7	-0.31	0.06	9440.6	-4.56	-0.04	-	-	-
100.0	0.02	0.02	2371.4	-0.34	0.07	10000.0	-5.12	-0.17	-	-	-
125.9	0.01	0.01	2511.9	-0.38	0.08	10592.5	-5.71	-0.31	-	-	-
158.5	0.01	0.01	2660.7	-0.42	0.09	11220.2	-6.15	-0.29	-	-	-
199.5	0.00	0.00	2818.4	-0.49	0.07	11885.0	-6.43	-0.11	-	-	-
251.2	0.00	0.00	2985.4	-0.55	0.07	12589.3	-6.72	0.05	-	-	-
316.2	-0.01	0.00	3162.3	-0.60	0.08	13335.2	-6.99	0.20	-	-	-
398.1	-0.01	-0.01	3349.7	-0.67	0.07	14125.4	-7.27	0.32	-	-	-
501.2	-0.02	0.02	3548.1	-0.75	0.07	14962.4	-7.62	0.35	-	-	-
631.0	-0.03	0.01	3758.4	-0.83	0.07	15848.9	-7.99	0.36	-	-	-
794.3	-0.05	0.04	3981.1	-0.93	0.07	16788.0	-8.07	0.65	-	-	-
1000.0	-0.07	0.05	4217.0	-1.04	0.07	17782.8	-8.37	0.74	-	-	-
1059.3	-0.08	0.05	4466.8	-1.16	0.07	18836.5	-8.86	0.65	-	-	-
1122.0	-0.09	0.05	4731.5	-1.29	0.08	19952.6	-9.80	0.13	-	-	-
1188.5	-0.10	0.05	5011.9	-1.44	0.09	-	-	-	-	-	-
1258.9	-0.11	0.05	5308.8	-1.60	0.10	-	-	-	-	-	-
1333.5	-0.12	0.06	5623.4	-1.78	0.10	-	-	-	-	-	-
1412.5	-0.13	0.06	5956.6	-1.98	0.09	-	-	-	-	-	-
1496.2	-0.15	0.05	6309.6	-2.20	0.09	-	-	-	-	-	-

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED
CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID 329042419Z.804

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 105105 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: In tolerance

As Left: In tolerance, unit enhanced

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3290424192.804

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 104975 Description: 1/2" Free-Field Microphone

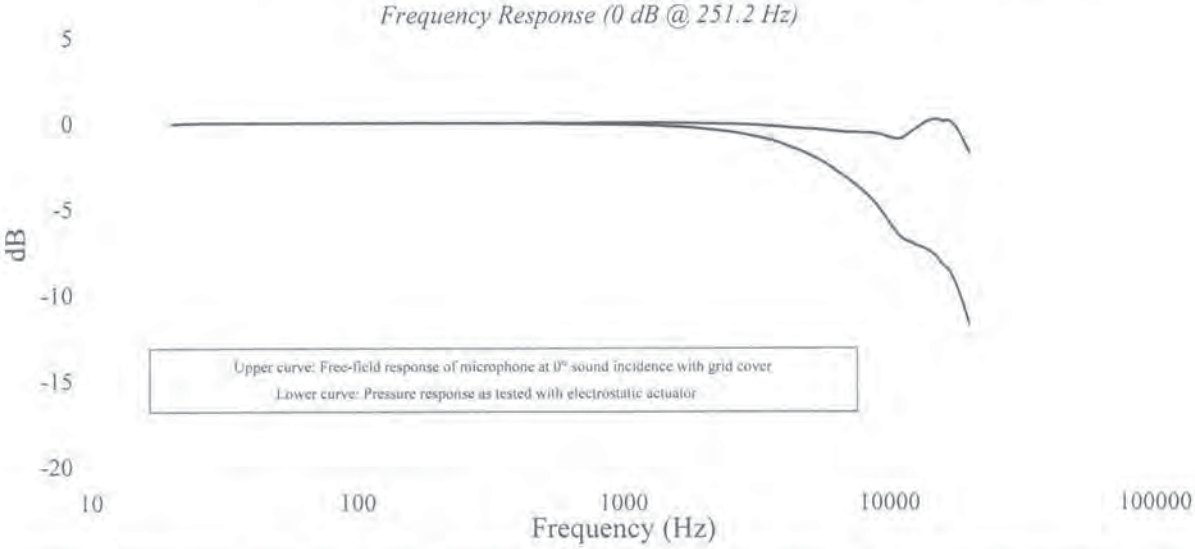
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 50.71 mV/Pa
-25.9 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.7 pF

Temperature: 73 °F (23°C) Ambient Pressure: 989 mbar Relative Humidity: 24 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	-0.03	-0.03	1584.9	-0.21	0.00	6683.4	-3.05	-0.53	-	-	-
25.1	0.01	0.01	1678.8	-0.23	0.00	7079.5	-3.33	-0.55	-	-	-
31.6	0.01	0.01	1778.3	-0.26	-0.01	7498.9	-3.63	-0.56	-	-	-
39.8	0.01	0.01	1883.7	-0.29	-0.01	7943.3	-3.97	-0.58	-	-	-
50.1	0.01	0.01	1995.3	-0.33	-0.02	8414.0	-4.32	-0.59	-	-	-
63.1	0.01	0.01	2113.5	-0.37	-0.03	8912.5	-4.74	-0.63	-	-	-
79.4	0.01	0.01	2238.7	-0.41	-0.04	9440.6	-5.25	-0.73	-	-	-
100.0	0.01	0.01	2371.4	-0.46	-0.05	10000.0	-5.80	-0.85	-	-	-
125.9	0.01	0.01	2511.9	-0.51	-0.05	10592.5	-6.35	-0.95	-	-	-
158.5	0.01	0.01	2660.7	-0.57	-0.06	11220.2	-6.76	-0.90	-	-	-
199.5	0.00	0.00	2818.4	-0.64	-0.08	11885.0	-6.94	-0.62	-	-	-
251.2	0.00	0.00	2985.4	-0.72	-0.10	12589.3	-7.13	-0.36	-	-	-
316.2	-0.01	0.00	3162.3	-0.80	-0.12	13335.2	-7.28	-0.09	-	-	-
398.1	-0.01	-0.01	3349.7	-0.89	-0.15	14125.4	-7.47	0.12	-	-	-
501.2	-0.02	0.02	3548.1	-0.99	-0.17	14962.4	-7.79	0.18	-	-	-
631.0	-0.04	0.00	3758.4	-1.10	-0.20	15848.9	-8.26	0.09	-	-	-
794.3	-0.06	0.03	3981.1	-1.23	-0.23	16788.0	-8.63	0.09	-	-	-
1000.0	-0.09	0.03	4217.0	-1.39	-0.28	17782.8	-9.38	-0.27	-	-	-
1059.3	-0.10	0.03	4466.8	-1.53	-0.30	18836.5	-10.47	-0.96	-	-	-
1122.0	-0.11	0.03	4731.5	-1.69	-0.32	19952.6	-11.69	-1.76	-	-	-
1188.5	-0.12	0.03	5011.9	-1.87	-0.34	-	-	-	-	-	-
1258.9	-0.14	0.02	5308.8	-2.07	-0.37	-	-	-	-	-	-
1333.5	-0.15	0.03	5623.4	-2.28	-0.40	-	-	-	-	-	-
1412.5	-0.17	0.02	5956.6	-2.52	-0.45	-	-	-	-	-	-
1496.2	-0.19	0.01	6309.6	-2.77	-0.48	-	-	-	-	-	-

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED
CALIBRATION CERT #1882.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3290423031.585

~ Certificate of Calibration and Compliance ~

Microphone Model: 377B02 Serial Number: 104975 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: In tolerance

As Left: In tolerance, unit enhanced

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION
3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

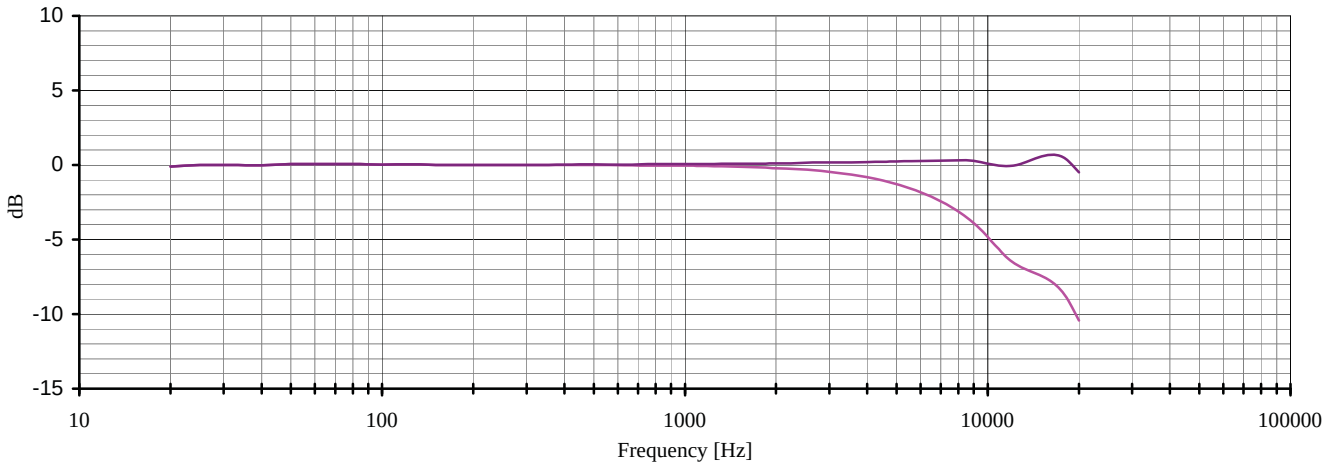
10-3590-023031.585

~Calibration Certificate~

3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 105346

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-26.92	-26.97	dB re. 1V/Pa
	45.09	44.84	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	20-Feb-2008	14:23:13	Temperature:	76 (24)	°F (°C)
Due Date:			Humidity:	23	%
Technician:	Ed Devlin		Pressure:	1021	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/3/2007	8/3/2008

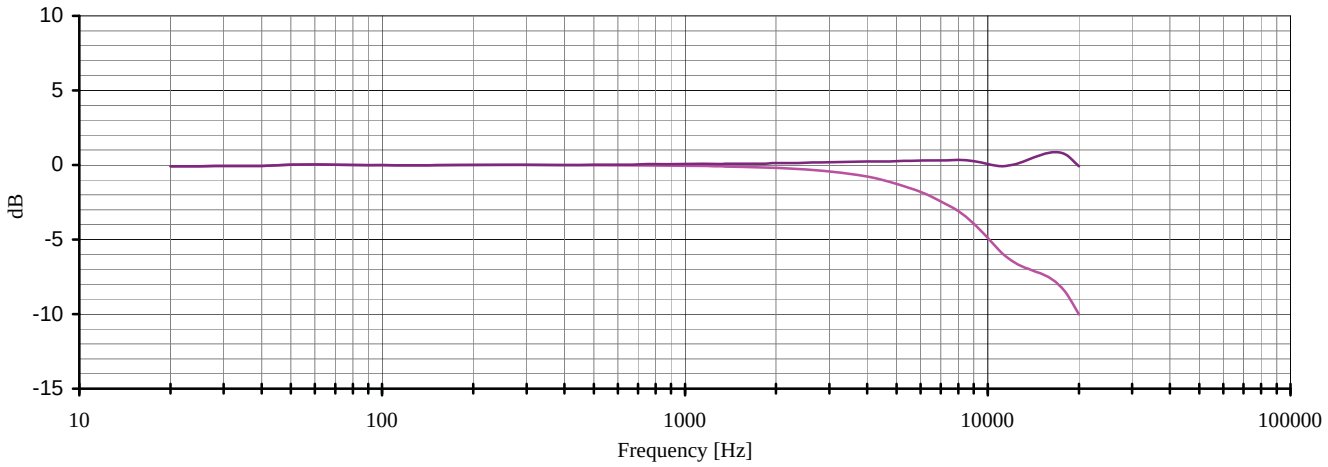
ACCREDITED
2649.01

~Calibration Certificate~

3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 105426

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-26.41	-26.46	dB re. 1V/Pa
	47.82	47.53	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	20-Feb-2008	14:14:01	Temperature:	76 (24)	°F (°C)
Due Date:			Humidity:	23	%
Technician:	Ed Devlin		Pressure:	1021	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/3/2007	8/3/2008

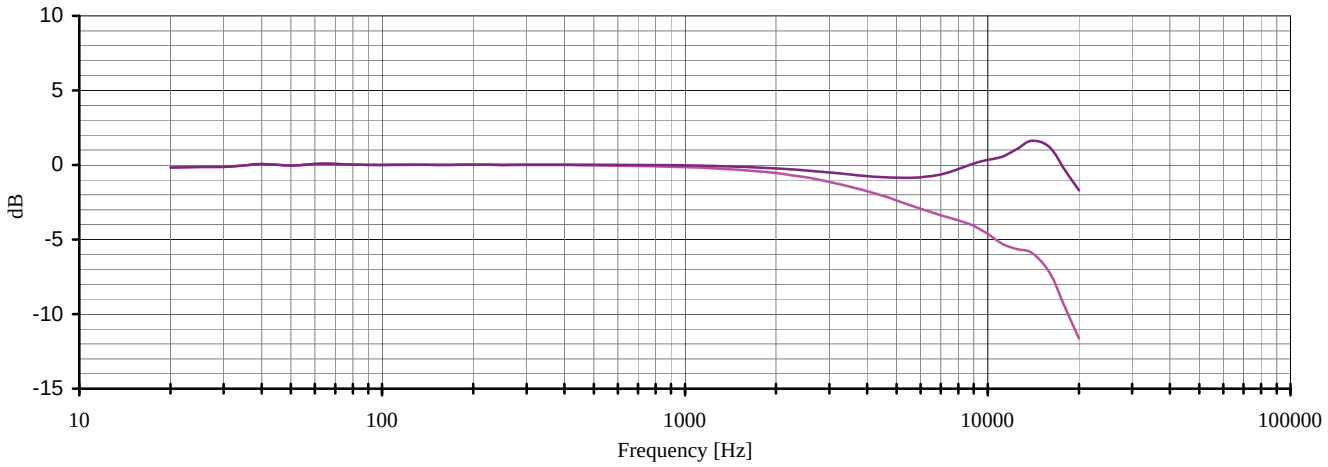
ACCREDITED
2649.01

~Calibration Certificate~

3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 104298

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-25.45	-25.59	dB re. 1V/Pa
	53.41	52.52	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	7-Jan-2008	11:52:27	Temperature:	75 (24)	°F (°C)
Due Date:			Humidity:	40	%
Technician:	Ed Devlin		Pressure:	1019	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/3/2007	8/3/2008

ACCREDITED
2649.01

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 106367 Description: 1/2" Free-Field Microphone

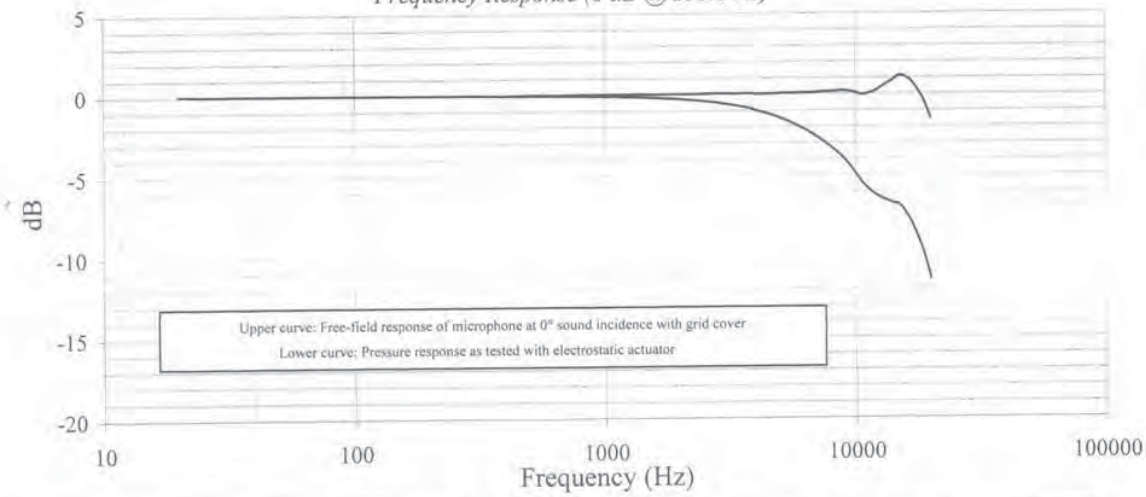
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 49.86 mV/Pa
-26.04 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.8 pF

Temperature: 71 °F (22°C) Ambient Pressure: 987 mbar Relative Humidity: 33 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	0.06	0.06	1584.9	-0.19	0.02	6683.4	-2.42	0.10	-	-	-
25.1	0.03	0.03	1678.8	-0.21	0.02	7079.5	-2.66	0.12	-	-	-
31.6	0.04	0.04	1778.3	-0.23	0.02	7498.9	-2.93	0.14	-	-	-
39.8	0.03	0.03	1883.7	-0.25	0.03	7943.3	-3.24	0.15	-	-	-
50.1	0.03	0.03	1995.3	-0.28	0.03	8414.0	-3.56	0.17	-	-	-
63.1	0.03	0.03	2113.5	-0.31	0.03	8912.5	-3.91	0.20	-	-	-
79.4	0.03	0.03	2238.7	-0.34	0.03	9440.6	-4.36	0.16	-	-	-
100.0	0.02	0.02	2371.4	-0.38	0.03	10000.0	-4.87	0.08	-	-	-
125.9	0.02	0.02	2511.9	-0.42	0.04	10592.5	-5.44	-0.04	-	-	-
158.5	0.01	0.01	2660.7	-0.46	0.05	11220.2	-5.84	0.02	-	-	-
199.5	0.01	0.01	2818.4	-0.50	0.06	11885.0	-6.18	0.14	-	-	-
251.2	0.00	0.00	2985.4	-0.57	0.05	12589.3	-6.41	0.36	-	-	-
316.2	-0.01	0.00	3162.3	-0.63	0.05	13335.2	-6.57	0.62	-	-	-
398.1	-0.02	-0.02	3349.7	-0.70	0.04	14125.4	-6.74	0.85	-	-	-
501.2	-0.03	0.01	3548.1	-0.77	0.05	14962.4	-6.85	1.12	-	-	-
631.0	-0.04	0.00	3758.4	-0.84	0.06	15848.9	-7.31	1.04	-	-	-
794.3	-0.06	0.03	3981.1	-0.98	0.02	16788.0	-7.98	0.74	-	-	-
1000.0	-0.09	0.03	4217.0	-1.09	0.02	17782.8	-8.88	0.23	-	-	-
1059.3	-0.09	0.04	4466.8	-1.20	0.03	18836.5	-9.99	-0.48	-	-	-
1122.0	-0.10	0.04	4731.5	-1.33	0.04	19952.6	-11.43	-1.50	-	-	-
1188.5	-0.12	0.03	5011.9	-1.47	0.06	-	-	-	-	-	-
1258.9	-0.13	0.03	5308.8	-1.63	0.07	-	-	-	-	-	-
1333.5	-0.14	0.04	5623.4	-1.81	0.07	-	-	-	-	-	-
1412.5	-0.15	0.04	5956.6	-1.99	0.08	-	-	-	-	-	-
1496.2	-0.17	0.03	6309.6	-2.20	0.09	-	-	-	-	-	-

Technician: Nancy Szeluga Date: September 8, 2008

ACCREDITED
CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION
3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3303716242.081

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 106367 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	02-400	41440497	LD-014	12/4/07	12/4/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4250	CA-1116	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: Out of tolerance, sensitivity and frequency response

As Left: In tolerance, unit repaired

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Nancy Szeluga Date: September 8, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

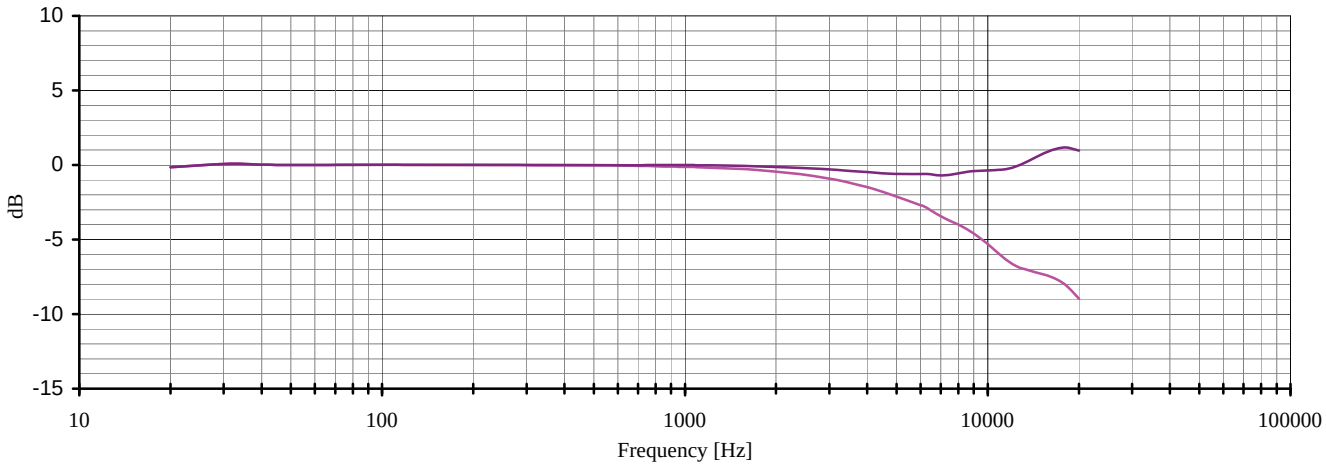
ID:3303716242.081

~Calibration Certificate~

THE MODAL SHOP INC. A PCB GROUP CO.
3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 106345

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-26.50	-26.63	dB re. 1V/Pa
	47.30	46.63	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	15-Jul-2008	10:49:28	Temperature:	77 (25)	°F (°C)
Due Date:			Humidity:	34	%
Technician:	Ed Devlin		Pressure:	1017	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/14/2007	8/14/2008

ACCREDITED
2649.01

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 107742 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	02-400	41440497	LD-014	12/4/07	12/4/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4250	CA-1116	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: Out of tolerance, frequency response

As Left: In tolerance, unit repaired

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Nancy Szeluga Date: September 8, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3303715781.356

~ *Calibration Report* ~

Microphone Model: 377B02 Serial Number: 107742 Description: 1/2" Free-Field Microphone

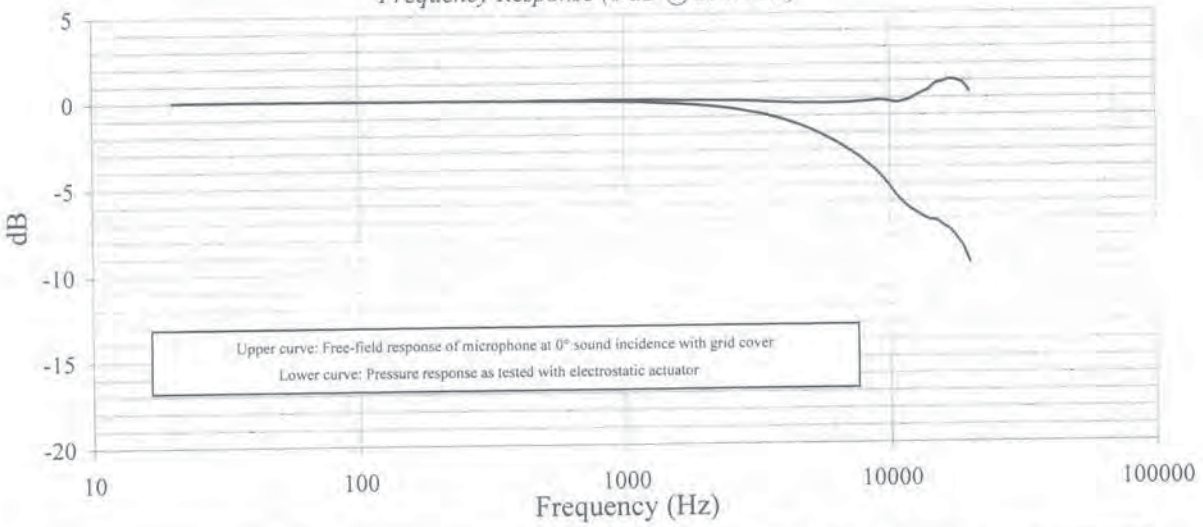
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 48.45 mV/Pa
-26.29 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 12 pF

Temperature: 71 °F (22°C) Ambient Pressure: 987 mbar Relative Humidity: 33 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	0.05	0.05	1584.9	-0.24	-0.03	6683.4	-2.79	-0.27	-	-	-
25.1	0.06	0.06	1678.8	-0.27	-0.04	7079.5	-3.04	-0.26	-	-	-
31.6	0.06	0.06	1778.3	-0.30	-0.05	7498.9	-3.30	-0.23	-	-	-
39.8	0.06	0.06	1883.7	-0.32	-0.04	7943.3	-3.60	-0.21	-	-	-
50.1	0.05	0.05	1995.3	-0.36	-0.05	8414.0	-3.92	-0.19	-	-	-
63.1	0.04	0.04	2113.5	-0.40	-0.06	8912.5	-4.26	-0.15	-	-	-
79.4	0.04	0.04	2238.7	-0.44	-0.07	9440.6	-4.67	-0.15	-	-	-
100.0	0.03	0.03	2371.4	-0.49	-0.08	10000.0	-5.15	-0.20	-	-	-
125.9	0.02	0.02	2511.9	-0.54	-0.08	10592.5	-5.68	-0.28	-	-	-
158.5	0.01	0.01	2660.7	-0.60	-0.09	11220.2	-6.08	-0.22	-	-	-
199.5	0.01	0.01	2818.4	-0.67	-0.11	11885.0	-6.43	-0.11	-	-	-
251.2	0.00	0.00	2985.4	-0.74	-0.12	12589.3	-6.66	0.11	-	-	-
316.2	-0.01	0.00	3162.3	-0.82	-0.14	13335.2	-6.90	0.29	-	-	-
398.1	-0.02	-0.02	3349.7	-0.90	-0.16	14125.4	-7.10	0.49	-	-	-
501.2	-0.03	0.01	3548.1	-1.00	-0.18	14962.4	-7.14	0.83	-	-	-
631.0	-0.05	-0.01	3758.4	-1.10	-0.20	15848.9	-7.43	0.92	-	-	-
794.3	-0.07	0.02	3981.1	-1.23	-0.23	16788.0	-7.66	1.06	-	-	-
1000.0	-0.11	0.01	4217.0	-1.35	-0.24	17782.8	-8.11	1.00	-	-	-
1059.3	-0.12	0.01	4466.8	-1.49	-0.26	18836.5	-8.68	0.83	-	-	-
1122.0	-0.13	0.01	4731.5	-1.63	-0.26	19952.6	-9.59	0.34	-	-	-
1188.5	-0.14	0.01	5011.9	-1.79	-0.26	-	-	-	-	-	-
1258.9	-0.16	0.00	5308.8	-1.97	-0.27	-	-	-	-	-	-
1333.5	-0.18	0.00	5623.4	-2.16	-0.28	-	-	-	-	-	-
1412.5	-0.20	-0.01	5956.6	-2.35	-0.28	-	-	-	-	-	-
1496.2	-0.22	-0.02	6309.6	-2.56	-0.27	-	-	-	-	-	-

Technician: Nancy Szeluga NS Date: September 8, 2008

ACCREDITED
CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION
3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID 330371578 1.356

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 108291 Description: 1/2" Free-Field Microphone

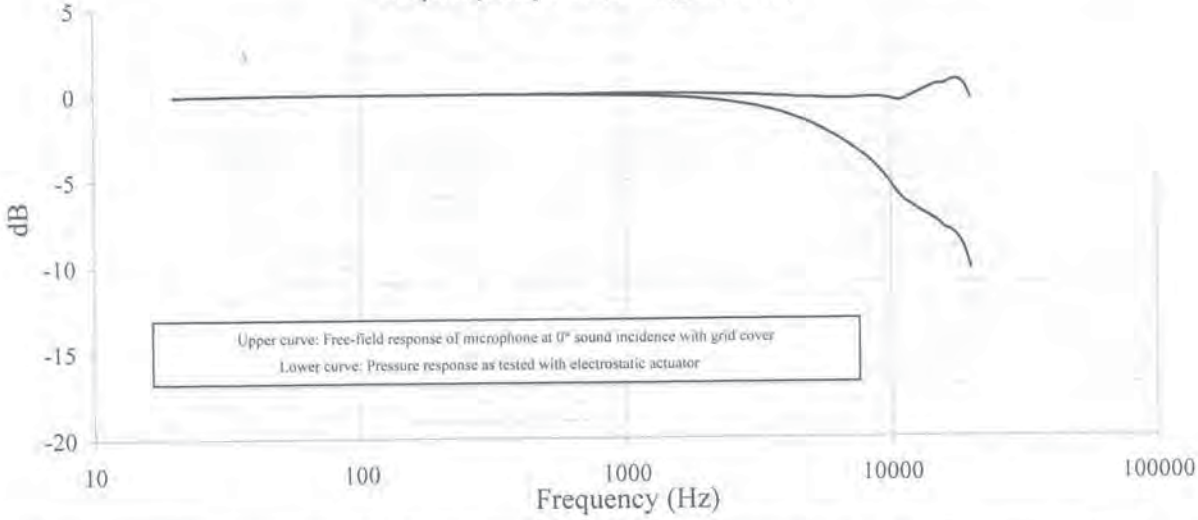
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 49.19 mV/Pa
-26.16 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 12.3 pF

Temperature: 73 °F (23°C) Ambient Pressure: 994 mbar Relative Humidity: 23 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	-0.08	-0.08	1584.9	-0.20	0.01	6683.4	-2.85	-0.33	-	-	-
25.1	-0.05	-0.05	1678.8	-0.22	0.01	7079.5	-3.10	-0.32	-	-	-
31.6	-0.03	-0.03	1778.3	-0.25	0.00	7498.9	-3.37	-0.30	-	-	-
39.8	-0.02	-0.02	1883.7	-0.28	0.00	7943.3	-3.67	-0.28	-	-	-
50.1	-0.01	-0.01	1995.3	-0.32	-0.01	8414.0	-3.99	-0.26	-	-	-
63.1	-0.01	-0.01	2113.5	-0.36	-0.02	8912.5	-4.37	-0.26	-	-	-
79.4	0.00	0.00	2238.7	-0.40	-0.03	9440.6	-4.82	-0.30	-	-	-
100.0	0.00	0.00	2371.4	-0.45	-0.04	10000.0	-5.32	-0.37	-	-	-
125.9	0.00	0.00	2511.9	-0.50	-0.04	10592.5	-5.86	-0.46	-	-	-
158.5	0.00	0.00	2660.7	-0.57	-0.06	11220.2	-6.28	-0.42	-	-	-
199.5	0.00	0.00	2818.4	-0.63	-0.07	11885.0	-6.53	-0.21	-	-	-
251.2	0.00	0.00	2985.4	-0.70	-0.08	12589.3	-6.79	-0.02	-	-	-
316.2	0.00	0.01	3162.3	-0.78	-0.10	13335.2	-7.03	0.16	-	-	-
398.1	-0.01	-0.01	3349.7	-0.87	-0.13	14125.4	-7.26	0.33	-	-	-
501.2	-0.01	0.03	3548.1	-0.97	-0.15	14962.4	-7.49	0.48	-	-	-
631.0	-0.03	0.01	3758.4	-1.07	-0.17	15848.9	-7.86	0.49	-	-	-
794.3	-0.05	0.04	3981.1	-1.19	-0.19	16788.0	-8.04	0.68	-	-	-
1000.0	-0.08	0.04	4217.0	-1.32	-0.21	17782.8	-8.39	0.72	-	-	-
1059.3	-0.09	0.04	4466.8	-1.47	-0.24	18836.5	-9.04	0.47	-	-	-
1122.0	-0.10	0.04	4731.5	-1.62	-0.25	19952.6	-10.23	-0.30	-	-	-
1188.5	-0.11	0.04	5011.9	-1.78	-0.25	-	-	-	-	-	-
1258.9	-0.13	0.03	5308.8	-1.97	-0.27	-	-	-	-	-	-
1333.5	-0.14	0.04	5623.4	-2.18	-0.30	-	-	-	-	-	-
1412.5	-0.16	0.03	5956.6	-2.38	-0.31	-	-	-	-	-	-
1496.2	-0.18	0.02	6309.6	-2.60	-0.31	-	-	-	-	-	-

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED
CALIBRATION CERT #1662.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 108291 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/21/07	3/21/08
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: N/A

As Left: New unit in tolerance

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED

CALIBRATION CERT #1662.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:328660376 899

PCB PIEZOTRONICS
A PCB GROUP COMPANY

Certificate of Calibration and Conformance

Certificate Number 2008-107159

Instrument Model 820, Serial Number 1706, was calibrated on 28MAY2008. The instrument meets factory specifications per Procedure D0001.8160, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

New Instrument
Date Calibrated: 28MAY2008

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL. DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0277 / 0109	12 Months	01APR2009	2008-105087

Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Temperature: 23 ° Centigrade

Relative Humidity: 27 %

Affirmations

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the U.S. National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at Provo Engineering & Manufacturing Center. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with the requirements of ISO 17025 and ANSI Z540. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. A one year calibration is recommended, however calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of the issuer.

Tested with PRM828-2667

Signed: Ron Harris
Technician: Ron Harris

Provo Engineering and Manufacturing Center, 1681 West 820 North, Provo, Utah 84601
Toll Free: 888.258.3222 Telephone: 716.926.8243 Fax: 716.926.8215
ISO 9001-2000 Certified

Certificate of Calibration and Conformance

Instrument Model **820**, Serial Number **1592**, was calibrated on May 30, 2008. The instrument meets factory specifications according to The Modal Shop Production Test Procedure PRD-P227, ISO 10012, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: May 30, 2008
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0760 / 0101	12 Months	2/18/2009	2008-102748

Certified Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

AMBIENT TEMPERATURE: 76.1°F RELATIVE HUMIDITY: 40%

Notes

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 10012. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

Due to state-of-the-art limitations, 4:1 calibration ratios are not possible on pressure measurement standards, microphones and acoustic calibrators. Calibration ratios for these types of devices are limited to 1:1.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Ed Devlin Signature: _____

Service Center: The Modal Shop, Inc.

THE MODAL SHOP INC. A PCB GROUP CO.

The Modal Shop
3149 East Kemper Road
Cincinnati, OH 45241
Ph (513) 351-9919
FAX (513) 458-2172

Certificate of Calibration and Conformance

Instrument Model **820**, Serial Number **1617**, was calibrated on June 30, 2008. The instrument meets factory specifications according to The Modal Shop Production Test Procedure PRD-P227, ISO 10012, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: June 30, 2008
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0760 / 0101	12 Months	2/18/2009	2008-102748

Certified Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

AMBIENT TEMPERATURE: 70.7°F RELATIVE HUMIDITY: 37%

Notes

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 10012. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

Due to state-of-the-art limitations, 4:1 calibration ratios are not possible on pressure measurement standards, microphones and acoustic calibrators. Calibration ratios for these types of devices are limited to 1:1.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Ed Devlin Signature: _____

Service Center: The Modal Shop, Inc.

THE MODAL SHOP INC. A PCB GROUP CO.

The Modal Shop
3149 East Kemper Road
Cincinnati, OH 45241
Ph (513) 351-9919
FAX (513) 458-2172

PCB PIEZOTRONICS
A PCB GROUP COMPANY

Certificate of Calibration and Conformance

Certificate Number 2008-107538

Instrument Model 820, Serial Number 1631, was calibrated on 11JUN2008. The instrument meets factory specifications per Procedure D0001.8160, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: NO
Date Calibrated: 11JUN2008
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL. DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0617 / 0104	12 Months	25JAN2009	2008-102768

Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Temperature: 22 ° Centigrade

Relative Humidity: 27 %

Affirmations

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the U.S. National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at Provo Engineering & Manufacturing Center. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with the requirements of ISO 17025 and ANSI Z540. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. A one year calibration is recommended, however calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of the issuer.

See "as received" data.

Signed: Sean Childs
Technician: Sean Childs

Provo Engineering and Manufacturing Center, 1681 West 820 North, Provo, Utah 84601
Toll Free: 888.258.3222 Telephone: 716.926.8243 Fax: 716.926.8215
ISO 9001-2000 Certified

Certificate of Calibration and Conformance

Instrument Model **820**, Serial Number **1635**, was calibrated on February 26, 2008. The instrument meets factory specifications according to The Modal Shop Production Test Procedure PRD-P227, ISO 10012, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: February 26, 2008
Calibration due:

Calibration Standards Used

Manufacturer	Model	Serial Number	Interval	Cal Due	Traceability No.
Larson Davis	LDSigGn/2209	0760 / 0101	12 Months	2/18/2009	2008-102748

Certified Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Ambient Temperature: 71.6°F Relative Humidity: 25%

Notes

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 10012. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

Due to state-of-the-art limitations, 4:1 calibration ratios are not possible on pressure measurement standards, microphones and acoustic calibrators. Calibration ratios for these types of devices are limited to 1:1.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Ed Devlin Signature: _____

Service Center: The Modal Shop, Inc.

THE MODAL SHOP INC.
A PCB GROUP CO.

The Modal Shop
3149 East Kemper Road
Cincinnati, OH 45241
Ph (513) 351-9919
FAX (513) 458-2172

Certificate of Calibration and Conformance

Instrument Model **820**, Serial Number **1642**, was calibrated on May 20, 2008. The instrument meets factory specifications according to The Modal Shop Production Test Procedure PRD-P227, ISO 10012, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: May 20, 2008
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0760 / 0101	12 Months	2/18/2009	2008-102748

Certified Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

AMBIENT TEMPERATURE: 70.7°F RELATIVE HUMIDITY: 37%

Notes

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 10012. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

Due to state-of-the-art limitations, 4:1 calibration ratios are not possible on pressure measurement standards, microphones and acoustic calibrators. Calibration ratios for these types of devices are limited to 1:1.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Ed Devlin Signature: _____

Service Center: The Modal Shop, Inc.

THE MODAL SHOP INC. A PCB GROUP CO.

The Modal Shop
3149 East Kemper Road
Cincinnati, OH 45241
Ph (513) 351-9919
FAX (513) 458-2172

Certificate of Calibration and Conformance

Instrument Model **820**, Serial Number **1666**, was calibrated on July 30, 2008. The instrument meets factory specifications according to The Modal Shop Production Test Procedure PRD-P227, ISO 10012, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: July 30, 2008
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0760 / 0101	12 Months	2/18/2009	2008-102748

Certified Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

AMBIENT TEMPERATURE: 75.2°F RELATIVE HUMIDITY: 40%

Notes

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 10012. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

Due to state-of-the-art limitations, 4:1 calibration ratios are not possible on pressure measurement standards, microphones and acoustic calibrators. Calibration ratios for these types of devices are limited to 1:1.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Ed Devlin Signature: _____

Service Center: The Modal Shop, Inc.

THE MODAL SHOP INC. A PCB GROUP CO.

The Modal Shop
3149 East Kemper Road
Cincinnati, OH 45241
Ph (513) 351-9919
FAX (513) 458-2172

Certificate of Calibration and Conformance

Instrument Model **820**, Serial Number **1663**, was calibrated on July 24, 2008. The instrument meets factory specifications according to The Modal Shop Production Test Procedure PRD-P227, ISO 10012, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: July 24, 2008
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0760 / 0101	12 Months	2/18/2009	2008-102748

Certified Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

AMBIENT TEMPERATURE: 79.7°F RELATIVE HUMIDITY: 33%

Notes

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 10012. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

Due to state-of-the-art limitations, 4:1 calibration ratios are not possible on pressure measurement standards, microphones and acoustic calibrators. Calibration ratios for these types of devices are limited to 1:1.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Ed Devlin Signature: _____

Service Center: The Modal Shop, Inc.

THE MODAL SHOP INC. A PCB GROUP CO.

The Modal Shop
3149 East Kemper Road
Cincinnati, OH 45241
Ph (513) 351-9919
FAX (513) 458-2172

Certificate of Calibration and Conformance

Instrument Model **820**, Serial Number **1672**, was calibrated on August 11, 2008. The instrument meets factory specifications according to The Modal Shop Production Test Procedure PRD-P227, ISO 10012, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: August 11, 2008
Calibration due:

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0760 / 0101	12 Months	2/18/2009	2008-102748

Certified Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

AMBIENT TEMPERATURE: 78.8°F RELATIVE HUMIDITY: 34%

Notes

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 10012. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

Due to state-of-the-art limitations, 4:1 calibration ratios are not possible on pressure measurement standards, microphones and acoustic calibrators. Calibration ratios for these types of devices are limited to 1:1.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Ed Devlin Signature: _____

Service Center: The Modal Shop, Inc.

THE MODAL SHOP INC. A PCB GROUP CO.

The Modal Shop
3149 East Kemper Road
Cincinnati, OH 45241
Ph (513) 351-9919
FAX (513) 458-2172

PCB PIEZOTRONICS
A PCB GROUP COMPANY

Certificate of Calibration and Conformance

Certificate Number 2008-107009

Instrument Model 820, Serial Number 1687, was calibrated on 22MAY2008. The instrument meets factory specifications per Procedure D0001.8160, ANSI S1.4 1983, IEC 651-Type 1 1979, and IEC 804-Type 1 1985.

Instrument found to be in calibration as received: YES
Date Calibrated: 22MAY2008
Calibration due: 22MAY2009

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL. DUE	TRACEABILITY NO.
Larson Davis	LDSigGn/2209	0277 / 0109	12 Months	01APR2009	2008-105087

Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Temperature: 22 ° Centigrade

Relative Humidity: 29 %

Affirmations

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the U.S. National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at Provo Engineering & Manufacturing Center. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with the requirements of ISO 17025 and ANSI Z540. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. A one year calibration is recommended, however calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of the issuer.

"AS RECEIVED" data same as shipped data.
Tested with test PRM828-0740

Signed: Ron Harris
Technician: Ron Harris

Provo Engineering and Manufacturing Center, 1681 West 820 North, Provo, Utah 84601
Toll Free: 888.258.3222 Telephone: 716.926.8243 Fax: 716.926.8215
ISO 9001-2000 Certified

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 107634 Description: 1/2" Free-Field Microphone

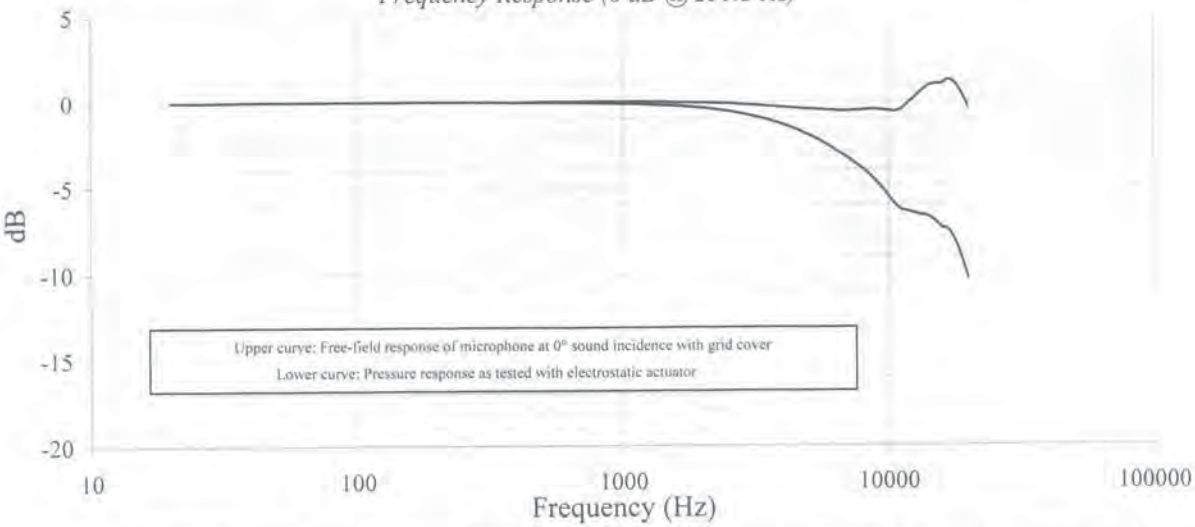
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 49.28 mV/Pa
-26.15 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.6 pF

Temperature: 73 °F (23°C) Ambient Pressure: 994 mbar Relative Humidity: 23 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	-0.01	-0.01	1584.9	-0.25	-0.04	6683.4	-3.11	-0.59	-	-	-
25.1	-0.01	-0.01	1678.8	-0.27	-0.04	7079.5	-3.35	-0.57	-	-	-
31.6	0.00	0.00	1778.3	-0.30	-0.05	7498.9	-3.63	-0.56	-	-	-
39.8	0.01	0.01	1883.7	-0.34	-0.06	7943.3	-3.93	-0.54	-	-	-
50.1	0.01	0.01	1995.3	-0.37	-0.06	8414.0	-4.24	-0.51	-	-	-
63.1	0.01	0.01	2113.5	-0.42	-0.08	8912.5	-4.61	-0.50	-	-	-
79.4	0.01	0.01	2238.7	-0.46	-0.09	9440.6	-5.06	-0.54	-	-	-
100.0	0.01	0.01	2371.4	-0.52	-0.11	10000.0	-5.53	-0.58	-	-	-
125.9	0.01	0.01	2511.9	-0.57	-0.11	10592.5	-6.02	-0.62	-	-	-
158.5	0.01	0.01	2660.7	-0.65	-0.14	11220.2	-6.35	-0.49	-	-	-
199.5	0.00	0.00	2818.4	-0.73	-0.17	11885.0	-6.45	-0.13	-	-	-
251.2	0.00	0.00	2985.4	-0.81	-0.19	12589.3	-6.56	0.21	-	-	-
316.2	-0.01	0.00	3162.3	-0.90	-0.22	13335.2	-6.64	0.55	-	-	-
398.1	-0.02	-0.02	3349.7	-0.99	-0.25	14125.4	-6.73	0.86	-	-	-
501.2	-0.03	0.01	3548.1	-1.10	-0.28	14962.4	-6.99	0.98	-	-	-
631.0	-0.04	0.00	3758.4	-1.22	-0.32	15848.9	-7.35	1.00	-	-	-
794.3	-0.07	0.02	3981.1	-1.35	-0.35	16788.0	-7.50	1.22	-	-	-
1000.0	-0.11	0.01	4217.0	-1.49	-0.38	17782.8	-8.07	1.04	-	-	-
1059.3	-0.12	0.01	4466.8	-1.64	-0.41	18836.5	-9.05	0.46	-	-	-
1122.0	-0.13	0.01	4731.5	-1.81	-0.44	19952.6	-10.28	-0.35	-	-	-
1188.5	-0.14	0.01	5011.9	-1.99	-0.46	-	-	-	-	-	-
1258.9	-0.16	0.00	5308.8	-2.18	-0.48	-	-	-	-	-	-
1333.5	-0.18	0.00	5623.4	-2.39	-0.51	-	-	-	-	-	-
1412.5	-0.20	-0.01	5956.6	-2.61	-0.54	-	-	-	-	-	-
1496.2	-0.22	-0.02	6309.6	-2.85	-0.56	-	-	-	-	-	-

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED
CALIBRATION CERT #1882.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3288823879.847

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 107634 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/21/07	3/21/08
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: N/A

As Left: New unit in tolerance

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED

CALIBRATION CERT #1962.01

PCB PIEZOTRONICS™
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3268623678.847

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 105105 Description: 1/2" Free-Field Microphone

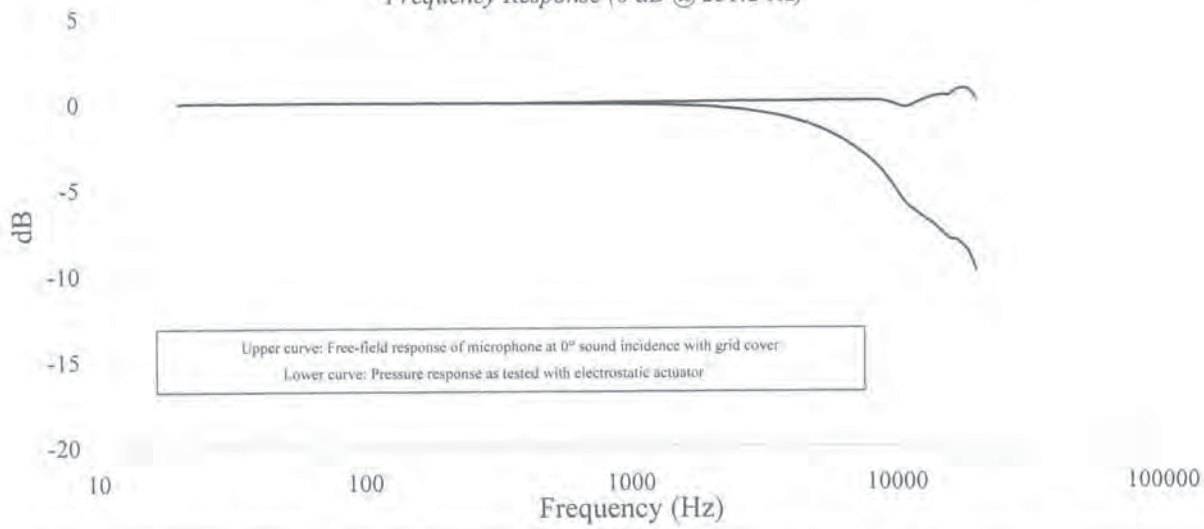
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 44.45 mV/Pa
-27.04 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.7 pF

Temperature: 73 °F (23°C) Ambient Pressure: 989 mbar Relative Humidity: 24 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	0.01	0.01	1584.9	-0.17	0.04	6683.4	-2.44	0.08	-	-	-
25.1	0.04	0.04	1678.8	-0.18	0.05	7079.5	-2.70	0.08	-	-	-
31.6	0.03	0.03	1778.3	-0.20	0.05	7498.9	-2.98	0.09	-	-	-
39.8	0.03	0.03	1883.7	-0.22	0.06	7943.3	-3.30	0.09	-	-	-
50.1	0.03	0.03	1995.3	-0.24	0.07	8414.0	-3.65	0.08	-	-	-
63.1	0.03	0.03	2113.5	-0.27	0.07	8912.5	-4.06	0.05	-	-	-
79.4	0.02	0.02	2238.7	-0.31	0.06	9440.6	-4.56	-0.04	-	-	-
100.0	0.02	0.02	2371.4	-0.34	0.07	10000.0	-5.12	-0.17	-	-	-
125.9	0.01	0.01	2511.9	-0.38	0.08	10592.5	-5.71	-0.31	-	-	-
158.5	0.01	0.01	2660.7	-0.42	0.09	11220.2	-6.15	-0.29	-	-	-
199.5	0.00	0.00	2818.4	-0.49	0.07	11885.0	-6.43	-0.11	-	-	-
251.2	0.00	0.00	2985.4	-0.55	0.07	12589.3	-6.72	0.05	-	-	-
316.2	-0.01	0.00	3162.3	-0.60	0.08	13335.2	-6.99	0.20	-	-	-
398.1	-0.01	-0.01	3349.7	-0.67	0.07	14125.4	-7.27	0.32	-	-	-
501.2	-0.02	0.02	3548.1	-0.75	0.07	14962.4	-7.62	0.35	-	-	-
631.0	-0.03	0.01	3758.4	-0.83	0.07	15848.9	-7.99	0.36	-	-	-
794.3	-0.05	0.04	3981.1	-0.93	0.07	16788.0	-8.07	0.65	-	-	-
1000.0	-0.07	0.05	4217.0	-1.04	0.07	17782.8	-8.37	0.74	-	-	-
1059.3	-0.08	0.05	4466.8	-1.16	0.07	18836.5	-8.86	0.65	-	-	-
1122.0	-0.09	0.05	4731.5	-1.29	0.08	19952.6	-9.80	0.13	-	-	-
1188.5	-0.10	0.05	5011.9	-1.44	0.09	-	-	-	-	-	-
1258.9	-0.11	0.05	5308.8	-1.60	0.10	-	-	-	-	-	-
1333.5	-0.12	0.06	5623.4	-1.78	0.10	-	-	-	-	-	-
1412.5	-0.13	0.06	5956.6	-1.98	0.09	-	-	-	-	-	-
1496.2	-0.15	0.05	6309.6	-2.20	0.09	-	-	-	-	-	-

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED
CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID 329042419Z.804

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 105105 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: In tolerance

As Left: In tolerance, unit enhanced

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3290424192.804

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 104975 Description: 1/2" Free-Field Microphone

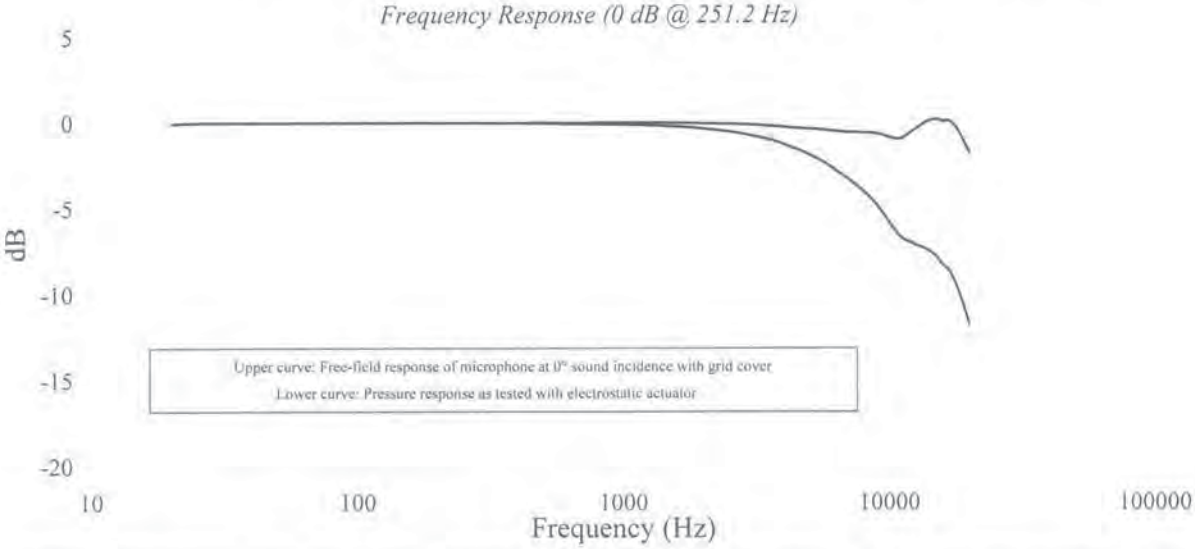
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 50.71 mV/Pa
-25.9 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.7 pF

Temperature: 73 °F (23°C) Ambient Pressure: 989 mbar Relative Humidity: 24 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	-0.03	-0.03	1584.9	-0.21	0.00	6683.4	-3.05	-0.53	-	-	-
25.1	0.01	0.01	1678.8	-0.23	0.00	7079.5	-3.33	-0.55	-	-	-
31.6	0.01	0.01	1778.3	-0.26	-0.01	7498.9	-3.63	-0.56	-	-	-
39.8	0.01	0.01	1883.7	-0.29	-0.01	7943.3	-3.97	-0.58	-	-	-
50.1	0.01	0.01	1995.3	-0.33	-0.02	8414.0	-4.32	-0.59	-	-	-
63.1	0.01	0.01	2113.5	-0.37	-0.03	8912.5	-4.74	-0.63	-	-	-
79.4	0.01	0.01	2238.7	-0.41	-0.04	9440.6	-5.25	-0.73	-	-	-
100.0	0.01	0.01	2371.4	-0.46	-0.05	10000.0	-5.80	-0.85	-	-	-
125.9	0.01	0.01	2511.9	-0.51	-0.05	10592.5	-6.35	-0.95	-	-	-
158.5	0.01	0.01	2660.7	-0.57	-0.06	11220.2	-6.76	-0.90	-	-	-
199.5	0.00	0.00	2818.4	-0.64	-0.08	11885.0	-6.94	-0.62	-	-	-
251.2	0.00	0.00	2985.4	-0.72	-0.10	12589.3	-7.13	-0.36	-	-	-
316.2	-0.01	0.00	3162.3	-0.80	-0.12	13335.2	-7.28	-0.09	-	-	-
398.1	-0.01	-0.01	3349.7	-0.89	-0.15	14125.4	-7.47	0.12	-	-	-
501.2	-0.02	0.02	3548.1	-0.99	-0.17	14962.4	-7.79	0.18	-	-	-
631.0	-0.04	0.00	3758.4	-1.10	-0.20	15848.9	-8.26	0.09	-	-	-
794.3	-0.06	0.03	3981.1	-1.23	-0.23	16788.0	-8.63	0.09	-	-	-
1000.0	-0.09	0.03	4217.0	-1.39	-0.28	17782.8	-9.38	-0.27	-	-	-
1059.3	-0.10	0.03	4466.8	-1.53	-0.30	18836.5	-10.47	-0.96	-	-	-
1122.0	-0.11	0.03	4731.5	-1.69	-0.32	19952.6	-11.69	-1.76	-	-	-
1188.5	-0.12	0.03	5011.9	-1.87	-0.34	-	-	-	-	-	-
1258.9	-0.14	0.02	5308.8	-2.07	-0.37	-	-	-	-	-	-
1333.5	-0.15	0.03	5623.4	-2.28	-0.40	-	-	-	-	-	-
1412.5	-0.17	0.02	5956.6	-2.52	-0.45	-	-	-	-	-	-
1496.2	-0.19	0.01	6309.6	-2.77	-0.48	-	-	-	-	-	-

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED
CALIBRATION CERT #1882.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3290423031.585

~ Certificate of Calibration and Compliance ~

Microphone Model: 377B02 Serial Number: 104975 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: In tolerance

As Left: In tolerance, unit enhanced

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: April 7, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION
3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

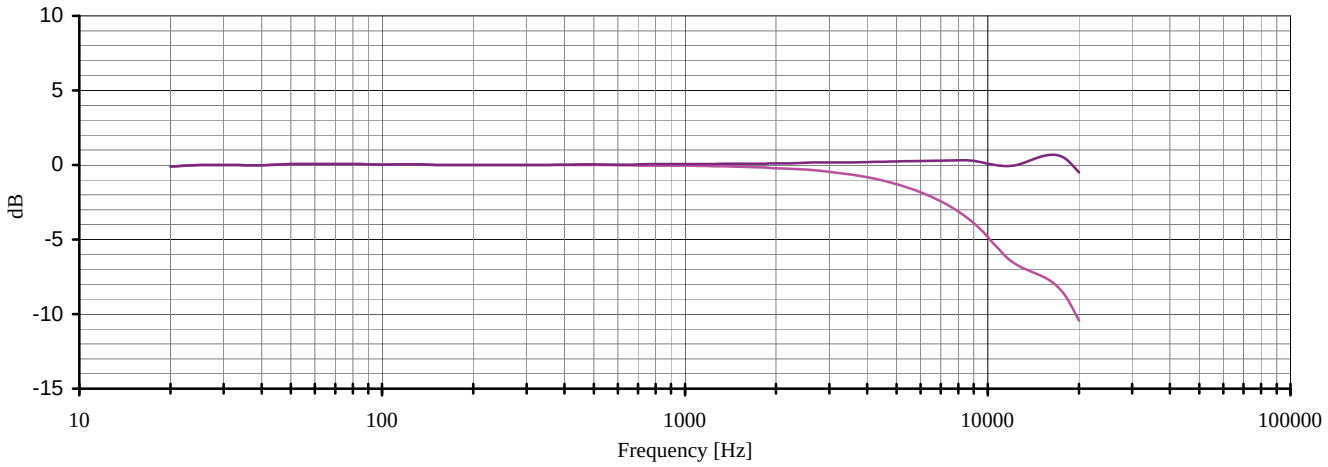
10-3590-023031.585

~Calibration Certificate~

3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 105346

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-26.92	-26.97	dB re. 1V/Pa
	45.09	44.84	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	20-Feb-2008	14:23:13	Temperature:	76 (24)	°F (°C)
Due Date:			Humidity:	23	%
Technician:	Ed Devlin		Pressure:	1021	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/3/2007	8/3/2008

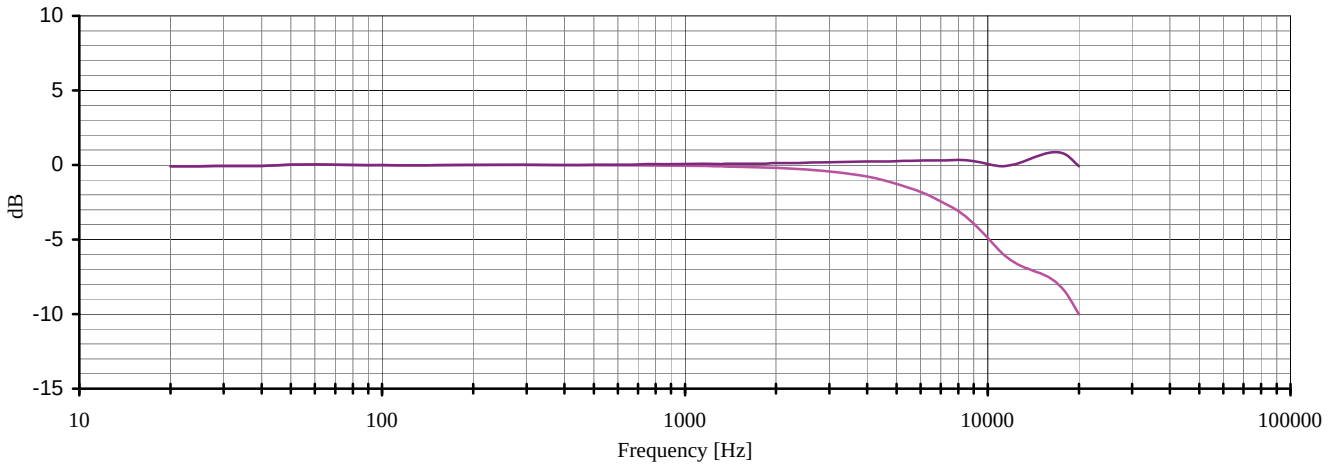
ACCREDITED
2649.01

~Calibration Certificate~

3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 105426

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-26.41	-26.46	dB re. 1V/Pa
	47.82	47.53	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	20-Feb-2008	14:14:01	Temperature:	76 (24)	°F (°C)
Due Date:			Humidity:	23	%
Technician:	Ed Devlin		Pressure:	1021	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/3/2007	8/3/2008

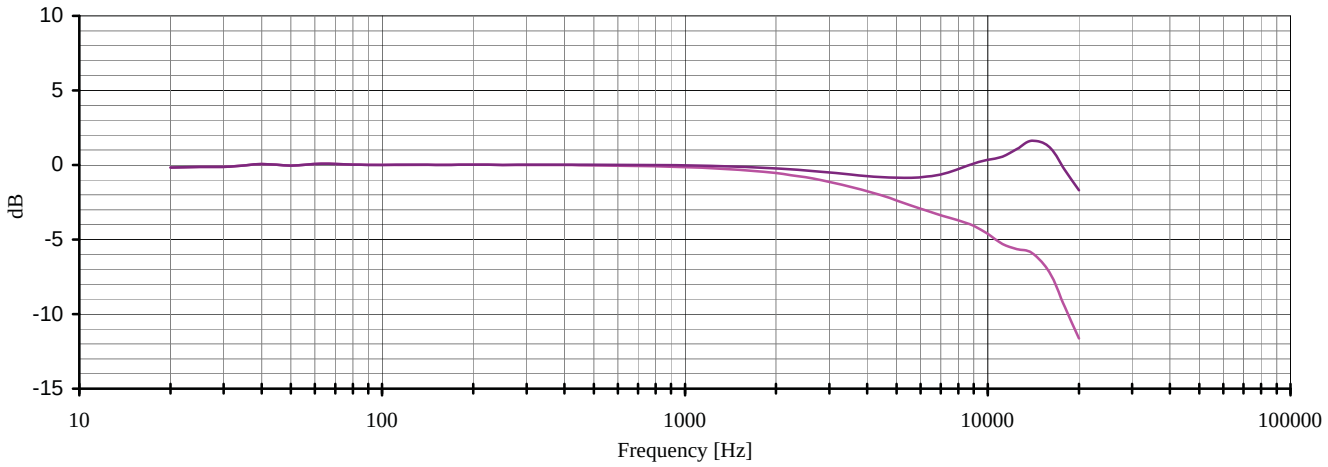
ACCREDITED
2649.01

~Calibration Certificate~

3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 104298

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-25.45	-25.59	dB re. 1V/Pa
	53.41	52.52	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	7-Jan-2008	11:52:27	Temperature:	75 (24)	°F (°C)
Due Date:			Humidity:	40	%
Technician:	Ed Devlin		Pressure:	1019	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/3/2007	8/3/2008

ACCREDITED
2649.01

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 106367 Description: 1/2" Free-Field Microphone

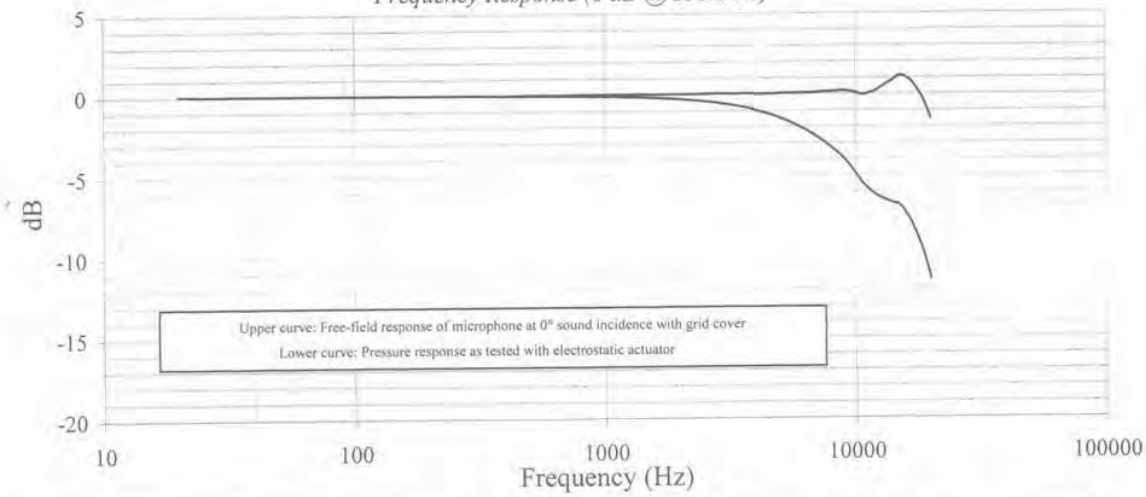
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 49.86 mV/Pa
-26.04 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 11.8 pF

Temperature: 71 °F (22°C) Ambient Pressure: 987 mbar Relative Humidity: 33 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	0.06	0.06	1584.9	-0.19	0.02	6683.4	-2.42	0.10	-	-	-
25.1	0.03	0.03	1678.8	-0.21	0.02	7079.5	-2.66	0.12	-	-	-
31.6	0.04	0.04	1778.3	-0.23	0.02	7498.9	-2.93	0.14	-	-	-
39.8	0.03	0.03	1883.7	-0.25	0.03	7943.3	-3.24	0.15	-	-	-
50.1	0.03	0.03	1995.3	-0.28	0.03	8414.0	-3.56	0.17	-	-	-
63.1	0.03	0.03	2113.5	-0.31	0.03	8912.5	-3.91	0.20	-	-	-
79.4	0.03	0.03	2238.7	-0.34	0.03	9440.6	-4.36	0.16	-	-	-
100.0	0.02	0.02	2371.4	-0.38	0.03	10000.0	-4.87	0.08	-	-	-
125.9	0.02	0.02	2511.9	-0.42	0.04	10592.5	-5.44	-0.04	-	-	-
158.5	0.01	0.01	2660.7	-0.46	0.05	11220.2	-5.84	0.02	-	-	-
199.5	0.01	0.01	2818.4	-0.50	0.06	11885.0	-6.18	0.14	-	-	-
251.2	0.00	0.00	2985.4	-0.57	0.05	12589.3	-6.41	0.36	-	-	-
316.2	-0.01	0.00	3162.3	-0.63	0.05	13335.2	-6.57	0.62	-	-	-
398.1	-0.02	-0.02	3349.7	-0.70	0.04	14125.4	-6.74	0.85	-	-	-
501.2	-0.03	0.01	3548.1	-0.77	0.05	14962.4	-6.85	1.12	-	-	-
631.0	-0.04	0.00	3758.4	-0.84	0.06	15848.9	-7.31	1.04	-	-	-
794.3	-0.06	0.03	3981.1	-0.98	0.02	16788.0	-7.98	0.74	-	-	-
1000.0	-0.09	0.03	4217.0	-1.09	0.02	17782.8	-8.88	0.23	-	-	-
1059.3	-0.09	0.04	4466.8	-1.20	0.03	18836.5	-9.99	-0.48	-	-	-
1122.0	-0.10	0.04	4731.5	-1.33	0.04	19952.6	-11.43	-1.50	-	-	-
1188.5	-0.12	0.03	5011.9	-1.47	0.06	-	-	-	-	-	-
1258.9	-0.13	0.03	5308.8	-1.63	0.07	-	-	-	-	-	-
1333.5	-0.14	0.04	5623.4	-1.81	0.07	-	-	-	-	-	-
1412.5	-0.15	0.04	5956.6	-1.99	0.08	-	-	-	-	-	-
1496.2	-0.17	0.03	6309.6	-2.20	0.09	-	-	-	-	-	-

Technician: Nancy Szeluga Date: September 8, 2008

ACCREDITED
CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION
3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3303716242.081

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 106367 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	02-400	41440497	LD-014	12/4/07	12/4/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4250	CA-1116	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: Out of tolerance, sensitivity and frequency response

As Left: In tolerance, unit repaired

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Nancy Szeluga Date: September 8, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

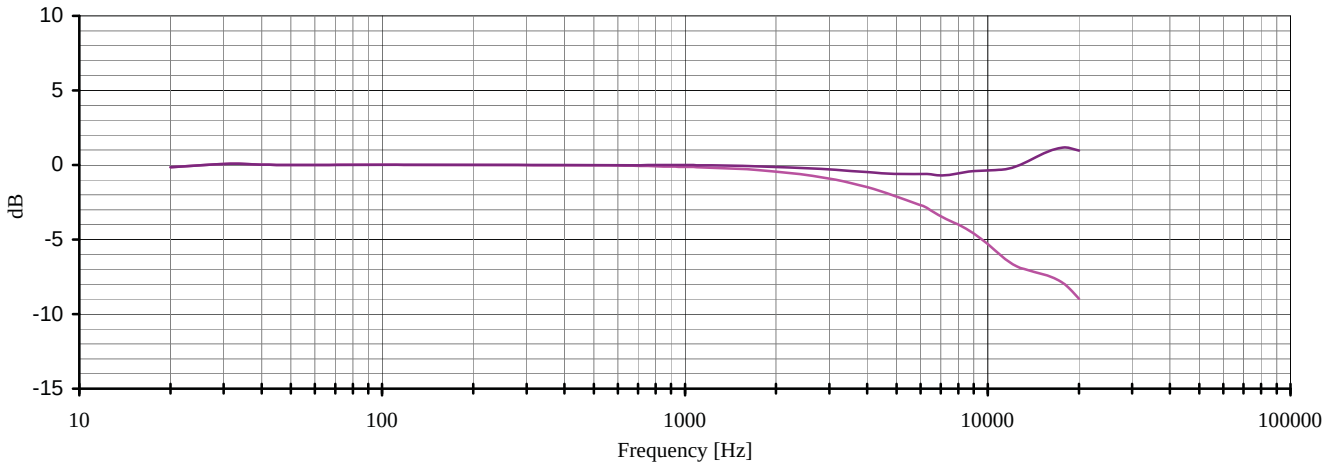
ID:3303716242.081

~Calibration Certificate~

THE MODAL SHOP INC. A PCB GROUP CO.
3149 East Kemper Rd.
Cincinnati, OH 45241
Ph : 513-351-9919
Fax: 513-458-2172
www.modalshop.com

Description: Free-Field Microphone
Manufacturer: PCB
Model Number: 377B02
Serial Number: 106345

Customer : TMS Rental



Test Results:

Sensitivity:	**250 Hz**	**1kHz**	
	-26.50	-26.63	dB re. 1V/Pa
	47.30	46.63	mV/Pa
Cal. Results:	In Tolerance		

Frequency Response Characteristics : The upper curve is the free field characteristic for the microphone with protection grid. The lower curve is the pressure response recorded by electrostatic actuator.

Sensitivity : The stated sensitivity is the open-circuit sensitivity. When used with a typical preamplifier the sensitivity will be 0.2 dB lower.

Polarization Voltage : 0 V

Traceability : The calibration is traceable through NIST TN 822/274345-07.

Notes :
Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty at 95% confidence level: 0.25 dB
Calibrated per procedure PRD-P204.

User Note : As Found / As Left: In Tolerance.

Cal Date:	15-Jul-2008	10:49:28	Temperature:	77 (25)	°F (°C)
Due Date:			Humidity:	34	%
Technician:	Ed Devlin		Pressure:	1017	mbar
Approval:					

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
G.R.A.S.	40AG	58093	8/14/2007	8/14/2008

ACCREDITED
2649.01

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 107742 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/19/08	3/19/09
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	02-400	41440497	LD-014	12/4/07	12/4/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4250	CA-1116	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: Out of tolerance, frequency response

As Left: In tolerance, unit repaired

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Nancy Szeluga Date: September 8, 2008

ACCREDITED

CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:3303715781.356

~ *Calibration Report* ~

Microphone Model: 377B02 Serial Number: 107742 Description: 1/2" Free-Field Microphone

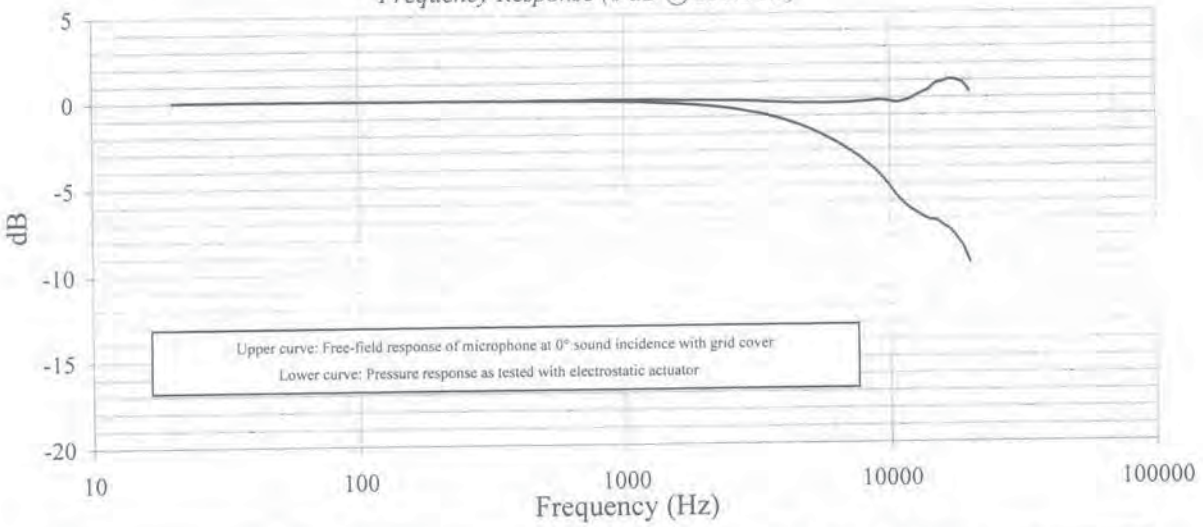
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 48.45 mV/Pa
-26.29 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 12 pF

Temperature: 71 °F (22°C) Ambient Pressure: 987 mbar Relative Humidity: 33 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	0.05	0.05	1584.9	-0.24	-0.03	6683.4	-2.79	-0.27	-	-	-
25.1	0.06	0.06	1678.8	-0.27	-0.04	7079.5	-3.04	-0.26	-	-	-
31.6	0.06	0.06	1778.3	-0.30	-0.05	7498.9	-3.30	-0.23	-	-	-
39.8	0.06	0.06	1883.7	-0.32	-0.04	7943.3	-3.60	-0.21	-	-	-
50.1	0.05	0.05	1995.3	-0.36	-0.05	8414.0	-3.92	-0.19	-	-	-
63.1	0.04	0.04	2113.5	-0.40	-0.06	8912.5	-4.26	-0.15	-	-	-
79.4	0.04	0.04	2238.7	-0.44	-0.07	9440.6	-4.67	-0.15	-	-	-
100.0	0.03	0.03	2371.4	-0.49	-0.08	10000.0	-5.15	-0.20	-	-	-
125.9	0.02	0.02	2511.9	-0.54	-0.08	10592.5	-5.68	-0.28	-	-	-
158.5	0.01	0.01	2660.7	-0.60	-0.09	11220.2	-6.08	-0.22	-	-	-
199.5	0.01	0.01	2818.4	-0.67	-0.11	11885.0	-6.43	-0.11	-	-	-
251.2	0.00	0.00	2985.4	-0.74	-0.12	12589.3	-6.66	0.11	-	-	-
316.2	-0.01	0.00	3162.3	-0.82	-0.14	13335.2	-6.90	0.29	-	-	-
398.1	-0.02	-0.02	3349.7	-0.90	-0.16	14125.4	-7.10	0.49	-	-	-
501.2	-0.03	0.01	3548.1	-1.00	-0.18	14962.4	-7.14	0.83	-	-	-
631.0	-0.05	-0.01	3758.4	-1.10	-0.20	15848.9	-7.43	0.92	-	-	-
794.3	-0.07	0.02	3981.1	-1.23	-0.23	16788.0	-7.66	1.06	-	-	-
1000.0	-0.11	0.01	4217.0	-1.35	-0.24	17782.8	-8.11	1.00	-	-	-
1059.3	-0.12	0.01	4466.8	-1.49	-0.26	18836.5	-8.68	0.83	-	-	-
1122.0	-0.13	0.01	4731.5	-1.63	-0.26	19952.6	-9.59	0.34	-	-	-
1188.5	-0.14	0.01	5011.9	-1.79	-0.26	-	-	-	-	-	-
1258.9	-0.16	0.00	5308.8	-1.97	-0.27	-	-	-	-	-	-
1333.5	-0.18	0.00	5623.4	-2.16	-0.28	-	-	-	-	-	-
1412.5	-0.20	-0.01	5956.6	-2.35	-0.28	-	-	-	-	-	-
1496.2	-0.22	-0.02	6309.6	-2.56	-0.27	-	-	-	-	-	-

Technician: Nancy Szeluga NS Date: September 8, 2008

ACCREDITED
CALIBRATION CERT #1862.01

PCB PIEZOTRONICS
VIBRATION DIVISION
3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID 330371578 1.356

~ Calibration Report ~

Microphone Model: 377B02 Serial Number: 108291 Description: 1/2" Free-Field Microphone

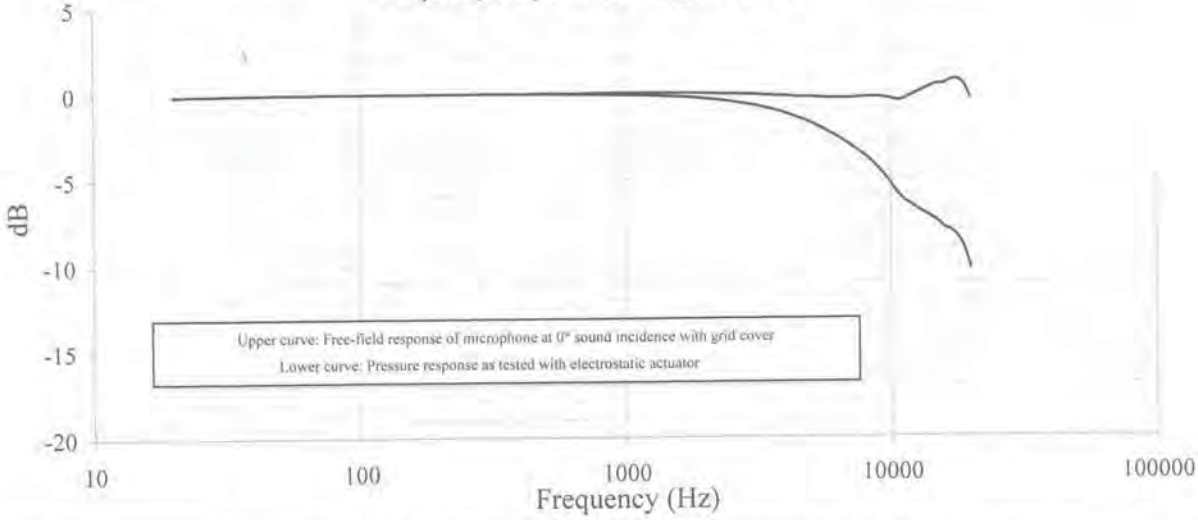
Calibration Data

Open Circuit Sensitivity @ 251.2 Hz: 49.19 mV/Pa
-26.16 dB re 1V/Pa

Polarization Voltage, External: 0 V
Capacitance: 12.3 pF

Temperature: 73 °F (23°C) Ambient Pressure: 994 mbar Relative Humidity: 23 %

Frequency Response (0 dB @ 251.2 Hz)



Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)	Freq (Hz)	Lower (dB)	Upper (dB)
20.0	-0.08	-0.08	1584.9	-0.20	0.01	6683.4	-2.85	-0.33	-	-	-
25.1	-0.05	-0.05	1678.8	-0.22	0.01	7079.5	-3.10	-0.32	-	-	-
31.6	-0.03	-0.03	1778.3	-0.25	0.00	7498.9	-3.37	-0.30	-	-	-
39.8	-0.02	-0.02	1883.7	-0.28	0.00	7943.3	-3.67	-0.28	-	-	-
50.1	-0.01	-0.01	1995.3	-0.32	-0.01	8414.0	-3.99	-0.26	-	-	-
63.1	-0.01	-0.01	2113.5	-0.36	-0.02	8912.5	-4.37	-0.26	-	-	-
79.4	0.00	0.00	2238.7	-0.40	-0.03	9440.6	-4.82	-0.30	-	-	-
100.0	0.00	0.00	2371.4	-0.45	-0.04	10000.0	-5.32	-0.37	-	-	-
125.9	0.00	0.00	2511.9	-0.50	-0.04	10592.5	-5.86	-0.46	-	-	-
158.5	0.00	0.00	2660.7	-0.57	-0.06	11220.2	-6.28	-0.42	-	-	-
199.5	0.00	0.00	2818.4	-0.63	-0.07	11885.0	-6.53	-0.21	-	-	-
251.2	0.00	0.00	2985.4	-0.70	-0.08	12589.3	-6.79	-0.02	-	-	-
316.2	0.00	0.01	3162.3	-0.78	-0.10	13335.2	-7.03	0.16	-	-	-
398.1	-0.01	-0.01	3349.7	-0.87	-0.13	14125.4	-7.26	0.33	-	-	-
501.2	-0.01	0.03	3548.1	-0.97	-0.15	14962.4	-7.49	0.48	-	-	-
631.0	-0.03	0.01	3758.4	-1.07	-0.17	15848.9	-7.86	0.49	-	-	-
794.3	-0.05	0.04	3981.1	-1.19	-0.19	16788.0	-8.04	0.68	-	-	-
1000.0	-0.08	0.04	4217.0	-1.32	-0.21	17782.8	-8.39	0.72	-	-	-
1059.3	-0.09	0.04	4466.8	-1.47	-0.24	18836.5	-9.04	0.47	-	-	-
1122.0	-0.10	0.04	4731.5	-1.62	-0.25	19952.6	-10.23	-0.30	-	-	-
1188.5	-0.11	0.04	5011.9	-1.78	-0.25	-	-	-	-	-	-
1258.9	-0.13	0.03	5308.8	-1.97	-0.27	-	-	-	-	-	-
1333.5	-0.14	0.04	5623.4	-2.18	-0.30	-	-	-	-	-	-
1412.5	-0.16	0.03	5956.6	-2.38	-0.31	-	-	-	-	-	-
1496.2	-0.18	0.02	6309.6	-2.60	-0.31	-	-	-	-	-	-

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED
CALIBRATION CERT #1662.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043
TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

~ *Certificate of Calibration and Compliance* ~

Microphone Model: 377B02 Serial Number: 108291 Manufacturer: PCB

Calibration Environmental Conditions

Environmental test conditions as printed on microphone calibration chart.

Reference Equipment

Manufacturer	Model #	Serial #	PCB Control #	Cal Date	Due Date
Hewlett Packard	34401A	MY41045214	LD-001	3/21/07	3/21/08
Bruel & Kjaer	4192	2493415	LD-028	9/11/07	9/11/08
Fisher Scientific	S40802	51253176	CA897	8/14/07	8/14/08
Larson Davis	PRM915	123	CA-866	not required	not required
Larson Davis	PRM902	4186	CA-1083	not required	not required
Larson Davis	PRM902	3773	CA-887	not required	not required
Larson Davis	PRM902	3766	CA-885	not required	not required
Larson Davis	2559LF	3216	CA-883	not required	not required
Larson Davis	ADP005	1	LD-017	not required	not required
Larson Davis	PRM916	129	CA-1084	not required	not required
Larson Davis	CAL250	4147	LD-018	not required	not required
Larson Davis	2201	115	TA-472	not required	not required
Larson Davis	2900	1079	CA-521	not required	not required
Larson Davis	PRA951-4	222	LD-026	not required	not required

Frequency sweep performed with B&K UA0033 electrostatic actuator.

Condition of Unit

As Found: N/A

As Left: New unit in tolerance

Notes

1. Calibration of reference microphone is traceable through PTB.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI/NCSL Z540-1-1994 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Open circuit sensitivity is measured using the insertion voltage method following procedure AT603-5.
6. Measurement uncertainty (95% confidence level with coverage factor of 2) for sensitivity is +/-0.20 dB.
7. Unit calibrated per ACS-20.

Technician: Joe Ziewicki Date: March 17, 2008

ACCREDITED

CALIBRATION CERT #1662.01

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, New York, 14043

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

ID:328660376 899