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APPLICATION NOTE No. 474

Optimizing Your Lab Environment with Low-Noise Endpoint PCR Cyclers

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Abstract

Sustained noise exposure has a negative impact on people's health, ability to concentrate and performance. A major part of the noise level in a lab is emitted by different types of equipment like smaller centrifuges, various power supplies and thermal cyclers. This application note evaluates the noise level generation of six thermal cyclers in 3 operational states. The obtained values reveal that the new Eppendorf Mastercycler® X40 stands out among its competitors both in terms of emitted noise levels and potential annoyance by tonality.

Introduction

The development of work processes in modern laboratories has led to an increased usage of electronic equipment emitting noise. The diverse negative effects of noise pollution on humans have been investigated in numerous scientific articles [1-4]. The WHO Environmental Noise Guidelines for the European Region delivers substantial evidence that connects environmental noise exposure to adverse health outcomes [5]. Hence, noise levels should be considered when comparing standard lab equipment such as thermal cyclers within the same market range. This application note evaluates both the absolute noise levels and an additional factor, the tonality, which can contribute to a perceived annoyance, of six thermal cyclers. A noise is tonal if it contains a recognizable tone for the human ear, that stand out from the average background noise [6]. The presence of such tone is perceived as annoying by most people [7]. All six devices were measured by the independent technical inspection association TÜV NORD under 3 different operational states.

Material and Methods

The sound power level was determined by TÜV NORD in A-weighted decibel [dB(A)] for six thermal cyclers listed in Table 1 in accordance with DIN EN ISO 3744.

Table 1: List of thermal cyclers under examination

Manufacturer	Model
Eppendorf	Mastercycler® X40
Bio-Rad®	T100™
VWR™	XT^{96}
Himedia®	Prima-96™
Applied Biosystems®	SimpliAmp™
Bioneer	AllinOneCycler™

The measurements were taken at the following three operational states:

1. Idle state: Thermal cycler switched on, temperature control of block and lid turned off, with no application running on device.
2. Continuous (hold step) temperature control of the block at 4 °C.
3. Standard 3-step PCR program shown in Table 2.

All measurements were performed using an inserted 96 well PCR plate (high profile unskirted Eppendorf twin.tec® PCR Plate 96). The plate positions of columns 1, 3, 5, 8, 10, 12 were filled with 30 µL H_2O each, thus filling 48 of the 96 well positions. The plate was sealed with Eppendorf Heat Sealing Foil using the HeatSealer 200 from Eppendorf to prevent evaporation.

Table 2: Settings of the used Standard 3-step PCR program

	Lid	105 °C
Eppendorf Header Settings	Energy-saving mode Temperature mode	ON Standard
3-step PCR program	Denaturation	95 °C/15 s
	Annealing	60 °C/15 s
	Elongation	72 °C/30 s

Result and Discussion

The six tested cyclers emitted different sound power levels in the three tested operational states (idle, PCR run and 4 °C). In particular, the average noise level of the Mastercycler X40 and Prima-96™ during idle state (Figure 1) were 30.2 and 30.1 dB(A), respectively. These values are too low for relevant differentiation of the operating noise to the surrounding sound level. However, thermal cyclers T100™ and AllinOneCycler™ emitted a comparable high sound power level of 54.2 and 57.7 dB(A) in the idle state, respectively. In human sound perception, an increase of sound power level by 10 dB(A) means a doubling of the loudness [8, 9]. Hence, the generated noise in the idle state of both cyclers is perceived more than 4 times stronger than noise emitted by the Mastercycler X40, and Prima-96.

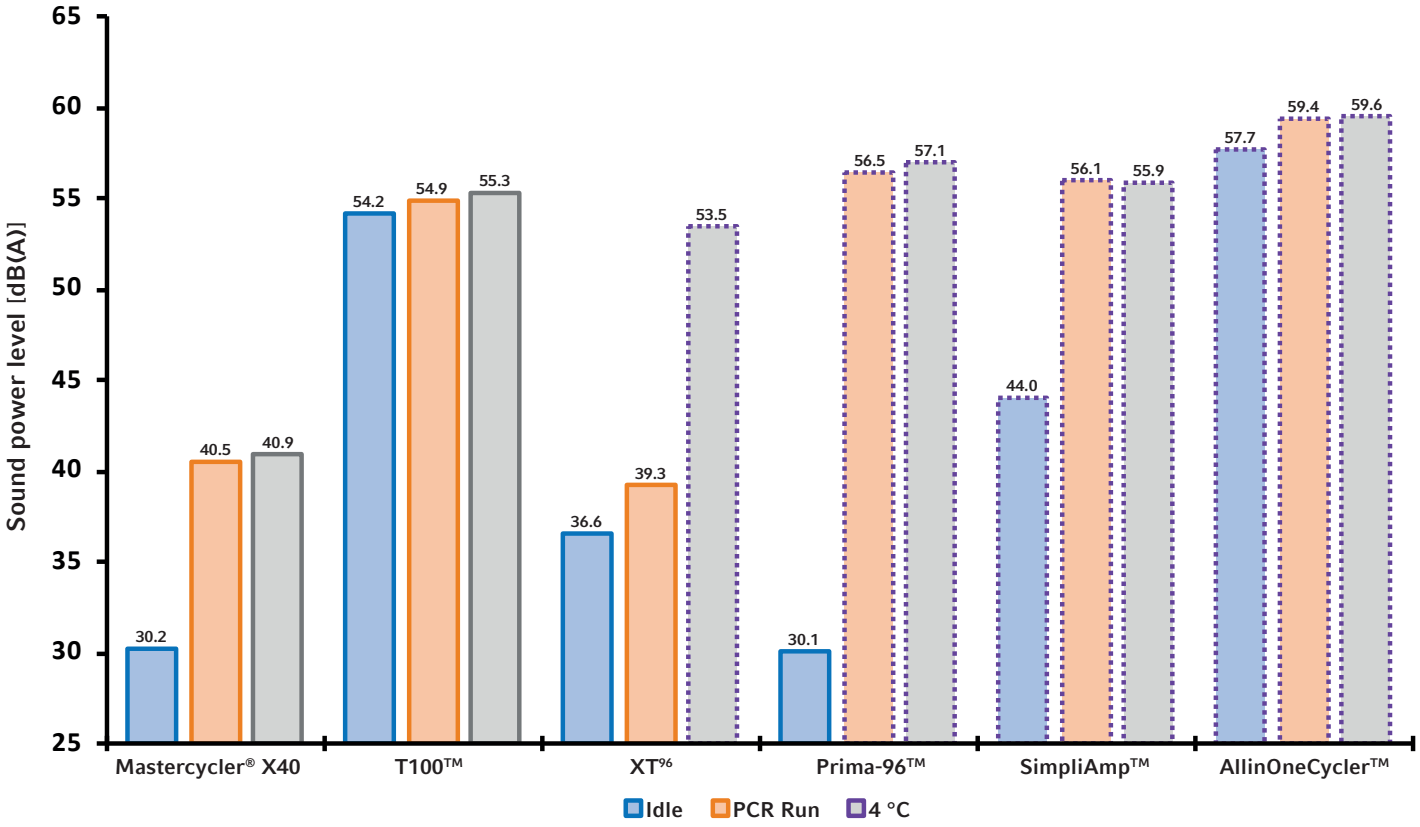

Figure 1: Sound power levels of the thermal cyclers during three operational states. Measurements with tonality indicated with purple lines.

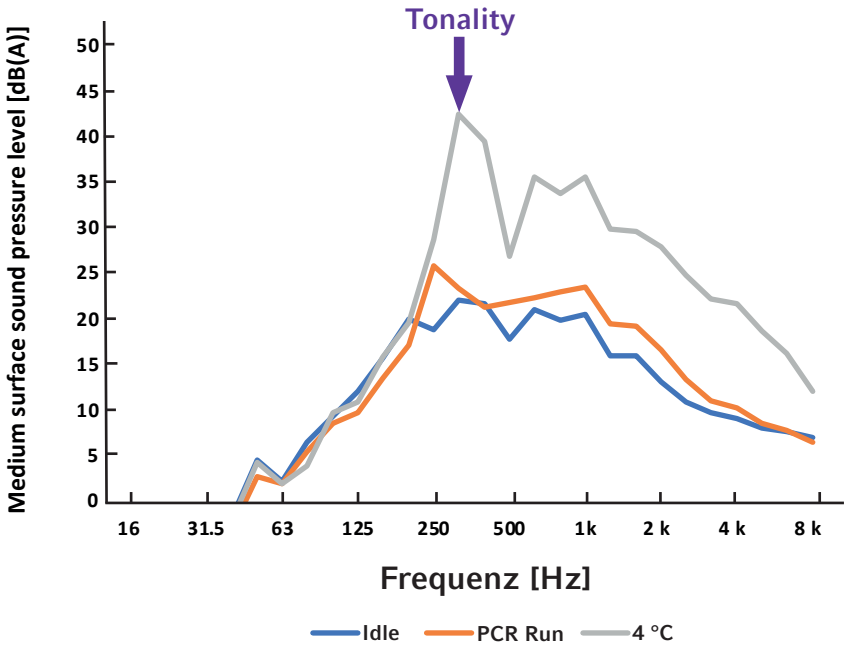

Figure 2: Exemplary medium surface sound pressure level in a 1 m distance in dB(A) from thermal cycler XT[96]. A tonality detected at 315 Hz during a continuous hold step at 4 °C is indicated with a purple arrow.

During a standard 3-step PCR program (table 2) the cycler XT[96] and Mastercycler X40 generated comparable low sound power levels of 39.3 and 40.5 dB(A), respectively.

As the following passages will pay attention to sound power levels and sound pressure level, the difference of both terms is explained shortly. The "sound power level is the acoustic energy emitted by a source which produces a sound pressure level at some distance. While the sound power level of a source is fixed, the sound pressure level depends upon the distance from the source and the acoustic characteristics of the area in which it is located" [10].
According to the recommendation of ISO 11690-1[11] the sound pressure should not exceed 45 dB(A) for meeting rooms or tasks involving concentration.
Since the here presented sound power levels were determined in an essentially free sound field above a reflecting plane, a correction factor of 8 dB(A) was subtracted (as recommended by the TÜV) to obtain the sound pressure level in a 1 m distance. A sound source will produce a higher sound pressure level in a small reflective room than in a large acoustically dead room [10].
The sound power levels of the cycler T100, Prima-96, SimpliAmp™ and AllinOneCycler ranged between 54.9 and 59.4 dB(A). Thus, these values represent corrected sound pressure levels between 46.9 and 51.4 dB(A) which are not recommended for tasks involving concentration.
Similarly, these four cyclers reached noise pressure values over 45 dB(A) during continuous temperature control of the block at 4 °C.

The intensity of the operational noise power level under different states for each thermal cycler varied within the range of approximately 1 (T100) and 27 dB(A) (Prima-96). Hereby, the biggest span is detected between cyclers that have very low noise when idle to being loudest when cooling at 4 °C, such as shown by thermal cyclers XT[96] and Prima-96 (Figure 1).

During all operational states the Mastercycler X40 did not exceed a sound power level of 41 dB(A). All other cyclers exceeded a sound power level of 55 dB(A) in at least one of the operational states. The AllinOneCycler generated the highest noise emission of 59.6 dB(A) during all three operational states.

Even if the here detected noise power levels do not lead to hearing hazard they can cause stress and can be perceived

as annoying. To evaluate potential additional annoyance generated by cyclers even during activities below a hearing hazard-causing noise level, the presence of tonality was tested according to Norm DIN 45645-2 2012-09[12]. A sound is tonal when sound components are clearly audible and their presence by a third-octave analysis can be demonstrated [6] (see an example for tonality in Figure 2). Consequently, cycler SimpliAmp and AllinOneCycler are tonal during all operational states (purple lines in Figure 1). Furthermore, tonality was detected for cycler Prima-96 (PCR, 4 °C) and cycler XT^{96} (4 °C). The Mastercycler X40 as well as the T100 showed no tonality.
It must be noted that the above data reflects the noise levels from a single thermal cycler. In a lab where there is usually more than one cycler at different operational states, the cumulative noise generation would be significant. Figure 3 shows the number of Mastercycler X40 devices which are theoretically needed to generate a comparable noise level as the other evaluated cyclers. Since cycler XT^{96} showed a similar sound power level than the Mastercycler X40 during the PCR run, one Mastercycler X40 device is needed to emit a comparable sound power level. 28, 40 and 36 Mastercycler X40 would have to be used simultaneously to emit a comparable noise level as the cycler T100, Prima-96 and SimpliAmp, respectively. As an extreme example, 78 Mastercycler X40 would be needed to reach the sound power level of one AllinOneCycler.

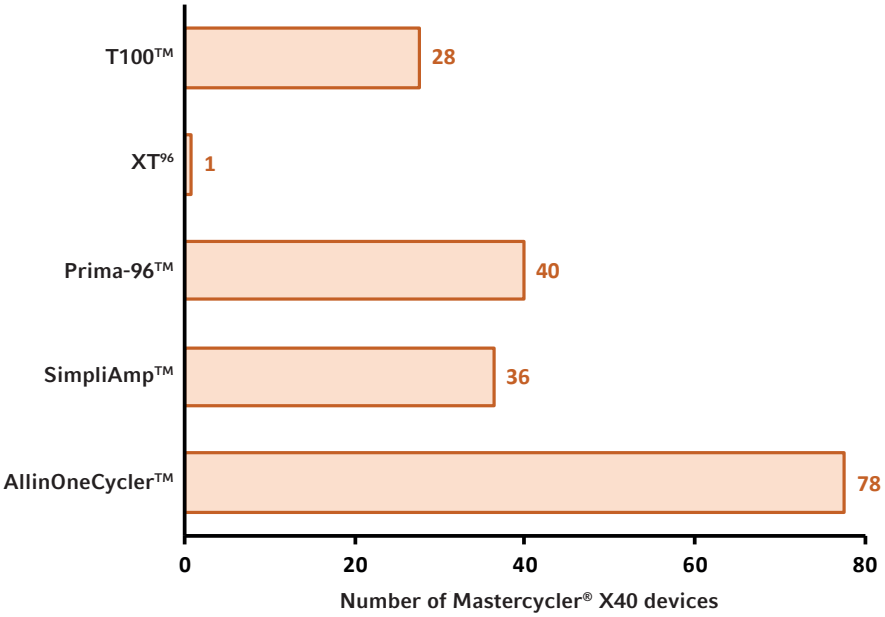

Figure 3: Number (rounded to 1) of the Mastercycler X40 devices needed to generate a corresponding sound power level of the other tested cycler during a PCR program. 10 cyclers correspond to a doubling of the sound power level due to the logarithmic relationship of both parameters.

Conclusion

During all operational states the measurement results presented here show that the Mastercycler X40 did not exceed a sound power level of 41 dB(A). Furthermore, no potential annoyance by tonality was detected for the Mastercycler X40 and the T100 in any operational state. In contrast, the cycler SimpliAmp and AllinOneCycler emitted higher sound power levels (up to 59.6 dB(A)) and tonality was detected in all operational states.

References

[1] Sivakumaran K, Ritonja JA, Waseem H, AlShenaibar L, Morgan E, Ahmadi SA, Denning A, Michaud D, Morgan RL. Impact of Noise Exposure on Risk of Developing Stress-Related Obstetric Health Effects: A Systematic Review and Meta-Analysis. Noise Health. 2022 Jul-Sep;24(114):137-144. doi: 10.4103/nah.nah_22_22.

[2] Thompson R, Smith RB, Bou Karim Y, Shen C, Drummond K, Teng C, Toledano MB. Noise pollution and human cognition: An updated systematic review and meta-analysis of recent evidence. Environ Int. 2022 Jan;158:106905. doi: 10.1016/j.envint.2021.106905

[3] Belojevic G. Noise and performance: research in Central, Eastern and South-Eastern Europe and Newly Independent States. Noise Health. 2013 Jan-Feb;15(62):2-5. doi: 10.4103/1463-1741.107146.

[4] Penney PJ, Earl CE: Occupational noise and effects on blood pressure: exploring the relationship of hypertension and noise exposure in workers. AAOHN J. 2004 Nov;52(11):476-80. PMID: 15587460.

[5] van Kempen E, Casas M, Pershagen G, Foraster M: WHO Environmental Noise Guidelines for the European Region: a systematic review on environmental noise and cardiovascular and metabolic effects: a summary. International Journal of Environmental Research and Public Health. 2018;15(2):379. doi: 10.3390/ijerph15020379

[6] Österreichischer Arbeitsring für Lärmbekämpfung: Schalltechnische Grundlagen für die Beurteilung von Richtlinie. Lärm Nr. 3 Blatt 2 (Lärm am Arbeitsplatz- Ausgabe 2018) ICS: 13.100; 13.140; 17.140.01

[7] Landström U, Åkerlund E, Kjellberg A, Tesarz M. Exposure levels, tonal components, and noise annoyance in working environments. Environment International, 1995; 21(3):265-275. doi.org/10.1016/0160-4120(95)00017-F

[8] Moore BCJ (2007). Cochlear hearing loss: physiological, psychological and technical issues. 2nd Ed. John Wiley & Sons Ltd. ISBN: 978-0-470-51633-1

[9] Stevens SS. On the psychophysical law. Psychological Review 1957; 64 (3): 153–181. DOI: 10.1037/h0046162

[10] Collman R: Sound Power, Sound Pressure.
https://www.acoustical.co.uk/acoustitips/i-sound-power-sound-pressure-technical/

[11] ISO 11690-1:2020. Acoustics - Recommended practice for the design of low-noise workplaces containing machinery - Part 1: Noise control strategies

[12] DIN 45645-2 2012-09: Ermittlung von Beurteilungspegeln aus Messungen – Teil 2:
Ermittlung des Beurteilungspegels am Arbeitsplatz bei Tätigkeiten unterhalb des Pegelbereiches der Gehörgefährdung

Ordering information

Description	Order no.
Eppendorf Mastercycler® X40	6381 000 018
Eppendorf twin.tec® PCR Plate 96 (unskirted, 250 µL)	0030 133 366
Eppendorf Heat Sealing Foil	0030127 854
Eppendorf HeatSealer S200	5392 000 005

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