

# Minimize Errors in Weigh-Scales With Zero-Drift, EMI-Hardened, Precision Amplifiers



Soufiane Bendaoud

## Precision Amplifiers

The accuracy of weigh scales is affected by several factors, including input offset voltage drift, vibration RFI, and electromagnetic interference (EMI). The EMI sources can emanate from light, long wires, relays, cell phones, and other electronic equipment in the vicinity. Weigh-scale accuracy is affected by radiated and conducted undesirable signals because these signals can cause erroneous readings, thereby impacting the sensitivity of the apparatus.

## Benefits of EMI Hardened Zero-Drift Amplifiers in Weigh Scales

Zero-drift amplifiers provide the advantage of very low input offset voltage, as well as very low offset drift. Errors attributed to the input offset voltage and offset drift affect the accuracy of the weigh scale.

For example, a 16-bit analog-to-digital converter (ADC) with a full-scale voltage range of 10 V yields 1 LSB of 153  $\mu\text{V}$ . An amplifier with an offset voltage of 0.5 mV is well above 1 LSB. To avoid quantization errors and maintain linearity, select a precision amplifier that yields  $\frac{1}{2}$  LSB. A zero-drift amplifier such as the [OPA2182](#) has 0.45  $\mu\text{V}$  of offset voltage and 0.003  $\mu\text{V}$  of offset voltage drift, as shown in [Figure 1](#).

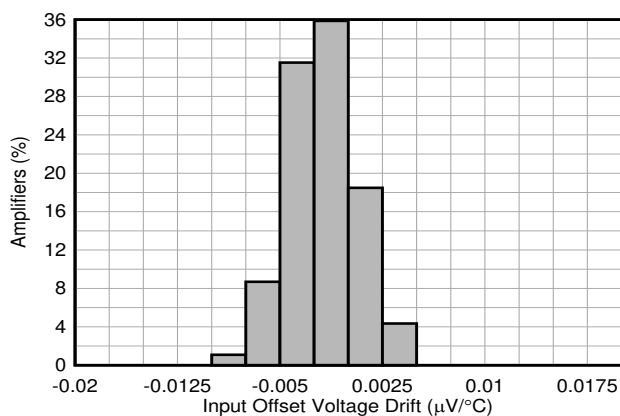


Figure 1. OPA2182 Input Offset Drift

At 70°C, the total offset error (with drift) amounts to 0.58  $\mu\text{V}$ ; well below 76  $\mu\text{V}$ .

Another benefit of zero-drift amplifiers is very-low flicker noise (1/f), even when compared to bipolar input op amps. The 1/f component can be a dominant source of error, and is particularly important in low-frequency bands because the impact of the op amp noise can be detrimental to the design. Noise causes a loss of digital counts and degrades ENOB performance, thereby reducing weigh scale accuracy. The ultra low offset [OPA2387](#) has a 1/f noise (peak to peak) of 177  $\text{nV}/\sqrt{\text{Hz}}$ .

## Advantages of EMI-Hardened Op Amps

To avoid problems associated with EMI, precautionary measures must be taken. These measures include shielding, proper grounding, and filtering. Passive filters at the input and output of the amplifier are not a trivial task. A simple low-pass RC filter, whether at the input or output, is likely to affect the dynamic performance of the amplifier. The most effective way to reject RF and EMI signals is to select op amps with integrated filters.

Texas Instruments precision amplifiers are designed with integrated filters that are closely matched on silicon. The additional filters reduce errors through the signal path feeding into the ADC. EMIRR plots are provided in the product data sheet and, much like PSRR or CMRR, these graphs show the rejection over a frequency band.

To better understand how EMI-hardened amplifiers reduce errors, consider this example:

Suppose a non-EMI-hardened op amp inherently provides 50 dB of rejection, is set up in a gain of 100, and interfaces with a 16-bit ADC with a full-scale voltage range of 5 V.

Next, assume an RF signal of  $-20$  dBV ( $0.1$  V) at the input of the amplifier. A quick computation yields  $0.31$  mV at the input or  $0.1 \text{ V} / 10^{(50/20)}$ . Multiplying by a gain of  $101$  gives  $32$  mV. With a  $5$ -V full-scale voltage range and a  $16$ -bit ADC we have  $5 / (2^{16}) = 76 \mu\text{V}$  as  $1$  LSB.

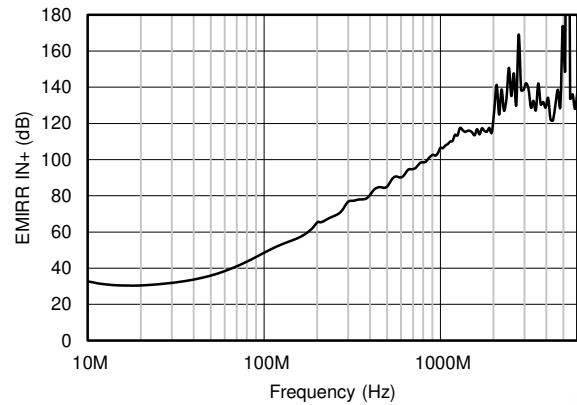
Taking the initial  $32$  mV and dividing by  $76 \mu\text{V}$  yields approximately  $420$ , which represents the loss of digital counts. Selecting an amplifier like the zero-drift [OPA187](#) provides  $100$  dB of EMIRR at  $1$  GHz, as shown in [Figure 2](#).

The following steps determine how much improvement can be achieved by using the OPA187.

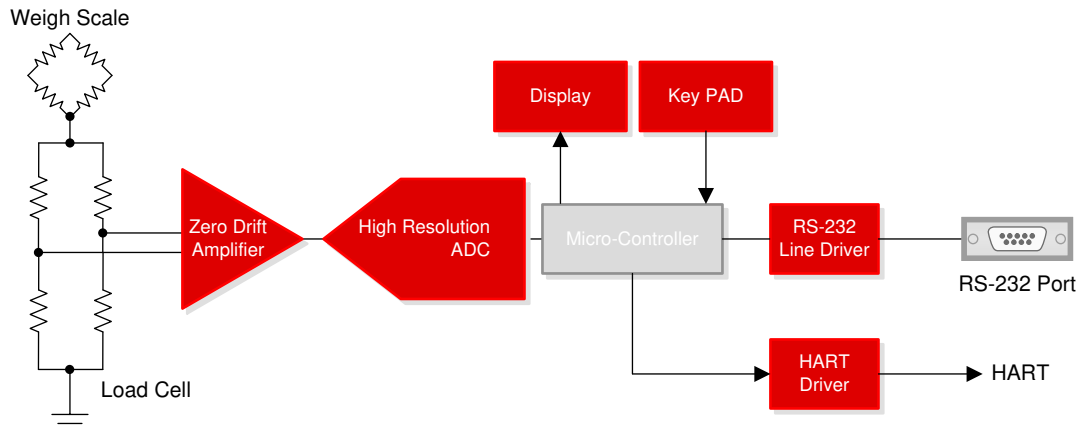
First, compute the shift at the output as:  $0.1 \text{ V} / (10^5) \times 101$ , which gives  $0.1$  mV at the output of the amplifier. To find the loss of counts, simply take  $0.1$  mV and divide by  $76 \mu\text{V}$ , which represents  $1$  LSB for  $16$  bits with a full-scale voltage range of  $5$  V. Write the equation as  $(0.1\text{E-}3 / (5 / 65536))$ , which yields

$1.3$  counts. An extraordinary improvement without compromise!

Check out this clip in [TI's video library](#) for some additional interesting information: [How to avoid electromagnetic interference \(EMI\)](#).



**Figure 2. OPA187 EMIRR IN+ vs Frequency**



**Figure 3. Typical Block Diagram of a Precision Weigh Scale**

**Table 1. Alternative Device Recommendations**

Device	Unity Gain Bandwidth	Description
<a href="#">OPA189</a>	14 MHz	14-MHz, MUX-Friendly, Low-Noise, Zero-Drift, RRO, CMOS, Precision Operational Amplifier
<a href="#">OPA188</a>	2 MHz	Precision, Low-Noise, Rail-to-Rail Output, 36-V, Zero-Drift Operational Amplifier
<a href="#">OPA2182</a>	5 MHz	Industry's Lowest Offset Drift Operational Amplifier
<a href="#">OPA187</a>	0.55MHz	Low Power, High Voltage Zero Drift Operational Amplifier
<a href="#">TLV2186</a>	0.75 MHz	24V, Cost Optimized Low Power Zero Drift Operational Amplifier
<a href="#">OPA388</a>	10 MHz	10-MHz, CMOS, Zero-Drift, Zero-Crossover, True RRIO, Precision Operational Amplifier
<a href="#">OPA2387</a>	5.7 MHz	Ultra High Precision, Low Input Bias Current Zero Drift Operational Amplifier
<a href="#">OPA333</a>	350 kHz	Zero-Drift microPower Operational Amplifier

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](http://ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2022, Texas Instruments Incorporated