Sarooma GmbH	Sarooma Recommendations for Residential Spaces	RRS 2023-03

Sarooma Recommendations for Residential Spaces (RSS 2023-03)

In these Sarooma Recommendations for Residential Spaces (RRS), desired reverberation time (RT-) values for typical residential spaces, namely: hallways/ staircases, living rooms, dining rooms, bedrooms, kitchens and living rooms for media usage are set.

An upper limit for the reverberation times in octave bands between 250 Hz and 4 kHz, respectively 125 Hz and 8 kHz for the media living room, is given. The target values are a function of the clear room height and combined with a frequency dependent tolerance range result in reverberation time guideline values. These guideline values should be achieved without consideration of absorption caused by residents.

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1 Motivation

In the past, Sarooma has been contacted by customers seeking advice for the design and planning of residential rooms repeatedly. While a growing demand to also consider acoustic well-being in the planning and design of residential spaces was noted, there seemed to be a gap regarding acoustic requirements and targets for these rooms. The German standard DIN 18041:2016-03 [1] does not target residential spaces, even if some room types covered are similar to residential rooms or can also be found in a residential situation. Especially some room types in group B of [1] are comparable to rooms found in the residential context, e.g., hallways, staircases, dining rooms/areas, residential rooms in care homes, libraries and so on.

This situation led to research and consequently formulation of the recommendations for acoustic target values for residential spaces. Naturally, the group B from DIN 18041:2016-03 provided a basis for this purpose.

2 Derivation from the German DIN 18041:2016-03 group B

Rooms from group B are rooms where acoustic treatment is recommended in order to achieve a reduction of noise and a limitation of the reverberation. In [1] guideline values for the A/V-ratio dependent on the clear room height h are given which apply consistently for all octave bands between 250 Hz and 2 kHz. The A/V-ratio is the ratio between the equivalent absorption area A in m^2 and the volume V in m^3 of the room. For rooms of group B, the equivalent absorption area does not include absorption caused by persons present in the room. The target values are lower limits that need to be achieved or exceeded by the room in planning. In [1], a separation is made between rooms with a clear room height below 2.5 m and rooms with a clear room height above 2.5 m. Table 3 in [1] gives the fixed values for rooms with a clear room height below 2.5 m and formulas for rooms with a clear room height above 2.5 m. The graph in Figure 1 shows the guideline A/V-ratio values for clear room heights from 2.0 m up to 10.0 m. It shows four graphs for the subgroups B2-B5, no requirements are set for B1 rooms in [1].

While the DIN 18041:2016-03 defines A/V-ratios as guideline values, it was our goal to use the reverberation time as the guideline value. This was done because it is a measure that can be (to a certain extend) directly and easily perceived by humans, its concept is easy to understand and it is accessible to measurement, also with non-professional equipment.

It is possible to translate these height dependent A/V-rations to corresponding reverberation times RT_{60} using the Sabine formula for reverberation times in a diffuse sound field at 20 °C:

$$RT_{60} = 0.161 \cdot \frac{V}{A} = 0.161 \cdot (A/V(h))^{-1} \tag{1}$$

Values for the reverberation time for rooms with clear room heights from 2 m up to 10 m for the groups B2-B5 are shown in Figure 2.

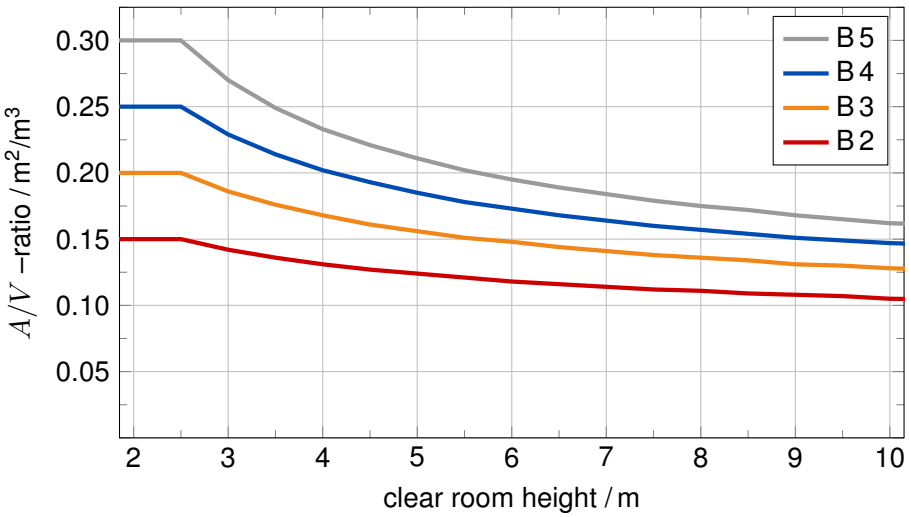


Figure 1: A/V-ratio for groups B2-B4 of the German DIN 18041:2016-03 for clear room heights from 2 m to 10 m.

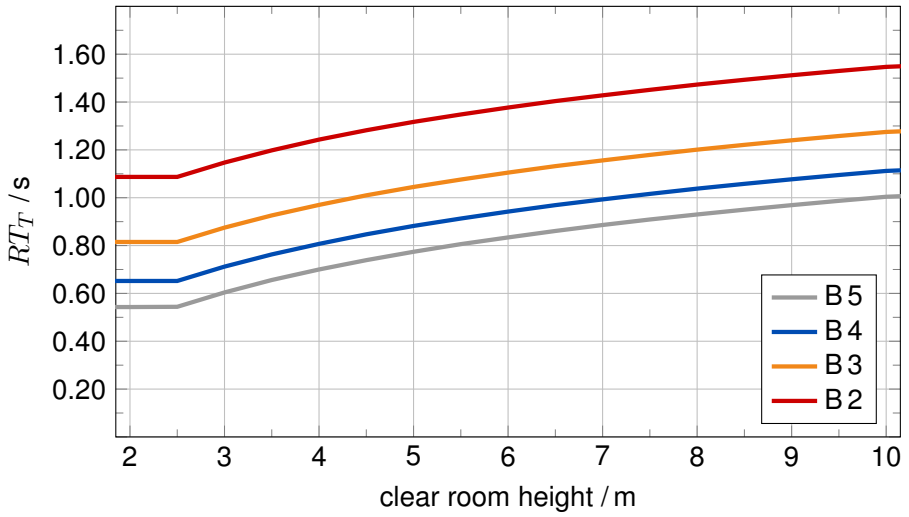


Figure 2: Target-value reverberation times calculated from the A/V-ratios given in [1] for room groups B2-B5.

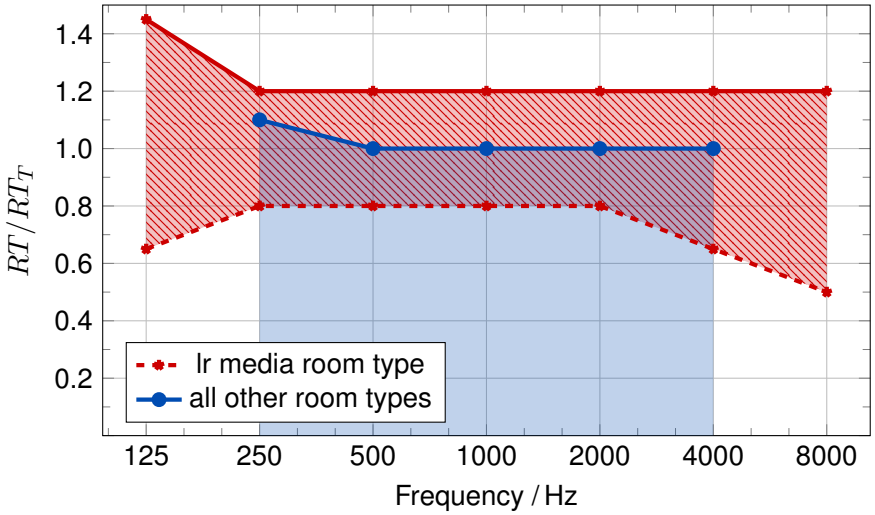


Figure 3: Tolerance ranges as function of frequency for the room types of the Recommendations for Residential Spaces.

While [1] defines constant guideline values for the octave bands from 250 Hz to 2 kHz, these new recommendations use those RT_{60} values as target values RT_T and additionally apply a frequency dependent tolerance range. Residential rooms are categorized into one of the four subgroups B2-B4 and corresponding RT_T are calculated.

3 Recommendations for Residential Spaces

A room is compliant with the (Sarooma) Recommendations for Residential Spaces (RRS) if its reverberation time stays within the reverberation time guideline values for its room type. The following room types are defined (abbreviations given in brackets):

1. Hallway or staircase (*hw/sc*)
2. Kitchen (*ki*)
3. Dining room (*dr*)
4. Bedroom (*br*)
5. Living room (*lr*)
6. Living room (media usage) (*lr media*)

The target reverberation time $RT_T\,(h)$ is dependent on the clear room height h. For each target reverberation time a frequency (f) dependent tolerance range in octave bands from 250 Hz to 4 kHz, respectively 125 Hz to 8 kHz for the living room (media usage) is defined. This yields frequency dependent reverberation guideline values $RT_G\,(h, f)$.

$$RT_G\,(h, f) = RT_T(h) \cdot TF(f) \tag{2}$$

Table 1: Frequency dependent tolerance ranges for the recommendations for domestic rooms in octave bands, as factors $TF\,(f)$.

Freq / Hz	125	250	500	1000	2000	4000	8000
living room (media usage), max	1.45	1.20	1.20	1.20	1.20	1.20	1.20
living room (media usage), min	0.65	0.80	0.80	0.80	0.80	0.65	0.50
all other room types, max	–	1.10	1.00	1.00	1.00	1.00	–

The values of the tolerance range $TF\,(f)$ are given as a factor to be multiplied with the target reverberation time $RT_T(h)$ in Table 1. Moreover, they are visualized in Figure 3. The tolerance range for the room type *lr media* is taken from [1] group A. Its lower limit is not binding but a recommendation instead. The tolerance range of the other room types is inspired by group B of [1], however its range has been extended to include the 4 kHz octave band due to its importance for speech and the fact that it is usually no issue due to abundance of absorption in residential spaces at high frequencies. Moreover, the tolerance for the 250 Hz octave band has been increased to 1.1 instead of 1.0 as it is often not feasible to achieve sufficient absorption in this band and it usually has little influence on the comfort in a residential space, where low frequency content is rare.
The target reverberation time for room type *hw/sc* is defined as follows:

$$RT_T(h) \leq \begin{cases} 1.073\,\mathrm{s} & \text{for} \quad h \leq 2.5\,\mathrm{m} \\ 0.161\,\mathrm{s} \cdot \left(4.800 + 4.690 \cdot \log\left(\frac{h}{1\,\mathrm{m}}\right)\right) & \text{for} \quad h > 2.5\,\mathrm{m} \\ 1.455\,\mathrm{s} & \text{for} \quad h \geq 8.0\,\mathrm{m} \end{cases} \tag{3}$$

It should be noted that these values are meant for hallways and staircases where people are not expected to be spending longer periods of time or where longer conversations are expected. If longer engagement is expected, one should strive for reverberation target values that are between the *hw/sc* and *lr/dr/br* room types.
The target reverberation time for room type *ki* is defined as follows:

$$RT_T(h) \leq \begin{cases} 0.805\,\mathrm{s} & \text{for} \quad h \leq 2.5\,\mathrm{m} \\ 0.161\,\mathrm{s} \cdot \left(3.130 + 4.690 \cdot \log\left(\frac{h}{1\,\mathrm{m}}\right)\right) & \text{for} \quad h > 2.5\,\mathrm{m} \\ 1.032\,\mathrm{s} & \text{for} \quad h \geq 5.0\,\mathrm{m} \end{cases} \tag{4}$$

The target reverberation time for room types *lr, dr* and *br* is defined as follows:

$$RT_T(h) \leq \begin{cases} 0.644\,\mathrm{s} & \text{for} \quad h \leq 2.5\,\mathrm{m} \\ 0.161\,\mathrm{s} \cdot \left(2.130 + 4.690 \cdot \log\left(\frac{h}{1\,\mathrm{m}}\right)\right) & \text{for} \quad h > 2.5\,\mathrm{m} \\ 0.957\,\mathrm{s} & \text{for} \quad h \geq 6.5\,\mathrm{m} \end{cases} \tag{5}$$

The target reverberation times for room type *lr media* is defined as follows:

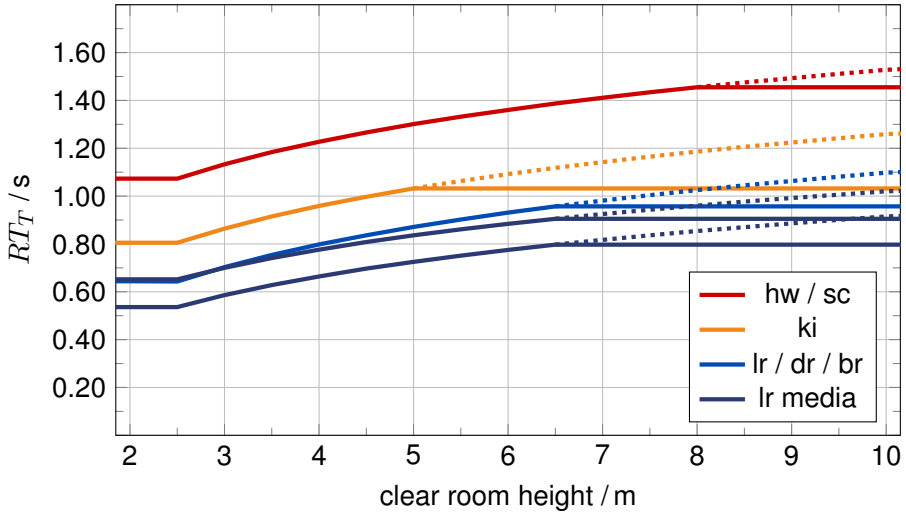


Figure 4: Reverberation time target values $RT_T(h)$ plotted over clear room height for the room types of RRS. Dotted lines show how the formula extends past the point of max recommended height for the room type.

$$RT_T(h) \leq \begin{cases} 0.536\,\text{s} & \text{for} \quad h \leq 2.5\,\text{m} \\ 0.161\,\text{s} \cdot 0.833 \cdot \left(2.130 + 4.690 \cdot \log\left(\frac{h}{1\,\text{m}}\right)\right) & \text{for} \quad h > 2.5\,\text{m} \\ 0.797\,\text{s} & \text{for} \quad h \geq 6.5\,\text{m} \end{cases} \tag{6}$$

Even though calculations and formulas are done respectively given with three decimal places, all guideline values are finally rounded to two decimal places. The values for these room types are visualized for clear room heights from 2.0 m to 10.0 m in Figure 4.
The room height limits where the reverberation time target values are restricted should be considered as upper limit guidelines for the corresponding room type. They are derived from typical residential storey heights and their multiples (e.g. some living rooms might span two storey heights etc.). It is not recommended to go above these values if it is needed however, special consideration is advised.
Reverberation times guidelines shall be met and hence be predicted without consideration of absorption caused by residents.

Moreover, typical absorption coefficients of furnishings for residential spaces such as beds, sofas or regular book-shelves etc. are not the focus of research and thus hardly found in documentations, literature or standards. Hence, collected typical values are supplied within this recommendation, although these should be used with caution and at own risk. Table 2 and Figure 5 show these equivalent absorption area values per object or absorption coefficients in octave bands.

Table 2: Equivalent absorption area A_{Obj} in m^2 or absorption coefficient α (when marked) for furnishings commonly found in residential spaces.

Freq / Hz	125	250	500	1000	2000	4000	8000
Resident	0.09	0.28	0.50	0.78	0.90	1.03	1.07
Desk table (160 x 80) cm	0.05	0.05	0.06	0.08	0.08	0.08	0.10
Dining table, 6p (160 x 90) cm	0.06	0.06	0.07	0.09	0.09	0.09	0.11
Sofa	3.38	4.01	4.90	5.75	7.16	8.10	8.50
Closet	1.88	1.93	1.33	1.28	1.45	1.65	1.75
Bookshelf (α)	0.20	0.22	0.24	0.25	0.25	0.25	0.25
Bed (200 x 160) cm	0.77	3.33	3.20	3.07	3.10	3.26	3.34

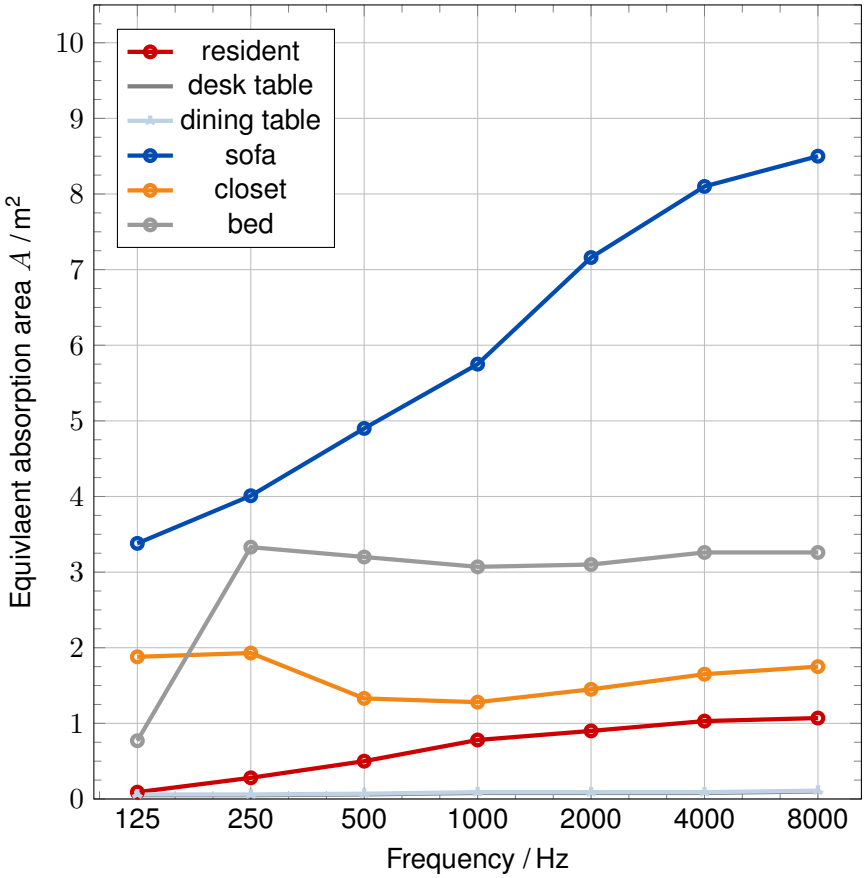


Figure 5: Equivalent absorption area of typical furnishings commonly found in residential spaces.

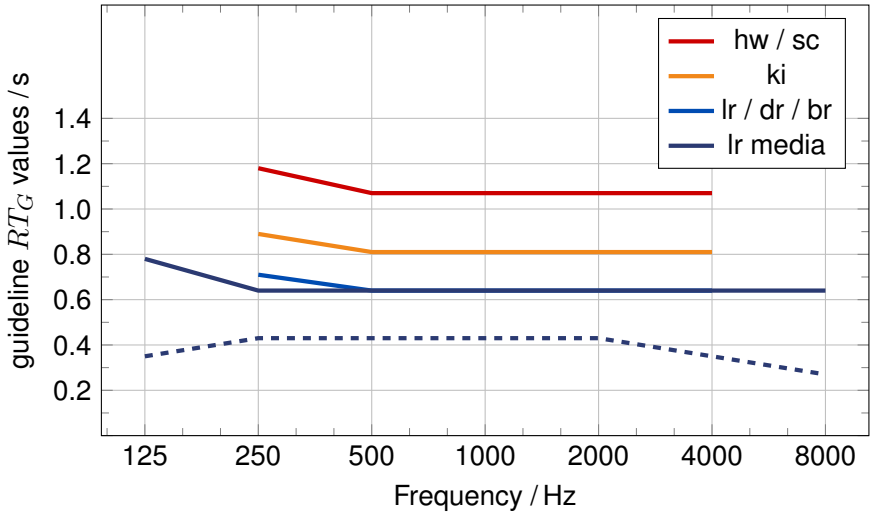


Figure 6: Guideline RT_G values for all room types of this recommendation for a clear room height of 2.5 m and below.

4 Example of calculation

In the following an example of how to calculate the guideline values for a desired room type is given. The guideline reverberation time is going to be calculated for a living room (*lr*) with a clear room height of 2.72 m. To begin with, the reverberation time target value is calculated applying equation (5): The height of 2.72 m is within the range of the formula, yielding:

$$RT_T(2.72\,\text{m}) \leq 0.161\,\text{s} \cdot \left(2.130 + 4.690 \cdot \log\left(\frac{2.72\,\text{m}}{1\,\text{m}}\right)\right) = 0.671\,\text{s}$$

This is the target value that still needs to be equipped with its tolerance range. For room type *lr* the tolerance range is 1.1 for the 250 Hz octave band and 1.0 at all other octave bands up to 4 kHz.
Accordingly, the following guideline values in the octave bands are obtained by multiplying the target value with the tolerance range value for each octave band. The results are shown in Table 3 before and after rounding the result to two decimal places:
A living room with a height of 2.72 m is compliant with the RRS if its reverberation time is less or equal to the RT guideline values given in the last row of Table 3 in all specified octave bands.

To give a better understanding of the recommended guideline values given in this document, Figure 6 shows the guideline values for all room types for a clear ceiling height of 2.5 mand below. These values are the lowest and therefor strictest guideline values encountered.

Table 3: Results of the calculation of guideline values for a living room with height of 2.72 m before and after rounding.

Freq / Hz	125	250	500	1000	2000	4000	8000
RT_G guidelines for living room with $h = 2.72$ m, before rounding / s	–	0.738	0.671	0.671	0.671	0.671	–
RT_G guidelines for living room with $h = 2.72$ m, after rounding / s	–	0.74	0.67	0.67	0.67	0.67	–

References

[1] DIN e.V. (Hrsg.): DIN 18041:2016-03, Acoustic quality in rooms – Specifications and instructions for the room acoustic design, Beuth-Verlag, Berlin, March 2016.