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IMPLEMENTATION OF 1 MHz SCALAR SPECTRUM ANALYZER USING PC-BASED ACQUISITION CARD

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Abstract – *The 1MHz scalar spectrum analyzer is implemented using PC-based acquisition card mounted in standard personal computer. Additional hardware, external oscillator and precision AC voltmeter are integrated on the printed circuit board, connected to acquisition card. Software part is developed using National Instruments LABVIEW package. Spectrum analyzer can be used in educational, as well as in research purposes for testing amplifiers and analog filters at low frequencies, up to 1MHz.*

1. INTRODUCTION

Computer based acquisition instruments followed development in personal computer industry. There are several types of acquisition equipment from various vendors. Most new implementations of legacy instruments like oscilloscopes, AVΩ-meters and spectrum analyzers have interface for connection with computer and software for data acquisition and manipulation. New types of stand-alone instruments and measurement equipment are embedded systems with adapted operating systems and acquisition software.

Measurement equipment based on computer hardware is realised as PCI card for desktop or rack-mounted computers or PCMCIA acquisition card for portable or PDA computers. The acquisition card needs device driver for operating system that runs on host machine and application software which provides data acquisition and manipulation.

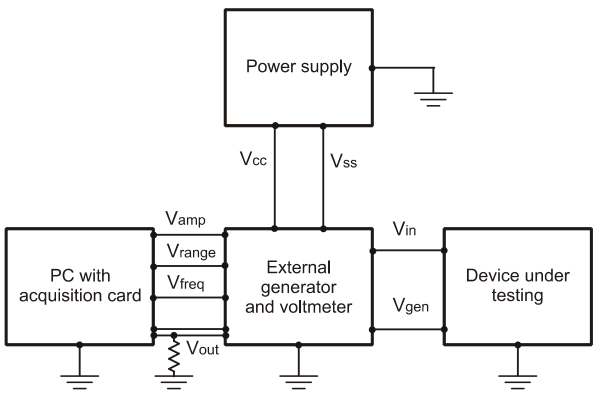

Figure 1. Picture of complete system

The scalar spectrum analyzer is implemented using National Instruments NIDAQ PCI-6014 acquisition card [1]. This card has 16 analog inputs with 200kS/s sampling rate, two analog outputs with 10kS/s sampling rate, 8 digital I/O channels and two 24-bit counters. PCI-6014 is PCI based acquisition card. External signals or devices under testing can be connected with acquisition card using CB-68LP block panel and SH68-68-EP cable.

Software part is developed in LABVIEW package. LABVIEW provides intuitive developing interface with possibility of developing GUI applications. National Instruments provides other development platforms such as Measurement Studio for Microsoft Visual Studio, and ANSI compatible LABWINDOWS. The operating system driver is common for all developing packages. It provides basic application interfaces, and elementary functions for configuring acquisition card.

2. HARDWARE

Sampling rate of the analog inputs of the acquisition card is limited to 200kS/s, and for the analog outputs to 10kS/s. The sampling rate limits the maximal frequency of input and output channels to 100kHz and 5kHz, respectively. The frequency measurement range of the acquisition card can be extended using external generator and external AC voltmeter.

The external generator and AC voltmeter used here are not stand-alone devices. The external generator transforms DC signals generated by acquisition card in AC signal with defined frequency and amplitude. The AC voltmeter transforms measured AC signal in DC voltage equal to real mean square value of input signal. The measurement process performed by acquisition card is reduced to DC voltage measurement. The frequency measurement range of whole system is determined by minimal and maximal frequency of external generator and frequency bandwidth of AC voltmeter.

The external generator is realized using XR-2206 integrated circuit (Figure 2). The XR-2206 is a monolithic function generator integrated circuit capable of producing sine, square, triangle, ramp, and pulse waveforms of high-stability and accuracy [2]. The output waveforms can be both amplitude and frequency modulated by an external voltage. In this application, frequency of operation can be selected externally over a range of 1Hz to 1MHz. The oscillator frequency is linearly swept with a 1000:1 frequency range with an external control voltage, while maintaining low distortion. Frequency of generated signal V_{gen} is proportional to the total timing current, I_T, drawn from timing terminal (pin 7), and can be represented with:

$$f = \frac{320 I_T(mA)}{C(\mu F)}(Hz) \tag{1}$$

where C is a value of timing capacitance across pin 5 and 6. Timing terminal is low-impedance point, and is internally biased at +3V, with respect to pin 12. Frequency varies linearly with I_T, over a wide range of current values, from 1µA to 3mA. The timing current I_T, can be controlled with external DC voltage V_{freq}, generated by acquisition card. The timing current is proportional to V_{freq}:

$$I_T = \beta \frac{V_{freq} - V_{BE} - V_{SS}}{R_2} \tag{2}$$

where V_{BE} and V_{SS} are constant and β is current gain parameter of transistor T_1. Following the (1) and (2), the frequency of oscillation can be represented with empiric formula:

$$f = \frac{320\beta(V_{freq} - V_{BE} - V_{SS})(V)}{R_2(k\Omega)C(\mu F)}(Hz) \qquad (3)$$

The frequency range can be changed by switching timing capacitor. The external TTL signal V_{range} generated by acquisition card controls the switching relay [3]. The relay driver is realized using simple BJT. When the TTL signal V_{range} is at low level, the current I_R is equal to zero, and the relay is opened. When V_{range} is at high level, the current I_R is equal to $\frac{V_{CC} - V_{CES}}{R_1}$, where R_R is resistance of relay coil, so the relay is closed. In first case, the total timing capacitance is equal to C_1, and in second to C_1+C_2.

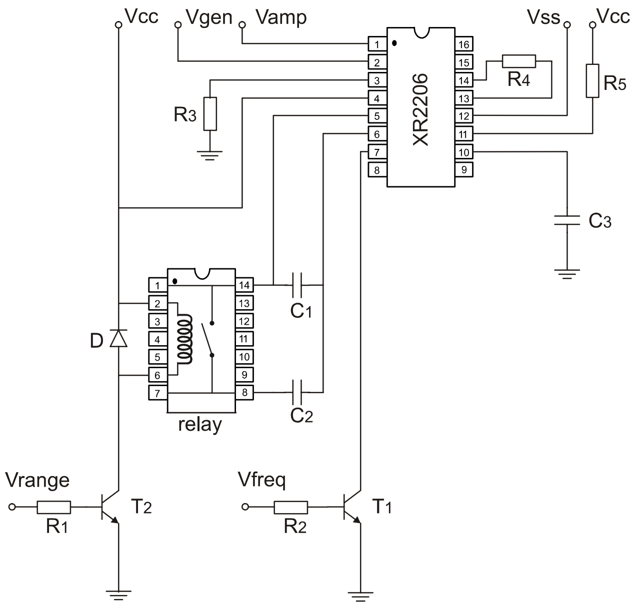

Figure 2. External signal generator

The output amplitude can be controlled with resistor R_3 and directly by applying a DC bias generated by acquisition card to pin 1. The internal impedance at pin 1 is approximately 100kΩ. Output amplitude varies linearly with the applied voltage at pin 1, for values of DC bias at this pin, as shown in Figure 3. As this bias level approaches to zero, the phase of the output signal is reversed, and the amplitude goes over zero. Total dynamic range of amplitude modulation is approximately 55dB.

The AC voltmeter is realized as precision rectifier with low-pass filter (Figure 4). The first operational amplifier is used for full-wave precision rectifier, presented by *Millman* and *Halkias* [4]. The output signal of the rectifier is full-wave rectified signal, with DC component U_{DC} proportional to real mean square of input AC voltage:

$$U_{DC} = \frac{2U_{RMS}\sqrt{2}}{T}\int_0^{T/2}\sin\left(\frac{2\pi}{T}t\right)dt = \frac{2\sqrt{2}}{\pi}U_{RMS} \qquad (4)$$

The second amplifier is used as active low-pass filter, which rejects the AC component of rectified signal. The trimmer R_8 is used for calibration. All resistors used in configuration of the AC voltmeter are low-tolerance (less then 1%) metal-film resistors. Integrated circuit LM-258 is used for operational amplifiers [5].

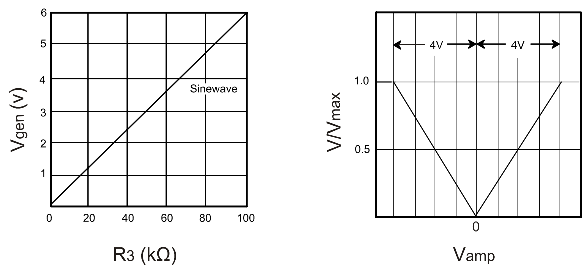

Figure 3. Output amplitude as a function of resistance R_3 and control voltage V_{amp}

External generator and voltmeter are placed at printed circuit board. PCB has connectors for input control signals V_{amp}, V_{freq} and V_{range}, generator AC output signal V_{gen}, measured AC signal V_{in} and output DC signal V_{out}. V_{amp} and V_{freq} are connected to analog outputs of acquisition card, V_{range} to the TTL logic channel of acquisition card, V_{out} to analog input of acquisition card, V_{gen} to the input of device under testing, and V_{in} to the output of device under testing (figure 1). There are connectors for power supply V_{CC}, V_{SS} and signal and power ground GND, too.

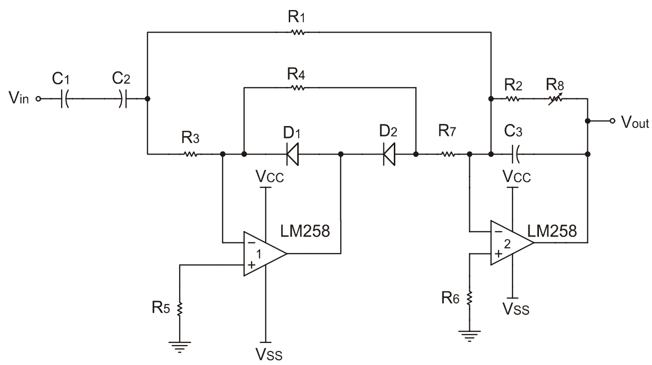

Figure 4. External AC generator

The acquisition card can supply only +5V/500mA, so it is necessary to use external ±12V split power supply, or monolitic isolated DC/DC converter for power conversion.

The analog inputs of acquisition card can be connected to AC voltmeter using NRSE – non referenced single-ended, RSE – referenced single-ended and differential measurement method. Differential method is used in this implementation, in order to decrease noise and increase the CMRR. This noise influences to measurement precision of small voltage values. Both of the connection points of a differential system are tied to instrumentation amplifier.

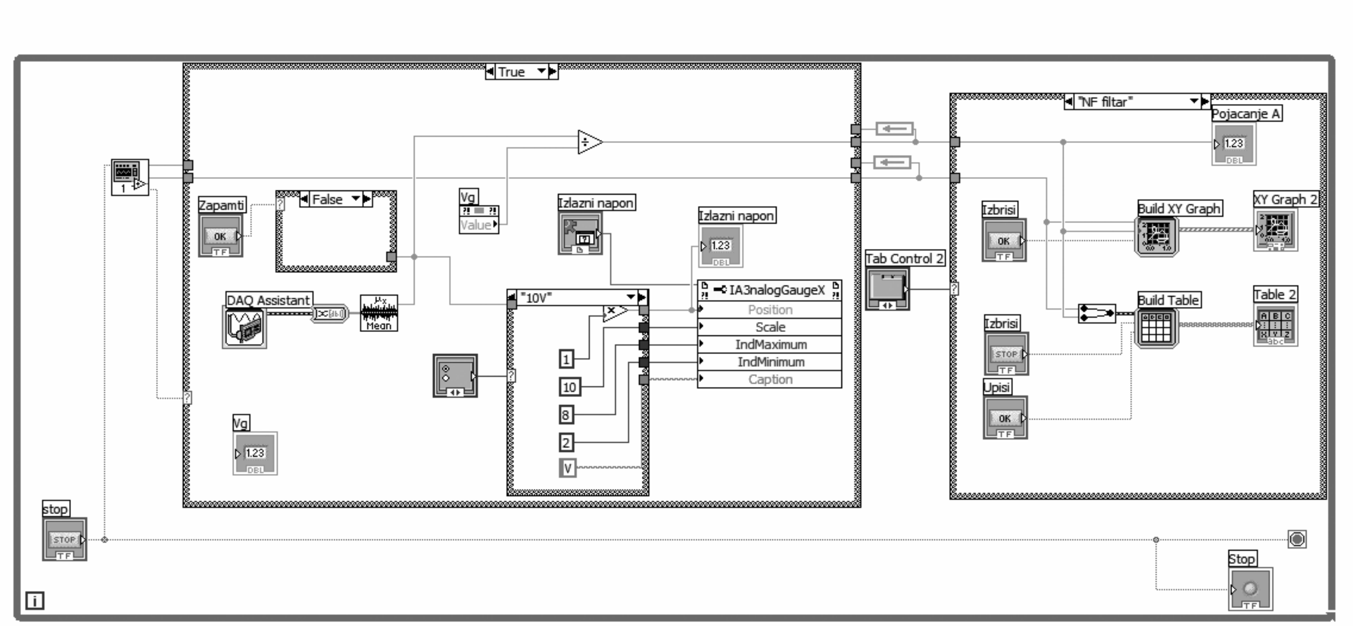

Figure 5. The main thread

There are no terminals connected to a fixed reference. In order to increase CMRR, a resistor can be connected between inverted input of instrumentation amplifier and ground. The resistance must have value of hundred equivalent Thevenin's resistance between connection points (inverted and non-inverted terminal of instrumentation amplifier). It is also possible to connect the second resistor between non-inverted terminal and ground. This configuration provides greater CMRR, but there is a systematic error in measurement caused by serial connection of resistors.

4. SOFTWARE

Software part of the 1MHz scalar spectrum analyzer is realized in National Instruments LABVIEW developing package, which provides simple realization of virtual instruments. Virtual instruments consist of interface to acquisition card and application with graphic user interface.

Interface to acquisition card is realized as device driver. PCI 6013/6014 cards are supported by Traditional NI DAQ and NI DAQmx drivers. All the measurements are performed using virtual channels. A virtual channel is collection of property settings that can include name, a physical channel, input terminal connections, the type of measurement or generation, and scaling information. A physical channel is a terminal or pin at which an analog signal can be measured or generated. Virtual channels can be configured globally at the operating system level, or using application interface in the program. Every physical channel on a device has a unique name.

When using NIDAQmx drivers, a number of similar virtual channels can be aggregated into a task. A task is a collection of one or more virtual channels with the same timing, triggering, and other properties. A task represents a measurement or generation process. As well as virtual channels, tasks can be configured globally at the system level, as well as using application interface.

For better performance, the main application has been separated in two threads. Main thread (Figure 5) performs the measurement process. It is a connection between user interface and low level device driver which controls acquisition card. Processes of signal generation and acquisition are controlled by DAQ Assistant. Main thread also includes functions for signal manipulations, range calculations, calculations of measured current, building data table and characteristic graphs. The second thread has functions for file manipulation and saving measured values (Figure 6). All measured values will be saved in HTML file format.

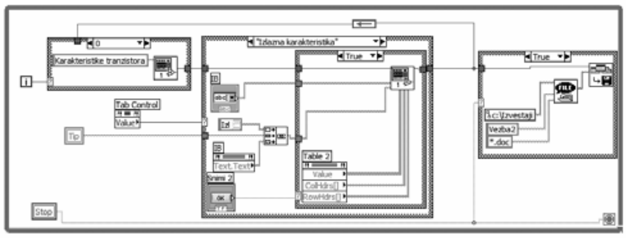

Figure 6. Data manipulation and saving thread

The user interface (Figure 7) of the scalar spectrum analyzer consists of visual controls and indicators. It provides basic functions for measurement. Visual controls – knobs and switches – provide control of analog signal generation. The indicators – gauges and graphs – show measured values. All measured values are placed in a table, and after the measurement process in appropriate file. User interface also provides controls for data manipulation and saving measured values.

4. CONCLUSION

The 1MHz scalar spectrum analyzer has educational purpose. It is a part of computer system for laboratory exercises in Electronics [6, 7, 8]. The main goal of this system is to simplify manipulation of instruments, faster measurement and

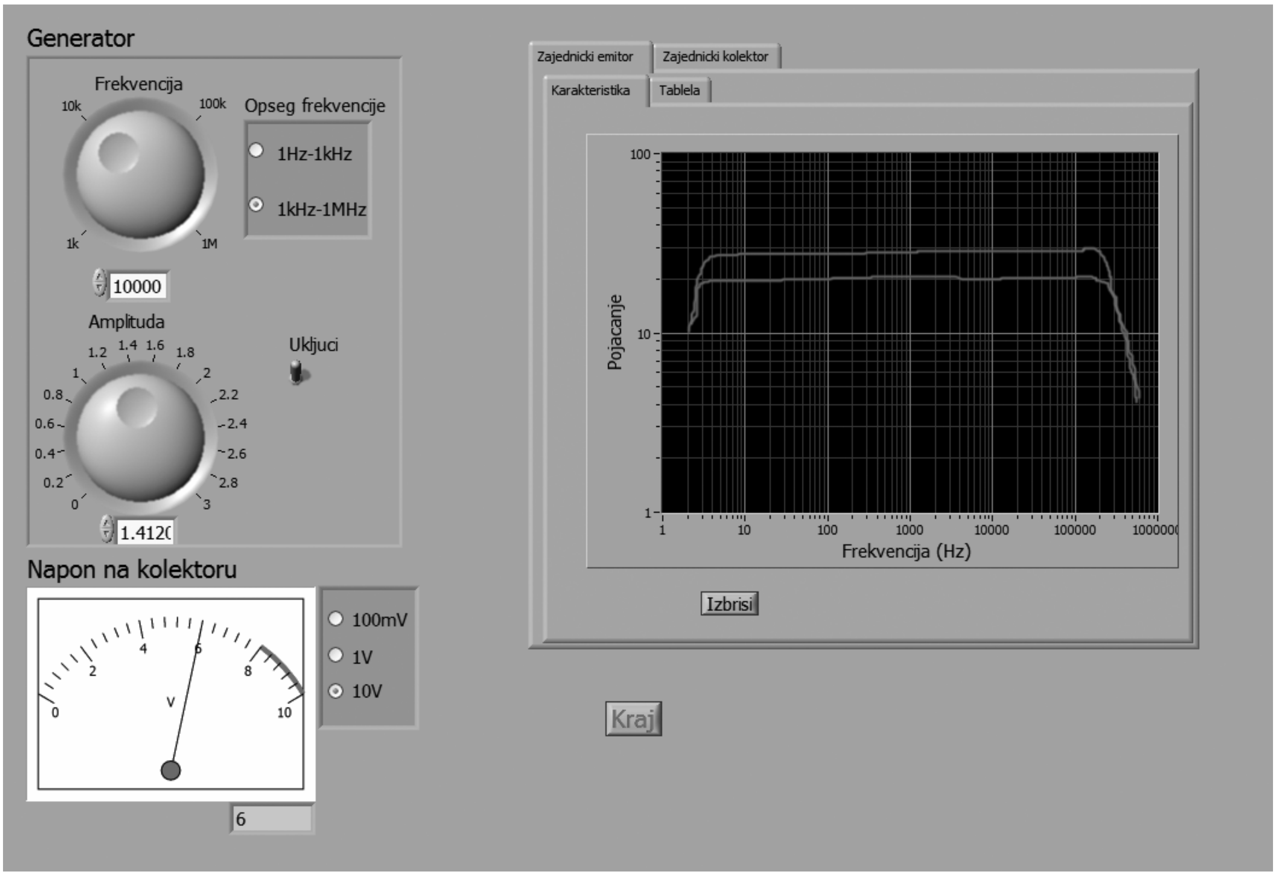

Figure 7. User interface

notation of the results, providing students to concentrate on measurement essence. This system can also be used in research purposes for measurement of amplitude characteristics of amplifiers and analog filters at low frequencies up to 1MHz.

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Sadržaj – *Skalarni spektralni analizator je realizovan pomoću akvizicione kartice ugrađene u personalni računar. Dodatni merni hardver, eksterni generator signala i AC voltmetar su ugrađeni na štampanoj ploči povezanoj sa karticom. Softverski deo sistema je realizovan upotrebom National Instuments LABVIEW programskog alata. Spektralni analizator može biti korišćen kako u edukativne, tako i u istraživačke svrhe za određivanje amplitudne karakteristike pojačavača i analognih filtara.*

IMPLEMENTACIJA 1MHz SKALARNOG SPEKTRALNOG ANALIZATORA UPOTREBOM PC AKVIZICIONE KARTICE

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