Using the HI7188 with a Single Supply

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Introduction

The HI7188 is an easy-to-use, 16-bit, 8-channel, sigma-delta A/D subsystem ideal for low frequency physical and electrical measurements in scientific, medical, and industrial applications. The device has sufficient on-chip capabilities to support moving the intelligence away from the system controller and towards the sensors for faster and more flexible configurability without the traditional drawbacks of low throughput per channel, higher power and cost per channel, extreme design complexity or excessive software overhead.

The purpose of this application note is to inform the system designer how to use the HI7188 with a positive analog supply if a negative analog supply is not available. The purpose of the negative supply is bias the analog section of the HI7188. There are two approaches to accomplish the single supply task. Each approach will maintain full operation of the HI7188. The first approach would involve using the ICL7660S voltage converter to derive an inexpensive low current negative power supply. The second approach involves offsetting the positive analog supply (AV_{DD}) to 10V, providing +5V to V_{CM}, and simply grounding the negative supply (AV_{SS}).

ICL7660S Voltage Converter

The ICL7660S Voltage Converter is a monolithic CMOS voltage conversion IC. The device performs supply voltage conversion from positive to negative for an input range of 1.5V to 12V, resulting in complementary output voltages of -1.5V to -12V. Only 2 noncritical external capacitors are needed for the charge pump and charge reservoir functions. The conversion chip contains a series DC power supply regulator, RC oscillator, voltage level translator, and four output power MOS switches. For detailed chip information please refer to the ICL7660S datasheet [1].

Functional Description

The ICL7660S single supply circuit is shown in Figure 1. This includes the HI7188, an ICL7660 voltage converter, and two 10μF capacitors. The HI7188 datasheet [2] contains information on the HI7188, therefore, this discussion will focus on the voltage conversion circuit.

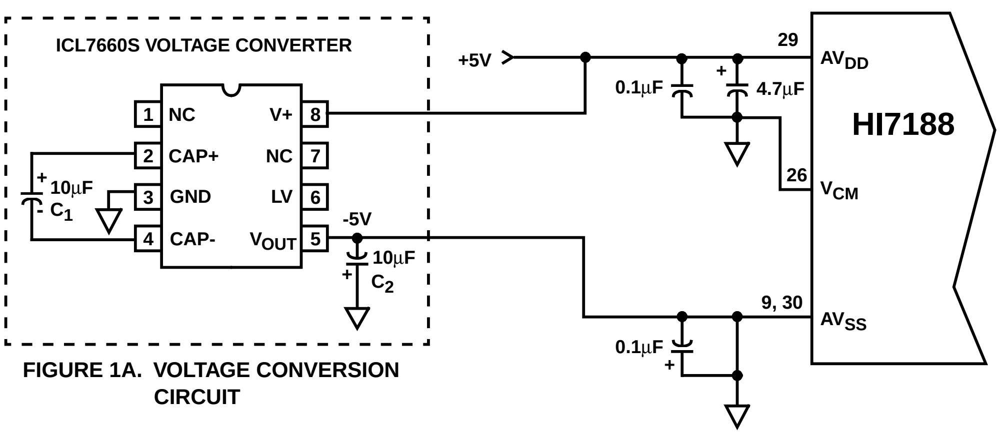

FIGURE 1. ICL7660S SINGLE SUPPLY CIRCUIT

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ICL7660 Theory of Operation [1]

The ICL7660S contains all the necessary circuitry to complete a negative voltage converter, with the exception of 2 external capacitors which may be inexpensive 10µF polarized electrolytic types. The mode of operation of the device may be best understood by considering Figure 2, which shows an idealized negative voltage converter. Capacitor C_1 is charged to a voltage, V+, for the half cycle when switches S_1 and S_3 are closed. (Note: Switches S_2 and S_4 are open during this half cycle.) During the second half cycle of operation, switches S_2 and S_4 are closed, with S_1 and S_3 open, thereby shifting capacitor C_1 to C_2 such that the voltage on C_2 is exactly V+, assuming ideal switches and no load on C_2. The ICL7660S approaches this ideal situation more closely than existing non-mechanical circuits.

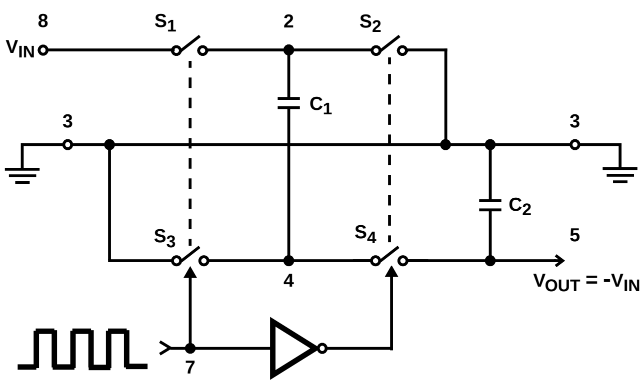

FIGURE 2. IDEALIZED NEGATIVE VOLTAGE CONVERTER

In the ICL7660S, the 4 switches of Figure 2 are MOS power switches; S_1 is a P-Channel devices and S_2, S_3 and S_4 are N-Channel devices. The main difficulty with this approach is that in integrating the switches, the substrates of S_3 and S_4 must always remain reverse biased with respect to their sources, but not so much as to degrade their "ON" resistances. In addition, at circuit start up, and under output short circuit conditions (V_{OUT} = V+), the output voltage must be sensed and the substrate bias adjusted accordingly. Failure to accomplish this would result in high power losses and probable device latchup.

This problem is eliminated in the ICL7660S by a logic network which senses the output voltage (V_{OUT}) together with the level translators, and switches the substrates of S_3 and S_4 to the correct level to maintain necessary reverse bias.

The voltage regulator portion of the ICL7660S is an integral part of the anti-latchup circuitry, however its inherent voltage drop can degrade operation at low voltages. Therefore, to improve low voltage operation "LV" pin should be connected to GND, disabling the regulator. For supply voltages greater than 3.5V the LV terminal must be left open to insure latchup proof operation, and prevent device damage.

ICL7660 Application Discussion

The output characteristics of the voltage converter (Figure 1A) can be approximated by an ideal voltage source in series with a resistance as shown in Figure 3. The voltage source has a value of -(V+) with a slight ripple voltage due to the ICL7660S switching between C_1 and C_2. The output impedance (R_O) is a function of the ON resistance of the internal MOS switches (shown in Figure 2), switching frequency, the value of C_1 and C_2, and the equivalent series resistance (ESR) of C_1 and C_2.

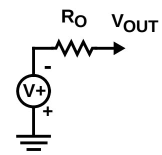

FIGURE 3. ICL7660S EQUIVALENT CIRCUIT

Below is an analysis of this application at 25°C. From the datasheet the MOS switch resistance is typically 23Ω, switching frequency is 10kHz. The capacitors C_1 and C_2 are 10µF, 16V Kemet Solid Tantalum capacitors type number "T350106K016AS" with ESR of 1Ω at 10kHz. The typical supply current into the HI7188 negative supply is 1mA. The low current requirement of the HI7188 is critical since the conversion chip is ONLY designed for low current applications. As defined in the ICL7660S datasheet, the inverted output voltage drops significantly from -5V to -4.25V when 10mA of current is required. If additional current is needed to drive supplementary devices, multiple ICL7660S units can be placed in parallel [1]. Below are the theoretical calculations for output impedance and ripple voltage.

$$R_O \cong 2 \times R_{SW} + \frac{1}{0.5 f_{OSC} \times C_1} + 4 \times ESR_{C1} + ESR_{C2} \Omega$$

$$R_O \cong 2 \times 23 + \frac{1}{(5 \times 10^3 \times 10 \times 10^{-6})} + 4 \times ESR_{C1} + ESR_{C2}$$

$$R_O \cong 46 + 20 + 5 \times 1\Omega \cong 71\Omega$$

$$V_{RIPPLE} \cong I_{OUT}\left(\frac{1}{2 \times f_{PUMP} \times C_2} + 2ESRC_2\right)$$

$$V_{RIPPLE} \cong I_{OUT}\left(\frac{1}{2 \times 10kHz \times 10\mu F} + 2\right)$$

$$V_{RIPPLE} \cong 7mV$$

Measured Performance

The circuit in Figure 1A was added to the evaluation platform to determine performance. The testing consisted of both noise and linearity with the standard -5V supply and a -5V supply derived from the ICL7660S. Noise data was derived from 100 readings while linearity involved single measurements in 0.5V increments. Comparison of the performance data showed no degradation of either noise or linearity while using the ICL7660S voltage converter.

+10V Supply Operation

The application circuit is shown in Figure 4. The positive analog supply (AV_{DD}) is tied to 10V while the negative supply (AV_{SS}) is analog ground. To ensure proper operation, the virtual ground pin (V_{CM}) must be set midway between the positive and negative supplies. In this case +5V. This is critical to ensure the chopper stabilized operational amplifier is biased correctly otherwise performance would be severely degraded.

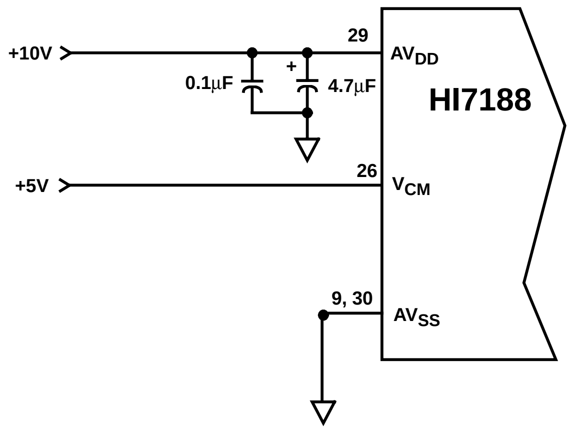

FIGURE 4. 10V SUPPLY CIRCUIT

Measured Performance

The circuit in Figure 4 was added to the evaluation platform to determine performance. The testing consisted of both noise and linearity with the standard +-5V supplies and the single 10V supply as shown in Figure 4. Noise data was derived from 100 readings while linearity involved single measurements in 0.5V increments. Comparison of the performance data showed no degradation of either noise or linearity while using the single 10V supply circuit.

Conclusion

This application note described two methods of using the HI7188 with a single positive analog supply if a negative analog supply was not available. The first method involved the ICL7660S voltage converter to derive an inexpensive low current negative power supply. The second method involved offsetting the positive analog supply (AV_{DD}) to 10V, grounding the negative supply (AV_{SS}) and biasing the virtual ground pin to +5V.

References

[1] ICL7660S Datasheet, File Number 3179, Intersil Corporation, Melbourne, Florida, 1994.

[2] HI7188 Datasheet, File Number 4016, Intersil Corporation, Melbourne, Florida, 1995.

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