# A2.4.4 Description of algorithms

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This document describes detailed internal function of algorithms developed in TracePQM activity A2.3.2 and their uncertainty calculation developed in A2.3.5. The algorithm files are located in the TWM project [1] in folder “octprog\QWTB”. They are all integrated in the copy of QWTB toolbox [3]. This document won’t describe principle of the QWTB toolbox as it is documented on the project webpage [2]. The method how the algorithms are called by the TWM toolbox, i.e. what input quantities they receive and what may be returned as a result is defined in the document [4].

In general, the goal of QWTB is to make a wrapper function (next it will be called just “wrapper”) that translates the algorithm specific inputs and outputs to a unified format of input and output quantities. This is job of the so called “low level” algorithm wrappers, e.g.: PSFE, SP-WFFT, etc. These also may or may not contain some uncertainty calculation method. However, non of these low level wrappers apply any HW component corrections defined by the TWM documents [4], [5]. Therefore, there is a second layer of QWTB wrappers (these will be called “TWM wrappers”), which starts with “TWM-” prefix. These wrappers contain all signal corrections defined by TWM. These wrappers perform the necessary TWM corrections and they call either a low level wrapper (e.g. PSFE) or calculate the result by themselves. Note some of the wrappers may call several other wrappers to achieve desired result. This approach reduces the duplication of code in the QWTB toolbox. One of these repeatedly called wrappers is “SP-WFFT” algorithm which is used for spectrum analysis.

## References

1. TWM tool, url: <https://github.com/smaslan/TWM>
2. QWTB toolbox, url: <https://qwtb.github.io/qwtb/>
3. GOLPI interface, url: <https://github.com/KaeroDot/GOLPI>
4. A232 Algorithms exchange format, url:

[https://github.com/smaslan/TWM/tree/master/doc/A232 Algorithm Exchange Format.docx](https://github.com/smaslan/TWM/tree/master/doc/A232%20Algorithm%20Exchange%20Format.docx)

1. A231 Correction Files Reference Manual, url:

<https://github.com/smaslan/TWM/tree/master/doc/A231 Correction Files Reference Manual.docx>

1. A231 Data Exchange Format, url:

[https://github.com/smaslan/TWM/tree/master/doc/A231 Data exchange format and file formats.docx](https://github.com/smaslan/TWM/tree/master/doc/A231%20Data%20exchange%20format%20and%20file%20formats.docx)

## TWM-PSFE – Phase Sensitive Frequency Estimator

CMI – High level:

The algorithm consists of two levels: (i) Low level wrapper “PSFE” and its uncertainty estimator; (ii) TWM wrapper “TWM-PSFE”. The overall structure is shown in the ###.

The TWM wrapper accepts following inputs and corrections:

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Default** | **Uncertainty** | **Description** |
| y  y\_lo | N/A | No  No | Input sample data vector and complementary low-side input data vector ‘y\_lo’ for differential mode only. |
| Ts  fs  t | N/A | No  No  No | Sampling period or sampling rate or sample time vector. Note the wrapper always calculates in equidistant mode, so ‘t’ is used just to calculate ‘Ts’. |
| comp\_timestamp | 0 | No | Enable compensation of phase shift by timestamp value: *phi = phi – 2\*pi\*f\_est\*time\_stamp* |
| lsb  adc\_nrng  adc\_bits | N/A  1000  40 | No  No  No | Either absolute ADC resolution ‘lsb’ or nominal range value ‘adc\_nrng’ (e.g.: 5 V for ±10 V range) and ‘adc\_bits’ bit resolution of ADC. |
| adc\_offset  lo\_adc\_offset | 0  0 | Yes  Yes | Digitizer input offset voltage. |
| adc\_gain  adc\_gain\_f  adc\_gain\_a  lo\_adc\_gain  lo\_adc\_gain\_f  lo\_adc\_gain\_a | 1  []  []  0  []  [] | Yes  No  No  Yes  No  No | Digitizer gain correction 2D table (multiplier). |
| adc\_phi  adc\_phi\_f  adc\_phi\_a  lo\_adc\_phi  lo\_adc\_phi\_f  lo\_adc\_phi\_a | 0  []  []  0  []  [] | Yes  No  No  Yes  No  No | Digitizer phase correction 2D table (additive). |
| adc\_freq | 0 | Yes | Digitizer timebase error CORRECTION:  *f\_tb’ = f\_tb\*(1 + adc\_freq.v)*  The effect on the estimated frequency is opposite:  *f\_est’ = f\_est/(1 + adc\_freq.v)* |
| adc\_jitter  lo\_adc\_jitter | 0 | No | Digitizer sampling period jitter [s]. |
| adc\_aper  lo\_adc\_aper | 0  0 | No | ADC aperture value [s]. |
| adc\_aper\_corr  lo\_adc\_aper | 0  0 | No | ADC aperture error correction enable:  *A’ = A\*pi\*adc\_aper\*f\_est/sin(pi\* adc\_aper \*f\_est)*  *phi’ = phi + pi\*adc\_aper\*f\_est* |
| time\_stamp | 0 | Yes | Relative timestamp of the first sample ‘y’. |
| adc\_sfdr  adc\_sfdr\_f  adc\_sfdr\_a  lo\_adc\_sfdr  lo\_adc\_sfdr\_f  lo\_adc\_sfdr\_a | 180  []  []  180  []  [] | No  No  No  No  No  No | Digitizer SFDR 2D table. |
| adc\_Yin\_Cp  adc\_Yin\_Gp  adc\_Yin\_f  lo\_adc\_Yin\_Cp  lo\_adc\_Yin\_Gp  lo\_adc\_Yin\_f | 1e-15  1e-15  []  1e-15  1e-15  [] | Yes  Yes  No  Yes  Yes  No | Digitizer input admittance 1D table. |
| tr\_type | ‘’ | No | Transducer type string (‘rvd’ or ‘shunt’). |
| tr\_gain  tr\_gain\_f  tr\_gain\_a | 1  []  [] | Yes  No  No | Transducer gain correction 2D table (multiplicative). |
| tr\_phi  tr\_phi\_f  tr\_phi\_a | 0  []  [] | Yes  No  No | Transducer phase correction 2D table (additive). |
| tr\_Zlo\_Rp  tr\_Zlo\_Cp  tr\_Zlo\_f | 1e3  1e-15  [] | Yes  Yes  No | RVD transducer low-side impedance 1D table. Note this is related to loading correction and it has effect only for RVD transducer and will work only if ‘adc\_Yin’ is defined as well. |
| tr\_Zca\_Rs  tr\_Zca\_Ls  tr\_Zca\_f | 1e-9  1e-12  [] | Yes  Yes  No | Loading corrections: Transducer high side terminal series impedance 1D table. |
| tr\_Zcal\_Rs  tr\_Zcal\_Ls  tr\_Zcal\_f | 1e-9  1e-12  [] | Yes  Yes  No | Loading corrections: Transducer low side terminal series impedance 1D table. |
| tr\_Yca\_Cp  tr\_Yca\_D  tr\_Yca\_f | 1e-15  1e-12  [] | Yes  Yes  No | Loading corrections: Transducer output terminals shunting impedance. |
| tr\_Zcam  tr\_Zcam\_f | 1e-12  [] | Yes  No | Loading corrections: Transducer output terminals mutual inductance 1D table. |
| Zcb\_Rs  Zcb\_Ls  Zcb\_f | 1e-9  1e-12  [] | Yes  Yes  No | Loading corrections: Cable series impedance 1D table. |
| Ycb\_Rs  Ycb\_Ls  Ycb\_f | 1e-15  1e-12  [] | Yes  Yes  No | Loading corrections: Cable series impedance 1D table. |

Output quantities:

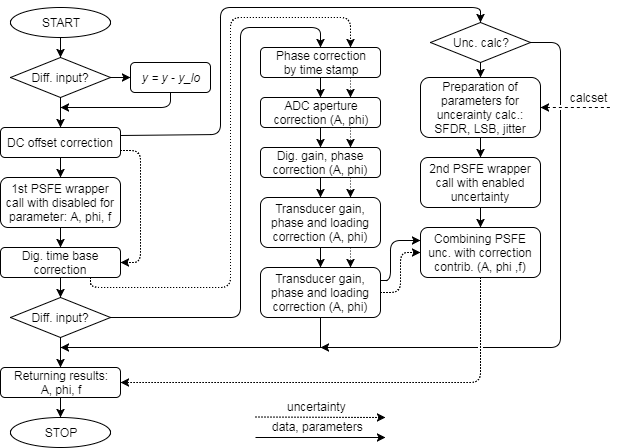
|  |  |  |
| --- | --- | --- |
| **Name** | **Uncertainty** | **Description** |
| f | Yes | Estimated frequency [Hz]. |
| A | Yes \* | Estimated amplitude. |
| phi | Yes \* | Estimated phase angle [rad]. |

\* The uncertainty contribution of correction is calculated, but PSFE contribution is not included! Not validated.

QWTB “calcset” options:

|  |  |
| --- | --- |
| **Name** | **Description** |
| calcset.unc | Uncertainty calculation mode. Supported ‘none’ or ‘guf’. |
| calcset.loc | Level of confidence [-]. |
| calcset.verbose | Verbose level. |

Block diagram of the TWM wrapper is shown in the following diagram:



The TWM wrapper partially supports differential transducer input. However, in the differential mode it only calculates frequency. The other parameters are ignored. Two differential inputs are directly subtracted (*y – y\_lo*) in the differential mode. This is not usable for amplitude or phase estimation, but for frequency this simplified difference should be sufficient. The DC offset correction is applied directly to the time domain signal “y”. Next the PSFE wrapper is called first time to obtain estimates of unscaled waveform. The uncertainty is disabled, not all required inputs to PSFE are available at this point. In single ended mode follow corrections of the estimated signal parameters along with calculation of correction uncertainties. When uncertainty calculation is enabled, the additional inputs, such as SFDR and LSB are calculated and PSFE wrapper is called again, this time with uncertainty estimation enabled. The returned uncertainties are combined with the correction contributions and combined with the estimates “A”, “phi” and “f”. Note in the differential mode only PSFE uncertainty estimate of the frequency is taken into account.

SIQ – Low level and uncertainty

## TWM-FPNLSF – Four Parameter Non Linear Sine Fit

## TWM-THDWFFT – Total Harmonic Distortion by Windowed FFT

## TWM-HCRMS – Half Cycle RMS calculator

## TWM-InDiSwell – Interruption Dip Swell detector

## TWM-Flicker – Flicker algorithm

CMI – High level, uncertainty

TUBITAK – Low level

## TWM-MODTDPS – Modulation analyser in Time Domain, by quadrature Phase Shifting

## TWM-PWRTDI – Power by Time Domain Integration

CMI – High level + uncertainty

JV – Low level