TERIDIAN SEMICONDUCTOR CORP.
A Maxim Integrated Products Brand

71M6513 Energy Meter IC

APPLICATION NOTE

AN_6513_029 FEBRUARY 2006

71M6513 Broadband VARh Harmonic Performance

Teridian Semiconductor Corporation has developed a custom compute engine firmware to support the energy metering in the presence of harmonics. The Compute Engine firmware CE13B11 was developed to provide the following capabilities:

1. Broadband VARh measurement capability
2. A zero-latency pulse output.

Deleted features from the previous version are VARPULSE and certain EQU features. Aside from VAR, EQU, WPULSE, and VARPULSE, no other features have been changed.

Broadband VAR

The previous CE code shifted the fundamental and all harmonics by 90 degrees, but exhibited a 1/f amplitude characteristic on harmonics. Specifically, the fundamental, regardless of frequency, was always shifted at unity gain. The third harmonic was attenuated by 3x, the fifth by 5x, etc.

The new code utilizes a digital all-pass filter having exact unity gain at all frequencies and nearly 90º phase shift from 40Hz to 1220Hz. The exact performance of this filter is as follows:

Frequency (Hz)	Phase Error (Deviation from 90 degrees)
40 to 1220	<3.7degrees
48.5 to 63	<0.05 degrees
50	<0.0002 degrees
60	<0.0005 degrees

Table 1: VAR Phase Shift Filter

The phase error introduced by this filter is digitally compensated.

Zero-Latency PULSE

A watt-hour meter can be visualized as a device that rotates a disk a certain number of degrees for each unit of energy it measures. Holes in the disk generate pulses.

The previous code integrated energy for a complete accumulation interval and then rotated its pulse generator disk at a uniform rate during the next accumulation interval. At the end of the accumulation cycle, the wheel had rotated the exact number of degrees corresponding to the accumulated energy. The result was an accurate meter, but with a latency time equal to the accumulation interval.

The new code rotates the pulse generator disk while power is accumulated, removing the latency time of the previous Compute Engine firmware versions. The new pulse generator can be configured to pulse on net Wh, sum Wh, net VARh, and sum VARh.

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This configuration for selectable pulse output is controlled by the PULSESTATE (CE RAM address 0x3B) variable according to following table.

PULSESTATE	Description (Assume EQU=5)
0	Net VARh = $\lvert SUM(I_A V_{A90} + I_B V_{B90} + I_C V_{C90}) \rvert$
1	Net Wh = $\lvert SUM(I_A V_A + I_B V_B + I_C V_C) \rvert$
2	Sum VARh = $SUM(\lvert I_A V_{A90}\rvert + \lvert I_B V_{B90}\rvert + \lvert I_C V_{C90}\rvert)$
3	Sum Wh = $SUM(\lvert I_A V_A\rvert + \lvert I_B V_B\rvert + \lvert I_C V_C\rvert)$

Table 2: Pulse Generator Options

Other parameters that affect the behavior of WPULSE output are PULSEMAX and PULSEWIDTH:

The PULSE_WIDTH (CE RAM address 0x3C) controls the width of the output pulse. A unity factor in the PULSEWIDTH register results in a pulse that is 396.7µs wide. The pulse is always negative going.

The PULSEMAX (CE RAM address 0x2D) value controls the pulse rate. That is, this value is useful to compute Kh using the following equation.

$$K_H = 9.4045x10^{-13} PULSEMAX \;\; VMAX \;\; IMAX / In8 \quad Wh / Pulse$$

The default value for PULSEMAX is 8,520,220, resulting in Kh =1.0Wh/pulse for Vmax=600V and Imax=208A.

Care must be taken to ensure PULSEWIDTH is not too large. If PULSEWIDTH is larger than the minimum period between pulses, the pulses will bridge together. When PULSEWIDTH = 1, the maximum pulse rate is 1260Hz.

New CE Variables

The new CE variables location is shown in Table 3.

Variable	Address (hex)
PULSESTATE	0x3B
PULSEMAX	0x2D
PULSEWIDTH	0x3C

Table 3: New CE Variables

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Cautionary Notes:

1. The pulse output is the net sum of PhaseA, PhaseB and PhaseC. Improper installation can result in less pulses than expected for NetWh and NetVarh sources.
2. The SumWh and SumVARh options for pulse outputs ignore polarity reversals. In meter installations with billing values based on import versus export, using SumWh and Sum VARh may result in confusion.
3. Any updates done to the EXT_PULSE (0x37), APULSEW and APULSER registers by MPU are ignored during CE operation.
4. The PULSE_FAST (0x28) and PULSE_SLOW (0x29) register functionality offered by the older CE firmware is no longer supported. These memory locations are used by the CE for internal use and should not be modified.
5. There is no change in the way CE registers are output for data transfer to the MPU.
6. Only 3-phase 4-wire WYE (VA * IA + VBN * IB + VC * IC) or 3-phase 3-wire (VA * IA + VB * IB) configurations are supported.
7. The Compute Engine will support only one pulse output, the WPULSE output at the maximum pulse rate of 1260Hz.
8. The voltage-to-voltage phase angle measurement is supported.
9. The line zero crossing detection using the MAIN_EDGE count register is supported. This feature can be used for RTC adjustment.
10. SAG detection for each phase voltage is supported. This feature may be used for early power fail warnings.

Harmonic performance will be demonstrated in the second part of this document.

Upgrading Firmware

The following files can be used for achieving the above CE specifications:

1. CE13B11Harmonics.ce
2. CE13B11Harmonics.dat
3. CE13B11Harmonics_ce.c
4. CE13B11Harmonics_dat.c

One can easily upgrade the existing CE code to the new version using the following procedure:

1. Using CE_merge technique. and upgrade the current hexadecimal file. That is the existing CE files (*.ce and *.dat) files will be updated to the new hex file without modifying the existing hex file.
2. If one is in development stage where one can include the files (*ce.c & *dat.c) for building project in the compiler environment.

Caution: *When upgrading the CE files to the new firmware one should be aware of the following:*

1. *This CE firmware does not support VAR pulse output.*
2. *The pulse rate is limited to maximum of 1260Hz.*
3. *The metering connections are limited to 3-phase 3-wire and 3-phase 4-wire WYE.*

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Harmonic Performance of the New CE Firmware CE13B11

Tests were conducted at TERIDIAN to evaluate the harmonic performance of the new CE13B11 firmware. Per IEC 62052/ IEC 62053 and ANSI C12.20 metering standards, the voltage applied to the meter under test was modulated with 10% harmonic component while the current was modulated with 40% harmonic content (the percentage values are relative to the fundamental). The following tools were used for verification of the performance:

1. Fluke 6100A used as phantom load with harmonic generation capability.
2. Fluke 6100A pulse input used for capturing the pulse output from the meter under test.

Figure 1 shows a screen capture of the FFT of the signals present at the output of ADC. These are the signals that were fed to the Compute Engine for processing.

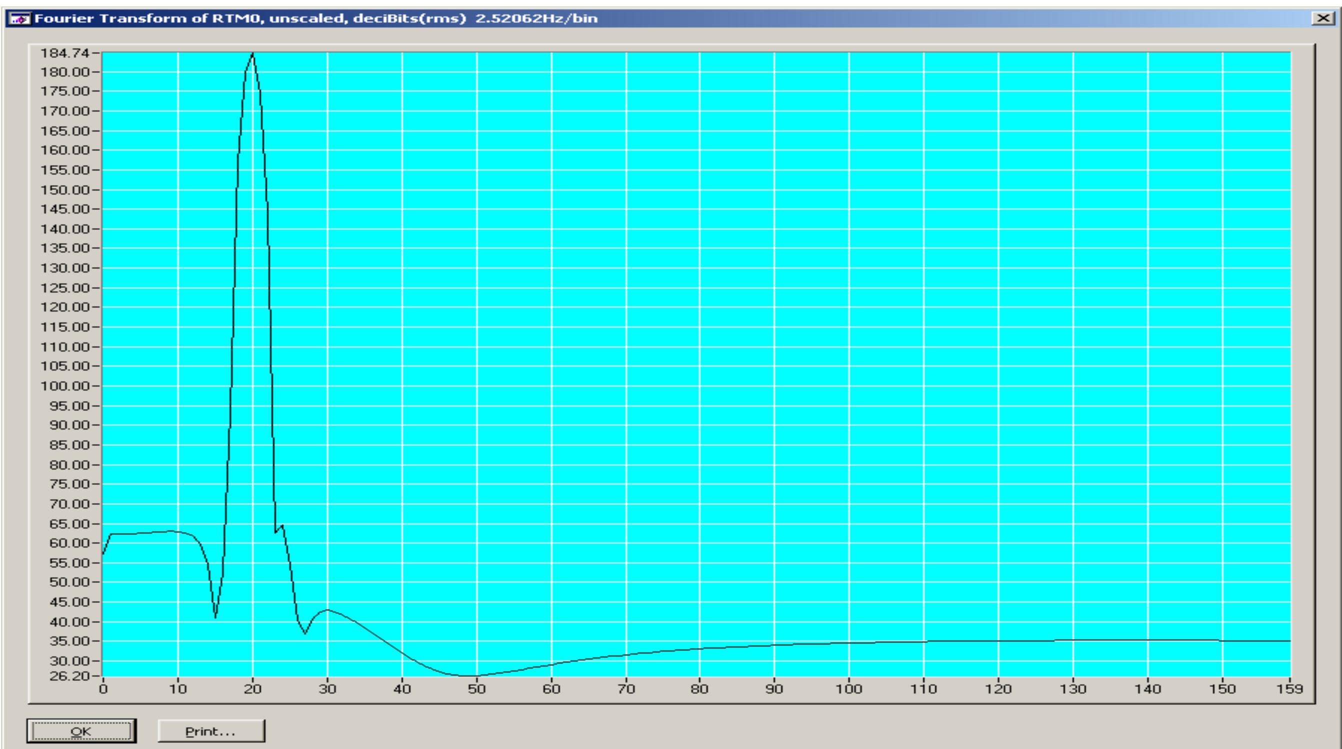

Figure 1: FFT of ADC Output (Fundamental)

ADC current input was 10A without any harmonics. Please note that the Y-axis is in deci-bits, that is for the following spectrum the peak value is (2 ^ 18.474) and the peak is occurring at 20*2.5206Hz, or 50Hz on the X-axis.

Figure 2 shows the ADC output with the current input containing 40% at the 3rd harmonic at 10A. The X-axis is in X value * 0.25206.

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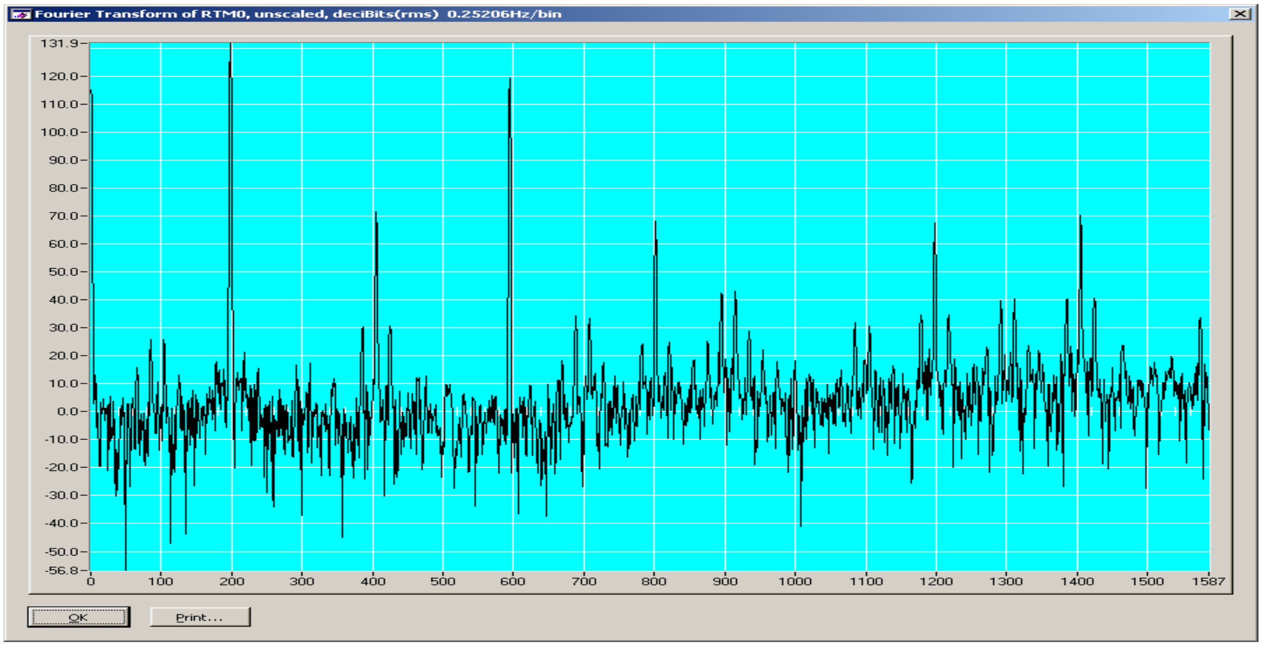

Figure 2: FFT of ADC Output (3rd Harmonic)

Figure 3 shows the processed current signal for the 3rd harmonic input for computing ISQH and WSUM registers.

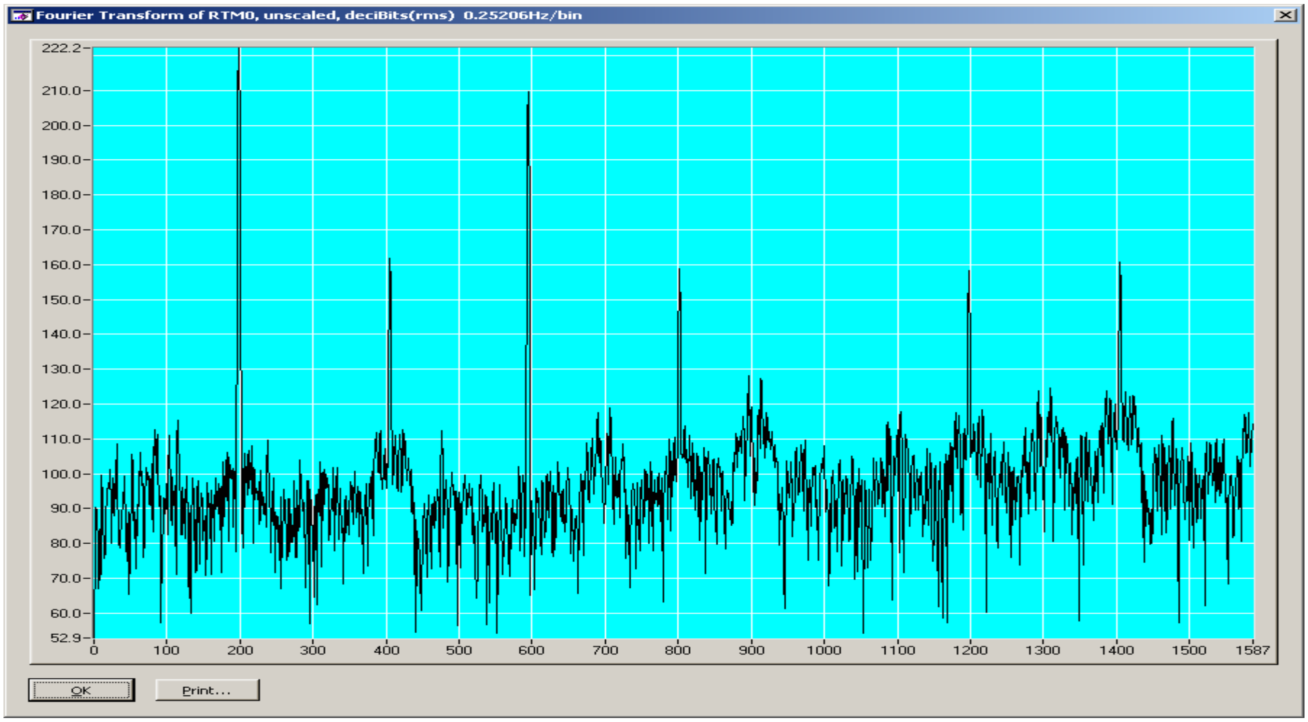

Figure 3: FFT of ADC Output

Figure 4 shows the processed Voltage input with the 3rd harmonic for WH/VSQH computation.

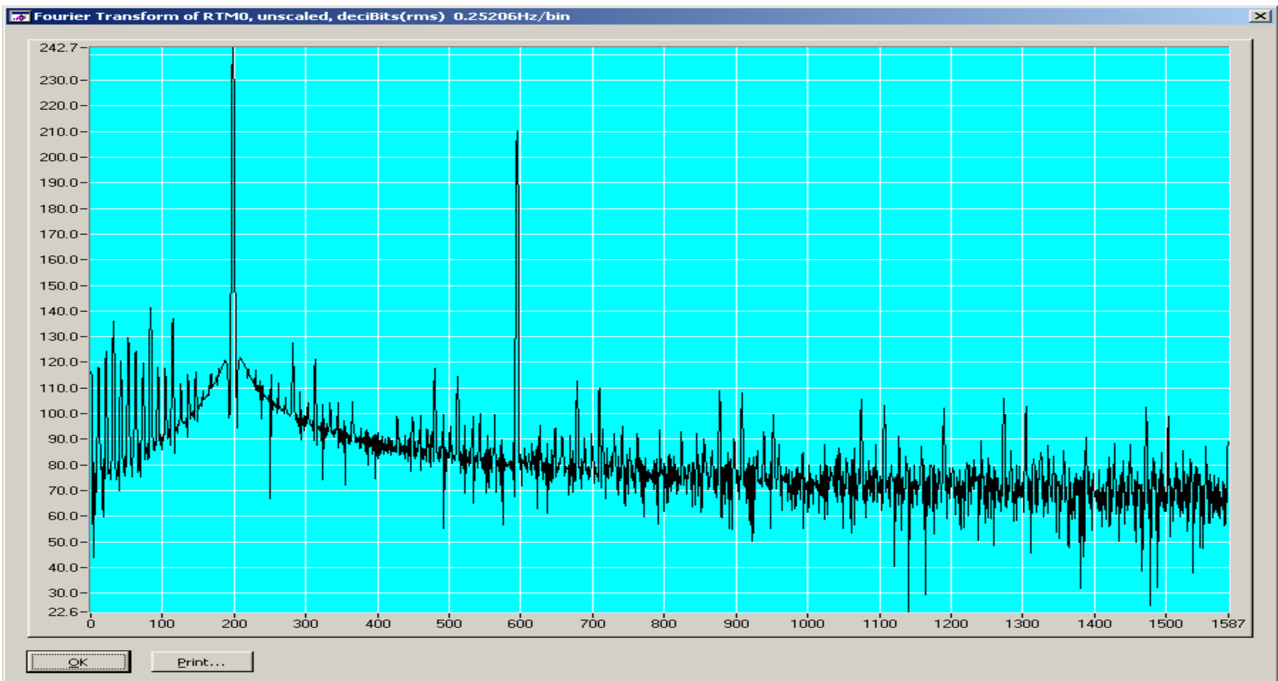

Figure 4: FFT of ADC Output

Figure 5 shows the voltage and current in real time present at the ADC inputs. Please note that orange (larger signal) is voltage and blue is the current.

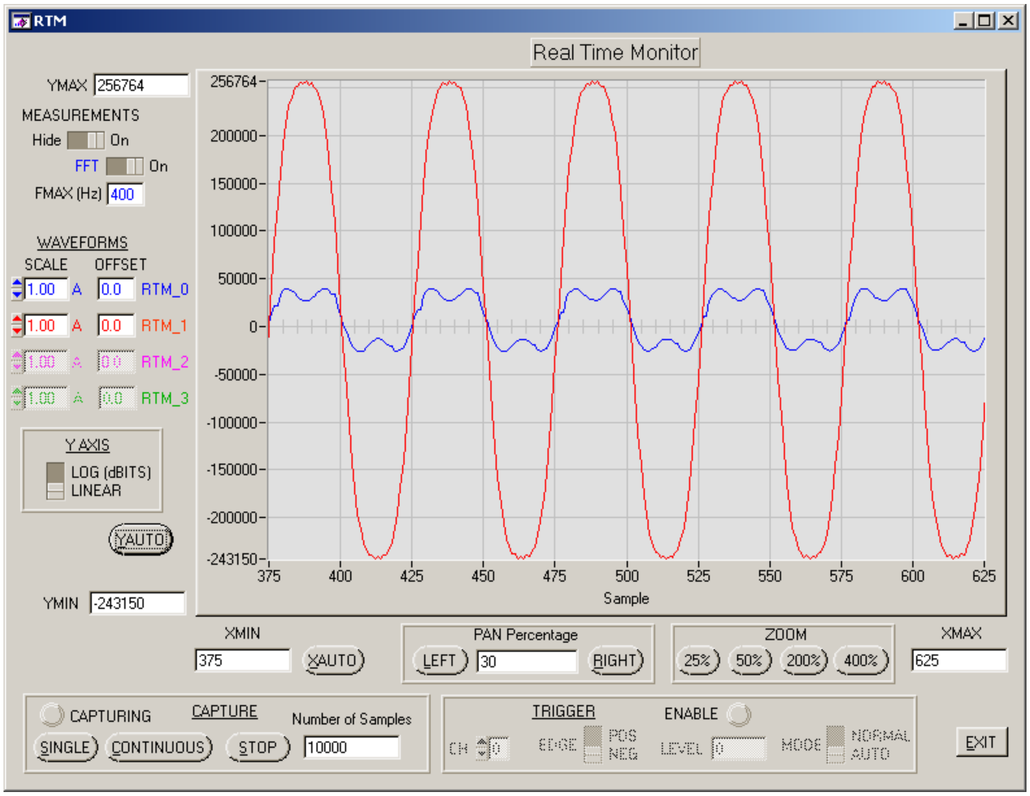

Figure 5: V and I in Time Domain

Table 4 shows results from Irms measurement with harmonics. The fundamental current applied was 10A, with 40% nth harmonic component resulting 10.77033A. A graph representing the values in Table 4 is shown in Figure 6.

Harmonic	Irsm_WB	%Error	Vrms_WB	%Error
1	10.0021	0.0210	239.9844	-0.0065
2	10.7722	0.0171	241.1759	-0.0087
3	10.7725	0.0200	241.1825	-0.0060
4	10.7723	0.0181	241.1853	-0.0048
5	10.7712	0.0081	241.1763	-0.0086
6	10.7714	0.0100	241.1756	-0.0089
7	10.7705	0.0014	241.1745	-0.0093
8	10.7701	-0.0024	241.1764	-0.0086
9	10.7704	0.0006	241.1885	-0.0035
10	10.7690	-0.0124	241.1819	-0.0063
11	10.7704	0.0006	241.1779	-0.0079
12	10.7720	0.0160	241.1696	-0.0114
13	10.7734	0.0281	241.1831	-0.0058
14	10.7730	0.0247	241.1750	-0.0091
15	10.7670	-0.0312	241.1726	-0.0101
16	10.7707	0.0031	241.1746	-0.0093
17	10.7670	-0.0312	241.1763	-0.0086
18	10.7688	-0.0140	241.1703	-0.0111
19	10.7668	-0.0328	240.7483	-0.1860
20	10.7718	0.0136	241.1764	-0.0086
21	10.7677	-0.0245	241.1618	-0.0146
22	10.7675	-0.0261	240.8016	-0.1639
23	10.7671	-0.0298	241.1745	-0.0093
24	10.7689	-0.0132	241.1705	-0.0110
25	10.7723	0.0181	240.8016	-0.1639
26	10.7722	0.0176	241.1442	-0.0219

Table 4: Irms Currents

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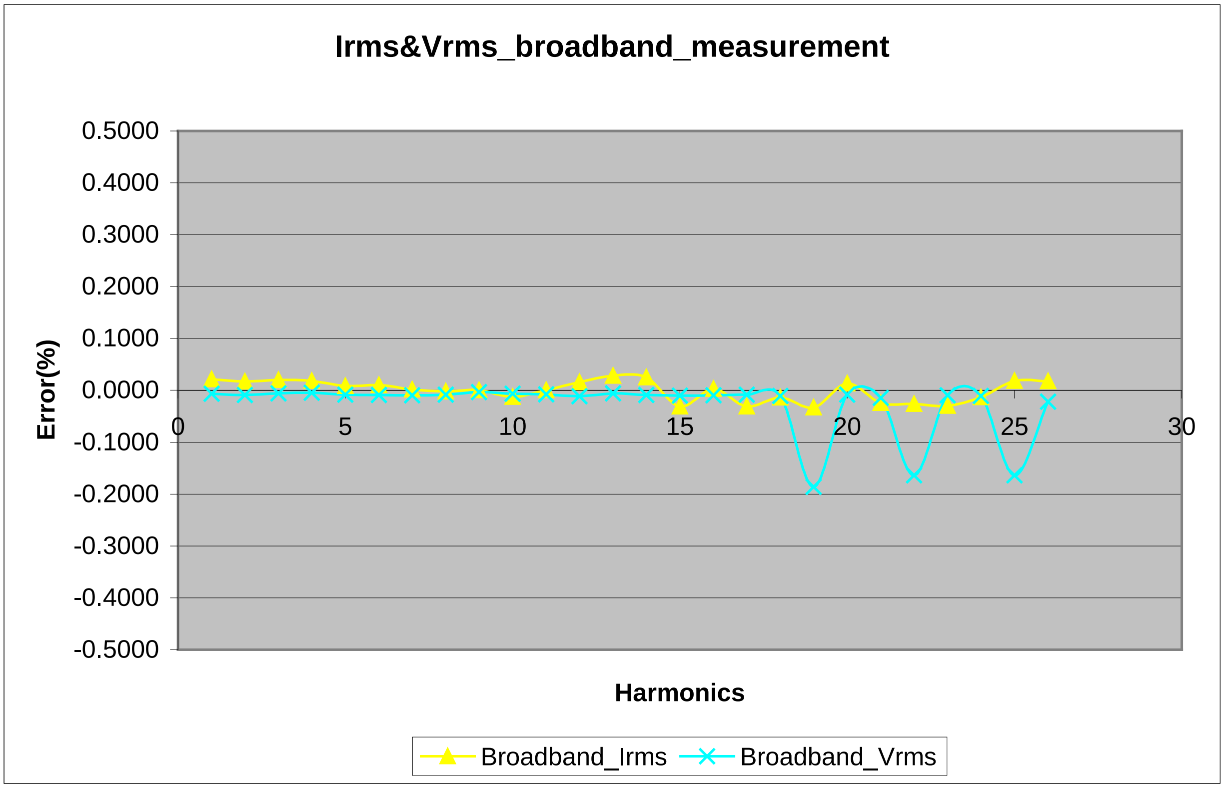

Figure 6: Accuracy for nth Harmonic

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Watt-Hour Performance:

Load Test:

A watt-hour load test was performed for accuracy using 208A rated CT output:

Watthour_load_test
Voltage: 240V Frequency: 50I

Amp	Error%
10	-0.002
3	0.012
1	-0.056
0.5	0.109
0.1	-0.185

The results are shown in Figure 7.

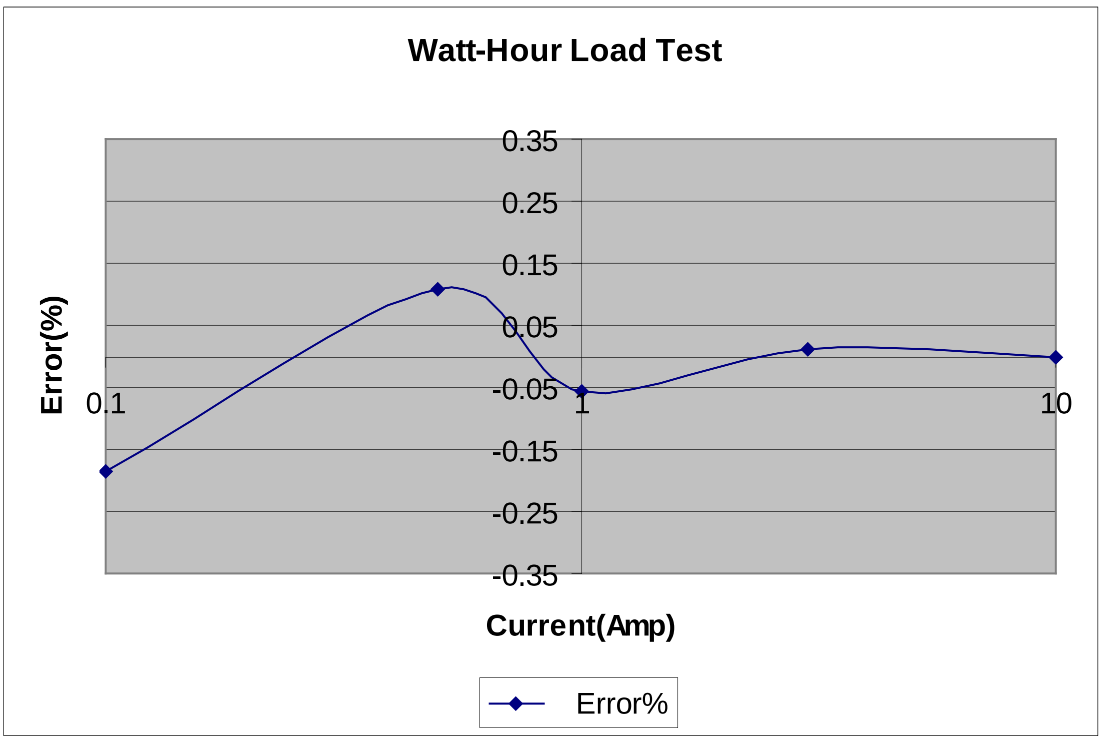

Figure 7: Watt-Hour Performance

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Watthour Harmonic Test

This register data for broadband watt-hour information is available. The pulse output from the meter was used for testing. Alternatively, the accumulation registers can also be used for testing the accuracy. Broadband watt-hour accuracy test results are shown on the following pages.

Watt-hour_Harmonic_Wideband_test
Voltage: 240V, Current=10A, Frequency: 50Hz,

VHarm%	IHarm%	NHarm	Error_Harmonic(%
0	0	0	-0.001
10	40	2	0
10	40	3	0.006
10	40	4	0.009
10	40	5	-0.002
10	40	6	0
10	40	7	0.014
10	40	8	0.009
10	40	9	0.009
10	40	10	-0.002
10	40	11	-0.005
10	40	12	0.006
10	40	13	0
10	40	14	-0.011
10	40	15	-0.011
10	40	16	-0.014
10	40	17	-0.014
10	40	18	-0.022
10	40	19	-0.045
10	40	20	-0.084
10	40	21	-0.152
10	40	22	-0.349
10	40	23	-0.928

Table 5: Broadband Watt-Hour Test Results

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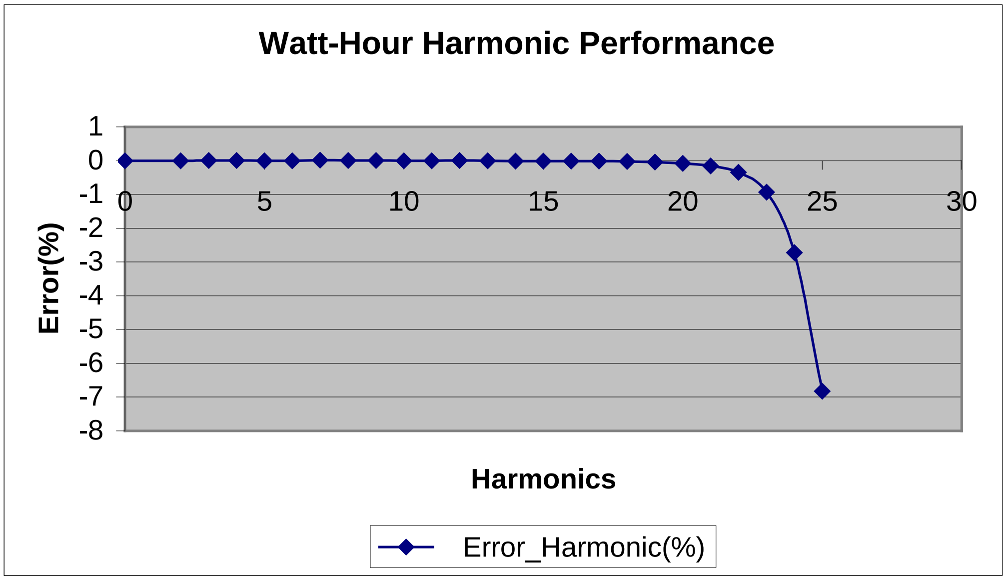

Figure 8: Watt-Hour Harmonic Performance

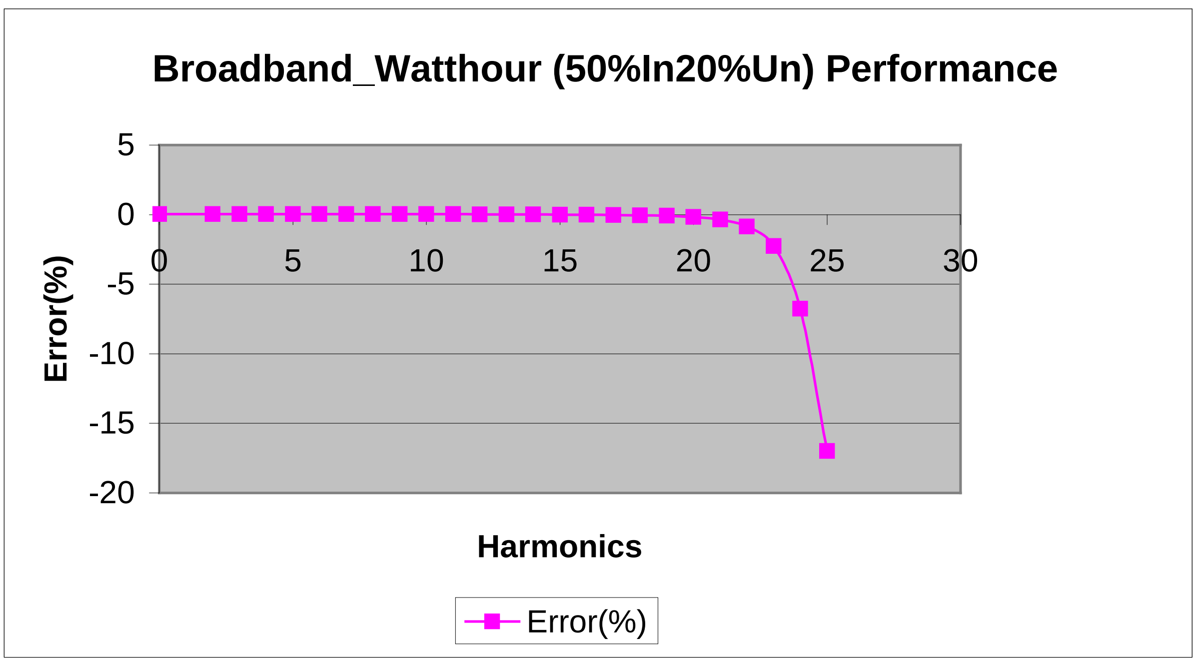

Figure 9: Broadband Watt-Hour Harmonic Performance

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VAR-Hour Performance:

Load Test:

A VARh load test was performed for accuracy using 208Ampere rated CT output:

Varh_load test
Voltage: 240V Frequency: 50H

Amp	Error%
10	-0.009
5	-0.021
3	-0.034
1	-0.077
0.5	-0.039
0.3	-0.178
0.1	0.175

The results are shown in Figure 10.

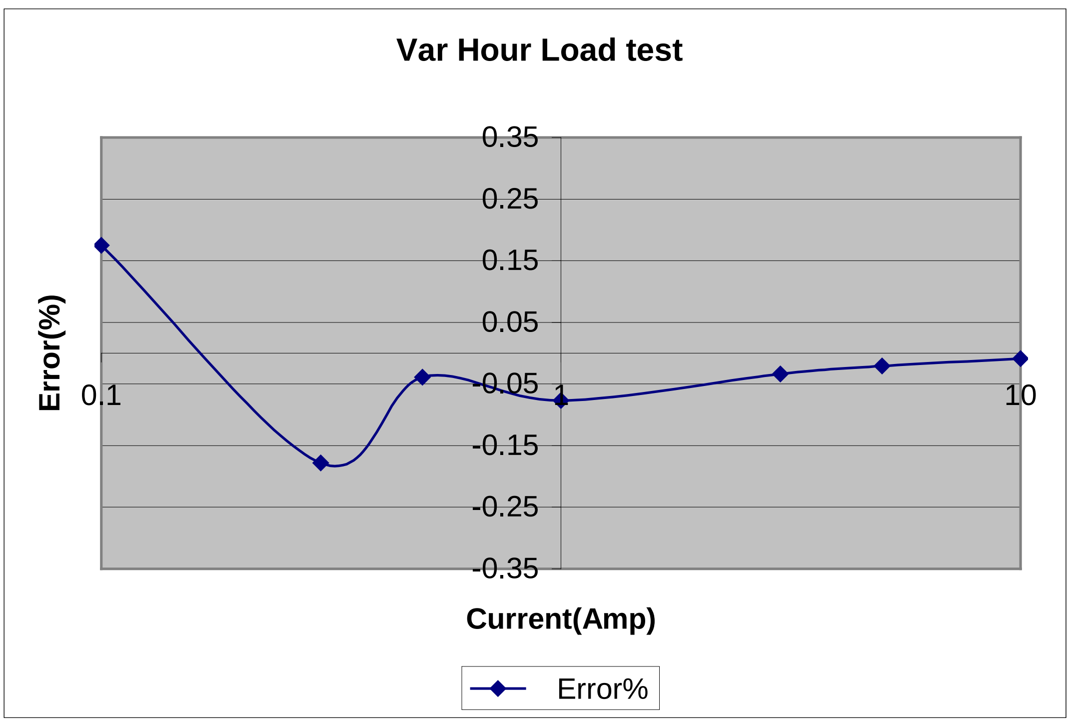

Figure 10: VAR-Hour Harmonic Performance

VAR-Hour Harmonic Test

Register data for broadband VARh information is available. The pulse output from the meter was used for testing. Alternatively the accumulation registers can also be used for testing the accuracy. Broadband results are shown on the following pages.

Varhour_Harmonic_Wideband_test
Voltage: 240V, Current=10A, Frequency: 50Hz, Kh

VHarm%	IHarm%	NHarm	Error_Harmonic(%)
0	0	0	0.006
10	40	2	-0.002
10	40	3	-0.002
10	40	4	-0.011
10	40	5	-0.011
10	40	6	-0.007
10	40	7	0.002
10	40	8	0.002
10	40	9	0.002
10	40	10	0.002
10	40	11	0.002
10	40	12	-0.002
10	40	13	-0.011
10	40	14	-0.011
10	40	15	-0.015
10	40	16	-0.024
10	40	17	-0.024
10	40	18	-0.028
10	40	19	-0.036
10	40	20	-0.053
10	40	21	-0.104
10	40	22	-0.29
10	40	23	-0.915

Table 6: Broadband VAR-Hour Test Results

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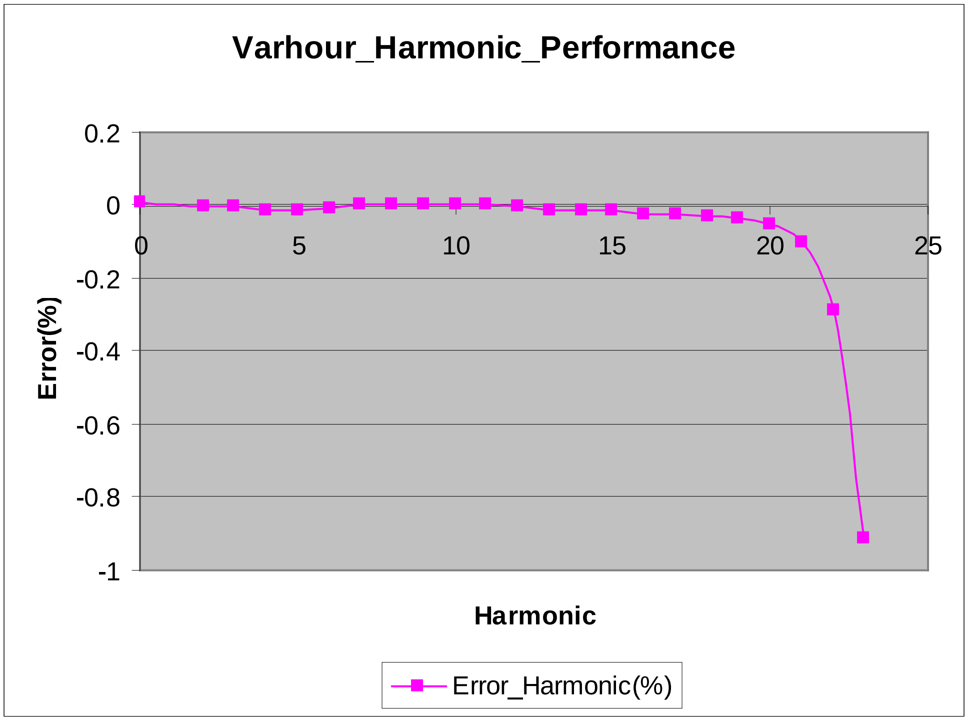

Figure 11: VAR-Hour Harmonic Performance

Summary

The capability of the 71M6513 with the new CE code for broadband and fundamental watt-hour measurement has been demonstrated. Requests for further details can be sent to: meter.support@teridian.com.

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