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Infrasonic Band in a Computer Signal Generator and Spectrum Analyzer

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Abstract—A computer sound card, modified in order to extend its frequency range to include the infrasound and dc regions and designed for use as a component of a computer-based signal generator and a multifunctional spectrum analyzer, is described. After the modification, the lower frequency limit is 10^{-3} Hz for the generator, 10^{-2} for the spectrum analyzer, and zero (dc) for the oscilloscope.

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In developing computer-based devices—a sound-frequency generator [1] and a multifunctional spectrum analyzer including an oscilloscope, dc/ac voltmeter, and meters for measuring frequency, phase, noise, nonlinear distortions, power, and input-signal amplitude density distribution [2]—the voltage frequency range had to be extended to include the infrasound and dc regions.

As digital-to-analog converters (DACs) and analog-to-digital converters (ADCs), the mentioned devices use a standard computer sound system. The lower-frequency limit of most of the existing sound cards is of the order of 10–20 Hz. As a rule, this limitation is caused by coupling capacitors present at the ADC input and DAC output. To simply eliminate the coupling capacitors may prove insufficient to provide operation in the infrasound and dc regions, since both the ADC input and DAC output are dc offset relative to the device's analog ground. The offset is due to the unipolar (conventionally, 5-V) power supply most frequently used for these codecs (coder–decoder, ADC and DAC, are on the same chip). Therefore, for the sound card to operate in the infrasound and dc regions, an additional offset-adjustment circuit must be used both for the input and output signals.

This approach is advisable for two reasons at least: (1) this circuit provides high parameters, being many times cheaper than dedicated ADCs and DACs, and (2) in designing a measuring system with a frequency range including the infrasound and dc regions, the existing software [1–3] can be used.

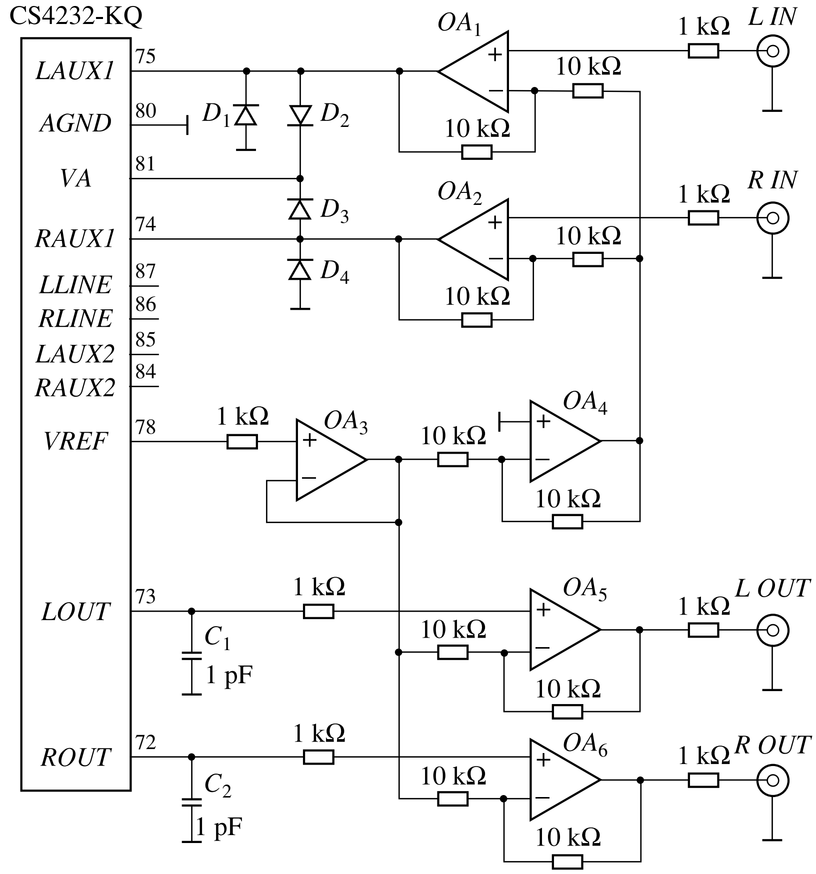
Let us consider the solution to this problem using a Crystal Semiconductor Co CS4232 two-channel 16-bit codec installed on a Turtle Beach Systems TBS2000 sound card as an example.

The circuit for adjusting the base level of the input and output signals and part of the codec circuit are shown in the figure. Also shown in the figure are the numbering and designations of the used leads of the CS4232 microcircuit, which is enclosed in a 100-lead TQFP package [4]. All connections to leads *LAUX1* and *RAUX1*, present on the sound card, must be removed. All elements except filtering capacitors C_1 and C_2, shown in the figure, must be disconnected from leads *LOUT* and *ROUT*.

As a reference-voltage source for the operational amplifiers of the level-adjusting circuit, reference-voltage source *VREF*, built into the CS4232 codec, is used. The CS4232 technical documentation indicates that the codec's input and output voltages are centered with respect to reference voltage *VREF*, which is 2.2 V [4]. Since this source allows no significant dc load [4], voltage follower OA_3 is connected to it as a buffer. The use of the reference-voltage source, built into the codec, considerably reduces the overall drift of the level-adjusting circuit caused by the temperature and supply-voltage variations. Reference-voltage inverter OA_4 is necessary for operation of the input-signal offset-adjustment circuit.

The offset-compensating circuit for the codec's output signals is built around operational amplifiers OA_5 and OA_6. Capacitors C_1 and C_2 are usually components of the sound card.

The offset-compensating circuit for the codec's input signals is built around operational amplifiers OA_1 and OA_2. Diodes D_1–D_4 at the outputs of the operational amplifiers are intended to protect the ADC inputs against the overvoltage, which occurs when the input signal exceeds the allowable level or during transient processes upon switching on or switching off the device.



Circuit for adjusting the base level of the input and output signals for the CS4232 codec: (OA_1–OA_6) AD743 and OA_5 AD745.

To feed the signal into the codec, input pairs *LLINE*, *RLINE* and *LAUX2*, *RAUX2* can be used. The feeding from these pairs is enabled by the program mixer, which is a component of the Windows operating system. All specified codec inputs may be supplied with offset-adjustment circuits. This would allow program switching of the feeding from three dual signal sources with no additional equipment used.

To fully realize the codec's potentialities (dynamic range of more than 80 dB [4]), low-noise devices with field-effect transistors placed in the input stages and with a rate of input-voltage rise of >1 V/μs in the unity-gain mode should be used as operational amplifiers OA_1–OA_6. Very good results are obtained with AD743 and AD745 low-noise operational amplifiers of foreign manufacture. The domestic 574UD1 and 544UD2 microcircuits are somewhat inferior in quality.

Large-offset operational amplifiers (574UD1 or 544UD2) should be supplemented with zero-correction circuits. Standard circuits should be used, which are usually given in the reference technical documentation. These correction circuits allow more accurate compensation for the zero offset of the codec's DAC and ADC. If the operational amplifiers require that external circuits be used to correct the frequency-response characteristic, then these circuits must also be made to their respective documentation.

All operational amplifiers are supplied from a bipolar low-noise dc source that furnishes a voltage of from ±5 to ±12 V. The ±12-V computer source may be used only if additional interference suppression is provided. All "ground" leads shown in the offset-adjustment circuit are connected to the sound card's "analog ground." In the CS4232, this is contact *AGND* (pin 80).

All resistors in the device must necessarily be low-noise ones, e.g., such as S2-1 metal-film resistors. For each operational amplifier, pairs of 10-kΩ resistors have been selected with a minimum spread in resistance values. This is essential in providing the best compensation for the offset. The nominal value of these resistors is of little significance and may be 5–10 kΩ. The 1-kΩ resistors are protection elements, and their spread in values is of no importance.

Diodes D_1–D_4 are any rf small-capacitance silicon diodes, e.g., KD509.

The optimal design of the offset-adjustment unit is a separate shielded printed-board assembly located above the sound card as a "second-floor" board. The additional board should be provided with a standard metal bracket with input and output connectors mounted on it.

Other sound cards built around various DAC and ADC microcircuits with a structure similar to that of the CS4232 can be modified in a similar way. It is obvious that their lead numeration and designations may differ from those shown in the figure. All these data must be obtained from the technical documentation on particular DAC and ADC microcircuits available on the manufacturers' websites.

One essential remark is necessary. In high-quality (and rather expensive) sound cards, digital high-pass filters with a cutoff frequency of an order of 1 Hz are sometimes used. This is the case, e.g., with Turtle Beach Systems' FIJI sound card. These filters are intended for compensation of the input ADC's offset and zero drift. The filters may be based on the chip of the built-in digital signal processor or be driver-based software filters. In neither case can very low frequencies be inputted into this sound card. Prior to the modification, this fact can be established only with a certain probability. The ADC's offset and zero drift should be measured in the absence of the input signal (with the input grounded), using the oscilloscope built in the multifunctional computer spectrum analyzer [2]. If the offset exceeds 5–10 lowest-order units and, in addition, changes with temperature, then, almost surely, no digital filter exists. A much smaller offset implies that either the ADC used is very good and stable or a digital high-pass filter is employed.

Another method of finding out if it is possible to apply the dc voltage consists in interconnecting leads *LAUX1* and *LOUT* (in designations of codec CS4232) and measuring the through amplitude–frequency characteristic in the region of extremely low frequencies (down to 10^{-3} Hz), using the generator [1] and oscilloscope [2]. This testing method is absolutely reliable, but it involves alterations (albeit minor ones) in the sound-card circuit.

The infrasound signals and direct current can nearly always be outputted without difficulty.

A computer signal generator [1] with the modified sound card provides an output-voltage lower frequency limit of 10^{-3} Hz. The lower frequency limit of the operating range of the computer spectrum analyzer [2] is 10^{-2} Hz and that the oscilloscope that is a component of the analyzer is zero (direct current). The upper limit of the operating frequency range is determined by the maximum sampling frequency of the CS4232 codec and is as high as 20 kHz. The nominal input and output voltages that correspond to the ADC and DAC full scale are ±1.4 V [4].

Upon compensation by the device developed, the ADC residual zero offset is determined by the ADC internal errors and does not exceed 0.1% of the converter's full scale. Further compensation for the ADC residual zero offset is performed by the software tools of the spectrum analyzer [2]. After compensation by the device developed, the DAC residual offset is determined by the DAC internal errors and does not exceed 0.05%. Measured with the input and output connected, the through dynamic range of the device, based on low-noise AD745 operational amplifiers of foreign manufacture, is 78 dB.

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