AwaSys 7
user manual

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AwaSys7

Two and three dimensional wave generation

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by Lykke Andersen, T., Meinert, P. and Frigaard, P.

The AwaSys is a wave generation program which is capable of generating both 2-D and 3-D waves including active absorption of reflected waves. Online analysis of incident and reflected waves are used to visualize generated waves to the user.

Three techniques for wave generation are implemented:
1. Random phase method
2. Random complex spectrum method
3. White noise filtering method

The random phase method is a deterministic method simulating random waves in the frequency domain by assigning random phases to each frequency component. Subsequent use of the inverse FFT transformation provides the time domain representation of the wave train. The random complex spectrum method is a non-deterministic method based on inverse FFT transformation. Both FFT based methods provides a discrete spectrum, i.e. energy is only introduced at certain frequencies.

The white noise filtering method is a non-deterministic method, which simulate random waves in the time domain by means of digital filtering of white noise. Filters are generated in accordance with the specified energy spectrum.

Non-linear interaction between the individual wave components in the wave trains give rise to the so-called group bounded long waves, which are of second order. In all wave synthesis techniques, a correct reproduction of the group bounded long waves is possible. For the InvFFT based methods a correct reproduction of the bound 2nd order superharmonics is possible.

Two active absorption systems are available.
1. System based on Frigaard and Brorsen (1995) method. The system uses two wave gauges in the far-field and the calculation of the paddle displacement correction signal needed for absorption of the reflected waves is determined by digital filtering and subsequent superposition of the two filtered surface elevation signals.
2. System based on Lykke Andersen et al. (2016). System has many similarities with systems presented by Milgram (1970) and Schäffer and Jakobsen (2003). The system uses one wave gauge on the paddle front to determine deviation from generated near-field waves. This deviation signal is send to a digital filter leading to a paddle correction signal. The advantage of the system is that it has better performance for long waves and can be applied in 3-D situations.

AwaSys 7 Help Document

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1. Installing AwaSys

Prior to installation of AwaSys, the device-drivers for the selected data-acquisition hardware must be installed. Currently hardware from Data Translation®, National Instruments® and Measurement computing® are supported as well as RS232 digital communication with two types of servo controllers.

Running "SetupAwaSys.exe" will start a wizard, which will guide through the installation process of AwaSys. First time AwaSys is run, the user will be prompted for the hardware manufacture to use for input and output. This question is asked only if the configuration file for AwaSys is not present.

If the hardware drivers are not installed for the manufacture selected, AwaSys will cause an error and terminate. Next time AwaSys is executed it will ask again.

If drivers are installed, but no hardware is found, AwaSys will ask whether to switch manufacture. This can be done seamless if driver and hardware for new manufacture are present. Manufacture can be altered later on in the program by holding SHIFT key down when starting the program.

To uninstall AwaSys, select the uninstall menu item in start menu or use add/remove programs in control panel. Only program files are removed, settings and previous parameters will not be deleted.

The calibration procedure of the wave generation involves:
1. Setup general parameters in preferences like generator type etc.
2. Determination of transfer constant for paddle. This can be done from manual signal by sending out different voltage levels and measure corresponding movements.
3. Calibration of feedback signal (see documentation for Preferences dialog)
4. Determine mechanical frequency response using measure gain and delay dialog.
5. Configuration of wave gauge setup (distance to paddle and calibration of gauges)
6. Self Test of system setup
7. Optimization of absorption filters for different water depths
8. Test of generated 2-D waves (regular and irregular) for low and high reflective conditions and different sea states
9. Test of generated 3-D waves for low and high reflective conditions and different sea states

2. Configuring PC for optimal performance

The standard configuration of most PCs will work fine with AwaSys. However, increased timing accuracy can be archived by following the recommendations given here.

Set below settings in BIOS and Windows. Note that some of the cost of some of these settings to increase timing accuracy is that the PC will use more power.

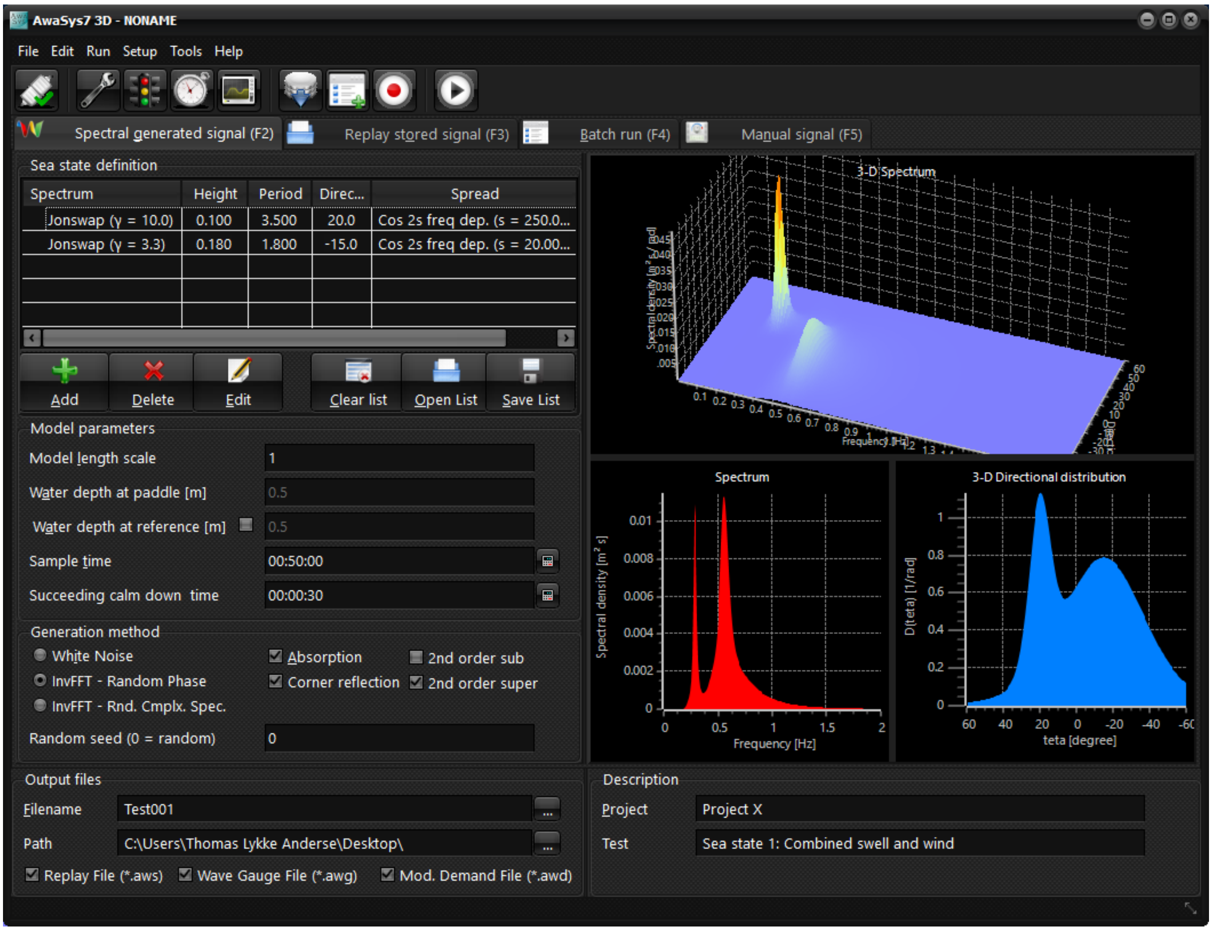
BIOS CPU configuration

- Ensure that the BIOS is up-to-date from the motherboard manufacturer
- Disable Hyperthreading

Windows Configuration

- Ensure that all system drivers are up-to-date from the chipset/motherboard/expansion card manufacturer.
- Apply all updates from Windows Update.
- Third party management software should not be installed, or stopped from running at start up, except where mandatory.
- To allow AwaSys to set real-time class for best timing accuracy the security policy has to be changed (Administrative tools->Local Security Policy->User Rights Assignment->Increase Scheduling Priorities). An alternative to modify the user rights is simply to run AwaSys as administrator.
- Use regedit to change the value of HKLM\System\CurrentControlSet\Control\PriorityControl \Win32PrioritySeparation to 28 hexadecimal (40 decimal) for short fixed thread quantum without foreground boosting.
- Control Panel -> Power Settings --> Change Plan Settings for High Performance--> Advanced Power Settings -> Switch off "PCIe Bus Link State Management"
- Control Panel -> Power Settings --> Change Plan Settings for High Performance --> Advanced Power Settings -> Disable "USB selective suspend setting"
- Windows Update->Change settings->Turn off "Automatic Update Checking" (check manually when AwaSys is not running)
- Ensure Windows Defender is not set to run automatically
- Disable the Indexing Service (Windows Search)

3. Main window



When starting AwaSys the main window is displayed, from which all operations are initiated.The main window consists of a menu-bar in the top and a toolbar below, for quick-access to some menu-items.

Icon		*Function*
	:	Toggle connection to DAQ board (connect/disconnect)
	:	Show Preferences
	:	Calibrate wave gauges
	:	Measure paddle gain and delay and create a mechanical transfer file
	:	Self-test to perform a self test of the system setup and to calibrate wave gauges by performing waves as an alternative to above direct calibration.
	:	Save test parameter file (for import in WaveLab Data Acquisition component)
	:	Add test to batch list
	:	Generate replay file
	:	Start generation

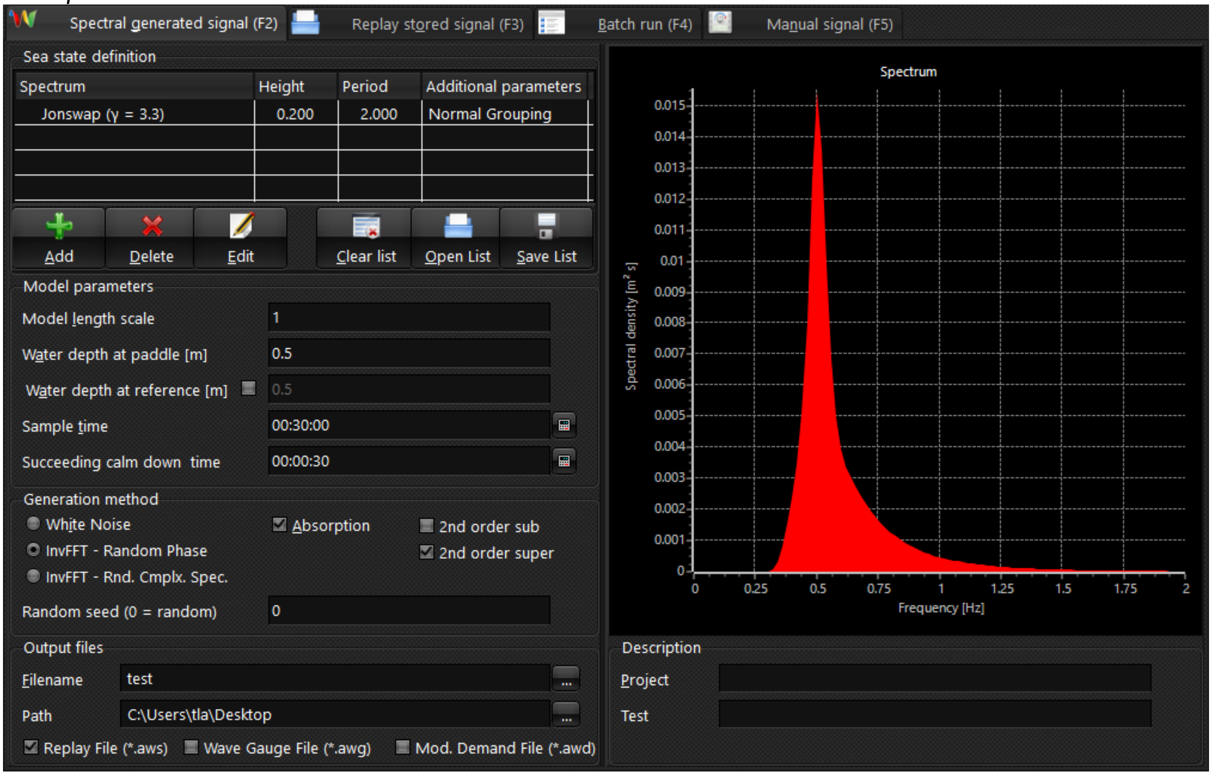
The body of the window is split into four pages:

1. Spectral generated signal
2. Replay stored signal
3. Batch run
4. Manual signal

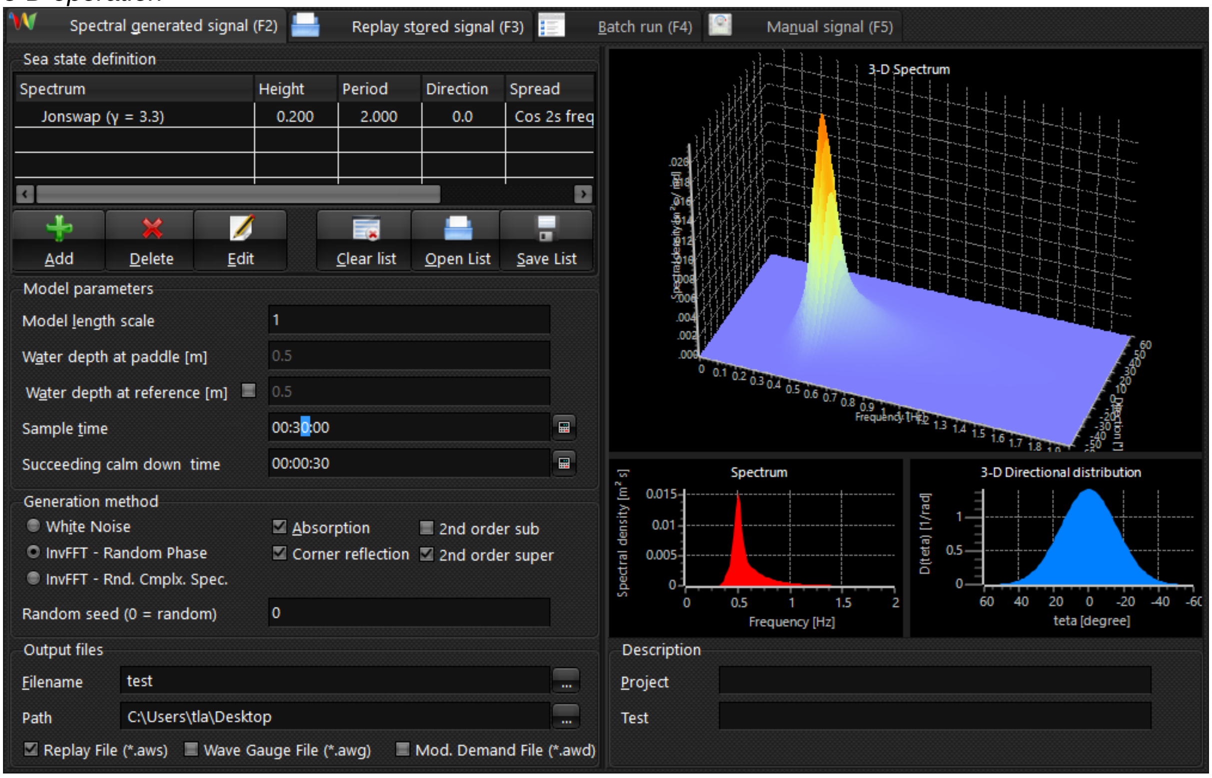
3.1 Spectral generated signal

The layout of the spectral generated signal tab differs depending on the setup. If AwaSys is setup for 3-D operation some additional input fields appears. To start a generation press Start button. A replay file can be generated according to selected sea state by clicking "Only generate replay file" button (record button). In this way the steering signal can be inspected before generation if wanted.

2-D operation



3-D operation



Sea state definition:

This list presents a summary of the sea state to produce. Normal sea states would contain only one item in the list, but advanced sea states can be generated as a combination of sea states. This can for example be a combination of two irregular seas to give combined wind and swell conditions or a combination of two regular waves to give bicromatic waves. Items can be added or removed from the list using the buttons below. List can also be saved and later opened again. To edit an item double click on the item or single click and select edit button.

Note that for bi-modal spectra (Torsethaugen) it is also possible to right click in the list and select to split selected spectra into individual components. In this way primary and secondary sea can have different main direction and directional spreading.

When selecting individual items the spectrum of that item is presented in the figures in the right hand side. When no item is selected the spectrum of the combined sea is shown.

Model parameters:
This group of parameters define parameters for the model (model scale):

Field		*Description*
Model length scale	:	Wave parameters can be provided in prototype scale. In that case model parameters are obtained from Froude scaling using the length scale ratio (Lp/Lm). Note: TimeScale = SquareRoot(LengthScale)
Water depth at paddle	:	Model water depth at wavemaker.
Water depth at reference	:	Model water depth reference for defined sea state. Waves are transformed to paddle by linear shoaling.
Sample time	:	Model sample time in the format HH:MM:SS. If 00:00:00 is automatic changed to 23:59:59 for generation until user intervention
Succeeding calm down time	:	Speed up testing by using absorption to calm down the water-surface after the sample time has elapsed.

Generation method:
This group of parameters define the wave synthesis method to use.

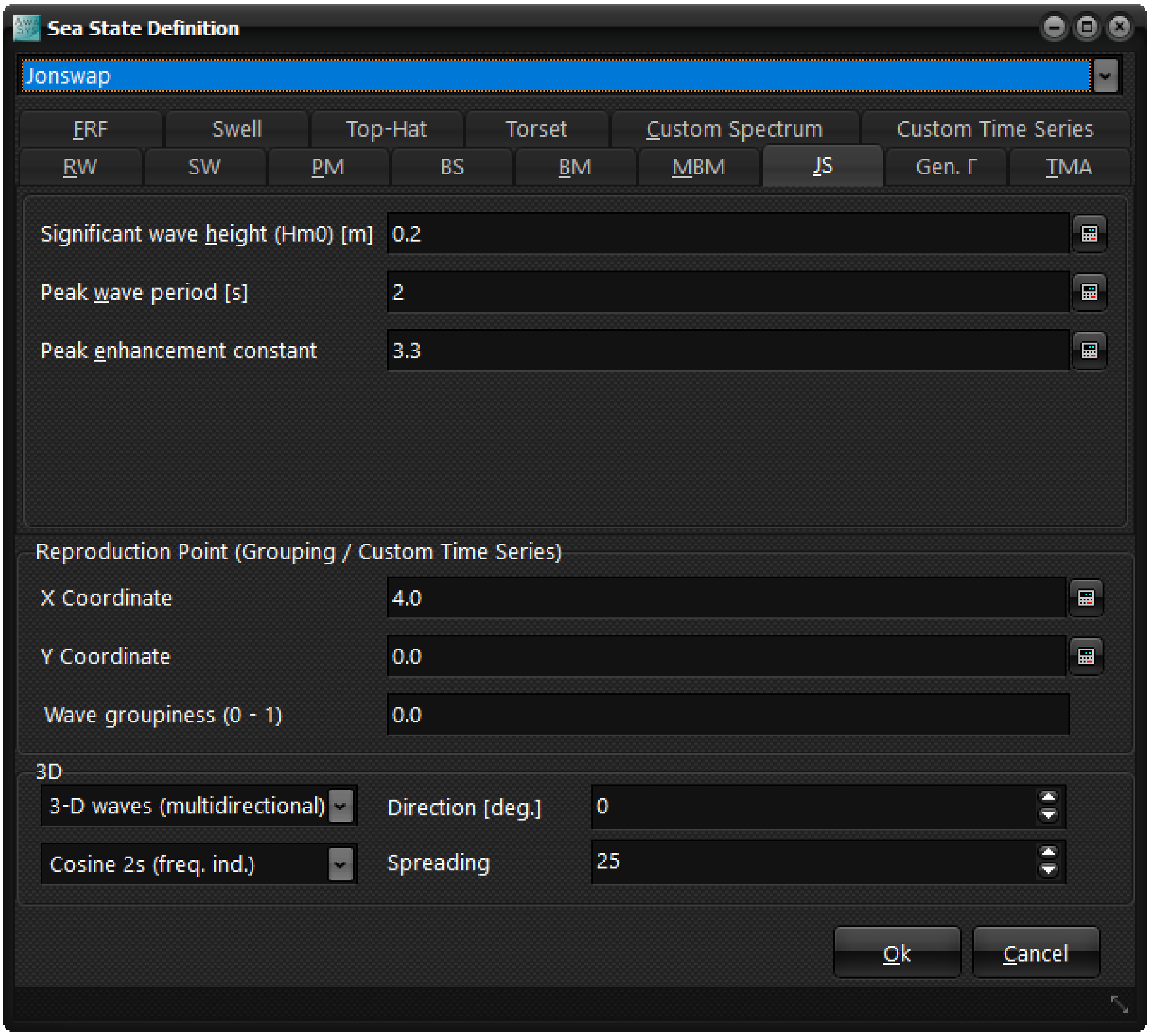
Field		*Description*
White noise	:	Generate waves using the white noise method (non-deterministic method).
InvFFT - Random phase	:	Generate spectra using the random phase method (deterministic method). The repeat time of the signal can be adjusted by adjusting "Inverse FFT length" and "Oversampling factor" under Additional settings.
InvFFT - Rnd. Cmplx. Spec.	:	Generate spectra using the random complex spectrum method (non-deterministic method). The repeat time of the signal can be adjusted by adjusting "Inverse FFT length" and "Oversampling factor" under Additional settings.
Random seed value	:	When generating with InvFFT based methods, the same series of waves can be repeated by setting a random seed value. If random seed value is set to 0, randomize is performed to set the seed value. Randomize sets uses a algorithm to set the seed value from the current value of the computers internal clock.
Absorption	:	Absorb reflected waves. Note that this require the absorption parameters and filters under Operation are set correct.
Corner Reflection		Increase area with correctly generated short-crested or oblique long-crested waves by using side reflectors. Setup side reflector length in preferences.
2nd order sub	:	Correct reproduction of bound 2nd order sub harmonics (bound long waves).
2nd order super	:	Correct reproduction of bound 2nd order super harmonics.

Output files:
Base file name for storing of replay file, wave gauge signals and modified demand signals into files. The replay file (aws) contains data needed for later replay of identical wave trains. For more information on the file layout refer to the help for replay. The wave gauge file (awg) contains the measured surface elevations as used for active absorption and online analysis. If secondary channels to be acquired have been defined then wave gauge file will also contain these signals. Note all signals in awg file are including the calibration coefficient and offset. The modified demand file (awd) contains

the modified steering signals including mechanical transfer, active absorption correction, clipping and gain up and down. The sample frequency of the replay file is communication frequency divided by oversampling factor for irregular waves and the communication frequency for regular and solitary waves. The sample frequency of the wave gauge and modified demand files is in all cases the communication sample frequency.

Description:
Description of project and test to be stored in header of output files.

3.2 Sea state definition



Parameters can be entered for generating waves as regular waves or according to various spectra. At this time, the following spectra are supported:

RW	= Regular waves (linear, 2nd order, approximative stream function theory)
SW	= Waves and other waves generated based on long wave theory (solitary, single waves, N-waves and custom profile, the last three for detailed tsunami reproduction). Piston generator required for all SW waves. At the start of test piston will move to initial back position (half of needed stroke) and wait for calm water before generation.
PM	= Pierson-Moskowitz
BS	= Bretschneider
BM	= Bretschneider-Mitsuyasi
MBM	= Bretschneider-Mitsuyasi modified
JS	= Jonswap

Gen. Γ	=	generalized Γ spectrum
TMA	=	Texel Marsen Arsloe
FRF	=	TMA with Kitaigorodskii's f^{-4} scaling
Swell	=	The Gaussian Swell spectrum
Top-Hat	=	The Top-Hat spectrum
Torset	=	Torsethaugen spectrum (bi-modal)
Custom Spectrum	=	Custom made spectra, read from file.
Custom Time Series	=	Custom made surface elevation time series, read from file

The list may be extended in future versions. The mathematical expressions used for the various spectra are given in the standard spectra section.

In the table below all input fields at current time are present. However, depending on the selected spectrum only some of them are needed.

Field		*Description*
Spectra	:	Type of waves to generate, for more information see above list and details here. Depending on this selection, only the relevant input field are shown
Wave height [m]	:	Prototype wave height for regular or SW waves
Wave period [s]	:	Prototype wave period for regular or SW waves
Significant wave height (Hm0) [m]	:	Prototype significant wave height
Significant wave period [s]	:	Prototype significant wave period
Wind speed [m/s]	:	Prototype wind speed
Peak wave period [s]	:	Prototype peak wave period
Peak enhancement constant	:	Peak enhancement constant
Phase	:	Initial phase for regular waves. Only relevant to specify when combining sea states. Positive values give a delay.
Stream function order	:	The number of Fourier terms to include in the stream function.
Amplitude ratio	:	Specify for N-waves (SW) the ratio of the height of the trough and the crest.
Initial position waiting time	:	Specifies for SW sea states the waiting time after moving to the initial position.
Instance	:	Specifies a delay in the reproduction of a SW wave. If zero is specified the generation of the SW wave will start immediately after the ramp up time. Values larger than zero can be used for combining sea states.
Custom spectrum file	:	Text file with lines of Frequency [Hz] and Spectral density [m^2s] separated by space or tab.
Custom time series file	:	Text file with lines of surface elevations [m]
File sample frequency [Hz]	:	Sample frequency of surface elevation tie series for custom time series reproduction
X-coordinate [m]	:	In case custom time series is selected the X-coordinate to reproduce custom time series surface elevations otherwise Y-coordinate to reproduce the specified grouping (in case Wave groupiness is different from zero) . Linear theory and constant depth assumed.
Y-coordinate [m]	:	In case custom time series is selected the Y-coordinate to reproduce custom time series surface elevations otherwise Y-coordinate to reproduce the specified grouping (in case Wave groupiness is different from zero) . Linear theory and constant depth assumed.
Wave groupiness	:	A wave group is generally defined as a sequence of waves. In AwaSys different amount of wave groupiness can be generated by correlating phases (φ) according to the formula: $\varphi_{i+1} = C \cdot \varphi_i + (1-C) \cdot random - k \cdot x$ where C = coefficient between 0 and 1, where 0 is normal groupiness (phases uncorrelated, *GF* = 1) and 1 is maximum groupiness (phases 100% correlated, i.e. a freak wave) k = wave number calculated using linear theory and

assumption of constant depth

x = Distance in meters from the paddle, where the waves should be grouped. Constant water depth from the paddle to the position is assumed.

Additonal 3-D parameters

Field		*Description*
3-D type	:	Oblique 2-D waves (unidirectional, long-crested) or irregular 3-D waves (multidirectional, short-crested).
Direction [degrees]	:	Direction of the generated waves. 0 degrees is perpendicular to flaps. Positive angle is to the left when standing back to the generators.
Spreading distribution	:	Type of spreading function used. Choose between cosine distribution (Longuet-Higgins) with frequency independent or dependent s value, normal circular distribution and user defined spreading function. Mathematical expressions given in the spreading functions section. For the user defined spreading function two options are available 1. Frequency independent. In that case file must contain two columns, first column direction in degree and second column spreading function. File must be ordered after direction. 2. Frequency dependent. In that case file must first contain one row defining the N frequencies (must be ordered) where spreading function is defined. Afterwards should follow a table with first column being the directions in degree followed by N columns with spreading function values at the defined frequencies.
Spreading	:	Spreading parameter in spreading function, i.e. s or smax in cosine distribution and A in normal circular distribution. For more information refer to expressions given in the spreading functions section.

3.3 Standard spectra

Pierson-Moskowitz

Pierson and Moskowitz (1964) put forward, on the basis of a similarity theory by S.A.Kitaigorodskii, some suggestions for deep water wave spectra for the sea state referred to as fully arisen sea. This wave condition refers to the case where the waves have reached an equilibrium state in which energy input from the wind is exactly balanced by energy loss. The equilibrium form of the Pierson-Moskowitz spectrum for fully-developed seas may be expressed in terms of wave frequency (f) and wind speed at 19.5m above mean sea level (U19.5) as:

$$S(f) = \frac{\alpha \cdot g^2}{(2\pi)^4} \cdot f^{-5} \cdot \exp\left[-0.74 \cdot \left(\frac{f_0}{f}\right)^4\right] \qquad (1)$$

where

$\alpha = 0.0081$

$f_0 = g \cdot (2 \cdot \pi \cdot U_{19.5})^{-1}$

The Pierson-Moskowitz spectrum describes a fully developed sea with one parameter, the wind speed, and assumes that both the fetch and duration are infinite. This idealization is justified when wind blows over a large area at a constant speed without substantial change in direction for tens of hours. The peak frequency can be found to $f_p = 0.877\ f_0$ (by calculating where dS/df = 0).

Pierson-Moskowitz parameterised (ITTC-81 spectrum)

The Pierson-Moskowitz spectrum is transformed to a parameterised spectrum by:

$$H_{m0} = 4 \cdot \sqrt{m_0} \qquad (2)$$

The parameterised spectrum is given by:

$$S(f) = \alpha \cdot H_{m0}^2 \cdot f_p^4 \cdot f^{-5} \cdot \exp\left[-\frac{5}{4} \cdot \left(\frac{f_p}{f}\right)^4\right] \tag{3}$$

where α = 5/16 = 0.3125.

Note that according to the Pierson-Moskowitz spectrum there is the relation $T_p = 15.7\ (H_{m0}/g)^{0.5}$ between peak period and significant wave height. If this relation is not fulfilled it is not a Pierson-Moskowitz spectrum, but instead a Bretschneider or JONSWAP spectrum and has to be defined like that in AwaSys (see below description).

Bretschneider (ISSC spectrum)

This was developed for the North Atlantic, unidirectional seas, with infinite depth, no swell and unlimited fetch. The spectrum shape is identical to parameterised Pierson-Moskowitz, but without the link between H_{m0} and T_p. Moreover, it is given in terms of $H_{1/3}$ instead of H_{m0} assuming they are identical.

$$S(f) = \alpha \cdot H_{1/3}^2 \cdot T_s^{-4} \cdot f^{-5} \cdot \exp\left[-1.25 \cdot (T_s \cdot f)^{-4}\right] \tag{4}$$

where α = 5/16 = 0.3125.

Bretschneider-Mitsuyasi

The modified Bretschenieder-Mitsuyasi spectrum uses $T_p = 1.05T_s$ to give the Bretscheider spectrum in terms of T_s.

$$S(f) = \alpha \cdot H_{1/3}^2 \cdot T_s^{-4} \cdot f^{-5} \cdot \exp\left[-1.03 \cdot (T_s \cdot f)^{-4}\right] \tag{5}$$

where
α = 0.257

Modified Bretschneider-Mitsuyasi

Later measurements suggested a more appropiate relation between peak and significant periods is $T_p \sim 1.1T_s$ and between spectral and time domain significant wave heights is $H_{1/3} \sim 0.95\ H_{m0}$. This led to the modified Bretschenieder-Mitsuyasi spectrum (see Goda (1988)):

$$S(f) = \alpha \cdot H_{1/3}^2 \cdot T_s^{-4} \cdot f^{-5} \cdot \exp\left[-0.75 \cdot (T_s \cdot f)^{-4}\right] \tag{6}$$

where
α = 0.205

JONSWAP

The Joint North Sea Wave Project (JONSWAP) was started in 1967 as a collaboration among institutes in Germany, Holland, UK and USA. The objectives of the project was originally partly to investigate the growth of waves under fetch-limited condition, and partly to investigate wave transformation from sea to shallow water area. Simultaneous measurements of waves and winds were taken at stations along a line extending 160 km in a westerly direction from the island of Sylt in the Germany Bright. During the processing of a large number of spectra corresponding to steady easterly wind, the so-called JONSWAP spectrum was obtained, cf. Hasselmann et al. (1973).

$$S(f) = \frac{\alpha \cdot g^2}{(2\pi)^4} \cdot f^{-5} \cdot \exp\left[-\frac{5}{4} \cdot \left(\frac{f_p}{f}\right)^4\right] \cdot \gamma^{\beta} \tag{7}$$

where

$$\alpha = 0.076 \cdot (g \cdot F \cdot U_{10}^{-2})^{-0.22}$$

$$f_p = \frac{3.5 \cdot g \cdot (g \cdot F \cdot U_{10}^{-2})^{-0.33}}{U_{10}}$$

$$\beta = \exp\left(-\frac{(f - f_p)^2}{2 \cdot \sigma^2 \cdot f_p^2}\right)$$

$$\sigma = \begin{cases} 0.07 & \text{for } f \le f_p \\ 0.09 & \text{for } f > f_p \end{cases}$$

The JONSWAP spectrum is characterized by a parameter γ, the so-called peak enhancement parameter, which controls the sharpness of the spectral peak. In the North Sea the peak enhancement coefficient ranges from 1 to 7, with an average value of 3.3.

JONSWAP parameterised

The parameterised JONSWAP spectrum reads:

$$S(f) = \alpha \cdot H_{m0}^2 \cdot f_p^4 \cdot f^{-5} \cdot \exp\left[-\frac{5}{4}\cdot\left(\frac{f_p}{f}\right)^4\right]\cdot\gamma^\beta \qquad (8)$$

where

$$\alpha = \frac{0.0624}{0.230 + 0.0336\cdot\gamma - \dfrac{0.185}{1.9+\gamma}}$$

$$\beta = \exp\left(-\frac{(f-f_p)^2}{2\cdot\sigma^2\cdot f_p^2}\right)$$

$$\sigma = \begin{cases} 0.07 & \text{for } f \le f_p \\ 0.09 & \text{for } f > f_p \end{cases}$$

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Generalized Γ-spectrum

Most spectral shapes can be represented by the generalized Γ spectrum given by:

$$S(f) = \tfrac{1}{16} G_0 \cdot A_\gamma \cdot H_{m0}^2 \cdot f_p^{N-1} \cdot f^{-N} \cdot \exp\left[-\frac{N}{M}\cdot\left(\frac{f_p}{f}\right)^M\right]\cdot\gamma^\beta \qquad (9)$$

where

$$G_0 = \frac{1}{\frac{1}{N}\cdot\left(\frac{N}{M}\right)^{-(N-1)/M}\cdot\Gamma((N-1)/M)}$$

$$\beta = \exp\left(-\frac{(f-f_p)^2}{2\cdot\sigma^2\cdot f_p^2}\right)$$

$$\sigma = \begin{cases} 0.07 & \text{for } f \le f_p \\ 0.09 & \text{for } f > f_p \end{cases}$$

No analytical solution is available for A_γ but for N=4 the following approximation was given by Torsethaugen (1993):

$$A_\gamma = \frac{1 + 1.1\cdot(\mathrm{Ln}(\gamma))^{1.19}}{\gamma}$$

The JONWAP spectrum is found from Eq. 9 by using N = 5 and M = 4. Torsethaugen and Haver (2004) used the spectrum with N = M = 4 to model the two peaks in the bi-modal spectrum.

TMA

The TMA spectrum is developed for finite water depth where the frequency scaling is different from the above given spectra which does not depend on depth. In effect the TMA spectrum change the decay of the spectral function of the high-frequency side from f^{-5} to f^{-3} in shallow waters by multiplication of JONSWAP spectrum with weighing factor Φ as derived by Kitaigorodskii et al. (1975). This gives a wider spectrum in shallow waters compared to the JONSWAP spectrum. Its validity is verified by measurements from TEXEL in the North Sea, MARSEN project in the North Sea and ARSLOE project in Duck, North Carolina. Here from comes the name of the spectrum.

$$\Phi(\omega, h_{finite}) = \frac{\left[k^{-3} \frac{\partial k}{\partial \omega}\right]_{h=h_{finite}}}{\left[k^{-3} \frac{\partial k}{\partial \omega}\right]_{h=\infty}}$$

$$\Phi(\omega, h) = \frac{1}{R(\omega_*)^2}\left[1 + \frac{2\omega_*^2 R(\omega_*)}{\sinh\left(2\omega_*^2 R(\omega_*)\right)}\right]^{-1}$$

....

$$\omega_* = \omega\sqrt{\frac{h}{g}}$$

$$R(\omega_*) \cdot \tanh\left(\omega_*^2 \cdot R(\omega_*)\right) = 1$$

FRF

The FRF spectrum by Miller et al. (1990) is similar to the TMA spectrum in the sense that it also included the weighing factor Φ as derived by Kitaigorodskii et al. (1975). However, the TMA spectrum uses a f^{-5} tail in deep water as suggested first by Phillips (1958) whereas the FRF spectrum uses an f^{-4} tail as suggested by Toba (1972).

$$S(f) = \alpha \cdot \frac{k^{-2.5}}{\frac{\partial k}{\partial \omega}} \cdot \exp\left[-\frac{5}{4} \cdot \left(\frac{f_p}{f}\right)^4\right] \cdot \gamma^\beta \qquad (10)$$

where

$$\sigma = \begin{cases} 0.115 & for\ f \le f_p \\ 0.114 & for\ f > f_p \end{cases}$$

$$\beta = \exp\left(-\frac{(f - f_p)^2}{2 \cdot \sigma^2 \cdot f_p^2}\right)$$

$$\sigma = \begin{cases} 0.07 & \text{for } f \le f_p \\ 0.09 & \text{for } f > f_p \end{cases}$$

Top-Hat

The Top-Hat spectrum is represented by constant spectra density between frequencies $f_1 = f_m - \Delta f/2$ and $f_2 = f_m + \Delta f/2$. The central frequency is f_m and the bandwidth is $\Delta f = f_2 - f_1$.

$$S(f) = \begin{cases} \frac{H_{m0}^2}{16(f_2 - f_1)} & \text{for } f_1 \le f \le f_2 \\ 0 & \text{elsewhere} \end{cases} \qquad (11)$$

This spectrum is sometimes used as an alternative to a real spectrum in order to make higher freak waves using the wave groupiness function.

Gaussian Swell

The Gaussian Swell spectrum is based on the normal (or Gaussian) probability density function and is given by:

$$S(f) = \frac{H_{m0}^2}{16\sigma\sqrt{2\pi}} \cdot \exp\left[-\frac{(f - f_p)^2}{2\sigma^2}\right] \qquad (12)$$

where σ is the standard deviation and thus giving the width of the spectrum. This spectrum is sometimes used for the swell components of a spectrum.

Torsethaugen (bi-modal)

The Torsethaugen spectrum is a double peak spectrum (bi-modal) to simulated combined swell and wind sea. The spectrum is given as a sum of two Generalized Γ spectra with parameters for the two sea types defined based on estimates of H_{m0} and T_p for the total sea, cf. Torsetaugen and Haver (2004). Based on this the most likely parameters for the swell and the wind sea is calculated by below partitioning procedure. Note that not all equations used are in dimensionless form so H_{m0} and T_p has to be given in prototype scale SI units.

The peak period for a fully developed sea (T_{pf}) is calculated in order to define if it is a wind or swell dominated sea using below formula:

$$T_{pf} = a_f \sqrt[3]{H_{m0}}$$

where a_f is only slightly dependent on the fetch. The value recommended by Torsetaugen and Haver (2004) is $a_f = 6.6$ s/m$^{1/3}$ corresponding to a fetch of F = 370 km.

General formula:

$k_g = 35.0$

$$R = (1 - a_2)\exp\left(-(\varepsilon / a_1)^2\right) + a_2$$

$$H_{m0,1} = RH_{m0}$$

$$H_{m0,2} = H_{m0}\sqrt{1 - R^2}$$

$$\gamma_f = k_g s^{6/7}$$

If $T_p \le T_{pf}$ we have a wind dominated sea and the following formulae are applied:

$a_1 = 0.5$; $a_2 = 0.7$; $b_1 = 2.0$ s

$$\varepsilon = \frac{T_{pf} - T_p}{T_{pf} - T_{pl}} \quad 0 \le \varepsilon \le 1$$

$$T_{p,2} = T_{p,f} + b_1$$

$$s = \frac{H_{m0,1}}{\frac{g}{2\pi} T_{p,1}^2}$$

$$\gamma_1 = \gamma_f$$

If $T_p > T_{pf}$ we have a swell dominated sea and the following formulae are applied:

$a_1 = 0.3$; $a_2 = 0.6$; $a_3 = 6$; $T_{pu} = 25$ s

$$\varepsilon = \frac{T_p - T_{pf}}{T_{pu} - T_{pf}} \quad 0 \le \varepsilon \le 1$$

$$T_{p,2} = a_f \sqrt[3]{H_{m0,2}}$$

$$s = \frac{H_{m0}}{\frac{g}{2\pi} T_{pf}^2}$$

$$\gamma_1 = \gamma_f (1 + a_3 \varepsilon)$$

The spectrum is then defined as a combination of two Generalized Γ spectra with N = M = 4 using the parameters (H_{m0} ; T_p ; γ) taken as ($H_{m0,1}$; T_p ; γ_1) for the primary sea and ($H_{m0,2}$; $T_{p,2}$; 1.0) for the secondary sea.

The Torsethaugen partitioning procedure is sensitive to accuracy of the total sea state parameters and also the partitioning in swell and wind sea is also expected to be highly site dependent (e.g. a wind dominated sea instead of a swell dominated sea might be predicted), cf. Bitner-Gregersen and Toffoli (2009). Therefore, it is recommended to apply the Torsethaugen partitioning model only for the Norwegian waters for which the model was developed. If wind sea and swell sea parameters are known it is always recommended to apply these values instead of the ones calculated from the Torsethaugen model.

When adding a Torsethaugen spectrum in AwaSys it is possible to split it into two Generalized Γ spectra with the parameters estimated from the Torsethaugen partitioning model (see Spectral generated signal). The individual seas can then be modified which makes it possible also to use individual main directions and directional spreading for the swell and the wind sea. Note that when spectrum is not splitted into two individula spectra then the frequency limits to generate (see *Spectrum low/high cut-off freq. factor* in preferences) is based on overall T_p and this might cut part of the secondary peak.

Ochi-Hubble (bi-modal)
The Ochi and Hubble (1976) spectrum is a double peak spectrum (bi-modal) to simulated combined swell and wind sea. For the moment this spectrum is not available in AwaSys.

References:

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Goda, Y. (1988). *Statistical variability of sea state parameters as a function of a wave spectrum*. Coastal Eng. in Jpn., JSCE 31, no. 1, 39–52

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Miller, H. and Vincent, C. (1990). *FRF Spectrum: TMA with Kitaigorodskii's f-4 Scaling*. J. Waterway, Port, Coastal, Ocean Eng., 10.1061/(ASCE)0733-950X(1990)116:1(57), 57-78.

Mituyasu, H. (1970). *On the growth of spectrum of wind-generated waves (2) - spectral shape of wind waves at finite depth*, Rep. 17, pp. 235-248, Res. Inst. Appl. Mech., Kyushu Univ., Kasuya, Japan, 1969

Ochi M. K. and Hubble E. N. (1976). *Six-parameter wave spectra*, Proc 15th Coastal Engineering Conference, 301-328.

Pierson, W. J. and Moskowitz, L. (1964) *A proposed spectral form for fully developed wind seas based on the similarity theory of A. A. Kitaigorodskii*. J. Geophys. Res., 69, 5181–5190.

Torsethaugen, K. and Haver, S. (2004). *Simplified double peak spectral model for ocean waves*, Paper No. 2004-JSC-193, ISOPE 2004 Touson, France.

3.4 Spreading functions

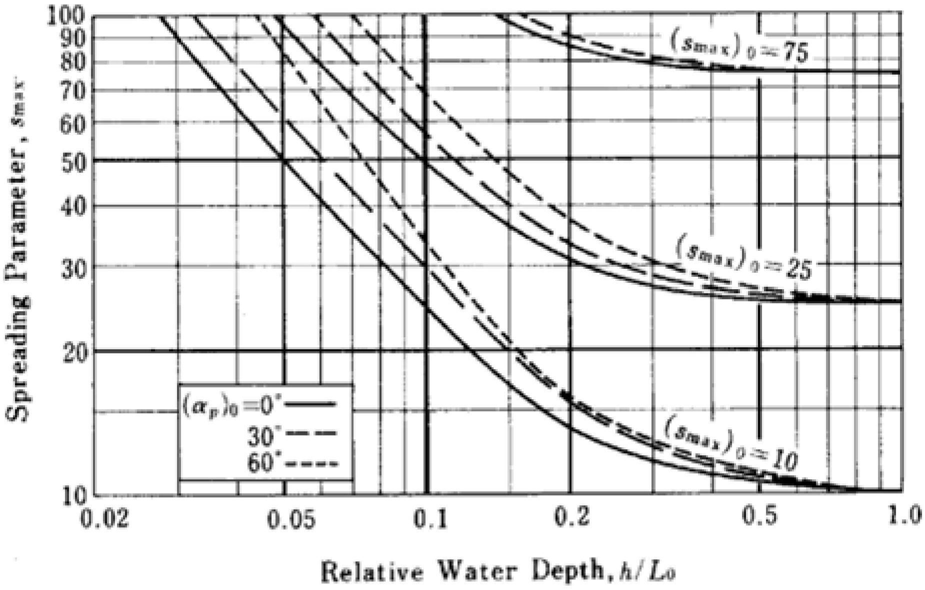
Cosine 2s distribution (Longuet-Higgins)

$$D(f,\theta) = \frac{2^{2s-1}}{\pi} \cdot \frac{\Gamma^2(s+1)}{\Gamma(2s+1)} \cdot \cos^{2s}\left(\frac{\theta-\theta_0(f)}{2}\right)$$

The spreading parameter s can be taken as a constant (frequency independent) or as frequency dependent. Prototype measurements show that s is maximum at the peak frequency (minimum spread). The frequency dependency in AwaSys is taken in accordance with Goda and Suzuki (1975):

$$\frac{s}{s_{max}} = \begin{cases} (f/f_p)^5 & \text{for } f < f_p \\ (f/f_p)^{-2.5} & \text{for } f \geq f_p \end{cases}$$

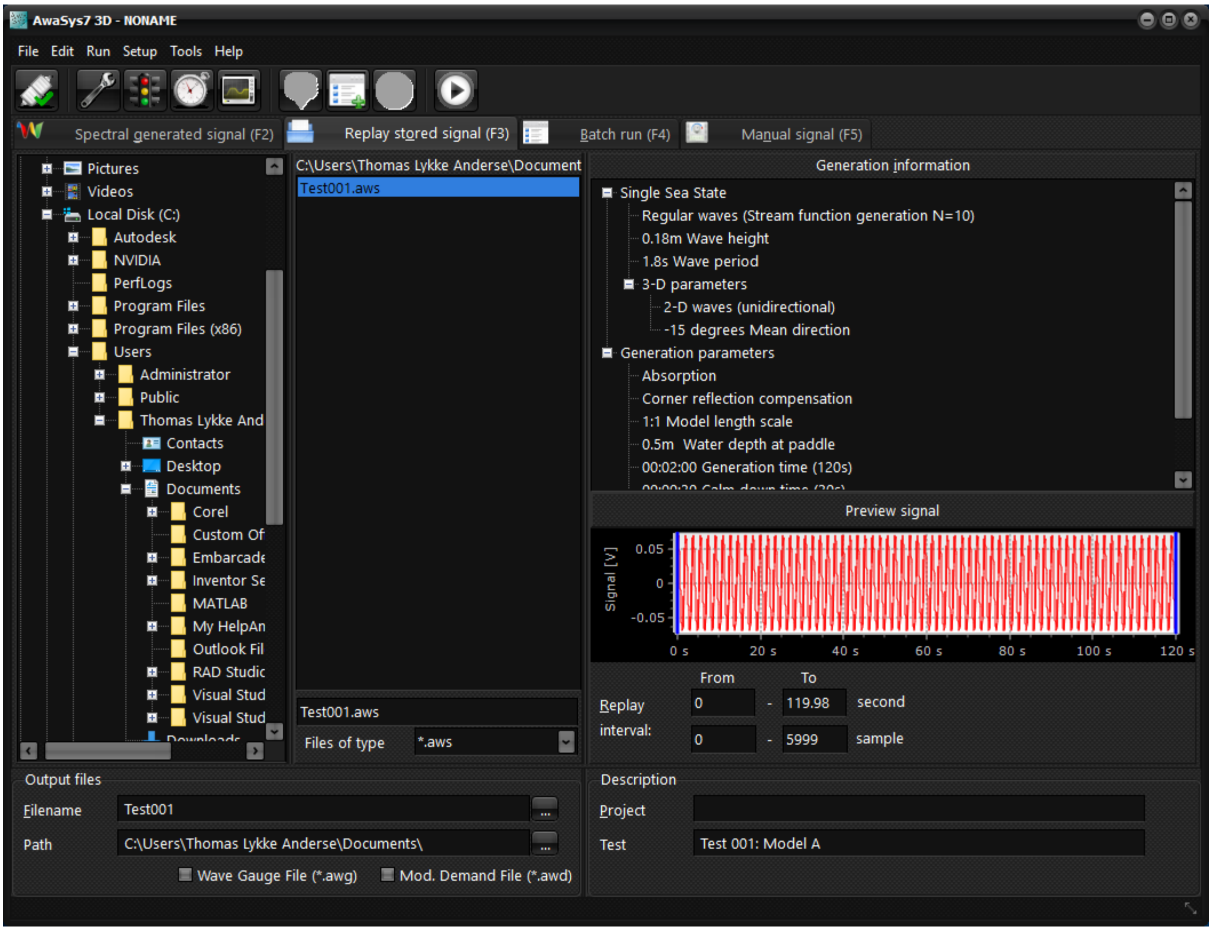
where s_{max} is the s-parameter for the peak frequency. For deep water Goda recommend smax = 10 for wind waves, s_{max} = 25 for swells with short decay distance and s_{max} = 75 for swells with long decay distance. In case of parallel depth contours s_{max} increases in finite depth due to refraction, cf. below figure from Goda and Suzuki (1975).



Normal circular distribution

$$D(f,\theta) = c \cdot \exp(A \cdot \cos(\theta - \theta_0(f)))$$

3.5 Replay stored signal

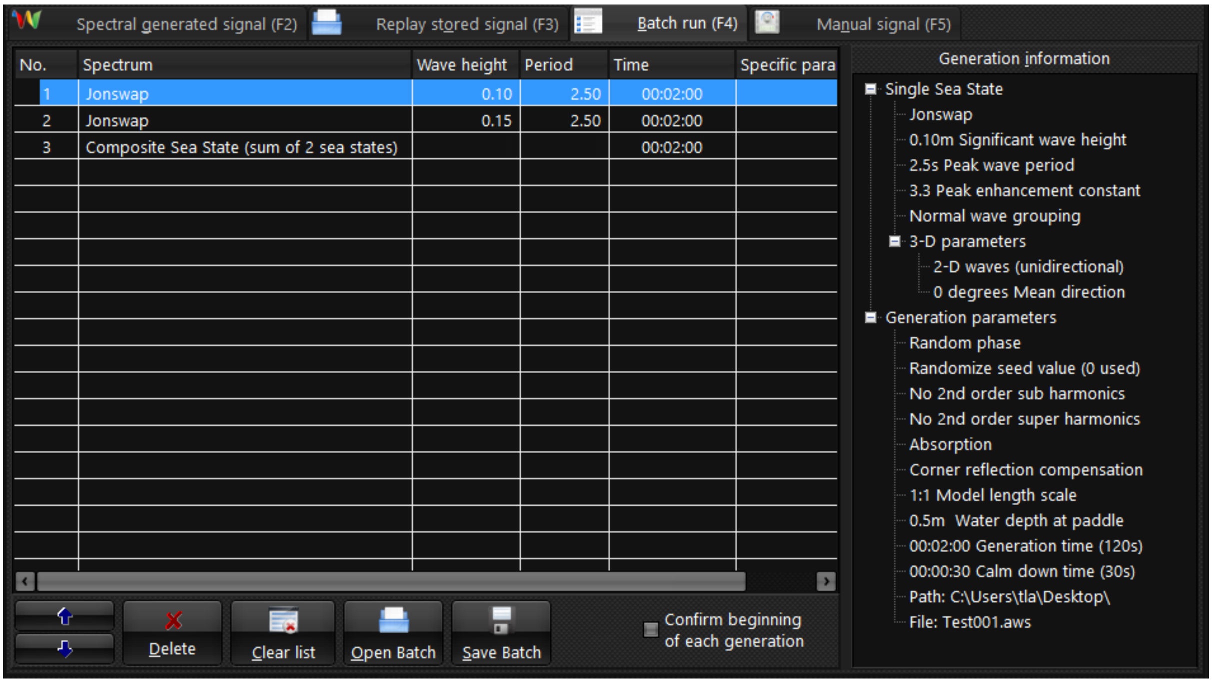


On this page, a previous stored wave signal can be replayed. By dragging the sliders on the graph in the button of the screen or entering start and stop time in seconds, it is possible to replay only part of the signal.

The wave signal file contains a header with the parameters used at generation time. These, parameter are shown generation information panel and before replay of a signal, AwaSys check that all parameters are correct setup. After the header the signals are stored in binary format. Awasys7 will only replay binary signals, but binary signals can be converted to and from textfiles (ASCII) using the file converter. AwaSys6 and older versions used always ASCII files and those have thus to be converted to binary if to be used in Awasys7.

The converted ASCII file contains the same header as the binary file and afterwards is stored in the first column the sample number followed by three columns per paddle. In First column for each paddle is the paddle demand signal including mechanical transfer correction but excluding clipping, active absorption gain up and down movement (given in voltage). The two other columns per generator includes signals used for the one gauge active absorption system for absorption signal computations and for online analysis. The second column is the near field surface elevation on the location of the surface elevation probe used (given in metre). The third column is the far field surface elevation at the paddle (i.e. excluding evanescent modes) used for online analysis only (given in metre). In case active absorption system is not selected to one gauge system or wave gauges not correctly defined these two last columns per generator will contain zeroes.

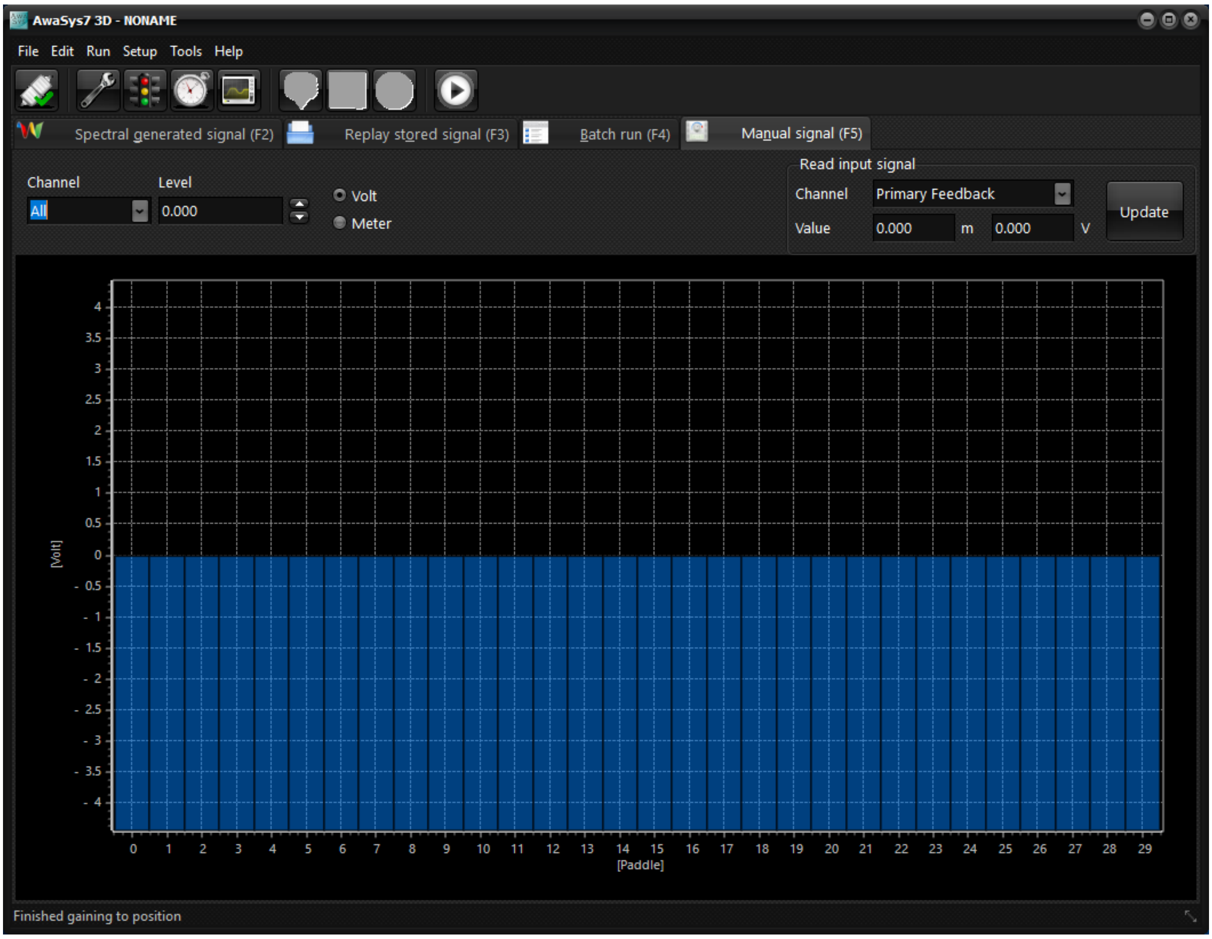
3.6 Batch run



Batch run allows to run a batch of wave generations with or without interaction. Stored signals can also be queued. When adding a new test to the batch list a dialog appears with the possibility of adding a pause before the following test. If a solitary wave generation is added to the batch list a dialog asking for the waiting time in final paddle position is also shown.

Add	:	Pressing this button on the spectral generated signal tab og replay stored signal will add the generation to the batch. If pressed while on the Batch run page, the page will change to spectral generate signal page for setting up a new entry.
Delete	:	Deletes selected entries from the batch
Clear list	:	Clear the whole list
Confirm begging of each generation	:	if checked a dialog will popup between generations to confirm the start of the next run

3.7 Manual signal

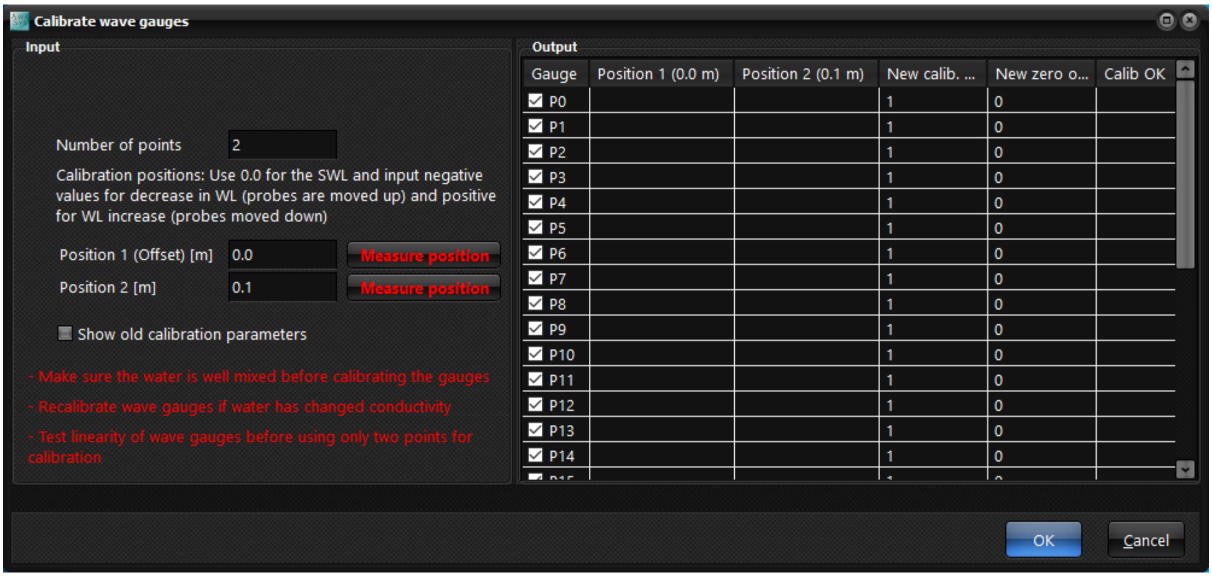


The manual signal page primarily intended for determination of the mechanical transfer constant of the paddles. This is done by sending a constant voltage signal to the paddle and measure the stroke from its middle position.

To avoid sudden movements, which could harm the paddle and generate a big damaging wave, the signal is changed according to the gain down speed setup in preferences

In this tab any signal (feedback or wave gauge) can also be manually read in the *Read input signal* box.

3.8 Calibrate wave gauges



For proper operation, the program needs a calibration coefficient for each wave gauge to determine the elevation. The offset (voltage at SWL) and wave gauge calibration factors should be set-up in preferences or measured using this dialog. For proper readings and operation, the wave gauge signal must always be within the voltage limits of the data acquisition hardware. This should be considered when the gain and offset of the wave gauge amplifiers are selected.

Gauges that have a fixed zero voltage elevation (VTI electronics) are recommended because in that case gauges can be calibrated using this dialogue with only the SWL (1 point calibration, see here how to define). If gauges do not have a fixed zero voltage then they can be calibrated using this dialogue only if they allow vertically movement of the wave-gauges or alternatively changes in water level (minimum 2 point calibration). In that case the default position 2 is at +0.1 m corresponding to an increase in WL or downwards movement of gauges of 10 cm from SWL. The number of points and their positions can be selected in the dialog.

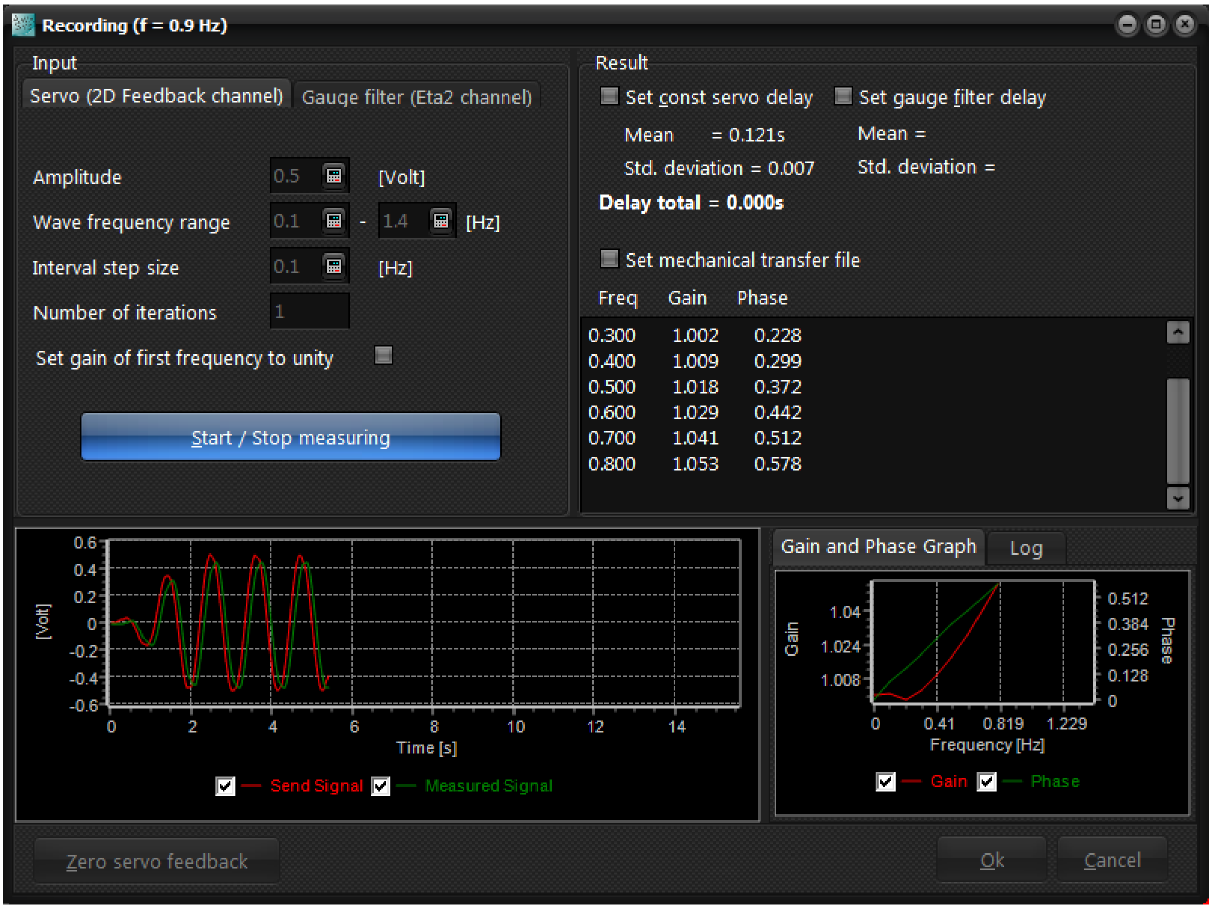
The offset is also determined in calibration procedure. The offset should be re-measured even when SWL has only slighly changed as it is important to avoid drift of the paddles when using active absorption. By clicking "Measure position" for position 1 the offset can be determined without needing to measure any other positions.

AwaSys performs a check on the calibration performed and report result of check in the line Calib OK.

The checkbox *Show old calibration parameters* might be used if old (prior to this calibration) and new (this calibration) coefficients should be compared.

If new calibration is not wanted to be applied in single gauges (for example secondary channels that are not wave gauges) those channels can be de-selected with the checkboxes.

3.9 Measure paddle gain and delay



Absorption performance can be improved by compensation of a possible delay. This dialog can measure the delay and performance of the wave generator and hereby automate the process of creating a mechanical transfer file. The dialog can also measure a delay introduced by sending the wave gauge signal through a filter.

Servo delay and gain
The dialog measures the gain and phase (delay) by sending a sinus signal to paddle at varying frequencies and comparing the send signal with the actual movement. The actual movement is obtained by connecting the feedback signal from the servo as specified in preferences (position feedback channel).

If feedback signal gain is not proper calibrated there is an option to set the gain of first frequency to unity. If this option is used it is important that the starting frequency is sufficiently low.

Filter delay
Measuring the delay of a filter is done in the same way as measurement of the servo-delay. However, with a few differences: The output of the filter should be connected to input channel 2 (same as wave gauge 2) and there is usually no need to go through several frequencies as delay is usually independent on frequency.

Input

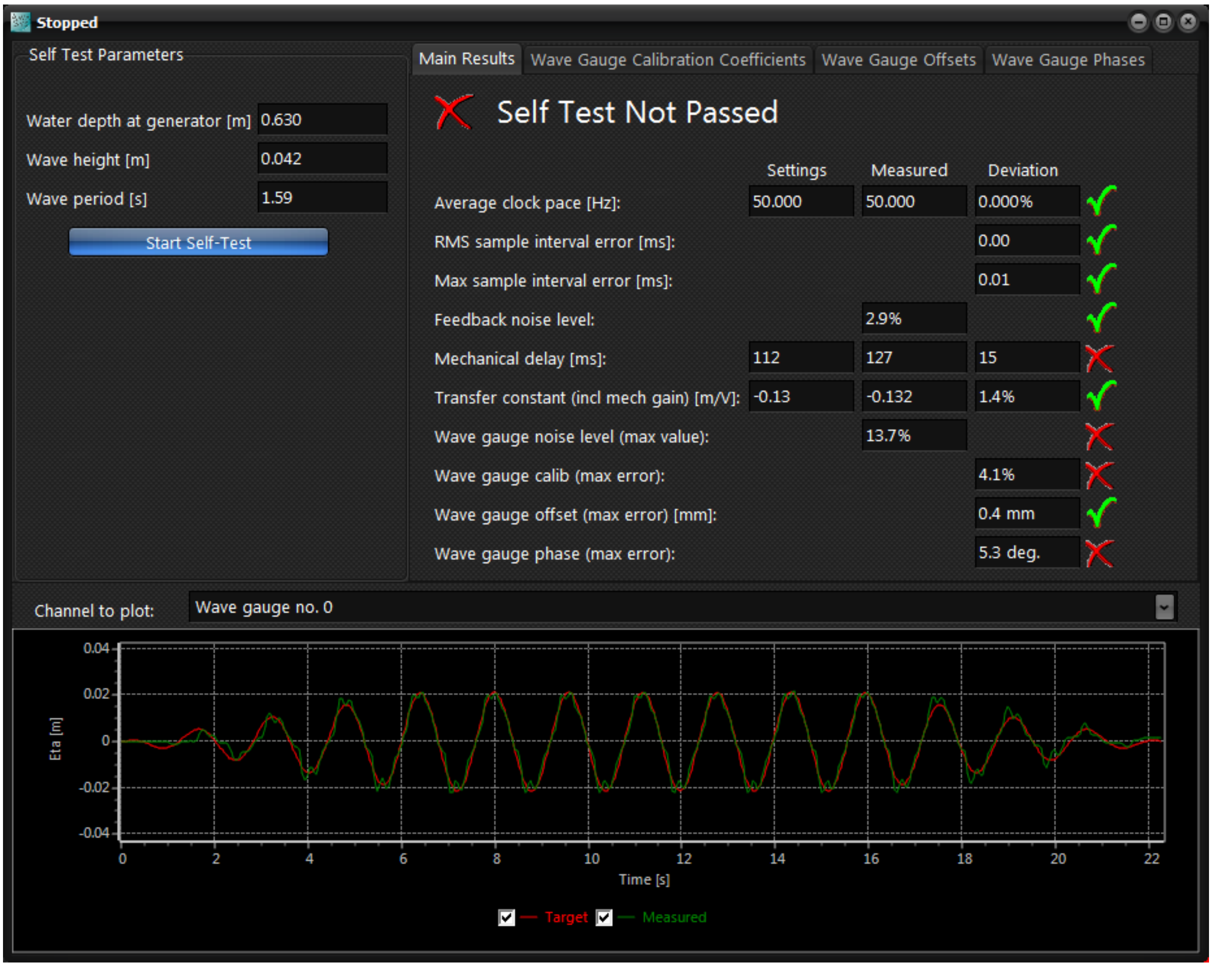
Field		*Description*
Sample frequency [Hz]	:	Sample frequency at which the measurements are performed.
Amplitude [Volt]	:	Amplitude of the sinus signal.
Wave frequency range [Hz]	:	Start and end frequency for the measurement. Measurement can be aborted at any time without loosing any measurement results.
Interval step size [Hz]	:	The frequency step size. This determine how detailed in the frequency domain the measurement will be.
Number of iterations	:	If set higher than 1, the program will repeat the measurements

utilizing the new gain

Result

Field		*Description*
Set constant servo delay	:	Include the servo delay in the constant delay
Set gauge filter delay	:	Include the filter delay in the constant delay
Set mechanical transfer file	:	Set preferences to use the mechanical transfer file created

3.10 Self Test



The self-test and self-calibration dialog serves as a test of the program has been correctly configured and calibrated. A short sequence of regular of regular waves is generated (4 waves to ramp up, 6 at full amplitude and 4 waves to ramp down). The four waves in the middle is used to compare servo feedback (if connected and setup in preferences) and wave gauge signals with target values. The system performance are checked according to:

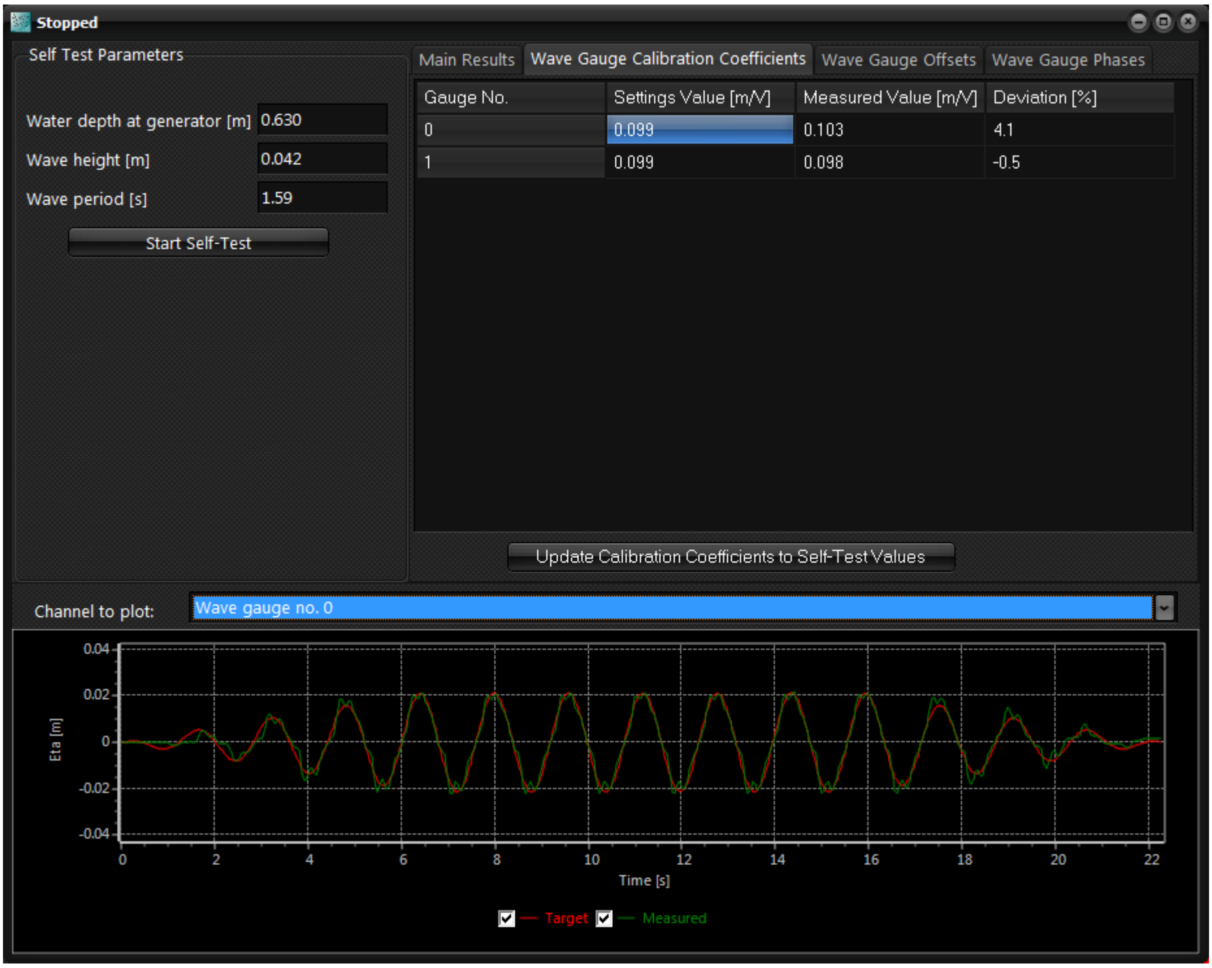
- *Average clock pace:* The average sample frequency from test beginning to end. This is usually matched very accurately.
- *RMS sample interval error.* The average pace does not say anything about timing of individual samples (jitter). Therefore the RMS timing error is given. This will usually be less than 0.1 ms.
- *Max sample interval error.* The maximum timing error gives the largest deviation in time interval between two samples. As AwaSys runs under a soft-realtime OS (Windows) this can be up to 1 ms and in very rare cases up to 10 ms.
- *No samples missing WG stream (for Com-port VTI and Ethernet VTI input manufacturer only).* This value shows how many samples where no data was available from VTI controller and previous measured value had to be reused. This value will typically be zero or in very rare cases up to a few samples.

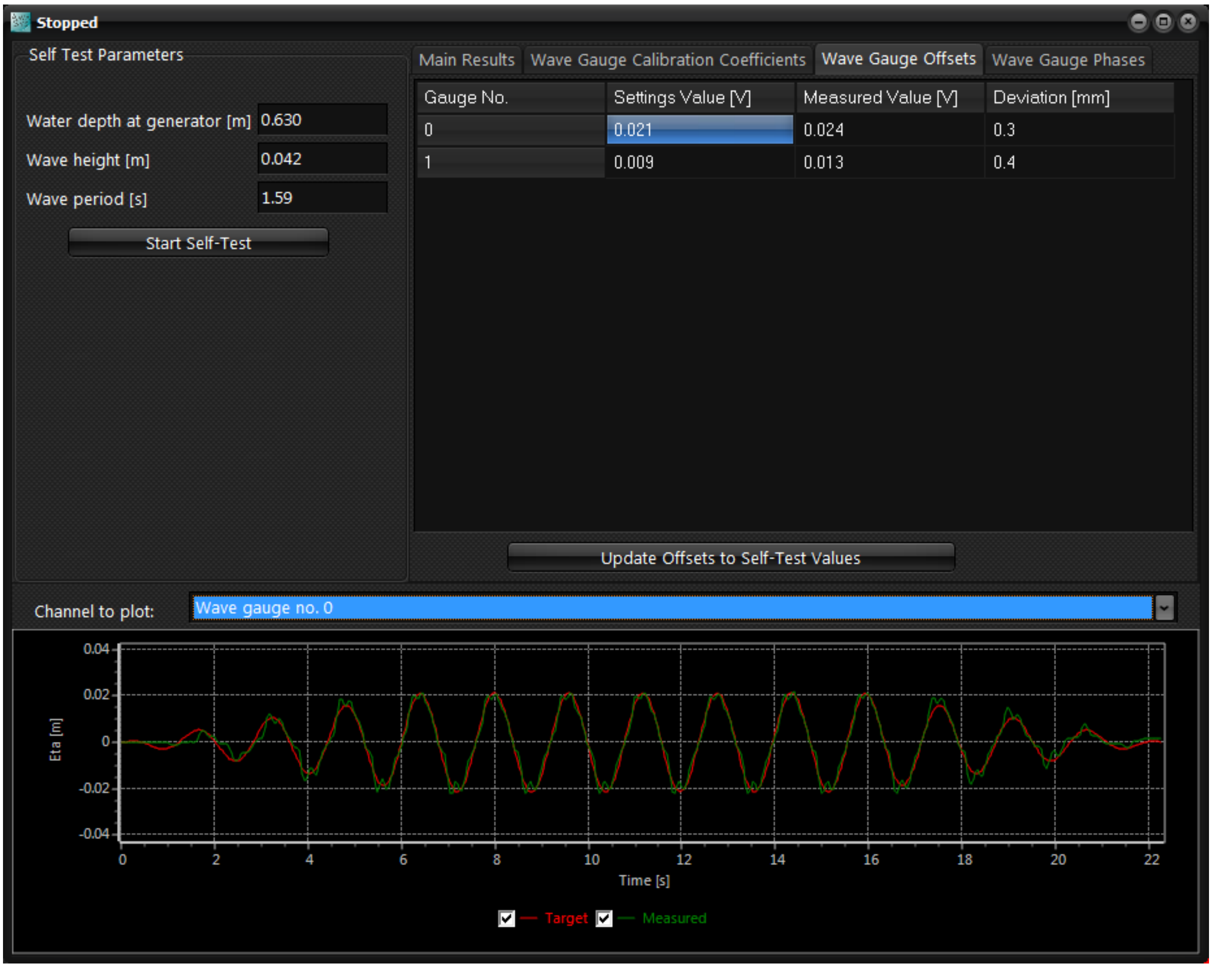
- *Feedback noise level.* The noise level on the feedback signal (if connected).
- *Mechanical delay.* Validation of mechanical delay settings (delay from demand to feedback signal)
- *Transfer constant.* Validation of transfer constant (amplitude of paddle movement).
- *Wave gauge noise level.* The noise level on wave gauge signals (deviation from a nearfield signal calculated by linear theory). If waves are non-linear then superharmonics will thus increase calculated noise level.
- *Wave gauge calibration error.* Validation of wave gauge calibration coefficients assuming linear theory valid and no reflection and cross-modes present.
- *Wave gauge offset error.* Validation of the wave gauge offset levels. To avoid drift of paddle due to active absorption correction it is important that errors on offset (signal drift) is minimized.
- *Wave gauge phase error.* Validation of pahse of nearfield surface elevations. Note that active absorption is very sensitive to phase errors.

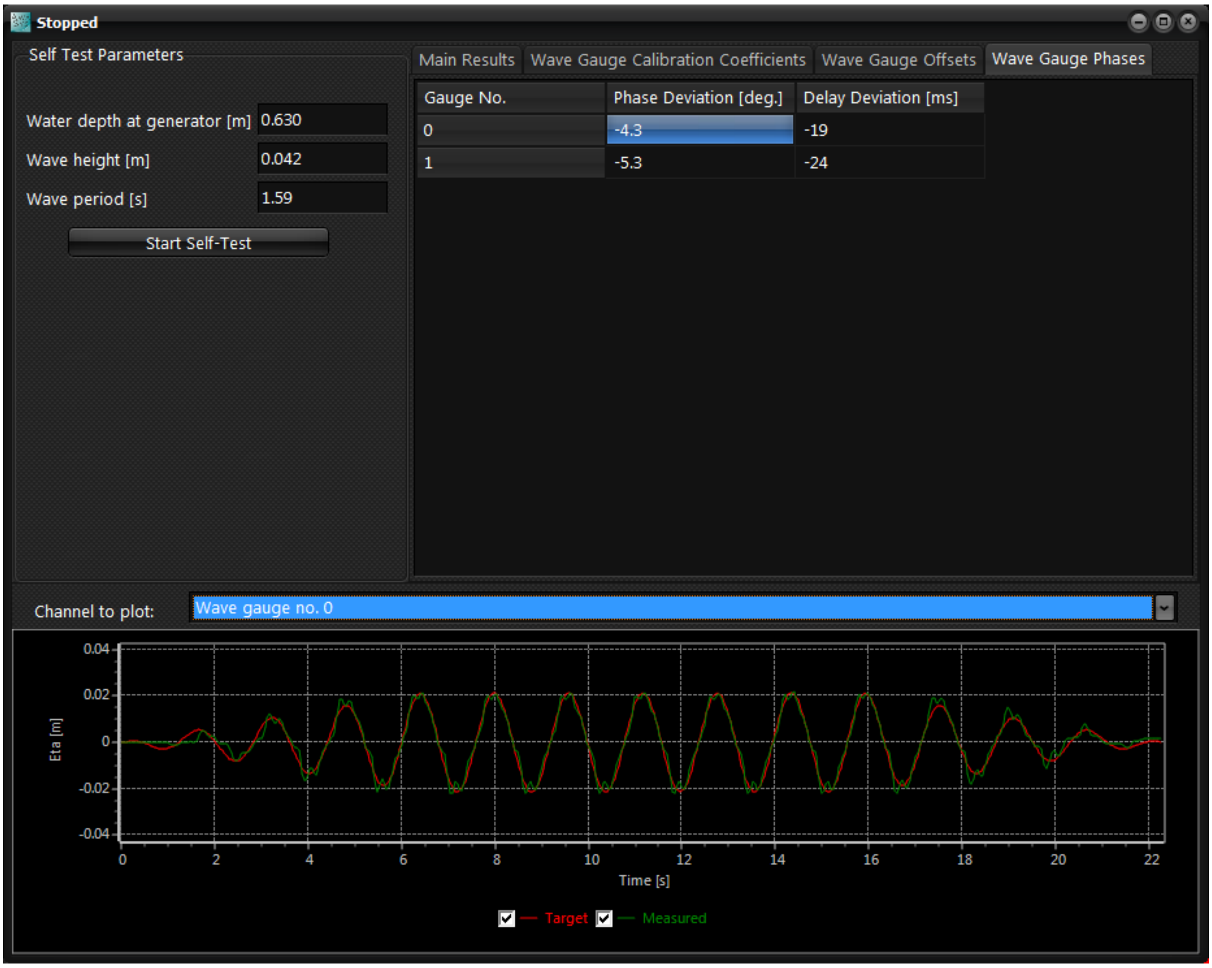
The errors reported on wave gauges is the maximum of all the individual gauges while individual tabs show errors per gauge.The last tab shows wave gauge phase deviation in degrees as well as in milliseconds.

Above given example is a self-test performed in an laboratory with AwaSys 7. Here the noise level on wave gauge signal is not passed (no analog filter applied to wave gauge signals). The noise can easily be seen in the time series in above figure. Despite of this noise active absorption worked well. It is possible to check time series of each channel by changing the channel to plot in the list which will update entire time series to the selected gauge. This is also possible after self-test has finished if performance problems are reported for specific gauges.

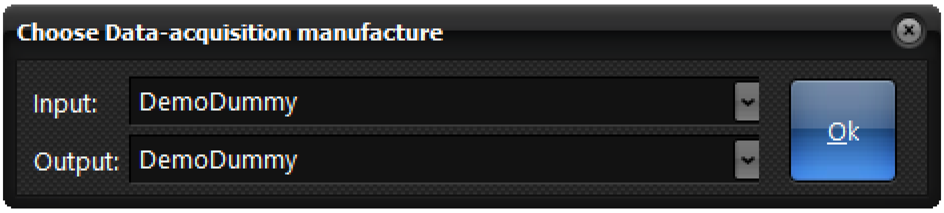
Direct calibration of wave gauges using for example the calibrate wave gauges dialog is in many cases not practical unless wave gauges support calibration using only one point (wave gauge has fixed zero volt level that is specified here). The self-calibration might be an alternative for gauges that do not have fixed zero voltage and has proven to be accurate at least in cases where significant reflections or cross-modes do occur within the measurement period (the 4 waves in the middle). Calibration coefficients and offsets determined during the self test can be transferred to the settings on the two tabs "Wave Gauge Calibration Coefficients" and "Wave Gauge Offsets" as shown below. Here also the current setting and self calibrated values can be seen for all gauges and the deviation.


Stopped
Self Test Parameters
Water depth at generator [m] 0.630
Wave height [m] 0.042
Wave period [s] 1.59
Start Self-Test
Main Results
Wave Gauge Calibration Coefficients
Wave Gauge Offsets
Wave Gauge Phases
Gauge No.
Settings Value [m/V]
Measured Value [m/V]
Deviation [%]
0 0.099 0.103 4.1
1 0.099 0.098 -0.5
Update Calibration Coefficients to Self-Test Values
Channel to plot:
Wave gauge no. 0
Eta [m]
Time [s]
Target
Measured


Stopped
Self Test Parameters
Water depth at generator [m] 0.630
Wave height [m] 0.042
Wave period [s] 1.59
Start Self-Test
Main Results
Wave Gauge Calibration Coefficients
Wave Gauge Offsets
Wave Gauge Phases
Gauge No. Settings Value [V] Measured Value [V] Deviation [mm]
0 0.021 0.024 0.3
1 0.009 0.013 0.4
Update Offsets to Self-Test Values
Channel to plot: Wave gauge no. 0
Eta [m]
Time [s]
Target
Measured


Stopped
Self Test Parameters
Water depth at generator [m]
0.630
Wave height [m]
0.042
Wave period [s]
1.59
Start Self-Test
Main Results
Wave Gauge Calibration Coefficients
Wave Gauge Offsets
Wave Gauge Phases
Gauge No.
Phase Deviation [deg.]
Delay Deviation [ms]
0
-4.3
-19
1
-5.3
-24
Channel to plot:
Wave gauge no. 0
Eta [m]
Time [s]
Target
Measured

3.11 Choose manufacture

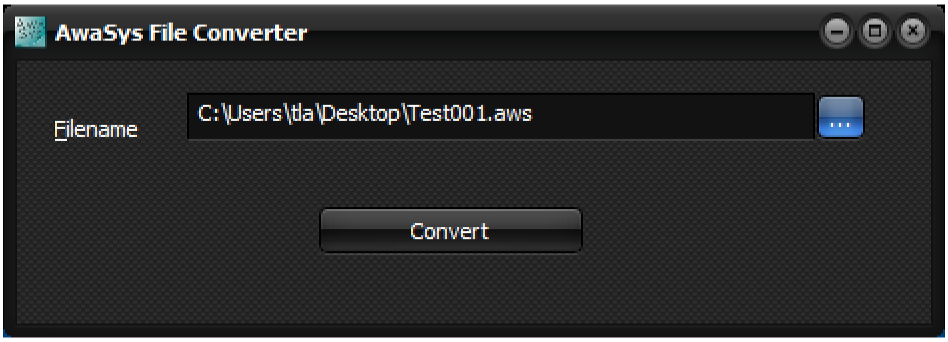


AwaSys has been developed to support a wide range of I/O hardware. AwaSys can use different hardware for output (paddles) and input (wave gauges). In all cases the DAQ is setup in single shot operation, i.e. timing controlled by AwaSys. Contious mode can not be used due to active absorption that has to run in real time.

The manufactures can either be single value (a call to DAQ for reading/sending one channel per call) or multi value (all channels read/send with one call per board). Below list shows the supported manufacturers and the sampling method. For National Instruments, where both methods has been implemented, it is recommended to use the multi value version.

Manufacturer	**Input supported**	**Output supported**	**Single value**	**Multi value**
DemoDummy (simulation mode)	X	X	X	
Data Translation	X	X	X	
National Instuments (single value)	X	X	X	
National Instuments (multi value)	X	X		X
Com-Port Naples		X		X
Com-Port Naples semi parallel		X		X
Com-Port Naples parallel		X		X
Measurement computing	X	X	X	
Com-Port VTI	X	X		X
Ethernet VTI	X	X		X

3.12 Binary/ASCII conversion



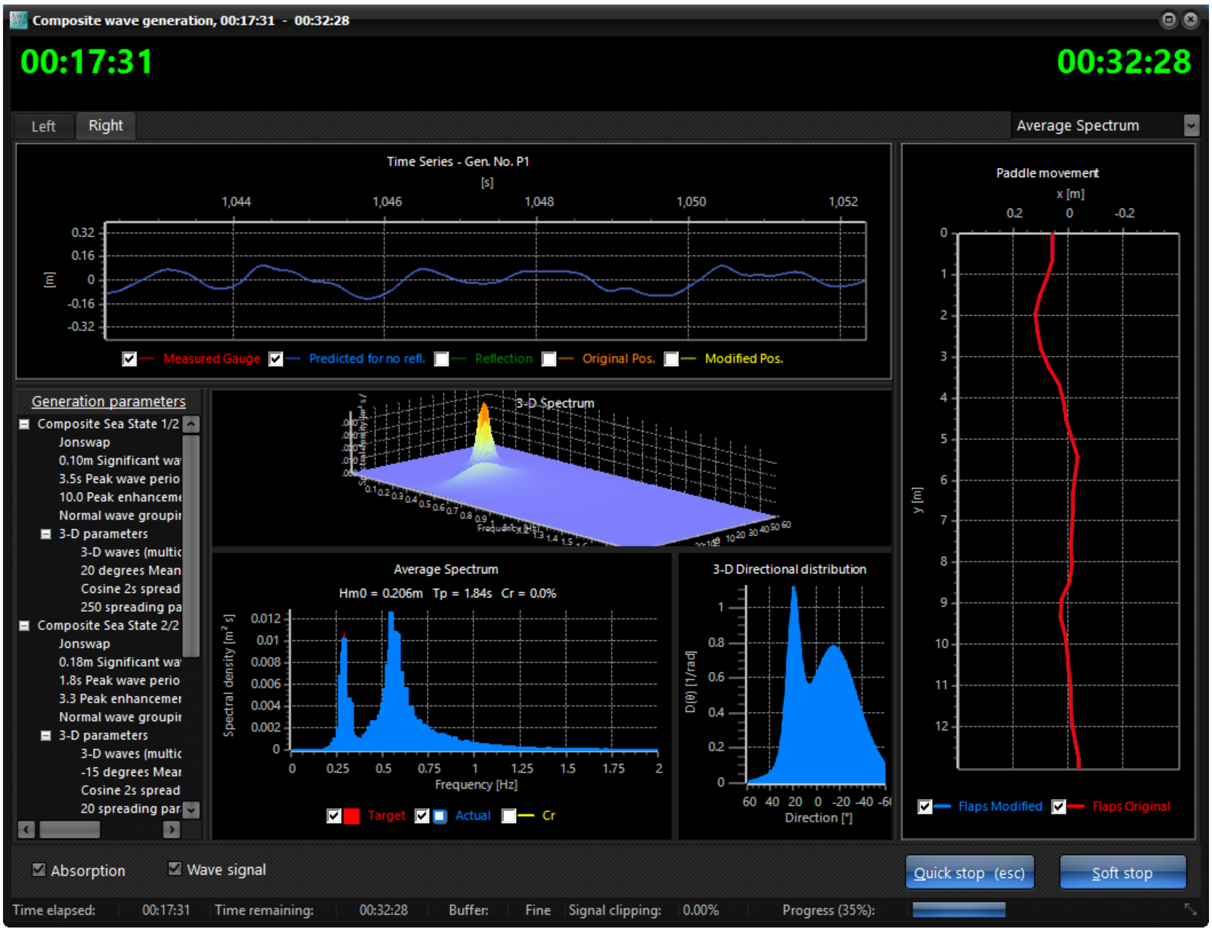
Replay files for this AwaSys version will have to be with binary data. Such files can be converted to and from ASCII using this tool.

4. Wave generation

The layout of the wave generation screen is depending on the setup (2-D vs. 3-D mode).

2-D operation

3-D operation



Plot Channel (3-D only)
In the upper right hand corner the user can choose the generator number to show in online monitoring. Average will show average spectrum from all generators and surface elevation time series from generator number zero.

Toggle signals
Absorption and wave-signal can be toggled on/off during generation using the check boxes in the lower left corner of the window. This is especially useful when testing the absorption settings.

Stopping and calm down
When the desired generation time has elapsed, the generation automatically stops. If absorption was selected on start, AwaSys will continue to absorp for the stated calm down period.
A test series can be aborted before time, by pressing the soft stop button. The generation is not abrupt stopped but is slowly gained down in order not to damage generators. Quick stop can be used as emergency stop and stops abrupt.

Generation parameters
This panel show a summary of the generation parameters.

Elevation
This chart displays the history of measured elevations by the wave gauges. Toggle between wave gauge(s) to show in list in upper right corner. Two gauge signals are shown in case of active absorption based on two gauges in the far-filed. In case of active absorption based on one gauge in the near-field is shown measured elevation, predicted elevation for no reflection. The difference between the two is the signal that goes trough the filter. This signal is termed reflection but include also near-field from active absorption signal and re-reflections. In 3-D mode it is further possible to show original (unclipped and without absorption correction) and modified (including clipping and active absorption) paddle movement history.

Real-time analysis
This panel provide information about the actual generated wave field. The target spectrum and

measured incident wave spectra are shown and the reflection coefficient as function of frequency is shown. In the caption is shown estimated wave height, period and total reflection coefficient. The estimated incident wave characteristics are updated and averaged over the total run time. The method used for online analysis depend on the active absorption method chosen. In case of two gauges in the far-field Goda and Suzuki (1979) is used while Schäffer and Hyllested (2000) is used for one gauge in the near-field. For later documentation, the spectrum and estimated wave characteristics can be printed or exported. This is done through the pop-up menu, which appears by right click on the chart.

Paddle movement and paddle movement history
The movement of the paddle(s) can be monitored real-time for original signal (unclipped and without absorption correction) and modified (including clipping and active absorption). For 2-D operation the time history of the original and modified paddle position signal is also shown.

Status bar
The status bar shows information on elapsed and remaining time, the buffer status of calculated new samples, the fraction of sample where clipping has been made. Clipping is made due to stroke limits, velocity and acceleration limits (termed 2-D clipping), maximum displacement between paddles (termed 3-D clipping). If clipping has occurred during the test a warning is showed after the test has finished with information on the number of samples modified due to 2-D and 3-D clipping respectively.

5. Preferences

The behaviour of AwaSys is configured in preferences. Settings in preferences are divided into user settings and facility settings. An administrator password can be set with the button "Admin. password". In case a password is given the facility settings are not editable unless the administrator login with the button "Admin. login". After admin login the facility settings are editable and also the password can be changed. Note setting an empty password removes the password protection.

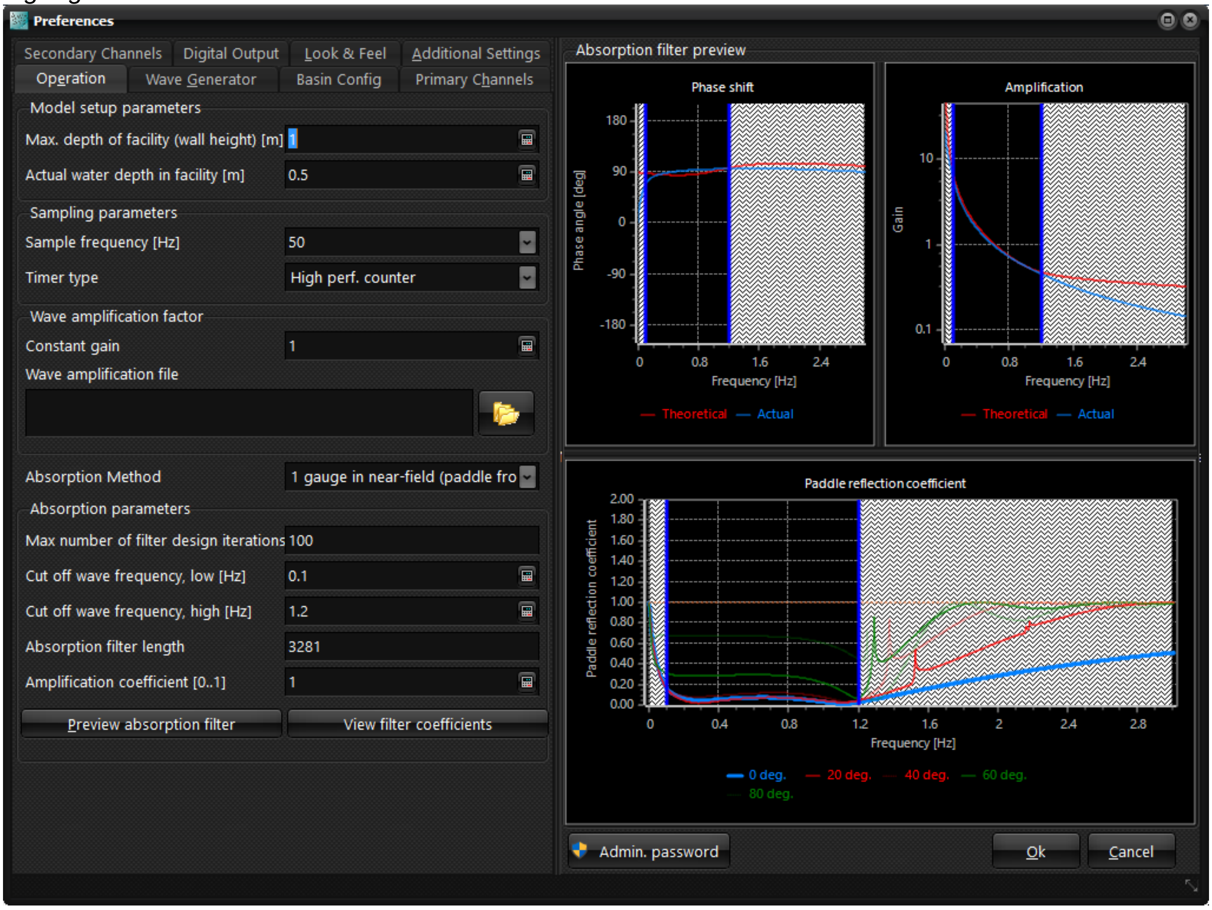
The various settings are split into the following tabs:

- Operation
- Wave generator
- Primary Channels
- Secondary Channels
- Digital Output
- Look & feel
- Additional settings

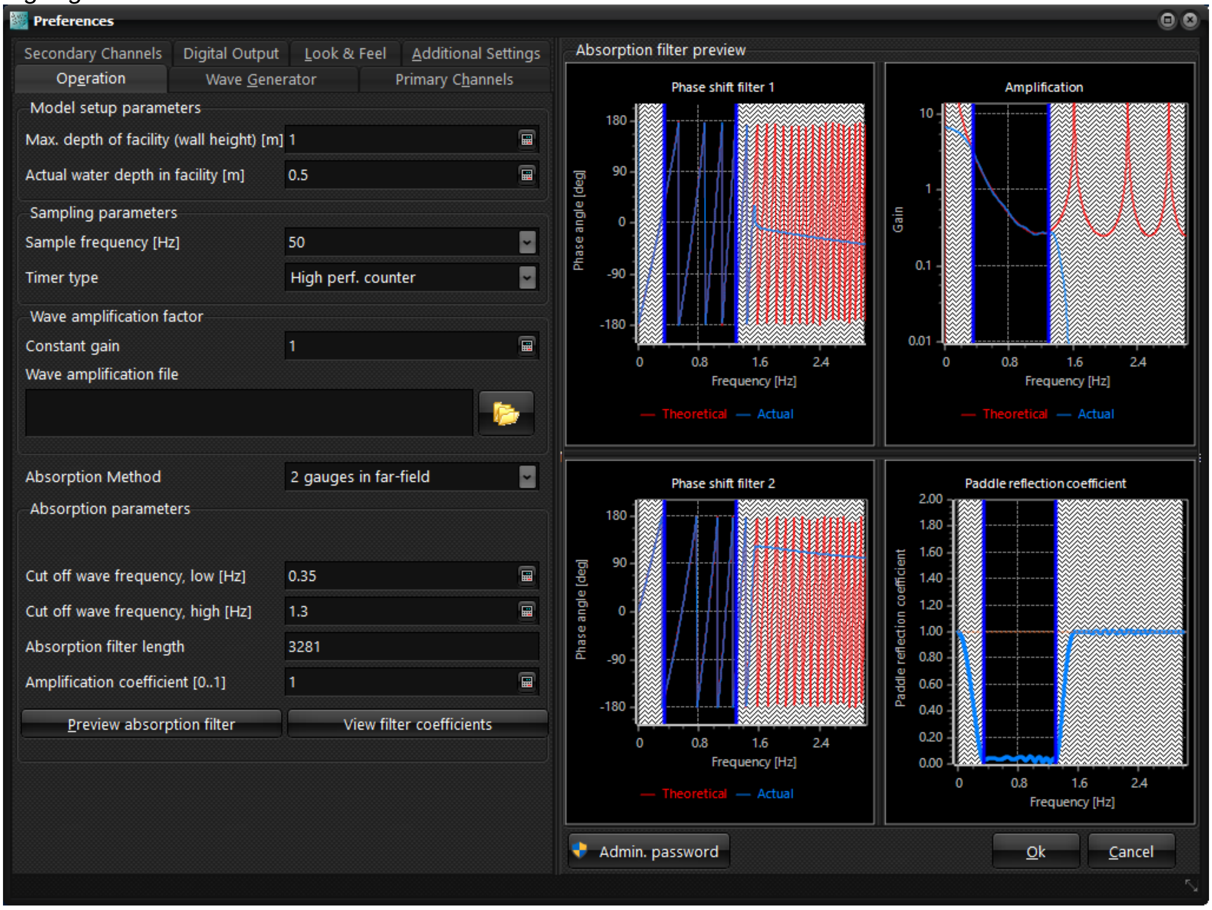
5.1 Operation

Below pictures show the operation tab for the two different absorption systems available. The figures on the right hand side presents the performance of the absorption system as further discussed below.

1 gauge near-field



2 gauges far-field



This page contains parameters for model setup, sampling and absorption. This is the parameters most likely to change between test setups.

Model setup parameters

Field		*Description*
Max depth of facility (wall height) [m]	:	Physical height of the flume, used for validation of generation parameters
Actual water depth in facility [m]	:	Water depth at the location of the paddle the wave gauge(s) used for absorption. If absorption method is two gauges in far-field and the flume bottom is slightly inclined, an average water depth from the generator to the gauges should be used.

Sampling parameters

Field		*Description*
Sample Frequency [Hz]	:	The frequency by which elevation is measured by the wave-gauges and control-signal is send to the servo. A high sample frequency is needed to have smooth operation. However, a high sample frequency can reduce the spectral resolution of the generation and on-line analysis. To compensate for this, it can be necessary to increase some of the filter lengths used during computation or the over sampling factor, see Additional settings. Note that some digital servo controllers require a fixed sample frequency (for example 50 Hz for VTI controllers).
Timer type	:	Looping thread, Int. Multimedia, Int. high perf. count. Looping thread uses a looping high priority thread. Can be used with any sample frequency and is accurate, but CPU consumption will be higher than with other timer types. Multimedia timer is a special kind of high precision timer offered by Microsoft Windows. Since intervals can only be set in milliseconds not all frequencies are supported. Only frequencies which can be divided into

1000 without remainder are possible. Timer is slightly less accurate than other two alternatives.

High performance counter. Most pc’s are equipped with a high performance counter, which is a hardware generated very fast and precise counter. By checking this counter and constantly adjusting the multimedia timer interval all frequencies can be simulated. This timer is slightly more precise than the Multimedia timer.

It is recommended to use the Internal High performance counter for optimum results.

Wave amplification factor
The setting here are used in case a very accurate reproduction of the wave parameters are needed in a specific point. The constant gain parameter is used to match accurately the height of the produced wave. The factor is established by first analysing and initial test with the factor set to 1.0. By analysing the waves the ratio of the target and measured wave height is used as the constant gain factor. The wave amplification file is making an adjustment per frequency to match very accurately a target wave spectrum. The file should contain two columns. The first column must be the frequency in Hertz (ordered) and the 2nd column must be the amplitude correction factor for each frequency. Such file can be exported from WaveLab analysis software.

Absorption parameters (general)
Two absorption methods are implemented and chosen between here.
1. System based on Frigaard and Brorsen (1995) method. The system uses two wave gauges in the far-field to sperate into incident and reflected waves in real time by means of digital FIR filters. In essence, the calculation of the paddle displacement correction signal needed for absorption of the reflected waves is determined by digital filtering and subsequent superposition of the two filtered surface elevation signals. This method can be used for 2-D situations only. In this system the online analysis is based on the principle of Goda and Suzuki (1979) and provides updated information about the actual generated wave's incident to the test structure.

2. System based on Milgram (1970), Schäffer and Jakobsen (2003) and others. The system uses one wave gauge on the paddle front to determine deviation from generated near-field waves. This deviation signal is send to a digital filter leading to a paddle correction signal. The method here is not based on a direct separation into incident and reflected waves but relay on the generated near field only. Therefore, accurate calibration is very important otherwise significant false reflections might be detected. The advantage of the system is that it has better performance for long waves and can be applied in 3-D situations. In this system the online analysis is based on the principle of Schäffer and Hyllested (2000) and provides updated information about the actual generated wave's incident to the test structure.

Absorption is possible if correct number of input channels have been defined under channels according to the absorption method selected; in that case, the preferences dialog is extended with charts helping to setup the optimum absorption filter parameters. The phase shift chart(s) and gain chart show a comparison between the theoretical phase shift and actual phase shift and gain realized by the filter(s). Phase shift and amplification combined is shown on the last chart and is named the Paddle reflection coefficient. It gives the coefficient of reflection as function of frequency. In case of 100% absorption the reflection coefficient equals zero while incase of no active absorption the reflection coefficient would equal 100%. For the system based on gauges on the paddle faces the reflection will be shown also for reflections approaching obliquely the generator. The absorption performance for highly oblique components can be increased by lowering the amplification coefficient leading to a wide range of frequencies and directions with very low coefficient of reflection. This lower amplification coefficient will also improve the stability of the system. When setting the absorption parameters the goal is to find filter parameters, which yields a reflection coefficient as close to zero within the desired area of application and without instability issues. Areas with reflection coefficient significant higher than unity are possible instability areas and should thus be avoided by proper absorption parameters. The charts are automatically updated if any of the involving parameters are changes.

Operation page

- Water depth in flume
- Sample frequency
- Servo delay
- Mechanical transfer file
- Cut off wave frequency low
- Cut off wave frequency high
- Absorption filter length
- Amplification coefficient

Channels page

- Dist. from paddle of wave gauges

Wave Generator page

- Generator Type
- Elevation position

Absorption parameters (2-gauges in far-field system)

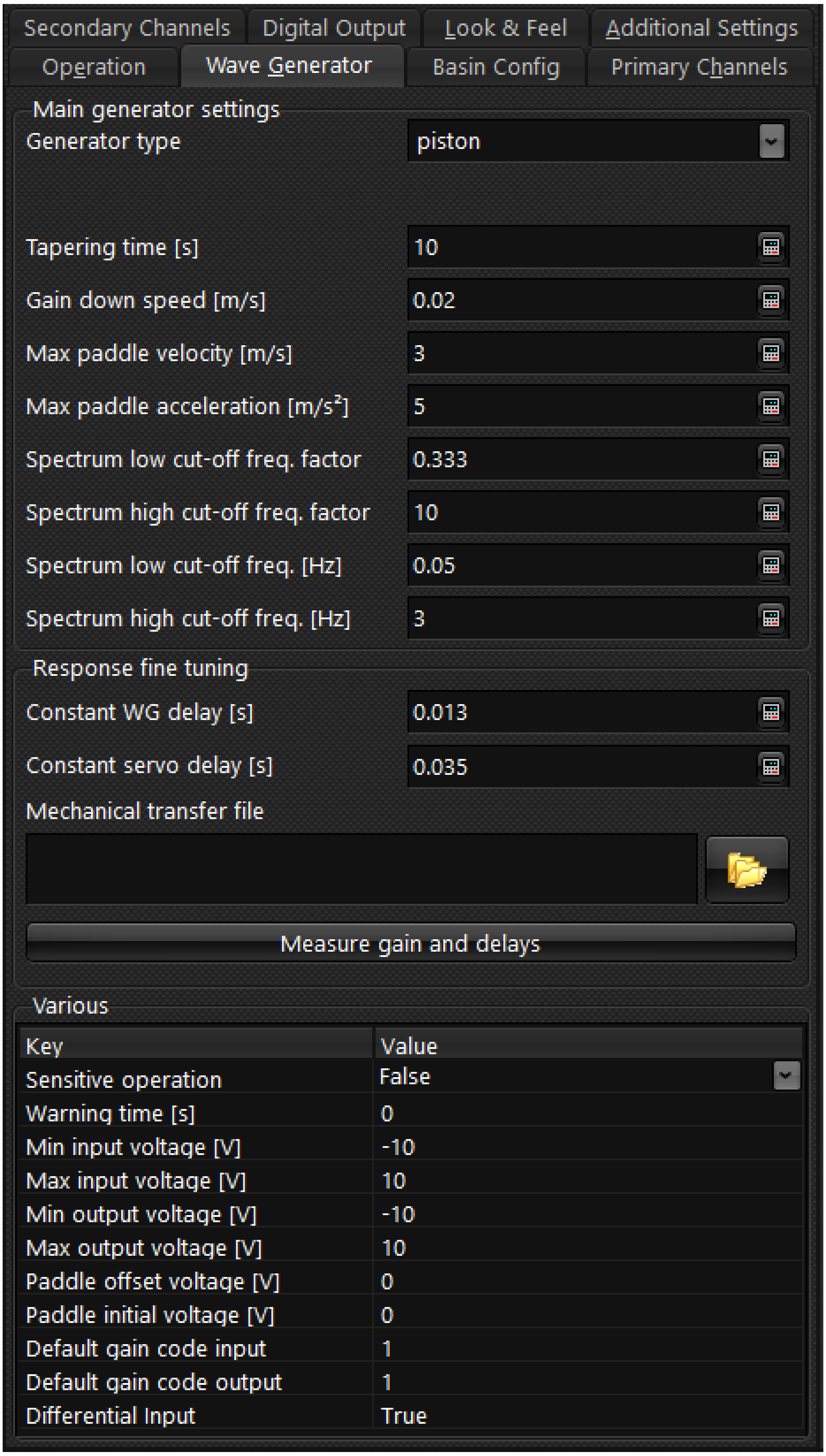
Field		*Description*
Cut off wave frequency low [Hz]	:	The lowest frequency, at which the wave absorption system is fully active. This low cutoff frequency is necessary to ensure a finite response at low frequencies to avoid significant drift of the paddles.
Cut off wave frequency high [Hz]	:	The highest frequency, at which the wave absorption system is fully active. This cut off frequency is necessary to avoid system to react on noise and to avoid the singularity due to the spacing between the two wave gauges.
Absorption filter length	:	The filter length of the absorption filter(s). Due to internal computation logic of the program, odd filter lengths are required. To obtain the best possible fit of the filters a long filter is desired. Fast filter preparation for the filter lengths 563,1013, 1823, 3281 Adjust the filter length to obtain the best reflection coefficient curve (value of zero, within the cut-off frequencies).
Amplification coefficient [0..1]	:	Can be set to any real value between 0 and 1. The amplification coefficient defines the efficiency of the active absorption system (1 is always recommend for this absorption system).
View Filter Coefficients	:	Can be used to view the filter coefficients of the two filters. The filter coefficients at time zero should approach zero. If not there are different solutions to improve performance: 1) position gauges further away from the generator 2) decrease filter length 3) increase cut off frequency low.

Absorption parameters (1-gauge in near-field system)

Field		*Description*
Max. number of filter design iterations	:	The maximum number of iterations in the filter design procedure. A value of 1 indicate no correction iterations performed, a value of 2 means only overall gain and delay adjusted, a value higher than two means filter is adjusted in an iterative manner. A maximum number of iterations around 30 seems appropriate in most cases
Cut off wave frequency low [Hz]	:	The lowest frequency, at which the wave absorption system is fully active. This low cutoff frequency is necessary to ensure a finite response at low frequencies. Response of filter is non-zero at 0 Hz meaning that filters will react on a water level change. The gain chart shows the gain on 0 Hz

		(typical gain value is five which means a water level drift of 1 cm will mean a generator drift of 5 cm).
Cut off wave frequency high [Hz]	:	The highest frequency, at which the wave absorption system is fully active. This cut off frequency is necessary to avoid system to react on noise and be unstable on high frequencies.
Absorption filter length	:	Due to internal computation logic of the program, odd filter lengths are required. Low frequency response is usually improved with longer filter lengths. Fast filter preparation for the filter lengths 563,1013, 1823, 3281.
Amplification coefficient [0..1]	:	Can be set to any real value between 0 and 1. The amplification coefficient defines the efficiency of the active absorption system (A value lower than one can be used to improve filter stability if needed). If there are frequencies where the reflection coefficient is significantly above one it is recommended to reduce the amplification coefficient in order to improve stability of the system.
View Filter Coefficients	:	Can be used to view the filter coefficients of the filter. The filter coefficients at the left end of the filter should approach zero otherwise filter is too short.

5.2 Wave generator



This page contains settings related to the hardware involved in generating the waves and the necessary communication setup.

Main generator settings

Field		*Description*
Generator type	:	Type of wave generator used. Piston, Hinged, Elevated Piston, Elevated Hinge, Combined (rot below bed level), Combined (piston and elevated flap). For the combined piston and elevated flap two independent actuation modes are used (the special issues related to setting up such generator in AwaSys is found here). The optimal ratio of the two modes is automatically used in generation and in 2-gauge in far field active absorption system. For 1-gauge active absorption system piston mode is always used for the absorption correction.
Elevation position	:	In case of Elevated Piston, Combined and Elevated Hinge paddle types, vertical position should be stated. A list of standard position can be maintained, by using the add new position entry to create one and delete button to erase current position.
Tapering time [s]	:	The time used for gaining up and down, when the wave generation starts and stops.
Gain down speed [m/s]	:	Determine how fast paddle(s) are allowed the move, when using the manual control feature or gaining down to/from initial and zero position (for example if generation is stopped using quick stop).
Max paddle velocity [m/s]	:	To protect the wave generation system the maximum allowed velocity of the paddles during generation can be set according to the design of the generators. For hinged and combined mode paddles the value is specified for the same level as the transfer constant. Generating waves where this limit is often exceeded in the original signal is not recommended as it will lead to decreased wave generation and absorption performance due to clipping modifications.
Max paddle acceleration [m/s^2]	:	To protect the wave generation system the maximum allowed acceleration of the paddles during generation can be set according to the design of the generators. For hinged and combined mode paddles the value is specified for the same level as the transfer constant. Especially electrical motors can impose some restrictions on the accelerations. Generating waves where this limit is often exceeded in the original signal is not recommended as it will lead to decreased wave generation and absorption performance due to clipping modifications.
Spectrum low cut-off freq. factor	:	Spectra low bound cut-off is at a frequency of peak frequency times this factor. Is included to prevent seiches in the facility and to prevent large paddle drift due to low frequencies. Energy in spectrum will be kept by scaling spectrum.
Spectrum high cut-off freq. factor	:	Spectra high bound cut-off is at a frequency of peak frequency times this factor. Energy in spectrum will be kept by scaling spectrum.
Spectrum low cut-off freq. [Hz]	:	Spectra low bound cut-off at fixed frequency. Energy in spectrum will be kept by scaling spectrum.
Spectrum high cut-off freq. [Hz]	:	Spectra high bound cut-off at fixed frequency. Can be set lower than default value if generators do not respond well to high frequency components. Energy in spectrum will be kept by scaling spectrum.

Paddle response fine tuning

Field		*Description*
Constant WG delay [s]		The delay on WG electronics (for example if analog lowpass filter is applied). This information is needed to optimize functionality of absorption.
Constant servo delay [s]	:	The delay from a signal is sent to the servo-controller until the piston move (usually 35 ms for VTI controller). This information is needed to optimize functionality of absorption.
Mechanical transfer file	:	File-name of a text file, which contains information about the

		phase and gain of some discrete frequencies. The file can be created by using the generation mechanical transfer file dialog. See "Measure gain and delay" below. The file should contain three columns: Frequency [Hz], Gain and Phase [radians]. If a mechanical transfer file is used together with a constant servo delay, the phase and delay are added. The mechanical transfer file should include three columns, i.e. 1) frequency, 2) gain and 3) phase shift.
Measure gain and delay	:	Brings up the Measure paddle gain and delay dialog

Various

Field		*Description*
Sensitive operation	:	Set this setting to true, if the wave generation is easily affected by user interaction. This has detected on systems using old ISA-bus acquisition cards. This switch will cause the program to start in full-screen and here-by make it more difficult to start working in other programs. Further more the only enabled control during wave generation is the stop buttons.
Warning time [s]	:	Setting this options >= zero display a warning every time the program will connect to the servo-controller. This is to prevent any sudden movement. Setting a time larger than zero, will cause the dialog to blocked for this time, forcing the operator to notice the warning. Setting a negative value will not display the warning.
Min input voltage	:	The minimum input voltage to be expected from wave gauges and feed back channel.
Max input voltage	:	The maximum input voltage to be expected from wave gauges and feed back channel.
Min output voltage	:	The minimum of the output range. Signal is clipped if this value is exceeded to avoid wrecking the wave generator
Max output voltage	:	The maximum of the output range. Signal is clipped if this value is exceeded to avoid wrecking the wave generator
Paddle offset voltage	:	At which voltage level the paddle(s) are in center position.
Paddle initial voltage	:	Which voltage level to position the paddle(s) on connection/disconnection. On connection the paddles will be gained from initial voltage to offset voltage and the opposite on disconnect.
Default gain code input	:	The input gain code, which should be used on Acquisition. This value acts like a default value when pressing the auto populate channel button on the channels page, since the gain code is stated in each input channel.
Default Output gain code	:	The output gain code, which should be used on Acquisition. This value acts like a default value when pressing the auto populate channel button on the channels page, since the gain code is stated in each input channel.
Differential input	:	Are the input channels connected as single ended or differential.

5.3 Basin config

Paddle configuration:
Choose between wavemakers on one or two sides (L-shape). Configuration with wavemakers on two sides might be an effective way of increasing the size of the area with high quality waves (testing area).

Corner reflectors:

Length of side reflectors [m]	:	The length of the side reflectors used for corner reflection compensation to increase area with correctly generated waves. It is recommended to have the first part near the generator as reflective and the last part with some absorption. For reflective side walls etending beyound the main testing area set instead the distance from the wavemaker to the main testing area.

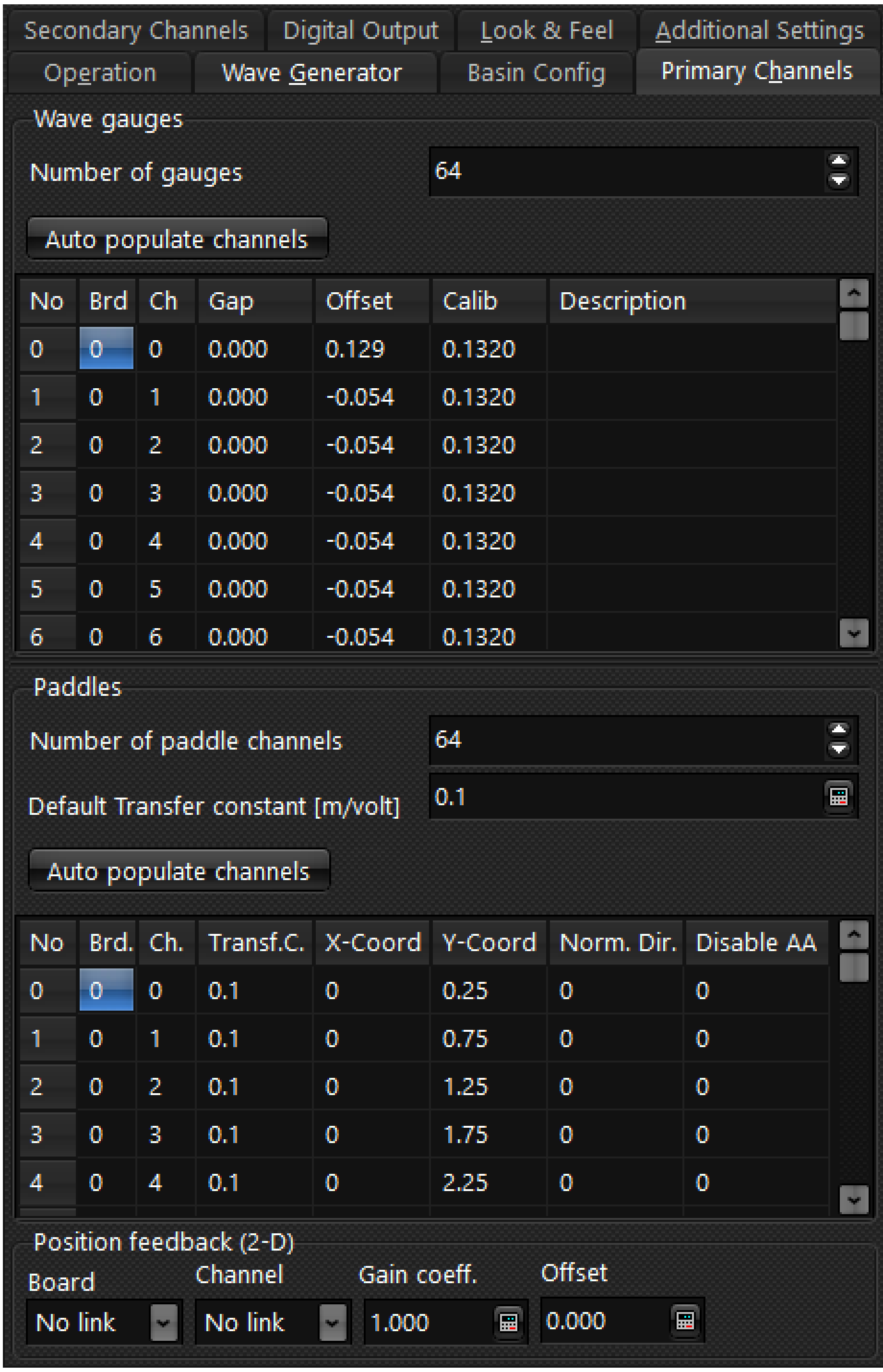
Side reflector coordinated [m]	:	The coordinate of the side wall reflectors. Standard layout is walls at 0.0 and length of the paddles on the face. For no wall option in one end of the wavemaker a coordinate some distance from the wavemaker might be used.

3-D mode generator settings:

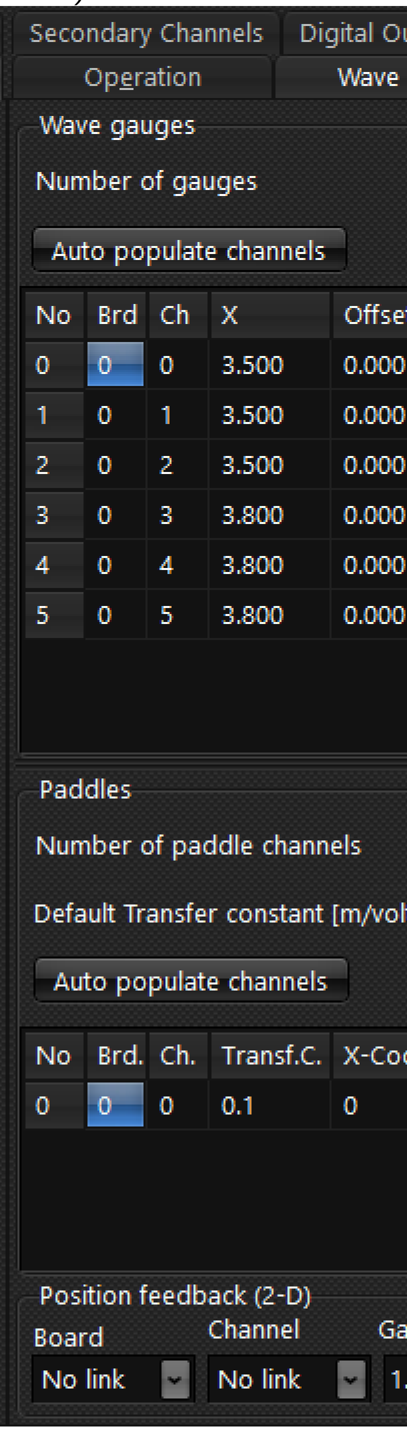
Flap width [m]	:	Width of each flap, (3-D operation only). If snake principle is used the first and last paddle should be half the width of the number given here.
Max. neighbour pos. difference [m]	:	Maximum displacement difference between neighbouring generators (3-D operation only). Should be used to prevent gaps when generators are not in snake principle and to prevent paddles to be removed if generators are in snake principle operation. Will also limit displacements between locked (transfer constant of zero) and normal operating generators. For hinged and combined generators the value refer to the level at which the transfer constant is given.
Angle width [degrees]	:	The maximum wave angle, which can be generated (3-D operation only). Note that this is a maximum value that the software will automatically lower if spurious wave amplitude is too high.
3D Flap Type	:	Generator face type, i.e. boxes (piecewise constant) or vertical hinged (piecewise linear). Used for spurious wave correction as vertical hinged paddles have increased generation possibilities (frequency, direction combinations) compared to box mode generators. The 3-D absorption performance curve will also depend on the flap type. Moreover it changes the visualization of the paddles.
3D reverse piston order	:	Uncheck for normal piston order and check for reverse piston order. Normal piston order is numbering from left to right when standing in front of the generators with face to the generators. Reverse piston order is opposite.

5.4 Primary channels

3-D operation (64 generators and 64 wave gauges)



2-D operation (1 generator and 6 below)



On this page, the number of channels to use for input and output is set up. Correct number of wave gauges (see below under number of gauges) will enable active absorption and the dialog will be extended with absorption filter charts see absorption under Operation.

Wave gauges

Field		*Description*
Number of gauges	:	The number of wave gauges. If active absorption method is two gauges in far-filed two channels per generator is needed (only recommended in 2-D). If active absorption is one gauge in the

		near-filed one channel per generator is needed. The gauges need to follow the same order as the paddle channels, i.e. first channels for paddle 0, then channels for paddle 1 and so on. If number of gauges is a multiplum of above given required channel numbers then signals are averaged (useful in 2-D to minimize influence of noise and cross-modes). In this case gauges that are averaged must follow each other in the list. See above example for 2-D operation (1 generator) and active absorption based on two gauges in the far-filed. In this example is used average of first three as signal one and average of last three as signal 2 in the absorption compensation.
Auto populate channels	:	Will automatic setup the stated number of channels using default values from the Wave generator page.
Brd	:	Data acquisition board number
Ch	:	Channel number on the board
X/Gap	:	The distance of the wave gauge from the paddle in metre (is used for calculating absorption filters).
Offset	:	Offset value from calibrating the wave gauges, i.e. the voltage level with still water. This value can be detected using the Calibrate wave gauges dialog or the self-test dialog. Surface elevations in metres are thus obtained by Eta = Calib*(Voltage-Offset).
Calib	:	Calibration coefficient in m/V obtained by calibrating the wave gauges. This value can be detected using the Calibrate wave gauges dialog or the self-test dialog. Surface elevations in metres are thus obtained by Eta = Calib*(Voltage-Offset).
Gain	:	Gain code for the data-acquisition input channel. Please refer to the manual of the data-acquisition for this value.

Paddles

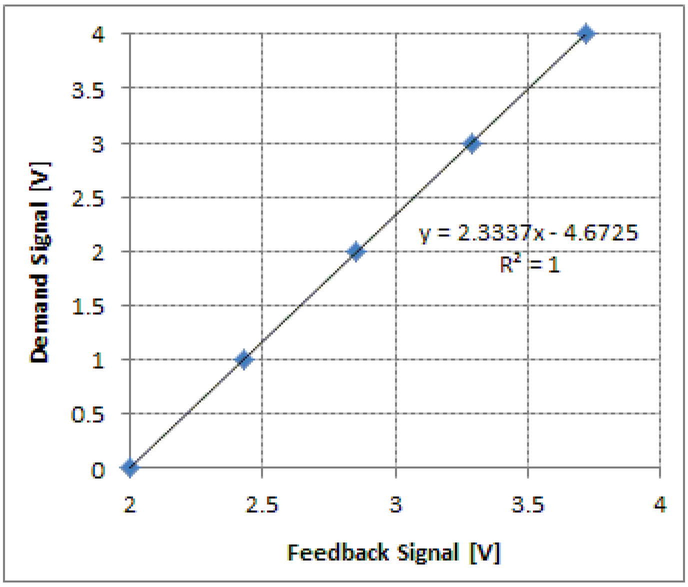
Field		*Description*
Number of paddle channels	:	The number of paddles connected to the system.
Auto populate channels	:	Will automatic setup the stated number of channels using default values from the Wave generator page
Brd	:	Data acquisition board number
Ch	:	Channel number on the board
Transf.C.	:	Transfer coefficient for the paddle in meters per volt. Use manual signal to determine this value. For the Hinged paddle type this value should give the displacement 1 m above hinge. To lock paddles at mean position specify a transfer constant of zero.
X-Coord / Y-coord	:	(X,Y) coordinate for actuation of paddle. For vertical hinged setup hinge position should be specified for box mode setup center of paddle should be specified. In one sided setups X-coord should be zero for all paddles. In standard setups the coordinates can be filled by using "Auto populate channels" button when basin configuration has first been setup.
Norm. Dir	:	The direction of an outward normal vector to the paddle in degrees. For one sided setups this should be zero. This value is automatically filled using "Auto populate channels" button when basin configuration has first been setup.
Disable AA	:	Makes it possible to disable absorption for individual paddles for example if wave gauge is malfunctioning (0 = absorption enabled, 1 = absorption disabled).

Position feedback (2-D)

As an extra safety measure a position feedback can be defined for 2-D setups. It is an input channel which is either connected to the output channel or the feedback signal from the servo-controller. If defined, AwaSys will measure the value on start up (connection) and gently gain from current to initially position if there is a difference. This will be a very seldom event, which only happens if paddle has moved for example during filling of the flume or if AwaSys is aborted/closed without moving to initial position. Nevertheless this can prevent unwanted shock waves, and possible damaging for the model, caused by paddle not being in initial position up connection. Moreover, if the servo feedback is connected to this channel AwaSys can automatically find the mechanical transfer of the generator using the Measure paddle gain and delay dialog.

Field		*Description*
Board	:	Data acquisition board number
Channel	:	Channel number on the board
Gain coeff.	:	Gain coefficient. The relation between the output signal and the feedback signal of the servo-controller (see below figure). If connected directly to the output channel, Gain coefficient = 1. Note that the raw servo feedback signal has in many cases opposite sign of the send signal i.e. gain coef. should be negative.
Offset	:	A possible offset between the output signal and the feedback signal from the servo-controller (see below figure). If connected directly to the output channel, offset = 0

Below picture shows an example of determination of feedback gain coefficient and offset. In this example gain coeff. = 2.334 and offset = -4.673 V.



5.5 Secondary channels

Secondary channels can be used for two options:
1. Additional wave generator channels that work as active absorption only (active rear end absorber). Wave generation direction can either be from primary towards secondary or opposite (set in operation tab)
2. Additional input channels to sample and store in .awg file (no secondary paddle channels to be defined).

In the later case the defined X coordinate (in model scale) of the channel will only be stored in header for easier processing in WaveLab reflection analysis. The other settings of the secondary channels are identical to the primary channels.

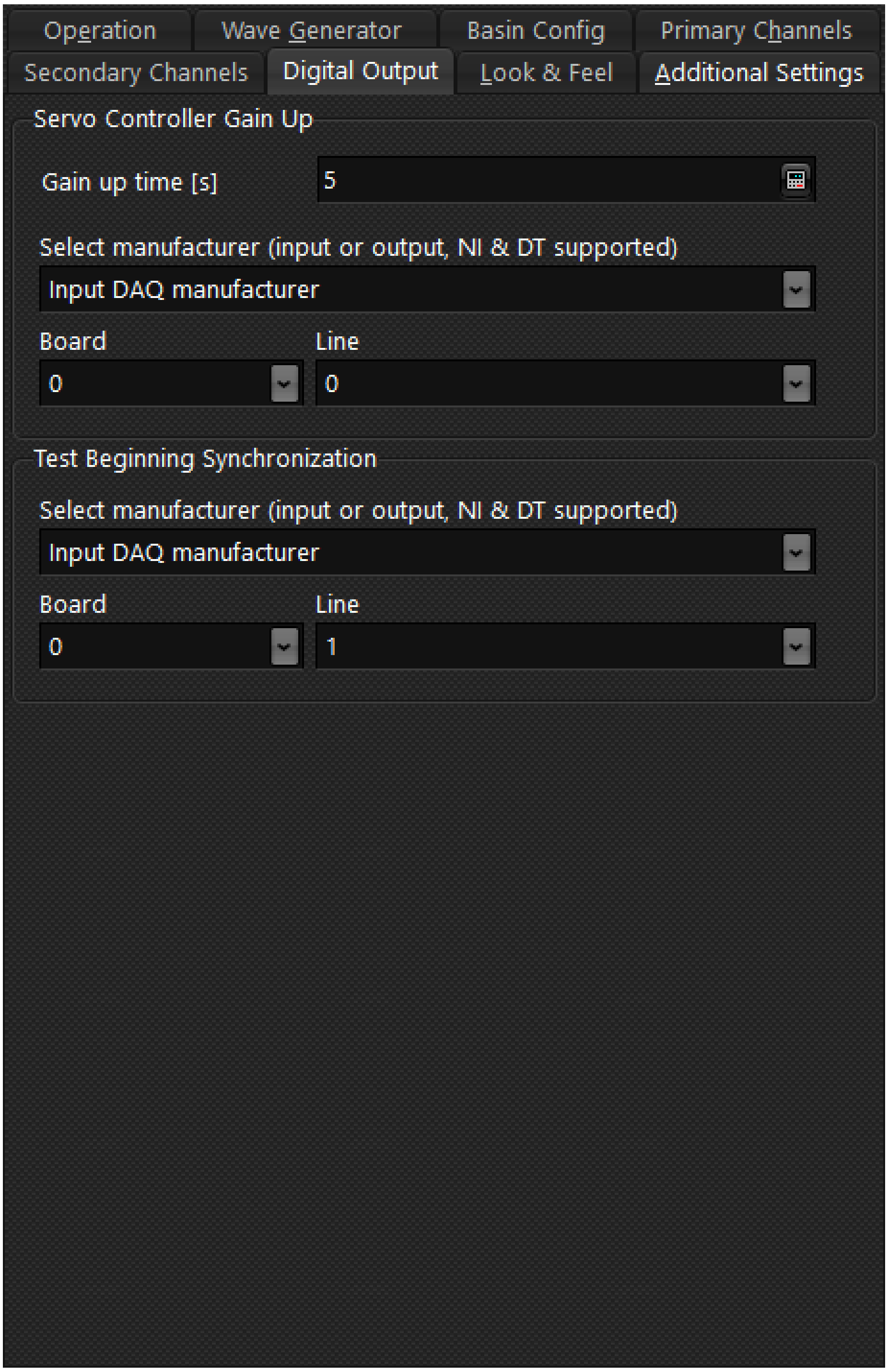
5.6 Digital output

On this page it can be configured to send out digital output to start up servo and to trigger data acquisition software to start (for example WaveLab). Just a digital output line on a board used by AwaSys need to be connected to a digital input line to the equipment to be controlled.

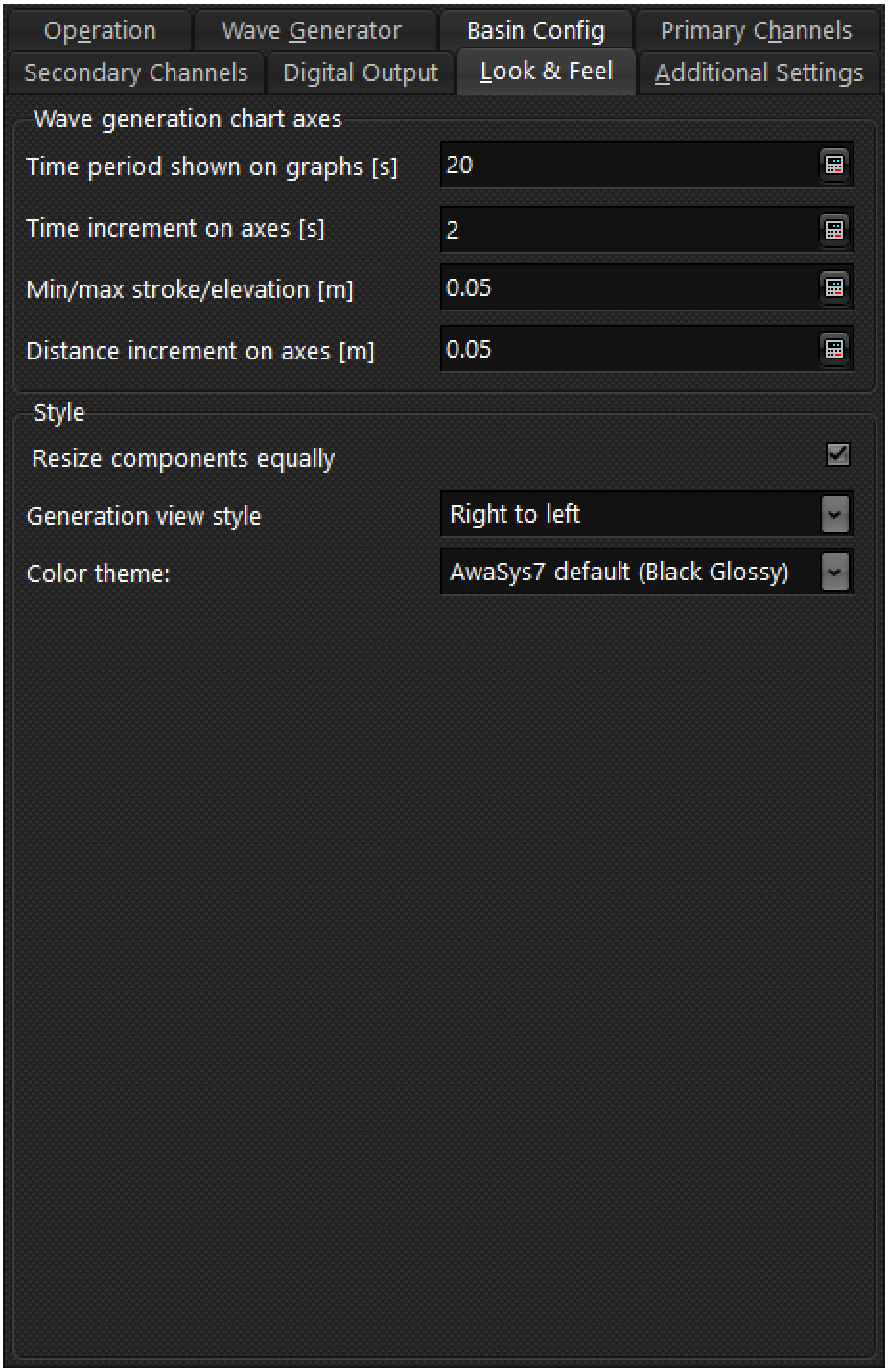
At the moment this feature has in AwaSys only been implemented for DAQ boards from National instruments and Data Translation. On Data Translation the bit used is always bit number zero on the specified port. You can select to use either input board manufacturer or output board manufacturer for the digital output.

For servo controller start up the digital signal is on when ever the servo needs to gain up to prepare for movement. The gain up delay of the servo controller can be given. The signal is off when servo no longer needs to be gained up (no movements).

For DAQ synchronization with WaveLab the line needs also to be configured in WaveLab. This synchronization is very useful when it is needed to know in the acquisition when the generation has started and especially also very useful when running tests in in batch mode. The signal i send when the generation starts and removed one second into the test.


Operation
Wave Generator
Basin Config
Primary Channels
Secondary Channels
Digital Output
Look & Feel
Additional Settings
Servo Controller Gain Up
Gain up time [s]
5
Select manufacturer (input or output, NI & DT supported)
Input DAQ manufacturer
Board
Line
0
0
Test Beginning Synchronization
Select manufacturer (input or output, NI & DT supported)
Input DAQ manufacturer
Board
Line
0
1

5.7 Look & feel



Settings on this page are all related to the behaviour and cosmetic of the program.

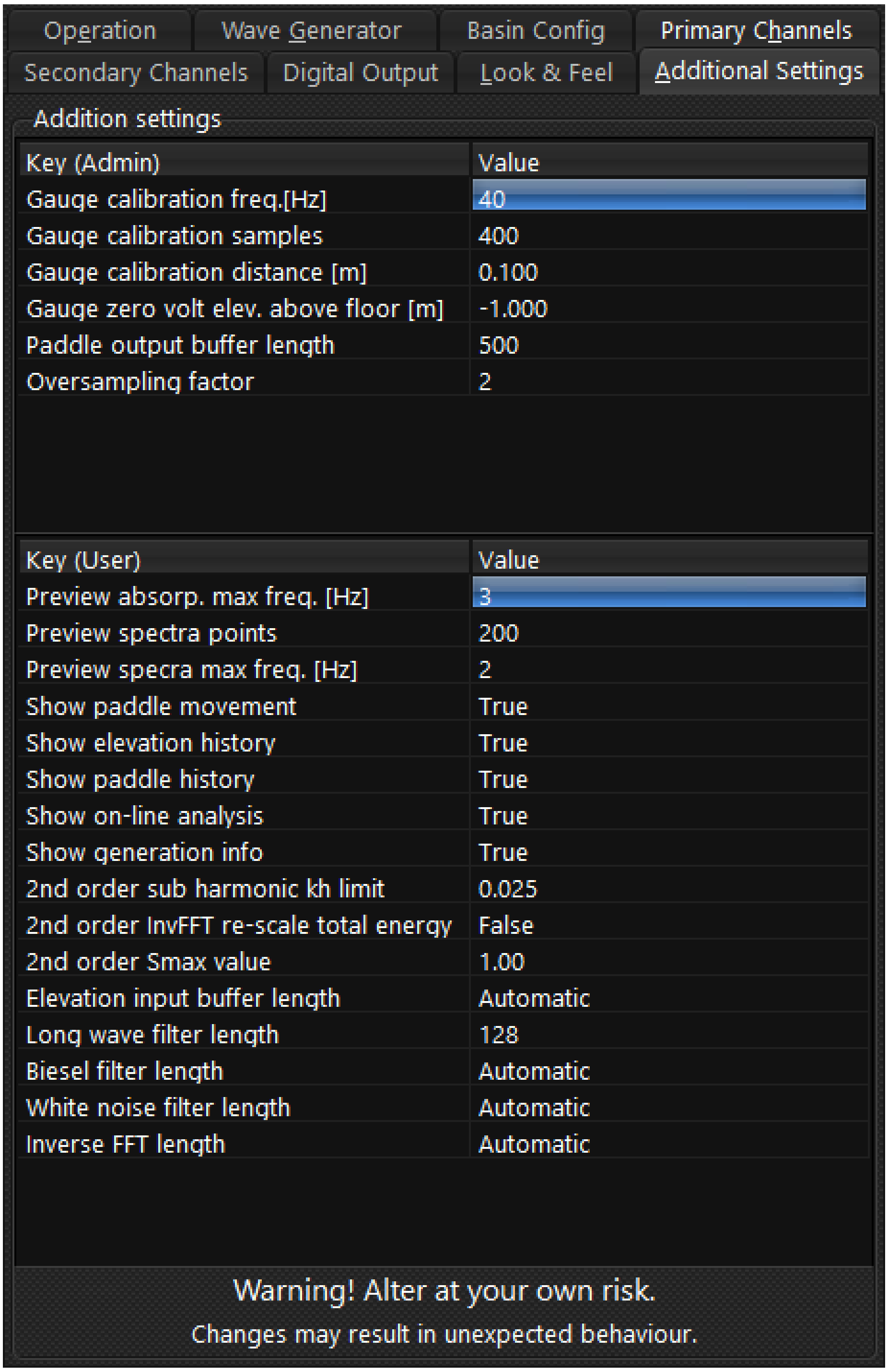
Wave generation chart axes

Field		*Description*
Time period shown on graphs [s]	:	History length in seconds of measured elevation and paddle movement
Time increment on axes [s]	:	Increment value of time axes
Min/max stroke/elevation [m]		Initial minimum and maximum of length axis on the elevation and paddle history charts. If this value is exceeded during generation, the charts will automatically adjust.
Distance increment on axes [m]	:	Increment value of distance axes

Style

Field		*Description*
Resize components equally	:	If checked the individual panels of a window, will their size-ratio on re-size of the window.
Generation view style	:	The layout of the generation window can be changed to fit the orientation of the flume.
Generation view colour style	:	A few colour schemes for the charts.
Custom colours	:	Only visible when custom colours is selected as colour style. Here each component can be assigned a custom colour

5.8 Additional settings



This page contains broad variety of program settings, which can customize behaviour of the program, but most likely never need to be changed. The settings can only be changed after checking the "change addition settings" check box.

Additional settings

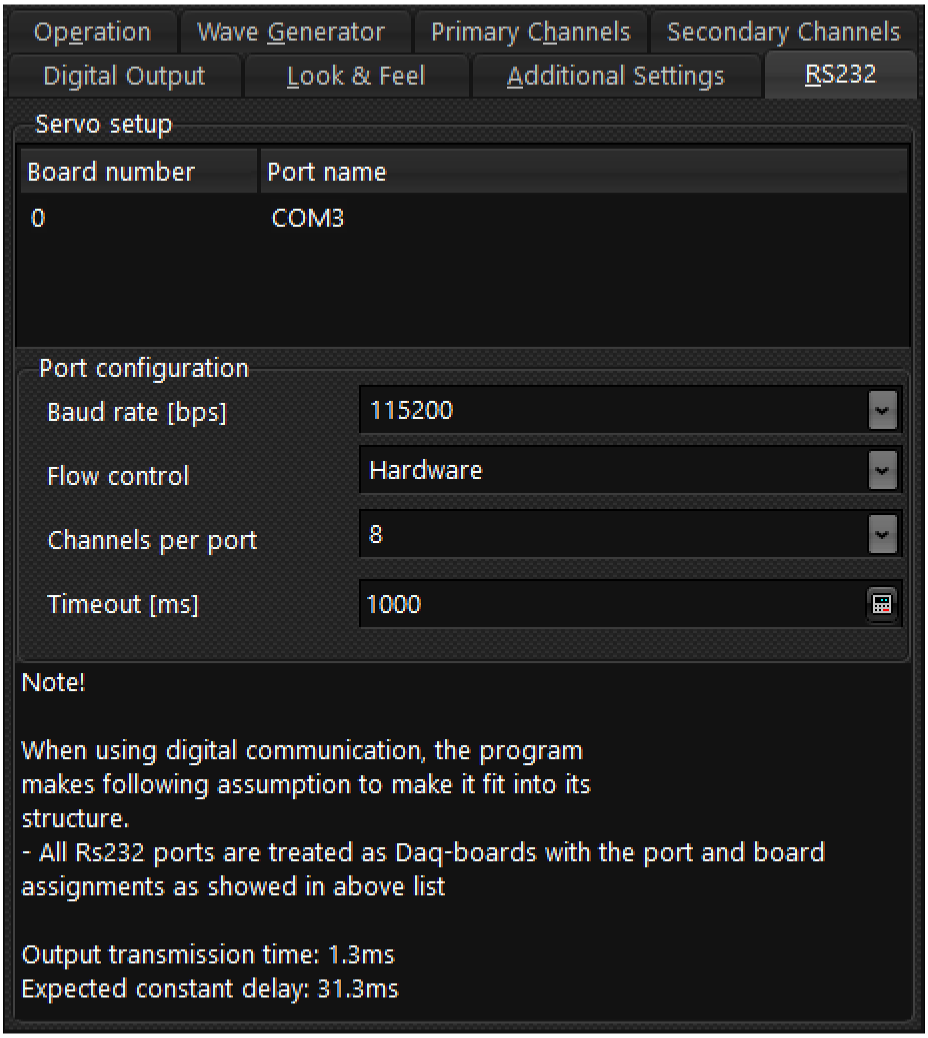
Field		*Description*
Gauge calibration freq [Hz]	:	Frequency at which the wave gauges are read during calibration in the calibration dialog, see section 6
Gauge calibration samples	:	Number of samples to average on when calibrating wave gauges in the calibration dialog.
Gauge calibration distance [m]	:	Distance between the wave gauges upper and lower position in meter. This is used in the calibration dialog.

Gauge zero volt elevation above floor [m]		The distance above the floor for the WG zero voltage. In case WGs do not have a fixed zero voltage level give a negative value.
Paddle output buffer length	:	Size of buffer to store pre calculated output signals.
Over sampling factor	:	Describes the number of times the synthesized signals are over sampled. If the over sampling factor is 10 this means that the actual sample frequency at which the signal is calculated is 10 times lower than the output sample frequency as specified in operation tab. The on-line analysis is also over sampled, i.e. an over sampling value of 10 means only every tenths elevation measurement are stored for online-analysis. Over sampling can be disabled by specifying a value of one. Over sampling is always disabled on regular wave generation.
Preview absorp. max freq. [Hz]	:	The maximum wave frequency shown on the absorption preview graphs
Preview spectra points	:	Number of point calculated and drawn on the spectrum preview graphs
Preview spectra max freq. [Hz]	:	The maximum wave frequency shown on the spectrum preview graphs
Show paddle movement	:	Show the real-time paddle movement during wave generation. Disabling this can ease the stress on a slow computer a little.
Show elevation history	:	Show the elevation history during wave generation. Disabling this will ease the stress on a slow computer
Show paddle history	:	Show the paddle movement history during wave generation. Disabling this will ease the stress on a slow computer.
Show on-line analysis	:	Show the on-line analysis during wave generation
Show generation info	:	Show generation info during wave generation
2nd order sub harmonic kh limit	:	The lower frequency limit to generate 2nd order bound subharmonics. The limit is given in terms of kh and is needed as the lowest frequencies would require very long stroke.
2nd order InvFFT re-scale total energy	:	For irregular waves 2nd order correction will introduce more energy than described Hm0. Enabling this option will rescale total spectrum including 2nd order correction to have desired Hm0 (only available for InvFFT generation and when active absorption system is set to 1-gauge nearfield).
2nd order Smax	:	Determines the maximum amount of second order energy (Smax = 1.0 is recommended value).
Elevation input buffer length	:	The number of elevation measurements on which the on-line spectrum analysis is based. A large buffer length gives a good spectral resolution but poor reliability of the energy distribution within the spectrum (large scatter). This makes the choice of buffer length a weight between fine spectral resolution and scatter. If "Automatic" is entered a proper value for the sea state to be generated will be used.
Long wave filter length	:	Length of longwave filter used for long wave computation (should be half of Biesel filter length in current implementation method)
Biesel filter length	:	Length of Biesel filter. There is an automatic option that sets a proper value for the sea state to be generated.
White noise filter length	:	Length of filter when using white noise generation method
Inverse FFT length	:	Length of inverse FFT transformation used for random phase generation method. FFT length should be long enough to prevent repetition of the signal (warning will be given if repetition will occur). There exist an automatic option that sets a proper value for the sea state to be generated.

All the above filter lengths should be as large as possible in order to give the best statistically distribution of the waves. However, big filter lengths results in longer computation time. It is recommended to use Automatic option for the parameters where it is available. Since the input on this page is only partly validated, wrong input may cause unintended behaviour.

5.9 Rs232

Two manufacturer are supported for com-port (RS232) communication with servo controller.The VTI servo controller uses a send and forget protocol, i.e. samples that are incorrect received is not retransmitted. Naples servo controller uses a protocol with handshaking, i.e. samples that are incorrect received will be resend for a given number of attempts. Below pictures show the RS232 tab when VTI is selected.

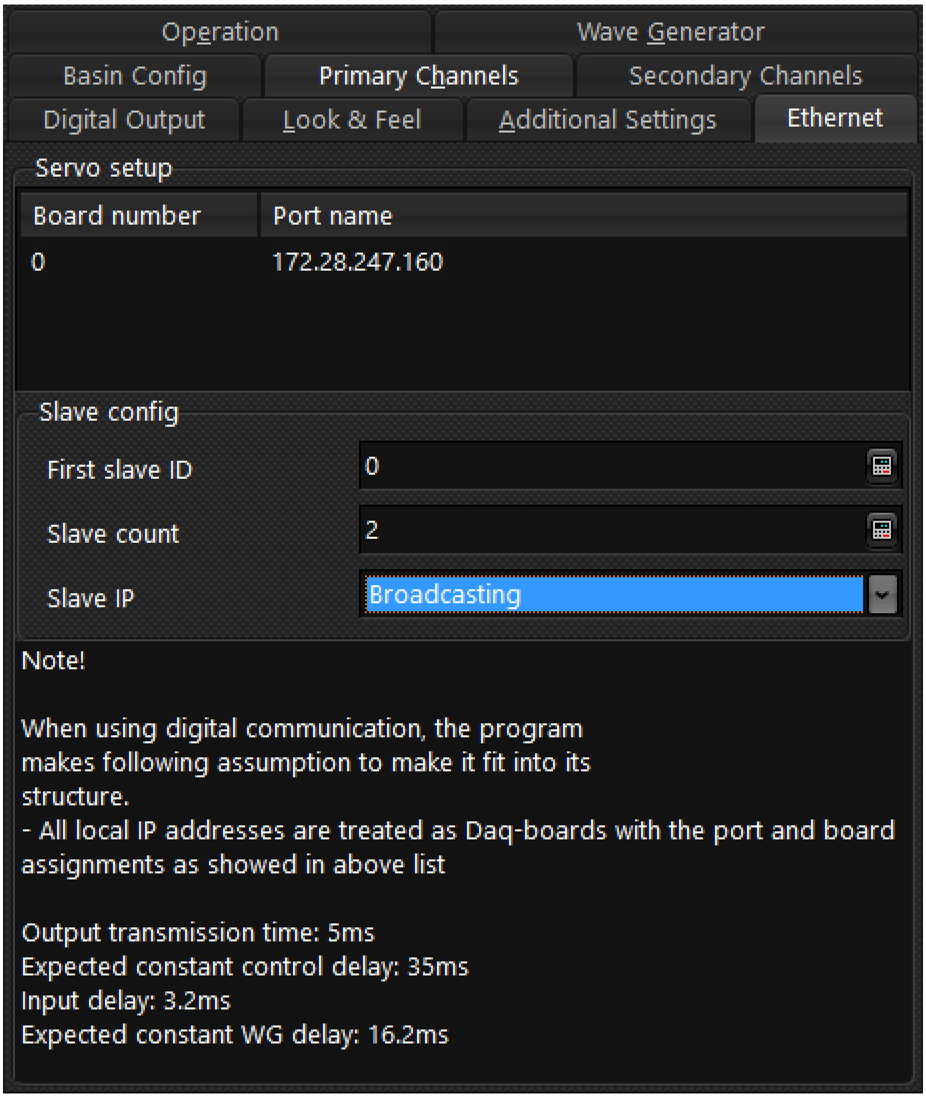


This tab is only present if output manufacture is set to Rs232. At the top is listet the availible ports and their corresponding board name.

Field		*Description*
Baud rate	:	The communication speed of the serial port
Flow control	:	none, software, hardware.
Channels per port	:	The number of pistons controlled by each port
Timeout [ms]	:	How long the program will wait for the servo to responds, before it reports an error. Setting this value to low will not give the servo-system enough time to responds.
No. of resend attempts	:	Number of time to resend information, if error (Naples servo controller only)
No. of Nak attemps	:	Number of times to resend information, if information is received but not acknowledged by the other part (Naples servo controller only)

5.10 Ethernet

AwaSys support using Ethernet protocol to communicate with some VTI servo controllers (DAQ input and output manufacturer).

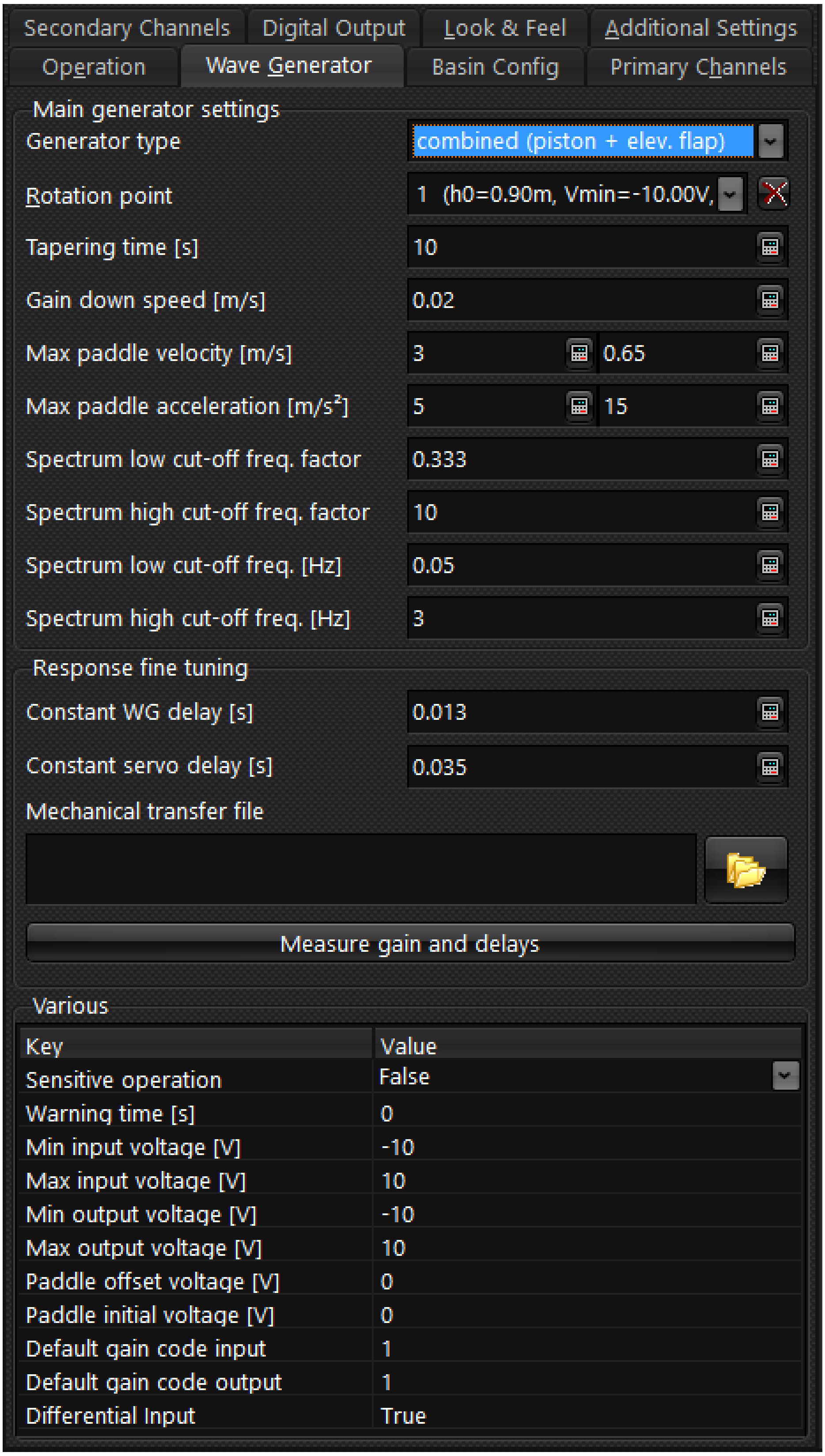


This tab is only present if output manufacture is set to Ethernet. At the top is listet the availible ethernet adapters and their IP address.

Field		*Description*
First slave ID	:	The ID of the first slave to use. This will usually be zero, but can be higher for example in a split configuration where a basin is splitted into 2 basins (or flume + basin).
Slave count	:	The number of servo controller slaves
Slave IP	:	Choose between "broadcasting" and "only detected slaves". Broadcasting is recommended for more than one slave. Only detected slaves is recommended for only one slave.

5.11 Combined piston flap generator

Under this item is explained the difference in preferences dialog for dual mode generators compared to single mode generators. The dual mode generator available in WaveLab is a combined piston and elevated flap wave maker. The rotation point for the elevated flap mode is defined on the wave generator page. When defining the rotation point also the voltage clip limits for the flap mode will be defined. The voltage clip limits for the piston mode are given in the various table. The velocity and acceleration limits are given for piston mode (left input field) and flap mode (right field).

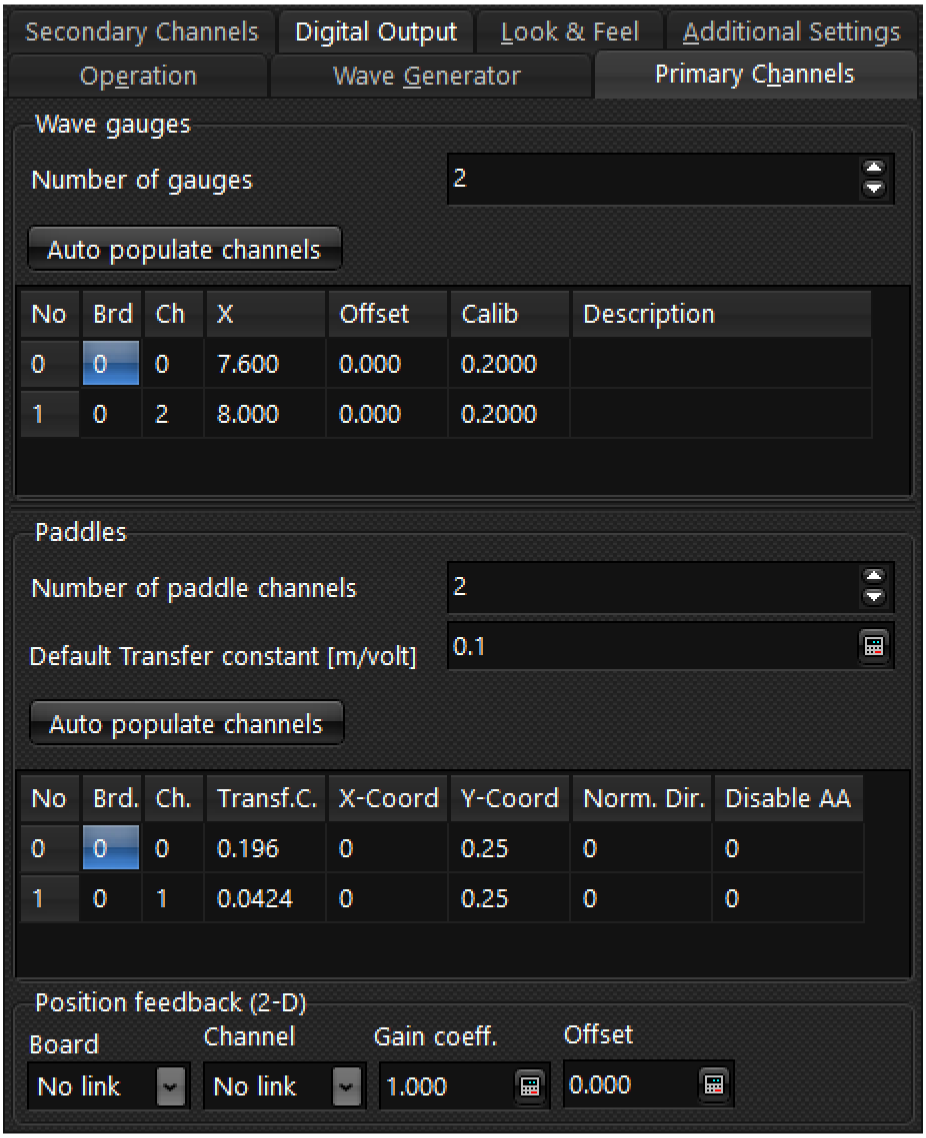


The two modes are independent and controlled by a control signal for each mode per generator. The channels need to be defined in the order:

- Ch. 0: Control signal for piston 1
- Ch. 1: Control signal for flap 1
- Ch. 2: Control signal for piston 2
- Ch. 3: Control signal for flap 2

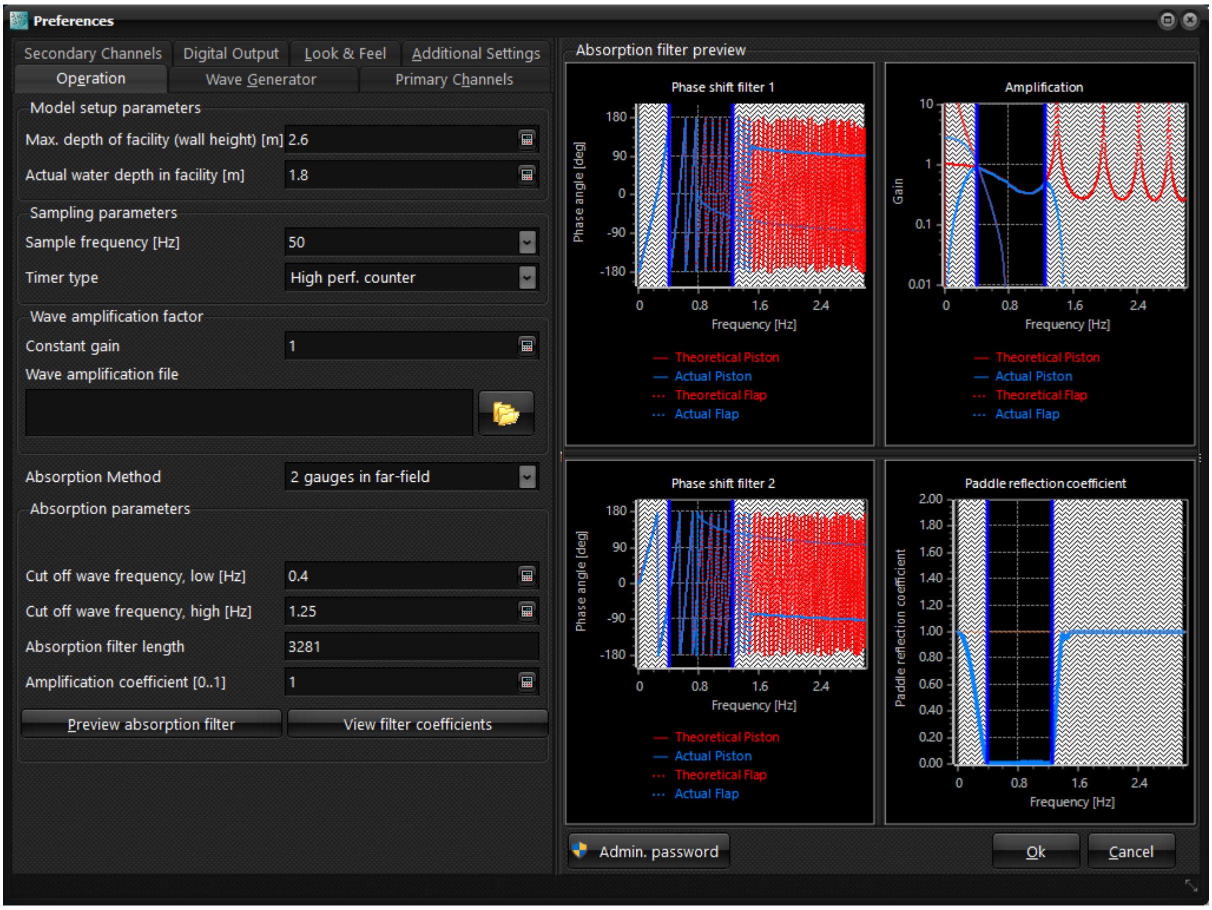
- and so forth

Below show and example of a flume channel configuration with a dual mode generator.



The mechanical transfer file should include five columns, i.e. 1) frequency, 2) gain for piston mode, 3) phase shift for piston mode, 4) gain for flap mode and 5) phase shift for flap mode.

For 1 gauge in the near-filed active absorption system the absorption is made in pure piston mode and is similar to that described for single mode generators. For 2 gauges in the far-field active absorption system the lowest frequencies are absorbed with piston mode and the highest frequencies with flap mode. In between a combination of the two is used (see example of gain on the two modes on below figure). The same distribution in the two modes is used for the generation and is chosen to minimize the near-field effects. For further information refer to the technical documentation.


Preferences
Secondary Channels
Digital Output
Look & Feel
Additional Settings
Operation
Wave Generator
Primary Channels
Model setup parameters
Max. depth of facility (wall height) [m] 2.6
Actual water depth in facility [m] 1.8
Sampling parameters
Sample frequency [Hz] 50
Timer type High perf. counter
Wave amplification factor
Constant gain 1
Wave amplification file
Absorption Method 2 gauges in far-field
Absorption parameters
Cut off wave frequency, low [Hz] 0.4
Cut off wave frequency, high [Hz] 1.25
Absorption filter length 3281
Amplification coefficient [0..1] 1
Preview absorption filter
View filter coefficients
Absorption filter preview
Phase shift filter 1
Amplification
Phase shift filter 2
Paddle reflection coefficient
Phase angle [deg]
Gain
Paddle reflection coefficient
Frequency [Hz]
Theoretical Piston
Actual Piston
Theoretical Flap
Actual Flap
Admin. password
Ok
Cancel