Designing with the Adaptive High Pass Filter

GENNUM CORPORATION

GR581/LS581 APPLICATION NOTE

DESCRIPTION

The LS581 and GR581 are unity gain adaptive 12 dB/oct. highpass Butterworth filters. The filter corner frequency varies from 200 Hz to 2 kHz, as the background noise level increases 20 dB above a predetermined threshold level of the internal rectifier. Once the noise level has increased 20 dB above the threshold, no further changes in the corner frequency will occur.

Designing with the GR/LS581 allows two options for placement of the filter section. It can be placed immediately after the microphone output or following a preamplifier. This choice is possible due to an input dynamic range of approximately 86 dB, based upon its typical noise floor level of 3 µV and large signal handling level of 65 mV at 5% distortion.

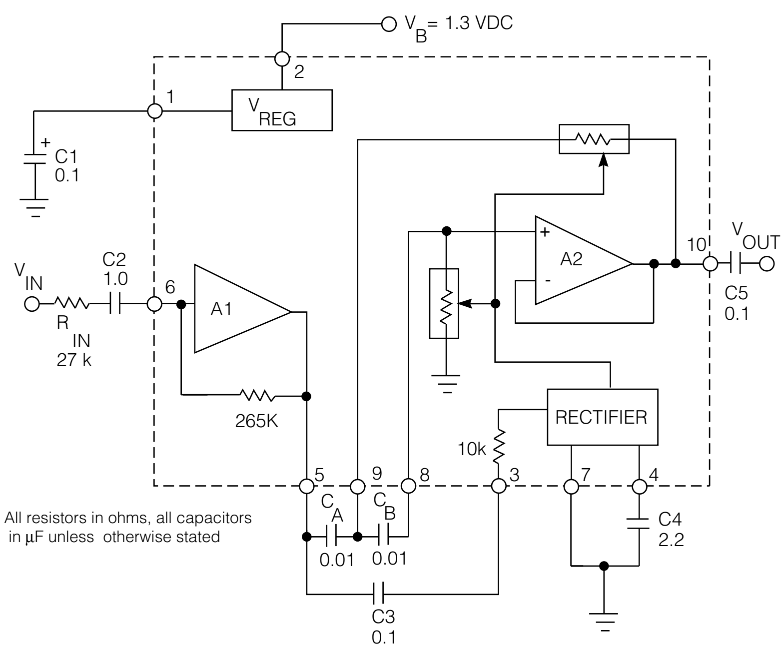
The rectifier on the GR/LS581 controls the position of the corner frequency of the filter. It has a typical input threshold of 2.5 mVRMS before it begins to adjust the corner frequency. Since 2.5 mVRMS input corresponds to 82 dBSPL (using a microphone with a sensitivity of -60 dBV / µB at 1 kHz) a preamplifier is required to lower the threshold to 60 dBSPL INPUT. Thus the GR/LS581 is required to have at least 20 dB of preamplification in front of the rectifier for operation. The preamplifier on the on the GR/LS581 is an inverting op-amp with a typical open loop gain of 45 dB. A 265 kΩ resistor is connected across the preamplifier to simplify gain setting and to reduce external components.

THEORY OF OPERATION

The GR/LS581 adaptive filter is designed to remove low frequency noise in the presence of speech. This is accomplished by using an adaptive filter with a varying corner frequency from 200 Hz to 2 kHz. The corner frequency location of the filter, depends upon two conditions, the amplitude and period of the incoming signal. The latter is the most important condition because it is this characteristic which differentiates between short term average speech and long term average noise.

The differentiation between speech and noise is accomplished by the setting of the attack time on the rectifier. With the attack time set to 30 ms or higher, the filter will not react as much to short term average speech frames less than 30 ms, but will be more responsive to relatively stationary background noise, which has a long term average level.

Once the rectifier has sensed the noise, the actual position of the filter corner frequency is dependent upon how far the noise level has exceeded the threshold level. This detection method provides a wideband response for speech and a narrow band for noise when present.



FUNCTIONAL BLOCK DIAGRAM

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This characteristic of differentiation of noise from speech is shown in the following figures.

Fig. 1 illustrates the frequency response of the filter measured at 3 input levels, 60 dBSPL, 70 dBSPL and 80 dBSPL. Pink noise is used as a source to simulate noisy conditions. Since the input is a constant noise the filter will always react to the signal once it is above the rectifier threshold. At 60 dBSPL IN the corner frequency of the filter begins at 200 Hz, while at 70 dBSPL IN it begins at 700 Hz and at 80 dBSPL IN, the corner frequency is at 2 kHz.

To demonstrate that the GR/LS581 is not as sensitive to speech as it is to noise, a simulated speech pulse is used as a test signal which simulates the temporal characteristic of speech. This speech weighted signal is filtered from 200 Hz to 4 kHz and it has a time period of 30 ms, see Fig. 2.

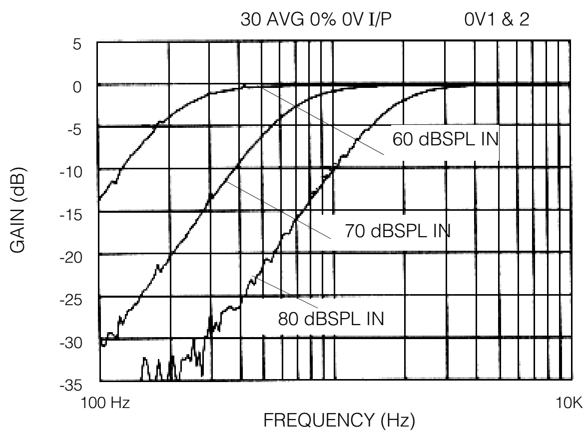


Fig. 1 Frequency Response of LS 581

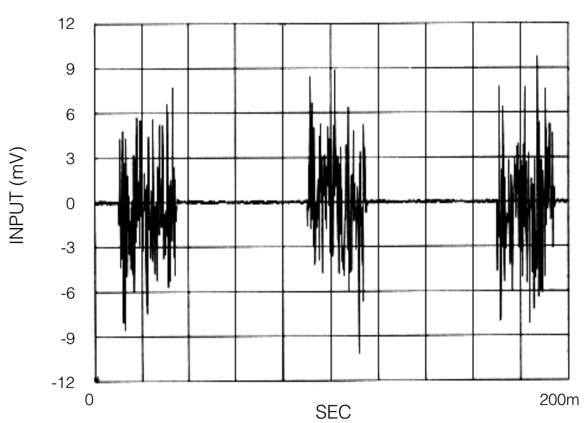
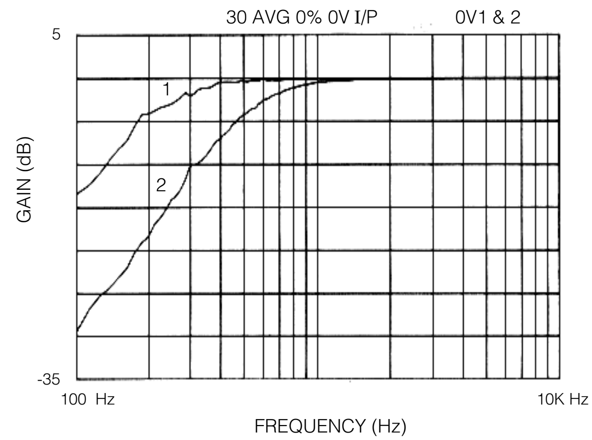


Fig. 2 Input vs. Time

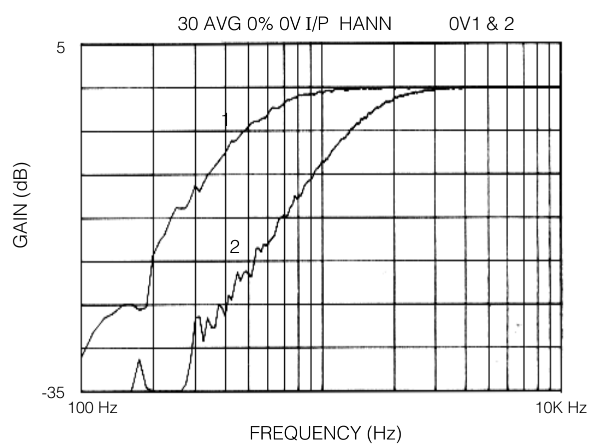
By applying the speech weighted signal to the input of the filter at a level equivalent to 70 dBSPL, a dual channel FFT analyser is used to extract the frequency response of the GR/LS581 filter and it is compared to the response of the filter with a pink noise input, also at 70 dBSPL IN, see Fig. 3.

The input levels for the speech weighted signal and pink noise are then increased to 80 dBSPL, with the resultant frequency response shown in Fig. 4.Notice that the frequency response of the speech weighted signal has increased slightly from Fig. 3 to Fig. 4. This is because the GR/LS581 filter, as previously stated, is also effected by signals exceeding the rectifier input threshold. However since it is pulsed noise, the average signal level is lower than that of the average signal level of pink noise at the same peak level.



Curve 1. Simulated speech at 70 dBSPL IN
Curve 2 Pink noise at 70 dBSPL IN

Fig. 3 Frequency Response of LS581



Curve 1. Simulated speech at 80 dBSPL IN
Curve 2 Pink noise at 80 dBSPL IN

Fig. 4 Frequency Response of LS581

APPLICATION CIRCUITS

The LS581 will operate in conjunction with linear amplifiers or compression amplifiers, and is compatible with a variety of output stages.

For the linear configuration, which is also the lowest parts count circuit, the LS581 could be combined with the LS505 as shown in Fig. 5. It is important that the gain of the preamplifier to the GR/LS581 rectifier be set to approximately 20 - 25 dB, in order to set the threshold to 60 dBSPL or as required.

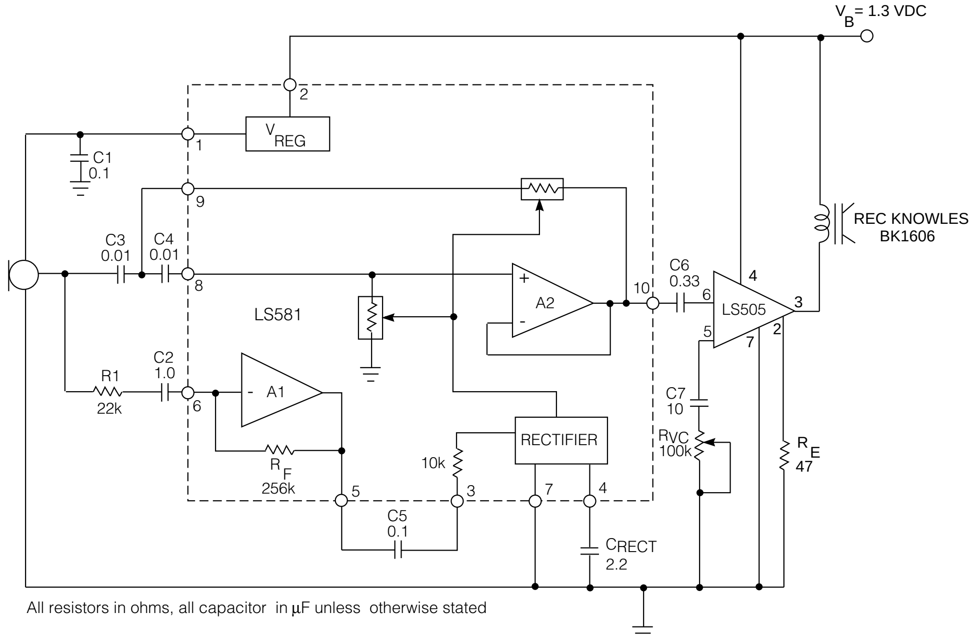


Fig. 5 LS581/LS505 Typical Application Circuit

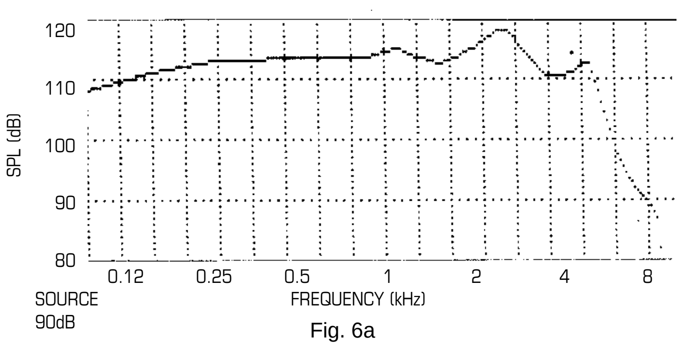


Fig. 6a

MAX OUTPUT
118.0 dBSPL
AT
1.900 kHZ

HF AVG
FULL ON GAIN
54.0 dB SPL
60.0 dB SPL
INPUT

RESP. CURVE GAIN
36.0 dB

90 dB HF AVG
113.5 dB SPL

90 dB HF AVG-77=
36.5 dB

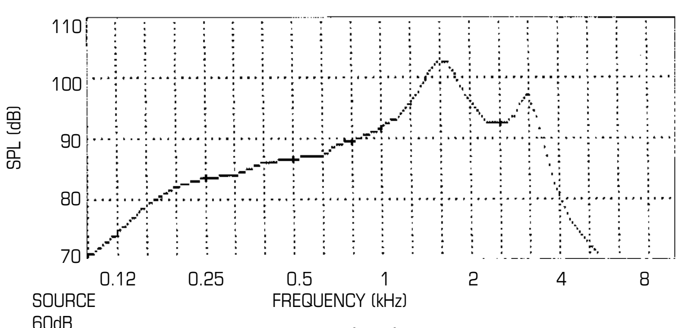


Fig. 6b

RESPONSE LIMIT: 76.0
F1: 0.136 kHz
F2: 4.438 kHz

EQUIVALENT
INPUT NOISE
27.5 dB SPL

TOTAL HARMONIC DIST:
1 % AT 0.5 kHz
% AT 0.8 kHz
1 % 1.6 kHz

BATT. CURRENT
1.12 MA AT
ZINC-AIR (1.30V)
SETTING WITH
65 dB SPL AND
1.000 kHz INPUT

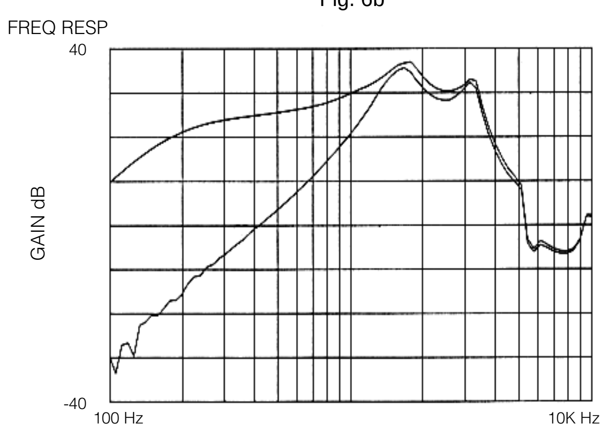


Fig. 6c

Figs. 6a,b,c Acoustic Performance Graphs of the LS581/LS505

Since the GR/LS581 filter section is unity gain, inserting it into an existing application such as the LS505 will not effect the HFA gain of the 505 hearing aid circuit, providing that the gain is measured when the filter has its corner frequency at its lowest point of 200 Hz. The acoustic performance of the 581 / LS505 is shown in Fig. 6.

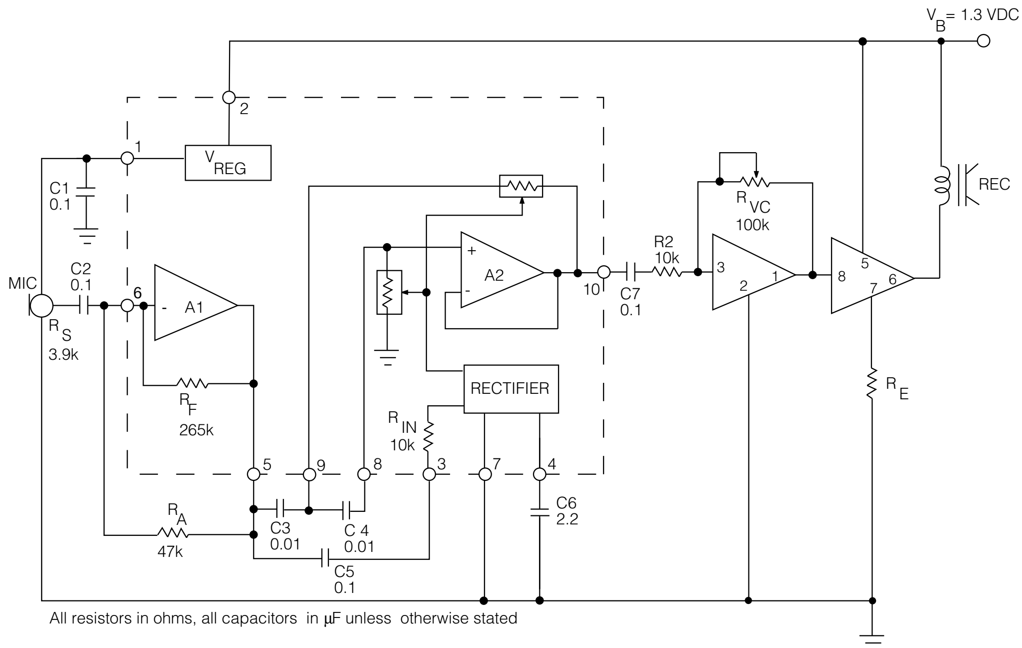


Fig. 7 LP508/LS581 Typical Application Circuit

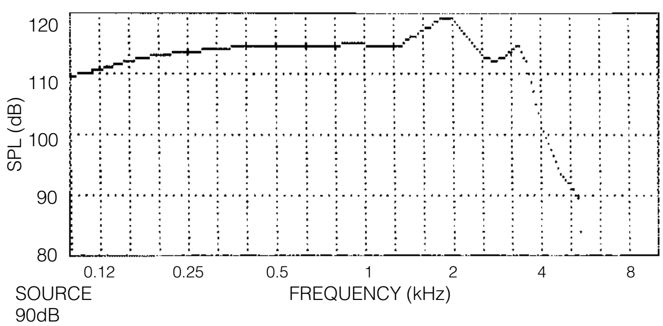


Fig. 8a

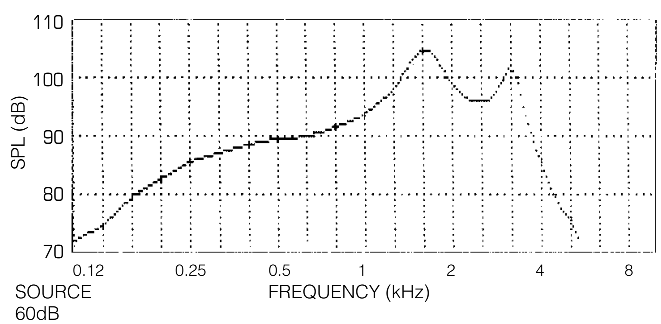


Fig. 8b

For an improved version where the gain of the hearing aid circuit can be trimmed, the GR/LS581 can be combined with the LP508, Fig.7, with the corresponding acoustic curves shown in Fig. 8.

If compression is required to limit high input transients, combine the GR/LS581 with the LD511 (Fig.9) for output compression, and the GR/LS581 with the LD512 (Fig. 10) for input compression.

It is not recommended that the compression amplifier drive the 581rectifier, because the gain of the compression amplifier is dependent upon the input signal level.

The LS581 device is replaced by the GR581 adaptive high pass filter. For differences between those devices refer to document number HP 2783.

RESPONSE LIMIT: 78.0
F1: 0.149 kHz
F2: 4.650 kHz

EQUIVALENT
INPUT NOISE
25.0 dB SPL

BATT. CURRENT
1.16 MA AT
ZINC-AIR (1.30V)
SETTING WITH
65 dB SPL AND
1.000 kHz INPUT

TOTAL HARMONIC DIST:
1 % AT 0.5 kHz
% AT 0.8 kHz
1 % 1.6 kHz

MAX OUTPUT
119.0 dBSPL
AT
2.000 kHz

HF AVG
FULL ON GAIN
52.0 dB SPL
60.0 dB SPL
INPUT

RESP. CURVE GAIN
38.5 dB

90 dB HF AL
115.0 dB SPL

30 dB HF AVG-77=
38.0 dB

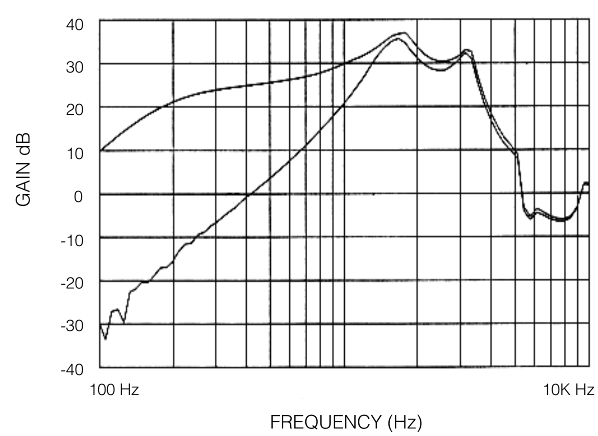


Fig. 8c

Figs 8a, b, c Acoustic Performance Graphs of the LP508/LS581

Since the gain of the compression amplifier is changing, the threshold of the GR/LS581 rectifier will not be constant. Instead, a linear preamplifier, such as the LS581 preamplifier or a section of the LC508, should be used to drive the rectifier control circuitry, making the threshold on the section of the LC508, should be used to drive the rectifier control circuitry, making the threshold on the GR/LS581 independent of the gain of the compression amplifier.

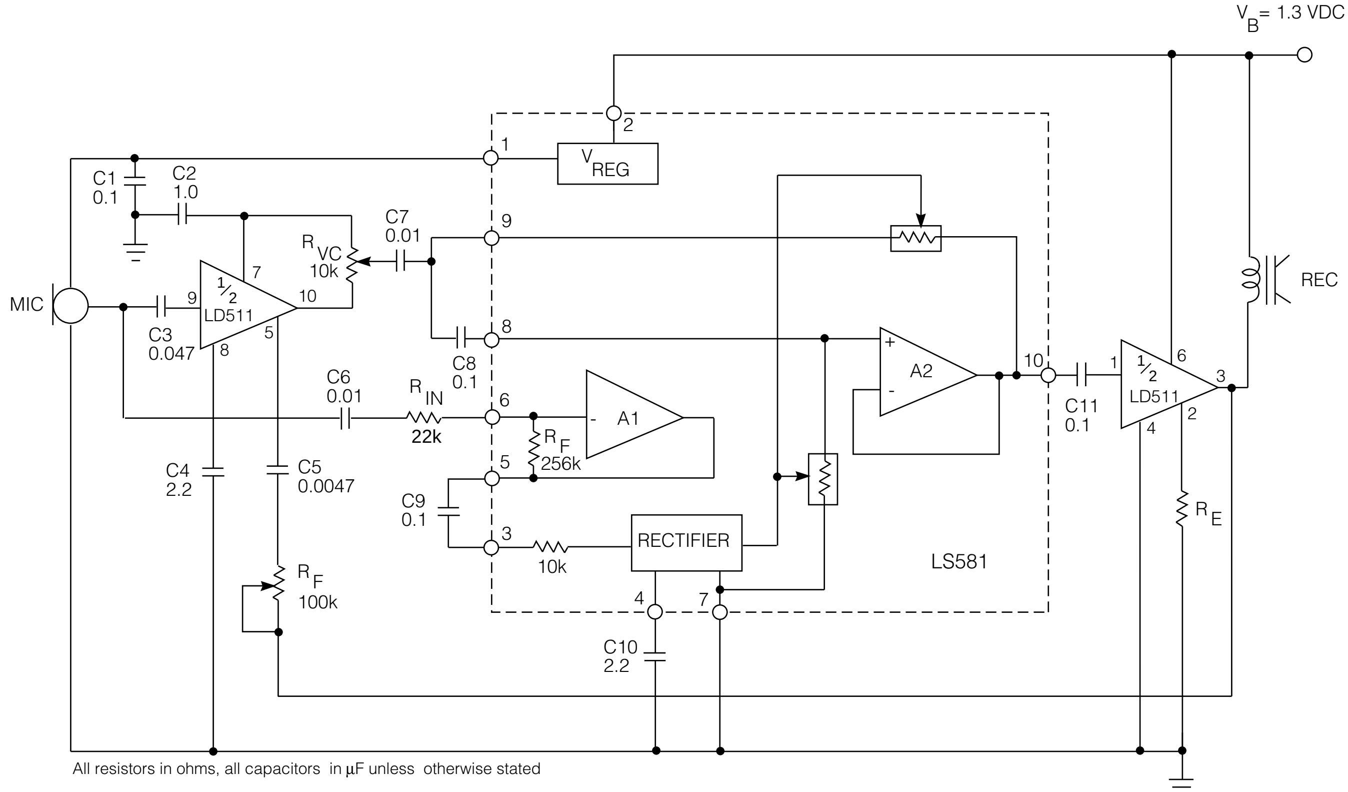


Fig. 9 LS581/LD511 Typical Application Circuit (for output compression)

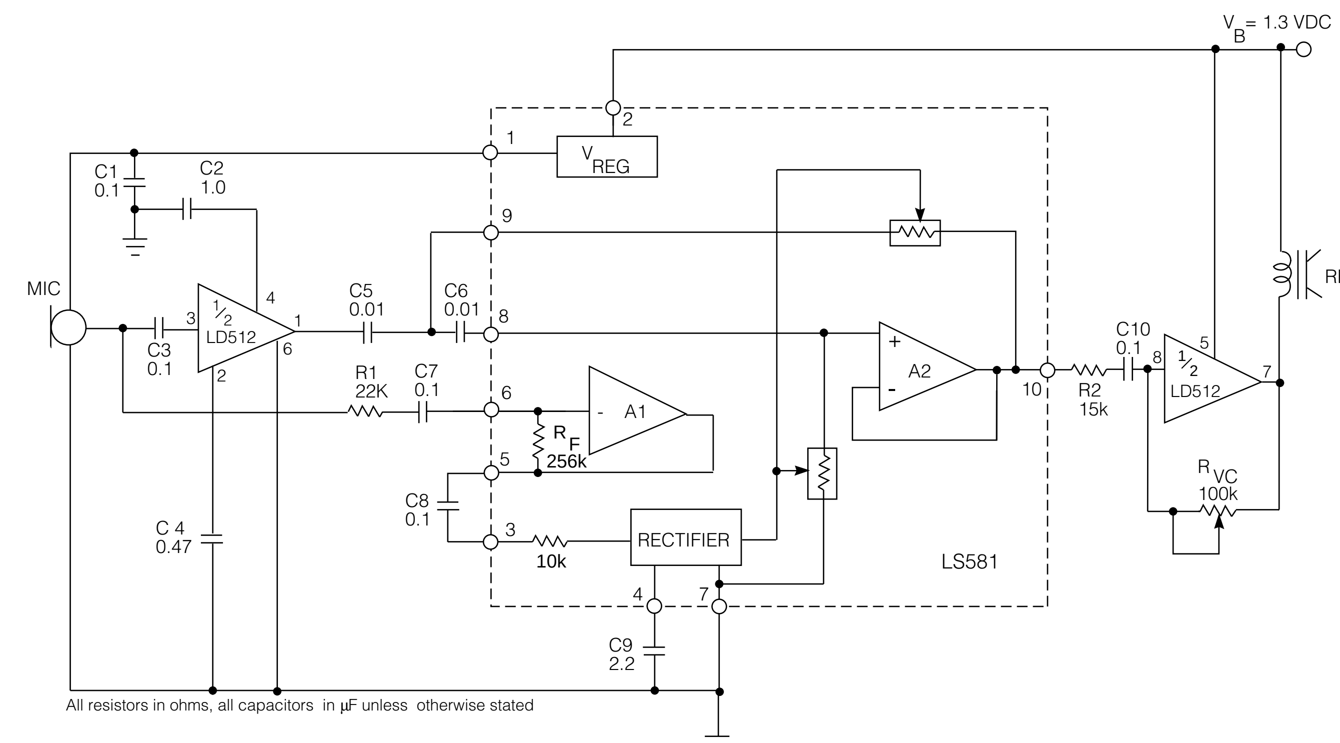


Fig. 10 LS581/LD512 Typical Application Circuit (for input compression)