MODEL 3090 ENGINE EXHAUST PARTICLE SIZER™ (EEPS™) SPECTROMETER ANALOG OUTPUT

APPLICATION NOTE EEPS-001

Four Analog Outputs

EEPS™ Model 3090 spectrometers now come standard with four configurable analog outputs. These analog outputs offer users a convenient way to incorporate particle emission measurements into the dynamometer host data collection system.

Each analog output operates independently, and is configurable for size range, weighting and concentration range using a linear or log scale output.

→Size Range: Adjustable, single channel output only up to full range (5.6nm – 562.3nm)
→Weighting: Number, Surface Area, Volume, Mass, Custom
→Concentration: Concentration (dN), Normalized Concentration (dN/dlogDp)

An example where a user might be interested to set a defined size range would be to output measurements of either the accumulation mode particles (i.e., soot) or the nucleation mode particles (SOF). Spin buttons in the software make it easy to select standard EEPS™ spectromenter channel boundaries, or specific sizes can be entered.

Specifications

Analog Output	4 channels; 500 V isolation
Resolution	14 bit D/A
Update Rate	1 Hz
Output	Configurable; 0–5 V and 0–10 V
Averaging Time	Adjustable; 1-10 seconds
Connector Type	BNC

Modified Back Panel

Figure 1

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Configuration

The analog outputs have standard calculations for number concentration, surface area concentration, volume concentration and mass concentration (when a density value is entered) as shown in Figure 2.

Weighting	Weighting Constant	Power of D (diameter)	Density	Units
Number	1	Zero	Not Applicable	#/cm^3
Surface Area	π	Squared	Not Applicable	nm^2/cm^3
Volume	π/6	Cubed	Not Applicable	nm^3/cm^3
Mass	π/6	Cubed	Selectable	µg/m^3
Custom	Selectable	Selectable	Selectable	µg/m^3

Figure 2

Note: *All standard calculations for surface area, volume and mass assume spherical particles. Since engine exhaust particles can be non-spherical there is a custom setting that allows a user to input any value for the weighting constant, power of diameter and density.*

Configuration of the analog output parameters is performed using the Analog Out tab of the Properties window in the EEPS™ spectromenter software (Figure 3).

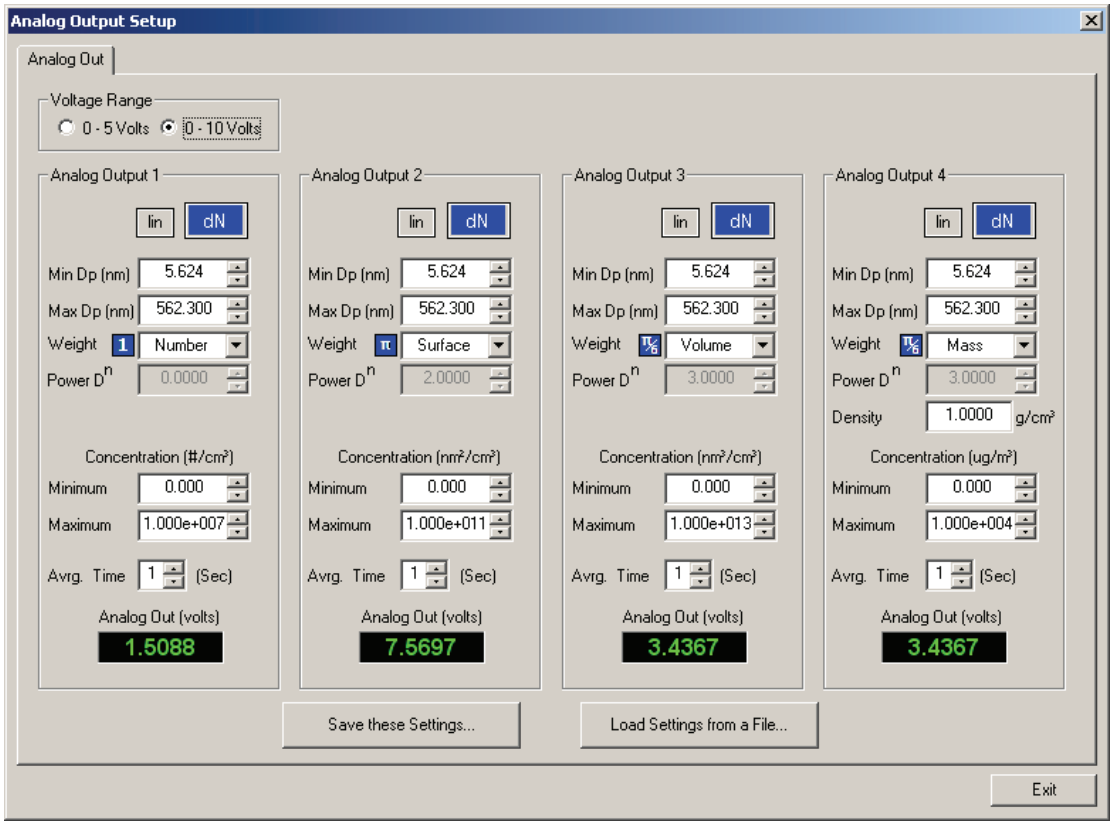

Figure 3

Calculations

The calculations for determining the output voltages for any choice of setting are based on the formulas shown below. The concentration calculation is based on summed concentrations in each EEPS™ spectrometer size channel (or portion of a size channel) to cover the total size range multiplied by a diameter weighting (diameter to some power) and multiplied by appropriate constants for the selected weighting and other settings:

Concentration Signal: $$C_S = \rho_e \cdot K \cdot \sum_{\mathrm{Dp,min}}^{\mathrm{Dp,max}} \left[\left(\frac{dN}{d \log D_{pc}} \right) \cdot \left(d \log D_{pw} \right) \cdot D_p{}^n \right] \cdot N_o$$

Where:

dN = Particle number concentration
ρ_e = Particle Density
K = Weighting Constant
$\sum_{Dp,min}^{Dp,max}$ = Summation of channels or partial channels within the overall size limits
D_{pc} = Particle diameter size channel limits
D_{pw} = Particle diameter range (that can be less than one channel width)
D_p^n = Particle diameter (midpoint of size range – channel or partial channel) to the n power

$$d\log D_{pc} = \log\left(\frac{D_{upper}}{D_{lower}}\right)$$

where D_{upper} and D_{lower} are the upper and lower channel size boundaries

$$d\log D_{pw} = \log\left(\frac{D_{upper}}{D_{lower}}\right)$$

where D_{upper} and D_{lower} are the upper and lower size boundaries

$$N_O = \frac{1}{\log\left(D_{p\max} / D_{p\min}\right)}$$ if Normalized mode is selected

$N_O = 1$ if Normalized mode is not selected

Output Voltage:

$$V_O = V_{fs} \cdot \frac{\left(C_s - C_{fs,\min}\right)}{\left(C_{fs,\max} - C_{fs,\min}\right)}$$ for linear mode

$$V_O = V_{fs} \cdot \frac{\left(\log C_s - \log C_{fs,\min}\right)}{\left(\log C_{fs,\max} - \log C_{fs,\min}\right)}$$ for log mode

Where:

$C_{fs,\min}$ = Concentration minimum value (cannot be zero is log mode is used)
$C_{fs,\max}$ = Concentration maximum value
V_{fs} = Voltage full scale

Upgrade Availability (Model 3090-Upgrade)

Engine Exhaust Particle Sizer™ Spectrometers manufactured prior to August 2006 can be upgraded during the recommended annual calibration and repair for an additional charge. Contact your TSI sales representative for pricing information.

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