Improving System-Level Performance and Robustness in Power Line Monitoring

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Background

For many applications, monitoring power lines implies the use of current transformers and resistor divider networks in order to sense the three phases and neutral voltages and currents, as shown in Figure 1. The AD7606B, due to its high input impedance, can directly interface with a sensor, easing the data acquisition system design as AD7606B provides all the required building blocks.

The AD7606B integrates, on-chip, eight individual signal chains that accept either ±10 V or ±5 V true bipolar analog input signals despite working from a single 5 V supply. These features eliminate the need for driver op amps and external bipolar supplies.

Each of these channels is comprised of 21 V analog input clamp protection, a resistive programmable gain amplifier with 5 MΩ input impedance, a first-order antialiasing filter, and a 16-bit SAR ADC. Also, an optional digital averaging filter with oversampling ratios of up to 256 and a low drift 2.5 V reference are included to help build a complete power line data acquisition system.

In addition to the complete analog signal chain provided, the AD7606B has plenty of calibration and diagnostic features to improve system-level performance and robustness.

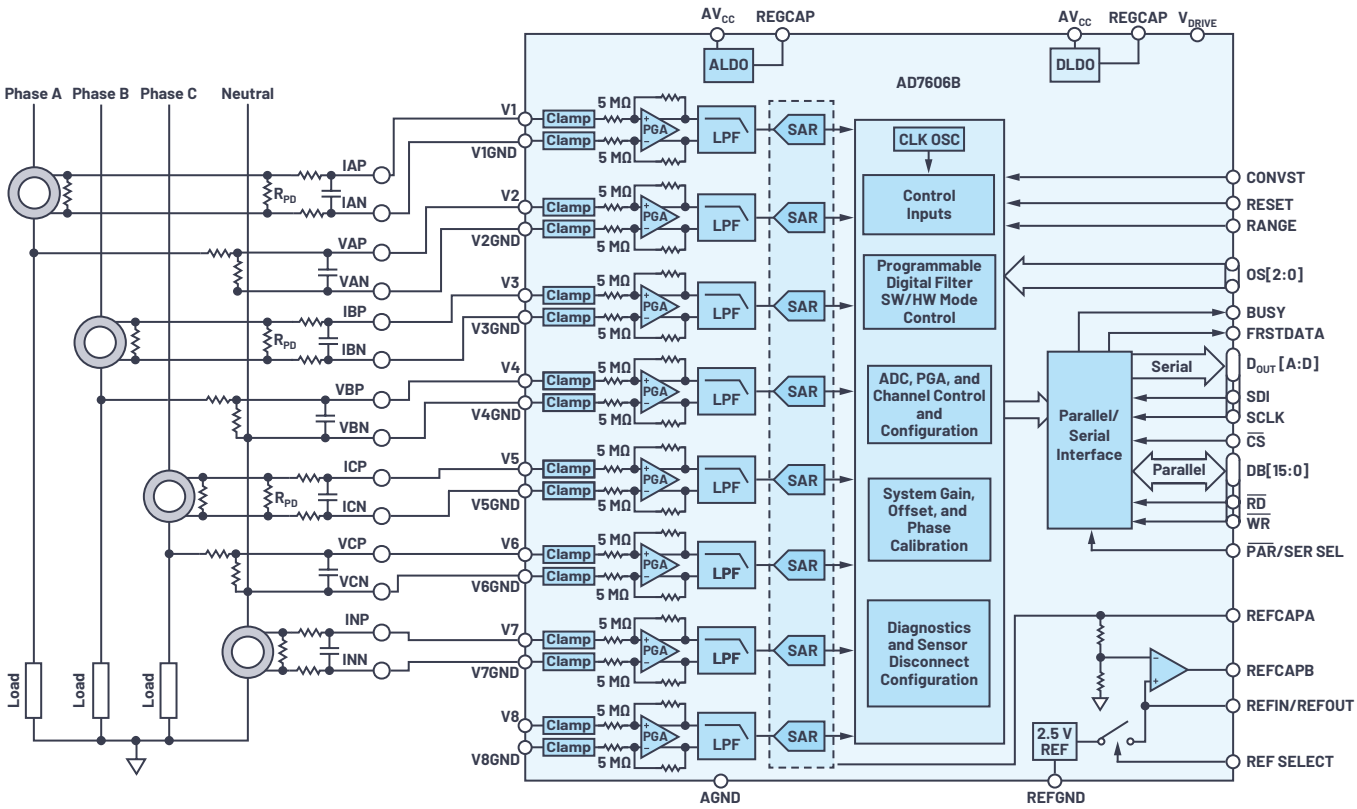

Figure 1. AD7606B in a typical power line monitoring application.

Direct Sensor Interface

Unlike AD7606, AD7606B input impedance has been increased to 5 MΩ, which allows for it to directly interface with a wide variety of sensors while granting two straightforward benefits:

- The gain error introduced by external series resistors (for example, the filtering or the resistor divider network) is reduced.
- The offset seen when the sensor is disconnected decreases, allowing for easy sensor disconnect detection features.

Gain Error Due to External Resistors

In factory trimming, there is tight control over R_{FB} and R_{IN} (5 MΩ typical) on a PGA, such that the AD7606B gain is accurately set. However, if an external resistor is placed in the front end, as shown in Figure 1, the actual gain then differs from the ideal trimmed R_{FB}/R_{IN}.

The higher the R_{FILTER}, the greater the gain error becomes, which will require compensation on the controller side. But the higher the R_{IN}, the less effect the same R_{FILTER} will have. Unlike the AD7606's 1 MΩ input impedance, the AD7606B has 5 MΩ input, meaning that the gain error will reduce about 1 over 5 for the same series resistor (R_{FILTER}) without any calibration, as shown Figure 2.

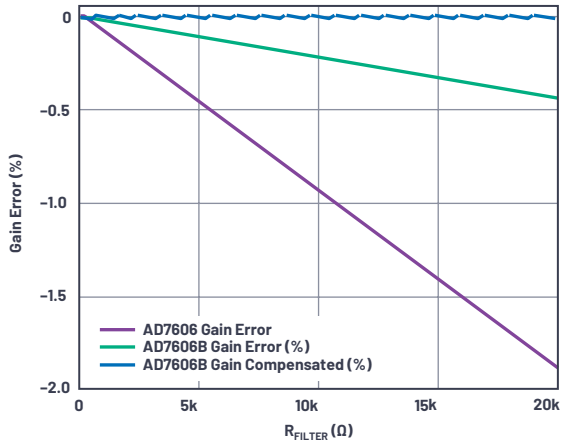

Figure 2. Gain error introduced by a series resistor.

However, by using the AD7606B in software mode, this system gain error can be automatically compensated on-chip, on a per channel basis, and completely eliminate the need for doing any gain calibration computation on the controller side.

Sensor Disconnect Detection

Traditionally, having a pull-down resistor (R_{PD}) in parallel with the sensor (current transformer shown in Figure 1) allows users to detect when the sensor disconnects by monitoring if an ADC output code lower than 20 LSBs repeats for a number of samples (N).

It is recommended to have an R_{PD} much larger than the source impedance of the sensor in order to minimize the error that this parallel resistor may introduce. However, the larger the R_{PD}, the larger the ADC output code generated when the sensor disconnects, which is not desired. A large ADC output code may lead to unnoticed sensor disconnection. Because the AD7606B has larger R_{IN} than the AD7606, for a given R_{PD}, the ADC output code is lower if the sensor disconnects, as shown in Figure 3, reducing the risk of false alarms.

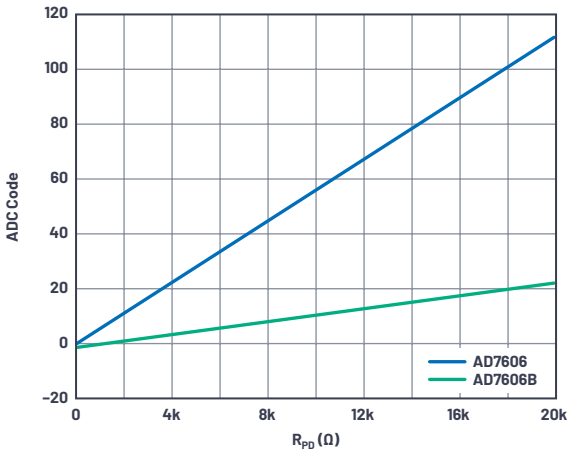

Figure 3. Offset error when the sensor gets disconnected from the ADC's analog inputs.

When entering software mode for the AD7606B, there is an open-circuit detection feature, eliminating the burden on the back-end software that detects the sensor disconnection. After programming the number of samples N (N = 3 on the example of Figure 4), if the analog input remains for several samples reporting a small dc value, the algorithm will automatically run and assert a flag if the analog input signal has been disconnected.

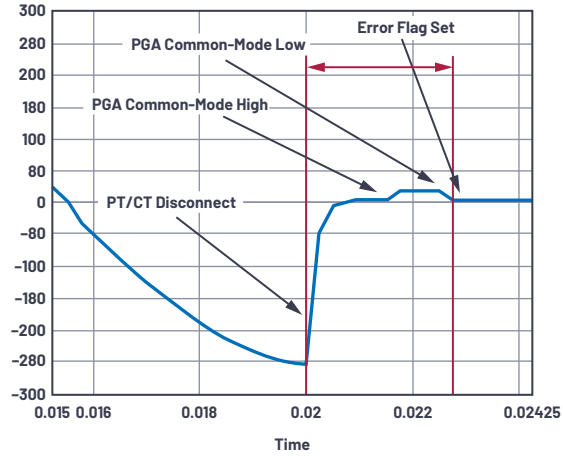

Figure 4. Sensor disconnect detection.

System-Level Performance

System Offset Calibration

When using a pair of external resistors, as seen in Figure 1, any mismatch between them will cause an offset. This offset can be measured as the ADC output code when the sensor is shortcut to ground. An offset from –128 LSBs to +127 LSBs can be then added to or subtracted from the conversion result by programming the corresponding channel offset register in order to compensate for that system offset.

System Phase Calibration

The CONVST pin manages the start of a conversion such that it triggers the process simultaneously on all channels. However, on applications where currents are measured through current transformers (CTs) while voltages are scaled down through a voltage divider, there will be a phase mismatch between current and voltage channels. To compensate for that, AD7606B can delay the sampling instant on any channels, such that the output signals can be realigned in phase, as shown in Figure 5.

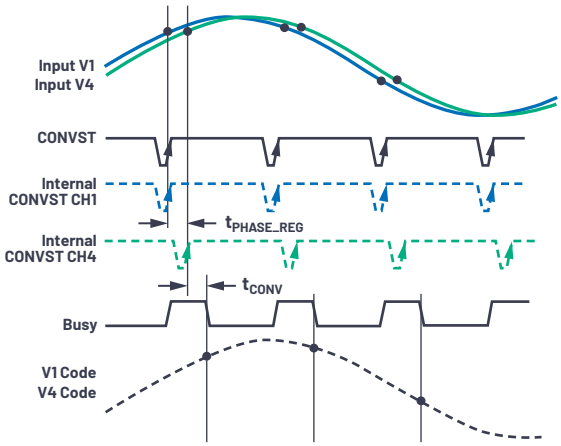

Figure 5. Phase realignment.

System Robustness

In order to increase system reliability, several diagnostic features have been included on-chip, namely:

- Overvoltage/undervoltage comparators on every channel.
- An interface check that clocks out fixed data on each channel in order to verify the communication.
- SPI invalid read/write alerts if there is an attempt to write to or read from an invalid register.
- BUSY STUCK HIGH alerts if the BUSY line continues longer than the normal time after a conversion has been initiated.
- Reset detection alerts if a reset has been detected for either a full, partial, or power-on reset on the internal LDO regulator.
- CRC can be performed in the memory map, ROM, and every interface communication in order to guarantee correct initialization and/or operation.

Conclusions

The AD7606B brings a complete data acquisition system on a chip to the market. All the analog front-end building blocks are implemented. It provides a complete set of advanced diagnostic features, as well as gain, offset, and phase-calibration. With this, the AD7606B reduces component cost and system design complexity, easing the journey to designing power line monitoring applications.

About the Author

Lluis Beltran Gil received his B.S. in electronics engineering in 2009 and in industrial engineering in 2012, both from the Universitat Politècnica de València, UPV (Technical University of Valencia). After graduation, Lluis joined Analog Devices in 2013 as an applications engineer in the Precision Converter Group in Limerick, supporting temperature sensors. Currently, Lluis is working on the SAR ADC Applications Team within the Precision Converters Group, and he is based in Valencia, Spain. He can be reached at lluis.beltrangil@analog.com.