XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6–11, 2009, Lisbon, Portugal

LABORATORY OF ANALOG SIGNAL PROCESSING AND DIGITIZING AT FEE CTU IN PRAGUE

Josef Vedral, Jakub Svatoš, Pavel Fexa

CTU of Prague, Faculty of Electrical Engineering, Technicka 2, 166 27 Prague,
vedral@fel.cvut.cz, svatoj1@fel.cvut.cz, fexap1@fel.cvut.cz

Abstract – In the paper are stated methods of education of electronic measurement circuits at Department of Measurement of FEE CTU in Prague. There are specified typically themes applied in bachelor and master grade of study. The education is supported by the set of electronic function units, universal laboratory units LABORO and simulation program MULTISIM.

Keywords: signal processing, sensor signal conditioning, signal digitizing and reconstruction.

1. INTRODUCTION

The topic Electronic Circuits for Measuring Technology was introduced to the Department of Measurement of the Czech Technical University in Prague [1]. There are the following related subjects available these days: “Circuits of Digital Measuring”, “Analogue signal pre-processing and digitizing” and “Elements of avionic systems”.

The course Analogue signal processing and digitizing is dedicated to methods and circuits for preprocessing, and digitizing of analog signals from typically sensors. It is focused to the methods for achieving of high precision of transmission and suppression of spurious components. The laboratory exercises are divided into two parts: the first part are classical tasks; the second one are individual works in form of realization of tasks from linear and non-linear signal processing domain, filtering, digitalization and reconstruction. The teaching is supported by the CAD system MULTISIM for measuring circuits [2].

2. NAME OF LECTURES

1. Low level, high impedance signal amplifica-tion, electrometric, instrumentation amplifiers
2. Signal processing for resistive, capacitive and inductive sensors, lock in amplifier
3. Galvanic signal isolation, transformer and optocoupler isolation amplifiers
4. Non-linear signal processing, log and antilog amplifiers and multipliers
5. Signal filtering, passive and active filters, biquad filters, switched capacitor filters
6. Multiplexing of analogue signals, BiFet and CMOS switches and multiplexers
7. Digitizing and reconstruction of signals, sampling, quantisation, coding
8. High speed signal digitizing, flash, half flash ADCs, nonlinearity error correction
9. High resolution signal digitizing, with dual and quad slope ADCs, V to f converters
10. Delta sigma ADCs, oversampling, noise shaping, dithering, multistage modulators
11. Testing of AD systems, sine wave fit test, fast Fourier transform test, histogram test
12. Hardware design techniques, grounding, shielding, EMI/RFI considerations

3. LABORATORY EXERCISES

The laboratory exercises consist of individual projects that cover design, simulation and realization of typical measuring circuits and principles like:

1. Signal conditioner for resistive bridge circuits
2. Signal conditioner for capacitive sensors
3. Signal conditioner for temperature RTD sensors
4. Signal conditioner for thermocouple sensors
5. Logarithmic and exponentional amplifiers
6. Universal biquad filters
7. Full wave rectifier
8. Logarithmic RMS convertor
9. Voltage to frequency converters
10. Delta sigma modulators
11. Digitizing of analog signals
12. Reconstruction of digital signals

For simulations of circuits is the program MULTISIM software used. It supports the following analysis: DC Operating Point, AC Frequency Sweep, Transient, Fourier Analysis, Noise, Distortion, Temperature Sweep, Monte Carlo and Worst Case Analysis.

4. CIRCUITS UNDER TEST

In Fig.1 is presented simulated conditioner for resistive bridge circuits with instrumentation amplifier.

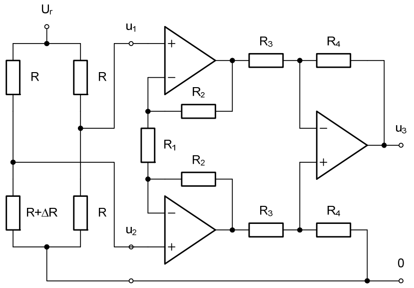

Fig.1. Signal conditioner for resistive bridge circuits.

In Fig. 2 is presented simulated signal conditioner for differences capacitive sensor with synchronous detector.

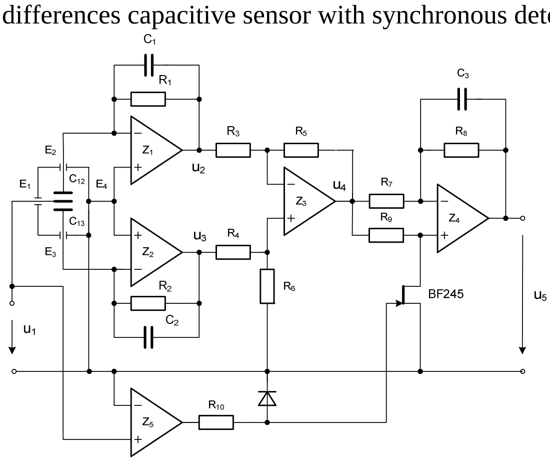

Fig. 2. Signal conditioner for differences capacitive sensors with synchronous detector.

In Fig. 3 is presented simulated signal conditioner for temperature RTD sensors.

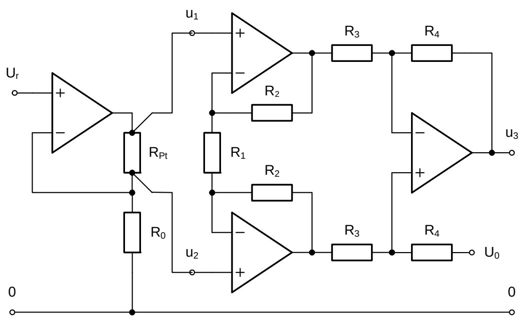

Fig. 3. Signal conditioner for temperature RTD sensor.

In Fig. 4 is presented simulated signal conditioner for thermocouple sensors with isothermal block.

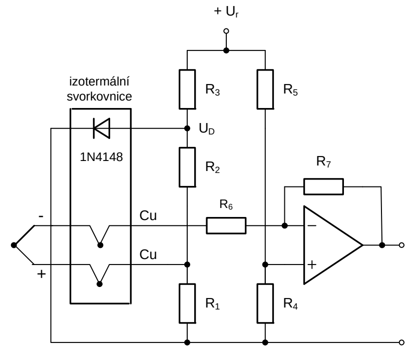

Fig. 4. Signal conditioner for thermocouple sensors with isothermal block.

In Fig. 5 is presented simulated universal biquad filtetr 2. order with lowpas, highpass and bandpass output.

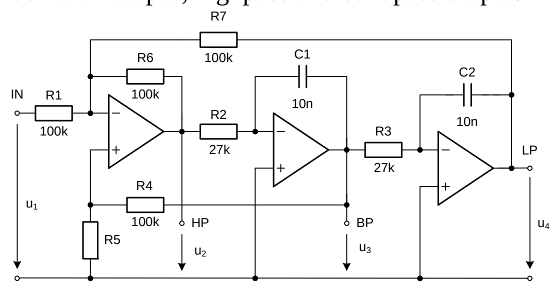

Fig. 5.

Universal biquad filter 2. order.

Nonlinear circuits for analog signal processing is presented with log, antilog, AC to DC converters .

In Fig. 6 is presented temperature compensated logarithmic amplifier with transfer characteristic 1V/dek.

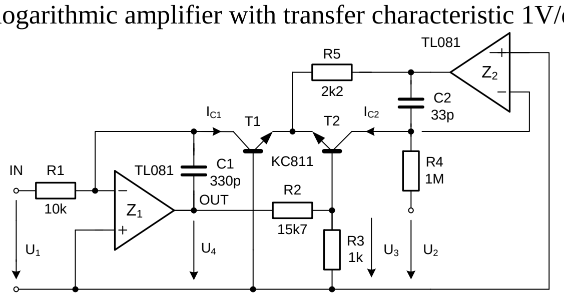

Fig. 6. Temperature compensated logarithmic amplifier.

In Fig.7. is presented temperature compensated antilog amplifier with transfer characteristic 1V/dek.

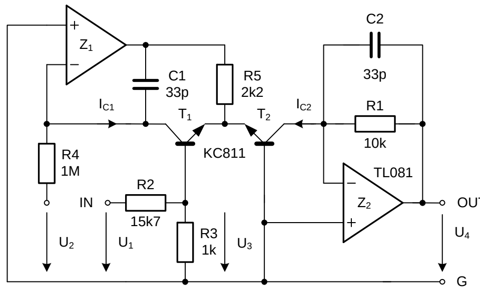

Fig. 7. Temperature compensated antilogarithmic amplifier.

For conversion of AC signals to DC signal is operational rectifier and RMS convertor used. In Fig. 8 is presented full wave rectifier for conversion of harmonic voltage signal to DC voltage.

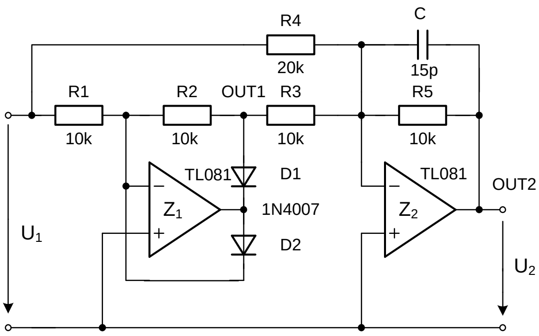

Fig. 8. Full wave rectifier.

For conversion of nonharmonic signals to DC signal is RMS convertor used.

In Fig. 9 is presented logarithmic RMS converter with full wave rectifier, logarithmic, exponentional convertors.

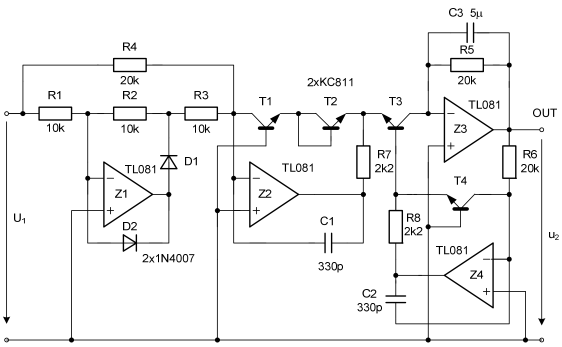

Fig. 9. Logarithmic RMS convertor.

For conversion of low frequency signal to frequency is V to F convertor used.

In Fig. 10 is presented V to F convertor with scale 1V/kHz used.

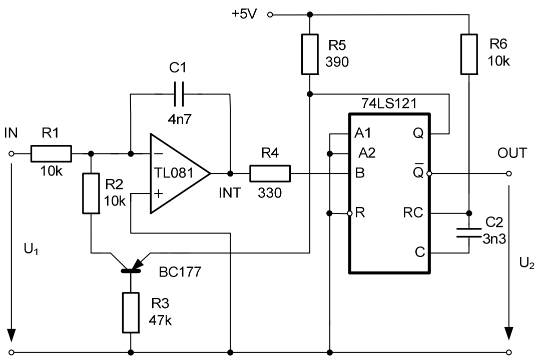

Fig. 10. Voltage to frequency convertor.

The shape of output signal of integrator and logic output is presented in Fig. 11.

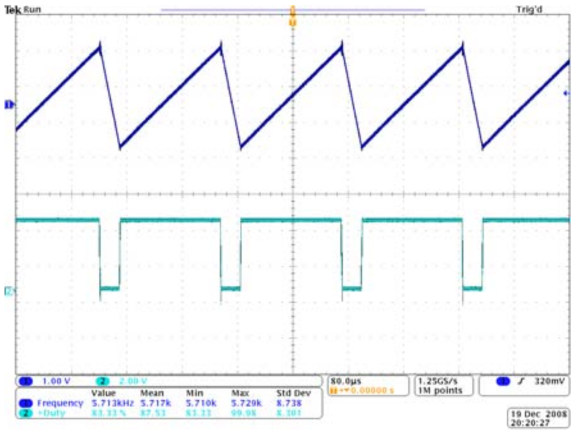

Fig. 11. The shape of output signal of integrator and logic output of V to F convertor.

For digitizing of high speed signal the especially video 8 bit 20 MSa/s flash ADC is used. For analysis of logical states of outputs of measured ADC the digital oscilloscope is used, see Fig. 12.

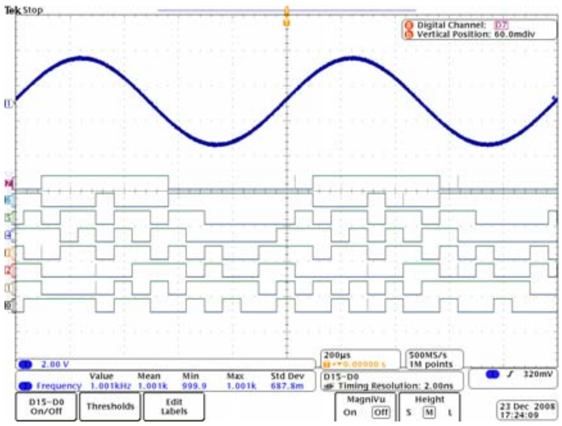

Fig. 12. The shape of input signal and logic output signals of tested ADC.

The quality of tested converter is judged by the best sin curve fit method, spectral analysis method and histogram method. These methods determine parameters like Effective Number of Bits (ENOB), Signal to Noise and Distortion Ratio (SINAD), Total Harmonic Distortion (THD) and Integral and Differential Non-linearity (INL, DNL).

For digitizing of low speed signal the especially delta sigma ADC is used.

In Fig. 13 is presented delta sigma modulator 1. order.

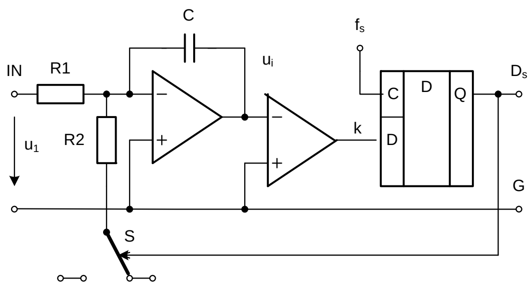

Fig. 13. Delta sigma modulator 1. order.

In Fig. 14, Fig. 15 and Fig. 16 is presented output signal of integrator, clock signal and logic signals of compatator and flip flop circuit.

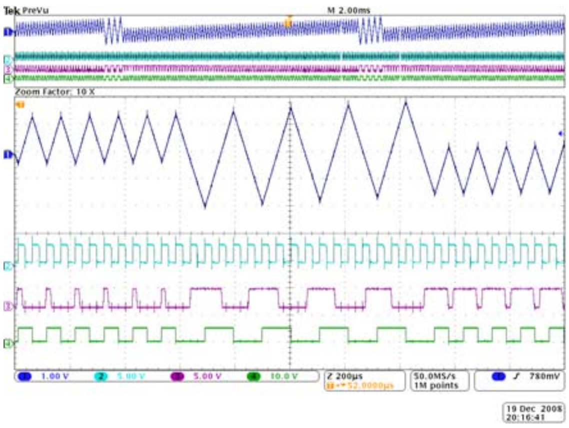

Fig. 14. The shape output signals of Δ–Σ ADC (grounded input).

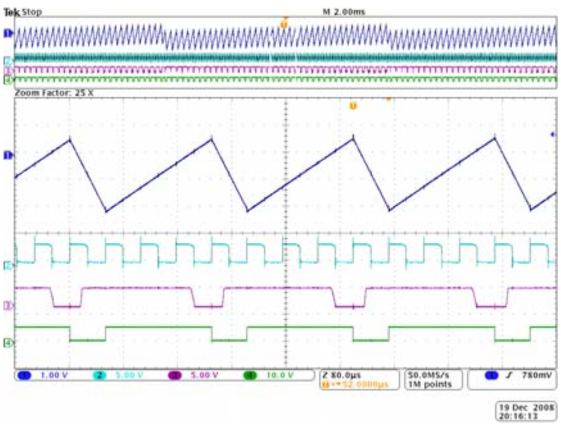

Fig. 15. The shape of output signals of Δ–Σ ADC (input signal + FS/2).

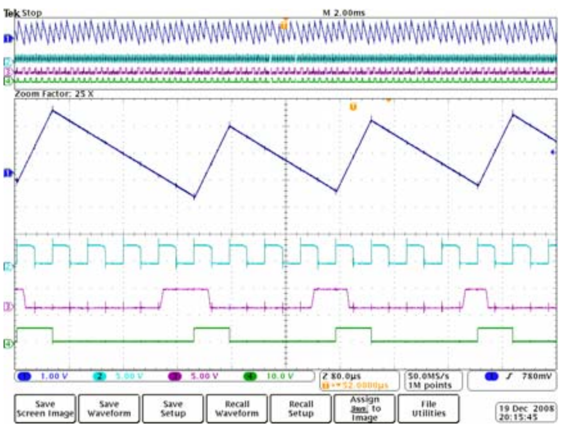

Fig. 16. The shape of output signals signals of Δ–Σ ADC (input signal – FS /2).

For spectral analysis of reconstructed signal from DAC the FFT analyzer (witch is component of stated oscilloscope) is used. From the theory of reconstruction of harmonic signal witch is reconstructed from equidistantly distributed steps results that in this manner generated signal includes odd harmonic components only.

The determination of quality of reconstructed signal is made from its Total Harmonic Distortion THD. The frequency spectrum of filtered and unfiltered harmonic reconstructed signals from time equidistant 8 samples are shown in Fig. 17 and Fig.18.

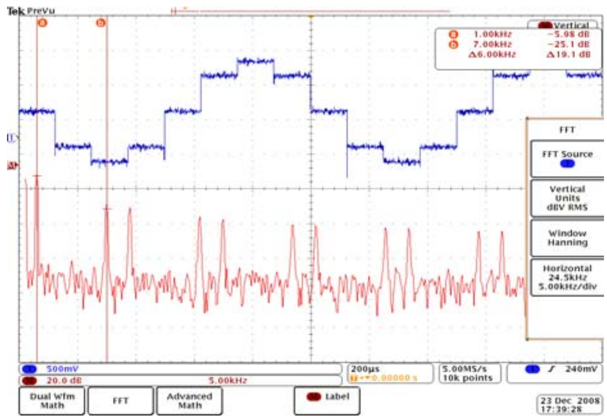

Fig. 17. The frequency spectrum of unfiltered harmonic signal reconstructed from 8 samples.

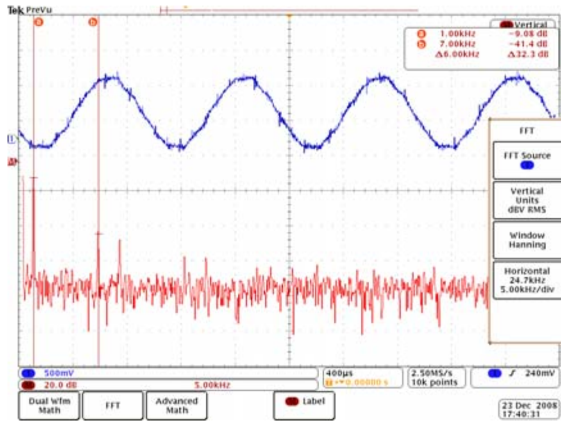

Fig.18. The frequency spectrum of filtered harmonic signal reconstructed from 8 samples.

5. CONCLUSION

In the article is laboratory of analog signal processing and digitizing at department of measurement of FEE CTU in Prague presented. For simulation parameters of circuits is program MULTISIM. from National Instruments. For project education is universal laboratory device LABORO used.

Presented education technology has been applied at 120 students in bachelor and magister courses in field of study „Measurement and Instrumentation techniques" at FEE CTU in Prague.

ACKNOWLEDGMENTS

This project is supported by the research program No.: MSM6840770015 "Research of Methods and Systems for Measurement of Physical Quantities and Measured Data Processing" of the CTU in Prague.

REFERENCES

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instructions

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