

LOCK-IN AMPLIFIER FOR CALIBRATING INDUCTIVE VOLTAGE DIVIDER

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Abstract: The paper presents the instrument and the technique for adjusting and calibrating the inductive voltage divider. The technique is based on comparing two AC voltages of identical frequency. The instrument distinctive feature is extracting and measuring of small differential-mode signal of the voltages being compared within nanovolt and microvolt range against the background of large common-mode signal. The instrument features, its technical and metrological parameters are also considered.

Keywords: Lock-in amplifier, calibrating, voltage divider.

1. INTRODUCTION

Inductive voltage dividers (IVD) are widely used for electrical measurements in an attempt to perform measurement traceability testing. They have been designed to provide for precise ratio for analogue signal [1].

The basic metrological characteristic of inductive voltage divider is transfer ratio at the specified frequency. The comparison technique for determining the ratio error or calibrating inductive voltage divider is given at the block diagram (Fig.1). The technique is based on comparing the voltage ratio of Standard inductive voltage divider (Standard IVD) with the investigated one (Test IVD) [2].

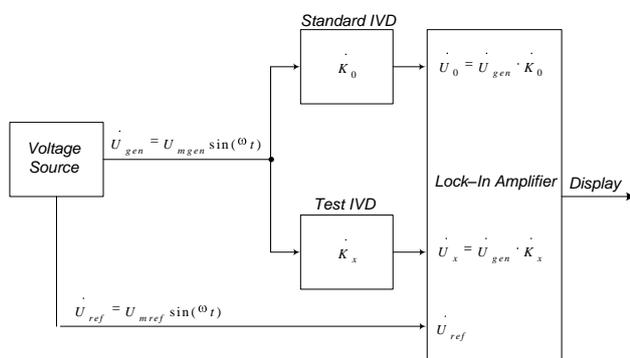


Figure 1. Comparison technique

As a device for comparing two AC voltages lock-in amplifier is used. By the lock-in amplifier we mean the instrument being sensitive to only specified frequency the output signal of which is proportional to the signal of the

frequency chosen being in phase with U_{ref} reference signal.

Lock-in amplifier falls within widely spread measuring tools providing extracting and measuring the values of two input signals differential component [3, 4]. This results in implementing differential measuring technique when the quantity being measured is compared with known homogeneous quantity distinguishing to a small extent from the value of the quantity being measured and when the difference between these two quantities is measured.

Lock-in amplifier for calibrating inductive voltage dividers has been developed at the Department of Computer- Aided Measurement Systems and Metrology in Tomsk Polytechnic University. The system distinctive feature is extracting and measuring of small differential-mode signal of the voltages being compared within nanovolt and microvolt range against the background of large in-phase component which can reach 10 V root-mean-square value by the signal-to-noise ratio up to – 60 dB with high impedance in the measuring inputs of the lock-in amplifier.

Low level characteristics of current electronic components make the computer system designing complicated. They are:

- insufficient suppression of amplifier common mode input signal, that is, low common mode rejection ratio (CMRR);
- rather small microchips power voltage;
- conditions of wide bandwidth and small noise level.

2. TECHNIQUE OF EXTRACTING DIFFERENTIAL MODE SIGNAL

For extracting the differential signal the input stage structure of lock-in amplifier with the tracking power supply in Figure 2 was proposed, with instrumental amplifier being used as voltage subtractor. In Figure 3 the pattern of the tracking power supply +E2 and – E2 diagram is presented. Due to tracking power supply for operating the subtractor and follower it has been possible to gain synchronous system large input impedances.

Assume that in the tracking power supply structure the voltage subtractor has an ideal differential gain K and an infinite CMRR, then the output voltage will be invariant to the follower departure from ideal and proportional to:

$$K(U_x - U_0) \quad (1)$$

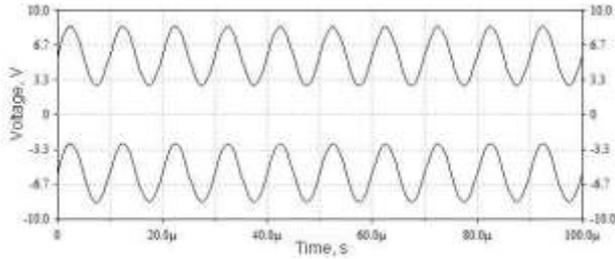


Figure 2. The tracking power supply +E2 and – E2 oscillogram

For Analog Device and Texas Instruments instrumental amplifiers the precision of differential gain is provided by laser elements adjustment. However, $CMRR$ is equal to 100 dB and it decreases with the rate of 20 dB per decade within the range of tens and hundreds of kHz at the cut-off frequency of 5 kHz. Therefore, along with the useful signal at the subtractor output the parasitic signal proportional to the quantity is developing:

$$\dot{U}_0 (1 - K_F) / CMRR, \quad (2)$$

where K_F is gain of voltage follower.

Voltage follower inertia can be represented as aperiodic first order chain. Thus, the tracking power supply at improper follower operation and strong $CMRR$ frequency dependence can result in growing the output signal with the frequency increase and overloading the measurement channel even in the conditions of the equality of voltages being compared. That is why the voltage follower inertia should match the input signal bandwidth. Besides, one can suppress the influence of common mode input signal residual voltage by introducing the operation of calibrating the system measuring channel. In this case one and the same U_0 signal is supplied to both inputs of voltage subtractor.

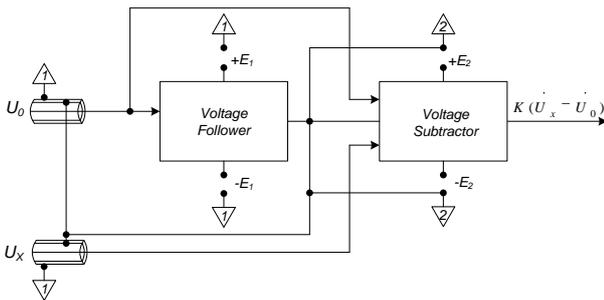


Figure 3. Input stages block diagram

2. INSTRUMENT STRUCTURE

The block diagram of lock-in amplifier is presented in Figure 4. The synchronous detector circuit is executed on the Analog Device AD734 microcircuit where for increasing the sensitivity the denominator value close to 1V was fixed. Sample-storage circuit is used for the operation “Setup 0”. By this operation the storage of the input signal in-phase component for its subsequent compensation in measuring

the differential signal is carried out. Low pass filter is the third order Bessel filter with the monotony transitive characteristic and cut-off frequency of 0.2 Hz. It is executed at the Analog Device OP 270 microcircuit. The microcontroller is controlling the Synchronous system code-control units, is measuring the differential voltage using ADC executed on MAX 110 microcircuit and is indicating the measurement results. For the lock-in amplifier use as a part of the automated measuring complex for calibrating inductive voltage divider the remote control from PC through USB interface is provided.

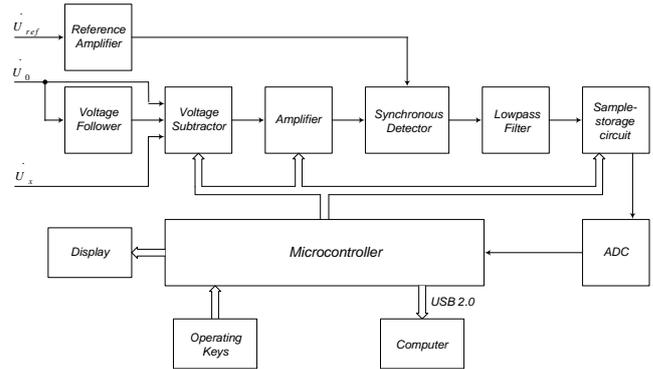


Figure 4. Block diagram of lock-in amplifier

Special software in the LabView environment of graphic programming was developed for synchronous system remote control including local network and Web. The user interface of the virtual device for controlling the lock-in amplifier is presented in Figure 5. For initiating the remote control by synchronous system the switch “Network” should be set on the top position.



Figure 5. Front panel of virtual lock-in amplifier

Initiating the measurement process is carried out by pressing the button “Measurement”. The indication U_X will be displayed. The sign of arrow and digital indicators defines the difference sign of differential signal. For stopping the work with virtual panel one should press the button “Close”

The lock-in amplifier is presented in Figure 6 and has characteristics:

- Frequency range 20 Hz – 100 kHz;
- Maximum Inputs 10 V;
- Full Scale Sensitivity 100 nV (10 on 1 kHz) to 12.5mV
- Input impedance at 1 kHz:
 - input U_0 – not less than 50 Mohm + 25pF,
 - input U_X – not less than 1 Gohm+25pF,
 - input U_{ref} – not less than 1 kOhm+25pF.
- Control – remote and manual.

- Power supply – 220 V, 50 Hz.



Figure 6. Signal level shift unit

5. REFERENCES

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