APPENDIX

B Integrated Level Calculations

Basic Integrated Level Calculations

The Larson Davis System 824 calculates all of its integrated levels based on equations from IEC standard 804. IEC-804 Section 3.3 defines L_{eq} as follows:

Equivalent continuous A-weighted sound pressure level (also average A-weighted sound pressure level) is defined as follows

$$L_{\mathrm{Aeq,T}} = 10\lg\left\{\left(\frac{1}{T}\int_{t_1}^{t_2} p_A^2(t)dt\right) \div p_0^2\right\}\mathrm{dB}$$

where:

$L_{Aeq,T}$ is the equivalent continuous A-weighted sound pressure level re 20 µPa, determined over a time interval $T=t_2-t_1$

$p_A(t)$ is the instantaneous A-weighted sound pressure of the sound signal

p_0 is the reference sound pressure of 20 µPa

When, a frequency weighting other than A is used, the frequency weighting used shall be included explicitly in the

title and the formula of the quantity, for example equivalent continuous C-weighted sound pressure level:

$$L_{\mathrm{Ceq,T}} = 10\lg\left\{\left(\frac{1}{T}\int_{t_1}^{t_2} p_C^2(t)\,dt\right) \div p_0^2\right\}\mathrm{dB}$$

If no frequency weighting is used, the quantity is simply called equivalent continuous sound pressure level.

The Larson Davis System 824 calculates many time-integrated levels or time-weighted averages (TWA) based on different parameters and time intervals. They are all designed and programmed to perform the equation specified in IEC 804 (above) with allowances for the following:

A, C and Flat frequency weighting characteristics

Various interval times, both fixed interval TWAs and variable interval event TWAs

Exchange-rates, or "doubling rates" can be entered that effect certain TWA measurements

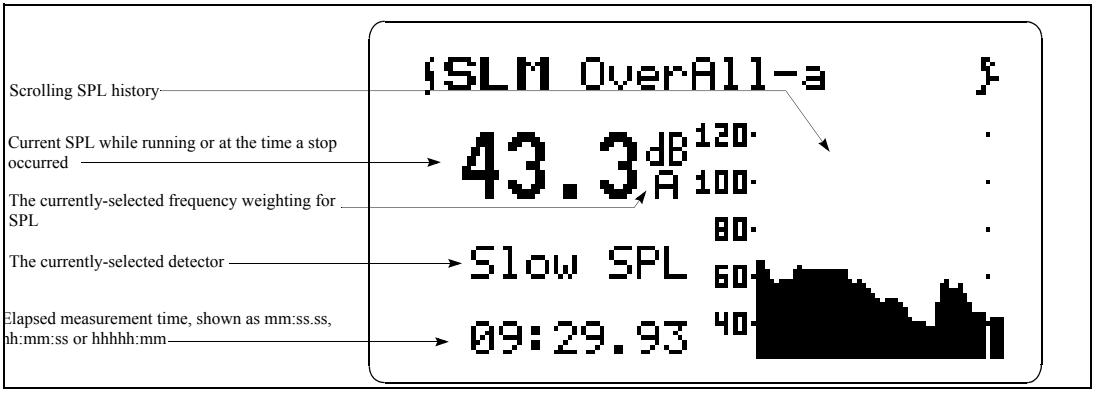
Certain TWA measurements include a programmable threshold with only levels above this threshold contributing to the measurement

The titles for the measurements are designed to indicate the current exchange rate in force: "L_{eq}" is used to designate TWAs based upon a 3 dB exchange rate, "L_{DOD}" (for United States Department of Defence) is used to designate TWAs based upon a 4 dB exchange rate, "L_{OSHA}" (for the United States Occupational Safety and Health Association) is used to designate TWAs based upon a 5 dB exchange rate, "L_{Avg}" (for average) is used to designate TWAs based upon a 6 dB exchange rate.

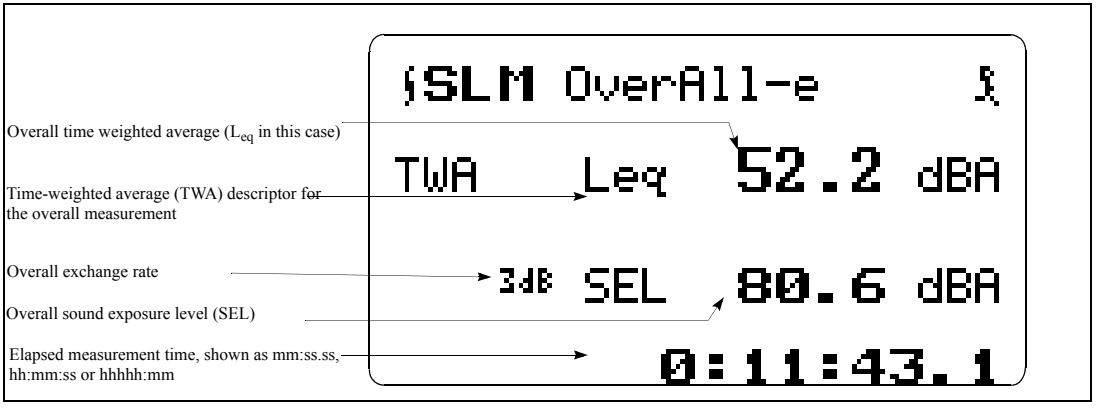
No attempt is made to meet the IEC-804 requirement to title the TWA by frequency weighting and time interval within the analyzer's display or report system. It is represented

though, by placing the weighting designation following the "dB" units indication associated with the numerical output. The actual measurement time is also provided for each TWA value to fulfil the time interval description requirements.

For example, the System 824's Logging SLM Overall-a display shows the current SPL (Sound Pressure Level) in 1/10th decibel (dB) resolution. The actual real-time resolution is 1/32nddB. The displayed SPL is followed by the text "dB" and then the frequency weighting in effect—set to **A** in this example.



The System 824's Logging SLM Overall-e display shows the overall measurement period and TWA. In this case the measurement is L_{eq} (because of the 3dB exchange rate). The quantity is A-weighted and has a measurement elapsed time of 11:43.1 (11 hours, 43 minutes, and 1 second).



The actual equations used within the analyzers are based on that for IEC-804 and are implemented according to this equation:

$$L_{TWA} = L_{cal} + k \bullet \log\left(\sum_{s=1}^{n} 10^{\frac{L_{(s)}}{k}}\right) - \log(n)$$

where:

$L_{(s)}$ is the current SPL at sample s (for measurements that include a threshold, $L_{(s)}$ is set to -× if $L_{(s)}$ is less than the Threshold Level L_t)

k is the exchange rate constant which is equal to:

10.00 for an exchange rate of 3 dB (L_{eq})

13.29 for an exchange rate of 4 dB (L_{DOD})

16.61 for an exchange rate of 5 dB (L_{OSHA})

20.00 for an exchange rate of 6 dB (L_{Avg})

n is the total number of samples taken in the measurement; the sample rate is 32 samples per second, and

L_{cal} is the calibration offset that corrects for various sensitivities of microphones

Accuracy is maintained by having large fixed point variables for the number of samples and the summation accumulator. The limit of *s* is 4,294,967,295 samples and is stored in a 32 bit integer variable within the System 824. This limit is greater than 1553 days or greater than 4 years and 4 months. The value that can be stored in the summation accumulator, a 96 bit integer, can be the overload level (maximum allowable signal amplitude into the System 824) for the maximum number of samples. Using large fixed point variables prevents the inaccuracies obtained in systems based upon floating point variables.

SEL Calculations

SEL is available for both the overall and current measurements and is calculated using this formula:

$$L_{TWA} = L_{cal} + k \bullet \log\left(\sum_{s=1}^{n} 10^{\frac{L_{(s)}}{k}}\right) - \log(32)$$

Since the sample rate is 32 samples per second and SEL is based on time in seconds, the log(32) is subtracted from the log of the accumulation to perform a division by 32. All of the SEL energy values in the analyzers utilize the Threshold and Exchange Rate settings. Care should be taken when modifying these settings since some standards or governments require SEL to be taken without a Threshold (set it to zero) and with an Exchange Rate of 3 dB.

Dose and Projected Dose Calculations

Dose is a measure of Sound Exposure and is defined in ANSI S1.25 Section 4.7 as:

$$D(Q) = \left(\frac{100}{T_c}\right) \cdot \int_0^T 10^{\left(\frac{L - L_c}{q}\right)} dt$$

where:

D(Q) is the percentage criterion exposure for exchange rate Q

T_C is the criterion sound duration = 8 hours

T is the measurement duration in hours

t is the time in hours

L is the SLOW, (or FAST) A-weighted sound level, a function of time, when the sound level is greater than or equal to *L*, or equals -× when the A-weighted sound level is less than L_t

L_t is the threshold sound level specified by the manufacturer

L_C is the criterion sound level specified by the manufacturer

Q is the exchange rate in dB, and *q* = the parameter that determines the exchange rate, where:

q = 10 for a 3 dB exchange rate

q = 5/log(2) for a 5 dB exchange rate

q = 4/log(2) for a 4 dB exchange rate

The factor of 100 in the equation produces a result that is a percentage.

Dose is obtained from the accumulations made for TWA and SEL using the formula:

where,

$L_{(s)}$ is the current SPL at sample *s*; for measurements that include a threshold $L_{(s)}$ is set to × if $L_{(s)}$ is less than the Threshold Level L_t

$$DOSE = 10^{\left[\log\left(\sum_{s=1}^{n} 10^{\frac{L_{(s)}}{k}}\right) - \frac{L_c}{k} - \log(T_c 115200) + \log(100)\right]}\%$$

k is the exchange rate constant which is equal to:

10.00 for an exchange rate of 3 dB (L_{eq}, or Ý 3 dB/log(2))

13.29 for an exchange rate of 4 dB (L_{DOD}, or = 4 dB/log(2))

16.61 for an exchange rate of 5 dB (L_{OSHA}, or = 5 dB/log(2))

20.00 for an exchange rate of 6 dB (L_{Avg}, or Ý 6 dB/log(2)),

n is the total number of samples taken in the measurement; the sample rate is 32 samples per second,

T_C is the criterion sound duration as set by the System 824's "Criterion Time Hours" setting which by default is set to 8 hours (since the time base for the instrument is 1/32nd samples per second, the number of hours is multiplied by 115200 to make samples per hour—60 minutes/hour times 60 seconds/minute times 32 samples/sec equals 115200 samples/second)

L_C is the criterion sound level as set by the System 824's "Overall Criterion" or "Current Criterion" settings

Addition of the term "log(100)" was used to implement the 100 multiplier of the ANSI equation that creates the percentage. Subtracting the log of the Criterion Time was used to implement the division of Criterion Time of the ANSI equation.

Projected Dose in the analyzers is obtained with an equation similar to that of Dose except that the actual duration (time) of the measurement is used rather than a Criterion Time, as thus:

$$\text{PROJDOSE} = 10^{\left[\log\left(\sum_{s=1}^{n} 10^{\frac{L_{(s)}}{k}}\right) - \frac{L_C}{k} - \log(n) + \log(100)\right]}\%$$

where the log(*n*) is the actual time factor, *n* being the total number of samples taken.