

# Product Data Bulletin

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## Audible Motor Noise Considerations with Pulse Width Modulation Drives File 8839

### INTRODUCTION

The modern pulse width modulated (PWM) AC drive is being used today to save energy and improve processes in the industrial/commercial market segments. Some applications may involve personnel working in close proximity to the AC drive controlled motor. For those applications, audible noise from the motor may be a consideration.

All motors generate audible noise when operating. How the motor is constructed, its physical size, loading, and the type of AC power applied determines how much noise is generated. The noise originates from the motor cooling fans, the motor bearings, and the humming of the stator laminations excited by the applied power. Because AC induction motors have been used for over 75 years on fixed voltage and frequency power systems, users have become accustomed to the type of noise generated by utility powered motors.

This document discusses motor audible noise and how it is affected when AC adjustable frequency drives are applied. Some of the topics discussed are:

- Definition of audible noise or sound
- Standards covering audible noise and rotating electrical machines
- The effect different types of applied power have on motor audible noise
- Noise abatement techniques

### AUDIBLE NOISE OR SOUND

The text book definitions of sound or noise are:

*Mark's Standard Handbook for Mechanical Engineers* defines sound as:

"Sound is an alteration in pressure, stress, particle displacement, and particle velocity, which is propagated in an elastic material. It is longitudinal in gasses but may also be transverse (shear) surface, or other types in elastic media which can support such energy. It may be reflected, diffracted, or refracted at boundaries and under suitable conditions may change from one form to another."

*Webster's Ninth New Collegiate Dictionary* defines sound as:

"Mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (as air) and is the objective cause of hearing."

Sound is a complicated subject. Our discussion will refer to it as a form of mechanical radiant energy which travels in air as pressure waves and will be limited to how it pertains to medium size induction motors.

## APPLICABLE STANDARDS

Sound is a form of energy which can be measured and quantified. There are standards which aid a user in defining and measuring the sound of electric motors. NEMA MG1-1993 Part 12.53 covers machine sound of medium induction motors. Part 12.53.1 explains that although these standards define the acceptable sound power level of motors, they cannot guarantee their acceptability because sounds of the same power level can have different sound quality.

IEEE Standard 85-1973 is a test procedure for measuring airborne sound of rotating electrical machinery. It applies to unloaded motors mounted in controlled environments operating at rated speed and voltage. It defines various operating environments, the necessary measuring equipment, possible frequency ranges of interest, and where measurements should be made in relation to the motor. Where sound levels of loaded motors are of interest, it recommends that the user and tester agree upon the following:

1. Mounting - Errors will be introduced into the sound measurement if the motor vibrations cause the base or floor to vibrate.
2. Method of Loading - The connected load induces error by contributing to the overall sound measured.
3. Background Noise - Any background noise in the frequency range of interest contributes to the overall sound measured inducing error.
4. Accuracy of Measurements - The type of equipment used and how it is used will yield different results for the same machine under the same load.
5. Power Input Requirements - The referenced standards are for a motor running with sinusoidal power at full voltage and rated speed. If other conditions are to be measured, a complete description of those conditions needs to be agreed upon.
6. Interpretation of Data - Both user and tester need to understand what is being measured, how it is being measured, external influences, and the accuracy of measurements in order to obtain useful data.

Since most users are interested in the actual operating conditions of their facility, IEEE 85-1973 would apply only in conjunction with NEMA MG3-1974. The NEMA MG3 standard gives users tools to estimate sound levels in commercial and industrial environments. It leads a user through steps to calculate the sound pressure levels workers may be exposed to after taking measurements of individual motors per IEEE 85 and applying the proper correction factors or adjustments.

## AUDIBLE MOTOR NOISE WITH SINE WAVE POWER

The audible noise produced by a motor originates from its stator core laminations. The stator core is made up of thin laminated metal sheets. When a 60 Hz sine wave voltage is applied to a motor, a magnetic flux is induced in the stator core. This magnetic flux causes the stator to vibrate 60 times per second producing a low pitch noise similar to that of a transformer.

## AUDIBLE MOTOR NOISE WITH PWM WAVE POWER

When a motor is powered from an adjustable frequency drive using a PWM (Pulse Width Modulated) output waveform, the audible noise produced by the stator laminations has a different sound quality than with sine wave power. The adjustable frequency drive produces an output voltage waveform made of high frequency pulses. The frequency of pulses is determined by the carrier frequency of the selected adjustable frequency drive. The motor stator core laminations vibrate at the carrier frequency changing the pitch of the audible noise. Whether the actual power level of the noise is increased due to a PWM waveform will depend upon the level of the applied excitation voltage.

## NOISE ABATEMENT TECHNIQUES

There are several solutions offered in the industry today to reduce audible motor noise when operating from a PWM adjustable frequency drive. Some of these are:

1. Motor Location - In HVAC and pumping applications, the motor should be located in an equipment room away from personnel. Motor location is typically not a concern in industrial applications because of the other ambient noise associated with the driven machinery.
2. Motor Selection - Totally enclosed non-ventilated (TENV) or totally enclosed fan cooled (TEFC) motors will operate more quietly than open drip proof (ODP) motors. The audible noise of TENV and TEFC motors is more contained in the motor housing compared to the ODP motor style construction.
3. Load Reactor - Installing a reactor on the output of the drive will reduce the audible motor noise when low leakage reactance motors are used.
4. NOLD Circuit - Select a drive that automatically adjusts its output voltage level to the motor load. The electrical motor audible noise will be reduced by lowering the effective motor voltage applied. This reduces the motor flux and resulting force on the stator laminations.
5. Random Modulated Carrier Frequency - Select a drive that randomly modulates the carrier frequency 1 kHz above and below the center frequency. This improves the sound quality of the motor by not allowing the stator laminations to vibrate at a distinct pitch which the human ear can easily detect. It also reduces the possibility of the motor mechanically resonating at the carrier frequency which would amplify the audible noise.
6. Low Noise Drives - Select a drive rated for low noise applications. These types of drives typically operate at a higher carrier frequency than other drives. The higher carrier frequency reduces motor current harmonics that contribute to stator lamination vibration and increased motor audible noise.

Selecting the proper motor type, its location, and a low noise type adjustable frequency drive will help reduce audible motor noise levels.

## SUMMARY

The ALTIVAR® 56 and 66 variable torque low noise (VTLN) adjustable frequency drives by Square D offer an effective solution to audible motor noise concerns. Their patented NOLD motor flux algorithm allows the motor to only develop the flux it needs reducing stator lamination vibration. They use a randomly modulated high carrier frequency output. This produces a good sinusoidal motor current waveform low in harmonics and ensures that the stator laminations will not vibrate at a distinct pitch. These combined features make them a unique choice for variable torque applications where audible motor noise is a concern.

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