AUTOMATED EVALUATION AND TEST OF READOUT INTERFACE FOR MEMS MICROPHONE PROTOTYPE CHIPS

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1. Introduction

Testing is an important part of design and production of integrated circuits. Such testing of proper function of the circuits consumes a lot of time and resources. It is necessary to set and evaluate lots of parameters in analog testing. It is very inefficient in manual implementation. This testing can be speeded up by using automatic measurements. Professional testing equipment are very expensive. For example, to measure the harmonic distortion is used spectrum analyzer, which is not standard equipment of most labs.

Therefore it is necessary to look for other approaches of cheaper testing by using more affordable of measuring instruments. For this purpose, we designed a computer software, which can perform automated measurements by using the function generator and oscilloscope.

2. Experimental part

In our experiment, we performed types of measurements. Measurements have been performed by using our software OntioLab. We programmed this software in C# language. It includes tool for automated measurement such as frequency and amlitude characteristics.Schematic diagram of measured circuit is shown on figure 1. We used the Tektronix AFG3252 function generator generate input sine signal into the measurement circuit. To obtain the output amplitude and phase the Tektronix DPO4104b oscilloscope was used.Osilloscope and function generator communicate with PC via USB iterface. Measureing circuit was microphone readout interface (MRI).The main role of the microphone readout interface is to convert the capacitance changes produced by the MEMS (Micro-Electro-Mechanical-System) microphone into electrical signal such as voltage, current, etc. [1-3]. Measured microphone readout interface was designed in the 0.35 μm CMOS technology with supply voltage of 3V. The basic block diagram and description of measured MRI is presented in [4].

Firstly, we used the function to measure the frequency characteristics of the measured circuit. Our software automatically measured the output gain of the circuit and phase shift. It was necessary to set amplitude of generated signal A_{IN}, offset and the frequency sweep parameters in the software for this type of measurement. These parameters consists of start frequency, stop frequency and number of points per decade.After running measuerement, software initialize the function generator and clear the oscilloscope measurements. Output amplitude is obtained from the oscilloscope after time interval between two measurements.This output amplitude was obtained by subtracting the differential output signals connected to channels 1 and 2 (channel1 – channel2).Then the software calculates the

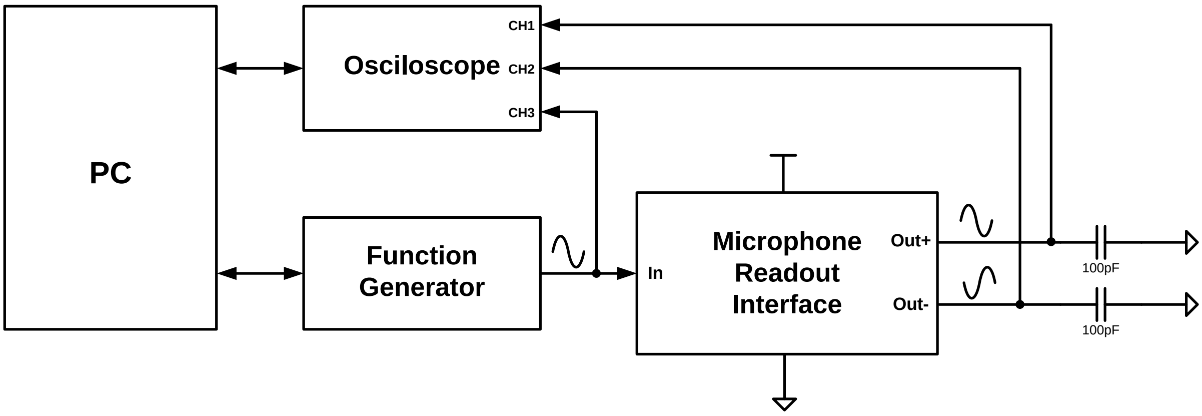


Fig.1. *Schematic diagram of the measurement circuit.*

output gain at given frequency. Calculation of the gain is represented by the equation 1, where A_{IN} is the amplitude of generated input signal and A_{OUT} is the output amplitude which is obtaiend from oscilloscope.Then the software calculates the output gain at given frequency. Calculation of the gain is represented by the equation 1, where A_{IN} is the amplitude of generated input signal and A_{OUT} is the output amplitude which is obtaiend from oscilloscope. Phase measurement between input (channel 3) and output (channel 1) signals were measured with the oscilloscope. After reading data software sets parameters for next frequency.

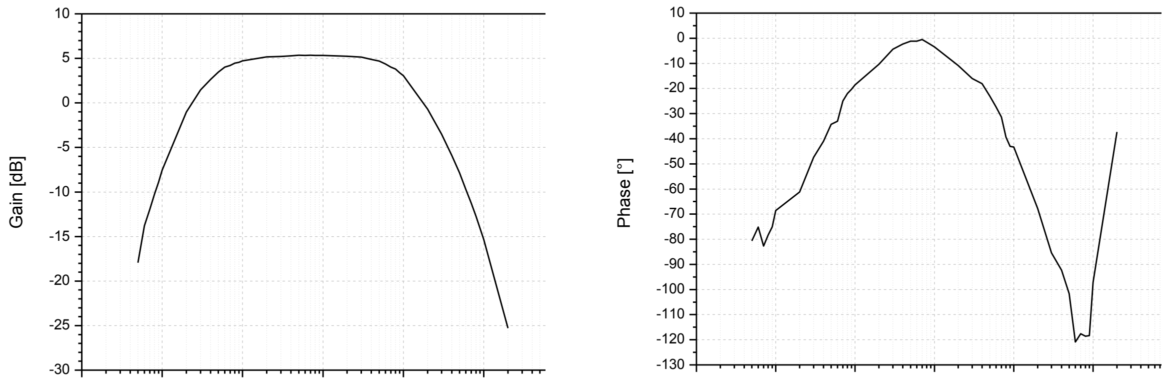
$$Gain = 20 * \log_{10}\left(\frac{A_{OUT}}{A_{IN}}\right) \tag{1}$$

Second function is used for measuring the harmonic distortion of circuit. It was necessary to set frequency of generated signal, offset and the amplitude sweep parameters in the software for this type of measurement. These parameters consists of start amplitude, stop amplitude and step. After running measuerement, software initialize the function generator and clear the oscilloscope measurements. Fast fourier trabsformation (FFT) spectrum was obtained from the oscilloscope after time interval between two measurements. This FFT spectrum oscilloscope obtain by subtracting the differential output signals. Software calculates total harmonic distortion (THD) from FFT spectrum of output signal.Calculation ofTHD was performed by equation 2, where $A_{1har}$is amplitude of first harmonic frequency and $A_{ihar}$is amplitude of i-th harmonic frequency. Our software automatically finds harmonic frequencies. First 10 harmonic frequencies were aplied in calculation process.After reading data software sets parameters for next amplitude.

$$THD = \frac{\sqrt{\sum_{i=2}^{10} A_{ihar}^2}}{A_{1har}} * 100 \tag{2}$$

3. Results

Measured circuit microphone readout interface was designed for frequency range from 30 Hz to 8 kHz. The input range is from0 V to 1,9V. Requirment to distortion of the output signal was less than 3%.We performed measurements on 10 samples.All measurements were carried out without microphone.

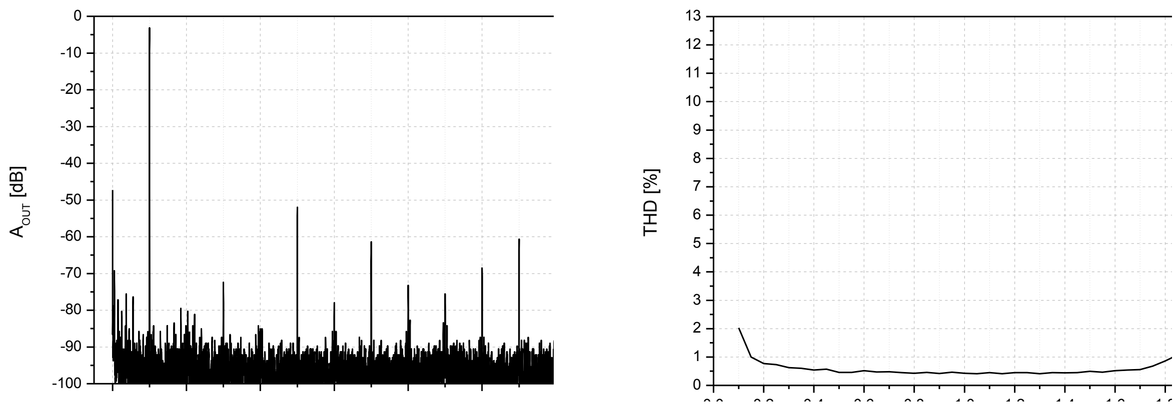


(a) *Gain* (b) *Phase shift*

Fig.2. *Exmaples of the frequency sweep measurement.*

Measured frequence characteristics of MRI circuit are shown on figure 2. These characteristics were measured with our software OntioLab. We set the start and stop frequency in range from 5 Hz to 200 kHz and 10 points per decade in automatic measurement mode. Fifure 2a shows amplitude frequency characteristic where is the gain in dependence on frequency. Gain was calculated by equation 1. We also obtained phase characteristic with this measurement, which is shown on figure 2b. Error values were measured in frequencies above 50 kHz. It was due to very low amplitude of output signal at these frequencies and therefore the oscilloscope was not able to trigger on this signal. Then the phase values measured above 50 kHz are incorrect.

Second automated measurement was based on amplitude change at the same frequency. The total harmonic distortion (THD) was evaluated in this measurement. Softwer sets amplitude in range from 0,1 V to 2 V with step of 50 mV. Frequency of generated signal was 1 kHz. THD was obtained throught FFT spectrum. Figure 3a shows the FFT spectrum of output signal with frequency 1 kHz and amplitude equal to 1 V. We can see 12 harmonic frequencies on this picture, but we calculated with only 10 harmonic frequencies. THD was



(a) *FFT spectrum* (b) *Total Harmonic Distortion (THD)*

Fig.3. *Exmaples of the harmonic distortion measurement.*

calcluated by equation 2. Measured characteristic of total harmonic distortion is shown on figure 3b. THD is below 2% in given amplitude range and therefore the microphone readout interface suit into the requirments. Error values were measured at small input amplitudes bellow 0,2 V. It is due to distorted signal generated with function generator for small amplitudes.Then was the generator distortion added to total distortion of MRI circuit.

4. Conclusion

We programmed software OntioLab for automatic measurements of frequency and amplitude characteristics on microphone readout interface. This software initializes and sts function generator and oscillocsope after setting the measurement parameters. It read and precesses measured data during measurement. Error values can be measured in frequencies above 50 kHz in measuring the phase characteristic, due to very low amplitude of output signal. Another error values are measured in amplitudes bellow 0.2 V, becasue the function generator has slightly distorted signal for small amplitudes. These error values influes the total harmonic distortion measurement. In future we will improve the THD measurement by software compensation the distortion of function generator.

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