Calculation of:

STC (Sound Transmission Class), R_W (European) as per ISO 717-1, MTC (Music/Machinery Transmission Class), OITC (Outdoor-Indoor Transmission Class)

Note: This document is an extension/adaptation of a document explaining STC and OITC to be found at http://www.peerlessproducts.com/acoustical/STCandOITC.doc
It is expanded (+ additional adjustments and more in-depth comments) with the MTC and R_W single number rating. The related mathematical MTC approach was explained by Dr. Noral D. Stewart a US acoustic consultant, member of ASTM to the Author Eric Desart, who adjusted/expanded this document for use in the studiotips acoustics group.

The additional MTC single number rating was designed by H. Stanley Roller, Architectural Construction Manager, Acoustics, United States Gypsum Company, in order to compensate for the neglect of the STC Class in view of low frequent noise as music and machinery.

TL: Transmission Loss · · · ASTM E-90

TL values per frequency band in one-third octave bands to be used for the calculation of the single number ratings are obtained as per ASTM E-90 and rounded to the nearest whole dB TL value.
This deviate from the European and ISO approach, which mostly use TL values rounded to 1/10 dB. The difference between both approaches can cause differences on the rounded resulting single number ratings of 1 dB. Suggestions were made within ASTM meetings to alter the ASTM E-90 approach to an accuracy of 1/10 dB. However most likely the standard used method of rounding TL values to whole dB values will continue to exist.

STC: Sound Transmission Class · · · ASTM E413-87 (Re-approved 1994)
Classification for Rating Sound Insulation

The Sound Transmission Class (STC) method assigns a single number rating to measured Sound Transmission Loss (TL) data obtained in accordance with ASTM E-90. The method compares a family of numbered contours with one-third octave band TL data covering the one-third octave bands from 125 Hz to 4000 Hz, inclusive. The number of the contour that best fits the data gives the STC rating.

All contours are defined across the one-third octave band range 125 Hz to 4000 Hz, inclusive, and are numbered according to their value at the 500 Hz band. The numbered contours are generated from a reference contour, which defines STC 0. The one-third octave band values of a numbered contour are computed by adding the contour number (which must be an integer) to the reference contour values for all bands.
For example, the 45 contour has a value of 45 dB in the 500 Hz band, as well as 29 dB (45–16 dB) in the 125 Hz band, 32 dB (45-13 dB) in the 160 Hz band, and so on.

STC Reference Contour								
1/3-Octave Band [Hz]	125	160	200	250	315	400	500	630
Reference Contour [dB]	**-16**	**-13**	**-10**	**-7**	**-4**	**-1**	**+0**	**+1**
STC Reference Contour (continued)								
1/3-Octave Band [Hz]	800	1000	1250	1600	2000	2500	3150	4000
Reference Contour [dB]	**+2**	**+3**	**+4**	**+4**	**+4**	**+4**	**+4**	**+4**

To calculate the STC,

1. Select a trial contour for comparison with the measured TL data.
2. Identify bands with "deficiencies", where the measured TL data fall below the contour under consideration. The magnitude of the deficiency is the difference between the TL value and the contour value for that band. *No credit is given for TL data above the contour.*
3. Sum the deficiencies and identify the maximum deficiency.
4. Increase the trial contour number in 1-dB increments to find the highest-numbered contour that meets both of the following criteria:
    a) The sum of the deficiencies is less than or equal to 32 dB, and
    b) The maximum deficiency in any one band does not exceed 8 dB.
5. The resulting value at 500 Hz represents the STC value.

R_W · · · ISO 717-1 ed. 1 1982 and ISO 717-1 ed. 2 1996
ISO European equivalent of the US STC Class

Basically the European approach equals the US approach. The main differences are the frequency range. STC covers the range 125 Hz to 4000 Hz, while R_W covers 100 Hz to 3150 Hz. So both cover 16 one-third octave bands.
STC equals the 500 Hz band of the reference curve with 0 dB, While R_W sets the 500 Hz reference value to 52 dB, equaling a standard separation between houses.
The calculation methods show that this level doesn't matter. Important is the shape of the reference curve (relative weighing), which are comparable for both standards.
ISO 717-1 ed.1 1982 uses the same maximum deficiency 8 dB rule as noted in point 4. b
As such the R_W calculation method of this edition equals exactly the principles described in points 1. to 4.
ISO 717-1 ed.2 1996 skipped this 8 dB rule, substituting this rule by new single number ratings (not covered by this document). The R_W however is still used as a standard single number rating, without inclusion this 8 dB rule (meaning old pré-1996 and new RW's calculated on the same TL values can differ from one another).

ISO 717-1 R_W Reference Contour								
1/3-Octave Band [Hz]	100	125	160	200	250	315	400	500
Reference Contour [dB]	**33**	**36**	**39**	**42**	**45**	**48**	**51**	**52**
ISO 717-1 R_W Reference Contour (continued)								
1/3-Octave Band [Hz]	630	800	1000	1250	1600	2000	2500	3150
Reference Contour [dB]	**53**	**54**	**55**	**56**	**56**	**56**	**56**	**56**

When we should shift this ISO 717-1 R_W reference contour one will notice that the contour is exactly similar to the ASTM E413-87 contour with this difference that ISO has an additional value for the 100 Hz band, and one lacking value for the 4000 Hz.
Since the lowest frequencies are often the most defining ones in the calculation of a single number rating, the standard European approach is a bit more stringent than the US approach.

ISO 717-1 R_W Shifted Reference Contour								
1/3-Octave Band [Hz]	100	125	160	200	250	315	400	500
Reference Contour [dB]	**-19**	**-16**	**-13**	**-10**	**-7**	**-4**	**-1**	**0**
ISO 717-1 R_W Shifted Reference Contour (continued)								
1/3-Octave Band [Hz]	630	800	1000	1250	1600	2000	2500	3150
Reference Contour [dB]	**1**	**2**	**3**	**4**	**4**	**4**	**4**	**4**

To calculate the RW,

1. Contrary to STC, the TL (in Europe called R) values must be given with an accuracy of 1/10 dB
2. Select a trial contour for comparison with the measured TL data.
3. Identify bands with "deficiencies", where the measured TL data fall below the contour under consideration. The magnitude of the deficiency is the difference between the TL value and the contour value for that band. *No credit is given for TL data above the contour.*
4. Sum the deficiencies and identify the maximum deficiency.
5. Increase the trial contour number in 1-dB increments to find the highest-numbered contour that meets both of the following criteria:
   a) The sum of the deficiencies is less than or equal to 32 dB, and
   b) The 8 dB rule
      - Old ISO 717-1 ed. 1 1982:
        The maximum deficiency in any one band does not exceed 8 dB.
      - New ISO 717-1 ed. 2 1996:
        The 8 dB rule is skipped all together and substituted by alternative single number correction factors, one for a more accurate calculated dB(A) weighting and a second for traffic/music noise (not covered by this document).

   This means one should be careful interpreting existing RW's, since values dated before ed. 2 of the standard, cover a bit a different content.
6. The resulting value at 500 Hz represents the R_W value.

MTC: Music/Machinery Transmission Class
Classification for Rating Sound Insulation for music and machinery

Even when R_W is a bit more stringent than STC, both standards, give a very low relative importance in relation to low frequencies, making it a bad approach to rate single number insulation values in function of traffic, mechanical noise sources and music.

Therefore a new class was designed by H. Stanley Roller, Architectural Construction Manager, Acoustics, United States Gypsum Company, in order to compensate for the neglect of the STC Class in view of this low frequent noise.

This class however never became an official standard, and most likely never will be.

The following is a poetic license by the author as a possible explanation (without knowing the exact history, open for corrective suggestions by readers of this document):
Both the European R_W and the ASTM STC class are old norms designed in a period, that computers and electronic calculators were still rare objects, hard to get by. That made logarithmic calculations, on which most acoustic calculations are based, difficult and time consuming, certainly for people the standards where meant for.
This resulted in a more graphical approach, only needing arithmetic calculations. In fact from a mathematical/acoustical approach this is a rather inaccurate approach, which is based on empirical statistics. New norms as OITC and lots of others, are much more logical from a mathematical point of view, taking the nowadays calculation means into account. In fact exact logarithmic calculated single number ratings are easier with current calculation means, than the old approach, which is much more complicated to put in simple formulae.
The MTC Class is 100% based on an STC calculation, with the same reference spectrum and the same frequency range, but with some added restrictions calculated on the two lowest frequency bands of 125 Hz and 160 Hz.
This method was most likely chosen, since it started from a well-known STC calculation procedure, meaning that acceptance of this rather graphical method (complex for easy calculation) could be expected to be good.
However the existence now of the later designed OITC class for outdoor noise (with a much more modern acoustic/mathematical approach) will most likely prevent the MTC to become a new official standard. One can expect that new norms will much more resemble the OITC approach.

STC Reference Contour								
1/3-Octave Band [Hz]	125	160	200	250	315	400	500	630
Reference Contour [dB]	**-16**	**-13**	**-10**	**-7**	**-4**	**-1**	**+0**	**+1**
STC Reference Contour (continued)								
1/3-Octave Band [Hz]	800	1000	1250	1600	2000	2500	3150	4000
Reference Contour [dB]	**+2**	**+3**	**+4**	**+4**	**+4**	**+4**	**+4**	**+4**

A) To calculate the MTC, one first starts with the standard STC procedure

1. Select a trial contour for comparison with the measured TL data.
2. Identify bands with "deficiencies", where the measured TL data fall below the contour under consideration. The magnitude of the deficiency is the difference between the TL value and the contour value for that band. *No credit is given for TL data above the contour.*
3. Sum the deficiencies and identify the maximum deficiency.
4. Increase the trial contour number in 1-dB increments to find the highest-numbered contour that meets both of the following criteria:
   a) The sum of the deficiencies is less than or equal to 32 dB, and

b) The maximum deficiency in any one band does not exceed 8 dB.
5. The resulting value at 500 Hz represents the STC value.

B) Then one adds the following restrictions/additions to the STC procedure:

6. Check if there are deficiencies or surpluses at the 125 Hz and 160 Hz bands (calculated contour versus TL values) after determining the STC contour.
    a) If you have deficiencies in one or both frequency bands, i.e. the TL is less than the contour:
        i) Lower the contour further until these deficiencies are eliminated.
        ii) Then read the MTC as the value of the contour at 500 Hz, yielding an MTC that is lower than the STC.
    b) If after determining the STC, you have surpluses at 125 AND 160 Hz, or surpluses at 125 OR 160 Hz while the other value is 0 (meaning contour not lowered by point 6. a) the MTC is going to be more than the STC:
        i) Add the surpluses at 125 and 160 Hz.
        ii) Divide that sum by 3, and round result to the unit (whole dB's).
        iii) Add the result to the STC, with this limit that the MTC can never be more than STC plus 4.

OITC: Outdoor-Indoor Transmission Class · · · ASTM E1332-90 (Re-approved 1994)
Standard Classification for Determination of Outdoor-Indoor Transmission Class

ASTM under the leadership of another USG staff member Keith Walker, did standardize another measure:
The Outdoor-Indoor Transmission Class (OITC) method assigns a single number rating to measured Sound Transmission Loss (TL) data obtained in accordance with ASTM E-90. The OITC is defined as the A-weighted sound level reduction of a test specimen in the presence of an idealized mixture of transportation noises: aircraft takeoff, freeway, and railroad passby. The rating is computed from measured TL data in one-third octave bands from 80 Hz to 4000 Hz, inclusive.

Note from the author: The OITC approach is a modern acoustic/mathematical logic and easy to calculate approach. One can enter the whole standard in one single formula. In fact one can easily substitute the reference spectrum by any custom spectrum covering any frequency range one desires. The level of the spectrum itself doesn't matter since the logarithmic sum factor 100.13 is integrated to correct the formula to a frequency related energetic distribution. In arithmetic terms: the spectrum and its sum is used to recalculate the relative contribution (percentage) of the individual frequency bands, versus a total of 100%.
In order to use this approach for other spectra, just enter a dB(A) weighted spectrum, calculate the logarithmic sum of this spectrum, and substitute the factor 100.13 by this logarithmic total.

To compute the OITC:

1. Subtract the measured specimen TL for each one-third octave band from the corresponding A-weighted Reference Spectrum for that band. A-weighted Reference Spectrum levels are:

A-weighted Reference Spectrum									
1/3-Octave Band [Hz]	80	100	125	160	200	250	315	400	500
A-weighted Reference Spectrum [dB(A)]	**80.5**	**82.9**	**84.9**	**84.6**	**86.1**	**86.4**	**87.4**	**88.2**	**89.8**
A-weighted Reference Spectrum (continued)									
1/3-Octave Band [Hz]	630	800	1000	1250	1600	2000	2500	3150	4000
A-weighted Reference Spectrum [dB(A)]	**89.1**	**89.2**	**89.0**	**89.6**	**89.0**	**89.2**	**88.3**	**86.2**	**85.0**

1. Perform a logarithmic sum of the one-third octave band results of Step 1,
2. The OITC is the difference, rounded to the nearest decibel, between the value 100.13 and the logarithmic sum from Step 2. Note this value of 100.13 is the to 2 decimals rounded logarithmic sum of the A-weighted reference spectrum

The entire process can be conveniently expressed in a mathematical equation:
where $AWRS_i$ is the A-wt. Reference Sound Level and TL_i is the Sound Transmission Loss, for each one-third octave band. (The second term of this equation is the logarithmic sum mentioned in Step 2.)

$$OITC = 100.13 - 10 \cdot \log \left\{ \sum_{i=80Hz}^{4000Hz} 10^{\frac{(AWRS_i - TL_i)}{10}} \right\}$$

Note – Older TL test reports, and TL test reports from some laboratories with smaller reverberation chambers, may not include data for the 80 Hz and 100 Hz bands. Such test reports cannot be used to compute OITC.

<u>Note from the Author</u>:
While indeed a deviating frequency range does not allow an official OITC value as per the current standard, the method easily allows to adjust the frequency range (explained before in document) resulting in an unofficial single number rating, but which is still much more representative than the alternative STC rating when low-frequent noise is involved.

Remember: One can easily apply the method for specific purposes as e.g. standardized music spectra.