Using the DynamEQ™ -1
with Class B and Class D

INFORMATION NOTE

OVERVIEW

Gennum's new GS3011 hybrid contains the GC514 chip and all required capacitors and resistors for a stand alone class A system.

The hybrid was designed to handle large input signals (approximately 110 dBSPL) and produce a distortion free output with moderate gain. However, should more gain be required than available from the GS3011 on its own, a class B or class D output stage may be added to the system.

This note will illustrate examples of how a class B and class D output stage can be added to the GS3011 to obtain a high gain system for profound hearing losses.

INTRODUCTION

The GC514 contains two unique AGC detection circuits that detect the average RMS energy of the incoming signal rather than the more traditional peak detector. The slow average circuit detects the long term or background energy in the users environment and sets the gain in Stage A accordingly. Should a sudden loud pulse occur whose average value exceeds that of the slow detector by 6 dB, the fast detector will take control and reduce the gain of Stage A for the duration of pulse.

Stage A is a high pass, 2:1 compression block. The output impedance of the microphone in conjunction with the input coupling capacitor, and the input resistance of the GC514 chip form a high pass filter with a corner frequency of approximately 2600 Hz. This implies that frequencies below 2600 Hz will be attenuated by 6 dB/oct. The hybrid has been designed to allow the manufacturer to lower this corner frequency by the addition of one external capacitor (CHP).

The amplitude of the input signal at which Stage A enters 2:1 compression is nominally -94 dBV. However, provisions have been made on the hybrid to allow the manufacturer to increase this threshold by adding one external resistor (R_{TH}).

Stage B is an "All Pass" unity gain preamplifier whose output is added to the output of Stage A via the summing network formed by R4 and R5. When the outputs of Stage A and Stage B are summed together the result is a response that has a TILL (Treble Increase at Low Levels) frequency characteristic. When the amplitude of the input signal is small, the output of Stage A will dominate the summed response. As the amplitude of the input signal increases, the signal out of Stage A will be compressed and the signal through the all pass preamplifier, Stage B, will begin to dominate the shape of the response. At an input level of approximately -45 dBV Stage B will begin to dominate the response and the system returns to a linear 1:1 output.

The gain of Stage C is determined by the ratio of the feedback resistor to the equivalent impedance formed by R4 and R5 (approximately 25 kΩ).

Stage D is a class A, current drive output whose voltage gain is determined by the ratio of AC impedance seen at pad 10 to the resistance from pad 11 to ground. Pad 11 is the unity gain non-inverting, buffered output of the signal applied to the input of Stage D. It is nominally DC biased at a voltage of 54 mV DC, which implies that this point is capable of an AC voltage swing of 54 mV peak (-28 dBV) before clipping occurs. The transducer current, or the current flowing into pad 10, is determined by the 54 mV DC bias at pad 11 divided by the resistance from pad 11 to ground.

AGC MEASUREMENT TECHNIQUES

Traditionally, AGC circuits have been measured with a swept pure tone signal, much the same way as a linear hearing instrument. This has been an excepted standard which unfortunately for a frequency dependent AGC system such as the DynamEQ™ -1 causes anomalies in the shape of the response obtained. In fact the measured results may not accurately represent what the user of the device actually experiences.

Figure 1 below depicts a simplified version of Stage A on the GS3011 hybrid with all of the associated resistors and capacitors.

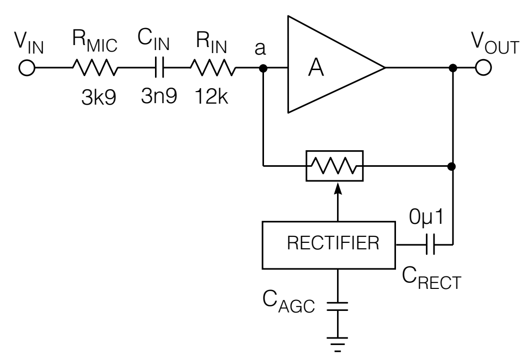

Fig. 1 Simplified Schematic of Stage A on GS3011

As previously mentioned, C_{IN}, R_{IN}, and R_{MIC} form a high pass filter with a corner frequency of approximately 2600 Hz. The input impedance of the rectifier and the 0.1µF input coupling capacitor C_{RECT} also form a high pass filter, however the -3 dB corner frequency of this filter is low enough that it can be disregarded.

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Figure 2 shows the results of measurements performed on Stage A of the GS3011 hybrid using a pure tone sweep and a random noise source of equal RMS amplitude.

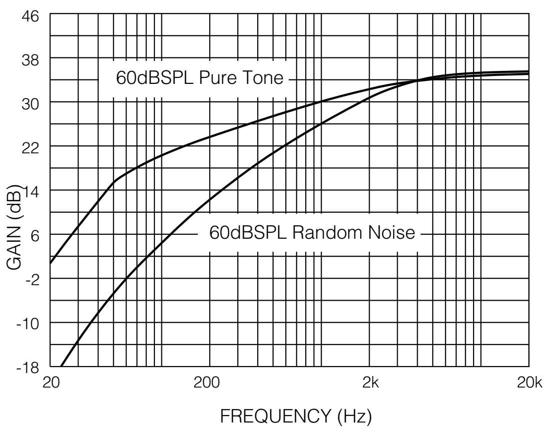


Fig. 2 Pure Tone Sweep vs Random Noise of Stage A on GS3011

Using the swept pure tone method of analysis where V_{IN} is a constant amplitude and the frequency is incrementally increased, the amplitude of the signal appearing at point "a" in Figure 1 will increase at a rate of 6 dB/oct due to the filtering action of R_{MIC}, C_{IN} and R_{IN}. Therefore, at very low frequencies, the signal appearing at point "a" will be very small and the amplitude of the signal appearing at V_{OUT} and the input to the rectifier will not be large enough to cause the gain of Stage A to be significantly reduced.

As the frequency more closely approaches 2600 Hz the amplitude of the signal appearing at point "a" will approach maximum, and the gain of the stage will be compressed to its maximum. The result of this is that the gain of the low frequencies is artifiicially boosted up.

Using a random noise source, all frequencies are presented to the input at the same time and the RMS signal appearing at the rectifier sense point is constant. This means for the entire frequency spectrum the gain of the stage is consistent, and the low frequencies are amplified by the same amount as the higher frequencies. Using this method more closely simulates real life situations, where for example, a room full of people are talking at the same time and more than one tone is present.

As can be seen in Figure 2 there is a significant difference in the results obtained between the two measurements. Since the random noise method more closely approximates a real life listening environment, all frequency measurements, both electrical and acoustic have been performed using a random noise source.

BANDWIDTH LIMITING

There have in the past been some oscillation problems occurring with the **DynamEQ™ -1** system when the person wearing the hearing instrument is in close proximity to a computer monitor or television. It was discovered that the cause of this was that Stage C has a very wide bandwidth and picks up the radiating frequency and amplifies it. To avoid this problem, it is required to restrict the bandwidth of the circuit, which we have done by placing a 150 pF capacitor across the volume control resistor. Therefore, as the gain is turned up the bandwidth is decreased to approximately 10 kHz, and as the gain is turned down the system bandwidth increases.

All of the application circuits discussed in this note will show this capacitor across the volume control. However, should the GS3011 be used as a stand alone class A system, a capacitor across the receiver may be used in place of the capacitor across the volume control to limit the bandwidth of the system.

CLASS B CONFIGURATION

GS3011 - LC549

In the circuit below we are driving the input of the LC549 from pad 11 of the GS3011, which as mentioned previously is the non-inverting unity gain output of Stage D. With pad 10 shorted to supply, pad 11 is capable of delivering -28 dBV of AC signal before clipping occurs.

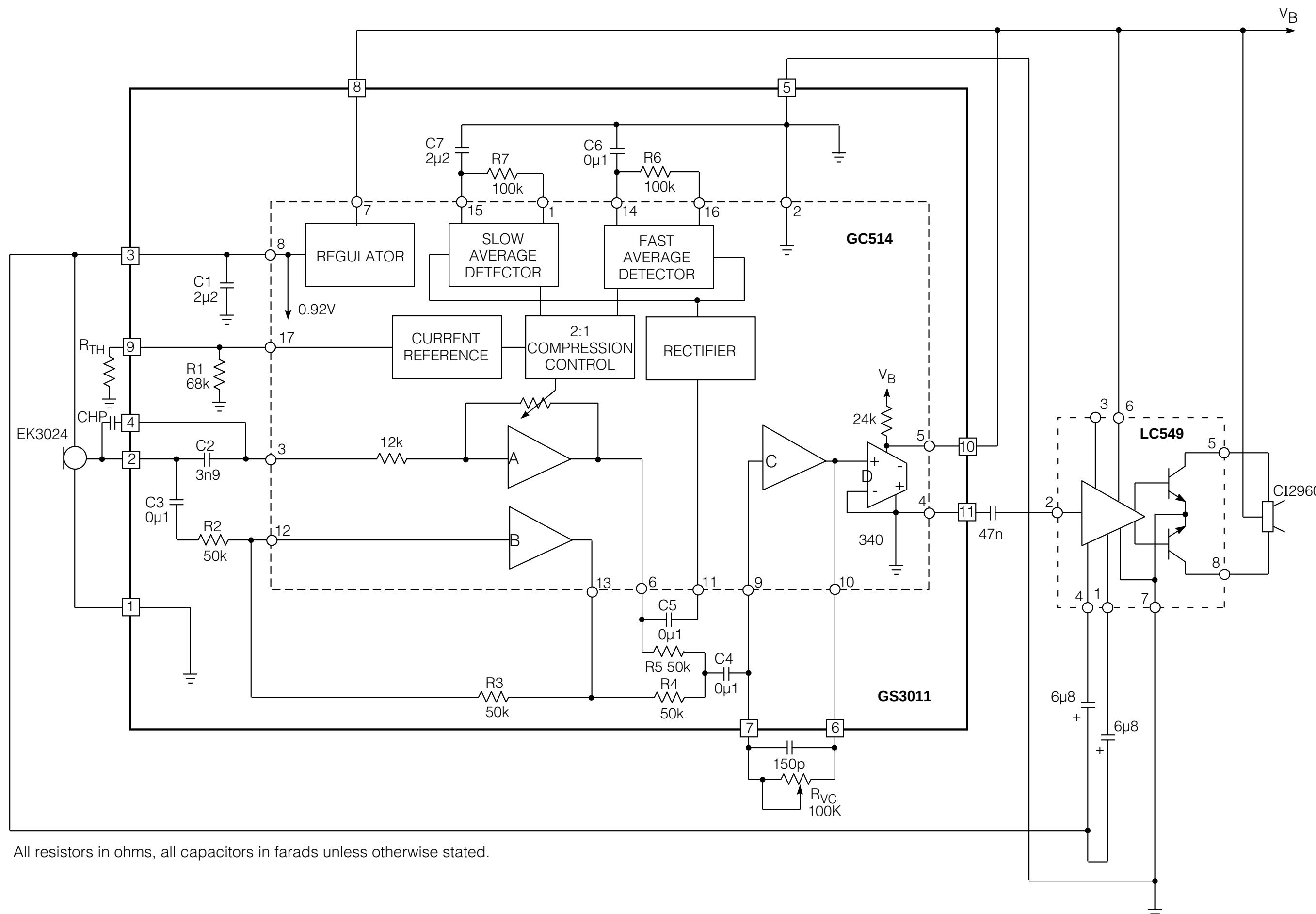


Fig. 3 GS3011 - LC549 Application Circuit

The LC549 Class B output stage is capable of driving low impedance loads and has a typical voltage gain of 40 dB. The two 6.8 μF decoupling capacitors are connected to the regulator of the GS3011 to minimize the start up current of the LC549.

Please see Application Note "Reduction of Startup Times for the LC549" for more information.

The circuit as configured is capable of almost 70 dB of acoustic gain. However, the penalty paid for this large amount of gain is that the system is no longer capable of handling large input signals cleanly. In fact, with R_{VC} at maximum (100 kΩ) the system will begin to overload at an input level between 70 and 80 dBSPL. For users who do not require this amount of gain, it is recommended that the value of the volume control potentiometer be reduced.

ELECTRICAL CHARACTERIZATION

To evaluate the electrical performance of the system the microphone was replaced with a series resistance of 3.9 kΩ and the receiver replaced with a 390 Ω transformer coupled load.

The curves on page 4 illustrate the electrical output of the system under various conditions.

ACOUSTIC RESPONSE

The acoustic responses on page 5 were obtained with R_{VC}=100 kΩ except Figure 11 where RVC≈25 kΩ. The intention of Figure 11 is to illustrate the signal handling capability of the system under more reasonable gain settings.

ELECTRICAL RESPONSE OF GS3011 - LC549

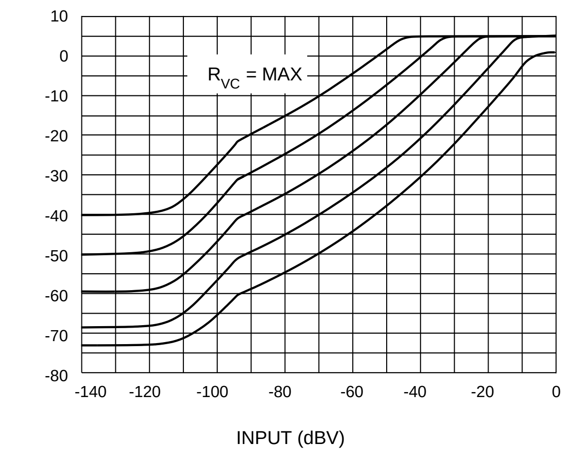


Fig. 4 Input vs Output as R_{VC} is Varied
(Frequency = 3kHz)

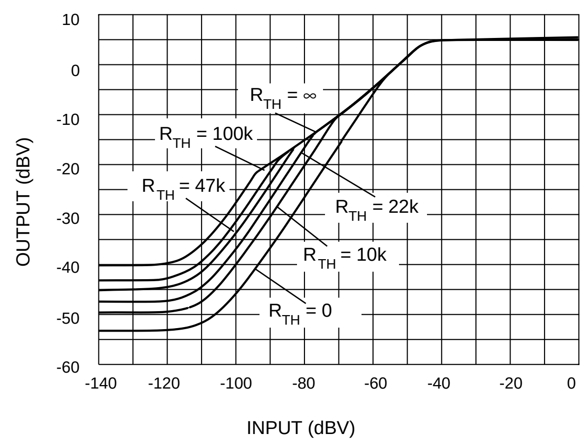


Fig. 5 Input vs Output as R_{TH} is Varied
(Frequency = 3kHz)

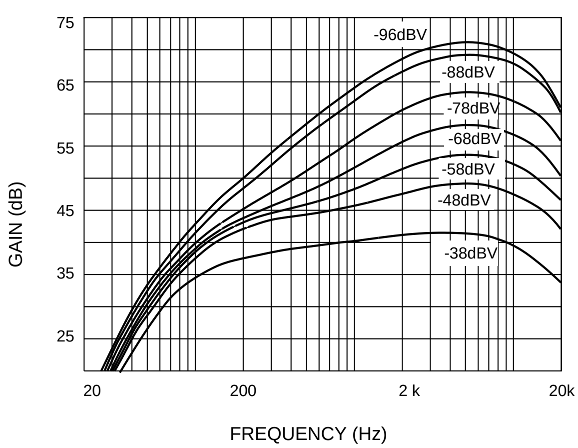


Fig. 6 Gain vs Input Level

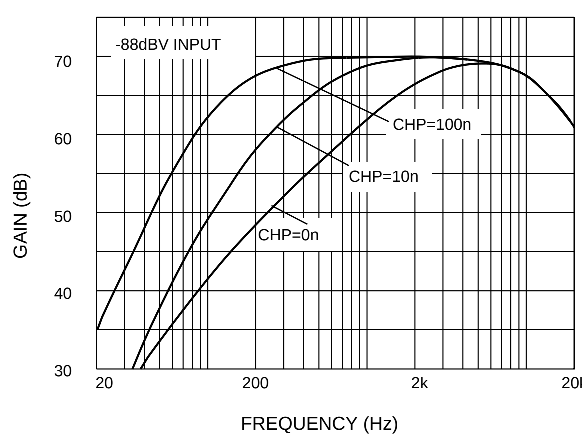


Fig. 7 Gain vs Frequency Response as CHP
is Varied

ACOUSTIC RESPONSE OF GS3011 - LC549

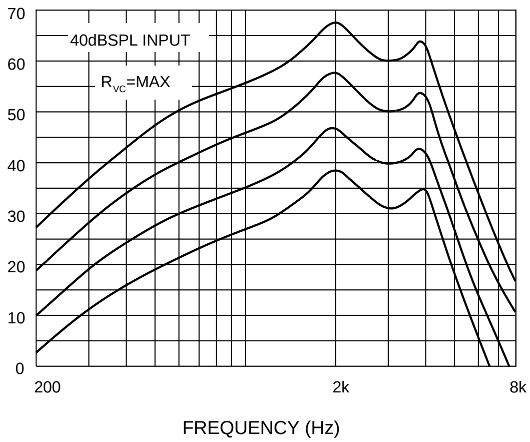


Fig. 8 Gain vs Frequency as R_{VC} is Varied

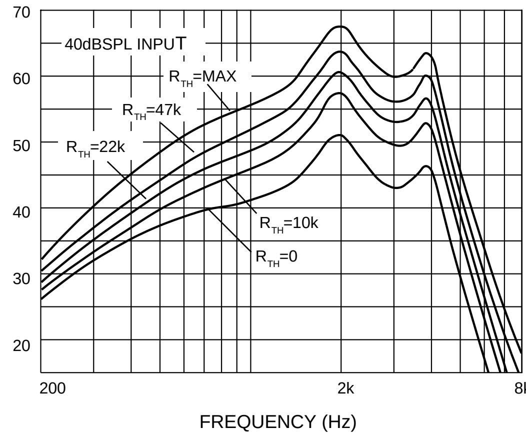


Fig. 9 Gain vs Frequency as R_{TH} is Varied

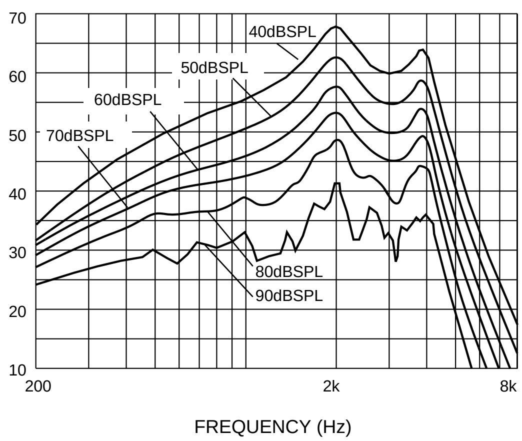


Fig. 10 Gain vs Frequency as Input Level is Varied (R_{VC} = 100 kΩ)

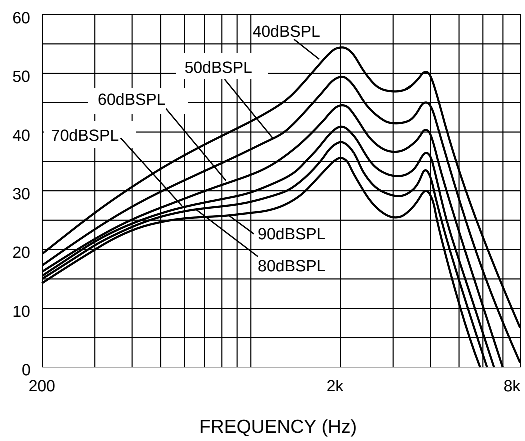


Fig. 11 Gain vs Frequency as Input Level is Varied (R_{VC} ≈25 kΩ)

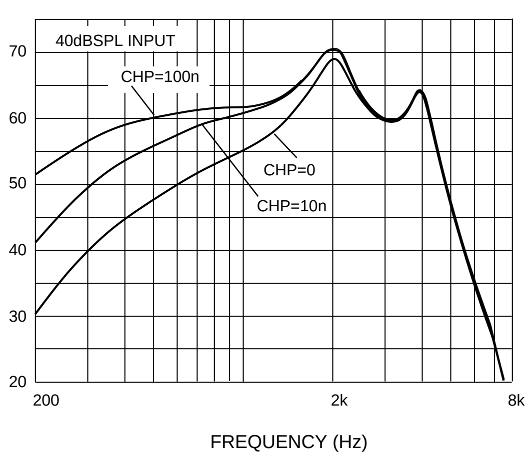
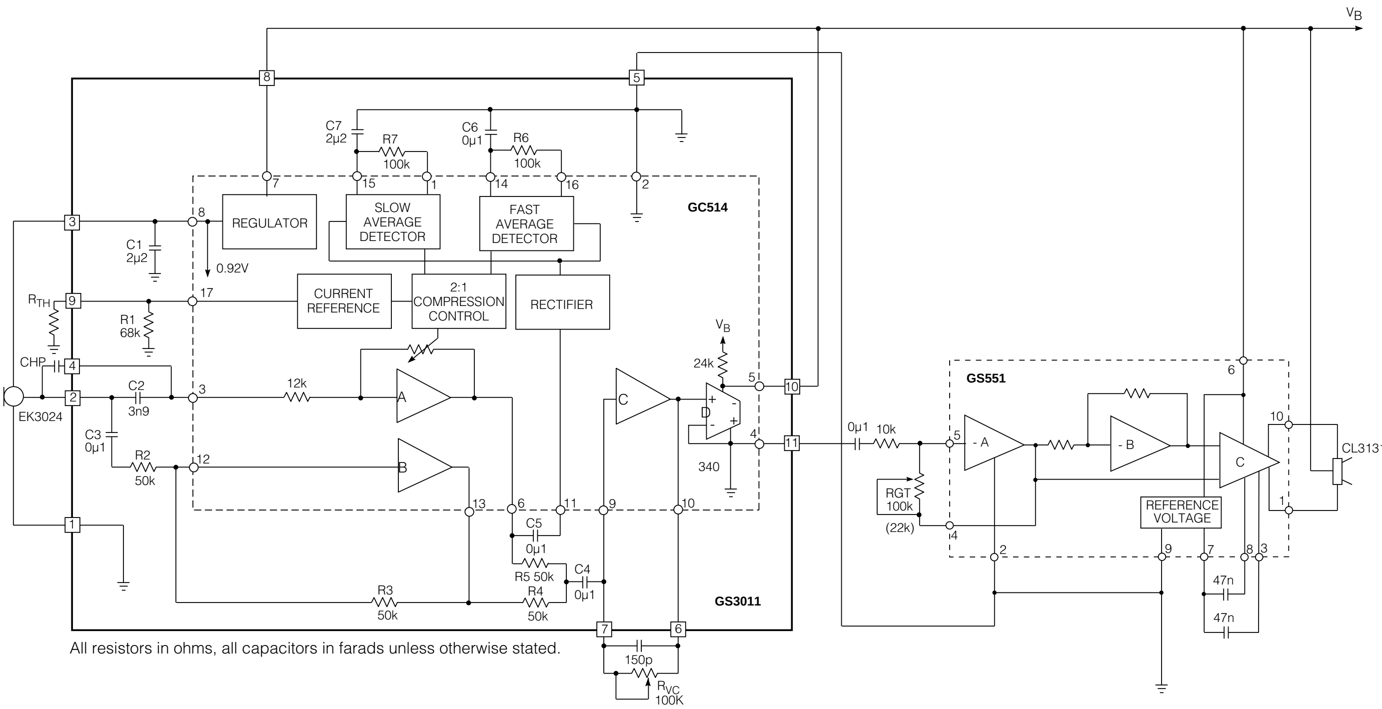


Fig. 12 Gain vs Frequency as CHP is Varied



GS3011 - GS551

Fig. 13 GS3011 - GS551 Application Circuit

As in the application circuit utilizing the LC549, we are once again driving the input of the GS551 from the emitter of the class A output transistor.

The GS551 class B driver is composed of 3 stages. Stage A is an inverting preamplifier with an open loop voltage gain of typically 50 dB and its closed loop set by two external resistors. Stage B is a unity gain inverting amplifier required to drive Stage C with alternating phases of the input signal. Stage C is a class B output driver and typically has a fixed AC voltage gain of 28 dB.

For stability reasons it is recommended that Stage A not be configured for more than 20 dB. This dictates a maximum total block gain of 48 dB.

This system, as the GS3011-LC549 previously discussed, has almost 70 dB of acoustic gain and is unable to handle input signals much greater than 70 dBSPL without distorting. Therefore, if this large amount of gain is not required, the value of the volume control and gain trim resistors could be reduced.

The following responses were obtained with R_{VC}=100 kΩ with the exception of Figure 11 where R_{VC}≈25 kΩ. The intention here again is to illustrate the signal handling capability of the system under more reasonable gain settings.

ELECTRICAL RESPONSE OF GS3011 - GS551

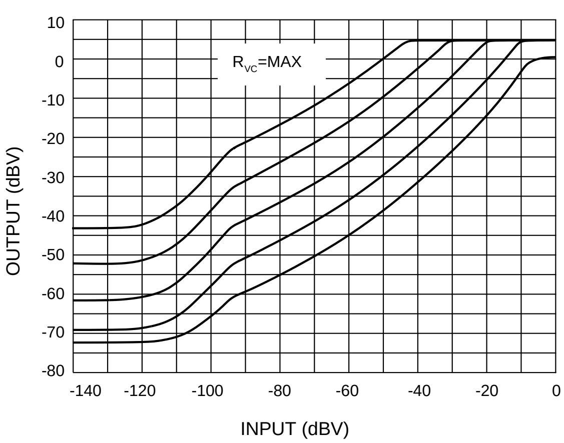


Fig. 14 Input vs Output as R_{VC} is Varied
(Frequency = 3kHz)

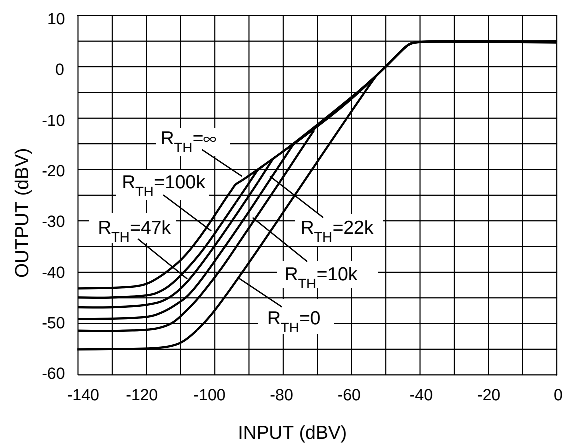


Fig. 15 Input vs Output as R_{TH} is Varied
(Frequency = 3kHz)

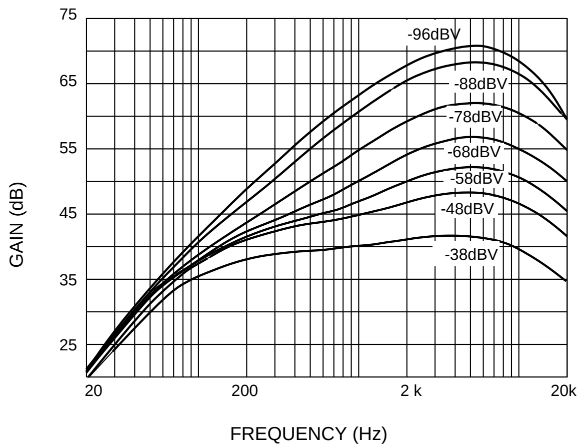


Fig. 16 Gain vs Input Level

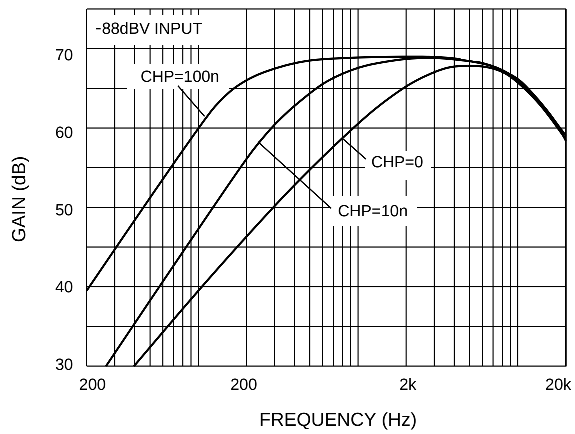


Fig. 17 Gain vs Frequency as CHP is Varied

ACOUSTIC RESPONSE OF GS3011 - GS551

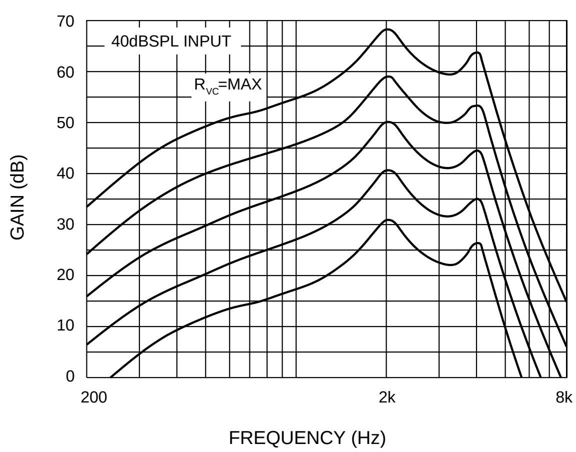


Fig. 18 Gain vs Frequency as R_{VC} is Varied

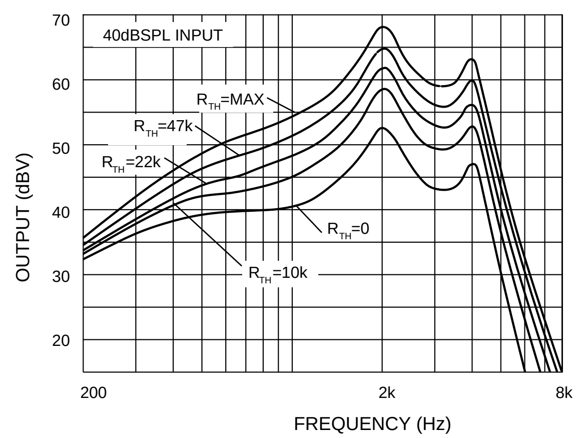


Fig. 19 Gain vs Frequency as R_{TH} is Varied

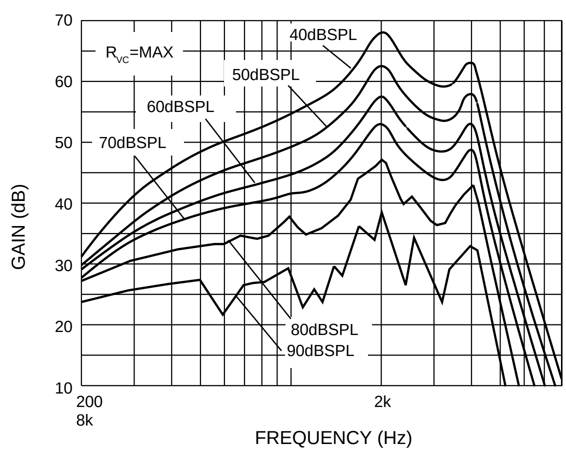


Fig. 20 Gain vs Frequency as Input Level is Varied (R_{VC} = 100 kΩ)

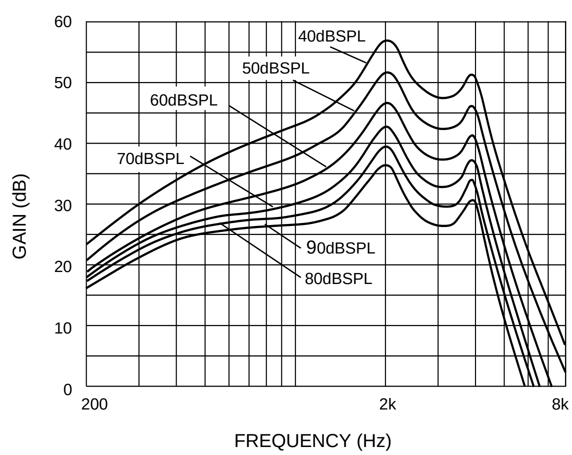


Fig. 21 Gain vs Frequency as Input Level is Varied (R_{VC} ≈25 kΩ)

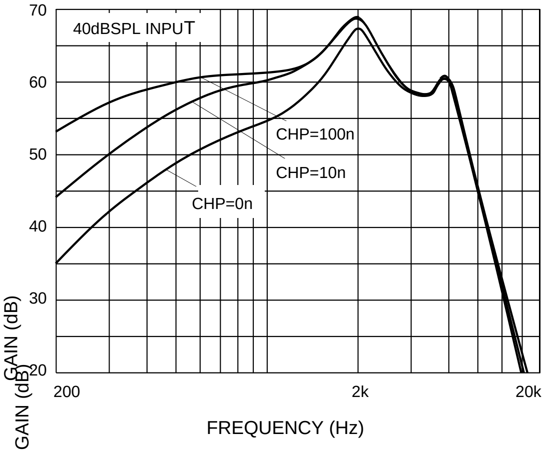


Fig. 22 Gain vs Frequency as CHP is Varied

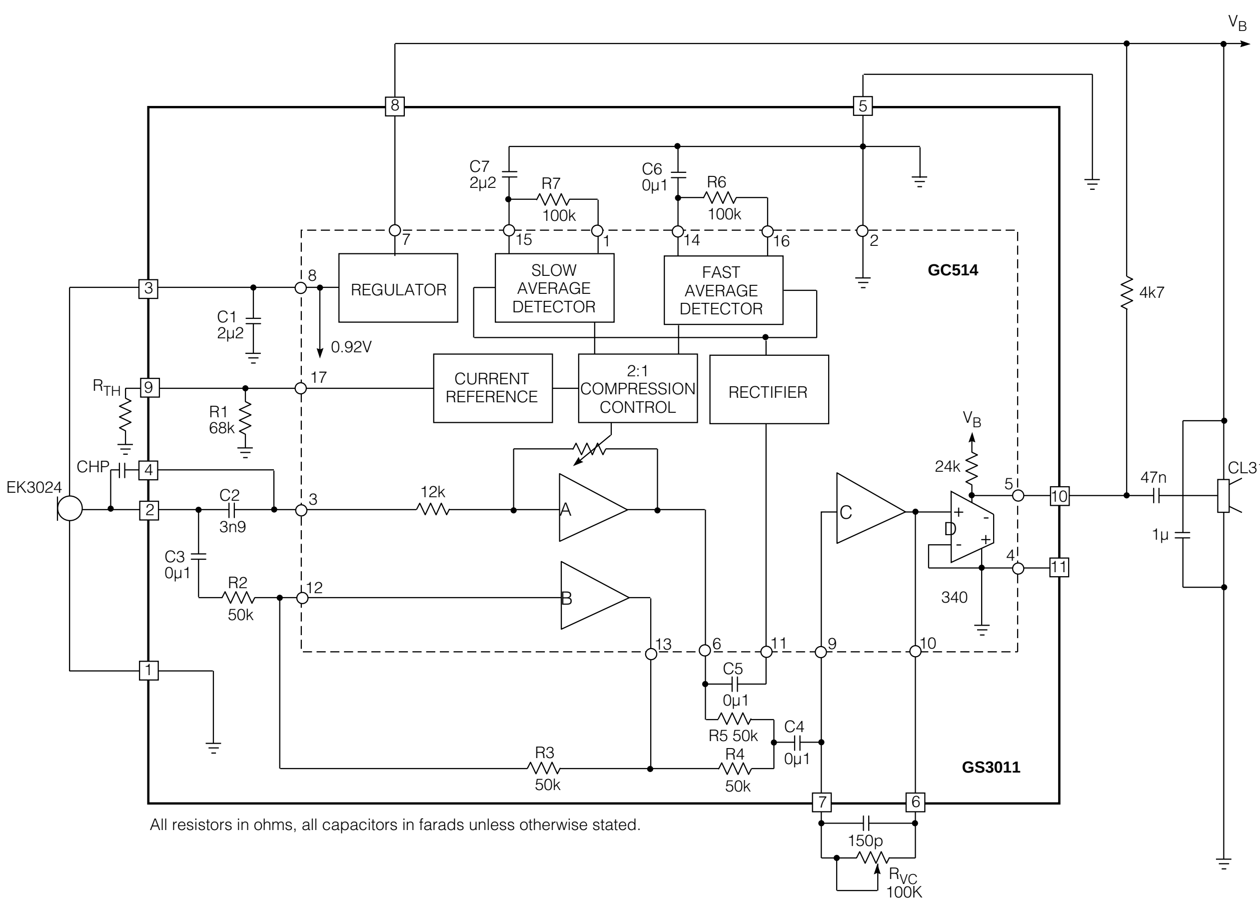
GS3011 - CLASS D

Knowles recommends that for best performance and minimum distortion, the circuit driving the class D receiver be "Mid Supply Referenced". This basically means that the impedance seen looking back into the driving amplifier is the same to the supply as it is to ground. Looking into Knowles class D receiver you see an equivalent AC impedance of 50 kΩ. To truly make Stage D of the GS3011 "Mid Supply Referenced" would require the addition of two resistors, one from pin 10 to supply and another from pin 10 to ground. Doing so may improve distortion, however it would also waste a significant amount of current.

Figure 23 illustrates a minimum component configuration of how we can compromise on distortion and save current. Stage D in the circuit is " Supply Referenced". The current flowing into pin 10 of the GS3011 is determined solely by the DC voltage at pin 11 divided by the equivalent resistance from pin 11 to ground. The DC voltage at pin 11 is nominally 54 mV and the on-chip resistance to ground is nominally 340 Ω . Therefore, the nominal transducer current will be 54 mV/3 4 0 Ω =1 6 0 µA. By placing the 4.7 kΩ resistor in parallel with the 24 kΩ on chip resistor, we have an equivalent resistance of 3930 Ω. Therefore, 160 µA flowing through 3930 Ω will produce a 0.623 V drop across the resistance. Assuming a battery voltage of 1.3 volts, means pad 10 will be biased at 1.3-0.623=0.677 V which is approximately half of the supply voltage. The reason we would like to bias pin 10 to half of the supply voltage is so that when the output begins to clip it will do so symmetrically. The gain of Stage D will be equal to 20 x (log(3930/340))= 21 dB.

This circuit like the previous two have a great deal of gain. Electrically the system has approximately 50 dB of gain, and the addition of the class D receiver and EK3024 microphone will add an additional 20 dB or more of gain. Should the user not require this amount of gain, once again the value of the volume control resistor could be reduced.

The curves on the following pages illustrate the electrical and acoustic response of the circuit. Figure 31 illustrates the large input signal handling capabilities of the system with the value of the volume control turned down to approximately 5 kΩ.



All resistors in ohms, all capacitors in farads unless otherwise stated.

Fig. 23 GS3011 - Class D Application Circuit

ELECTRICAL RESPONSE OF GS3011 - CLASS D

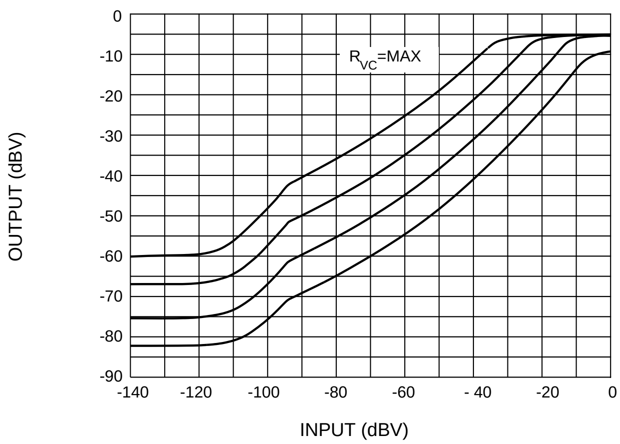


Fig. 24 Input vs Output as R_{VC} is Varied
(Frequency = 3kHz)

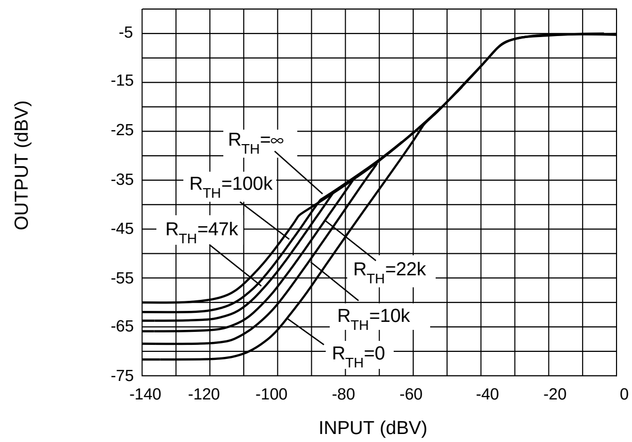


Fig. 25 Input vs Output as R_{TH} is Varied
(Frequency = 3kHz)

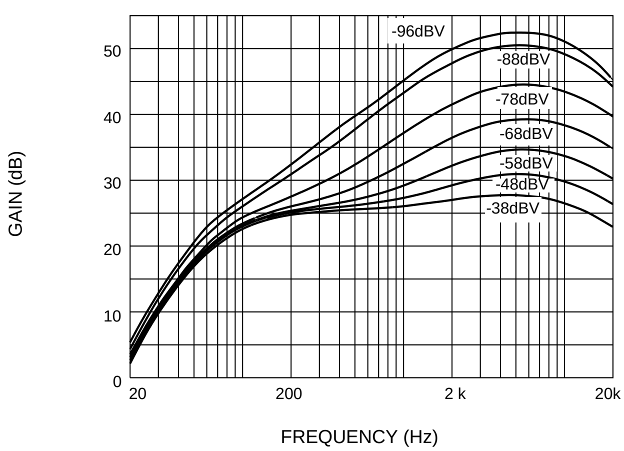


Fig. 26 Gain vs Input Level

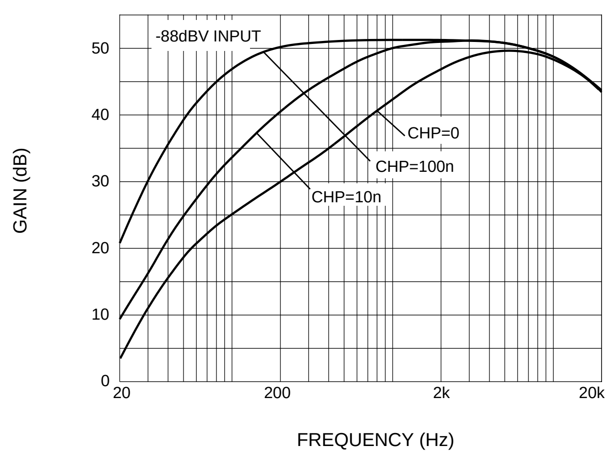


Fig. 27 Gain vs Frequency as CHP
is Varied

ACOUSTIC RESPONSE OF GS3011 - CLASS D

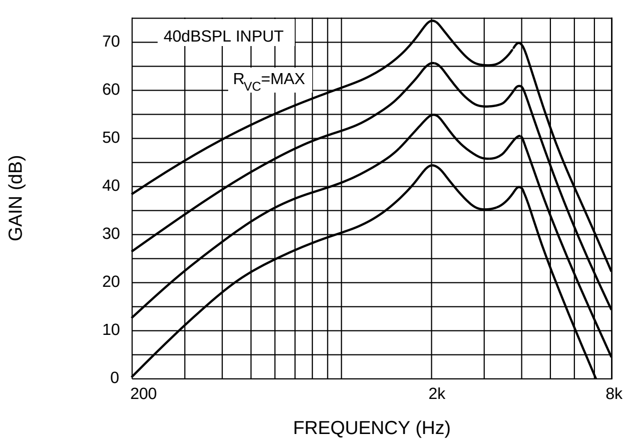


Fig. 28 Gain vs Frequency as R_{VC} is Varied

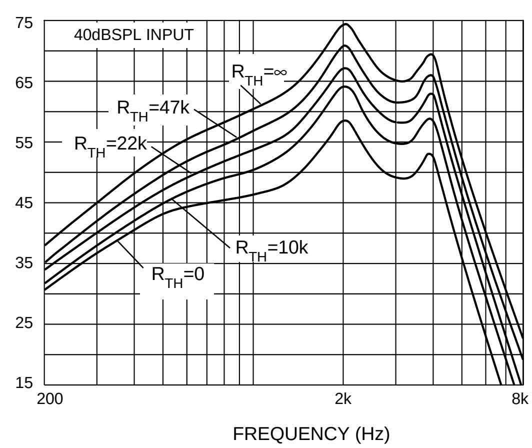


Fig. 29 Gain vs Frequency as R_{TH} is Varied

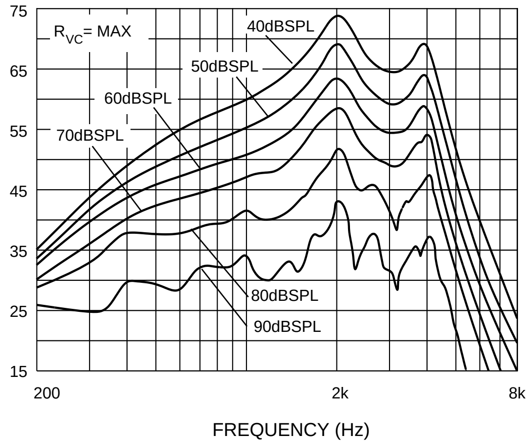


Fig. 30 Gain vs Frequency as Input Level is Varied (R_{VC} =100 kΩ)

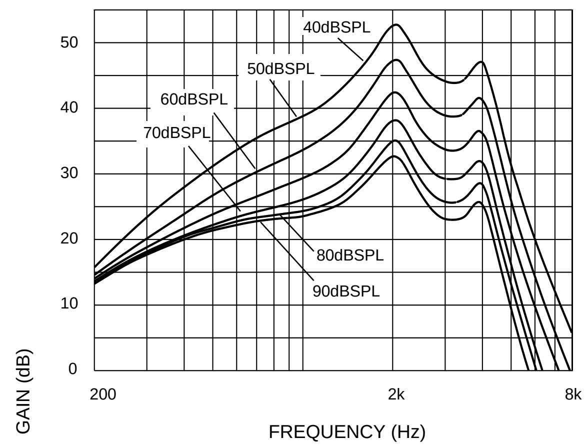
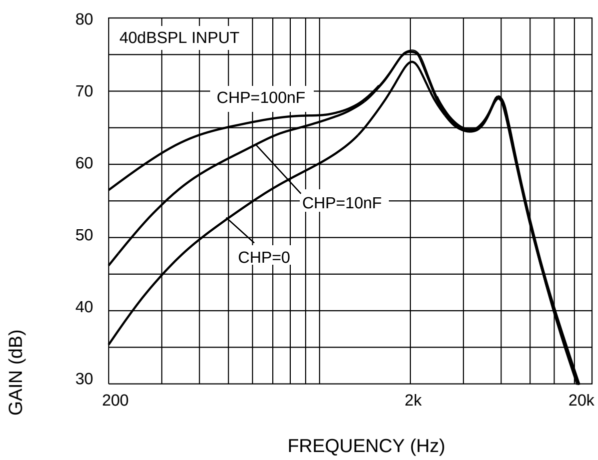


Fig. 31 Gain vs Frequency as Input Level is Varied ($R_{VC} \approx$ 5 kΩ)



GAIN (dB)

Fig. 32 Gain vs Frequency as CHP Level is Varied

Figure 33 illustrates an alternate GS3011 class D configuration which requires a greater number of external parts. This more closely approaches a “Mid Supply” referenced system. In this configuration we use approximately 13 µA more current and lose 6 dB of gain from that in Figure 23. Looking back from the class D receiver into Stage D of the GS3011, we basically see a mid supply referenced signal with 27 kΩ to ground and 25.93 kΩ to supply. This will improve the distortion of the circuit, at the cost of current and gain. With the system configured as in Figure 33 and the volume control resistance decreased to approximately 5 kΩ, the amplitude of the input signal was varied from 40 dBSPL to 90 dBSPL. The results of this are shown in Figure 34.

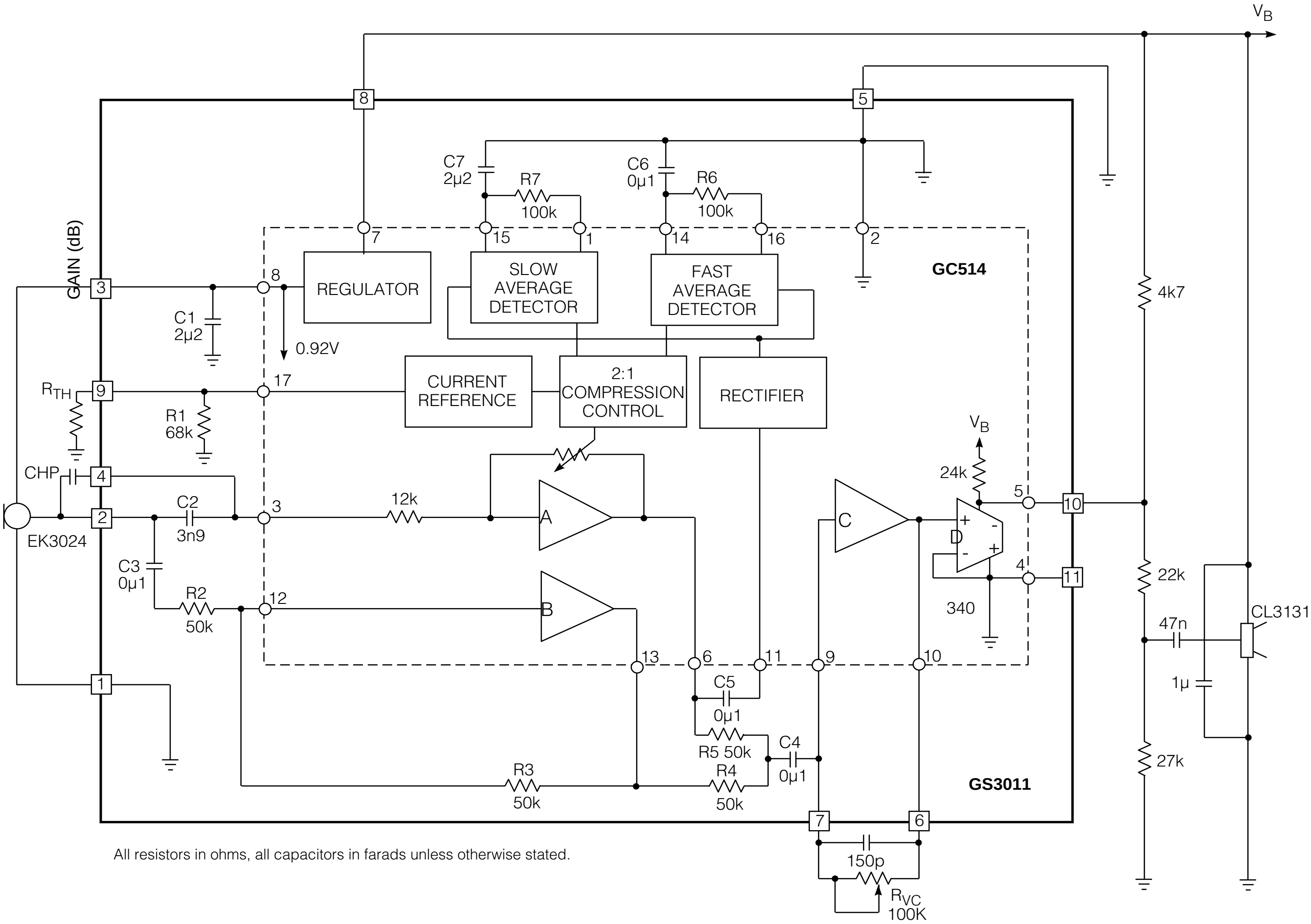


Fig. 33 Pseudo "Mid Supply" Referenced GS3011 Class D Application Circuit

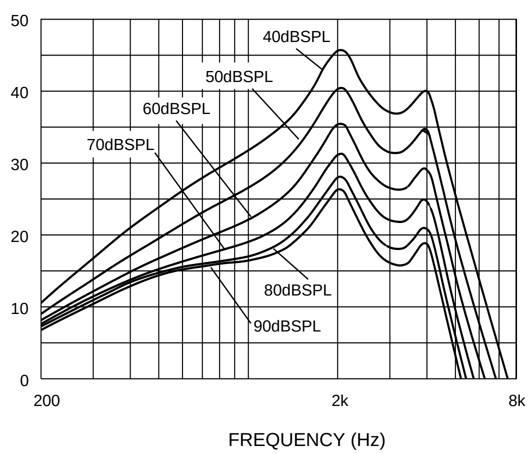


Fig. 34 Gain vs Frequency as Input Level is Varied ($R_{VC} \approx 5\ k\Omega$)