Application Note 2287
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LMH6881 Making Differential Amplifier Design Easy

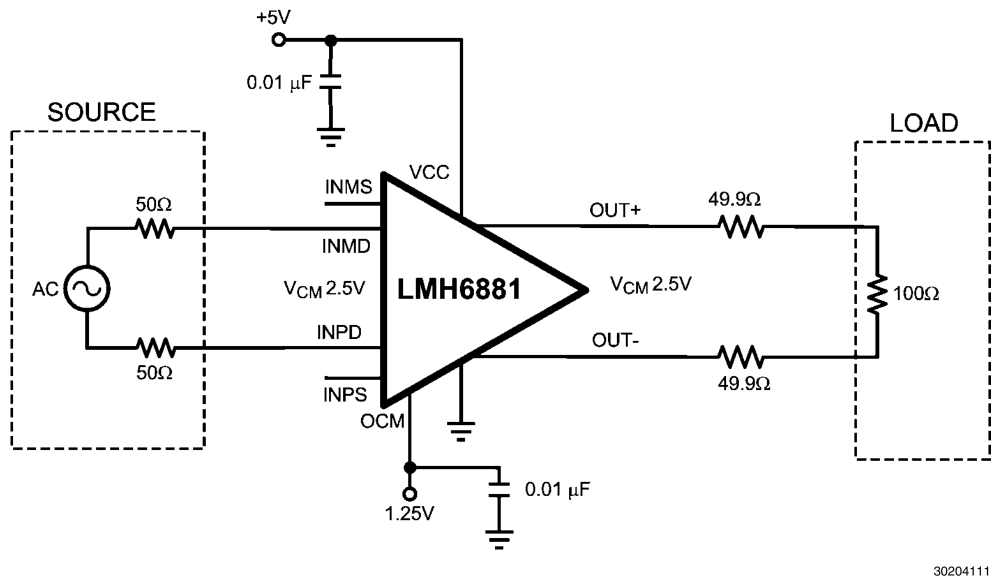

FIGURE 1. Typical Connection

The LMH6881 was designed to make differential amplifier circuits easy to implement with a new programmable gain architecture. The LMH6881 offers flexible gain, low parts count and consistent performance over the entire gain range. The input is terminated at 100Ω for differential signals and a single 50Ω resistor is sufficient to terminate the single ended input port.

The LMH6881 is a high speed, high performance fully differential amplifier. With a bandwidth of 2.4GHz and high linearity OIP3 of 44dBm, the LMH6881 is suitable for a wide variety of signal conditioning applications. The LMH6881 Programmable Differential Amplifier (PDA) family takes the best of both worlds; fully differential amplifiers (FDA) and variable gain amplifiers offers superior noise and distortion performance over the entire gain range without external resistors, enabling using one device for multiple applications requiring different gain settings. The LMH6881 has been designed to be an easy to implement amplifier that can replace both fully differential, fixed gain amplifiers as well as variable gain amplifiers. The LMH6881 requires lower parts count than a comparable fully differential amplifier.

Traditional fully differential amplifiers require external components to set the closed loop gain. As shown in *Figure 1* the LMH6881 does not require external resistors to set the gain. Circuit balance common mode rejection and gain accuracy are ensured by using well matched internal components. The LMH6881 is a fully differential amplifier that requires no external resistors to set the closed loop gain. Gain can be set in 2dB increments by external pins, or an internal gain register allows the use of 0.25dB gain steps. The internal gain resister is accessed through an SPI compatible control bus.

Consistent Performance

In contrast to a typical fully differential amplifier, the LMH6881 offers very consistent performance over a wide voltage gain range. Key parameters are insensitive to the voltage gain setting. With a fully differential amplifier the bandwidth, noise figure and distortion performance all change significantly over the usable gain range. In figures *Figure 4*, *Figure 5* are two FDA circuits one at 8dB of gain and the other at 26dB. From the example it is obvious that the input impedance changes drastically between the two gain settings. In addition to the input impedance, the noise contributed by external resistors will be different. For a feedback amplifier the loop gain is defined as the ratio of the open loop gain to the closed loop gain. The FDA will have large changes in loop gain when the closed loop gain is changed. . As can be seen in *Figure 2* the LMH6881 frequency response is insensitive to voltage gain. A traditional FDA style amplifier frequency response is shown in *Figure 3* this graph shows that

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frequency response is very dependent on gain. As shown in the OIP3 is very consistent across the entire voltage gain range as well.

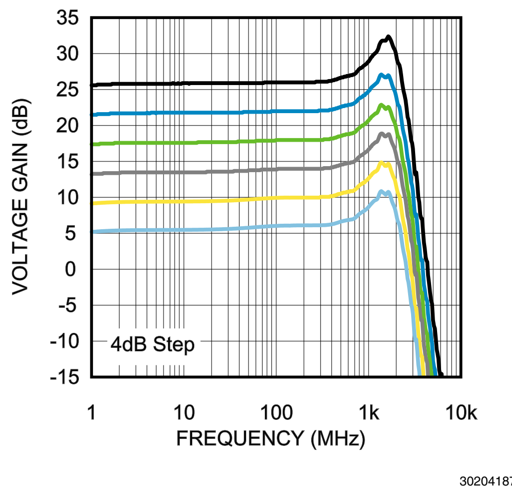


FIGURE 2. LMH6881 Frequency Response with 4dB Voltage Gain Steps

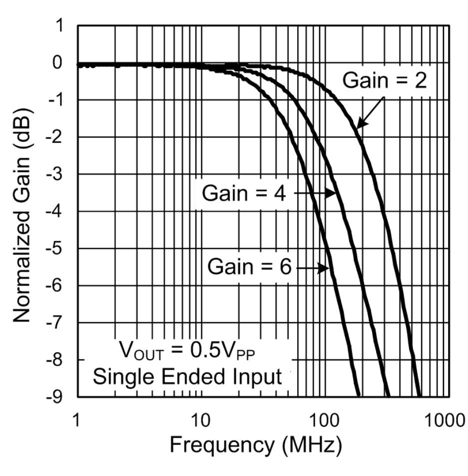


FIGURE 3. Frequency Response for Fully Differential Amplifier

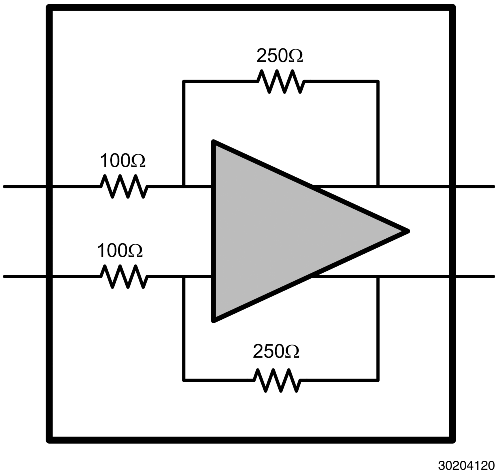


FIGURE 4. Differential Amplifier 8dB Gain

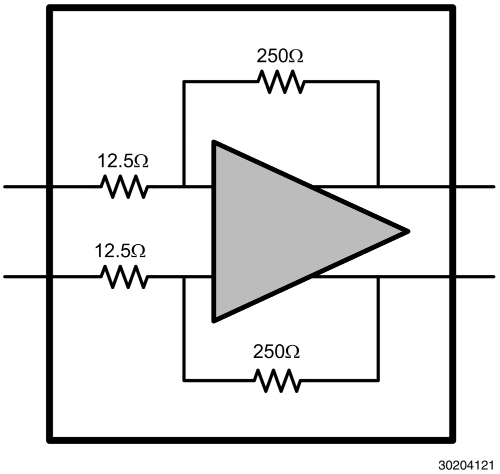


FIGURE 5. Differential Amplifier 26dB Gain

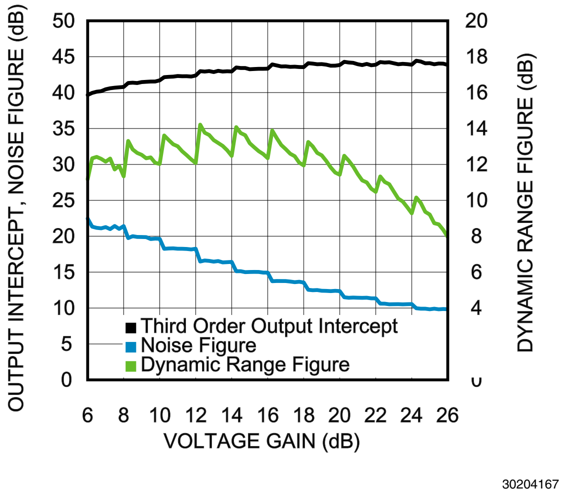


FIGURE 6. Dynamic Range Figure: Using IIP3 — NF to Characterize Input Dynamic Range Capabilities

Introduced here is the concept of a figure of merit called the Dynamic Range Figure. This figure of merit is calculated by subtracting the noise figure (NF) from the input third order intercept point (IIP3). The Dynamic Range Figure is a good proxy for the overall dynamic range of an amplifier. The chart in *Figure 6* shows the Dynamic Range Figure plotted along with more conventional parameters of noise figure and output third order intercept. This chart shows that the LMH6881 retains very good dnyamic range performance over the entire gain range with best performance in the middle portion of the gain range. With a traditional DVGA the figure of merit is highest at maximum gain and usually decreases markedly at the lower end of the gain range. This figure of merit is described in more detail below.

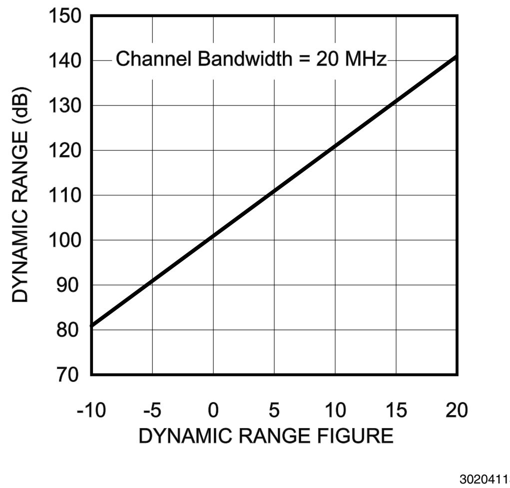


FIGURE 7. Overall Dynamic Range vs Dynamic Range Figure

The chart in *Figure 7* shows the relationship between the Dynamic Range Figure and the available dynamic range at the input of the amplifier. In this example the channel bandwidth is 20MHz and the overall dynamic range is the difference between the peak amplitude of the two intermodulation tones and the noise floor. The strength of the intermodulation tones is the tone amplitude where the IMD3 products are equal to the noise floor.

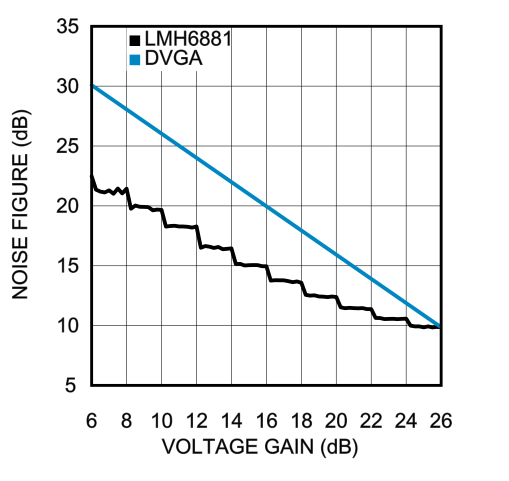


FIGURE 8. Noise Figure of LMH6881 Compared to Noise Figure of Traditional Variable Gain Amplifier

The LMH6881 has an internal architecture that avoids the 1:1 increase in noise figure with gain changes that is characteristic of a traditional DVGA. This allows the LMH6881 to maintain a good Dynamic Range Figure through out the entire gain range. For comparison *Figure 8* shows how the noise figure would compare with a conventional DVGA.

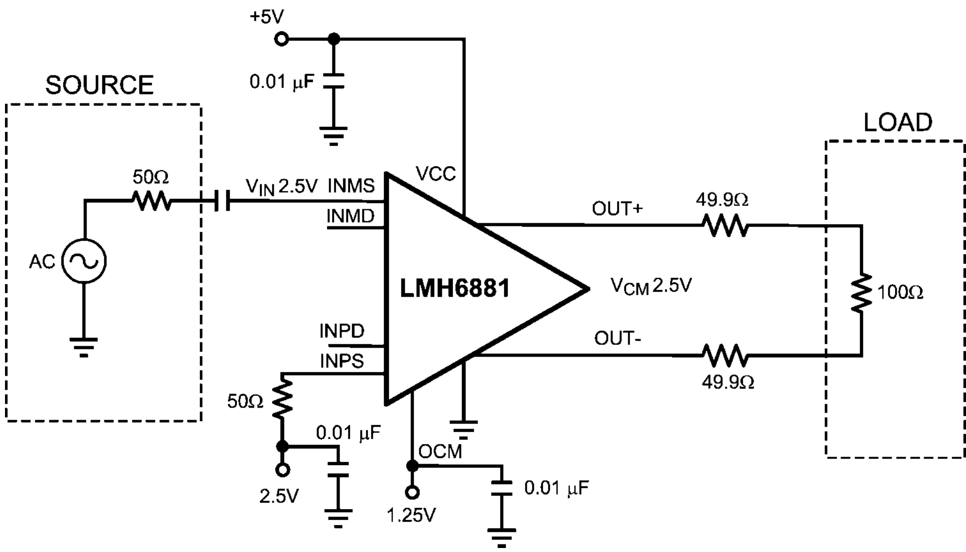


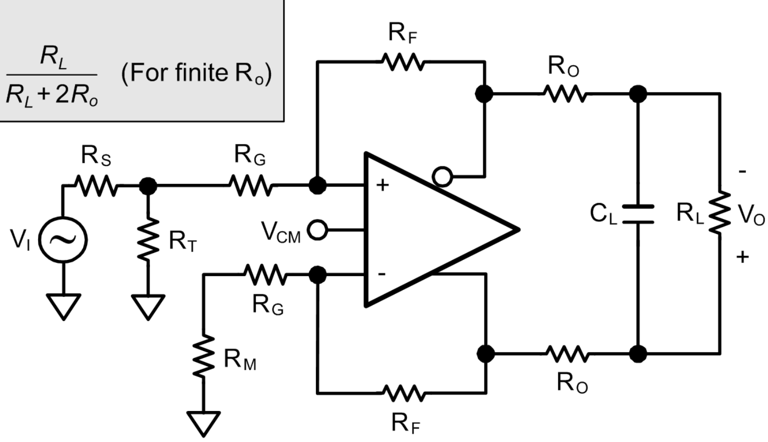
FIGURE 9. Input Configuration for Single Ended Signal.

The LMH6881 can accept either a fully differential input signal on the two differential input pins. The input impedance is set by an on chip resistor to 100 Ohms. By having a fixed input impedance the LMH6881 does not need external resistors to match many common existing signal sources. If a higher input impedance is desired external resistors can be used. The LMH6881 also has the option of accepting a single ended input. By using the single ended input pins the LMH6881 can be configured to accept 50 Ohm signals. Only one 50 Ohm external resistor is required as shown in *Figure 9*.

In contrast the schematic in *Figure 10* shows what is required to set the input impedance for a traditional fully differential amplifier. What makes things even more complicated is that a change in gain for a fully differential amplifier requires a change in the resistors. With the new PDA architecture the input impedance is fixed at a convenient 50 Ohms and does not change as the gain settings change.

$$\frac{V_o}{V_I} = \frac{R_F}{2R_G} \qquad (\text{For } R_o = 0\Omega)$$

$$\frac{V_o}{V_I} = \frac{R_F}{2R_G} \cdot \frac{R_L}{R_L + 2R_o} \qquad (\text{For finite } R_o)$$



$$\text{SET } R_M = R_T \| R_S$$

$$\text{SET } R_T = \frac{1}{\left(\frac{1}{R_S} - \frac{1}{R_{IN}}\right)} \qquad R_{IN} = \frac{R_G}{1 - \left(\frac{R_F}{2^*(R_F + R_G)}\right)}$$

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FIGURE 10. Traditional Fully Differential Amplifier Input Impedance Calculations

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