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Overcoming Common Mode Range Issues When Using Intersil Integrating Converters

Introduction

Some applications which utilize Intersil's integrating analog to digital converters may require a way to overcome Common Mode Range (CMR) issues that may arise. Intersil's integrating analog to digital converters such as those listed in Table 1 operate consistently with an input which is within the CMR and the full-scale voltage set by the user. As a result, the converter's full scale range may vary from 200mV to as much as 2V.

TABLE 1. INTERSIL INTEGRATING CONVERTERS

ICL7106	$3^1/_2$ Digit LCD Display ADC
ICL7107	$3^1/_2$ Digit LED Display ADC
ICL7136	$3^1/_2$ Digit LCD Low Power Display ADC with Overrange Recovery

Applications

Figure 1 illustrates a typical application for the ICL7107, 31/2 Digit LED Display ADC, using a single 5V supply and full scale range set to 200mV. Here, the IN LO input is tied to analog COMMON, and the differential input is measured with respect to it. Analog COMMON sets a voltage which is approximately 2.8V less than the positive supply, V+, when V+ to V- $\geq$ 6.8V. Here, V+ to V- = 5V, so a fixed 1.2V reference is used. The CMR is defined as: (V- + 1.0V) < V_{IN} < (V+ - 0.5V). Not only does the input need to be within the common mode range, but also the full-scale range as well.

When operating these converters from a single supply and with an input voltage referenced to ground instead of COMMON, the designer can quickly run out of common mode range with which to work. In Figure 1, V+ = 5V and V- = 0V. V_{IN} is limited to a common mode range of +1V to +4.5V, but has a full scale of 200mV. The 200mV full scale is below the common mode range of the device. Even if full-scale is adjusted to 2V, the full scale range of the device is limited to a 1V swing ranging from 1 to 2V.
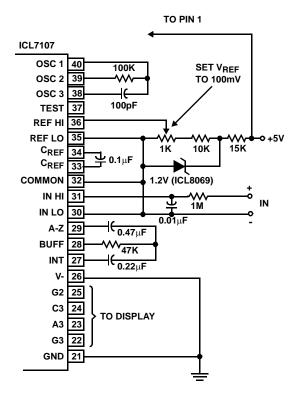

FIGURE 1. ICL7107 OPERATED FROM A SINGLE +5V SUPPLY

One solution is to separate COMMON and IN LO and tie IN LO to ground. The problem here is that gross errors can occur if IN LO is pulled to far from COMMON. A much better solution is to use a simple, non-inverting amplifier adder circuit as seen in Figure 2. A Intersil CA3130 operational amplifier was chosen because it operates from a single 5V supply, has rail-to-rail output swing and an input range that includes ground.
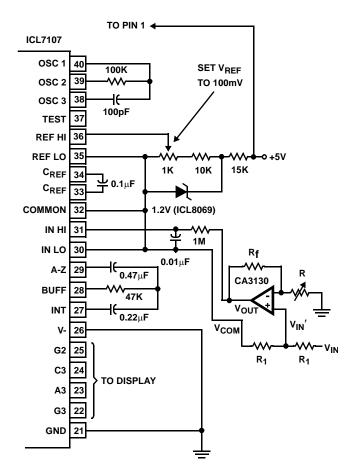
FIGURE 2. SIMPLE SUMMING AMP TO RESOLVE CMR PROBLEM

By analyzing the circuit in Figure 2, we see that:

$$V_{OUT} = \left(1 + \frac{R_f}{R}\right) \times V_{IN}' \qquad \text{(EQ. 1)}$$

where

$$V_{IN}' = \frac{1}{2}(V_{IN} + V_{COM}) \qquad \text{(EQ. 2)}$$

to define the operational amplifier output.

Substituting equation 2 into equation 1, and setting $R_f = R$ yields:

$$V_{OUT} = 2\left(\frac{1}{2}(V_{IN} + V_{COM})\right) = V_{IN} + V_{COM} \qquad \text{(EQ. 3)}$$

Using this circuit, the operational amplifier's output signal (V_{OUT}) is now the sum of the incoming signal (V_{IN}) and COMMON. In other words, V_{IN} is now referenced with respect to COMMON and not ground. With a single 5V supply, an external voltage reference must be used because the internal reference is only active when V+ to V- $\geq$ 6.8V, and V_{COM} = COMMON $\cong$ V+ - 1.2V = 3.8V. The signal input to the ICL7107 will now be offset by 3.8V, which is well within the common mode range of the device. Even if V+ changes, as in battery applications, COMMON will keep the signal within the common mode range of the converter.

Measuring the Supply Rail

In battery applications where a designer wishes to not only power the converter from a single supply, but also monitor and display the battery voltage, common mode range issues again arise. From the CMR equation we note that:

$$1V < V_{IN} < (V+ - 0.5V)$$

At first glance, it may seem that an easy solution would be to use a simple resistor voltage divider and reduce V_{IN} by a factor of 10, set full-scale to 2V and supply this to the ADC. For common battery voltages of 6V to 12V, the corresponding input voltages would be 0.6 to 1.2V. However, if we go back to the above common mode range equation, it states that V_{IN} must be greater than 1V. Figure 3 illustrates another operational amplifier configuration to solve this problem. Again a CA3130 was chosen because of its characteristics.
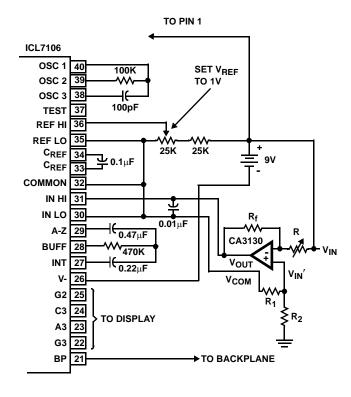

FIGURE 3. SIMPLE OP AMP CIRCUIT TO MEASURE SUPPLY RAIL (V+)

Here an ICL7106, $3^1/_2$ Digit LCD Display ADC with full scale set to 2V is shown. In this circuit, the operational amplifier is set in an inverting gain configuration, because gains of 0.1 are desirable, and because we are only concerned with positive input voltages.

Again analyzing the operational amplifier configuration, we note that:

$$\frac{(V_{IN}' - V_{IN})}{R} = \frac{(V_{OUT} - V_{IN}')}{R_F}$$ (EQ. 4)

and that:

$$V_{IN}' = V_{COM}\left(\frac{R_2}{R_1 + R_2}\right)$$ (EQ. 5)

Setting $R = 10R_F$, $R_F = R_1$ and $R_2 = 10R_1$, the equations can be reduced to:

$$V_{IN}' - V_{IN} = 10(V_{OUT} - V_{IN}')$$ (EQ. 6)

and

$$V_{IN}' = \left(\frac{(10 \times V_{COM} \times R_1)}{11R_1}\right) = \frac{10V_{COM}}{11}$$ (EQ. 7)

Combining equations 6 and 7 reveals that:

$$V_{OUT} = V_{COM} - \frac{V_{IN}}{10}$$ (EQ. 8)

The output of the operational amplifier (V_{OUT}), which is the input of the ADC, is now $-0.1V_{IN}$ with respect to COMMON, and since $V_{IN} = V_+$, the ADC will measure -10% of the supply. Simply driving the proper decimal point and not driving the sign indicator will display the proper voltage. For example, a battery voltage of 11.6V will be measured as -1.16V and can easily be displayed as 11.60V on a $3\frac{1}{2}$ Digit Display.

For more information on Intersil integrating analog to digital converters, please refer to the following data sheets:

TABLE 2

DEVICE	DESCRIPTION
ICL7106	$3\frac{1}{2}$ Digit LCD/LED Display ADC
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