Application Report

SNOA505B–September 2007–Revised May 2013

AN-1718 Differential Amplifier Applications Up to 400 MHz

1 Introduction

The LMH6515 is a fully differential amplifier optimized for signal path applications up to 400 MHz and has a 200Ω input. The absolute gain is load dependent; however the gain steps are always 1 dB. The LMH6515 output stage is a class A amplifier.

This class A operation provides excellent distortion and linearity characteristics, making the LMH6515 ideal for voltage amplification and an ideal ADC driver where high linearity is necessary.

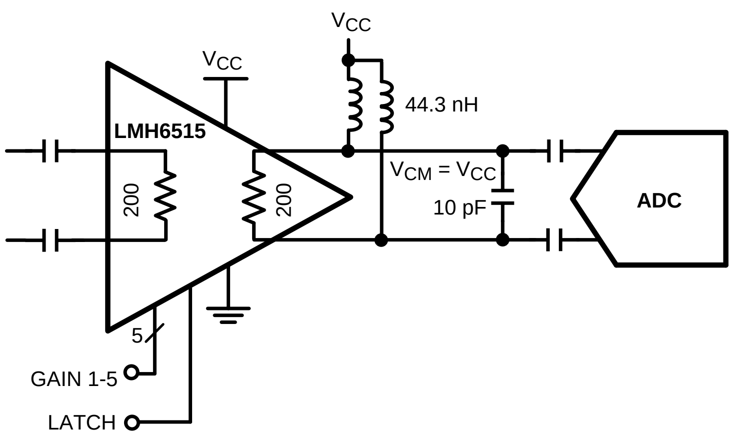

Figure 1. LMH6515 With Output Pull-Up Inductors

The LMH6515 output common mode should be set carefully; using inductors is one preferred method that will give maximum output swing. AC coupling of the output is recommended. The inductors mentioned above will shift the idling output common mode to the positive supply. Also, with the inductors, the output voltage can exceed the supply voltage. Other options for setting the output common mode require supply voltages above 5V. When using a supply higher than 5V make sure the output common mode does not exceed the 5.25V supply rating.

Note the maximum voltage limit for the OUT+ and OUT− pins is 6.4V. When using inductors these pins will experience voltage swings beyond the supply voltage. A 5V output common mode operating point makes the effective maximum swing 5.6 V_{PP} differential so system calibration and automatic gain control algorithms should be tailored to avoid exceeding this limit.

2 Input Characteristics

The LMH6515 input impedance is set by internal resistors to a nominal 200Ω. Process variations will result in a range of values as shown in the *5V Electrical Characteristics* table in the *LMH6515 600 MHz, Digital Controlled, Variable Gain Amplifier Data Sheet* (SNOSAX4). At higher frequencies, parasitics start to impact the impedance. This characteristic depends on board layout and should be verified on the customer's system board.

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At maximum gain the digital attenuator is set to 0 dB and the input signal will be much smaller than the output. At minimum gain the output is 12 dB or smaller than the input. In this configuration, the input signal size may limit the amplifier output amplitude, depending on the output configuration and the desired output signal voltage. The input signal cannot swing more than 0.5V below the negative supply voltage (normally 0V) nor should it exceed the positive supply voltage. If it is too large, the input signal will clip and cause severe distortion. Because the input stage self biases to approximately 1.4V the lower supply voltage will impose the limit for input voltage swing. To drive larger input signals the input common mode can be forced higher than 1.4V to allow for more swing. An input common mode of 2.0V will allow an 8 V_{PP} maximum input signal. The trade off for input signal swing is that as the input common mode is shifted away from the 1.4V internal bias point the distortion performance will suffer slightly.

3 Output Characteristics

The LMH6515 is an open collector topology and has the option of two different output configurations. Each output has an on chip 200Ω pull-up resistor. In addition, there is an internal 400Ω resistor between the two outputs. This results in a 200Ω or a 400Ω differential load in parallel with the external load. The 400Ω option is the high gain option while the 200Ω provides for less gain and is recommended unless more gain is required.

The output common mode of the LMH6515 must be set by external components. Most applications benefit from the use of inductors on the output stage and in particular, the 400Ω option requires inductors to be able to develop an output voltage. The 200Ω option also requires inductors since the voltage drop due to the on chip 200Ω resistors will saturate the output transistors. Although It is possible to use resistors and high voltage power supplies to set the output common mode, this operation is not recommended unless it is necessary to DC couple the output. If DC coupling is required the input common mode and output common mode voltages must be taken into account.

Maximum bandwidth with the LMH6515 is achieved by using the low gain, low impedance output option and using a low load resistance. With an effective load of 67Ω a bandwidth of nearly a 1 GHz can be realized. As the effective resistance on the output stage goes up the capacitance of the board traces and amplifier output stage limit bandwidth in a roughly linear fashion. At an output impedance of 100Ω the bandwidth is down to 600 MHz, and at 200Ω the bandwidth is 260 MHz. For this reason driving very high impedance loads is not recommended.

Although bandwidth goes down with higher values of load resistance, the distortion performance improves and gain increases. The LMH6515 has a common emitter Class A output stage and minimizing the amount of current swing in the output devices improves distortion substantially.

The LMH6515 output stage is powered through the collectors of the output transistors. Power for the output stage is fed through inductors and the reactance of the inductors allows the output voltage to develop. In Figure 1 the inductors are shown with a value of 44.4 nH. The value of the inductors used will be different for different applications. In Figure 1 the inductors have been chosen to resonate with the ADC and the load capacitor to provide a weak band pass filter effect. For broad band applications, higher value inductors will allow for better low frequency operation. However, large valued inductors will reduce high frequency performance, particularly inductors of small physical sizes such as 0603 or smaller. Larger inductors will tend to perform better than smaller ones of the same value even for narrow band applications. This is because the larger inductors will have a lower DC resistance and less inter-winding capacitance and hence a higher Q and a higher self resonance frequency. The self resonance frequency should be higher than any desired signal content by at least a factor of two. Another consideration is that the power inductors and the filter inductors need to be placed on the circuit board such that their magnetic fields do not cause coupling. Mutual coupling of inductors can compromise filter characteristics and lead to unwanted distortion products.

4 Digital Control

The LMH6515 has 32 gain settings covering a range of 31 dB. To avoid undesirable signal transients the LMH6515 should be powered on at the minimum gain state (all logic input pins at 0V). The LMH6515 has a 5-bit gain control bus as well as a latch pin. When the latch pin is low, data from the gain control pins is immediately sent to the gain circuit (i.e. gain is changed immediately). When the latch pin transitions high the current gain state is held and subsequent changes to the gain set pins are ignored. To minimize gain change glitches multiple gain control pins should not change while the latch pin is low. In order to achieve the very fast gain step switching time of 5 ns the internal gain change circuit is very fast. Gain glitches could result from timing skew between the gain set bits. This is especially the case when a small gain change requires a change in state of three or more gain control pins. If continuous gain control is desired the latch pin can be tied to ground. This state is called transparent mode and the gain pins are always active. In this state the timing of the gain pin logic transitions should be planned carefully to avoid undesirable transients.

The LMH6515 was designed to interface with 3.3V CMOS logic circuits. If operation with 5V logic is required a simple voltage divider at each logic pin will allow for this. To properly terminate 100Ω transmission lines, a divider with a 66.5Ω resistor to ground and a 33.2Ω series resistor will properly terminate the line as well as give the 3.3V logic levels. Care should be taken not to exceed the 3.6V absolute maximum voltage rating of the logic pins.

5 Exposed Pad LLP Package

The LMH6515 is in a thermally enhanced package. The exposed pad is connected to the GND pins. It is recommended, but not necessary, that the exposed pad be connected to the supply ground plane. In any case, the thermal dissipation of the device is largely dependent on the attachment of this pad. The exposed pad should be attached to as much copper on the circuit board as possible, preferably external copper. However, it is also very important to maintain good high speed layout practices when designing a system board. For suggested layout techniques, see the *AN-1580 LMH6515EL Digital Controlled, Variable Gain Amplifier Evaluation Board User' Guide* (SNOA482).

6 Interfacing to ADC

The LMH6515 was designed to be used with high speed ADCs such as the ADC14155/V155. AC coupling provides the best flexibility especially for IF sub-sampling applications. Any resistive networks on the output will also cause a gain loss because the output signal is developed across the output resistors. The chart *Maximum Gain vs. External Load* shows the change in gain when an external load is added.

The inputs of the LMH6515 will self bias to the optimum voltage for normal operation. The internal bias voltage for the inputs is approximately 1.4V. In most applications the LMH6515 input will need to be AC coupled.

The output common mode voltage is not self biasing, it needs to be pulled up to the positive supply rail with external inductors as shown in Figure 1. This gives the LMH6515 the capability for large signal swings with very low distortion on a single 5V supply. The internal load resistors provide the LMH6515 with very consistent gain. A unique internal architecture allows the LMH6515 to be driven by either a differential or single ended source. If driving the LMH6515 single ended the unused input should be terminated to ground with a 0.01 µF capacitor. Directly shorting the unused input to ground will disrupt the internal bias circuitry and will result in poor performance.

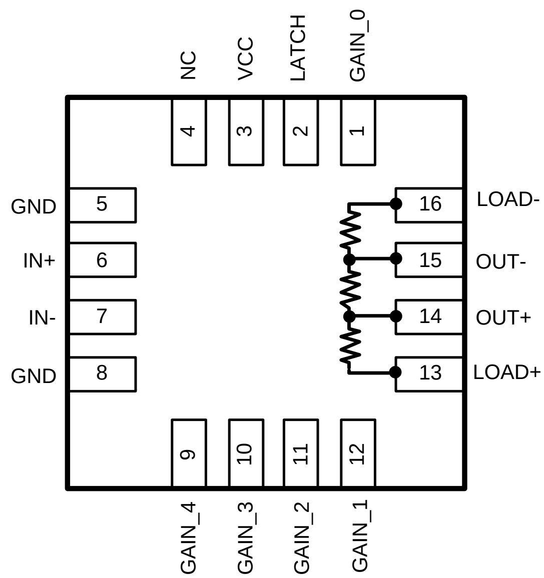

Figure 2. Internal Load Resistors

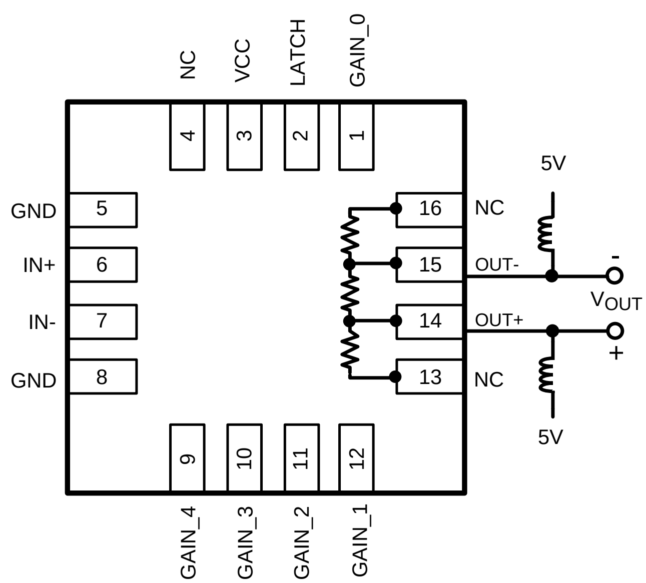

Figure 3. Using High-Gain Mode (400Ω Load)

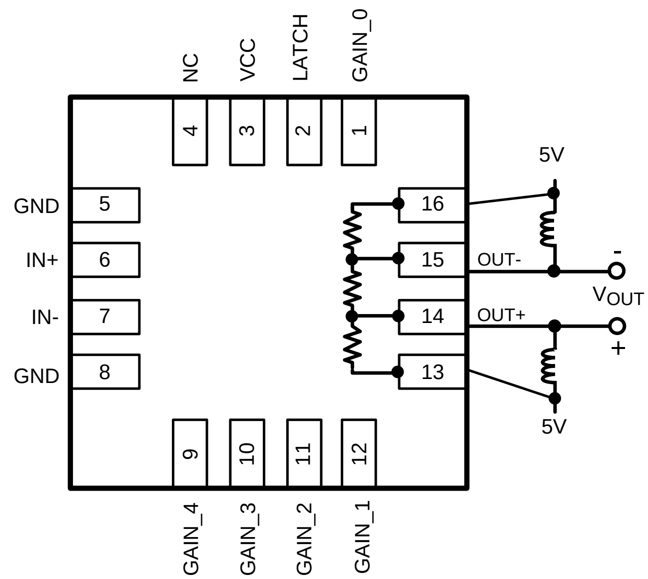

Figure 4. Using Low-Gain Mode (200Ω Load)

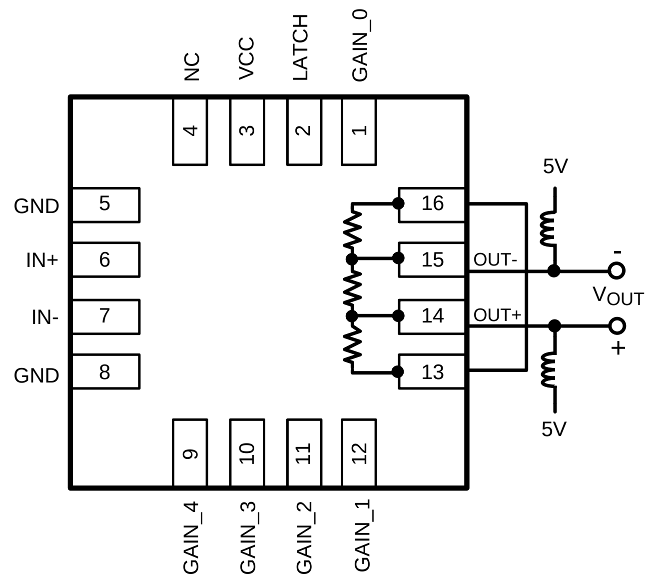

Figure 5. Alternate Connection for Low-Gain Mode (200Ω Load)

7 Power Supplies

As shown in Figure 2, the LMH6515 has a number of options for power supply connections on the output pins. Pin 3 (VCC) is always connected. The output stage can be connected as shown in Figure 3, Figure 4, and Figure 5. The supply voltage range for VCC is 4V to 5.25V. A 5V supply provides the best performance while lower supplies will result in less power consumption. Power supply regulation of 2.5% or better is advised.

Of special note is that the digital circuits are powered from an internal supply voltage of 3.3V. The logic pins should not be driven above the absolute maximum value of 3.6V. For details, see Section 4. Additional information on the LMH6515 can be found online in the product folder and in the datasheet.

8 References

- *LMH6515 600 MHz, Digital Controlled, Variable Gain Amplifier Data Sheet* (SNOSAX4)
- *AN-1580 LMH6515EL Digital Controlled, Variable Gain Amplifier Evaluation Board User' Guide* (SNOA482)

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