Development of Model for Dynamic Measurement of Gain Frequency Response

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Abstract – **Measuring of Gain Frequency Response (GFR) has always been a challenge to audio engineers. Multiple model solutions have been made and due to them the amplitude characteristic is reported in different ways. At first, several input frequencies are set and the output results are reported. The data obtained are recorded in a table and then are put in graphics. This approach is good and even the measurement of nonlinear distortions is still widely applied, but while examining the GFR of 1962 the so called Vobel generators are developed and they are used for dynamic testing of GFR. The most popular use of this type of generators is in high frequency area and equipment, and less attention is paid to the low frequencies till 20 kHz.**

Keywords – **measurement, gain frequency response.**

I. TASK OF THE ARTICLE

A. Base structure of the new measurement system

The Proposed method of measurement (Fig.1.) is a dynamic system for the study of GFA. The Sowtooth generator controls the output frequency of a waveform generator; this system is used for dynamic control of output frequency of Waveform generator while maintaining constant amplitude. The resulting amendment is filed at the entrance of the test amplifier, which reacts with different output amplitude according to the applied input frequency. This reaction is used for dynamic output indication to scope. To obtain a stable baseline image matching is necessary to phase signals from Sowtoot generator with those of the test amplifier. The role of the phase compensator is implemented by the phase correction circuit which has set, in advance, the format of the output signal. Thus, equalization is achieved, by phase, of the output generator with the frequency reading on the oscilloscope.

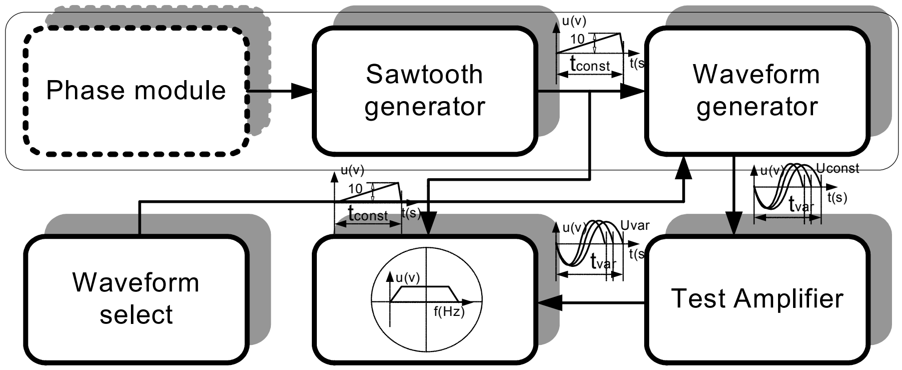

Fig.1. Base structure of new measurements system

The proposed method for measuring GFR generator uses a sawtooth generator which controls an external waveform generator. This generator provides the phase compensation, if needed. The signal from the sawtooth generator is simultaneously submitted to the oscilloscope (XY mode), thus the output response of the test amplifier is synchronized. The system provides measurement of GFR of all modern audio amplifiers - Class AB, G, H and D [1] and sets higher linearity requirements for the control of the generator (sawtooth generator). Multiple solutions of such generators are known [2], some of them generate output signal but with poor linearity. In others, good linearity is found but instability of the temperature relation is seen. To solve this problem is necessary to use a broadband generator till 10MHz, which enables the separation of generations starting area with a high linearity in the desired frequency range. The more important system requirements are:

- The frequency of the output signals from the Sawtooth generator must be lower than the lowest one in the frequency range being measured, otherwise the accurately measuring the low frequency range in GFR to 200Hz will not be possible;
- Control of the output signal format the waveform generator. This application is used to study various types of audio amplifiers;
- DC offset possibility of displacement of the test signal. The purpose of this offset is compensation at the output of the audio amplifier being studied;
- Output stage possibility of measuring the GFR of the digital audio amplifiers. This implies a rectangular shape of the test signals and significantly higher work rate, than 1MHz;
- Wide operating temperature range of up to +50°C This requirement implies a high linearity of signals generated, regardless of the temperature;

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- Low power consumption measurement system. It is required in the research of high-fidelity audio amplifiers, in particular those with battery power.

To fulfil these requirements in the development we will use specialized MAX038 waveform generator with the possibility of transformation as sawtooth. Let us now consider some of its basic parameters. The method developed for dynamic study of Gain Frequency Response allows high precision measurement in a wide frequency range. Its work in a wide frequency domain without using filters groups ensures low distortion and high non-linearity during the measurement.

B. Sawtooth and waveform generator MAX038. Basic parameters.

MAX038 is a precise waveform generator manufactured by the MAXIM company. Specialized circuit can generate triangular, sinusoidal and rectangular (pulse) signals.

Output frequency can be adjusted in the range from 0,1Hz to 20MHz by internal reference voltage source of 2.5V and with external RC group included. The working cycle can be adjusted in a wide range by applying a voltage in the range ±2V. This facilitates pulse with modulation [4] (PWM) and sawtooth generator.

Sinusoidal, rectangular or triangular signals can be achieved at the output by submitting an appropriate code at two TTL compatible inputs. The spreading to all the source signals is 2 Vp-p.

Low impedance output can be loaded to ±20mA. The TTL compatible SYNC output from the internal oscillator supports 50% working cycle, regardless of the operating cycle of the output signal. Thus, the generator can be used for synchronization of other elements of the system. An opportunity for external synchronization of the internal generator by TTL terminal (PDI) is also provided.

The generator is of relaxation type and is managed by control of load and dilution with constant current of C_F (Fig.2). The time for loading and dilution is controlled by current entrant Iin. The times may also be changed by tensions applied to FADJ and DADJ. The current Iin can be changed from 2μA to 750μA decades for a frequency value of C_F, thus providing more than two frequency ranges. Submitting U_T=2.4V to FADJ changes the nominal frequency ± 70%, and may be used for fine tuning of the generator.

Working cycle (duty cicle) can be controlled from 15% to 75% using ± *2,3V*, applied to pin DADJ. This voltage changes the ratio of loading and any dilution of CF, maintaining a constant output frequency.

Submission of the reference voltage to pin REF enables a simplified set of Iin, FADJ or DADJ.

Sine shaper turns lateens generated voltage in a stable sinusoidal signal with constant amplitude. Triangular, rectangular and sinusoidal signals are received in the three inputs of the integrated multiplexer.

The form of the output signals in the MAX038 is determined by the addressing of the inputs of the MUX. This is achieved by giving the logic level to inputs A1 and A0. The scheme provides an additional triangular signal which is given to a comparator. It forms a rectangular SYNC signal used for external synchronization. SYNC has a separate supply chain findings, thus it may be excluded if necessary. Two signals are generated in the main generator and are submitted to a scheme "exclusion or". The other input of phase detector (PDI) can be connected to an external generator, if necessary. The output of the phase detector is a source of signal, which

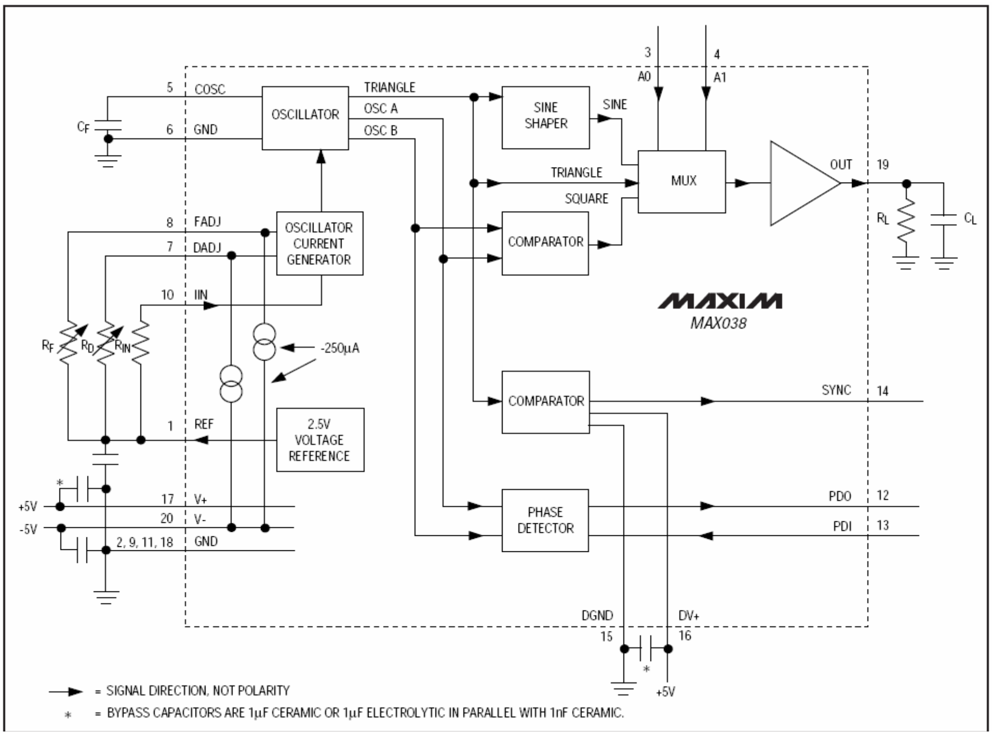

Fig.2. Base Structure of MAX038 [5]

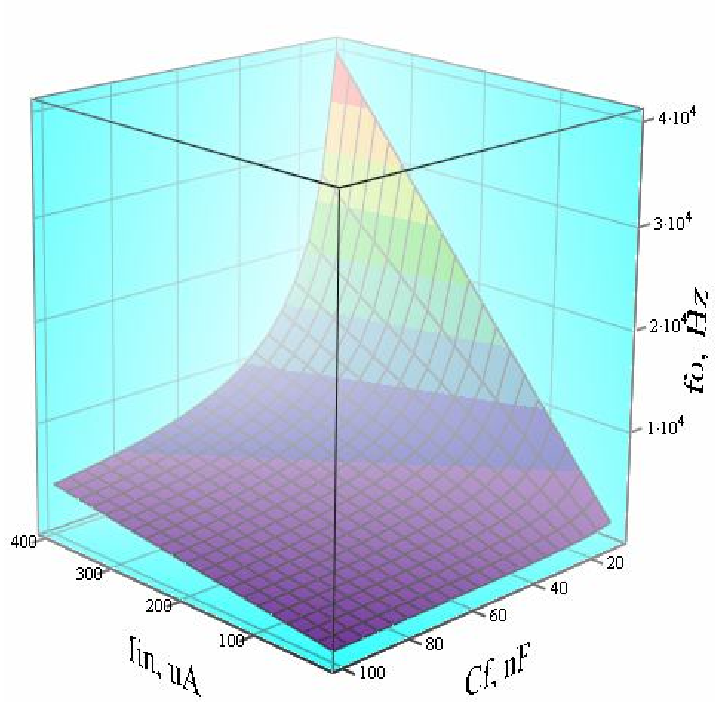

Fig.3. Numerical experiment to determine the output frequency

can be connected directly to FADJ MAX038 of sync with an external generator. The specific things about FADJ are that it should not be left open or with voltage lower than –3,5V [5].

TTL/CMOS logic findings address selects the form of the output signal, shown on table.1.[5].

TABLE.I.
SELECT THE FORM OF THE OUTPUT SIGNAL [5]

A1	*AO*	*Output signal*
X	1	Sinusoidal
0	0	Square wave
1	0	Triangle

X– log. "0" or log. "1"

C. Defining the output frequency

The selected waveform generator MAX038 is produced by the MAXIM company. The bandwidth (without the implementation of PCB unit) covers the frequency range of 0,05Hz÷20MHz, which ensures stable operation in frequency area of 0,1Hz ÷ 10MHz.

The output signals are generated with the same output amplitude of $2V_{p\text{-}p}$ and are obtained from one and the same output. This approach leads to a linear operation of the scheme using a common amplifier and internal MUX.

The set way for managing the generated output frequency is determined by several factors:

- Amplitude of current I_{in}
- Capacity of the C_F connected between COSC and GND
- Value of U_{fadj} connected to FADJ, if $U_{fadj} = 0V$ the output frequency is defined by the equation [5]:

$$f_o = \frac{I_{in}}{C_F} \qquad (1)$$

where:
I_{in} – control current (range 2μA ÷ 750μA);
C_F – capacity connected between COSC and GND (range 20pF до 100μF)

Optimal operation of the scheme is achieved when the range of current is I_{in} between 10μA to 400μA. Values outside the range are not recommended because of defiance of nonlinear distortions in the high output signal [5].

Current I_{in} can be achieved by a voltage or current source. When we use a voltage source, we need to connect an external resistor $R_{in.}$

Numerical experiment to determine the output frequency f_o with $I_{in} = 10 \div 400\mu A$ change of the current and capacity $C_F = 10 \div 100nF$ is shown in Fig.3.

When using the voltage source, the frequency is determined by the equation:

$$f_0 = \frac{U_{in}}{R_{in}C_f} \qquad (2)$$

The control current Iin can control the frequency in the range ±70%, with a change of the voltage to pin FADJ. In case of a variation of the output frequency – D%, the voltage to FADJ is determined by the equation [5]:

$$U_{fadj} = -0{,}0343 D_0 \quad (3)$$

Other way to determine the U_{fadj} is the equation [5]:

$$U_{fadj} = \frac{(f_0 - f_x)}{0{,}2915 f_0} \quad (4)$$

where:
f_0 – output frequency, when $U_{fadj} = 0$V;
f_x – output frequency in the rest of the cases.

If we know the voltage U_{fadj}, the output frequency is determined by the equation [5]:

$$f_x = f_0 (1 - 0{,}2915 U_{fadj}) \quad (5)$$

D. Major constraints in designing [5]

- Resistors and capacitors, defining the output frequency, can affect the characteristics of the functional generator. The resistors must be metal-layer (with low inductance). The condensers must be of low TC in the temperature range - the ceramic ones are suitable;
- The voltage of the COSC is triangularly shaped and varies from 0V to 1V. Polarized capacitors are not recommended, but if you use such the negative inference should be associated with the COSC, and the positive one - with GND. The great value capacitors, needed for very low frequencies, must be selected carefully because large losses may hinder loading and dilution of the CF. If possible, for a certain frequency could be used the lowest current I_{in} in order to reduce the capacity of the capacitor being used;
- The realizing of the full capabilities of the MAX038 requires precise connection of the power source. Low impedance bus, connecting all GND equi-potential points, should be used. Parallel to the V^+ and V^- is connected a ceramic capacitor 0.1μF or tantalium capacitor 1μF in parallel with 1nF ceramic. The findings of the capacitor must have a minimum length to reduce the successive parasitic inductance. DV^+ terminal of the integrated circuit, power SYNC digital terminal should be connected to V^+, DGND - with GND bus and parallel to them (terminals 15 and 16) a ceramic capacitor 1nF must be connected;
- Electrical wire in printed circuit board, which is connected to pin COSC (and the area of GND bus in COSC) should be minimal in order to reduce the parasitic capacity. Similar precautions should be taken in respect of DADJ, FADJ and Iin. C_F should be placed so that its contact to ground is near to pin (GND).

Compliance with all restrictions and implementation of system requirements, as presented (Fig.1.), ensures accurate measurement of the amplitude characteristics for all types of audio amplifiers.

II. Conclusion

The method developed for dynamic study of Gain Frequency Response allows high precision measurement in a wide frequency range. Its work in a wide frequency domain without using filters groups ensures low distortion and high non-linearity during the measurement;

The developed structural scheme allows DC offset of the test signal in order to compensate for the output signals in one polarity power supply.

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