Application Brief

Digital Interfaces for Current Sensing Devices

Dennis Hudgins, Mitch Morse

Current Sensing Products

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^2C, 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^2C, 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. I^2C, SMBus, and PMBus devices commonly exist on the same physical bus; however, differences exist. Table 1 highlights some of the key differences among I^2C, SMBus, and PMBUS devices.

I^2C, SMBus, and PMBus devices can easily co-exist on the same bus since all logic low thresholds are at 0.4 V. 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^2C by adding a bus timeout requirement 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^2C, SMBus, and PMBus Interfaces

Parameter		I^2C	SMBus	PMBus
Electrical Levels	Output Logic Low, V_{OL}	0.4 V, sinking 3 mA	0.4 V, sinking 350 µA (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 protocol 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 INA228 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 shunt voltage, bus voltage, die temperature, current, power, energy accumulation, and charge accumulation. The INA228 is available in a VSSOP-10 package, is an ultra-precise digital current monitor with a 20-bit delta-sigma ADC, has a gain error of only 0.05%, and a maximum offset voltage of 1 μV. Table 2 provides a summary of current sense devices that are compatible with I^2C and SMBus.

Table 2. I^2C/SMBus Compatible Devices

Device	Optimized Parameters	Performance Trade-Off
INA209	Internal analog comparators for critical over current detection	26-V, 12-bit ADC, Large TSSOP-16 package
INA219	Low pin count, SOT23-8 package	No alert pin, 26-V, 12-bit ADC, VBUS tied to IN-
INA220	Independent bus voltage measurement	No alert pin, 26-V, 12-bit ADC,VSSOP-10 package
INA226	High accuracy, 16-bit ADC, Current / Power Monitor	36-V, VSSOP-10 package
INA228	Highset Accuracy, 85-V, 20-Bit ADC, Power / Energy / Charge / Temperature Monitor	VSSOP-10 package
INA230	High accuracy, 16-bit ADC, 3mm x 3mm QFN	28-V, Higher offset and gain error than similar device INA226
INA231	High Accuracy, 16-bit ADC, Smallest Package (WCSP-12), 1.8-V I2C interface	28-V, Higher offset and gain error than similar device INA226
INA234	Small DSBGA 8 package	28-V, 12-bit ADC, One address pin for a maximum of 4 addresses
INA236	High accuracy, 48-V, 16-bit ADC, small DSBGA 8 package	One address pin for a maximum of 4 addresses
INA237	85-V, 16-Bit ADC, Power / Energy / Charge / Temperature Monitor	VSSOP-10 package, Higher offset and gain error than similar INA238 device
INA238	High Accuracy, 85-V, 16-Bit ADC, Power / Energy / Charge / Temperature Monitor	VSSOP-10 package, Higher offset and gain error than similar INA228 device
INA260	Internal Shunt, high accuracy (total solution), 16-bit ADC	36-V, Large TSSOP-16 package, Maximum current is 15A
INA3221	3 channel voltage and current monitor	26-V, 12-bit ADC, Lower effective sample rate

Texas Instruments also has the INA233, which features a PMBus compatible interface and can monitor current, voltage, power, and energy. The INA233 is also available in a VSSOP-10 package, can monitor current very accurately with a gain error of only 0.1%, and has a maximum offset error of 10 μV. Table 3 provides a summary of current sense devices that are compatible with I^2C, SMBus, and PMBus.

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

Device	Optimized Parameters	Performance Trade-Off
INA233	High accuracy, 16-bit ADC, Fast Sampling Rate, Energy Monitor / Power Accumulator	36-V, VSSOP-10 package

Another digital interface that is 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 the RC time constant established by the value of the pull-up resistor and bus capacitance. One example is the INA229, which has the same current sensing specifications as the INA228, but allows data clock rates as high as 10 MHz. Table 4 provides a summary of current sense devices that are compatible with SPI.

Table 4. SPI Compatible Devices

Device	Optimized Parameters	Performance Trade-Off
INA229	Highset Accuracy, 85-V, 20-Bit ADC, Power / Energy / Charge / Temperature Monitor	VSSOP-10 package
INA239	High Accuracy, 85-V, 16-Bit ADC, Power / Energy / Charge / Temperature Monitor	VSSOP-10 package, higher offset and gain error than similar INA229 device

Table 5. Adjacent Application Briefs

SBOA511	Getting Started with Digital Power Monitors
SBOA167	Integrating the Current Sensing Signal Path
SBOA179	Integrated, Current Sensing Analog-to-Digital Converter
SBOA194	Power and Energy Monitoring with Digital Current Sensors

IMPORTANT NOTICE AND DISCLAIMER

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265