

# ***AN-1704 LMH6555 Application as High Speed ADC Input Driver***

---

## **ABSTRACT**

This application note discusses the use of the LMH6555 as a high-speed ADC input driver.

---

## **Contents**

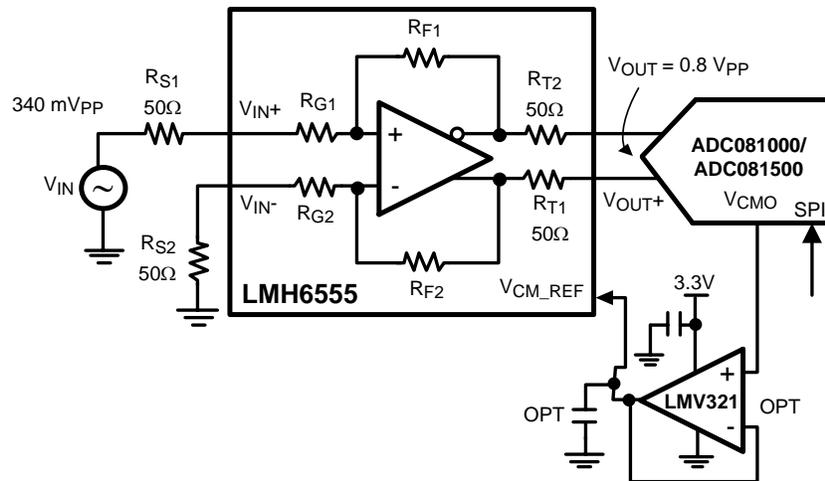
1	Introduction .....	2
2	Summary .....	3

## **List of Figures**

1	Active Single Ended to Differential Conversion for Broadband Applications.....	2
2	Setting the LMH6555 Gain while Maintaining Matched Input Impedance.....	3

## 1 Introduction

The LMH6555 differential amplifier is designed to drive the 100Ω differential input of GigaSample per second (GSPS) A/D Converters (ADCs) with up to 0.8 V<sub>P-P</sub>, and to present constant 50Ω input impedance to get high return loss at the input port. This amplifier can be used either as a single ended input to differential output, or simply as a differential input/output driver. The mostly widely-used application is in DC coupled (or wide band) applications where a single-ended input is to be sampled by a high-speed differential input ADC. Compared to balun transformers, which are often used to perform this function, the LMH6555 offers several advantages: Common Mode (CM) voltage can be set (needed for ADC DC coupling), the ability to provide voltage gain, it can be DC-coupled (Baluns must be AC-coupled), the output voltage swing is matched with inputs of GSPS ADCs, and there is higher Input Return-loss by maintaining 50Ω input impedance to ground over a wide frequency range, and better Gain balance.



**Figure 1. Active Single Ended to Differential Conversion for Broadband Applications**

The LMH6555 spans the frequency range from DC up to 1.2 GHz (-3 dB bandwidth limit of the LMH6555). Accurate output CM voltage control is maintained by tying the V<sub>CM0</sub> of the ADC to the V<sub>CM\_REF</sub> input of the LMH6555. This enables the capture of the full signal spectrum while the LMH6555 automatically maintains common mode control. The buffer (LMV321) shown in Figure 1 boosts the current out of the ADC V<sub>CM0</sub> pin so there is adequate drive for the V<sub>CM\_REF</sub> input. This buffer may or may not be needed, depending on the output current capability of the ADC. Most other commercially available drivers have a similar output CM control scheme, though the adjustment range of each is different and is closely related to the range of voltages expected by the intended ADC.

For AC-coupled applications, ADC inputs are internally biased and there is no need for common mode feedback control. For these applications, the ADC V<sub>CM0</sub> is grounded and the ADC inputs are internally biased. The LMH6555 V<sub>CM\_REF</sub> pin needs to be biased to ~1.2V DC using a crude voltage divider from the 3.3V supply.

The LMH6555's gain (differential output to V<sub>in+</sub> in Figure 1) is fixed at 4.7 V/V where R<sub>S1</sub> = R<sub>S2</sub> = 50Ω. This gain includes the loading of the ADC (100Ω in this case) onto the driver's 50Ω outputs. When the input amplitude is larger, lower the LMH6555 insertion gain by increasing the value of R<sub>S2</sub> and R<sub>S1</sub>. These two resistors should always be equal in order to keep the input balance for low output offset. Figure 2 is an example where the single ended input is driven by a 50Ω transmission line that needs 50Ω to ground for proper termination. In this figure, the gain of the LMH6555, which is at the receiving end of a 50Ω cable, is reduced using R<sub>x</sub> and R<sub>y</sub>. By proper selection of component values, the input impedance to the LMH6555 circuitry (at J1) is kept at 50Ω to maintain impedance matching. The two LMH6555 inputs see an equivalent impedance of 64.5Ω to ground each with the component values shown in order to maintain low output offset voltage (LMH6555 architecture requires good matching between these two impedances for low output offset voltage). The input/output swing relationship of the LMH6555 is shown in Equation 1:

$$V_{OUT} (V_{PP}) = V_{IN} (V_{PP}) * [ R_F / (2R_S + R_{IN\_DIFF}) ] \quad (1)$$

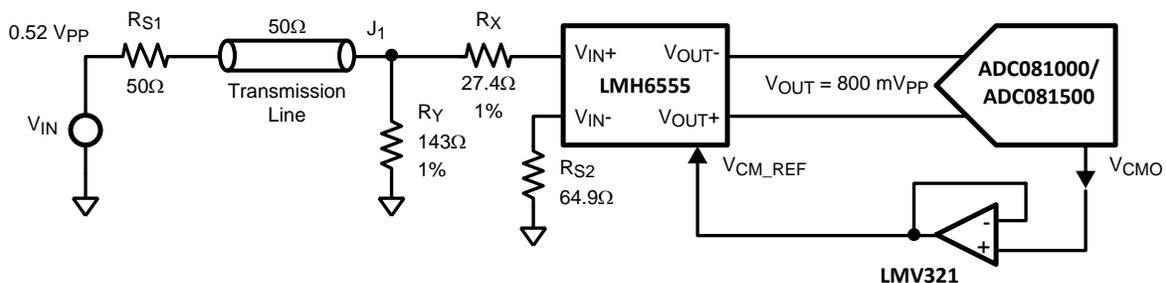
where R<sub>F</sub> = 430Ω and R<sub>IN\_DIFF</sub> = 78Ω and are LMH6555 specific values.

$R_S$  is the equivalent resistance that each of the LMH6555 inputs sees to ground (assuming that they are equal to each other). Increasing  $R_S$  will reduce the gain. The ADC shown requires 0.8  $V_{p,p}$  across its differential input.

The series and shunt resistances,  $R_X$  and  $R_Y$ , present the proper cable termination (50 $\Omega$ ) and achieve the correct Thevenin resistance (64.5 $\Omega$ ) so that there is 0.8  $V_{pp}$  generated across the ADC inputs. In Equation 1, " $V_{IN}$  ( $V_{pp}$ )" would be the Thevenin equivalent voltage of the input network ( $R_{S1}$ ,  $R_Y$ , and  $R_X$ ) and  $R_S$  would be the Thevenin equivalent resistance:

$$V_{Th} = 0.52 V_{pp} \cdot R_Y / (R_Y + R_{S1}) = 0.385 V_{pp}$$

$$R_{Th} = R_X + 1 / (1/R_{S1} + 1/R_Y) = 64.5\Omega$$



**Figure 2. Setting the LMH6555 Gain while Maintaining Matched Input Impedance**

You can use a spreadsheet to arrive at the proper values of  $R_X$  and  $R_Y$  in Figure 2. Use "goal seek" to find the value of  $R_X$  which would allow 0.8  $V_{p,p}$  output swing. Similarly,  $R_Y$  can be adjusted for 50 $\Omega$  input termination. Repeating this procedure will generate the resistor values needed. The LMH6555 architecture maintains low noise (19 nV/RtHz output referred flat-band) irrespective of the  $R_S$  on its inputs.

Most amplifier-ADC interfaces require the use of series resistance and shunt capacitance in order to improve the transient response due to charge switching on the input of the ADC. In the case of the LMH6555 and its interface to the Texas Instruments GPS ADC family, the amplifier-ADC connection does not require this R-C network because the LMH6555 has built-in series output resistances on each output to provide load isolation.

This ADC family requires that the CM voltage of its differential inputs be very close (within  $\pm 50$  mV) to the  $V_{CMO}$  reference output it generates. This is one consequence of its 1.9V operating supply voltage because it constricts the voltage headroom of the ADC internal circuitry. If this CM operating condition is not maintained, the ADC full scale distortion performance will suffer.

## 2 Summary

Single-ended to differential conversion of signals for interface to high speed ADCs is a challenging task and should not be overlooked when high performance is required. This application note has examined some of the considerations and challenges of the input signal interface and has introduced LMH6555 to alleviate this important task. Additional differential drivers intended for ADC interface, at the time of this writing, include the LMH6550/51/52.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)