Establishment of Automated Multi-Range Multipliers Combined with TVC

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Abstract – An automated multi-range multipliers (range resistors) system is established for the AC voltage measurements by using a thermal voltage converter. It is performed automatically by selecting the appropriate multiplier whose voltage range contains the voltage to be measured without changing it manually through a new designed system. It consists of control part through a micro-controller controlled by specified prepared Lab-VIEW program and switching part through electronic relays in one circuit as clearly described in this work. It is used for measuring the ac voltage in the range from 1 V to 200 V. Also, it can be used for the voltage ranges up to 1 000 V by putting some factors into consideration. The AC-DC transfer differences for these multipliers combined with thermal voltage converter are determined automatically against another standard thermal voltage converter by using another Lab-VIEW program.

Key words – *AC voltage measurement*; *thermal voltage converter*; *AC-DC transfer standard*; *multipliers*; *uncertainty*

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1 Introduction

AC voltage is most accurately measured by comparison with DC voltage using Thermal Voltage Converters (TVCs) which respond nearly equally to AC and DC voltage[1]. This TVC is used for the ac voltage measurements from 100 mV to 1 000 V. Its main component is the Thermal Element (TE) constructed from a heater and a thermocouple attached to its midpoint through small glass or ceramic bead. This TE is limited in rating, so range resistors are used and attached coaxially, through *N*-type male and female, with the TVC to extend the measurement of the ac voltage ranges to 1 000 V[2]. The present TVC consists of two TEs and a set of six range resistors as an example[3]. Changing the suitable range resistor for calibration of the required voltage range is carried out manually after measuring each range. This leads to consuming more effort and time by the user.

The introduced automated multi-range multipliers consist of a hardware circuit derived by Lab-VIEW program. These multipliers are changed automatically by switching on the selected electronic relay that connects the suitable multiplier according to the measurand AC voltage under investigation. The new designed multipliers system is used for the AC voltages up to 200 V. Its range can be easily extended to 1 000 V, but there are some precautions that should be taken into consideration, such as the frequency compensation due to the reactance of the structure and the voltage coefficients. Moreover, the AC-DC transfer differences for these automated multipliers combined with the thermal voltage converters are determined automatically against another standard TVC at different AC voltage ratings and frequencies by using an additional Lab-VIEW program.

One of the most important applications of this system is the calibration of AC calibrators and AC voltmeters by using the AC-DC thermal transfer standard. In such calibrations, changing the measured AC voltage values, their corresponding multipliers can be done completely by an automatic way according to this work.

2 Construction of the multi-range multipliers system

The automated multi-range multipliers system consists of four range resistors to cover the AC voltage ranges from 2 V to 200 V. Their values are 800 Ω, 3.6 kΩ, 12 kΩ and 40 kΩ corresponding to AC voltages ranges 6 V, 20 V, 60 V and 200 V respectively. Each multiplier is used to measure the AC voltage in the range of 50% to 120% of the rated voltage range. These range resistors are axial-lead resistors. They have non-inductive performance and excellent long-term stability. Furthermore, These resistance films bonded to a high strength solid ceramic core to be suitable for the precise AC voltage measurement applications. When the electronic relay receives the control signal from AT89C2051 micro-controller, it is switched on, and its resistor is connected to the system. Its construction is illustrated in Fig. 1.

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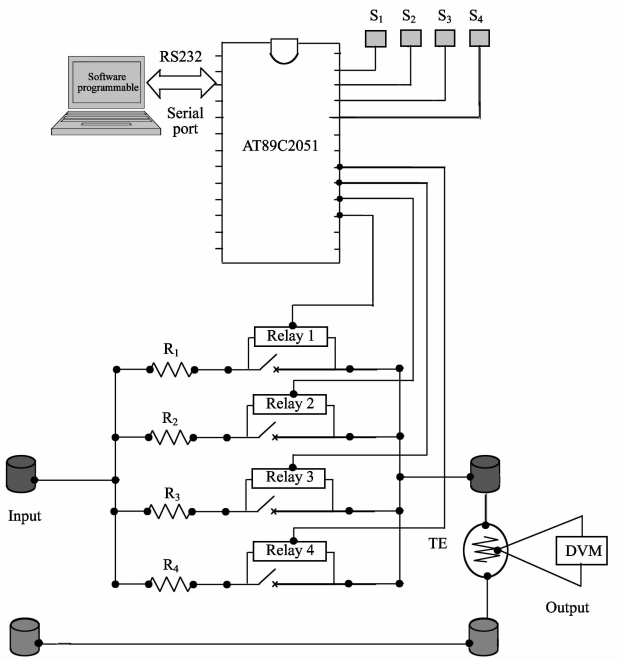

Fig. 1 Schematic construction of the new system

The fabricated circuit of the new multi-range multipliers is shown in Fig. 2. This PCB circuit may operate manually with or without the computer. Manual operation without the computer is accomplished by adjusting the on-off switch in manual mode.

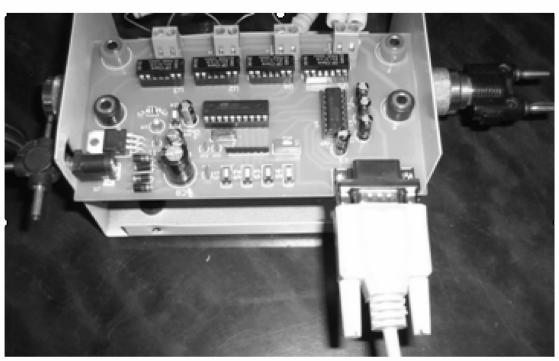

Fig. 2 Fabricated circuit of the new multi-range multiplier

By using one of the four push-button switches, we can transfer the control signal from the micro-controller to the corresponding relay. Hence the nominal coil voltage of this electronic relay is 5 V and its internal construction is shown in Fig. 3.

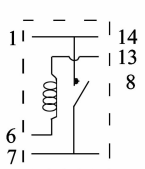

Fig. 3 Construction of the PRME 15005A electronic relay

An assembly language program is stored in the micro-controller ROM to drive the circuit in this mode. After choosing the suitable resistor, the measurand AC voltage is supplied to the circuit through the shown input terminals. Then the e. m. f of the TVC, which is connected to the circuit output terminal, can be measured. Accordingly, the AC-DC thermal transfer technique is easily realized. Automatic operation is obtained by adjusting the on-off switch in automatic mode and connecting the serial cable, shown in Fig. 2, to connect the circuit with the computer serial port. Then the circuit can be driven automatically from the computer by using the designed Lab-VIEW program as shown in Fig. 4.

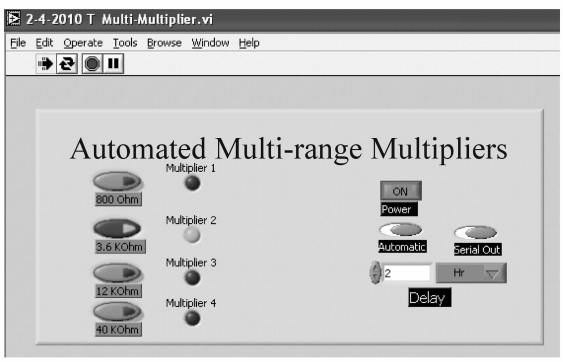

Fig. 4 Lab-VIEW program to drive the multi-range multipliers circuit

The required resistors can be connected with any optional sequence and separation time due to the prepared settings before running the program. It also operates manually by changing the control button from automatic position to manual position.

3 Calibration of the new system

The new automated multi-range multipliers combined with TVC are calibrated automatically against another standard TVC by the principle of AC to DC transfer to determine their AC-DC differences (correction factors).

The automatic system, used to calibrate the new multi-range multipliers, consists of a programmable calibrator which can generate DC and AC voltages, two programmable Digital Volt-Meters (DVM) which measure the TVCs outputs e. m. f. It also consists of a TVC combined with the new multi-range multipliers, the standard TVC, tee connector used to supply AC and DC voltage in parallel and at the same time to the two TVCs (The standard TVC and the u. u. t TVC) and a computer programmed with the suitable software. The front panel of the Lab-VIEW program is shown in Fig. 5.

It is calibrated at voltage ranges 6 V, 20 V, 60 V and 200 V at frequencies 20 Hz, 55 Hz, 400 Hz, 1 kHz, 10 kHz and 20 kHz. Suggested test sequence is AC, + DC, − DC, AC. After switching the source, waiting some time period (usually 20 to 60 seconds) before taking the reading for AC and DC[4], the vau-lues of AC-DC difference (δ_t) of the unit under test are determined by[5]

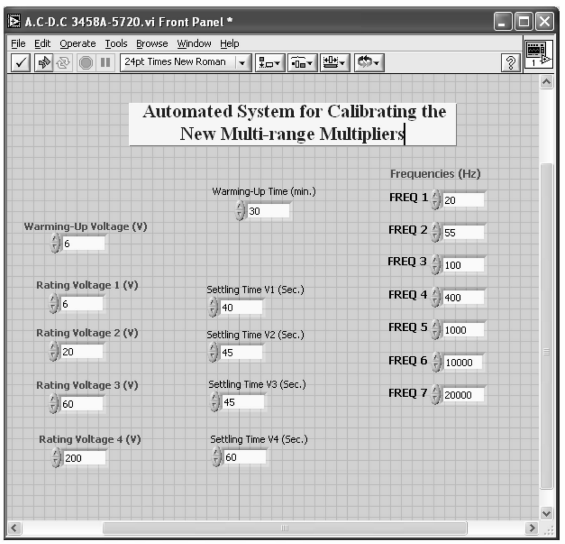

Fig. 5 Front panel of new muli-range calibration program

$$\delta_t = \frac{E_{as} - E_{ds}}{n_s E_{ds}} - \frac{E_{at} - E_{dt}}{n_t E_{dt}} + \delta_s , \qquad (1)$$

where δ_s is correction factor of the standard TVC, E_{as} and E_{at} denote the two readings′ average values of r. m. s of the AC voltage applied to the standard and the u. u. t TVC, respectively, E_{ds} and E_{dt} are average values of positive and negative DC voltage applied to the standard and the u. u. t TVC respectively, n_t, and n_s denote factor which are measured automatically as said before.

Tab. 1 The AC-DC transfer differences and the expanded uncertainties for range 6 V

Voltage Range (V)	f (Hz)	AC-DC difference (μA)	Exp. Uncertainty (μA)
6 V	20	22	41.4
	55	0.69	15.5
	400	24.4	16
	1 000	11.6	15.3
	10 000	10.4	15.6
	20 000	48.5	15.6

Tab. 2 The AC-DC transfer differences and the expanded uncertainties for range 20 V

Voltage Range (V)	f (Hz)	AC-DC difference (μA)	Exp. Uncertainty (μA)
20 V	20	42.4	41.7
	55	14.13	14.1
	400	53.4	20.1
	1 000	1.95	15.4
	10 000	44.1	22.9
	20 000	−98.8	15.5

Also, the uncertainty is evaluated for the previous results. The uncertainty budget consists of the sources, such as repeatability (Type A), the calibration certificate of the standard TVC and the calibration certificate of the reference DC voltage (Type B). Tab. 1, Tab. 2, Tab. 3 and Tab. 4 show the AC-DC differences and their corresponding expanded uncertainties of the new system.

Tab. 3 The AC-DC transfer differences and the expanded uncertainties for range 60 V

Voltage Range (V)	f (Hz)	AC-DC difference (μA)	Exp. Uncertainty (μA)
60 V	20	37.7	42.5
	55	22.8	20.9
	100	6.2	28.3

Tab. 4 The AC-DC transfer differences and the expanded uncertainties for range 200 V

Voltage Range (V)	f (Hz)	AC-DC difference (μA)	Exp. Uncertainty (μA)
200 V	20	56.3	40.3
	55	−3.2	30.4
	100	45.4	30.3
	400	−56.71	30.2

Fig. 6 shows the correction factors (δ) of the new automated multi-range multipliers combined with the TVC. These values are determined for different AC voltage ranges at different frequencies.

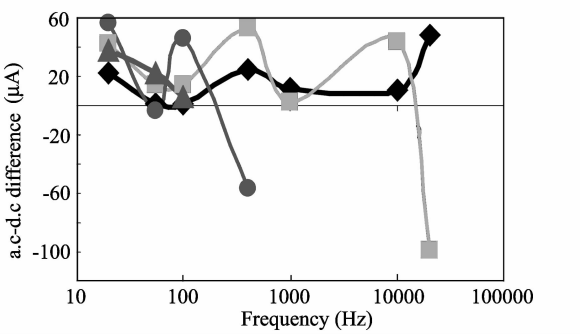

Fig. 6 The AC-DC differences for ranges 6 V, 20 V, 60 V and 200 V

4 Conclusions

An automated multi-range multipliers system is established for AC voltage measurement such as the calibration of ac calibrators and ac voltmeters. The system is considered valuable and reliable in the measurement of a multiple ranges of ac voltage. It consumes the time and the effort of the metrologist.

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