Power Quality Meter

Test Procedure

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Table of Contents

1 Introduction

This document describes the Test Procedure, used for testing Power Quality Meter DSP Engine. Initialy, this test procedure intended for testing DSP Engine in nonrealtime environment on PC or target with file input/output in Test Bench. Later, this procedure can be adopted for real time testing on target hardware.

1.1 General guidelines

To perform test, Test Bench should be run with the specified configuration file and input sample file (or files for 3-phase input mode). Test Bench will perform all measurements and produce test results files, which should be manually compared to specified test results. If the measurement results correspond to desired result value, the test is passed.

Tests are grouped on the basis of the input samples file. Each test case allows to check several measurement parametes at once.

Test Bench described in Test Bench Description [1] document.

1.2 Test result checking

Here is a guideline on test result checking. Each test performed in the following way: input signal is applied to Test Bench for some interval, and then next input signal is applied. In general, next signal is not the continuation of previous signal, so some signal interruption is present on the interval boundary.

Measurement results are saved to file with report interval. Report interval is several time less than input signal interval. For example, Input signal interval is 1 second; report interval is 200 ms, so 5 output values saved to 5 lines of output file.

Because of input signal interruption on the signal interval boundary, first result line can be corrupted, but all other result lines should be equal to desired value with specified accuracy. They should be checked and test case is successfully passed if all measured values with the exception of first one are equal to desired value. In general, this procedure is repeated several times for test case.

Let us consider following example: 3 input values tests are performed, input value is 2000 for 1-st second, 1000 for 2-nd second, 500 for 3-rd second. Report interval is 200 ms, measurement accuracy is 1 percent.

Here are report file lines with comments:

`1977.875` - ignore

`2005.750` - compare to 2000 ± 1%

`2005.750` - compare to 2000 ± 1%

`2005.750` - compare to 2000 ± 1%

`2005.750` - compare to 2000 ± 1%

`1073.188` - ignore

`1005.250` - compare to 1000 ± 1%

`1005.250` - compare to 1000 ± 1%

`1005.250` - compare to 1000 ± 1%

`1005.250` - compare to 1000 ± 1%

`537.813` - ignore

`503.813` - compare to 500 ± 1%

`503.813` - compare to 500 ± 1%

`503.813` - compare to 500 ± 1%

`503.813` - compare to 500 ± 1%

In this example, the test case is successfully passed.

For array value, such as harmonics, inter harmonics and above harmonics, this procedure should be applied to each array item.

2 Measurement in normal condition

2.1 Voltage in range from 10 to 707 V

Purpose:

This test case is designed to check ability of DSP Engine to analyze voltage input signal with level from 10 to 707V rms in steady state and normal conditions. Phase voltage, inter-phase voltage (the other phase voltage is zero), current, under voltage and over voltage, apparent power, crest factor and derating factor are checked in this test case.

Conditions:

This test runs in single input file mode, text file output, 50 Hz main frequency, report interval is 200ms. Input voltage and current are pure sine wave without any harmonics. Leading angle (voltage to current angle) is zero.

It uses `707to10v.pcm` input sample file. Current is constant for all intervals, it is 2.0 A. Voltage takes following values: 707, 500, 200, 100, 50, 20, 10 V rms. Duration of each interval is 1 second or 5 report lines per interval. Corresponding voltage magnitudes in dB (to full scale sine wave) are: -0.2, -3.2, -11.2, -17.2, -23.2, -31.2, -37.2 dB. Voltage magnitude tolerance is about 1 percent or 0.1dB.

Configuration session (contents of `707to10v.txt` file) is listed below:

```
infile 707to10v.pcm
logtime 200
logpar v_per, v_rms, v_under, v_over, v_sr, v_crest, v_derat
logpar c_rms, vpp_rms, apppwr
run 707to10v_
```

To run test, the following command should be executed

```
TestBench.exe 707to10v.txt
```

Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter	Desired value
707to10v_v_rms.dat	Phase voltage for 200 ms (10 periods)	707, 500, 200, 100, 50, 20, 10 V
707to10v_v_per.dat	Phase voltage for 20 ms (1 period)	707, 500, 200, 100, 50, 20, 10 V
707to10v_v_sr.dat	Sliding reference voltage, fixed Vdin = 220V	220 V for all intervals
707to10v_v_over.dat	Over voltage (V-Vsr)/Vsr	2.214, 1.273, 0.000, 0.000, 0.000, 0.000, 0.000
707to10v_v_under.dat	Under voltage (Vsr-V)/Vsr	0.000, 0.000, 0.091, 0.545, 0.773, 0.909, 0.954
707to10v_v_crest.dat	Voltage crest factor	1.41 for all intervals
707to10v_v_derat.dat	Voltage derating factor	1.00 for all intervals
707to10v_c_rms.dat	Current for 200 ms	2.0 A for all intervals
707to10v_apppwr.dat	Apparent power	1414, 1000, 400, 200, 100, 40, 20 VA
707to10v_vpp_rms.dat	Phase-to-phase (A to B) voltage (B voltage is 0)	707, 500, 200, 100, 50, 20, 10 V

2.2 Current in range from 0.01 to 5.656 A

Purpose:

This test case is designed to check ability of DSP Engine to analyze current input signal with level from 0.01 to 5.656V rms in steady state and normal conditions. Phase current, voltage, under current and over current, apparent power, crest factor and derating factor are checked in this test case.

Conditions:

This test runs in single input file mode, text file output, 50 Hz main frequency, report interval is 200ms. Input voltage and current are pure sine wave without any harmonics. Leading angle (voltage to current angle) is zero.

It uses `5656to001a.pcm` input sample file. Voltage is constant for all intervals, it is 200 V. Current takes following values: 5.656, 4.00, 2.00, 1.00, 0.40, 0.20, 0.10, 0.040, 0.02, 0.01 A rms. Duration of each interval is 1 second or 5 report lines per interval. Corresponding current magnitude in dB (to full scale sine wave) are: -0.2, -3.2, -9.2, -15.2, -23.2, -29.2, -35.2, -43.2, -49.2, -55.2 dB. Current magnitude tolerance is about 1 percent or 0.1dB.

Configuration session (contents of `5656to001a.txt` file) is listed below:

```
infile 5656to001a.pcm
logtime 200
logpar c_per, c_rms, c_under, c_over, c_sr, c_crest, c_derat
logpar v_rms, apppwr
run 5656to001a_
```

To run test, the following command should be executed

```
TestBench.exe 5656to001a.txt
```

Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter	Desired value
5656to001a_c_rms.dat	Current for 200 ms (10 periods)	5.656, 4.00, 2.00, 1.00, 0.40, 0.20, 0.10, 0.04, 0.02, 0.01 A
5656to001a_c_per.dat	Current for 20 ms (1 period)	5.656, 4.00, 2.00, 1.00, 0.40, 0.20, 0.10, 0.04, 0.02, 0.01 A
5656to001a_c_sr.dat	Sliding reference current	Very slowly follow 200ms RMS value on all intervals
5656to001a_c_over.dat	Over current (I-Isr)/Isr	1.828, 1.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000
5656to001a_c_under.dat	Under current (Isr-I)/Isr	0.000, 0.000, 0.000, 0.500, 0.800, 0.900, 0.950, 0.980, 0.990, 0.995
5656to001a_c_crest.dat	Current crest factor	1.41 for all intervals
5656to001a_c_derat.dat	Current derating factor	1.00 for all intervals
5656to001a_v_rms.dat	Voltage for 200 ms	200 V for all intervals
5656to001a_apppwr.dat	Apparent power	1131.3, 800, 400, 200, 80, 40, 20, 8.0, 4.0, 2.0 VA

2.3 Lead Angle in range from 0 to 90 degree

Purpose:

This test case is designed to check ability of DSP Engine to measure Lead Angle (voltage to current angle) and Real Power in present of reactive load in steady state and normal conditions. Lead angle, real, apparent, reactive power, displacement power factor and true power factor are checked in this test case.

Conditions:

This test runs in single input file mode, text file output, 50 Hz main frequency, report interval is 1s. Input voltage and current are pure sine wave without any harmonics.

It uses `0to90dg.pcm` input sample file. Voltage and current are constant for all intervals, they are 200 V and 2.0 A. Leading angle (voltage to current angle) is changing from 0 to 90 degrees with step of 10 degrees (0 to 1.5707 rads with step 0.1745 rads). Duration of each interval is 5 seconds or 5 report lines per interval.

Configuration session (contents of `0to90dg.txt` file) is listed below:

```
infile 0to90dg.pcm
logtime 1000
logpar ldangl, rlpwr, apppwr, rctpwr, displpf, truepf
run 0to90dg_
```

To run test, the following command should be executed

`TestBench.exe` 0to90dg`.txt`

Measurement value tolerance is 1% referenced to maximal value.

Important, values are calculated based on smoothed harmonics FFT calculation, desired values are approximated at end of interval only.

Result checking:

File name	Measurement parameter	Desired value
0to90dg_ldangl.dat	lead angle, rad	0, 0.1745, 0.3491, 0.5236, 0.6981, 0.8727, 1.0472, 1.2217, 1.3963, 1.5708
0to90dg_rlpwr.dat	real power	400.00, 393.92, 375.88, 346.41, 306.42, 257.12, 200.00, 136.81, 69.46, 0 VA
0to90dg_apppwr.dat	apparent power	400 VA for all intervals
0to90dg_rctpwr.dat	reactive power	0, 69.46, 136.81, 200.00, 257.12, 306.42, 346.41, 375.88, 393.92, 400.00 VA
0to90dg_displpf.dat	displacement power factor	1.0000, 0.9848, 0.9397, 0.8660, 0.7660, 0.6428, 0.5000, 0.3420, 0.1736, 0.0000
0to90dg_truepf.dat	true power factor	1.0000, 0.9848, 0.9397, 0.8660, 0.7660, 0.6428, 0.5000, 0.3420, 0.1736, 0.0000

2.4 Kilo-watt hours measurement

Purpose:

This test case is designed to check ability of DSP Engine to measure watt-hour in steady state and normal conditions. Watt-hour, volt-ampere-hour and volt-ampere-hour-reactive are checked in this test case.

Conditions:

This test run in single input file mode, text file output, 50 Hz main frequency, report interval is 1s. Input voltage and current are pure sine wave without any harmonics.

It uses `kwh.pcm` input sample file. Voltage and current are constant, they are 200 V and 2 A. Measurement interval is 10 seconds.

Configuration session (contents of `kwh.txt` file) is listed below:

```
infile kwh.pcm
logtime 1000
logpar rlpwr, apppwr, rctpwr, wh, vah, vahr
run kwh_
```

To run test, the following command should be executed

```
TestBench.exe kwh.txt
```

Measurement value tolerance is 1% referenced to maximal value.

Important, for kWh and kVAh increment per 1 second and final value at the end of 10s interval are specified.

Result checking:

File name	Measurement parameter	Desired value
kwh_rlpwr.dat kwh_apppwr.dat	Real and apparent power	400 VA
kwh_kwh.dat kwh_kvah.dat	Watt-hour and volt-ampere-hour	Increment - 0.111 WH per second (report interval) Final value - 1.111 WH

2.5 3-phase measurement

Purpose:

This test case is designed to check ability of DSP Engine to analyze 3-phase input signal in steady state and normal conditions. All previous tests were devoted to singe-phase measurement for simplicity. Phase A to phase B inter-phase voltage, real power, total 3-phase real power, kilo-watt hours, total 3-phase kilo-watt hours, neutral voltage and current are checked in this test case.

Conditions:

This test runs in 3-phase input file mode (4 input files for 3 phase + neutral), text file output, 50 Hz main frequency, report interval is 500ms. Input voltage and current for all phase are pure sine wave without any harmonics. Leading angle (voltage to current angle) is zero. Phase to phase angle is 120 degree.

It uses `3ph_X.pcm` input sample file. Voltage and current for Phase A , B and C are constant, they are 200 V and 2.00 A. Voltage and current for Neutral are constant, they are 100 V and 1.00 A. There is only one interval; its duration is 5 seconds.

Configuration session (contents of `3ph.txt` file) is listed below:

```
infile 3ph.pcm
logtime 1000
logpar v_rms, vpp_rms, rlpwr, t_rlpwr, kwh, t_kwh, vn_rms, cn_rms
run 3ph_
```

To run test, the following command should be executed

```
TestBench.exe 3ph.txt
```

Measurement value tolerance is 1% referenced to maximal value.

Important, for kWh and kVAh increment per 1 second and final value at the end of 10s interval are specified.

Result checking:

File name	Measurement parameter	Desired value
3ph_v_rms.dat	Phase voltage	200 V
3ph_vpp_rms.dat	Inter-phase A to B voltage	346 V
3ph_rlpwr.dat	Real power	400 VA
3ph_kwh.dat	Kilo-watt hours	Increment - 0.111 WH per second (report interval) Final value - 0.555 WH
3ph_t_rlpwr.dat	Total 3 phase real power	1200 VA
3ph_t_kwh.dat	Total 3 phase kilo-watt hours	Increment - 0.333 WH per second (report interval) Final value - 1.666 WH
3ph_vn_rms.dat	Neutral voltage	100 V
3ph_cn_rms.dat	Neutral current	1.00 A

2.6 Positive/negative/zero sequence and negative/zero/NEMA imbalance

Purpose:

This test case is designed to check ability of DSP Engine to analyze sequence parameters in steady state and normal all other conditions. Positive, negative and zero sequence voltage and current as far as negative, zero and NEMA imbalance values are checked in this test case.

Conditions:

This test runs in 3-phase input file mode (4 input files for 3 phase + neutral), text file output, 50 Hz main frequency, report interval is 500ms. Input voltage and current for all phase are pure sine wave without any harmonics. Leading angle (voltage to current angle) is zero.

It uses `seq_X.pcm` input sample files. There are three measurement intervals; each durations are 5 seconds. First interval represents pure positive sequence signal, voltage and current for Phase A, B and C are constant, they are 200 V and 2.00 A, phase is 0, 120 and -120 degree. At the second interval negative sequence signal with level 0.03 presents: normal signal from Phase B multiplied by 0.03 is added to Phase C, normal signal from Phase C multiplied by 0.03 is added to Phase B, Phase A signal is multiplied by 1.03. At the third interval zero sequence signal with level 0.03 presents: normal signal from Phase A multiplied by 0.03 is added to Phase A, B and C. Voltage and current for Neutral are constant for all three intervals, they are 0 V and 0 A.

Configuration session (contents of `seq.txt` file) is listed below:

```
3phmode 1
infile seq.pcm
logtime 500
logpar v_rms, v_seqpos, v_seqneg, v_seqzero, v_imneg, v_imzero
logpar c_rms, c_seqpos, c_seqneg, c_seqzero, c_imneg, c_imzero
```

```
logpar v_imnema, vpp_imnema, c_imnema
run seq_
```

To run test, the following command should be executed

```
TestBench.exe seq.txt
```

Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter	Desired value
seq_v_rms.dat seq_c_rms.dat	Phase voltage/current	200.0 / 2.00, 206.0 / 2.06, 206.0 / 2.06 V/A
seq_v_seqpos.dat seq_c_seqpos.dat	Positive sequence voltage/current	200.0 / 2.00, 200.0 / 2.00, 200.0 / 2.00 V/A
seq_v_seqneg.dat seq_c_seqneg.dat	Negative sequence voltage/current	0.00 / 0.00, 6.00 / 0.06, 0.00 / 0.06 V/A
seq_v_seqzero.dat seq_c_seqzero.dat	Zero sequence voltage/current	0.00 / 0.00, 0.00 / 0.00, 6.00 / 0.06 V/A
seq_v_imneg.dat seq_c_imneg.dat	Negative voltage/current imbalance	0.00, 0.03, 0.00
seq_v_imzero.dat seq_c_imzero.dat	Zero voltage/current imbalance	0.00, 0.00, 0.03
seq_v_imnema.dat seq_c_imnema.dat	NEMA voltage/current imbalance	0.00, 0.03, 0.03
seq_vpp_imnema.dat	NEMA Inter-phase voltage imbalance	0.00, 0.03, 0.00

3 Harmonics measurement

3.1 Harmonics and subgrouped harmonics measurement

Purpose:

This test case is designed to check ability of DSP Engine to analyze nonsinusoidal input signal in steady state and normal all other conditions. Harmonics values, total harmonic distortion, K-factor and true power factor are checked in this test case.

Conditions:

This test runs in single input file mode, text file output, 50 Hz main frequency, report interval is 2 s. Leading angle (voltage to current angle) is zero.

It uses `harm.pcm` input sample file. The file consists from three signal intervals; duration of all intervals is 20 seconds. Voltage and current values are 200 V and 2.00 A for all intervals. At first interval, voltage and current are pure sine wave, there is no harmonics. At second interval, 5-th, 9-th, 13-th and 17-th harmonics are present with level of 0.01 (-40 dB) for all harmonics. At third interval, 2-nd, 3-rd, 5-th, 7-th and 9-th harmonics are present with level of 0.10, 0.32, 0.10, 0.03 and 0.01 (-20, -10, -20, -30, -40 dB).

Configuration session (contents of `harm.txt` file) is listed below:

```
infile harm.pcm
logtime 2000
logpar v_harm_mag, v_harm_sq, v_harm_ang, v_harm_perc
logpar v_thd_thd, v_thd_ohd, v_thd_ehd
logpar c_harm_mag, c_harm_sq, c_harm_ang, c_harm_perc
logpar c_thd_thd, c_thd_ohd, c_thd_ehd
logpar harm_pwr, harm_dir, ldangl
logpar v_harmsg_mag, v_harmsg_sq, v_harmsg_ang, v_harmsg_perc
logpar v_thd_thdsg, v_thd_ohdsg, v_thd_ehdsg, v_kfact
logpar c_harmsg_mag, c_harmsg_sq, c_harmsg_ang, c_harmsg_perc
```

```
logpar c_thd_thdsg, c_thd_ohdsg, c_thd_ehdsg, c_kfact
logpar harmsg_pwr, harmsg_dir
run harm_
```

To run test, the following command should be executed

```
TestBench.exe harm.txt
```

Because of harmonics smoothing, output value reaches its desired value at the end of interval. Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter		Desired value for intervals		
			1-st	2-nd	3-rd
harm_v_harm_mag.dat harm_v_harmsg_mag.dat	nongrouped/subgrouped voltage harmonic magnitude, V	1-st harmonic	200.0	199.9	188.3
		2-nd harmonic	000.0	000.0	018.8
		3-rd harmonic	000.0	000.0	059.5
		5-th harmonic	000.0	002.0	018.8
		7-th harmonic	000.0	000.0	006.0
		9-th harmonic	000.0	002.0	001.9
		13-th harmonic	000.0	002.0	000.0
		17-th harmonic	000.0	002.0	000.0
		other harmonics	000.0	000.0	000.0
harm_c_harm_mag.dat harm_c_harmsg_mag.dat	nongrouped/subgrouped current harmonic magnitude, A	1-st harmonic	2.000	1.999	1.883
		2-nd harmonic	0.000	0.000	0.188
		3-rd harmonic	0.000	0.000	0.595
		5-th harmonic	0.000	0.020	0.188
		7-th harmonic	0.000	0.000	0.060
		9-th harmonic	0.000	0.020	0.019
		13-th harmonic	0.000	0.020	0.000
		17-th harmonic	0.000	0.020	0.000
		other harmonics	0.000	0.000	0.000
harm_v_harm_sq.dat harm_v_harmsg_sq.dat	nongrouped/subgrouped voltage harmonic power (squared magnitude), V^2	1-st harmonic	40000	39960	35457
		2-nd harmonic	0.00	0.00	354.0
		3-rd harmonic	0.00	0.00	3546.0
		5-th harmonic	0.00	3.99	354.0
		7-th harmonic	0.00	0.00	35.4
		9-th harmonic	0.00	3.99	3.54
		13-th harmonic	0.00	3.99	0.00
		17-th harmonic	0.00	3.99	0.00
		other harmonic	0.00	0.00	0.00
harm_c_harm_sq.dat harm_c_harmsg_sq.dat	nongrouped/subgrouped current harmonic power (squared magnitude), A^2	1-st harmonic	4.000	3.996	3.546
		2-nd harmonic	0.000	0.000	0.035
		3-rd harmonic	0.000	0.003	0.355
		5-th harmonic	0.000	0.000	0.035
		7-th harmonic	0.000	0.003	0.003

		9-th harmonic	0.000	0.003	0.000
		13-th harmonic	0.000	0.003	0.000
		17-th harmonic	0.000	0.003	0.000
		other harmonic	0.000	0.000	0.000
harm_harm_pwr.dat harm_harmsg_pwr.dat	nongrouped/subgrouped harmonic power, VA	1-st harmonic	400.0	399.6	354.6
		2-nd harmonic	0.000	0.000	3.546
		3-rd harmonic	0.000	0.000	35.46
		5-th harmonic	0.000	3.996	3.546
		7-th harmonic	0.000	0.000	0.346
		9-th harmonic	0.000	3.996	0.034
		13-th harmonic	0.000	3.996	0.000
		17-th harmonic	0.000	3.996	0.000
		other harmonic	0.000	0.000	0.000
harm_harm_dir.dat harm_harmsg_dir.dat	nongrouped/subgrouped harmonic direction, boolean, (--- means undefined value)	1-st harmonic	1	1	1
		2-nd harmonic	---	---	1
		3-rd harmonic	---	---	1
		5-th harmonic	---	1	1
		7-th harmonic	---	---	1
		9-th harmonic	---	1	1
		13-th harmonic	---	1	---
		17-th harmonic	---	1	---
		other harmonic	---	---	---
harm_v_harm_ang.dat harm_v_harmsg_ang.dat harm_c_harm_ang.dat harm_c_harmsg_ang.dat	nongrouped/subgrouped voltage/current harmonic angle, rad; (--- means undefined value)	1-st harmonic	1.57	1.57	1.57
		2-nd harmonic	---	---	1.57
		3-rd harmonic	---	---	1.57
		5-th harmonic	---	1.57	1.57
		7-th harmonic	---	---	1.57
		9-th harmonic	---	1.57	1.57
		13-th harmonic	---	1.57	---
		17-th harmonic	---	1.57	---
		other harmonics	---	---	---
harm_v_harm_perc.dat harm_v_harmsg_perc.dat harm_c_harm_perc.dat harm_c_harmsg_perc.dat	nongrouped/subgrouped voltage/current harmonic percentage	1-st harmonic	1.000	1.000	1.000
		2-nd harmonic	0.000	0.000	0.100
		3-rd harmonic	0.000	0.000	0.316
		5-th harmonic	0.000	0.010	0.100
		7-th harmonic	0.000	0.000	0.032
		9-th harmonic	0.000	0.010	0.010
		13-th harmonic	0.000	0.010	0.000
		17-th harmonic	0.000	0.010	0.000
		other harmonics	0.000	0.000	0.000
harm_v_thd_thd.dat	nongrouped/subgrouped voltage/current		0.000	0.020	0.348

harm_v_thd_thdsg.dat harm_c_thd_thd.dat harm_c_thd_thdsg.dat	total harmonic distortion			
harm_v_thd_ehd.dat harm_v_thd_ehdsg.dat harm_c_thd_ehd.dat harm_c_thd_ehdsg.dat	nongrouped/subgrouped voltage/current total even harmonic distortion	0.000	0.000	0.100
harm_v_thd_ohd.dat harm_v_thd_ohdsg.dat harm_c_thd_ohd.dat harm_c_thd_ohdsg.dat	nongrouped/subgrouped voltage/current total odd harmonic distortion	0.000	0.020	0.333
harm_v_kfact.dat harm_c_kfact.dat	voltage/current K-factor	1.000	1.027	1.415
harm_ldangl.dat	leading/lagging angle, rad	0.000	0.000	0.000

3.2 Inter-harmonics measurement

Purpose:

This test case is designed to check ability of DSP Engine to analyze nonsinusoidal input signal in steady state and normal all other conditions. Inter-harmonics values are checked in this test case.

Conditions:

This test run in single input file mode, text file output, 50 Hz main frequency, report interval is 2 s. Leading angle (voltage to current angle) is zero.

It uses `inth.pcm` input sample file. The file consists from single interval; duration of it intervals is 20 seconds. Voltage and current rms values are 200 V and 2.00 A. Signal consists from 50 Hz first harmonic, and 75, 125 and 1625 Hz inter-harmonics sine waves. First harmonic amplitude is 200V, inter-harmonics level is 0.01 (-40 dB) of first harmonic.

Configuration session (contents of `inth.txt` file) is listed below:

```
infile inth.pcm
logtime 2000
logpar v_inth_mag, v_inth_sq, v_inth_perc
logpar c_inth_mag, c_inth_sq, c_inth_perc
logpar inth_pwr, inth_dir, v_thd_tihd, c_thd_tihd
run inth_
```

To run test, the following command should be executed

```
TestBench.exe inth.txt
```

Because of harmonics smoothing, output value reaches its desired value at the end of interval. Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter		Desired value
			1-st
inth_v_inth_mag.dat	voltage inter-harmonic magnitude, V	1-st inter-harmonic	2.000
		2-nd inter-harmonic	2.000
		32-th inter-harmonic	2.000
		other inter-harmonics	0.000
inth_c_inth_mag.dat	current inter-harmonic magnitude, A	1-st inter-harmonic	0.020
		2-nd inter-harmonic	0.020
		32-th inter-harmonic	0.020
		other inter-harmonics	0.000
inth_v_inth_sq.dat	voltage inter-harmonic power (squared	1-st inter-harmonic	4.000
		2-nd inter-harmonic	4.000

	magnitude), V^2	32-th inter-harmonic	4.000
		other inter-harmonics	0.000
inth_c_inth_sq.dat	current inter-harmonic power (squared magnitude), A^2	1-st inter-harmonic	0.000
		2-nd inter-harmonic	0.000
		32-th inter-harmonic	0.000
		other inter-harmonics	0.000
inth_inth_pwr.dat	inter-harmonic power, VA	1-st inter-harmonic	0.040
		2-nd inter-harmonic	0.040
		32-th inter-harmonic	0.040
		other inter-harmonics	0.000
inth_inth_dir.dat	inter-harmonic direction, boolean, (--- means undefined value)	1-st inter-harmonic	1
		2-nd inter-harmonic	1
		32-th inter-harmonic	1
		other inter-harmonics	---
inth_v_inth_perc.dat inth_c_inth_perc.dat	voltage/current inter-harmonic percentage	1-st inter-harmonic	0.010
		2-nd inter-harmonic	0.010
		32-th inter-harmonic	0.010
		other inter-harmonics	0.000
inth_v_thd_tihd.dat inth_c_thd_tihd.dat	voltage/current total inter-harmonic distortion		0.017

3.3 Sub-harmonics measurement

Purpose:

This test case is designed to check ability of DSP Engine to analyze nonsinusoidal input signal in steady state and normal all other conditions. Sub-harmonics values are checked in this test case.

Conditions:

This test run in single input file mode, text file output, 50 Hz main frequency, report interval is 2 s. Frequency is exactly 50 Hz. Leading angle (voltage to current angle) is zero.

It uses `subh.pcm` input sample file. The file consists from single interval; duration of it intervals is 20 seconds. Voltage and current rms values are 200 V and 2.00 A. Signal consists from 50 Hz first harmonic, and 25 Hz sub-harmonics sine waves. First harmonic amplitude is 200V, sub-harmonics level is 0.01 (-40 dB) of first harmonic.

Configuration session (contents of `inth.txt` file) is listed below:

```
infile subh.pcm
logtime 2000
logpar v_subh_mag, v_subh_sq, v_subh_perc
logpar c_subh_mag, c_subh_sq, c_subh_perc
logpar subh_pwr, subh_dir, v_thd_tshd, c_thd_tshd
run subh_
```

To run test, the following command should be executed

```
TestBench.exe subh.txt
```

Because of harmonics smoothing, output value reaches its desired value at the end of interval. Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter	Desired value
		1-st
subh_v_subh_mag.dat	voltage sub-harmonic magnitude, V	2.000
subh_c_subh_mag.dat	current sub-harmonic magnitude, A	0.020

subh_v_subh_sq.dat	voltage sub-harmonic power (squared magnitude), V^2	4.000
subh_c_subh_sq.dat	current sub-harmonic power (squared magnitude), A^2	0.000
subh_subh_pwr.dat	sub-harmonic power, VA	0.040
subh_subh_dir.dat	sub-harmonic direction, boolean, (--- means undefined value)	1
subh_v_subh_perc.dat subh_c_subh_perc.dat	voltage/current sub-harmonic percentage	0.010
subh_v_thd_tshd.dat subh_c_thd_tshd.dat	voltage/current sub-harmonic distortion	0.010

3.4 Above harmonics measurement

Purpose:

This test case is designed to check ability of DSP Engine to analyze nonsinusoidal input signal in steady state and normal all other conditions. Above harmonics values are checked in this test case.

Conditions:

This test run in single input file mode, text file output, 50 Hz main frequency, report interval is 2 s. Leading angle (voltage to current angle) is zero.

It uses `abvh.pcm` input sample file. The file consists from single interval; duration of it is 20 seconds. Voltage and current rms values are 200 V and 2.00 A for all intervals. Signal consists from 50 Hz first harmonic, and 2100, 3100 and 8900 Hz above-harmonics sine waves. First harmonic amplitude is 200V, above-harmonics level is 0.01 (-40 dB) of first harmonic.

Configuration session (contents of `abvh.txt` file) is listed below:

```
infile abvh.pcm
logtime 2000
logpar v_abvh_mag, v_abvh_sq, v_abvh_perc
logpar c_abvh_mag, c_abvh_sq, c_abvh_perc
logpar abvh_pwr, abvh_dir, v_thd_tahd, c_thd_tahd
run abvh_
```

To run test, the following command should be executed

```
TestBench.exe abvh.txt
```

Because of harmonics smoothing, output value reaches its desired value at the end of interval. Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter		Desired value for intervals
			1-st
abvh_v_abvh_mag.dat	voltage above harmonic magnitude, V	2000 to 2200 Hz, 1-st band above harmonic	2.000
		3000 to 3200 Hz, 6-th band above harmonic	2.000
		8800 to 9000 Hz, 35-th band above harmonic	2.000
		other above harmonics	0.000
abvh_c_abvh_mag.dat	current above harmonic magnitude, A	1-st above harmonic	0.020
		6-th above harmonic	0.020
		35-th above harmonic	0.020
		other above harmonics	0.000
abvh_v_abvh_sq.dat	voltage above	1-st above harmonic	4.000

	harmonic power (squared magnitude), V^2	6-th above harmonic	4.000
		35-th above harmonic	4.000
		other above harmonics	0.000
abvh_c_abvh_sq.dat	current above harmonic power (squared magnitude), A^2	1-st above harmonic	0.000
		6-th above harmonic	0.000
		35-th above harmonic	0.000
		other above harmonics	0.000
abvh_abvh_pwr.dat	above harmonic power, VA	1-st above harmonic	0.040
		6-th above harmonic	0.040
		35-th above harmonic	0.040
		other above harmonics	0.000
abvh_abvh_dir.dat	above harmonic direction, boolean, (--- means undefined value)	1-st above harmonic	1
		6-th above harmonic	1
		35-th above harmonic	1
		other above harmonics	---
abvh_v_abvh_perc.dat abvh_c_abvh_perc.dat	voltage/current above harmonic percentage	1-st above harmonic	0.010
		6-th above harmonic	0.010
		35-th above harmonic	0.010
		other above harmonics	0.000
abvh_v_thd_tahd.dat abvh_c_thd_tahd.dat	voltage/current total above harmonic distortion		0.017

3.5 DC offset measurement

Purpose:

This test case is designed to check ability of DSP Engine to analyze DC offset of input signal in steady state and normal all other conditions.

Conditions:

This test run in single input file mode, text file output, 50 Hz main frequency, report interval is 2 s. Frequency is exactly 50 Hz. Leading angle (voltage to current angle) is zero.

It uses `dcoffsh.pcm` input sample file. The file consists from single interval; duration of it intervals is 20 seconds. Voltage and current rms values are 200 V and 2.00 A. DC offset is 10 V and 0.40 A.

Configuration session (contents of `dcoffs.txt` file) is listed below:

```
infile dcoffs.pcm
logtime 2000
logpar v_dcoffs, c_dcoffs
run dcoffs_
```

To run test, the following command should be executed

```
TestBench.exe dcoffs.txt
```

Because of harmonics smoothing, output value reaches its desired value at the end of interval. Measurement value tolerance is 1% referenced to maximal value.

Result checking:

File name	Measurement parameter	Desired value
		1-st
dcoffs_v_dcoffs.dat	voltage sub-harmonic magnitude, V	010.0
dcoffs_c_dcoffs.dat	current sub-harmonic magnitude, A	0.400

4 Other measurement

4.1 Aggregation measurement

Purpose:

This test case is designed to check ability of DSP Engine to do aggregation of measured parameters. Only small part of parameters is checked in this test: voltage/current RMS value and voltage/current 1-st harmonic magnitude are checked.

Conditions:

This test run in single input file mode, text file output, 50 Hz main frequency, report interval is 1000ms. Input voltage and current are pure sine wave without any harmonics.

It uses `aggr.pcm` input sample file. Voltage and current are constant for all intervals, they are 200 V and 2.0 A. Total duration is 10 seconds.

Configuration session (contents of `aggr.txt` file) is listed below:

```
infile aggr.pcm
logtime 1000
logpar v_rms_aggr_3s, c_rms_aggr_3s, v_harm_mag_aggr_3s, c_harm_mag_aggr_3s
logpar v_rms_min_3s, c_rms_min_3s, v_harm_mag_min_3s, c_harm_mag_min_3s
logpar v_rms_max_3s, c_rms_max_3s, v_harm_mag_max_3s, c_harm_mag_max_3s
logpar v_rms_aggr_user, c_rms_aggr_user
logpar v_harm_mag_aggr_user, c_harm_mag_aggr_user
logpar v_rms_aggr_auto, c_rms_aggr_auto
logpar v_harm_mag_aggr_auto, c_harm_mag_aggr_auto
logpar rlpwr_aggr_3s, rlpwr_min_3s, rlpwr_max_3s
logpar rlpwr_aggr_user, rlpwr_aggr_auto
run aggr_
```

To run test, the following command should be executed

```
TestBench.exe aggr.txt
```

Measurement value tolerance is 1% referenced to maximal value.

Result checking:

<table>
<tr><th>File name</th><th colspan="2">Measurement parameter</th><th>Desired value</th></tr>
<tr><td>kwh_v_rms_aggr_3s.dat
kwh_v_rms_min_3s.dat
kwh_v_rms_max_3s.dat
kwh_v_rms_aggr_user.dat
kwh_v_rms_aggr_auto.dat</td><td colspan="2">Phase voltage average / minimum / maximum for 3-secon interval, User (1 minute) interval, Auto (3 seconds, 30 seconds, 1 minute etc.) interval</td><td>200 V</td></tr>
<tr><td rowspan="2">kwh_v_harm_mag_aggr_3s.dat
kwh_v_harm_mag_min_3s.dat
kwh_v_harm_mag_max_3s.dat
kwh_v_harm_mag_aggr_user.dat
kwh_v_harm_mag_aggr_auto.dat</td><td rowspan="2">Voltage harmonics magnitude average / minimum / maximum for 3-secon interval, User (1 minute) interval, Auto (3 seconds, 30 seconds, 1 minute etc.) interval</td><td>1-st harmonic</td><td>200 V</td></tr>
<tr><td>other harmonics</td><td>0.0 V</td></tr>
<tr><td>kwh_c_rms_aggr_3s.dat
kwh_c_rms_min_3s.dat
kwh_c_rms_max_3s.dat
kwh_c_rms_aggr_user.dat
kwh_c_rms_aggr_auto.dat</td><td colspan="2">Phase current average / minimum / maximum for 3-secon interval, User (1 minute) interval, Auto (3 seconds, 30 seconds, 1 minute etc.) interval</td><td>2.00 A</td></tr>
<tr><td rowspan="2">kwh_c_harm_mag_aggr_3s.dat
kwh_c_harm_mag_min_3s.dat
kwh_c_harm_mag_max_3s.dat</td><td rowspan="2">Current harmonics magnitude average / minimum / maximum for 3-secon interval, User (1 minute) interval, Auto (3 seconds, 30 seconds, 1</td><td>1-st harmonic</td><td>2.00 A</td></tr>
<tr><td>other harmonics</td><td>0.0 A</td></tr>
</table>

kwh_c_harm_mag_aggr_user.dat kwh_c_harm_mag_aggr_auto.dat	minute etc.) interval		
kwh_rlpwr_aggr_3s.dat kwh_rlpwr_min_3s.dat kwh_rlpwr_max_3s.dat kwh_rlpwr_aggr_user.dat kwh_rlpwr_aggr_auto.dat	Real power average / minimum / maximum for 3-secon interval, User (1 minute) interval, Auto (3 seconds, 30 seconds, 1 minute etc.) interval		400 VA

4.2 Demand measurement

Demand measurement test case is not currently implemented. Demand monitoring interval is 1 day, so it takes too long time and too long input files size to test it.

4.3 Flicker measurement

Purpose:

This test case is designed to check ability of DSP Engine to measure flicker.

Conditions:

This test run in single input file mode, text file output, 50 Hz main frequency, report interval is 1 s.

It uses `flick.pcm` input sample file, it is repeated 100 times. The file consists from two intervals; at first interval voltage rms value is 200 V, at second interval voltage value is 197.06 V or 1.47 % less than at first interval. Duration of both intervals are 8.57 seconds, total duration is 17.14 seconds so repetition rate is 7 cycles per minutes. This parameters correspond to flicker value of 1.00.

Configuration session (contents of `flick.txt` file) is listed below:

```
infile flick.pcm 100
logtime 1000
logpar ifl, plt, pst, v_rms
run flick_
```

To run test, the following command should be executed

```
TestBench.exe flick.txt
```

Short term flicker measurement interval is 600 seconds, first measured value is corrupted by voltage slope at start of measurement. So desired measurement result reached after 1200 seconds passed. Long term flicker is not checked, because measurement interval is 2 hours. If required, test can be made longer to check long term flicker, desired value is 1.00 too.

Result checking:

File name	Measurement parameter	Desired value, after 1200 seconds
`flick_pst`.dat	Short term flicker	1.00

5 Event detection and waveform capture

5.1 Frequency event

Purpose:

This test case is designed to check ability of DSP Engine to detect Frequency Events.

Conditions:

This test runs in single input file mode, text file output. All events excepting User Event are enabled. Default frequency thresholds are 49.5 and 50.5 Hz.

It uses `evFreq.pcm` input sample file. Voltage is pure sine wave. Frequency takes following values: 50, 51, 50 Hz, interval durations are 10.0, 10.0 and 20.0 second.

Configuration session (contents of `evFreq.txt` file) is listed below:

```
infile evFreq.pcm
```

```
enaevt 1
logtime 1000
logpar freq
run evFreq_
```

To run test, the following command should be executed

```
TestBench.exe evFreq.txt
```

Result checking:

Frequency event should be detected and following event messages should be recorded to `evFreq_evt.txt` file.

```
_/''' AV_freq_N1 beg:20.000
'''\_ AV_freq_N1 dur:10.019 mean:50.988 min:50.988 max:50.988
```

Waveform should be captured to `evfreq_AV_freq_N1_AV.pcm` file (mono, 6250 SPS), following waveform capture packet messages should be recorded to `evFreq_wave.txt` file.

```
AV_freq_N1_AV len-1025 dec-8 at-20.144
AV_freq_N1_AV len-1025 dec-8 at-20.308
…
AV_freq_N1_AV len-1025 dec-8 at-29.984
AV_freq_N1_AV len-343 dec-8 at-30.039 END
```

5.2 Magnitude event

Purpose:

This test case is designed to check ability of DSP Engine to detect Magnitude Events.

Conditions:

This test runs in single input file mode, text file output. All events excepting User Event are enabled. Default magnitude thresholds are for voltage: overvoltage 110%, undervoltage 90%, outage 5% limit, Vdin – 220 V, for current overvoltage 120%, undervoltage 80%, outage 10% limit, Vdin – sliding reference.

It uses `evMagn.pcm` input sample file. Voltage and current are pure sine wave with levels 220 V and 2 A. There are following events: overvoltage at 1.0 to 1.1 second with level 120%, under current at 1.5 to 1.6 second with level 70% and outage at 2.0 to 2.1 seconds with level 3%.

Configuration session (contents of `evMagn.txt` file) is listed below:

```
infile evMagn.pcm
enaevt 1
logtime 10
logpar v_per, v_rms, c_per, c_rms
run evMagn_
```

To run test, the following command should be executed

```
TestBench.exe evMagn.txt
```

Result checking:

Instantaneous magnitude events should be detected and following event messages should be recorded to `evMagn_evt.txt` file.

```
_/''' AV_magn_N1 beg:1.030
'''\_ AV_magn_N1 dur:0.100 Instantaneous Over mean:261.344 min:242.516
max:264.016
_/''' AC_magn_N4 beg:1.530
'''\_ AC_magn_N4 dur:0.090 Instantaneous Under mean:1.472 min:1.471 max:1.475
_/''' AV_magn_N5 beg:2.020
'''\_ AV_magn_N5 dur:0.110 Instantaneous Outage mean:33.531 min:6.578 max:154.906
```

There are several transitions events detected in this case, but they will be examined in particular test case.

Waveform should be captured to following files (mono, 6250 SPS); following waveform capture packet messages should be recorded to `evMagn_wave.txt` file.

```
AV_magn_N1_AV len-875 dec-8 at-1.130 END
AV_magn_N1_AC len-875 dec-8 at-1.130 END
AC_magn_N4_AC len-812 dec-8 at-1.620 END
AV_magn_N5_AV len-937 dec-8 at-2.130 END
AV_magn_N5_AC len-937 dec-8 at-2.130 END
```

5.3 Imbalance event

Purpose:

This test case is designed to check ability of DSP Engine to detect Imbalance Events.

Conditions:

This test runs in 3 phase input file mode, text file output. All events excepting User Event are enabled. Imbalance thresholds is 2% for negative, zero and NEMA imbalance.

It uses `evImb_A.pcm`, `evImb_B.pcm`, `evImb_C.pcm` and `evImb_N.pcm` input sample files. Voltage and current are pure sine wave with levels 220 V and 2 A. There is 3% negative sequence at 1.0 to 2.0 second and there is 3% zero sequence at 2.0 to 3.0 second.

Configuration session (contents of `evImb.txt` file) is listed below:

```
3phmode 1
infile evImb.pcm
enaevt 1
logtime 200
logpar v_imneg, v_imzero, c_imneg, c_imzero
logpar v_imnema, vpp_imnema, c_imnema
run evImb_
```

To run test, the following command should be executed

```
TestBench.exe evMagn.txt
```

Result checking:

Instantaneous magnitude events should be detected and following event messages should be recorded to `evImb_evt.txt` file.

```
_/''' AV_imbal_N1 beg:1.200
_/''' AC_imbal_N2 beg:1.200
_/''' AVPP_imbal_N3 beg:1.200
'''\_ AVPP_imbal_N3 dur:1.000 NEMA imb: mean:0.025 min:0.025 max:0.030
'''\_ AV_imbal_N1 dur:2.200 Neg imb: mean:0.016 min:0.000 max:0.030 Zero imb:
mean:0.015 min:0.000 max:0.030 NEMA imb: mean:0.029 min:0.005 max:0.030
'''\_ AC_imbal_N2 dur:2.200 Neg imb: mean:0.015 min:0.000 max:0.030 Zero imb:
mean:0.015 min:0.000 max:0.030 NEMA imb: mean:0.029 min:0.005 max:0.030
```

There are several magnitude events detected in this case, but they will be examined in particular test case.

Waveform should be captured to following files (mono, 6250 SPS); following waveform capture packet messages should be recorded to `evImb_wave.txt` file.

```
AV_imbal_N1_AV len-1025 dec-8 at-1.344
AV_imbal_N1_BV len-1025 dec-8 at-1.344
AV_imbal_N1_CV len-1025 dec-8 at-1.344
AV_imbal_N1_AC len-1025 dec-8 at-1.344
AV_imbal_N1_BC len-1025 dec-8 at-1.344
AV_imbal_N1_CC len-1025 dec-8 at-1.344
AC_imbal_N2_AC len-1025 dec-8 at-1.344
AC_imbal_N2_BC len-1025 dec-8 at-1.344
AC_imbal_N2_CC len-1025 dec-8 at-1.344
…
```

```
AV_imbal_N1_AV len-700 dec-8 at-3.260 END
AV_imbal_N1_BV len-700 dec-8 at-3.260 END
AV_imbal_N1_CV len-700 dec-8 at-3.260 END
AV_imbal_N1_AC len-700 dec-8 at-3.260 END
AV_imbal_N1_BC len-700 dec-8 at-3.260 END
AV_imbal_N1_CC len-700 dec-8 at-3.260 END
AC_imbal_N2_AC len-700 dec-8 at-3.260 END
AC_imbal_N2_BC len-700 dec-8 at-3.260 END
AC_imbal_N2_CC len-700 dec-8 at-3.260 END
```

5.4 Harmonics and THD event

Purpose:

This test case is designed to check ability of DSP Engine to detect Harmonics (sub-grouped harmonics and inter-harmonics) and THD (THDS and TIHDS) Events.

Conditions:

This test runs in single input file mode, text file output. All events excepting User Event are enabled. Default event detection parameters: detected harmonics 2, 3, 5, 7, 9 with thresholds 2.0, 5.0, 6.0, 5.0% and 1.5, detected inter-harmonics 1, 2, 3, 5, 7 with thresholds 5.0, 4.8, 4.6, 4.2, 3.8%, THD threshold 10.0%, TIHD thresholds 5.0%.

It uses `evHarmThd.pcm` input sample file. Voltage and current are 220 V and 2 A. There are harmonics for voltage and inter-harmonics for current, they start at 1.0 second and last to 5.0 second. Voltage harmonics level: 2-nd - 5%, 3-rd - 10% and 5-th 10%, Current inter-harmonics level: 1-st (between fundamental and 2-nd harmonics) 7.5%, 2-nd - 7.5%, 3-rd - 7.5%.

Configuration session (contents of `evHarmThd.txt` file) is listed below:

```
infile evHarmThd.pcm
enaevt 1
logtime 200
logpar v_rms, v_harmsg_mag, v_harmsg_perc, v_thd_thdsg, v_thd_tihd
logpar c_rms, c_inth_mag, c_inth_perc, c_thd_thdsg, c_thd_tihd
run evHarmThd_
```

To run test, the following command should be executed

```
TestBench.exe evHarmThd.txt
```

Result checking:

Harmonics and THD events should be detected and following event messages should be recorded to `evHarmThd_evt.txt` file.

```
_/''' AV_harm_N1 beg:1.321
_/''' AC_harm_N2 beg:1.321
_/''' AC_thd_N3 beg:1.321
_/''' AV_thd_N4 beg:1.541
'''\_ AV_thd_N4 dur:4.65156 THDS: mean:0.133 min:0.108 max:0.146
'''\_ AC_harm_N2 dur:5.500  Inth 1: mean:0.068 min:0.047 max:0.078  Inth 2:
mean:0.068 min:0.047 max:0.078  Inth 3: mean:0.068 min:0.047 max:0.078
'''\_ AV_harm_N1 dur:6.601  Harm 2: mean:0.039 min:0.021 max:0.048  Harm 3:
mean:0.078 min:0.041 max:0.097  Harm 5: mean:0.078 min:0.041 max:0.097
'''\_ AC_thd_N3 dur:7.040 TIHDS: mean:0.106 min:0.051 max:0.135
```

There are several transitions events detected in this case, but they will be examined in particular test case.

Waveform should be captured to following files (mono, 6250 SPS); following waveform capture packet messages should be recorded to `evHarmThd_wave.txt` file.

```
AV_harm_N1_AC len-1250 dec-8 at-1.321
AC_harm_N2_AC len-1250 dec-8 at-1.321
AC_thd_N3_AC len-1250 dec-8 at-1.321
```

```
AV_harm_N1_AV len-1250 dec-8 at-1.321
AV_harm_N1_AC len-1025 dec-8 at-1.485
AC_harm_N2_AC len-1025 dec-8 at-1.485
AC_thd_N3_AC len-1025 dec-8 at-1.485
AV_harm_N1_AV len-1025 dec-8 at-1.485
AV_thd_N4_AV len-1250 dec-8 at-1.541
…
AV_harm_N1_AV len-1025 dec-8 at-8.045
AV_harm_N1_AC len-1025 dec-8 at-8.045
AV_harm_N1_AV len-481 dec-8 at-8.122 END
AV_harm_N1_AC len-481 dec-8 at-8.122 END
AC_thd_N3_AC len-1025 dec-8 at-8.209
AC_thd_N3_AC len-1025 dec-8 at-8.373
AC_thd_N3_AC len-1025 dec-8 at-8.537
AC_thd_N3_AC len-150 dec-8 at-8.561 END
```

5.5 DC offset event

Purpose:

This test case is designed to check ability of DSP Engine to detect DC offset Events.

Conditions:

This test runs in single input file mode, text file output. All events excepting User Event are enabled. Default DC offset detection threshold is 1.0%.

It uses `evDcoffs.pcm` input sample file. Voltage and current are 220 V and 2.0 A. There are DC offset for voltage and current, it start at 1.0 second and last to 3.0 second. DC offset level is 2%.

Configuration session (contents of `evDcoffs.txt` file) is listed below:

```
infile evDcoffs.pcm
enaevt 1
logtime 200
logpar v_rms, v_dcoffs, c_rms, c_dcoffs
run evDcoffs_
```

To run test, the following command should be executed

```
TestBench.exe evDcoffs.txt
```

Result checking:

DC offset events should be detected and following event messages should be recorded to `evDcoffs_evt.txt` file.

```
_/''' AV_dcoff_N1 beg:1.541
_/''' AC_dcoff_N2 beg:1.541
'''\_ AC_dcoff_N2 dur:3.300 mean:0.040 min:0.021 max:0.058
'''\_ AV_dcoff_N1 dur:3.65276 mean:5.219 min:2.281 max:8.219
```

Waveform should be captured to following files (mono, 6250 SPS); following waveform capture packet messages should be recorded to `evDcoffs_wave.txt` file.

```
AV_dcoff_N1_AV len-1250 dec-8 at-1.541
AV_dcoff_N1_AC len-1250 dec-8 at-1.541
AC_dcoff_N2_AC len-1250 dec-8 at-1.541
…
AC_dcoff_N2_AC len-350 dec-8 at-5.041 END
AV_dcoff_N1_AV len-1025 dec-8 at-5.149
AV_dcoff_N1_AC len-1025 dec-8 at-5.149
AV_dcoff_N1_AV len-1025 dec-8 at-5.313
```

```
AV_dcoff_N1_AC len-1025 dec-8 at-5.313
AV_dcoff_N1_AV len-1025 dec-8 at-5.477
AV_dcoff_N1_AC len-1025 dec-8 at-5.477
AV_dcoff_N1_AV len-25 dec-8 at-5.481 END
AV_dcoff_N1_AC len-25 dec-8 at-5.481 END
```

5.6 Transient event

Purpose:

This test case is designed to check ability of DSP Engine to detect Transient and notch Events.

Conditions:

This test runs in single input file mode, text file output. All events excepting User Event are enabled. Default event detection parameters: peak threshold - 500 V, slope threshold - 200 V, window RMS threshold - 50 V and window length is 0.1 of cycle, cycle RMS threshold - 20V, notch peak and slope variation - 100V, notch time variation 20 samples at 50 kSPS.

It uses `evTrans.pcm` input sample file. Voltage and current are 220 V and 2 A. There are following transients: single positive 620 V peak at 1.0 seconds, single negative 310 slope at 1.5 second, 1000 Hz 110V sine oscillations with 2 ms duration (0.1 cycle) at 2.0 second, 2000 Hz 22 V sine wave oscillation with 20 ms duration (1 cycle) at 2.5 second, 7 repetitive 820 V peak with small amplitude and time deviation to be detected as single notch, starting at 3.0 second.

Configuration session (contents of `evTrans.txt` file) is listed below:

```
infile evTrans.pcm
enaevt 1
logtime 100
logpar v_rms
run evTrans_
```

To run test, the following command should be executed

```
TestBench.exe evTrans.txt
```

Result checking:

DC offset events should be detected and following event messages should be recorded to `evTrans_evt.txt` file.

```
_!_AV_trans_N1 beg:1.026 Peak: +625.500 Wind: 79.406 Cycle: 24.594
_!_AV_trans_N2 beg:1.046 Wind: 79.406 Cycle: 24.594
_!_AV_trans_N3 beg:1.526 Slope: +311.250 -311.250 Wind: 50.219
_!_AV_trans_N4 beg:1.546 Wind: 50.219
_!_AV_trans_N5 beg:2.025 Wind: 79.984 Cycle: 24.781
_!_AV_trans_N6 beg:2.045 Wind: 79.969 Cycle: 35.047
_!_AV_trans_N7 beg:2.065 Cycle: 24.797
_!_AV_trans_N8 beg:2.537 Cycle: 20.125
_!_AV_trans_N9 beg:2.557 Cycle: 21.875
_!_AV_trans_N10 beg:3.026 Peak: +817.000 Slope: +504.250 -196.750 Wind: 101.688
Cycle: 31.500
_!_AV_trans_N11 beg:3.046 Peak: +748.250 Slope: +435.500 -177.250
_/''' AV_notch_N12 beg:3.046
_!_AV_trans_N13 beg:3.066 Peak: +827.000 Slope: +514.250 -216.750
_!_AV_trans_N14 beg:3.085 Peak: +836.750 Slope: +524.250 -0.000 Wind: 84.547
Cycle: 26.672
_!_AV_trans_N15 beg:3.105 Wind: 84.547 Cycle: 30.797
_!_AV_trans_N16 beg:3.106 Peak: +817.000 Slope: +504.250 -216.750
_!_AV_trans_N17 beg:3.125 Peak: +758.000 Slope: +446.250 -196.750 Wind: 88.078
Cycle: 45.281
_!_AV_trans_N18 beg:3.145 Wind: 88.078 Cycle: 41.250
```

```
_!_AV_trans_N19 beg:3.146 Peak: +817.000 Slope: +504.250 -187.000
_!_AV_trans_N20 beg:3.165 Cycle: 30.719
_!_AV_trans_N21 beg:3.166 Wind: 99.141
'''\_ AV_notch_N12 dur:0.122 On peak On slope
_!_AV_trans_N22 beg:3.185 Cycle: 30.719
```

Waveform should be captured to following files (mono, 50000 SPS); following waveform capture packet messages should be recorded to `evTrans_wave.txt` file.

```
AV_trans_N1_AV len:3000 dec:4 at:1.026
AV_trans_N2_AV len:3000 dec:4 at:1.046
AV_trans_N1_AV len:1000 dec:4 at:1.046 END
AV_trans_N2_AV len:1000 dec:4 at:1.066 END
AV_trans_N3_AV len:3000 dec:4 at:1.526
AV_trans_N4_AV len:3000 dec:4 at:1.546
AV_trans_N3_AV len:1000 dec:4 at:1.546 END
AV_trans_N4_AV len:1000 dec:4 at:1.566 END
AV_trans_N5_AV len:3000 dec:4 at:2.025
AV_trans_N6_AV len:3000 dec:4 at:2.045
AV_trans_N5_AV len:1000 dec:4 at:2.045 END
AV_trans_N6_AV len:1000 dec:4 at:2.065 END
AV_trans_N7_AV len:3000 dec:4 at:2.065
AV_trans_N7_AV len:1000 dec:4 at:2.085 END
AV_trans_N8_AV len:3000 dec:4 at:2.537
AV_trans_N9_AV len:3000 dec:4 at:2.557
AV_trans_N8_AV len:1000 dec:4 at:2.557 END
AV_trans_N9_AV len:1000 dec:4 at:2.577 END
AV_trans_N10_AV len:3000 dec:4 at:3.026
AV_trans_N11_AV len:3000 dec:4 at:3.046
AV_notch_N12_AV len:3000 dec:4 at:3.046
AV_trans_N10_AV len:1000 dec:4 at:3.046 END
AV_trans_N11_AV len:1000 dec:4 at:3.066 END
AV_trans_N13_AV len:3000 dec:4 at:3.066
AV_notch_N12_AV len:1050 dec:4 at:3.067
AV_trans_N14_AV len:3000 dec:4 at:3.085
AV_trans_N13_AV len:1000 dec:4 at:3.086 END
AV_notch_N12_AV len:1050 dec:4 at:3.088
AV_trans_N15_AV len:3000 dec:4 at:3.105
AV_trans_N14_AV len:1000 dec:4 at:3.105 END
AV_trans_N16_AV len:3000 dec:4 at:3.106
AV_notch_N12_AV len:1050 dec:4 at:3.109
AV_trans_N17_AV len:3000 dec:4 at:3.125
AV_trans_N15_AV len:1000 dec:4 at:3.125 END
AV_trans_N16_AV len:1000 dec:4 at:3.126 END
AV_notch_N12_AV len:1050 dec:4 at:3.130
AV_trans_N17_AV len:1000 dec:4 at:3.145 END
AV_trans_N18_AV len:3000 dec:4 at:3.145
AV_trans_N19_AV len:3000 dec:4 at:3.146
AV_notch_N12_AV len:1050 dec:4 at:3.151
AV_trans_N20_AV len:3000 dec:4 at:3.165
AV_trans_N18_AV len:1000 dec:4 at:3.165 END
```

```
AV_trans_N19_AV len:1000 dec:4 at:3.166 END
AV_trans_N21_AV len:3000 dec:4 at:3.166
AV_notch_N12_AV len:1050 dec:4 at:3.172
AV_trans_N20_AV len:1000 dec:4 at:3.185 END
AV_trans_N22_AV len:3000 dec:4 at:3.185
AV_trans_N21_AV len:1000 dec:4 at:3.186 END
AV_notch_N12_AV len:800 dec:4 at:3.188 END
AV_trans_N22_AV len:1000 dec:4 at:3.205 END
```

5.7 User event

Purpose:

This test case is designed to check ability of DSP Engine to generate User Events.

Conditions:

This test runs in single input file mode, text file output. All events including User Event are enabled. User event generated once per 1 second.

It uses `evUser.pcm` input sample file. Voltage and current are 220 V and 2 A pure sine wave.

Configuration session (contents of `evUser.txt` file) is listed below:

```
infile evUser.pcm
enaevt 2
logtime 100
logpar v_rms
run evUser_
```

To run test, the following command should be executed

```
TestBench.exe evUser.txt
```

Result checking:

DC offset events should be detected and following event messages should be recorded to `evUser_evt.txt` file.

```
_!_AV_user_N1 beg:1.000
_!_AC_user_N2 beg:1.000
_!_AVPP_user_N3 beg:1.000
_!_AV_user_N4 beg:2.000
_!_AC_user_N5 beg:2.000
_!_AVPP_user_N6 beg:2.000
```

Waveform should be captured to following files (mono, 25000 SPS); following waveform capture packet messages should be recorded to `evUser_wave.txt` file.

```
AV_user_N1_AV len:1000 dec:4 at:1.010 END
AC_user_N2_AC len:1000 dec:4 at:1.010 END
AVPP_user_N3_AVPP len:1000 dec:4 at:1.010 END
AV_user_N4_AV len:1000 dec:4 at:2.010 END
AC_user_N5_AC len:1000 dec:4 at:2.010 END
AVPP_user_N6_AVPP len:1000 dec:4 at:2.010 END
```

6 Special conditions

6.1 Input range control

Purpose:

This test case is designed to check ability of DSP Engine automatically switch ADC input range to ensure best ADC performance in all input voltage and current range.

Conditions:

This test runs in in 3-phase input file mode (4 input files for 3 phase + neutral), text file output. Input voltage and current are pure sine wave without any harmonics. Voltage / current RMS magnitudes for all 3 phase and neutral are slowly changing from 200 V / 2.0 A to 20 V / 0.2 A and back to 200 V / 2.0 A. The same test is run twice: in 3-phase + neutral measurement mode and in 4 independent channels mode.

Configuration session (contents of `rngCtrl.txt` file) is listed below:

```
infile rngCtrl.pcm
4files 1
4indep 0
logtime 100
logpar v_rms
run rngCtrl_
infile rngCtrl.pcm
4files 1
4indep 1
logtime 100
logpar v_rms
run rngCtrl_4i_
```

To run test, the following command should be executed

```
TestBench.exe rngCtrl.txt
```

ADC input range change is displayed in `msg_log.txt` file (this file will be rewritten with next `TestBench.exe` run, so it is recommended rename it to `rngCtrl_msg_log.txt` to save results). Message is looks like:

```
ADC range 3 2 2 2 1 0 0 0
```

It means that A voltage range is `ENG_VR_600V`, B, C, N voltage range is `ENG_VR_300V`, A current range is `ENG_CR_30V`, B, C, N current range is `ENG_CR_17V`,

Result checking:

Following messages should be present in `msg_log.txt` file

For 3-phase + neutral mode:

```
00000 ADC range 3 3 3 3 1 1 1 1
02800 ADC range 2 2 2 2 1 1 1 1
03400 ADC range 2 2 2 2 0 0 0 0
04600 ADC range 1 1 1 1 0 0 0 0
05400 ADC range 0 0 0 0 0 0 0 0
06400 ADC range 1 1 1 1 0 0 0 0
06600 ADC range 2 2 2 2 0 0 0 0
07800 ADC range 2 2 2 2 1 1 1 1
08400 ADC range 3 3 3 3 1 1 1 1
```

For 4 independent channels mode:

```
00000 ADC range 3 3 3 3 1 1 1 1
02200 ADC range 2 3 3 3 1 1 1 1
02400 ADC range 2 2 3 3 1 1 1 1
02600 ADC range 2 2 2 3 1 1 1 1
02800 ADC range 2 2 2 2 0 1 1 1
03000 ADC range 2 2 2 2 0 0 1 1
03200 ADC range 2 2 2 2 0 0 0 1
03400 ADC range 2 2 2 2 0 0 0 0
04000 ADC range 1 2 2 2 0 0 0 0
04200 ADC range 1 1 2 2 0 0 0 0
04400 ADC range 1 1 1 2 0 0 0 0
```

```
04600 ADC range 1 1 1 1 0 0 0 0
04800 ADC range 0 1 1 1 0 0 0 0
05000 ADC range 0 0 1 1 0 0 0 0
05200 ADC range 0 0 0 1 0 0 0 0
05400 ADC range 0 0 0 0 0 0 0 0
06400 ADC range 1 0 0 0 0 0 0 0
06600 ADC range 2 1 0 0 0 0 0 0
06800 ADC range 2 2 1 0 0 0 0 0
07000 ADC range 2 2 2 1 0 0 0 0
07200 ADC range 2 2 2 2 0 0 0 0
07800 ADC range 2 2 2 2 1 0 0 0
08000 ADC range 2 2 2 2 1 1 0 0
08200 ADC range 2 2 2 2 1 1 1 0
08400 ADC range 3 2 2 2 1 1 1 1
08600 ADC range 3 3 2 2 1 1 1 1
08800 ADC range 3 3 3 2 1 1 1 1
09000 ADC range 3 3 3 3 1 1 1 1
```

A, B, C, N voltage range is changing from `ENG_VR_600V` to `ENG_VR_300V` `ENG_VR_150V`, `ENG_VR_75V` and back to `ENG_VR_600V`. A, B, C, N current range is changing from `ENG_CR_30V` to `ENG_CR_17V` and back to `ENG_CR_30V`.

6.2 Main frequency deviation from 42.5 to 57.5 Hz

Purpose:

This test case is designed to check ability of DSP Engine to measure voltage, power and kwh in case fast frequency change from 42.5 to 57.5 Hz (it introduce lost of synchronization). Phase voltage, phase current, real and apparent power and kilo-watt hours are checked in this test case.

Conditions:

This test runs in single input file mode, text file output, report interval is 100 ms. Input voltage and current are pure sine wave without any harmonics. Leading angle (voltage to current angle) is zero.

It uses `425to575Hz.pcm` input sample file. Voltage and current are constant for all intervals, they are 200 V and 2.00 A. Main frequencies takes values from 42.5 to 57.5 Hz with step 2.5 Hz.

Configuration session (contents of `425to575Hz.txt` file) is listed below:

```
infile 425to575Hz.pcm
logtime 1000
logpar v_rms, c_rms, rlpwr, apppwr, kwh
run 425to575Hz_
```

To run test, the following command should be executed

```
TestBench.exe 425to575Hz.txt
```

Measurement value tolerance is 1% referenced to maximal value.

Important, for kWh and kVAh increment per 1 second and final value at the end of 10s interval are specified.

Result checking:

File name	Measurement parameter	Desired value
425to575Hz_v_rms.dat	phase voltage	200 V for all intervals
425to575Hz_c_rms.dat	phase current	2.00 A for all intervals
425to575Hz_rlpwr.dat	real power	400 VA for all intervals
425to575Hz_apppwr.dat	apparent power	400 VA for all intervals
425to575Hz_kwh.dat	kilo-watt hours	Increment - 0.0111 WH per 100 ms (report interval) Final value - 0.777 WH

6.3 Slow main frequency drift

Purpose:

This test case is designed to check ability of DSP Engine to measure main frequency and adjust harmonics DFT interpolation ratio to keep DFT window synchronized to periods of main frequency. Main frequency is slowly changing from 50 to 51.111Hz. Main frequency, harmonics, inter-harmonics and phase voltage are checked in this test case.

Conditions:

This test runs in single input file mode, text file output, report interval is 1s. Input voltage and current are pure sine wave without any harmonics. Leading angle (voltage to current angle) is zero.

It uses `slow50to51_111Hz.pcm` input sample file. Voltage and current are constant for all intervals, they are 200 V and 200 A. Main frequency is slowly changing from 50 Hz to 51.111Hz during 50 seconds and then stay 51.111Hz for 22 seconds.

Configuration session (contents of `slow50to51_111Hz.txt` file) is listed below:

```
infile slow50to51_111Hz.pcm
logtime 1000
logpar freq, v_harm, v_inth, v_subh_mag
run slow50to51_111Hz_
```

To run test, the following command should be executed

```
TestBench.exe slow50to51_111Hz.txt
```

Measurement value tolerance is 1% referenced to maximal value for all parameters, excepting frequency, for frequency tolerance is 0.1%.

Result checking:

File name	Measurement parameter	Desired value	
slow50to51_111Hz_freq.dat	main frequency	1-60-th seconds	Linear growth from 50.000 to 51.111 Hz
		61-72-th seconds	51.111 Hz
slow50to51_111Hz_v_harm.dat	harmonics	1-60-th seconds	unspecified
		61-72-th seconds, 1-st harmonic	200 V
		61-72-th seconds, all other harmonics	0 V
slow50to51_111Hz_v_inth.dat slow50to51_111Hz_v_subh.dat	1-st inter-harmonics subharmonics	1-60-th seconds	unspecified
		61-72-th seconds, all inter-harmonics	0 V

References

[1] Software Description, Version 0.2.

[2] IEC 61000 - 4 - 7. Electromagnetic compatibility (EMC) Part 4-7: Testing and measurement techniques – Power quality measurement methods.

[3] IEC 61000 - 4 - 30. Electromagnetic compatibility (EMC) Part 4-30: Testing and measurement techniques – General guide on harmonics and interharmonics measurement and instrumentation, for power supply system and equipment connected thereto.