Digital Interfaces for Current Sensing Devices

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Devices that monitor and report system current can either provide an analog output that is proportional to the sensed current, or communicate the current to a host processor digitally. Use of a digital current sense amplifier is sometimes preferred because the integrated analog to digital conversion allows data to be sent directly to the host controller or processor. Interaction with a host processor requires a digital interface that can both allow sending and receiving of instructions as well as data. For current sensing applications, the most commonly used digital interfaces are I^{2}C, SMBus, PMBus, and SPI. Each interface has different strengths and weaknesses; selecting the correct interface for a given application can allow better system optimization, faster system response time, and a reduction in software development time.

I^{2}C, SMBus, and PMBus all utilize open drain clock and data lines that require pull-up resistors to an external power supply. SMBus and PMBus compatible devices feature an active low alert output to notify the host processor of fault conditions. It is common to see I^{2}C and SMBus/PMBus devices exist on the same physical bus; however differences exist. Table 1 shown below, highlights some of the key differences among I^{2}C, SMBus, and PMBUS devices.

I^{2}C, SMBus and PMBus devices can easily co-exist on the same bus since all logic low thresholds are at 0.4V. Differences in the logic high thresholds usually are not an issue since the open-drain clock and data lines will go up to VDD when not held low. SMBus expanded on the frame work laid by I^{2}C by adding a bus timeout requirements that prevents a device from holding data lines low for extended amounts of time. SMBus also clearly defined many different types of transaction protocols that support the transmission of data from the bit level to blocks of bytes. The SMBus and PMBus specifications are very similar because PMBus leverages the electrical characteristics and communications protocols as defined by the SMBus specification. PMBus incorporates the SMBus electrical specification, while also standardizing the address locations for common commands that are used in power systems. The address/command standardization allows one software driver to support many devices without the need to be completely rewritten to support new devices or devices from different manufacturers.

Table 1. Comparison of I^{2}C, SMBus, and PMBus Interfaces

Parameter		I^{2}C	SMBus	PMBus
Electrical Levels	Output Logic Low, V_{OL}	0.4 V, sinking 3 mA	0.4V, sinking 350 uA (Low Power) sinking 4 mA (High Power)	Same as SMBus
	Input Logic Low, V_{IL}	0.3 x Vdd	0.8 V	Same as SMBus
	Input Logic High, V_{IH}	0.7 x Vdd	2.1 V	Same as SMBus
Speed	Minimum	-	100 kHz	Same as SMBus
	Maximum	5 MHz	400 kHz, 1 MHz	Same as SMBus
Number of wires/pins		2: SDA, SCL	3: SDA, SCL, $\overline{\text{SMBALERT}}$	3-4: SDC, SCL, $\overline{\text{SMBALERT}}$, CONTROL(optional)
Time-out requirement		No	Yes	Yes
Specified Transaction Protocols		No	Yes	Yes
Alert Capability		No	Yes	Yes
Address Resolution Protocol		No	Yes, but optional	Yes, but optional
CRC error checking support		No	Yes, but optional	Yes, but optional
Group Protocol support		No	Yes, but optional	Yes, required for PMBus
Standardized Commands / Register Set		No	No	Yes, both standard and device specific commands supported

SMBus adds support for dynamic address resolution, CRC checking to increase communications robustness, and group protocol that allows communication to multiple devices within a single transaction. Support for group protcol is optional for SMBus devices but is required for all PMBus devices.

Most digital current sense amplifiers available from Texas Instruments are compatible with both I^2C and SMBus interfaces. For example, the INA226 supports the high-speed mode (up to 2.94 MHz) offered by I^2C, but also features an Alert pin and error resolution protocols as defined by SMBus. The device can monitor and report the current, voltage, and power. The INA226 is available in a VSSOP-10 package and can monitor current very accurately with a gain error of only 0.1% and a maximum offset error of 10 µV. Table 2, shown below, provides a summary of current sense devices that are compatible with the I^2C and SMBus interfaces.

Table 2. I^2C/SMBus Compatible Devices

Device	Optimized Parameters	Performance Trade-Off
INA209	Internal analog comparators for critical over current detection	Larger package, 12-bit ADC
INA219	Low pin count, SOT23-8 package	No alert pin, voltage measurements made in respect to IN- Pin, 12-bit ADC
INA220	Independent bus voltage measurement	Larger VSSOP-10 package, 12-bit ADC
INA226	Highest Accuracy, 16-bit ADC, VSSOP-10 package	Leaded package
INA230	High Accuracy, 16-bit ADC, 3mm x 3mm QFN	Higher offset and gain error than INA226
INA231	High Accuracy, 16-bit ADC, Smallest Package (WCSP-12)	Higher offset and gain error than INA226
INA260	Internal Shunt, Highest accuracy (total solution)	Larger package, Maximum current is 15A
INA3221	3 channel voltage and current monitor	12-bit accuracy, Lower effective sample rate

Texas Instruments also has several devices that can monitor current, power and voltage that feature a PMBus compatible interface. The INA233 a can monitor current, voltage, power, and energy. The INA233 is pin-out compatible with the INA226 and has the same specification for gain error and offset; however the gain error drift of the INA233 is reduced to 25 PPM/°C. A block diagram of the INA233 is shown in Figure 1

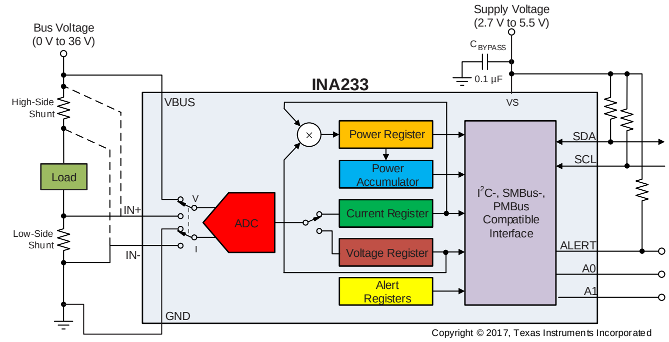

Figure 1. INA233 Block Diagram

A comparison of PMBus compatible current monitoring devices are shown in Table 3.

Table 3. I^2C/SMBus/PMBus Compatible Devices

Device	Optimized Parameters	Performance Trade-Off
INA233	Highest Accuracy, 16-bit ADC, Faster Sampling Rate, Energy Monitor/Power Accumulator	No remote temperature monitoring
LM25056	Auxiliary voltage measurement input, Remote temperature sensing	12-bit ADC, Less Accuracy, No power accumulator
LM5056A	High Voltage (80V), AUX input, Remote temperature sensing	12-bit ADC, Less Accuracy, No power accumulator

Another digital interface that is sometimes used in current monitoring devices is the SPI interface. The SPI interface is a 4-wire interface that does not require external pull-up resistors like I^2C and can operate at much higher clock frequencies. The pull-up resistors used in I^2C limit the operational speed due to RC time constant established by the value of the pull-up resistor and bus capacitance. The LMP92064 features two 12 bit high speed ADCs that can support 125 kSps conversion rates making it ideal for high speed low-side sensing applications. One of the ADCs is dedicated to measuring voltage while the other ADC measures the shunt voltage drop. The two ADC approach allows for the simultaneous conversion of the current and voltage to avoid time alignment errors in the power calculation. The SPI interface used in the LMP92064 allows data clock rates as high as 20 MHz.

Table 4. Adjacent TechNotes

SBOA167	Integrating the Current Sensing Signal Path
SBOA179	Integrated, Current Sensing Analog-to-Digital Converter
SBOA194	Power and Energy Monitoring with Digital Current Sensors

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