Technical University of Lodz

Department of Semiconductor and Optoelectronics Devices

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ELECTRONIC MEASUREMENT LAB.

Experiment No 3

ELECTRONIC WATT-METER AND ENERGY CONTER- METHODS OF MEASUREMENT AND INSTRUMENTS CALIBRATION

Goal:

The goal of this experiment is to familiarise students with digital methods of electrical power energy measurement and power counters. Students will become acquainted with developing of power and power counters based on integrated transducers

SPECIFICATION OF USED INSTRUMENTS:

The following instruments and software are used:

Instruments

1. Electrical power transducer and power meter - VOLTCRAFT EC3000
2. 2-channet Digital Oscilloscope type RIGOL 1052E
3. 12-bit Multifunction measurement Module USB-4711A (Advantech)
4. Digital Sampling Multimeter RIGOL DM3051
5. Student's ,,ADE7753-Kit"
6. Power supply DF1743005C

Software:

1. Software supporting Multifunction Measurement Module USB-4711A
2. Data Acquisition software ADE7753_63EVALR5P2 supporting ADE7753-Kit
3. Microsoft EXCEL for measurement data handling

THEORY

Analogue electrical power measurement method is based on reaction of electromagnetic fields induced by two coils: the current coil, which is in fact formed by fixed two coils and a voltage movable coil known also as the potential coil. A current flowing through the current coil generates an electromagnetic field around the coil. The strength of this field is proportional to the line current and in phase with it. The potential coil has, as a general rule, a high-value resistor connected in series with it to reduce the current that flows through it. The potential coil carries a needle that moves over a scale to indicate the measurement. Such instrument is called an electrodynamic wattmeter. Fig 1 shows lectromeagnetig voltmeter

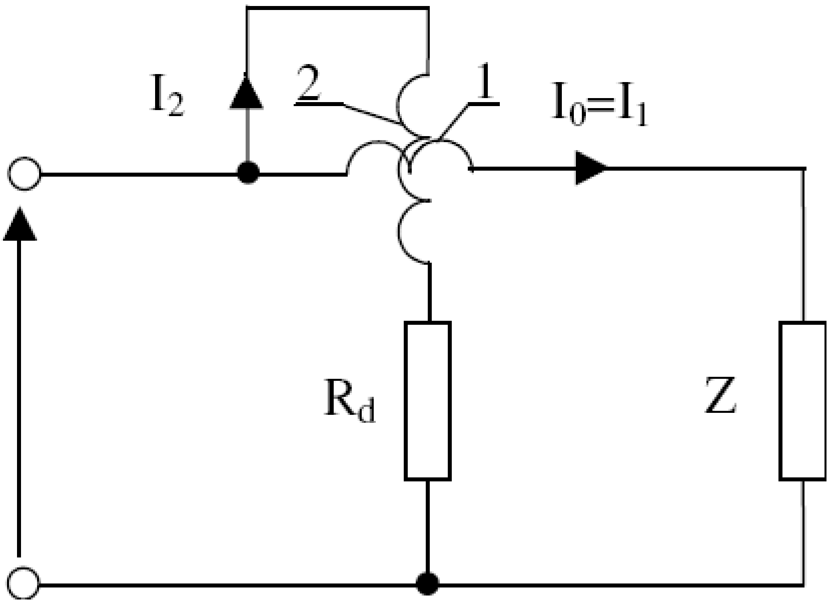

Fig 1 Electrodymanic wattmeter: 1- current coil, 2- voltage coli with and resistor Rd to reduce current I2 consumed by wattmeter. Z-impedance

The current coils connected in series with the circuit, while the potential coil is connected in parallel.

The result of this arrangement is that on a dc circuit, the deflection of the needle is proportional to both the current and the voltage, thus conforming to the equation P=VI. On an ac circuit the deflection is proportional to the average instantaneous product of voltage and current, thus measuring true power, and possibly (depending on load characteristics) showing a different reading to that obtained by simply multiplying the readings showing on a stand-alone voltmeter and a stand-alone ammeter in the same circuit.

The two circuits of a wattmeter can be damaged by excessive current. The ammeter and voltmeter are both vulnerable to overheating — in case of an overload, their pointers will be driven off scale — but in the wattmeter, either or even both the current and potential circuits can overheat without the pointer approaching the end of the scale! This is because the position of the pointer depends on the power factor, voltage and current. Thus, a circuit with a low power factor will give a low reading on the wattmeter, even when both of its circuits are loaded to the maximum safety limit. Therefore, a wattmeter is rated not only in watts, but also in volts and amperes.
Wattmeter indication is proportional to current in current coil, current in voltage coil and cosine of angle between vectors of these two currents.

$$P \sim I_1 \cdot I_2 \cdot \cos\left(\underline{I_1}, \underline{I_2}\right)$$

where: I_1 - current in current coil

I_2- current in voltage coil, and $I_2 \cong \frac{V}{R_d}$

cos(between vectors of currents in coils 1and 2) proportional to phase ange between voltage across and current though impedance Z, which is under test.

The digital methods in the simples form are using electrical power transducer of which output voltage (Fig 2) is proportional to product of voltage across and current trough and cos between them and next the voltage is converted to numerical form.

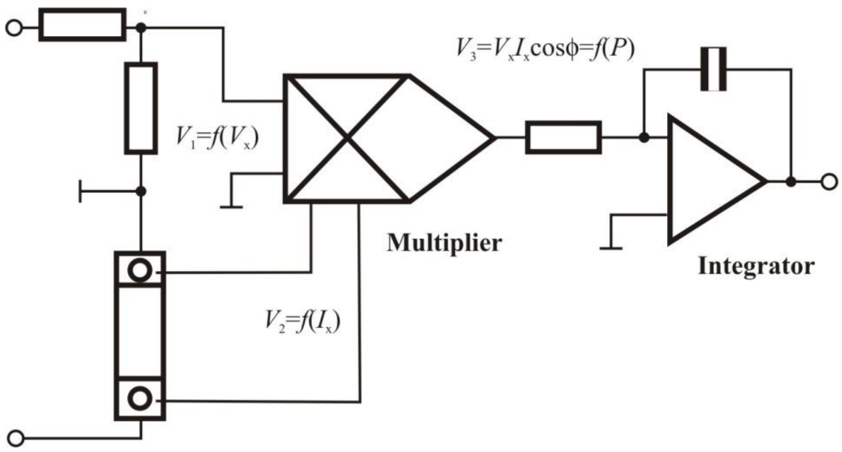

Fig 1. Electricalpower transducer with an analogue multiplying device

Other digital method of power and energy metering is that one in which TDM – Time Division Multiplier is applied.

The TDM method is presented in Fig. 3. The method allows to obtain a sequence of rectangular pulses of which amplitude is proportional to one input quantity and their width is proportional to other input quantity. If one of the input quantity is proportional to input voltage, and the other to input current thus the area of each pulse is proportional to product of these two input quantities.

Let V_1 be a first input quantity, which is connected to Integrator of which the other input is connected to reference voltage V_{ref}

V_i, which is a voltage at the output of integrator is connected to one of the input of the comparator, and to the other input is a V_t a triangular (saw-tooth) shape voltage. At the moment when the Vi and Vt are equal each other, then the comparator is switching both keys: V_{ref} and changes the polarity of V_2 input signal of the second integrator. V_{out} is proportional to V_1 and V_2:

$$V_{out} = \int_0^{T_1} V_2(t)\,dt - \int_{T_1}^{T_1+T_2} V_2(t)\,dt = V(T_1 - T_2) = \frac{T_g}{V_{ref}} V_1 V_2$$

where: T_g is a period of saw-tooth voltage

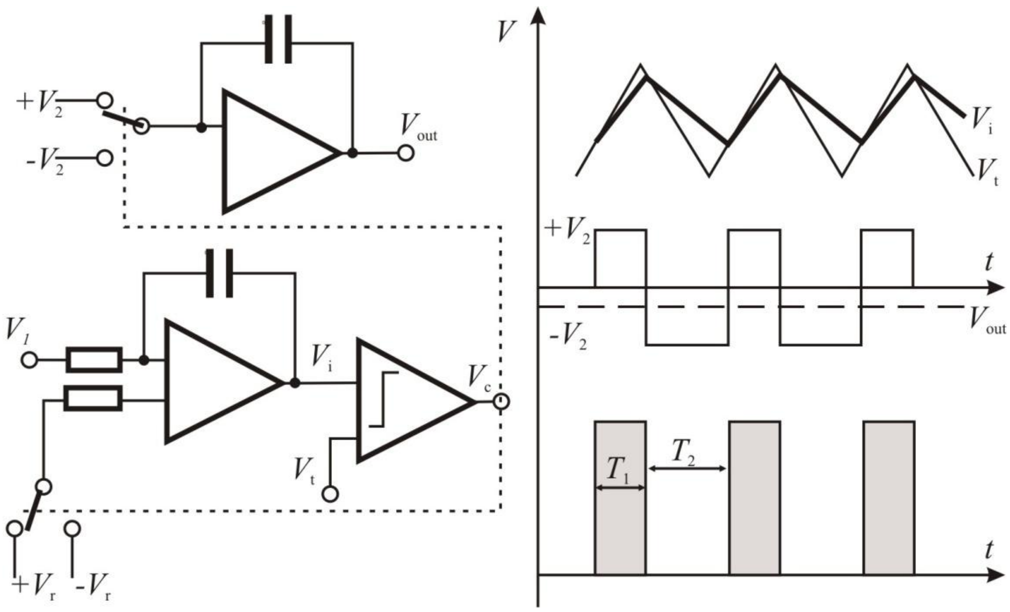

Fig 3 TDM Transducer [1]

In Fig 4 is presented a block diagram of digital electrical power transducer. The input signal are converted to digits by using two 16 bit Delta-sigma ADC.

One of the input signal is proportional to voltage while the other to current of the object under test. The next is an operation over sampled data according to formulas:

$$P = \frac{1}{N}\sum_{0}^{N-1} v_i i_i$$

$$Q = \frac{1}{N}\sum_{0}^{N-1} v_i i_i \text{ where } i_i \text{ is a current data by } \frac{N}{4}$$

$$S = \sqrt{\frac{1}{N}\sum_{0}^{N-1} v_i^2} \cdot \sqrt{\frac{1}{N}\sum_{0}^{N-1} i_i^2}$$

if N is a number of samples in one period

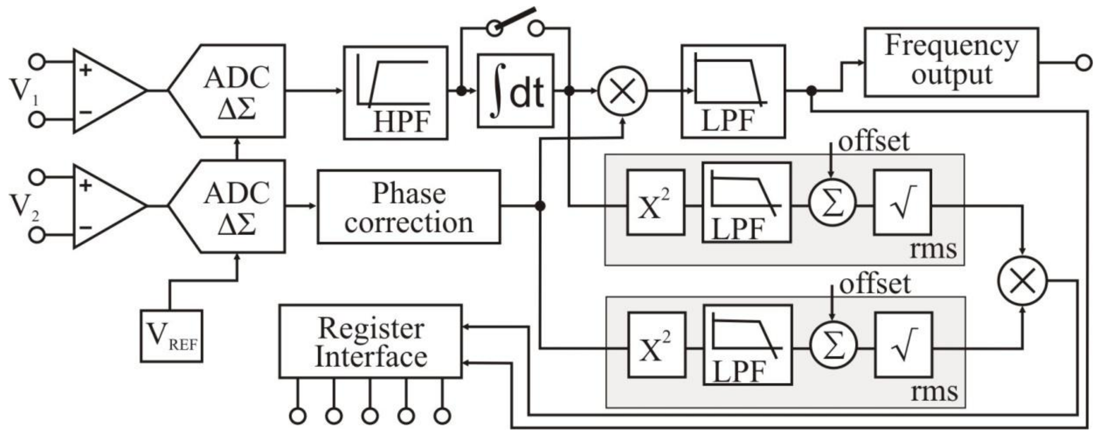

Fig 4 Block diagram of electrical power transducer of AD 7753 type produced by Analog Device

TASKS:

TASK 1:

Single-Phase active electrical Power measurement by means of electronic "Energy Check 3000" measuring device *and using ADC measurement card j*

The "Energy Check 3000" measuring device (briefly: EC) was developed for monitoring and measuring power-consuming electrical equipment.

Energy-Check 3000 specification;

Technical Specification of Energy Monitoring Device: voltage: 230 V/AC, measuring range 1 Wh - 9999 kWh, accuracy: 1% + 1 digit, measuring range of active power: 1,5 - 3500 W, resolution 0,1 W, instrument power consumption: 1,8 W, recording time max. 4 months, dimensions: (w x h x d.) 135 x 82 x 70 mm

Fig **Energy-Check 3000**

An electrical scheme dedicated to single phase electrical power measurement is presented in Fig 1. Voltcraft EC300 is a commercial electronic watt meter and energy counter, Advantech4711Ais is an industrial typical 12 – bit Multifunction ADC card with USB interface.

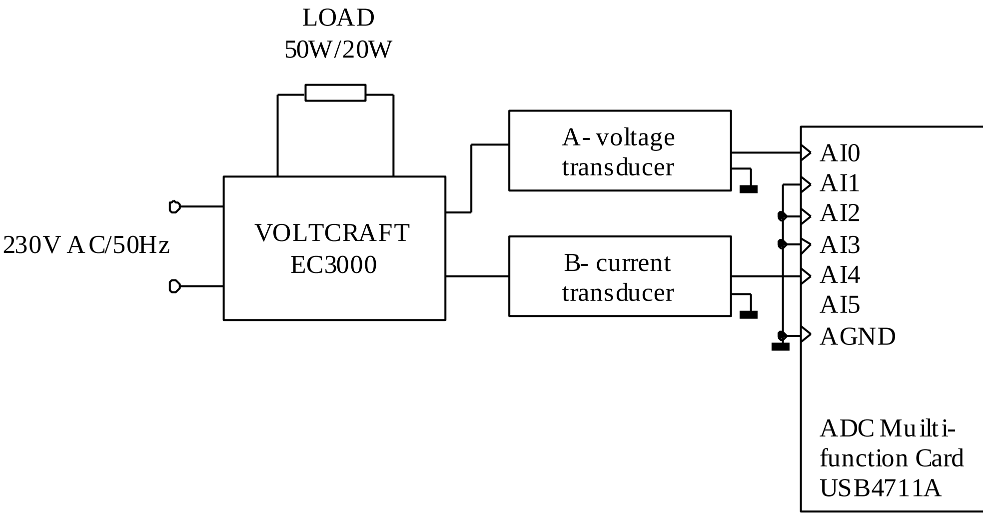

Fig 4 Wiring of electrical power and power counter VOLTCRAFT EC3000 and Advantech USB4711A multifunction ADC card type USB47111A

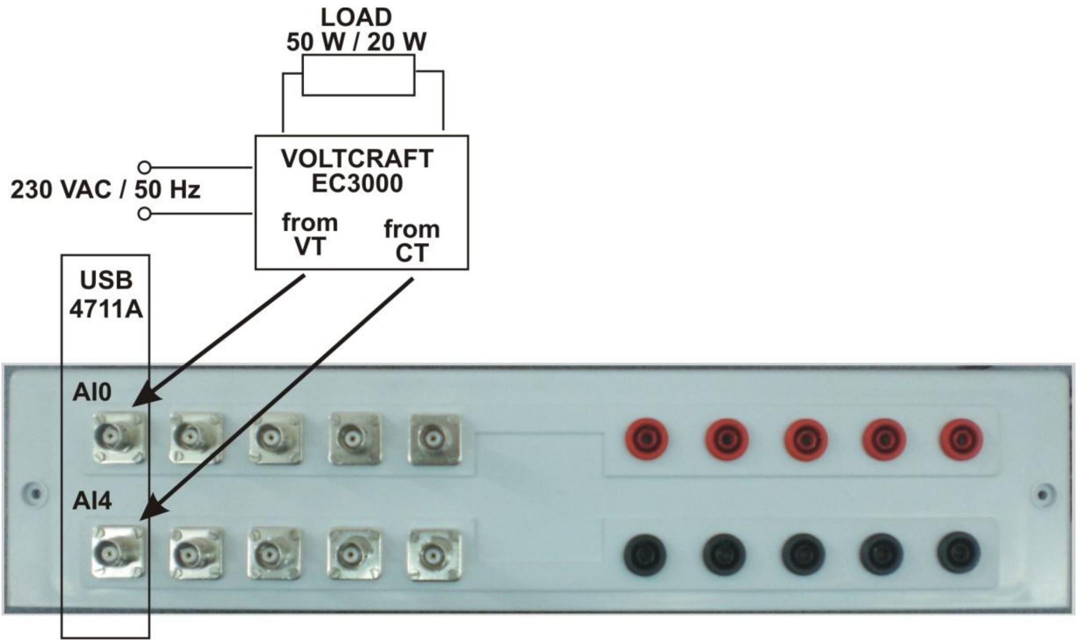

Fig 5 Wiring of power and energy meter EC3000 to data acquisition module USB47111A

Specification of the divices used in the experiment:

A) Voltage tranducer is a effective AC voltage to AC voltage converter: **230V** the input to **6V** at the outout. A prcize **1:0,037** resitance divider is used to condition signal to voltage input of ADC converter of USB47111A

B) Current tramsformer of **1:1500** A precize resitor of **100Ω** is at the output of current transformer t**o** condition signal to voltage input of ADC converter of USB47111A

Precise constants of VOLTCRAFT EC3000 module to calculate power and energy consumption using ADE7753 are noted (are given) on chassis of each EC3000 meters

Ku(DAQ) – Voltage coefficient while USB47111A is used

Ku(ADE) – Voltage coefficient while ADE7753 module is used

$\mathbf{Q_u}$=48,44μV – voltage quantum value of 16-bit A/C of voltage measurement channel of ADE7753 module for gain, G=1

$\mathbf{Q_I}$=0,189μV – voltage quantum value of 24-bit A/C of voltage measurement channel of ADE7753 module for gain, G=1 and for input voltage of +/-0,5V

1. Perform wiring according to scheme given in Fig 4 and make measuremet of power of two different load of 50W i 20W. 50W load isa a Halogen source of light and as 20 W load use LCD TFT monitor

2. Take notes of power indicated by EC3000 and compare to your own calculations. For power calculation use discrete values recorded by means of data acquisition module USB47111A.
3. Based on sampled data calculate the phase between volage and current.
4. Regarding indication of EC3000 as reference value calculate the apparent error power measured and calculated by sampling Voltage and current.
5. Make comments of sources of errors while using EC3000 and data acquisition module USB47111A for power measurement of objects under test in the experiment.
6. Sketch sampled data vs. time of: voltage, current and power.

TASK 2

Single-Phase active electrical Power measurement by means of electronic "Energy Check 3000" measuring device and ADE7753 IC module

The ADE7753 is a high accuracy electrical power measurement IC with a serial interface and pulse output. The ADE7753 incorporates two second-order Σ-Δ ADCs, reference circuitry, temperature sensor, and all the signal processing required to perform active, reactive, and apparent energy measurement.

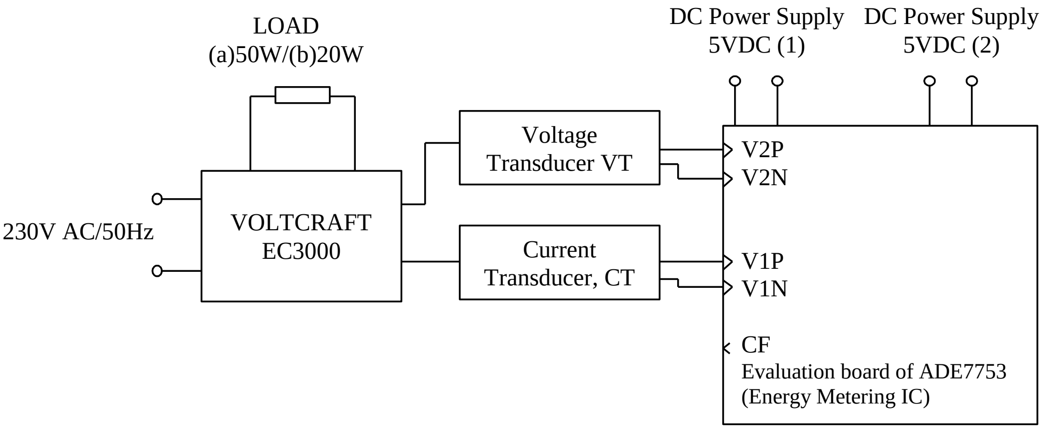

Fig 6 Block diagram for wiring VOLTCRAFT EC3000 and evaluation board of ADE7753

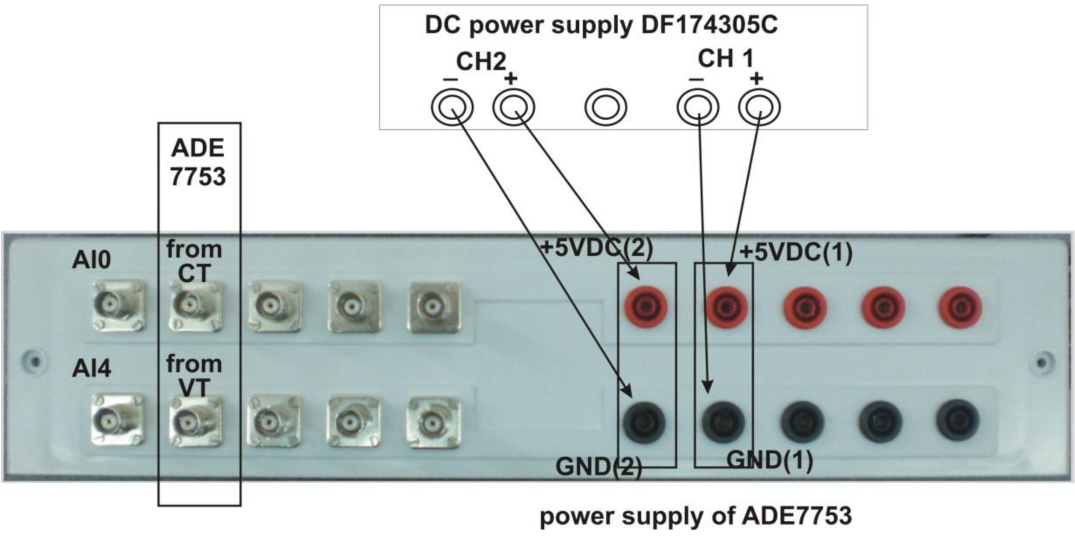

Fig.7 External wiring of Evaluation board ADE7753: power supply and inputs from Voltage and current transformers.

Technical data of CT and VT plus necessary constant values for calculations:

A) VT is working at ratio: **230V:6V** RMS and the output winding is loaded by precise voltade divider of ratio **0,035** while using ADE7753 module.

B) CT current transformer of ratio: **1:1500** loaded by precise resistor of **100Ω**

Precise constants of VOLTCRAFT EC3000 module to calculate power and energy evaluation

Ku(DAQ) – Voltage coefficient while USB47111A is used

Ku(ADE) – Voltage coefficient while ADE7753 module is used

Q_u=48,44μV – voltage quantum value of 16-bit A/C of voltage measurement channel of ADE7753 module for gain, G=1

Q_I=0,189μV – voltage quantum value of 24-bit A/C of voltage measurement channel of ADE7753 module for gain, G=1 and for input voltage of +/-0,5V

1. Perform wiring according to scheme given in Fig 7 and make measuremet of power of two different load of 50W i 20W. 50W load isa a Halogen source of light and as 20 W load use LCD TFT monitor
2. Take notes of power indicated by EC3000 and compare to your own calculations. For power calculation use discrete values recorded from ADE7753
3. Regarding indication of EC3000 as reference value calculate the apparent error power measured by means of evaluation board of ADE7753
4. Make comments of sources of errors while using EC3000 and data acquisition module ADE7753 for power measurement of objects under test in the experiment.
7. Sketch sampled data vs. time of: voltage, current and power.

FINAL REMARKS

Average value of discrete signal in the range

$$\bar{x} = \frac{1}{n_2 - n_1 + 1} \sum_{n=n_1}^{n_2} x(n)$$

The mean value of whole discrete signal

$$\bar{x} = \lim \frac{1}{2N+1} \sum_{n=-N}^{N} x(n)$$

The mean value of discrete periodic signals

$$\overline{x_N} = \frac{1}{N} \sum_{n=n_0}^{n_0+(N-1)} x(n), N - period$$

Energy of the whole discrete Signal

$$E_x = \sum_{n=-\infty}^{+\infty} x^2(n)$$

Average power in the certain range of discrete Signal

$$P_x = \overline{x^2} = \frac{1}{n_2 - n_1 + 1} \sum_{n=n_1}^{n_2} x^2(n)$$

Average power the entire signal (mean square value)

$$P_x = \bar{x} = \lim \frac{1}{2N+1} \sum_{n=-N}^{N} x^2(n)$$

Average power of discrete periodic signals

$$P_x = \overline{x^2{}_N} = \frac{1}{N} \sum_{n=n_0}^{n_0+(N-1)} x^2(n), N - period$$

RMS value of discrete signal

$$x_{RMS} = \sqrt{P_x}$$

LITERATURE AND OTHER RECOMMENDED MATERIAL

1. Joseph McGhee, Wlodek Kulesza, M. Jerzy Korczyński, I. A. Henederson, Measurement Data Handling Theoretical Technique, Published by Technical University of Lodz, printed by: ACGM LODART S. A. Łódź, 2001, ISBN 83-7283-007-X, pages 267 vol. 1
2. Joseph McGhee, Wlodek Kulesza, M. Jerzy Korczyński, I. A. Henederson, Measurement Data Handling Hardware Technique, Published by Technical University of Lodz, printed by: ACGM LODART S. A. Łódź, 2001, ISBN 83-7283-007-8, pages 267 vol. 2
3. S. Tumański Technika Pomiarowa, Wydawnictwa Naukowo-Techniczne WNT, Warszawa 2007
4. T.P. Zieliński Od teorii do cyfrowego przetwarzania sygnałów, Wydawnictwo ANTYKWA, Kraków 2002
5. T.P. Zieliński Zarys cyfrowego przetwarzania sygnałów. Od teorii do zastosowań Wydawnictwo WKŁ, Warszawa 2006
6. Applicatio note of ADE7753module www.analog.com

Additional literature:

1. *www.dspguide.com*
2. www.analog.com/processors/learning/training/dsp_book_index.html

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Group number
Academic year

LABORATORY REPORT

Experiment No 3

ELECTRONIC WATT-METER AND ENERGY CONTER-
METHODS OF MEASUREMENT AND INSTRUMENTS CALIBRATION

STUDENT'S NAMES	**DATE**	MARK FOR REPORT	LECTURER'S SIGNATURE

USB-4711A

150 kS/s, 12-bit, 16-ch Multifunction USB Module

Main Features

- Supports USB 2.0
- Portable
- Bus-powered
- 16 analog input channels
- 12-bit resolution AI
- Sampling rate up to 150 kS/s
- 8 DI/8 DO, 2 AO and one 32-bit event counter
- Wiring terminal on modules
- Suitable for DIN-rail mounting
- One lockable USB cable for secure connection included

Description

The USB-4700 series consists of true Plug & Play data acquisition modules. You no longer need to open the chassis to install DAQ modules. Just plug in the module, then get the data. It's easy and efficient. Reliable and rugged enough for industrial applications, yet inexpensive enough for home projects, the USB-4700 series module is the perfect way to add measurement and control capability to any USB capable computer. The USB-4700 series is fully Plug & Play and with onboard terminal block for easy usage. It obtains all required power from the USB port, so no external power connection is ever required. USB-4711A is a multifunction module, with 16-ch Analog Input, 2-ch Analog Output, 16-ch Digital I/O and counter channel which is able to output a constant frequency square wave. With the features of USB-4700 series; USB-4711A is your most cost effective choice of lab or production line test & measurement tool.

Specification:
Part Number:USB-4711A-AE

Analog Input	**Bipolar Inputs (V)**	±10, 5, 2.5, 1.25,0.625 V
	Channels	16 S.E./8 Diff
	Resolution	12 bits
	Sampling Rate	150 kS/s
	Unipolar Input (v)	-
Analog Output	**Resolution**	12 bits
Digital I/O	**Digital Input Channels**	8
	Digital Output Channels	8
Timer/Counter	**Resolution**	32 bits
	Time Base	1 kHz