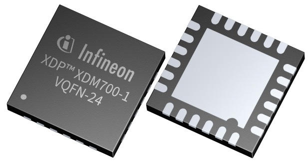
XDM700-1

Fully digital current sensing and system monitoring IC with PMBus®



Features

- Wide input voltage range: 5 V to 80 V
- Transient withstand: up to 100 V for 500 ms
- Voltage sensing range: 0 V to 22 V / 0 V to 44 V / 0 V to 88 V
- High-Side or Low-Side Current Sensing
- 4-level programmable current sense differential range: 12.5 mV / 25 mV / 50 mV / 100 mV
- Dedicated Current and Voltage ADCs: 12-bit resolution, ~102 us refresh rate
- Dedicated internal temperature sensor and support for an external temperature sensor
- Analog current (IMON) or power (PMON) reporting signal
- Precision input and output voltage monitoring and reporting: ≤ 0.4%
- Precision current monitoring and reporting: ≤ 0.5% @ 50 mV / 100 mV or ≤ 1% @ 12.5 mV / 25 mV
- Precision input power monitoring and reporting: ≤ 1.5%
- Energy monitoring and reporting: ≤ 3%
- Integrated 5 V regulator (10 mA output capability)
- PMBus® interface: up to 1 MHz
- Reporting telemetry peaks (V/I/P/T_{EXT}) and valleys (V/I/T_{EXT})
- Programmable under-voltage, over-voltage, over-current, over-power and over-temperature warnings
- Programmable device addresses by hardware setting (15x) and via PMBus® (128x)
- PG-VQFN-24 lead, 4 mm x 4 mm package
- -40°C to 125°C Junction temperature

Potential applications

- Servers and Datacenters
- Power Metering
- Power Distribution Systems
- Network Routers and Switches
- Power Supplies and Test Equipment

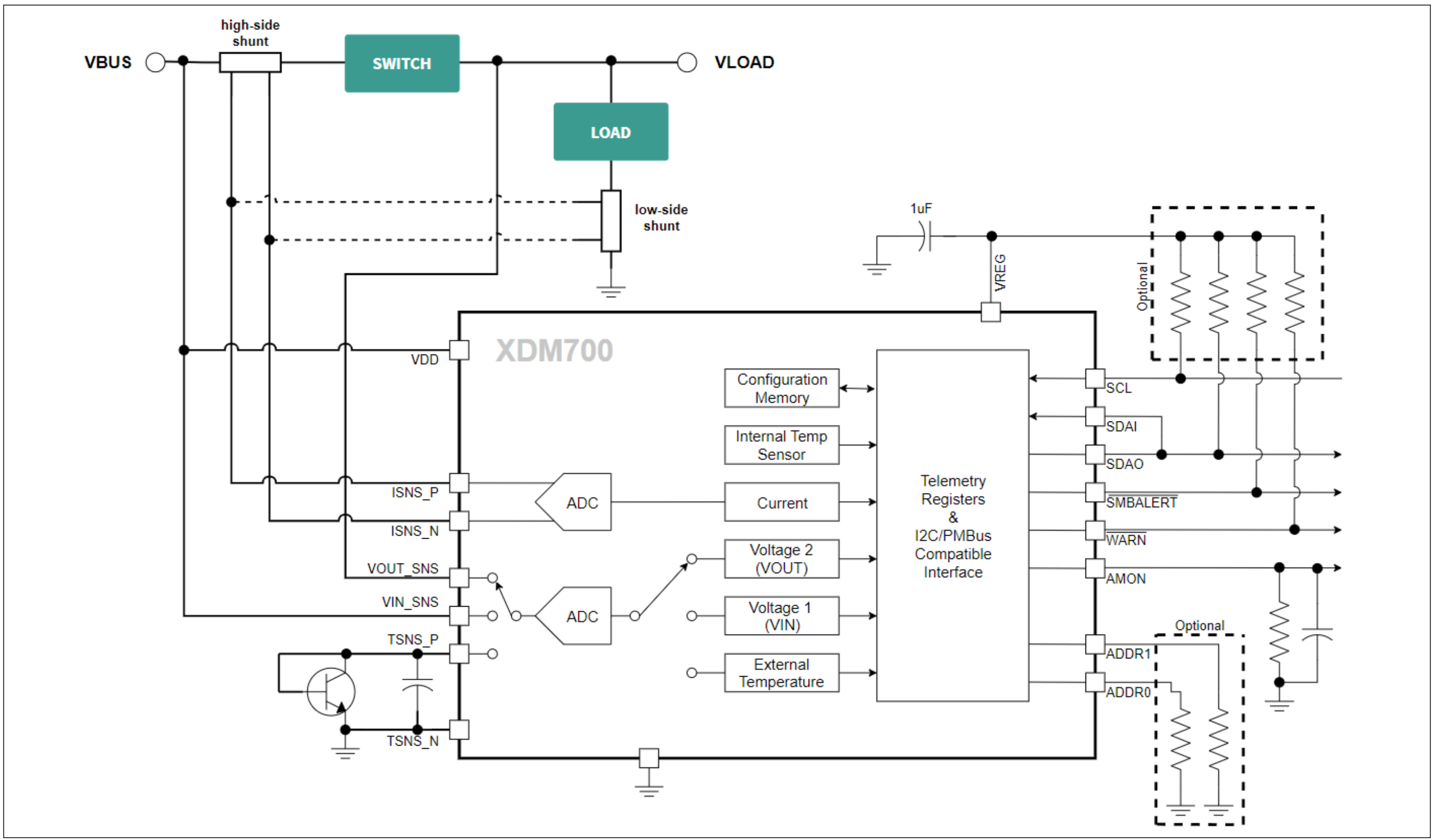
Product validation

Qualified for industrial applications according to the relevant tests of JEDEC47/20/22.

Description

XDM700 is a high-side/low-side current sensing and system monitoring IC with a wide input voltage range (5 V to 80 V). In addition to current sensing, it also provides continuous monitoring of input voltage, input power, output voltage, on-chip and external temperature using a dedicated 12-bit ADC. With 4-level programmable current sense differential range (12.5 mV / 25 mV / 50 mV / 100 mV) and a dedicated 12-bit current ADC, it provides an accuracy of up to 1% for the current measurements. The analog current proportional to the load current or input power can be reported at the AMON pin for post-processing. Additionally, the built-in power accumulator ensures reliable energy monitoring and reporting over time. A simplified schematic is shown below for reference.

It incorporates several warnings for safe operation and generates various protection responses through WARN and SMBALERT outputs. There is a 5V internal voltage regulator that can be used for low-power peripheral circuitry. It is PMBus® v1.3 compliant up to 1 MHz and has up to 128 unique programmable device addresses. This device is available in a 4 mm x 4 mm PG-VQFN package, specified over a -40°C to +125°C junction temperature range.


high-side shunt
VBUS
SWITCH
VLOAD
LOAD
low-side shunt
1uF
VREG
Optional
XDM700
VDD
Configuration Memory
Internal Temp Sensor
ISNS_P
ISNS_N
ADC
Current
VOUT_SNS
VIN_SNS
ADC
Voltage 2 (VOUT)
Voltage 1 (VIN)
TSNS_P
External Temperature
TSNS_N
Telemetry Registers & I2C/PMBus Compatible Interface
SCL
SDAI
SDAO
SMBALERT
WARN
AMON
Optional
ADDR1
ADDR0

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1 Pin configuration

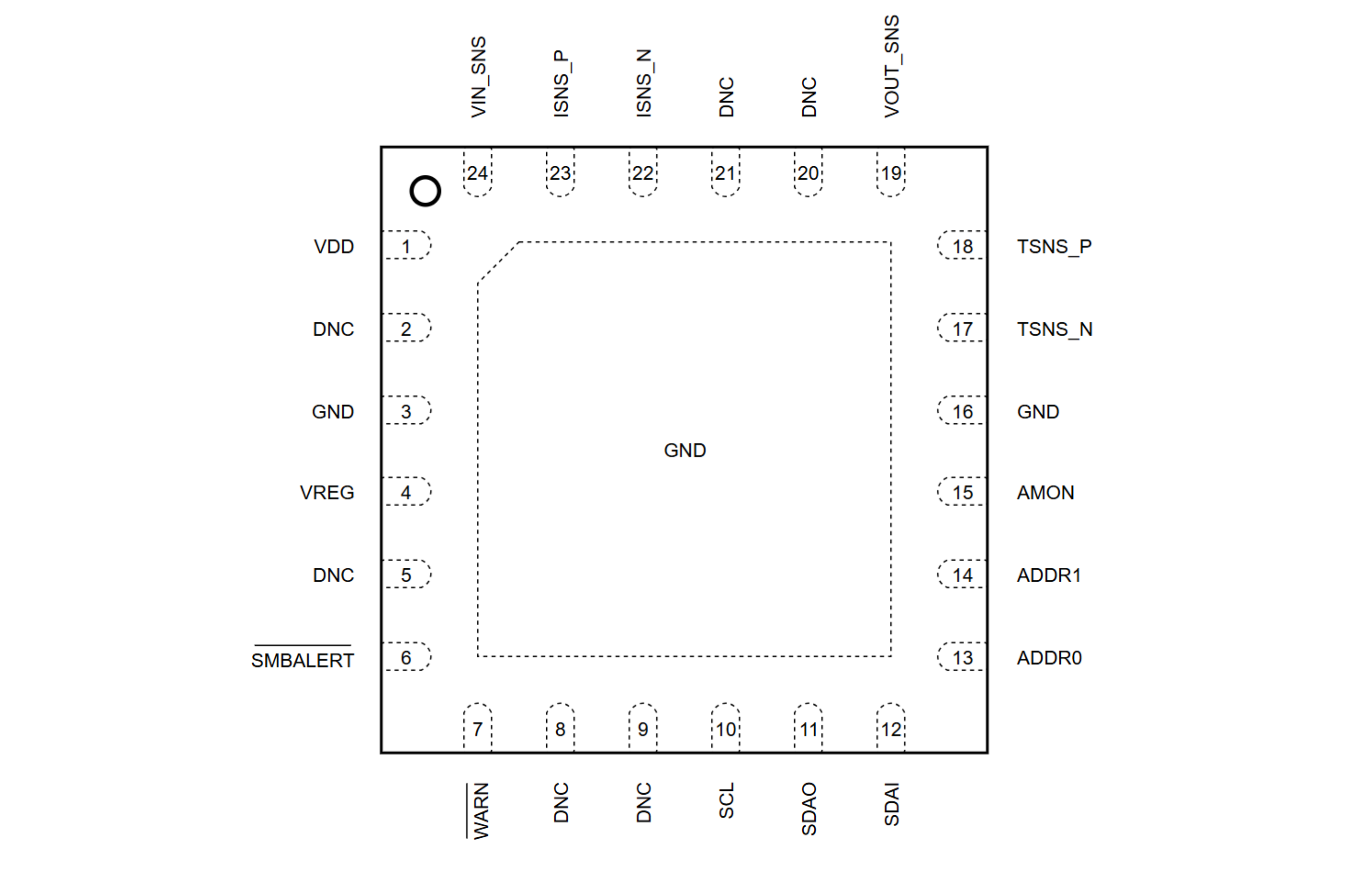

Figure 1 XDM700 device pinout (top view)

Table 1 XDM700 pinout description

Pin#	Name	I/O	Type	Description	If unused, connect to
1	VDD	I	P	Power supply pin. A 100 Ω - 100 nF capacitor from this pin to GND is strongly recommended.	VDD
2	DNC	-	-	Do not connect pin. This pin must be connected to GND pins.	GND
3	GND	-	G	Ground reference terminal. This pin must be connected to the system ground.	GND
4	VREG	O	P	VREG (internal 5 V regulator) output pin. A 1 μF capacitor from this pin to GND is mandatory.	Connect a 1 μF capacitor from this pin to GND
5	DNC	-	-	Do not connect pins.	Open
6	SMBALERT	O	D	SMBALERT# open drain output pin. This pin is latched "Low" when a warning has occurred. The warnings that can trigger this pin can be configured.	Open

(table continues...)

Table 1 (continued) XDM700 pinout description

Pin#	Name	I/O	Type	Description	If unused, connect to
7	WARN	O	D	WARN# open drain output pin. This pin asserts "Low" when a warning has occurred. The warnings that can trigger this pin can be configured.	Open
8	DNC	-	-	Do not connect pins.	Open
9	DNC	-	-	Do not connect pins.	Open
10	SCL	I	D	PMBus® clock input pin. The interface is rated to 1 MHz.	Pull-up to VREG or external source
11	SDAO	O	D	PMBus® data output pin (1).	Pull-up to VREG or external source
12	SDAI	I	D	PMBus® data input pin (1).	Pull-up to VREG or external source
13	ADDR0	I	A	Device address configuration input pins. These pins can be tied to GND, left open or tied to GND through a resistor for a total of fifteen unique PMBus® device addresses.	Open
14	ADDR1	I	A		
15	AMON	O	A	Analog monitor output pin. This pin reports an analog current proportional to the monitored load current (IMON) or input power (PMON) level.	Open
16	GND	-	G	Ground reference terminal. This pin must be connected to the system ground.	GND
17	TSNS_N	IO	A	Temperature sense negative input pin. Tie this pin to the emitter of an external NPN BJT to sense the external temperature.	GND
18	TSNS_P	IO	A	Temperature sense positive input pin. Tie this pin to the base and collector of an external NPN BJT to sense the external temperature. A 1 nF capacitor is recommended between the TSNS_x pins.	GND
19	VOUT_SNS	I	A	Output voltage sense pin.	VOUT (i.e. voltage sense signal-2)
20	DNC	-	-	Do not connect pin. This pin must be connected to GND pins.	GND
21	DNC	-	-	Do not connect pin. This pin must be connected to GND pins.	GND
22	ISNS_N	I	A	Current sense negative input pin.	GND
23	ISNS_P	I	A	Current sense positive input pin. A 100 nF capacitor is recommended between the ISNS_x pins.	GND

(table continues...)

Table 1 (continued) XDM700 pinout description

Pin#	Name	I/O	Type	Description	If unused, connect to
24	VIN_SNS	I	A	Input voltage sense pin.	VDD (i.e. voltage sense signal-1)
EP	GND	-	G	Ground reference terminal. The exposed pad must be connected to the system ground.	GND

***Note**: (1) PMBus® serial data is split into an input and an output for easy use with isolators.*

2 Block diagram

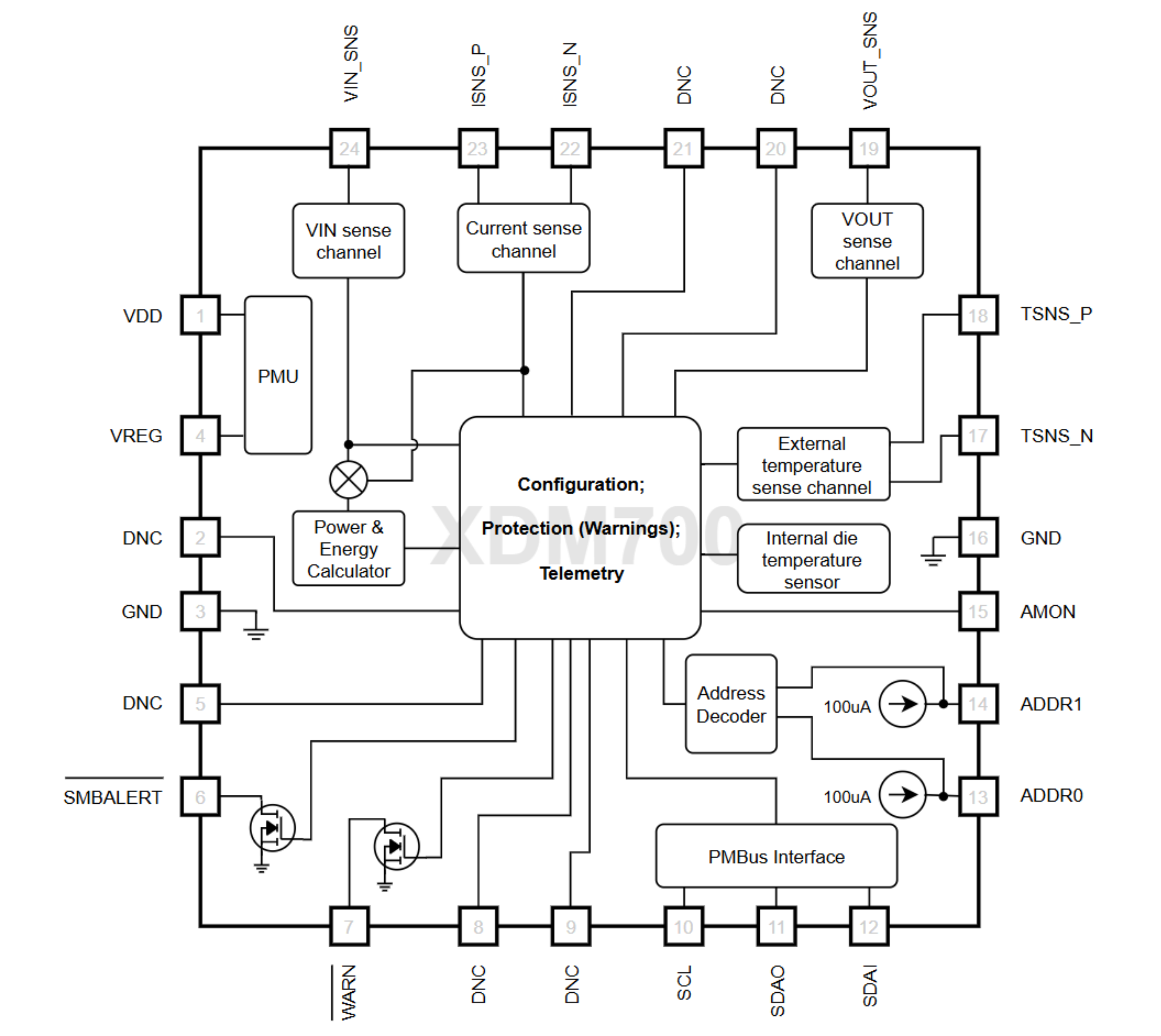

Figure 2 XDM700 block diagram

3 Functional description

XDM700-1 commonly referred to as XDM700 is a fully digital current sensing and system monitoring IC with a wide input voltage range. The 12-bit current ADC ensures up to 1% accuracy for the current measurements. In addition to current sensing, it also provides continuous monitoring of input voltage, input power, output voltage, on-chip and external temperature using a dedicated 12-bit ADC. XDM700 has a built-in power accumulator that ensures reliable energy monitoring and reporting over time. It can report instantaneous or averaged telemetry data along with "Peaks" and "Valleys" information. Additionally, the analog current proportional to the load current or input power can be reported at the AMON pin for post-processing. It incorporates several warnings for safe operation and generates various protection responses through WARN and SMBALERT outputs.

3.1 Device address

The XDM700 has up to 128 unique programmable PMBus® device addresses, of which 15 addresses can be set using the two address pins i.e. ADDRx. These pins can be left floating, tied to GND through a resistor or tied directly to GND for a total of 15 unique PMBus® device addresses as shown in Table 2.

Table 2 Configuration of ADDR1/0 pins

ADDR1 pin voltage (V)	ADDR1 pin resistance (kΩ)	ADDR0 pin voltage (V)	ADDR0 pin resistance (kΩ)	Base address field [6:4]	Device address field [3:0]
$V_{ADDR1} < 0.8$	GND	$V_{ADDR0} < 0.8$	GND	set via PMBUS_CFG command (Default = 3'b001)	0000
$V_{ADDR1} < 0.8$	GND	$0.8 \leq V_{ADDR0} < 1.6$	12		0001
$V_{ADDR1} < 0.8$	GND	$1.6 \leq V_{ADDR0} < 2.4$	20		0010
$V_{ADDR1} < 0.8$	GND	$V_{ADDR0} \geq 2.4$	Open		0011
$0.8 \leq V_{ADDR1} < 1.6$	12	$V_{ADDR0} < 0.8$	GND		0100
$0.8 \leq V_{ADDR1} < 1.6$	12	$0.8 \leq V_{ADDR0} < 1.6$	12		0101
$0.8 \leq V_{ADDR1} < 1.6$	12	$1.6 \leq V_{ADDR0} < 2.4$	20		0110
$0.8 \leq V_{ADDR1} < 1.6$	12	$V_{ADDR0} \geq 2.4$	Open		0111
$1.6 \leq V_{ADDR1} < 2.4$	20	$V_{ADDR0} < 0.8$	GND		1000
$1.6 \leq V_{ADDR1} < 2.4$	20	$0.8 \leq V_{ADDR0} < 1.6$	12		1001
$1.6 \leq V_{ADDR1} < 2.4$	20	$1.6 \leq V_{ADDR0} < 2.4$	20		1010
$1.6 \leq V_{ADDR1} < 2.4$	20	$V_{ADDR0} \geq 2.4$	Open		1011
$V_{ADDR1} \geq 2.4$	Open	$V_{ADDR0} < 0.8$	GND		1100
$V_{ADDR1} \geq 2.4$	Open	$0.8 \leq V_{ADDR0} < 1.6$	12		1101
$V_{ADDR1} \geq 2.4$	Open	$1.6 \leq V_{ADDR0} < 2.4$	20		1110
$V_{ADDR1} \geq 2.4$	Open	$V_{ADDR0} \geq 2.4$	Open		set via PMBUS_CFG command (Default = 4'b0000)

3.2 Warnings

Warnings are alerted through the WARN pin to the system MCU so that it can decide if any action is needed in response. Each warning has a corresponding bit in the STATUS_WARNS command that is set when a warning has occurred.

The SMBALERT pin provides a latched summary of all triggered warnings. A mask command (MASK_WARNS) allows the user to select which warnings will be reflected on the WARN and SMBALERT pins. Warnings can be disabled by clearing their enable bits in the ENABLE_WARNS command, which means they won't be detected or reported.

Masking a warning will only affect the WARN pin reporting but not its status bit. The WARN pin is released either after the warning condition is removed or when the warning status bit is cleared. The warning status bits will remain set until they are cleared:

- using CLEAR_FAULTS command
- or by a device power cycle

***Note**: Due to the nature of the COMM warning, there are some exceptions on the way it is reported through the WARN pin and the way it is cleared. Refer Chapter 3.2.5 for details.*

The following figure shows the flow of all warnings.

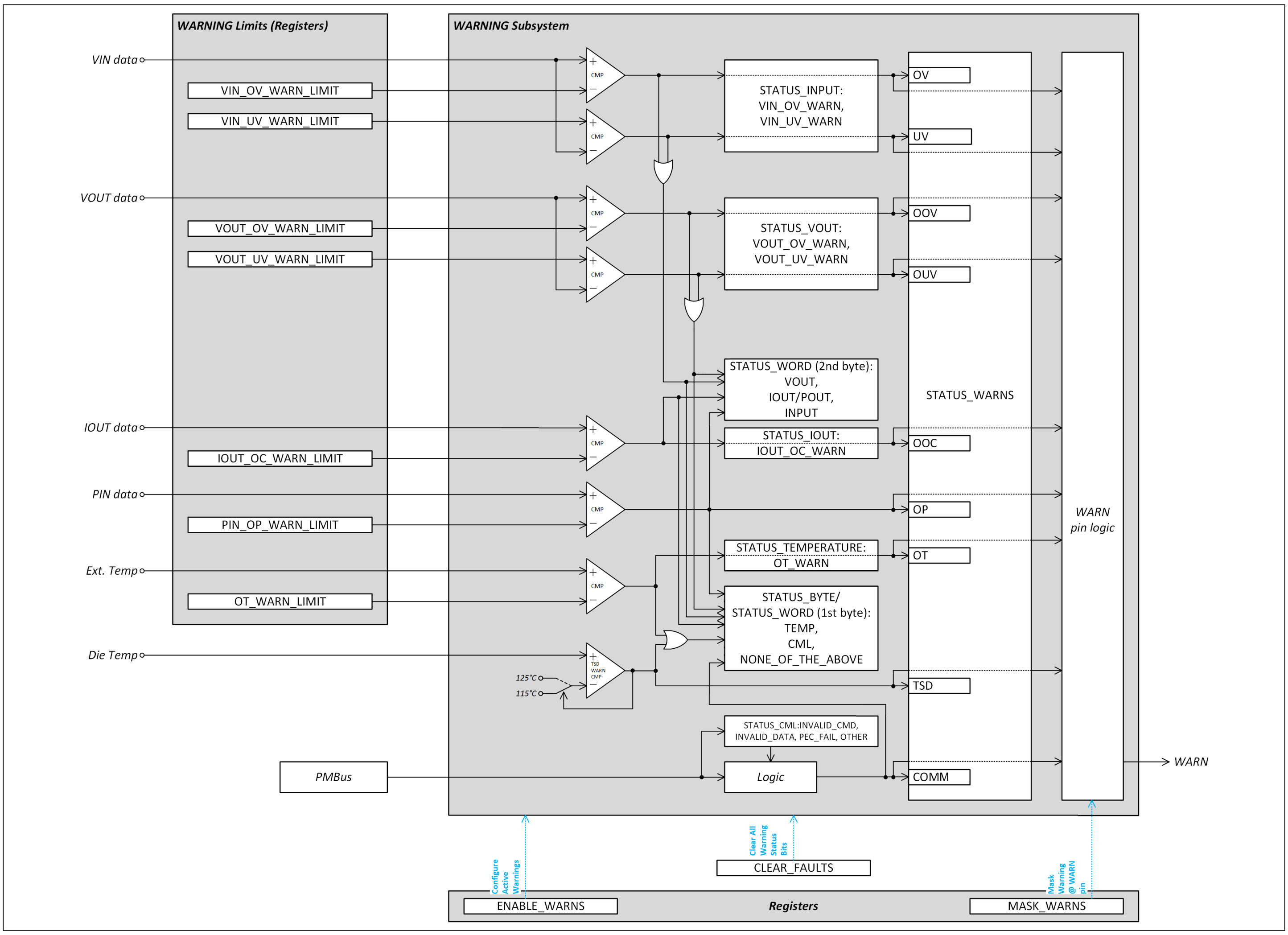

Figure 3 **Warnings flow**

3.2.1 Current warning

Output overcurrent (OOC) warning

An OOC warning is detected if the load current sensed by the voltage drop across the sense resistor exceeds the limit set by the IOUT_OC_WARN_LIMIT command. Using the TELEMETRY_AVG command, this warning can be configured to respond to the averaged current telemetry. The OOC warning is cleared if the current goes below the IOUT_OC_WARN_LIMIT minus a digital hysteresis of 0x80 = 128 dec, which corresponds to the following current levels, depending on the V_{SNS_CS} setting and assuming a 1 mΩ sense resistor:

Table 3 Current hysteresis

V_{SNS_CS} (mV)	12.5	25	50	100
Current (A)	0.55	1.11	2.2	4.4

3.2.2 Input voltage and power warnings

Input undervoltage (UV) warning

If the input voltage at the VIN_SNS pin drops to/below the warning level programmed using the VIN_UV_WARN_LIMIT command, the UV warning is triggered. Using the TELEMETRY_AVG command, this warning can be configured to respond to the averaged voltage telemetry. The UV warning is cleared when the input voltage rises above this level plus a hysteresis of 0x60 = 96 dec, which corresponds to the following voltage levels, depending on the V_{TLM_RNG} setting:

Table 4 Voltage hysteresis

V_{TLM_RNG} (V)	88	44	22
Voltage (V)	2.06	1.03	0.52

Input overvoltage (OV) warning

If the input voltage at the VIN_SNS pin reaches or rises above the warning level programmed using the VIN_OV_WARN_LIMIT command, the OV warning is triggered. Using the TELEMETRY_AVG command, this warning can be configured to respond to the averaged voltage telemetry. It is cleared when the voltage falls below this limit minus a hysteresis of 0x60 = 96 dec (see Table 4), the warning is cleared.

Input overpower (OP) warning

If the input power (VIN * IOUT) goes above the programmed PIN_OP_WARN_LIMIT, the system generates an OP warning. It is cleared when the input power goes below the limit minus a digital hysteresis of 0x100 (which corresponds to typically 0.4% of the maximum power). Averaging of power for this warning is done by the same setting as telemetry i.e. using TELEMETRY_AVG command.

3.2.3 Output voltage warning

Output undervoltage (OUV) warning

If the output voltage measured at the VOUT_SNS pin reaches or falls below VOUT_UV_WARN_LIMIT, an OUV warning is triggered. Using the TELEMETRY_AVG command, this warning can be configured to respond to the averaged voltage telemetry. If the voltage rises above this limit plus a hysteresis of 0x60 = 96 dec (see Table 4), the warning is cleared.

Output overvoltage (OOV) warning

This warning bit will be set if the output voltage measured at the VOUT_SNS pin exceeds the limit set by the VOUT_OV_WARN_LIMIT command. Using the TELEMETRY_AVG command, this warning can be configured to respond to the averaged voltage telemetry. If the output voltage falls below the limit minus a hysteresis of 0x60 = 96 dec (see Table 4), the warning is cleared.

3.2.4 Temperature warnings

External overtemperature (OT) warning

If the external temperature measured at TSNS_P and TSNS_N pins raises above OT_WARN_LIMIT, an OT warning is issued. The warning is cleared when the temperature falls below OT_WARN_LIMIT minus a fixed hysteresis of 25°C.

Controller thermal shutdown (TSD) warning

XDM700 has an on-chip temperature sensor. If the internal die temperature exceeds an upper threshold $TSDW_{UTH}$, a warning is triggered. This warning is cleared when the die temperature falls below $TSDW_{LTH}$.

3.2.5 Communication warning

PMBus® interface communication (COMM) warning

This warning is triggered if the PMBus® communication (read or write) detects any failures.

***Note**: WARN pin is not cleared by clearing the STATUS_CML command after a COMM warning. WARN pin is a reflection of the COMM bit in the STATUS_WARNS command, so this bit has to be cleared to release the WARN pin.*

3.3 Telemetry

XDM700 provides real time accurate measurement and calculation data for:

- Input voltage
- Output voltage
- Current (by means of voltage drop over external shunt resistor)
- Input power
- Energy
- External temperature
- Controller's on-chip temperature

All information is provided through the PMBus® interface by issuing the corresponding commands. The figure below shows the detailed telemetry flow of the device.

The figure below shows the telemetry flow:

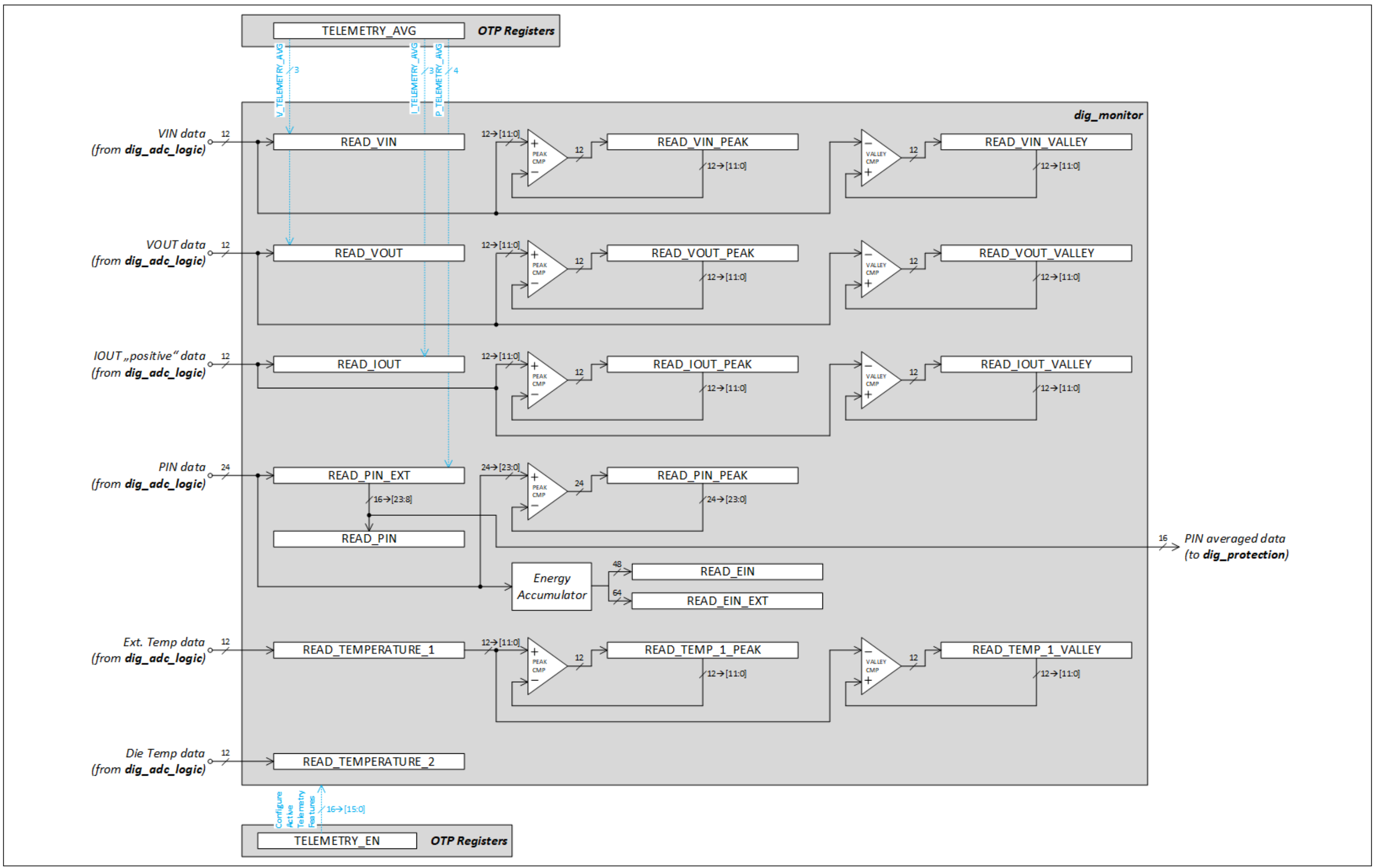

Figure 4 **XDM700 telemetry flow**

The following table shows the sensing points of the different telemetry features and their associated PMBus® commands.

Table 5 **Telemetry summary**

Parameter	Sensing	Averaging configuration	Telemetry data		
			Instantaneous/ averaged	Peak	Valley
Input voltage	VIN_SNS pin	V_TELEMETRY_AVG	READ_VIN	READ_VIN_PEAK	READ_VIN_VALLEY
Current	ISNS_P/ISNS_N pins	I_TELEMETRY_AVG	READ_IOUT	READ_IOUT_PEAK	READ_IOUT_VALLEY
Output voltage	VOUT_SNS pin	V_TELEMETRY_AVG	READ_VOUT	READ_VOUT_PEAK	READ_VOUT_VALLEY
Input power (16 bits)	Input voltage x Current	P_TELEMETRY_AVG	READ_PIN	-	-
Input power (24 bits)			READ_PIN_EXT	READ_PIN_PEAK	-
Energy (48 bits)	Input power accumulated over time	-	READ_EIN	-	-
Energy extended (64 bits)		-	READ_EIN_EXT	-	-
External temperature	TSNS_P/TSNS_N pins	-	READ_TEMPERATURE_1	READ_TEMP_1_PEAK	READ_TEMP_1_VALLEY
Controller's on-chip temperature	Internal die temperature sensor	-	READ_TEMPERATURE_2	-	-

3.3.1 Averaged and instantaneous telemetry

Averaged telemetry data

The TELEMETRY_AVG command is used to configure the averaging settings for the input voltage, output voltage, load current and input power telemetry data. The voltages and current can be averaged up to 128 samples, while the power can be averaged up to 32768 samples.

Table 6 **Telemetry averaging (Voltage and Current)**

Bits settings	Averaged amount of samples
000	1
001	2
010	4
011	8
100	16
101	32
110	64
111	128

Table 7 Telemetry averaging (Power)

Bits settings	Averaged amount of samples
0000	1
0001	2
0010	4
0011	8
0100	16
0101	32
0110	64
0111	128
1000	256
1001	512
1010	1024
1011	2048
1100	4096
1101	8192
1110	16384
1111	32768

Instantaneous telemetry data

Instantaneous measurements are obtained by setting the corresponding TELEMETRY_AVG:x_TELEMETRY_AVG bits to "0", so that only one sample is taken.

3.3.2 Peaks and valleys

x_PEAK and x_VALLEY commands are used to report the maximum and minimum values respectively, measured since the last time the command was read by the user.

Peaks information is available for the following parameters:

- Input voltage
- Output voltage
- Current
- Input power
- External temperature

Valleys information is available for the following parameters:

- Input voltage
- Output voltage
- Current
- External temperature

The x_PEAK and x_VALLEY commands are cleared after reading their contents or through a device power cycle. After reset, the first value read is compared to the previous peak (0x000) or valley (0xFFF) and it becomes the new peak or valley respectively. This process continues until the user reads this data. As shown in Figure 4, peaks and valleys are calculated from instantaneous data before it is averaged regardless of the averaging setting.

3.3.3 Telemetry via PMBus

The following formula converts from PMBus® direct format to "real world" values:

$$X = \frac{1}{m} \times \left(Y \times 10^{-R} - b\right) \quad (1)$$

where:
X = Calculated "real world" value in the appropriate units (A, V, °C, etc)
m = Slope coefficient, is a two byte, two's complement integer
Y = Two byte two's complement integer received from the PMBus® device
b = Offset, is a two byte, two's complement integer
R = Exponent, is a one byte, two's complement integer

To convert from "real world" values to PMBus® direct format, use the following formula:

$$Y = \left(mX + b\right) \times 10^{R} \quad (2)$$

where:
Y = Two byte two's complement integer to be sent to the unit
m = Slope coefficient, is the two byte, two's complement integer
X = "real world" value, in units such as Amperes or Volts, to be converted for transmission
b = Offset, is the two byte, two's complement integer
R = Exponent, is the decimal value equivalent to the one byte, two's complement integer.

The coefficients for these formulae are specified in the following table:

Table 8 PMBus® coefficients

Parameter	Command	VTLM_RNG	V_{SNS_CS}	m	b	R
Voltage	VOUT_UV_WARN_LIMIT, VOUT_OV_WARN_LIMIT, VIN_UV_WARN_LIMIT, VIN_OV_WARN_LIMIT, READ_VIN, READ_VIN_PEAK, READ_VIN_VALLEY, READ_VOUT, READ_VOUT_PEAK, READ_VOUT_VALLEY	88	-	4653	0	-2
		44		9307	0	-2
		22		18614	0	-2
Current	IOUT_OC_WARN_LIMIT, READ_IOUT, READ_IOUT_PEAK, READ_IOUT_VALLEY	-	12.5	23165	0	-2
			25	11582	0	-2
			50	5791	0	-2
			100	28956	0	-3
Power and Energy	READ_PIN_EXT,	88	12.5	10780	0	0

(table continues...)

Table 8 (continued) PMBus® coefficients

Parameter	Command	VTLM_RNG	V_{SNS_CS}	m	b	R
	READ_PIN_PEAK		25	5390	0	0
			50	26949	0	-1
			100	13474	0	-1
		44	12.5	21559	0	0
			25	10780	0	0
			50	5390	0	0
			100	26949	0	-1
		22	12.5	4312	0	1
			25	21559	0	0
			50	10780	0	0
			100	5390	0	0
	PIN_OP_WARN_LIMIT, READ_PIN, READ_EIN, READ_EIN_EXT	88	12.5	4211	0	-2
			25	21054	0	-3
			50	10527	0	-3
			100	5263	0	-3
		44	12.5	8422	0	-2
			25	4211	0	-2
			50	21054	0	-3
			100	10527	0	-3
		22	12.5	16843	0	-2
			25	8422	0	-2
			50	4211	0	-2
			100	21054	0	-3
External temperature	OT_WARN_LIMIT, READ_TEMPERATURE_1, READ_TEMP_1_PEAK, READ_TEMP_1_VALLEY	-	-	52	14321	-1
Controller's on-chip temperature	READ_TEMPERATURE_2	-	-	23	6225	-1

***Note**: Current and power coefficients are normalized to a 1 mΩ sense resistor. Refer Chapter 5.5 for examples.*

3.3.4 Input power calculation

The input power is a multiplication of the load current (IOUT) and the input voltage (VIN) values. The power calculation is performed each time a current measurement is taken, multiplying the recent values of load current and the input voltage before their corresponding averaging. Input power is reported in 16 bits format (READ_PIN) and extended 24 bits format (READ_PIN_EXT).

3.3.5 Energy calculation

Energy is the input power accumulated over time. The calculated input power value is added to a power accumulator command that may increment a rollover counter if the value exceeds the maximum accumulator value. The power accumulator command also increments a power sample counter. The power accumulator and power sample counter are read using the same READ_EIN (or READ_EIN_EXT) command to ensure that the accumulated value and sample count are from the same point in time.

The system MCU reading the data assigns a time stamp when the data is read. By calculating the time difference between consecutive uses of READ_EIN (or READ_EIN_EXT) and determining the delta in power consumed, it is possible for the MCU to determine the total energy consumed over that period.

READ_EIN_EXT command has 16 extra ROLLOVER_COUNT bits for an extended energy reading.

3.4 Analog IMON/PMON

The analog reporting (AMON) of the load current (IMON) or input power (PMON) signal is provided at the AMON pin by configuring the corresponding bits in the TELEMETRY_AVG command. As shown in the Figure 5, information is taken from the IOUT data path and PIN data output, which goes into a digital multiplexer (1), configurable by means of TELEMETRY_AVG command. The output of the multiplexer then goes to an IDAC (2), which outputs a current level proportional to the corresponding current or power digital input at the AMON pin.

To reduce the noise, it is recommended to add an output RC low-pass filter with a bandwidth of 50 to 80 KHz at the AMON pin. To calculate this filter and corresponding current and power levels based on the AMON output, see Chapter 5.6.

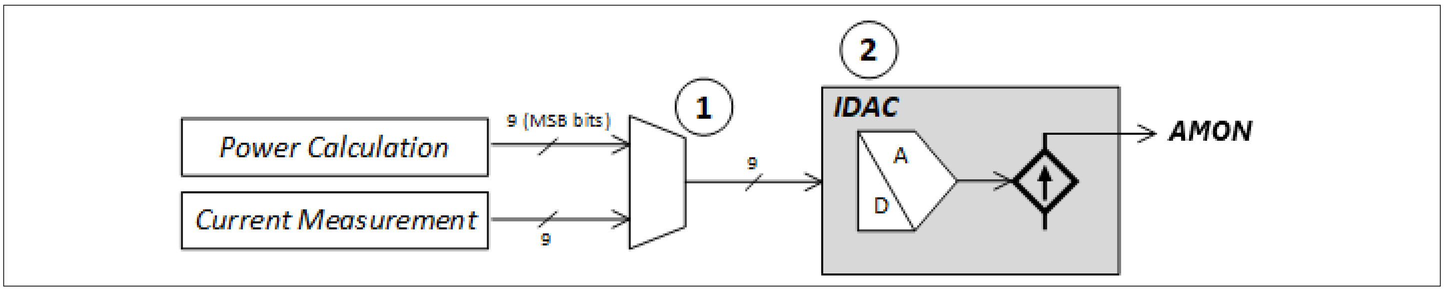

Figure 5 AMON generation

3.5 Communication interface (PMBus)

The Power Management Bus (PMBus®) is an open-standard digital power management protocol: simple, standard, flexible, extensible, and easy to program. The PMBus® command language enables communication between components of a power system: CPUs, power supplies, power converters, and more.

XDM700 supported features and commands are based on the PMBus® Specification Rev 1.3.1 parts I, II and III.

Communication via PMBus® is possible right after the internal circuitry initialization, which takes around 2 ms after input supply voltage (VDD) is applied.

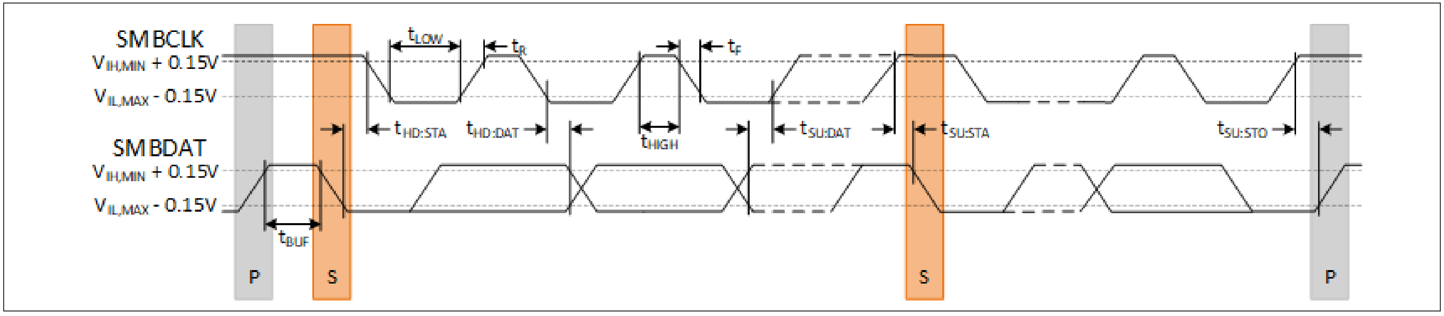

Figure 6 PMBus timing diagram

3.5.1 Supported functions

The PMBus® is specified to cover a lot of different applications in the realm of power management. For the VI monitor application, only a subset of commands is used.

3.5.1.1 Addressing

The device has a slave address controlled by the PMBUS_CFG command or by address pins. There are 15 different addresses available for external resistor settings. See Table 2.

3.5.1.2 Protocol violations

XDM700 supports the following protocol violations:

- Command not valid
- Command too short
- Data not valid
- Error at repeated start
- Extra byte in command
- Page not valid
- Read bit set in address
- Read too few bits
- Read too many bytes
- Send too few bits
- Send too many bytes

3.5.1.3 Timeout

If a device is holding onto the bus then the bus may freeze. If the MCU sees such an issue, it may stop the clock for $t_{TIMEOUT}$. This may also happen if another slave holds the bus incorrectly. This causes all the slaves to reset their PMBus® interfaces and be ready for a new start command.

3.5.2 Protocol

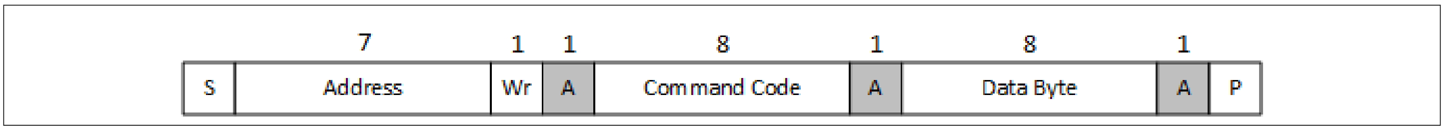

Figure 7 Write byte protocol

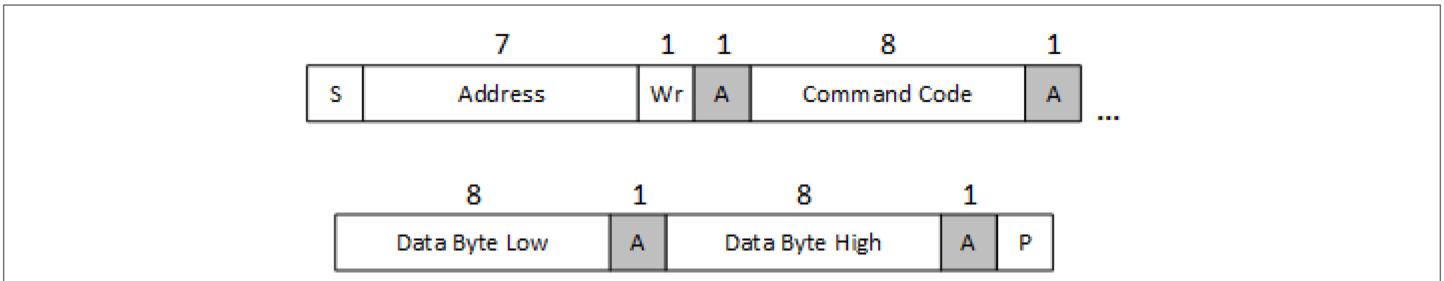

Figure 8 Write word protocol

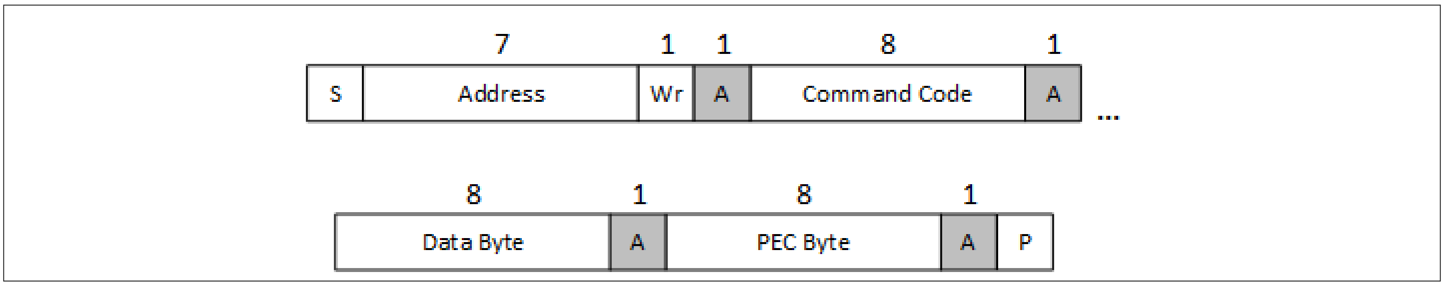

Figure 9 Write byte protocol with PEC

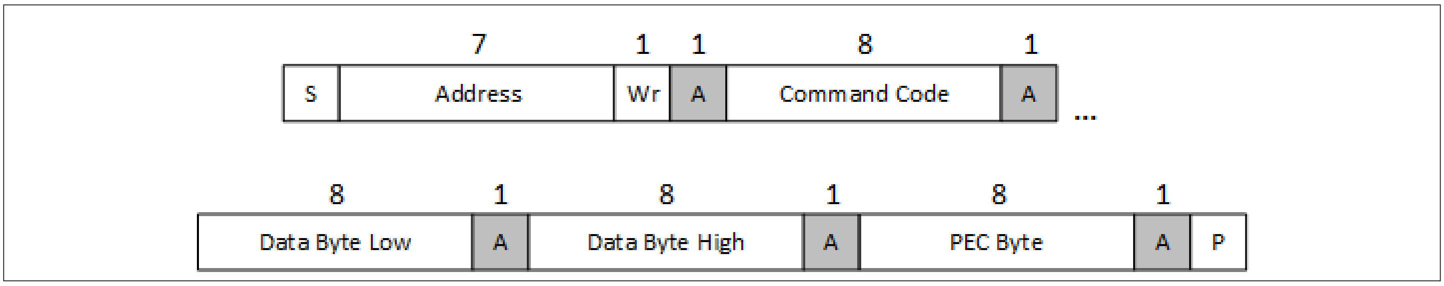

Figure 10 Write word protocol with PEC

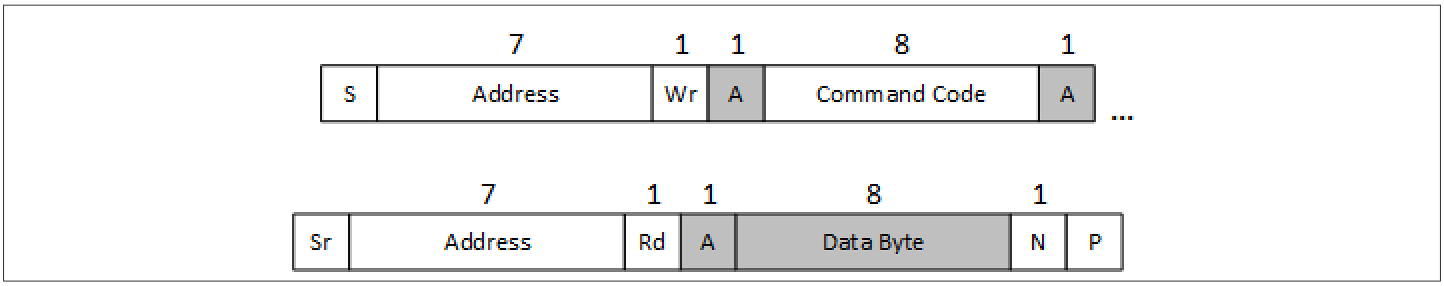

Figure 11 Read byte protocol

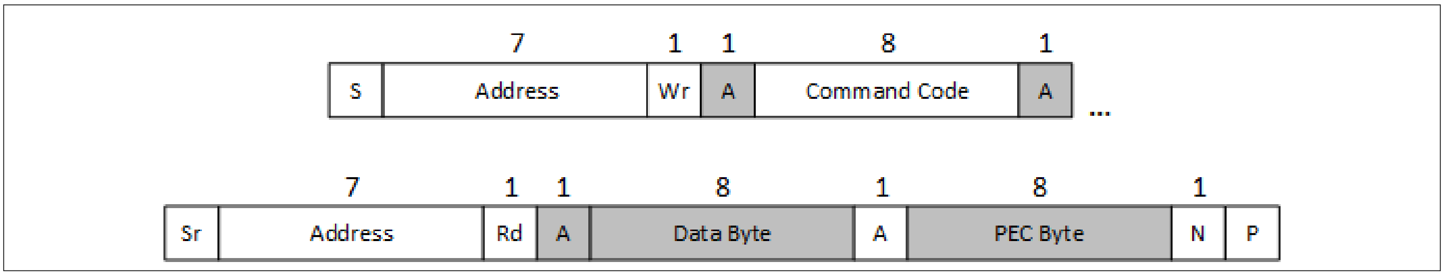

Figure 12 Read byte protocol with PEC

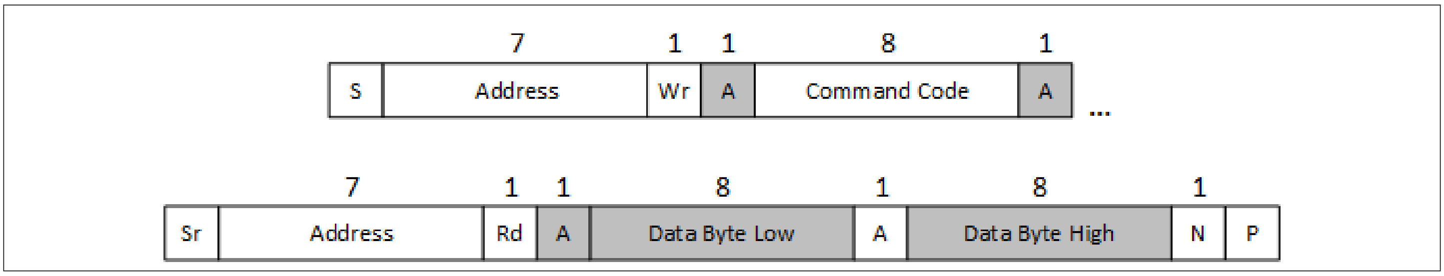

Figure 13 Read word protocol

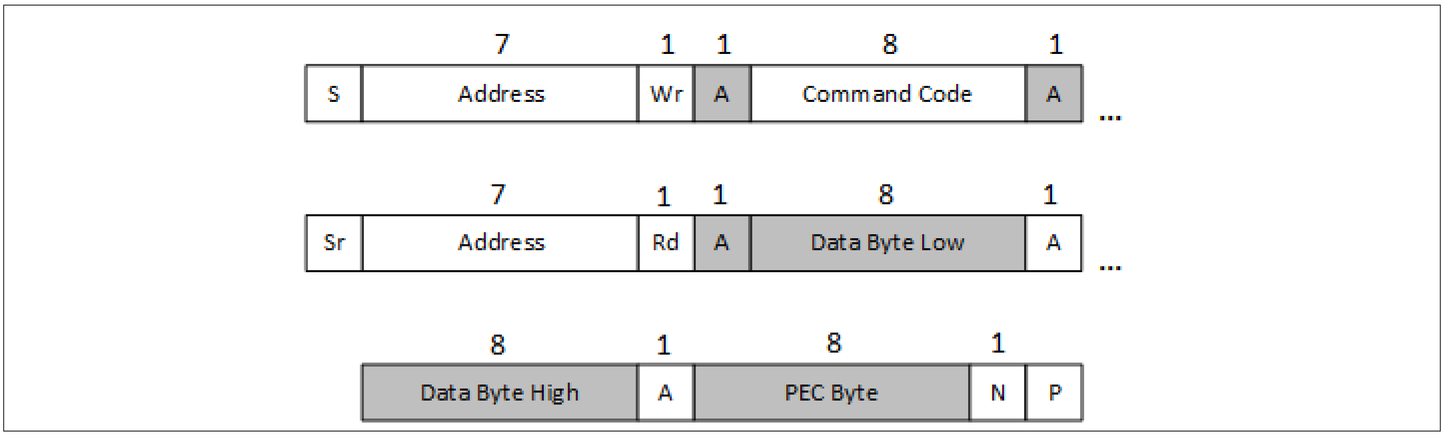

Figure 14 **Read word protocol with PEC**

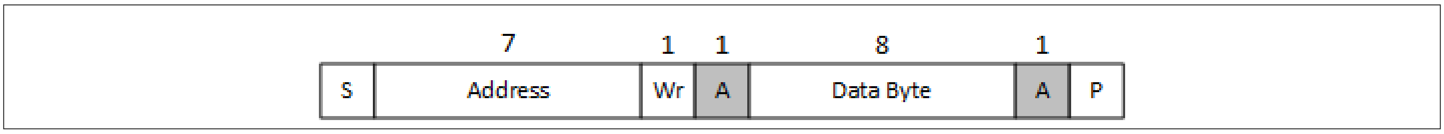

Figure 15 **Send byte protocol**

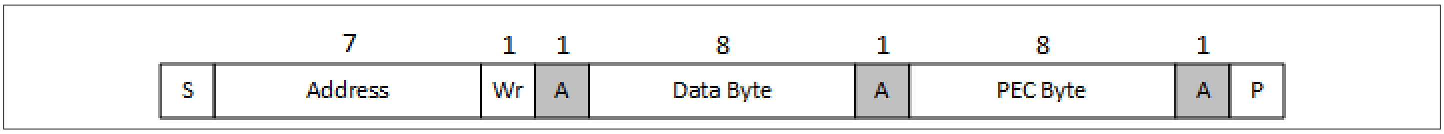

Figure 16 **Send byte protocol with PEC**

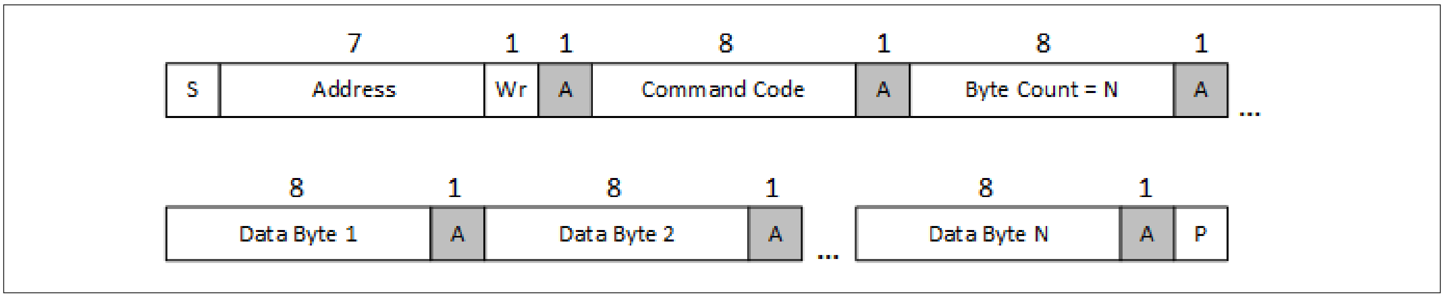

Figure 17 **Block write**

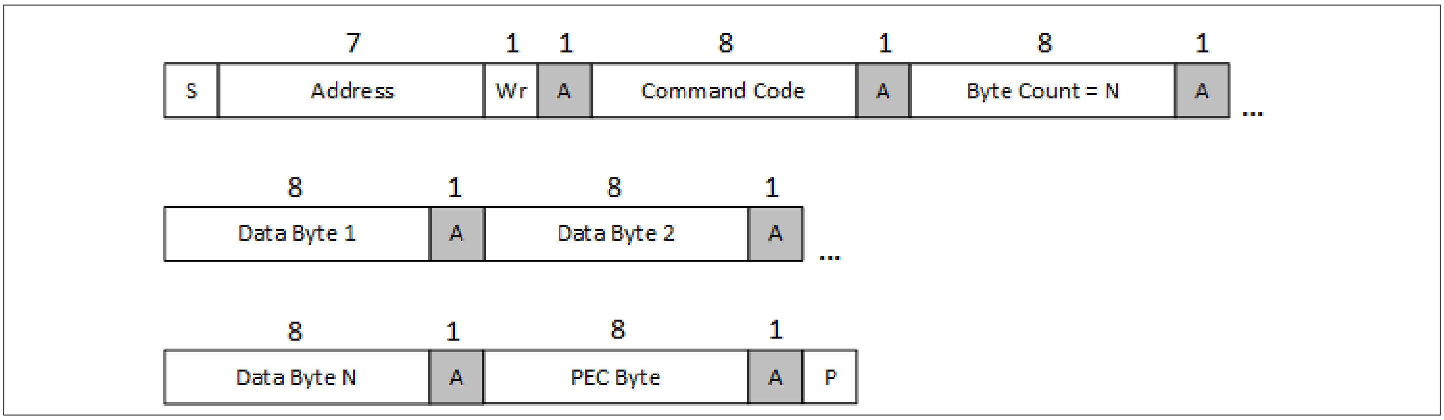

Figure 18 **Block write with PEC**

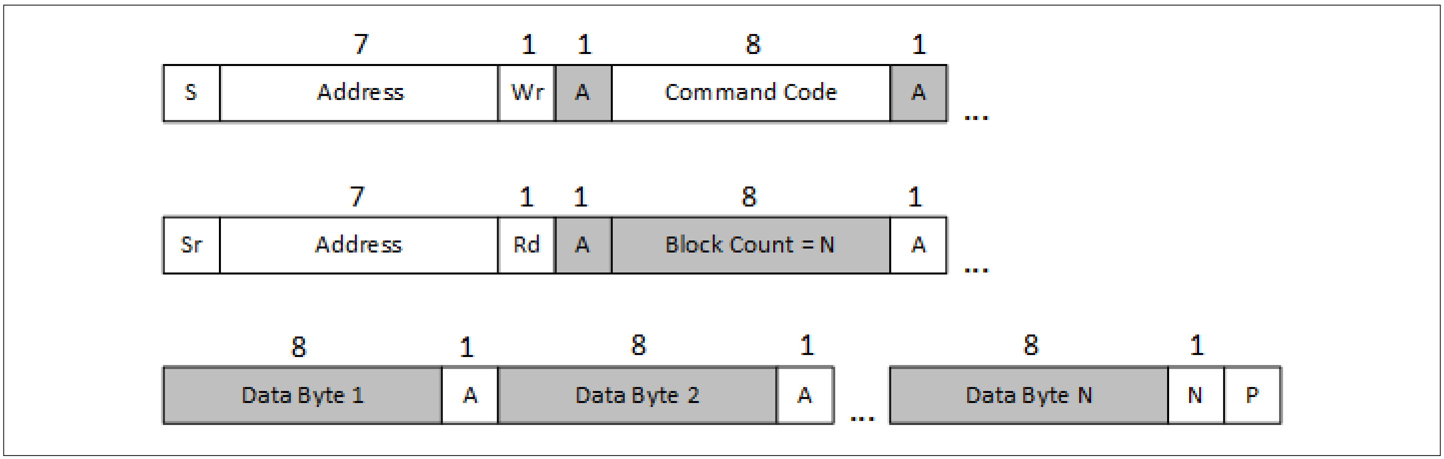

Figure 19 **Block read**

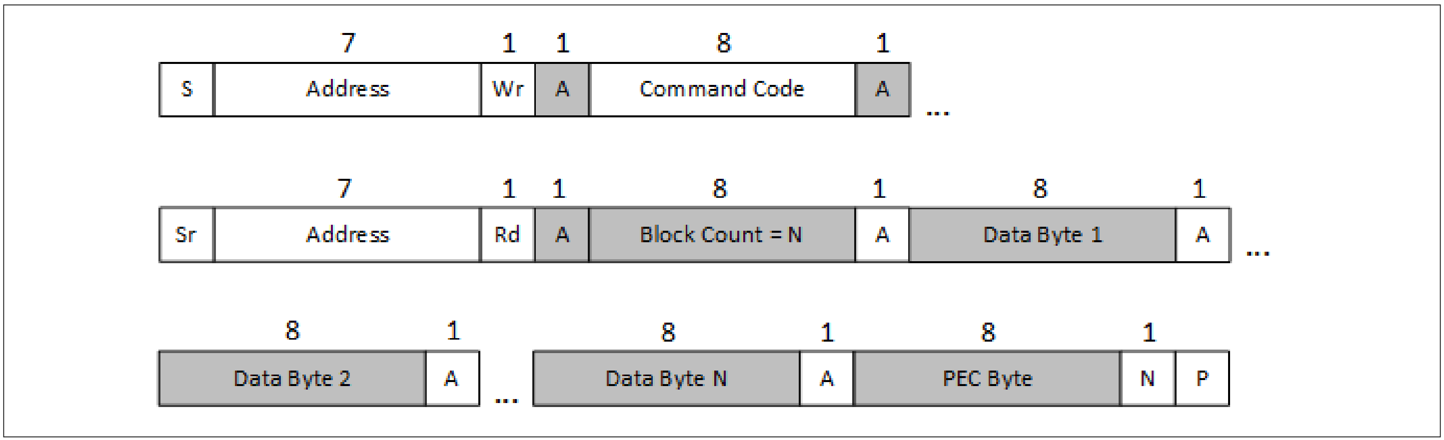

Figure 20 **Block read with PEC**

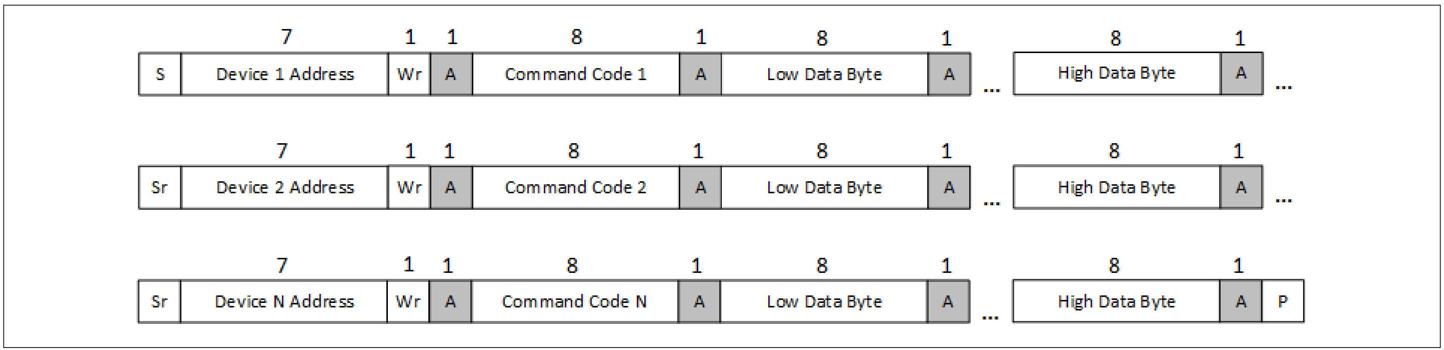

Figure 21 **Group command protocol**

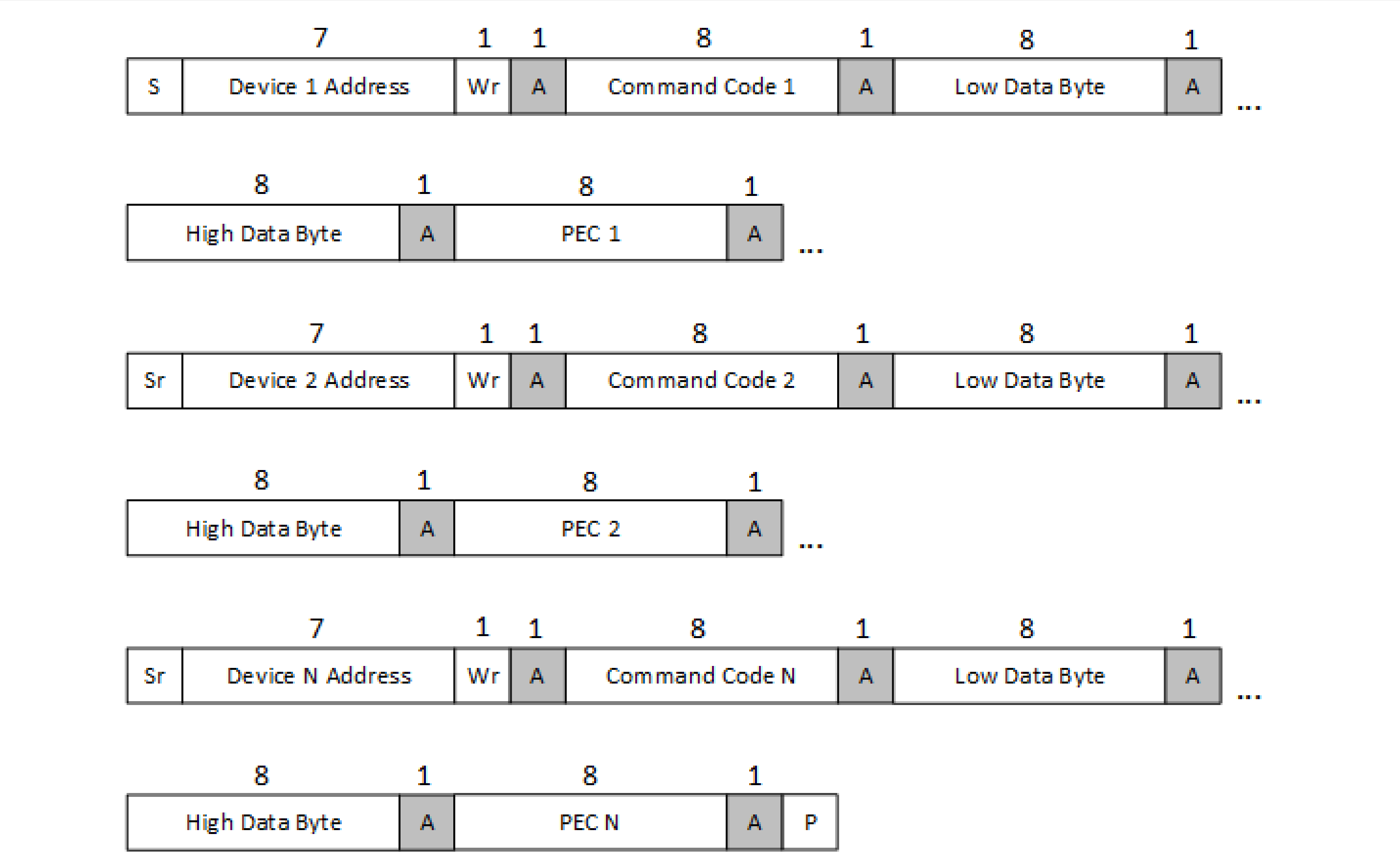

Figure 22 Group command protocol with PEC

3.5.2.1 Alert Response Address (ARA) Protocol

XDM700 supports SMBus alert response address. This is a method to allow the MCU to locate the first device that has issued an alert i.e. SMBALERT, if there are multiple devices connected to the same bus.

1. Device issues an alert on the SMBALERT pin. This is just a normal warning being signalled.
2. MCU sends a special address 0x0C with READ bit "1" (i.e. 0x19).
3. Device responds with its own address:
   - If more than one device responds, the lowest address wins and disables its alert.
4. The microcontroller continues to process all alerts by the same process until there are no alerts signalled.

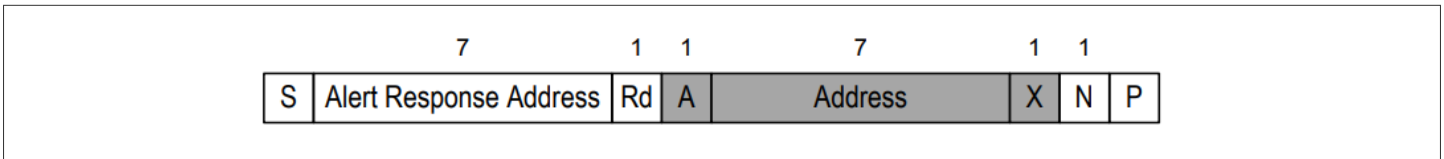

Figure 23 ARA Command protocol

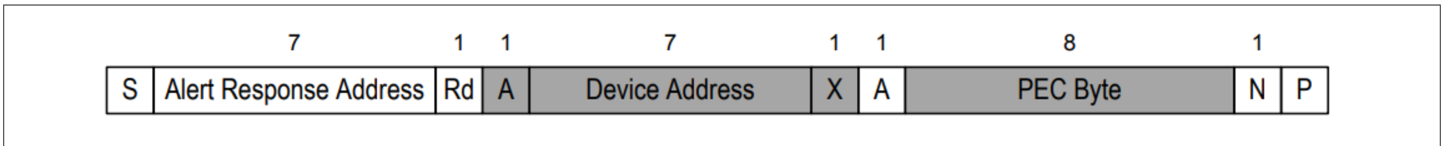

Figure 24 ARA Command protocol with PEC

Figure 25 shows an example of the ARA protocol. In this case, the PMBus® device address was set to 0x10, and the device releases its SMBALERT pin after responding to the ARA protocol request.

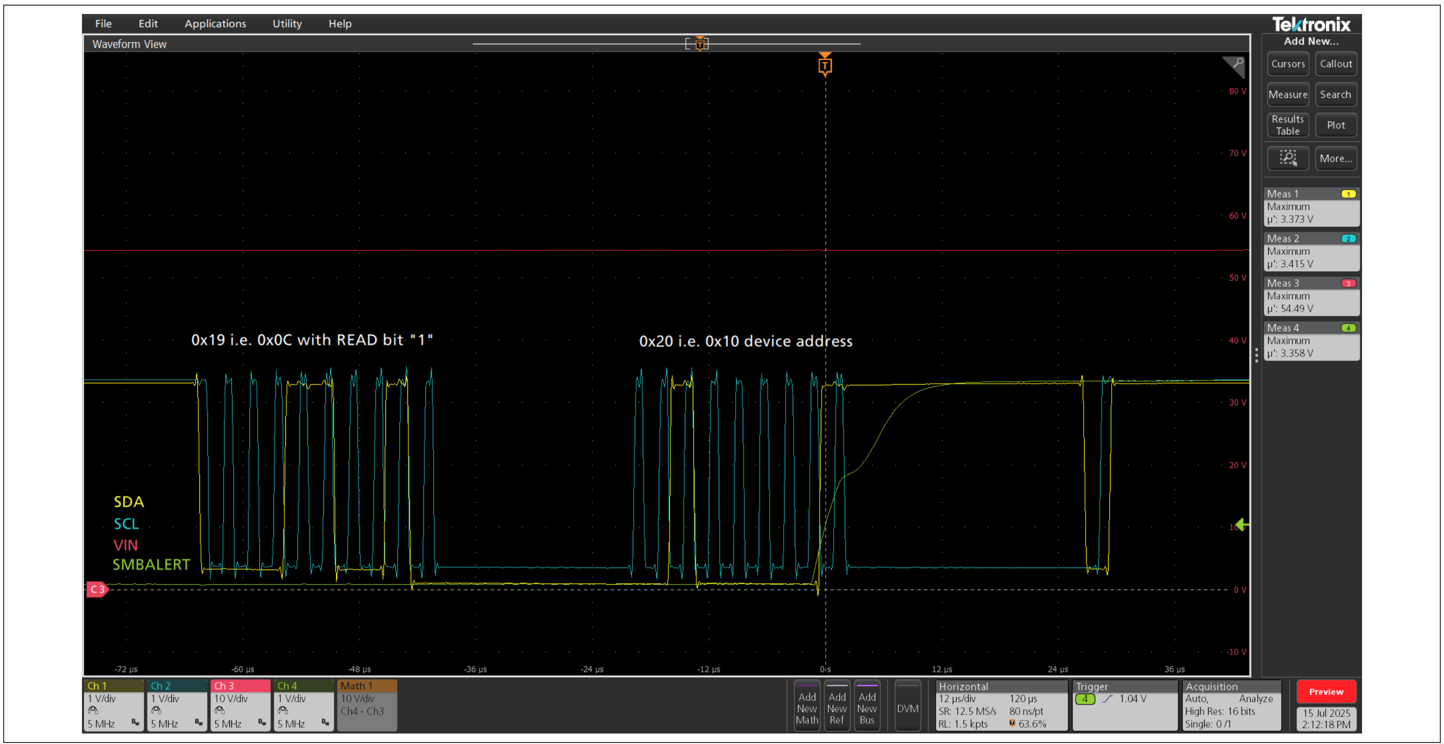

Figure 25 **SMBALERT pin being released after a successful ARA protocol**

3.5.3 PMBus commands

Table 9 **List of PMBus® commands**

Command Name	Command Code	Type	Description	Default Value
CLEAR_FAULTS	0x03	W	Used to clear any warning bits that have been set.	0x0000
CAPABILITY	0x19	R	Supported PMBus® features	0xD0
VOUT_OV_WARN_LIMIT	0x42	R/W	Sets the output overvoltage warning limit.	0x0FFF
VOUT_UV_WARN_LIMIT	0x43	R/W	Sets the output undervoltage warning limit.	0x0000
IOUT_OC_WARN_LIMIT	0x4A	R/W	Sets the output overcurrent warning limit.	0x0FFF
OT_WARN_LIMIT	0x51	R/W	Sets the external overtemperature warning limit at TSNS_x pins.	0x0827
VIN_OV_WARN_LIMIT	0x57	R/W	Sets the input overvoltage warning limit.	0x0FFF
VIN_UV_WARN_LIMIT	0x58	R/W	Sets the input undervoltage warning limit.	0x0000
PIN_OP_WARN_LIMIT	0x6B	R/W	Sets the input overpower warning limit.	0xFFFF
STATUS_BYTE	0x78	R	Returns a summary of the most critical warnings.	0x40
STATUS_WORD	0x79	R	Returns a summary of the most critical warnings. The STATUS_BYTE occupies the low byte in this command.	0x0840

(table continues...)

Table 9 (continued) List of PMBus® commands

Command Name	Command Code	Type	Description	Default Value
STATUS_VOUT	0x7A	R	Returns a summary of the output voltage warnings.	0x00
STATUS_IOUT	0x7B	R	Returns a summary of the current warning.	0x00
STATUS_INPUT	0x7C	R	Returns a summary of the input warnings.	0x00
STATUS_TEMPERATURE	0x7D	R	Returns a summary of the external temperature warning.	0x00
STATUS_CML	0x7E	R	Returns a summary of the communication interface and memory fault/warning.	0x00
STATUS_OTHER	0x7F	R	Returns the status of SMBALERT.	0x00
READ_EIN	0x86	R	Returns the instantaneous input energy reading.	0x000000000000
READ_VIN	0x88	R	Returns the instantaneous input voltage reading.	0x0000
READ_VOUT	0x8B	R	Returns the instantaneous output voltage reading.	0x0000
READ_IOUT	0x8C	R	Returns the instantaneous current reading.	0x0000
READ_TEMPERATURE_1	0x8D	R	Returns the instantaneous external temperature reading at TSNS_x pins.	0x0000
READ_TEMPERATURE_2	0x8E	R	Returns the instantaneous on-chip controller's temperature reading.	0x0000
READ_PIN	0x97	R	Returns the instantaneous input power reading.	0x0000
PMBUS_REVISION	0x98	R	Returns the PMBus® revision to which the device is compliant.	0x33
MFR_ID	0x99	R	Returns manufacturer ID name.	0x004649
MFR_MODEL	0x9A	R	Returns manufacturer device model name.	0x00003030374D4458
MFR_REVISION	0x9B	R	Returns manufacturer device silicon revision.	0x0001
PMBUS_CFG	0xD0	R/W	Used to configure the PMBus® device address and speed selection.	0x10
V_SNS_CFG	0xD4	R/W	Used to configure voltage monitoring range.	0x0000
I_SNS_CFG	0xD5	R/W	Used to configure current sense range.	0x0040
I_SNS_OFFSET_COMP	0xD6	R/W	Used to set the current telemetry offset.	0x0000
ENABLE_WARNS	0xE1	R/W	Used to enable/disable all the warnings.	0x1FCC
MASK_WARNS	0xE2	R/W	Used to mask/unmask the warnings on the WARN pin.	0x1FCC
STATUS_WARNS	0xE3	R/W	Returns the status of all the warnings.	0x0000
TELEMETRY_EN	0xE8	R/W	Used to enable/disable different telemetry.	0x7FFF

(table continues...)

Table 9 (continued) List of PMBus® commands

Command Name	Comm and Code	Type	Description	Default Value
TELEMETRY_AVG	0xE9	R/W	Used to configure the V/I/P telemetry averaging and AMON pin.	0x0000
READ_PIN_EXT	0xEE	R	Returns the instantaneous input power reading (extended).	0x000000
READ_VIN_PEAK	0xEF	R	Returns the most recent maximum VIN value. It is automatically cleared when the data is read.	0x0000
READ_VOUT_PEAK	0xF0	R	Returns the most recent maximum VOUT value. It is automatically cleared when the data is read.	0x0000
READ_IOUT_PEAK	0xF1	R	Returns the most recent maximum IOUT value. It is automatically cleared when the data is read.	0x0000
READ_PIN_PEAK	0xF2	R	Returns the most recent maximum PIN value. It is automatically cleared when the data is read.	0x000000
READ_TEMP_1_PEAK	0xF3	R	Returns the most recent maximum external temperature value. It is automatically cleared when the data is read.	0x0000
READ_VIN_VALLEY	0xF4	R	Returns the most recent minimum VIN value. It is automatically cleared when the data is read.	0x0FFF
READ_VOUT_VALLEY	0xF5	R	Returns the most recent minimum VOUT value. It is automatically cleared when the data is read.	0x0FFF
READ_IOUT_VALLEY	0xF6	R	Returns the most recent minimum IOUT value. It is automatically cleared when the data is read.	0x0FFF
READ_TEMP_1_VALLEY	0xF7	R	Returns the most recent minimum external temperature value. It is automatically cleared when the data is read.	0x0FFF
CONFIG_ID	0xFA	R/W	Used to configure a user-based device identification code.	0x00
READ_EIN_EXT	0xFB	R	Returns the instantaneous input energy reading (extended).	0x00000000

4 General product characteristics

4.1 Absolute maximum ratings

Attention: ***Absolute maximum ratings are not subject to production test, specified by design.***

Table 10 Absolute maximum ratings

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the device. All voltage parameters are referenced to GND unless otherwise specified, positive currents are flowing into the pin, $T_A = 25°C$.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply voltage at VDD pin	VDD_{DC}	-0.3	-	80	V	-
Supply voltage transients at VDD pin	VDD_{AC}	-	-	100	V	For 500 ms maximum.
Voltage slew rate at VDD pin	VDD_{SR}	-	-	80	V/µs	The RC filter (i.e. 10 Ω / 100 nF, or 100 Ω / 10 nF, etc.) on the pin is recommended, especially for high voltage (i.e. VDD = 48 V) applications.
Input voltage at VIN_SNS, VOUT_SNS, ISNS_P and ISNS_N pins	VIN_SNS_{DC}, $VOUT\_SNS_{DC}$, $ISNS\_P_{DC}$, $ISNS\_N_{DC}$	-0.3	-	80	V	-
Input voltage transients at VIN_SNS, VOUT_SNS, ISNS_P and ISNS_N pins	VIN_SNS_{AC}, $VOUT\_SNS_{AC}$, $ISNS\_P_{AC}$, $ISNS\_N_{AC}$	-	-	100	V	For 500 ms maximum.
Voltage slew rate at VIN_SNS, ISNS_P and ISNS_N pins	VIN_SNS_{SR}, $V_{ISNS\_P\_SR}$, $V_{ISNS\_N\_SR}$	-	-	80	V/µs	The resistor (i.e.10 Ω) in series to the pin is recommended if an excessive dV/dt may occur in the application.
Voltage slew rate at VOUT_SNS pin	$VOUT\_SNS_{SR}$	-	-	80	V/µs	An output cap (10 µF min) limits a slew rate on the pin.
Output voltage at VREG pin	V_{VREG}	-0.3	-	6	V	-
Digital pins output voltage (WARN, SMBALERT, SDAO)	V_{WARN}, $V_{SMBALERT}$, V_{SDAO}	-0.3	-	6	V	-
Current Sense input voltage (ISNS_P - ISNS_N)	$V_{\Delta ISNS}$	-0.8	-	0.8	V	-
Analog pins input voltage (ADDRx and TSNS_N)	V_{ADDRx}, V_{TSNS_N}	-0.3	-	6	V	-

(table continues...)

Table 10 (continued) Absolute maximum ratings

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the device. All voltage parameters are referenced to GND unless otherwise specified, positive currents are flowing into the pin, T_A = 25°C.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Analog pin output voltage (AMON)	V_{AMON}	-0.3	-	6	V	-
Input voltage at TSNS_P pin	V_{TSNS_P}	-0.3	-	2.5	V	-
Digital pins input voltage (SCL, SDAI)	V_{SCL}, V_{SDAI}	-0.3	-	6	V	-
Junction temperature range	T_J	-40	-	150	°C	-
Storage temperature range	T_S	-55	-	150	°C	-

4.2 Functional range

Table 11 Functional and performance ranges description

Absolute voltage range at VDD (V)	Communication interface	VREG
0 ≤ Vin < 5	Off	Off
5 ≤ Vin ≤ 80	On	5V (typ)

Table 12 Recommended operating range

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the device. All voltage parameters are referenced to GND unless otherwise specified, positive currents are flowing into the pin, T_A = 25°C.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply voltage at VDD pin	*VDD*	5	-	80	V	-
VIN_SNS sense pin input voltage	*VIN_SNS*	0	-	80	V	-
VOUT_SNS sense pin input voltage	*VOUT_SNS*	0	-	80	V	-
Current sense input voltage (ISNS_P - ISNS_N)	$V_{\Delta ISNS}$	-0.4	-	0.4	V	-
Output voltage at VREG pin	V_{VREG}	4.5	5	5.5	V	At 10 mA maximum external load, with C_{VREG} = 1 uF

(table continues...)

Table 12 (continued) Recommended operating range

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the device. All voltage parameters are referenced to GND unless otherwise specified, positive currents are flowing into the pin, T_A = 25°C.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Analog pin input voltage (ADDRx)	V_{ADDRx}	0	-	5.5	V	-
Analog pins input voltage TSNS_P/N	$V_{TSNS\_P/N}$	0	-	1.1	V	-
Analog pin output voltage (AMON)	V_{AMON}	0	-	5.5	V	-
Digital pins input voltage (SCL, SDAI)	V_{SCL}, V_{SDAI}	0	-	5.5	V	-
Digital pins output voltage (WARN, SMBALERT, SDAO)	V_{WARN}, $V_{SMBALERT}$, V_{SDAO}	0	-	5.5	V	-
Junction temperature range	T_J	-40	-	125	°C	-

4.3 Thermal characteristics

Attention: ***Thermal data is not subject to production test, specified by design.***

Table 13 Thermal characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Thermal resistance Junction-to-case (bottom)	$R_{\Theta JC\_Bot}$	-	21	-	K/W	PCB simulation setup as described in Table 14.
Thermal resistance Junction-to-case (top)	$R_{\Theta JC\_Top}$	-	49	-	K/W	PCB simulation setup as described in Table 14.
Thermal resistance Junction-to-Ambient	$R_{\Theta JA}$	-	56	-	K/W	PCB simulation setup as described in Table 14.
Package power dissipation	P_{PAK}	-	-	0.65	W	-

Table 14 PCB characteristics for thermal simulation

		λ_{therm} [W/m-K]
Metalization	JEDEC 2s2p (JESD 51-7, JESD 51-5)	388
Cooling Area [mm^2]	none	388

Note: *Thermal performance is directly linked to printed circuit board (PCB) design and operating environment. Careful attention to PCB thermal design is required.*

4.4 ESD robustness

Attention: ***ESD robustness data is not subject to production test, specified by design.***

Table 15 ESD robustness

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
ESD Robustness HBM	V_{ESD_HBM}	-2000	-	+2000	V	Human Body Model sensitivity as per ANSI/ESDA/JEDEC JS-001
ESD Robustness CDM	V_{ESD_CDM}	-500	-	+500	V	Charge Device Model sensitivity as per ANSI/ESDA/JEDEC JS-002

4.5 Electrical characteristics

Attention: ***Electrical parameters are not subject to production test, specified by design, unless otherwise noted.***

Table 16 Electrical characteristics

VDD - GND = 48 V, VIN_SNS = V_{ISNS_P}, $V_{\Delta ISNS}$ = (V_{ISNS_P} - V_{ISNS_N}) = 0 V, T_J = −40°C to +125°C, unless otherwise noted.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
VDD						
Supply voltage at VDD pin	V_{VDD}	5	-	80	V	(1)
Current consumption	I_{VDD}	-	7	10	mA	(1) VDD supply current; Telemetry is ON
VIN_SNS, VOUT_SNS						
Input current	I_{VIN_SNS}, I_{VOUT_SNS}	-	15	-	µA	(1) At 48 V
ISNS_P, ISNS_N						
Current sense differential voltage range	V_{SNS_CS}	-	-	-	-	Set via I_SNS_CFG:CS_RNG[1:0]:
		-	12.5	-	mV	0x0
		-	25	-	mV	0x1 (default)
		-	50	-	mV	0x2
		-	100	-	mV	0x3
Minimum detectable differential voltage level	V_{SNS_MIN}	0.01 * V_{SNS_CS}	-	-	mV	Between ISNS_P and ISNS_N pins

(table continues...)

Table 16 **(continued) Electrical characteristics**

VDD - GND = 48 V, VIN_SNS = V_{ISNS_P}, $V_{\Delta ISNS}$ = (V_{ISNS_P} - V_{ISNS_N}) = 0 V, T_J= −40°C to +125°C, unless otherwise noted.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Current sense ADC resolution	ADC_I	-	12	-	bits	-
TSNS_P, TSNS_N						
TSNS_P operating voltage range	V_{TSNS_P}	0.25	-	1	V	-
TSNS_N operating voltage	V_{TSNS_N}	-	0	-	V	-
Telemetry						
Monitored voltage range (input and output voltages)	V_{TLM}	-	-	-	-	Set via V_SNS_CFG:VTLM_RNG[1:0]:
		-	88	-	V	0x0 (default)
		-	44	-	V	0x1
		-	22	-	V	0x2
Input voltage measurement accuracy	VIN_SNS_{ACC}	-0.4	-	0.4	%	At VIN_SNS vs GND: VIN_SNS = 40 V to 80 V, 20 V to 40 V or 10 V to 20 V depending on the corresponding programmed range V_{TLM_RNG}
Output voltage measurement accuracy	$VOUT\_SNS_{ACC}$	-0.4	-	0.4	%	At VOUT_SNS vs GND: VOUT_SNS = 40 V to 80 V, 20 V to 40 V or 10 V to 20 V depending on the corresponding programmed range V_{TLM_RNG}
Current measurement accuracy	$V_{\Delta ISNS\_ACC}$	-0.5	-	0.5	%	Between ISNS_P & ISNS_N pins. $V_{\Delta ISNS}$ = 50 mV or 100 mV depending on the corresponding programmed range V_{SNS_CS}
		-1.0	-	1.0	%	Between ISNS_P & ISNS_N pins. $V_{\Delta ISNS}$ = 12.5 mV or 25 mV depending on the corresponding programmed range V_{SNS_CS}.
Calculated input power accuracy	PIN_{ACC}	-1.5	-	1.5	%	Input voltage: VIN_SNS = 40 V to 80 V, 20 V to 40 V or 10 V to 20 V depending on the corresponding programmed range V_{TLM_RNG}. Current sensing: $V_{\Delta ISNS}$ = 12.5 mV or 25 mV or 50 mV or 100 mV depending on the corresponding programmed range V_{SNS_CS}.

(table continues...)

Table 16 (continued) Electrical characteristics

VDD - GND = 48 V, VIN_SNS = V_{ISNS_P}, $V_{\Delta ISNS}$ = (V_{ISNS_P} - V_{ISNS_N}) = 0 V, T_J = −40°C to +125°C, unless otherwise noted.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Calculated energy accuracy	EIN_{ACC}	-3.0	-	3.0	%	Input voltage: VIN_SNS = 40 V to 80 V, 20 V to 40 V or 10 V to 20 V depending on the corresponding programmed range V_{TLM_RNG}. Current sensing: $V_{\Delta ISNS}$ = 12.5 mV or 25 mV or 50 mV or 100 mV depending on the corresponding programmed range V_{SNS_CS}.
External temperature measurement accuracy	$TEMP1_{ACC}$	-	±4.0	±12.5	°C	Sourcing current in TSNS_P pin. Sense the voltage between TSNS_P & TSNS_N pins. External transistor is MMBT3904.
On-chip temperature monitored range	$TEMP2_{RNG}$	-40	-	150	°C	-
On-chip temperature measurement accuracy	$TEMP2_{ACC}$	-5	-	5	°C	-
VREG						
Output voltage	V_{VREG}	4.5	5.0	5.3	V	(1) 5 V ≤ VDD ≤ 80 V
Current capability to supply external load	I_{REG}	-	-	10	mA	-
WARN, SMBALERT						
Output low voltage	V_{L_OL}	-	-	0.4	V	(1) At 10 mA
Input low voltage	V_{L_IL}	-	-	0.8	V	(1)
Input high voltage	V_{L_IH}	2.0	-	-	V	(1)
Leakage current	I_L	-	-	5	µA	(1) At 5.5 V, output is HiZ.
SDAI, SDAO, SCL						
Input high voltage	V_{IH}	2.0	-	-	V	(1)
Input low voltage	V_{IL}	-	-	0.8	V	(1)
Output low voltage	V_{OL}	-	-	0.4	V	(1) At 20 mA
Input leakage current	I_{LK}	-	-	5.0	µA	(1) At 5.5 V
Nominal bus voltage	V_{BUS}	3.0	3.3 or 5.0	5.5	V	-
Capacitive load per bus segment	C_{BUS}	-	-	400	pF	-
Pin capacitance	C_{SDA}	-	5	10	pF	-

(table continues...)

Table 16 (continued) Electrical characteristics

VDD - GND = 48 V, VIN_SNS = V_{ISNS_P}, $V_{\Delta ISNS}$ = (V_{ISNS_P} - V_{ISNS_N}) = 0 V, T_J= −40°C to +125°C, unless otherwise noted.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
ADDRx						
Pin sense current	I_{ADDRx}	93	100	107	µA	(1)
On-chip thermal shut down						
On-chip thermal shut-down warning upper limit	$TSDW_{UTH}$	-	125	-	°C	-
On-chip thermal shut-down warning lower threshold	$TSDW_{LTH}$	-	115	-	°C	-
AMON						
AMON output level	I_{AMON}	-	2	-	mA	$V_{\Delta ISNS}$ = V_{SNS_CS}, where V_{SNS_CS} = 12.5 mV, 25 mV, 50 mV or 100 mV
IMON signal accuracy	$IMON_{ACC}$	-	-	6	%	$V_{\Delta ISNS}$ = 0.175 * V_{SNS_CS}, where V_{SNS_CS} = 12.5 mV
		-	-	4	%	$V_{\Delta ISNS}$ = 0.375 * V_{SNS_CS}, where V_{SNS_CS} = 12.5 mV
		-	-	3	%	$V_{\Delta ISNS}$ = V_{SNS_CS}, where V_{SNS_CS} = 12.5 mV
		-	-	5	%	$V_{\Delta ISNS}$ = 0.175 * V_{SNS_CS}, where V_{SNS_CS} = 25 mV, 50 mV or 100mV
		-	-	3	%	$V_{\Delta ISNS}$ = 0.375 * V_{SNS_CS}, where V_{SNS_CS} = 25 mV, 50 mV or 100mV
		-	-	2	%	$V_{\Delta ISNS}$ = V_{SNS_CS}, where V_{SNS_CS} = 25 mV, 50 mV or 100mV
PMON signal accuracy	$PMON_{ACC}$	-	±2.2	±3	%	At ISNS_P vs GND voltage: ISNS_P = 40 V to 80 V, V_{TLM} = 88 V. And $V_{\Delta ISNS}$ = V_{SNS_CS}, where V_{SNS_CS} = 12.5 mV
		-	±1.9	±2.4	%	At ISNS_P vs GND voltage: ISNS_P = 40 V to 80 V, V_{TLM} = 88 V. And $V_{\Delta ISNS}$ = V_{SNS_CS}, where V_{SNS_CS} = 25 mV
		-	±1.9	±2.1	%	At ISNS_P vs GND voltage: ISNS_P = 40 V to 80 V, V_{TLM} = 88 V. And $V_{\Delta ISNS}$ = V_{SNS_CS}, where V_{SNS_CS} = 50 mV or 100 mV

(table continues...)

Table 16 (continued) Electrical characteristics

VDD - GND = 48 V, VIN_SNS = V_{ISNS_P}, $V_{\Delta ISNS}$ = (V_{ISNS_P} - V_{ISNS_N}) = 0 V, T_J= −40°C to +125°C, unless otherwise noted.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
AMON Compliance Voltage	V_{CMPL}	3.0	3.3	3.6	V	-
IDAC accuracy during PMON reporting	ε_{IDAC_PMON}	-1.5	-	1.5	%	IDAC accuracy on top of digital PMON accuracy

***Note**: (1) Tested in production*

4.6 Timing characteristics

***Attention**: Timing parameters are not subject to production test, specified by design, unless otherwise noted.*

Table 17 Timing characteristics

VDD - GND = 48 V, V1_SNS = V_{ISNS_P}, $V_{\Delta ISNS}$ = (V_{ISNS_P} - V_{ISNS_N}) = 0 V, T_J= −40°C to +125°C, unless otherwise noted.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
ADC						
Conversion rate of current and voltage measurements	t_{ADC_IV}	-	102.4	-	µs	-
Conversion rate of temperature measurements	t_{ADC_T}	-	200	-	ms	-
PMBus						
Clock frequency	f_{SCL}	10	-	1000	kHz	-
Detect clock low timeout	$t_{TIMEOUT}$	25	-	35	ms	-
Bus free time between STOP and START Condition	t_{BUF}	0.5	-	-	µs	See Figure 6
Hold time after (REPEATED) START Condition	$t_{HD:STA}$	0.26	-	-	µs	After this period, the first clock is generated. See Figure 6
REPEATED START condition setup time	$t_{SU:STA}$	0.26	-	-	µs	See Figure 6
STOP condition setup time	$t_{SU:STO}$	0.26	-	-	µs	See Figure 6
Data hold time	$t_{HD:DAT}$	0	-	-	ns	See Figure 6

(table continues...)

Table 17 (continued) Timing characteristics

VDD - GND = 48 V, V1_SNS = V_{ISNS_P}, $V_{\Delta ISNS}$ = (V_{ISNS_P} - V_{ISNS_N}) = 0 V, T_J= −40°C to +125°C, unless otherwise noted.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Data setup time	$t_{SU:DAT}$	50	-	-	ns	See Figure 6
Clock low period	t_{LOW}	0.5	-	-	µs	See Figure 6
Clock high period	t_{HIGH}	0.26	-	50	µs	See Figure 6
Clock/data fall time	t_F	-	-	120	ns	The fall time measurement limits are defined as follows: Fall time limits: ($V_{IH,MIN}$ + 0.15 V) to ($V_{IL,MAX}$ - 0.15 V) See Figure 6
Clock/data rise time	t_R	-	-	120	ns	The rise time measurement limits are defined as follows: Rise time limits: ($V_{IL,MAX}$ - 0.15 V) to ($V_{IH,MIN}$ + 0.15 V) See Figure 6
PMBus deglitch time	t_{DGL_PMBUS}	50	-	-	ns	-
AMON						
AMON Signal Time Constant	τ_{IMON}	2.9	-	4.0	µs	-
IMON Signal Delay	t_{DEL_IMON}	-	-	5	µs	Signal delay shall be tested using a load step from 0% to 100% and a di/dt of 10 A/µs without external capacitance connected to the power supply's main output.

5 Application information

5.1 Typical application schematic

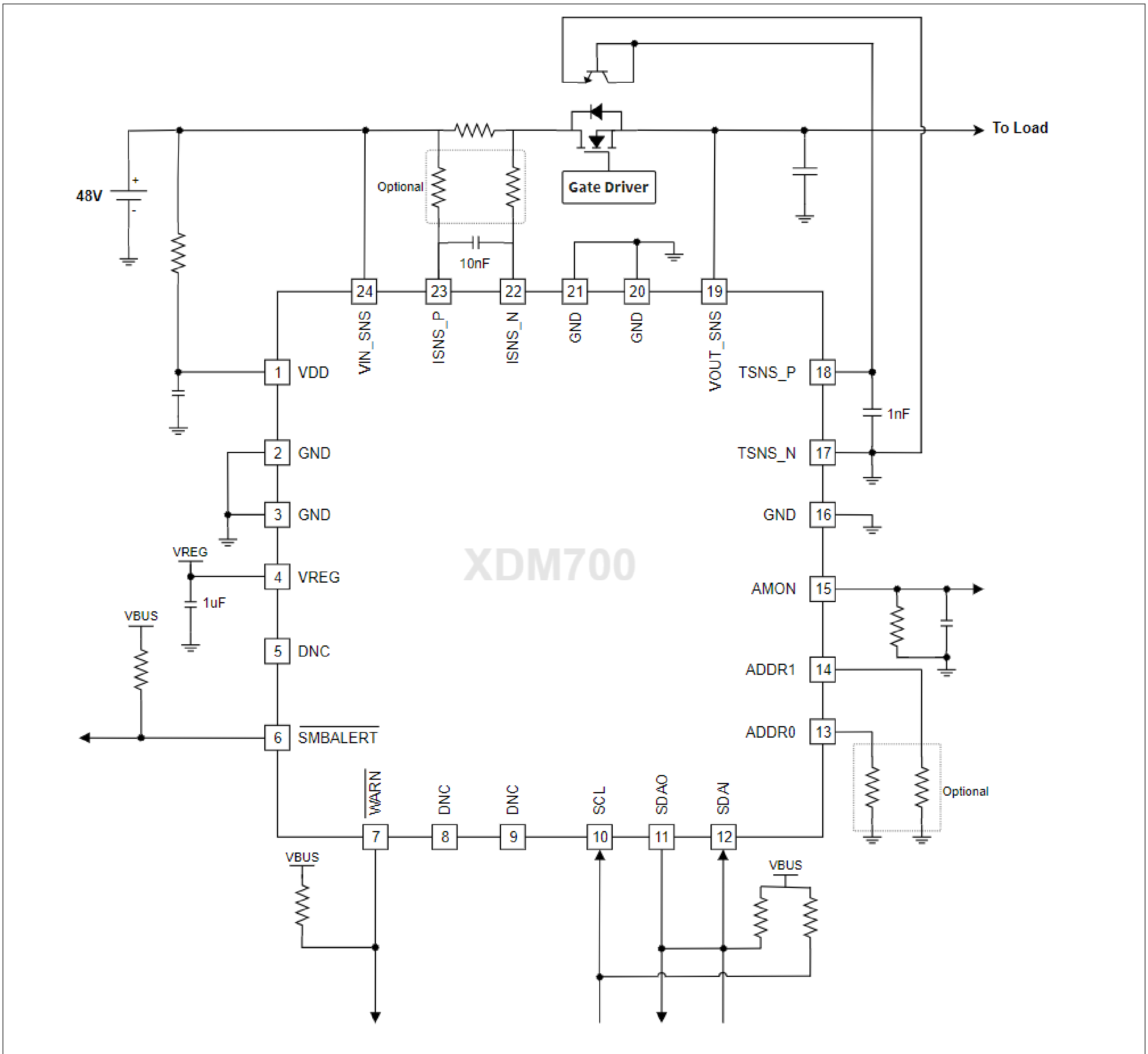

Figure 26 XDM700 application schematic

5.2 Setting the Voltage at ADDR1/0 pins

To set the voltage at the ADDRx pins, choose the resistor from the corresponding pin to GND by dividing the desired voltage by the pin current (100 µA ± 7%).

Due to the wide voltage range, 5% tolerance resistors can be used:

Table 18 **Setting ADDRx pins voltage**

Voltage (V)	ADDR1/0 pin resistor (kΩ)
1.2	12
2.0	20

5.3 Handling external current at VREG pin

An internal LDO provides 5 V (typically) supply for the internal circuitry and could also be used as voltage reference for communication pull-up resistors. Its current capability to supply external circuitry is 10 mA. Make sure not to exceed the package maximum power dissipation P_{PAK}.
To calculate the additional power due to external load:

$$P_{REG\_EXT} = ABS(VDD - VREG) * i_{REG} \quad (3)$$

So, in the case of a 48 V input supply, with a 10 mA load on VREG = 5 V:

$$P_{REG\_EXT} = ABS(48V - 5V) * 10mA = 430mW \quad (4)$$

The rest of current consumption comes from XDM700's circuitry.
To keep the package power dissipation within the P_{PAK} limit and allow additional consumption due to external load of LDO, a series resistor may be required at the VDD pin in high input voltage applications. It helps not to exceed the P_{PAK} limit:

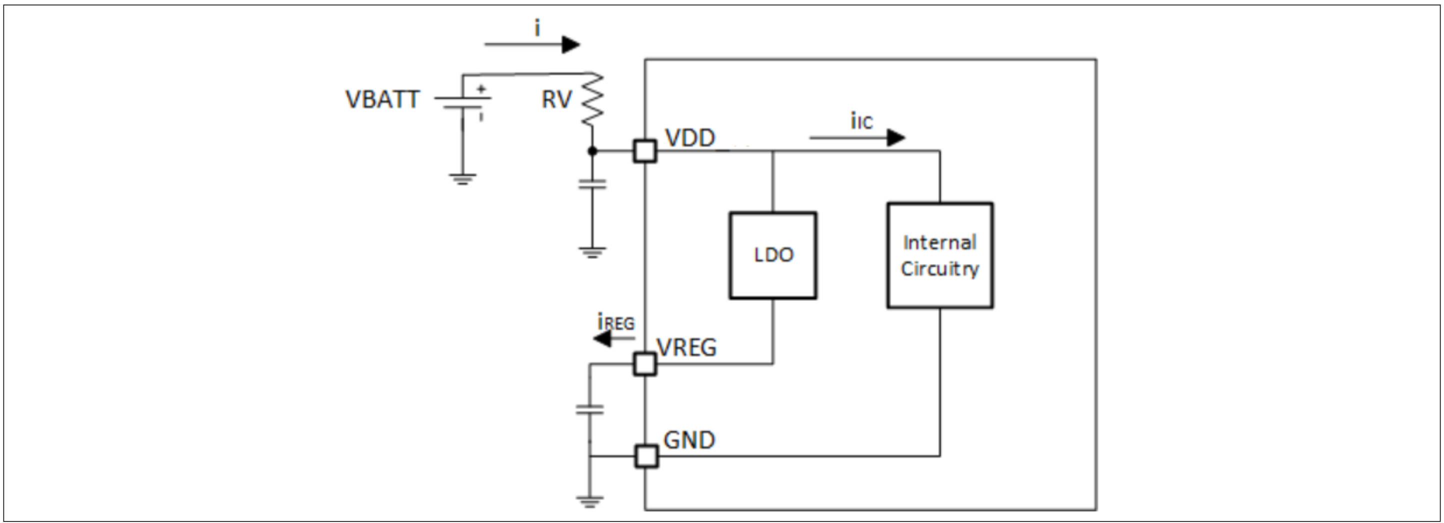

Figure 27 **Handling external current at VREG pin**

To calculate RV:

$$RV = \frac{P_{TOT} - P_{PAK}}{i^2} = \frac{VBATT}{i} - \frac{V_{REG} * i_{REG} + P_{PAK}}{i^2} \quad (5)$$

where:

$$P_{TOT} = (VBATT * i) - (VREG * i_{REG}) \quad (6)$$

and P_{PAK} = 0.65 W, V_{REG} = 5 V (typically), i_{REG} is the expected current consumption of the external circuitries supplied by *VREG* and *i* is the expected current consumption of the whole device supplied by *VBATT*.

So, for an expected maximum internal current consumption (i_{IC}) of 10 mA:

$$i = i_{IC} + i_{REG} = 10mA + 10mA = 20mA \quad (7)$$

$$RV = \frac{VBATT}{i} + \frac{VREG * i_{REG} + P_{PAK}}{i^2} = \frac{48V}{20mA} - \frac{5V * 10mA + 0.65W}{(20mA)^2} = 650\Omega \quad (8)$$

The power dissipated by the resistor is:

$$P_{RV} = i^2 \times RV = (20mA)^2 \times 650\Omega = 0.26W \quad (9)$$

***Note**: A negative result in the calculation of the resistance RV means that the total power dissipation of the package P_{PAK} is not being exceeded. In this case, RV is not needed.*

To protect XDM700, if the die temperature goes above 163 ±10°C, VREG is turned off. Thus, communication is not possible and the status of WARN and SMBALERT pins is not reliable.

Special considerations:

- RV must be limited to 1KΩ max.
- If RV is used, a 100nF cap from VDD to GND is mandatory.

5.4 ISNS input filter

In noisy or high dV/dt applications, an input filter from RSNS to ISNS_P and ISNS_N pins is recommended as shown in the following figure.

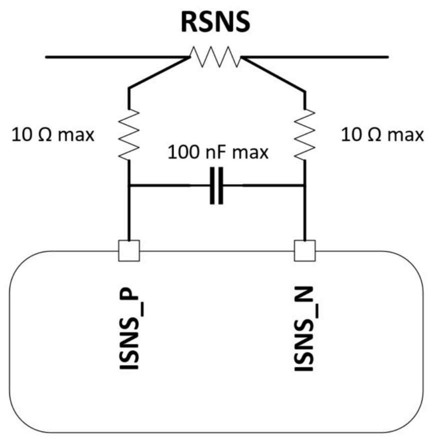

Figure 28 ISNS input filter

5.5 PMBus direct format data conversion

Voltage

Voltage limits calculations are straight forward using the formulas and coefficients specified in Telemetry via PMBus. As an example, the VIN_OV_WARN_LIMIT is taken.

System characteristics and configuration:

VTLM_RNG = 88 V

Based on VTLM_RNG value, from the coefficients table:

m = 4653

b = 0

R = -2

For a VIN_OV_WARN_LIMIT of 64 V, the following formula is applied:

$$Y = \left(mX + b\right) * 10^{R} \tag{10}$$

$$Y = \left(4653 * 64 + 0\right) * 10^{-2} \tag{11}$$

$$Y = 2978 = 0xBA2 \tag{12}$$

So the value to be programmed in VIN_OV_WARN_LIMIT is 0xBA2.

To convert from PMBus direct format to "real world" value, let's suppose the value from the ADC in the READ_VIN command is 0x8B9 = 2233 decimal. System characteristics, configuration and coefficients are the same as above. The following formula is applied:

$$X = \frac{1}{m} * \left(Y * 10^{-R} - b\right) \tag{13}$$

$$X = \frac{1}{4653} * \left(2233 * 10^{2} - 0\right) \tag{14}$$

$$X = 48V \tag{15}$$

Current

Values in Table 8 are normalized to a 1 mΩ resistor. Therefore, to convert to a PMBus direct format value, the result has to be divided by the value of the sense resistor in mΩ. To convert to a "real world" value, the result must be multiplied. For example, if a value of 35 A is desired for IOUT_OC_WARN_LIMIT:

System characteristics and configuration:

Rsns = 0.5 mΩ

V_{SNS_CS} = 12.5 mV

Based on V_{SNS_CS} value, the coefficients are:

m = 23165

b = 0

R = -2

To get the limit value, the following formula is applied:

$$Y = \left(\left(mX + b\right) * 10^{R}\right) * Rsns\left(m\Omega\right) \tag{16}$$

$$Y = \left(\left(23165 * 35 + 0\right) * 10^{-2}\right) * 0.5 \tag{17}$$

$$Y = 8108 * 0.5 \tag{18}$$

$$Y = 4054 = 0x0FD5 \tag{19}$$

So the value 0x1301 must be programmed in IOUT_OC_WARN_LIMIT.

Similarly, to obtain the "real world" value from the ADC reading in READ_IOUT. Let's suppose the reading is 0x910 = 2320 decimal. The following formula is applied:

$$X = \frac{\frac{1}{m} * \left(Y * 10^{-R} - b\right)}{Rsns\left(m\Omega\right)} \tag{20}$$

$$X = \frac{\frac{1}{23165} * \left(2320 * 10^{2} - 0\right)}{0.5} \tag{21}$$

$$X = \frac{10}{0.5} = 20A \tag{22}$$

Power

Input power is the result of multiplying input voltage (VIN_SNS) times the current (IOUT through RSNS). Power coefficients are also normalized to 1 mΩ, so it is also necessary to multiply or divide by the sense resistor value in mΩ to obtain direct format or "real world" values respectively.

If an 1100 W value is desired as PIN_OP_WARN_LIMIT:

System characteristics and configuration:

VTLM_RNG = 88 V

Rsns = 0.5 mΩ

V_{SNS_CS} = 12.5 mV

Based on these, coefficients are:

m = 4211

b = 0

R = -2

To obtain the limit, the following formula is applied:

$$Y = \left(\left(mX + b\right) * 10^{R}\right) * Rsns\left(m\Omega\right) \quad (23)$$

$$Y = \left(\left(4211 * 1100 + 0\right) * 10^{-2}\right) * 0.5 \quad (24)$$

$$Y = 23159 = 0x5A77 \quad (25)$$

So the value 0x5A77 must be programmed in PIN_OP_WARN_LIMIT.

The power reading can be 16 bits (READ_PIN) or 24 bits (READ_PIN_EXT). In the case of READ_PIN, coefficients are the same as specified for PIN_OP_WARN_LIMIT. So, if the reading of READ_PIN is 0xCD9A = 52634 decimal, the following formula is applied:

$$X = \frac{\frac{1}{m} * \left(Y * 10^{-R} - b\right)}{Rsns\left(m\Omega\right)} \quad (26)$$

$$X = \frac{\frac{1}{4211} * \left(52634 * 10^{2} - 0\right)}{0.5} \quad (27)$$

$$X = 2500W \quad (28)$$

If 24 bits power reading is desired (READ_PIN_EXT), corresponding coefficients based on the system characteristics and configuration specified above are:

m = 10780

b = 0

R = 0

For an example reading of 0xB4EE53 = 11857491 decimal, the formula becomes:

$$X = \frac{\frac{1}{10780} * \left(11857491 * 10^{0} - 0\right)}{0.5} \quad (29)$$

$$X = 2200W \quad (30)$$

Temperature

Temperature calculation is straight forward too and it only requires to apply the coefficients to the formulas. If an OT_WARN_LIMIT of 110°C is desired, the corresponding coefficients are:

m = 52

b = 14321

R = -1
By applying the direct format formula, the following is obtained:

$$Y = \left(mX + b\right) * 10^{R} \tag{31}$$

$$Y = \left(52 * 110 + 14321\right) * 10^{-1} \tag{32}$$

$$Y = 2004 = 0x07D4 \tag{33}$$

So the value 0x07D4 must be programmed in OT_WARN_LIMIT.

Note: *OT_WARN_LIMIT can be programmed from -273°C (0x000) to 512°C (0xFFF). Care must be taken to program it within the system operating temperature range.*

The reading from READ_TEMPERATURE_1 is translated to "real world" by solving the equation for X. If the reading is 0x7A0 = 1952 decimal:

$$X = \frac{1}{m} * \left(Y * 10^{-R} - b\right) \tag{34}$$

$$X = \frac{1}{52} * \left(1952 * 10^{1} - 14321\right) \tag{35}$$

$$X = 100°C \tag{36}$$

Energy

Energy is calculated based on 16-bit power, therefore, the same coefficients shall be used. Two readings of the READ_EIN register are required. Since energy is power times time, it is also required to know the time between the samples.

In the following example, system characteristics and configuration are:
VTLM_RNG = 88 V
Rsns = 0.5 mΩ
V_{SNS_CS} = 12.5 mV
Based on these, from Table 8, the coefficients are:
m = 4211
b = 0
R = -2

The samples read are:

Table 19 Energy read samples

	First Sample		Second Sample	
	Hex	**Dec**	**Hex**	**Dec**
SAMPLE_COUNT	1000	4096	3FFF	16383
ROLLOVER_COUNT	10	16	FF	255
ENERGY_COUNT	01FF	511	1FAC	8108

And the time between the samples for this example is 1200ms.

First, the power difference is calculated by substracting the ENERGY_COUNT of the first sample from the second sample. Note that the ENERGY_COUNT is concatenated with the ROLLOVER_COUNT:

$$Power \quad difference = 0xFF1FAC - 0x1001FF = 0xEF1DAD \tag{37}$$

Next step is to calculate the SAMPLE_COUNT difference by subtracting the SAMPLE_COUNT of both samples:

$$Sample \quad count \quad difference = 0x3FFF - 0x1000 = 0x2FFF = 12287d \tag{38}$$

Then the average power per sample is calculated by dividing the power difference over the sample count difference:

$$Average \quad power = \frac{0xEF1DAD}{0x2FFF} = 0x4FB = 1275d \tag{39}$$

Now X can be determined by using the PMBus direct format formula:

$$X = \frac{\frac{1}{m} * \left(Y * 10^{-R} - b\right)}{Rsns(m\Omega)} \tag{40}$$

$$X = \frac{\frac{1}{4211} * \left(1275 * 10^{2} - 0\right)}{0.5} \tag{41}$$

$$X = 60.55 \quad W \tag{42}$$

The time between samples can either be measured or calculated. The XDM700 has a ADC conversion rate of 102.4μs. This is also the time it takes to get a sample of energy, so the time between samples can be determined by multiplying the SAMPLE_COUNT difference times 102.4μs:

$$11719 * 102.4\mu s = 1.2s \quad (43)$$

Finally, energy is determined by multiplying power times time:

$$E = 60.55W * 1.2s \quad (44)$$

$$E = 72.66 \quad J \quad (45)$$

5.6 Calculating AMON parameters

Calculating AMON RC filter

If configured for current sensing, AMON outputs a current level of i_{AMON} = 2 mA at the maximum configured V_{SNS_CS}. To calculate the RC filter:

1. Define the maximum desired voltage drop on the resistor (V_{AMON}) taking into account the maximum voltage is 3.3V
2. Calculate R_{AMON} according to the following formula:

$$R_{AMON} = \frac{V_{AMON}}{i_{IMON}} \quad (46)$$

3. Define the desired bandwidth (BW) between 80 and 100 KHz and calculate C_{AMON} according to the following formula:

$$C_{AMON} = \frac{1}{BW * 2 * \pi * R_{AMON}} \quad (47)$$

Calculating AMON current

If configured as a current monitor, AMON's output current level (I_{OUT}) can be calculated based on the voltage at the AMON pin (V_{DROP}):

$$I_{OUT} = V_{SNS\_CS} * \frac{V_{DROP}/V_{AMON}}{R_{SNS}} \quad (48)$$

Where R_{SNS} is the populated sense resistor.

Calculating AMON power

If configured as a power monitor, the system input power can be calculated based on AMON's output current level (I_{OUT}) as follows:

$$i_{PMON} = \frac{V_{DROP}}{R_{AMON}} \quad (49)$$

The IDAC is designed so that a code of 0d361 = 2 mA of current at the output of the AMON. So to get the code:

$$IDAC \quad code = \frac{361 * i_{PMON}}{2mA} \tag{50}$$

Internally, the result of the power calculation, which consists on 24 bits, is truncated to 15 MSBs. In other words, it is divided by 2^{15}. Therefore, to determine the power, the inverse operation must be applied:

$$Power \quad calculation = IDAC \quad code * 2^{15} \tag{51}$$

Once the power calculation is determined, the system input power can be determined by using the PMBus coefficients and formulas as specified in Chapter 5.5.

Example:
V_{DROP} = 1.2 V
R_{AMON} = 900 Ω
VTLM_RNG = 88 V
Rsns = 0.5 mΩ
V_{SNS_CS} = 25 mV
Based on these and since the calculations are done based on 24 bit power, the coefficients are:
m = 5390
b = 0
R = 0

$$i_{PMON} = \frac{V_{DROP}}{R_{AMON}} = \frac{1.2V}{900\Omega} = 1.33mA \tag{52}$$

$$IDAC \quad code = \frac{361 * i_{PMON}}{2mA} = \frac{361 * 1.33mA}{2mA} = 240.67 \tag{53}$$

$$Power \quad calculation = IDAC \quad code * 2^{15} = 240.67 * 32768 = 7886165 \tag{54}$$

$$X = \frac{\frac{1}{m} * \left(Y * 10^{-R} - b\right)}{Rsns(m\Omega)} = \frac{\frac{1}{5390} * \left(7886165 * 10^{0} - 0\right)}{0.5m\Omega} = 2926W \tag{55}$$

5.7 Layout guidelines

The following guidelines shall be followed when designing an XDM700 PCB:

- Maximum supply current of the XDM700 is 10 mA. The traces at the supply pin VDD don't need to be that thick.
- VREG capacitor must be placed right next to the VREG pin.
- I2C traces need a single-ended controlled impedance of 50 Ω. Therefore, their width must be adjusted accordingly.
- TSNS filter capacitor must be placed right next to the TSNS pins.
- If used, the TSNS BJT shall be placed right next to the point to be sensed. It is best to place the sensor next to the hottest part of the system. In the case of Infineon's D2PAK FETs, the die is attached to the drain pad on bottom of the package, so this is the section that will get hotter in case of high power dissipation.

- ISNS filter capacitor also has to be placed right next to the ISNSx pins.
- Exposed pad must have a solid connection to GND through many vias.
- The path that will need to handle the highest amount of current goes from the input voltage source through the sense resistor to the load, including its corresponding return path to ground. Make sure this path is robust enough to support the current level required by the system.
- ISNS lines must be connected directly to sense pins of the sense resistor, separately from the power plane.

6 Package Information

6.1 Ordering information

Table 20 Ordering information

Basic part number	Orderable part number	Description
XDM700-1	TBD	Fully digital current sensing and system monitoring IC

6.2 Package outline

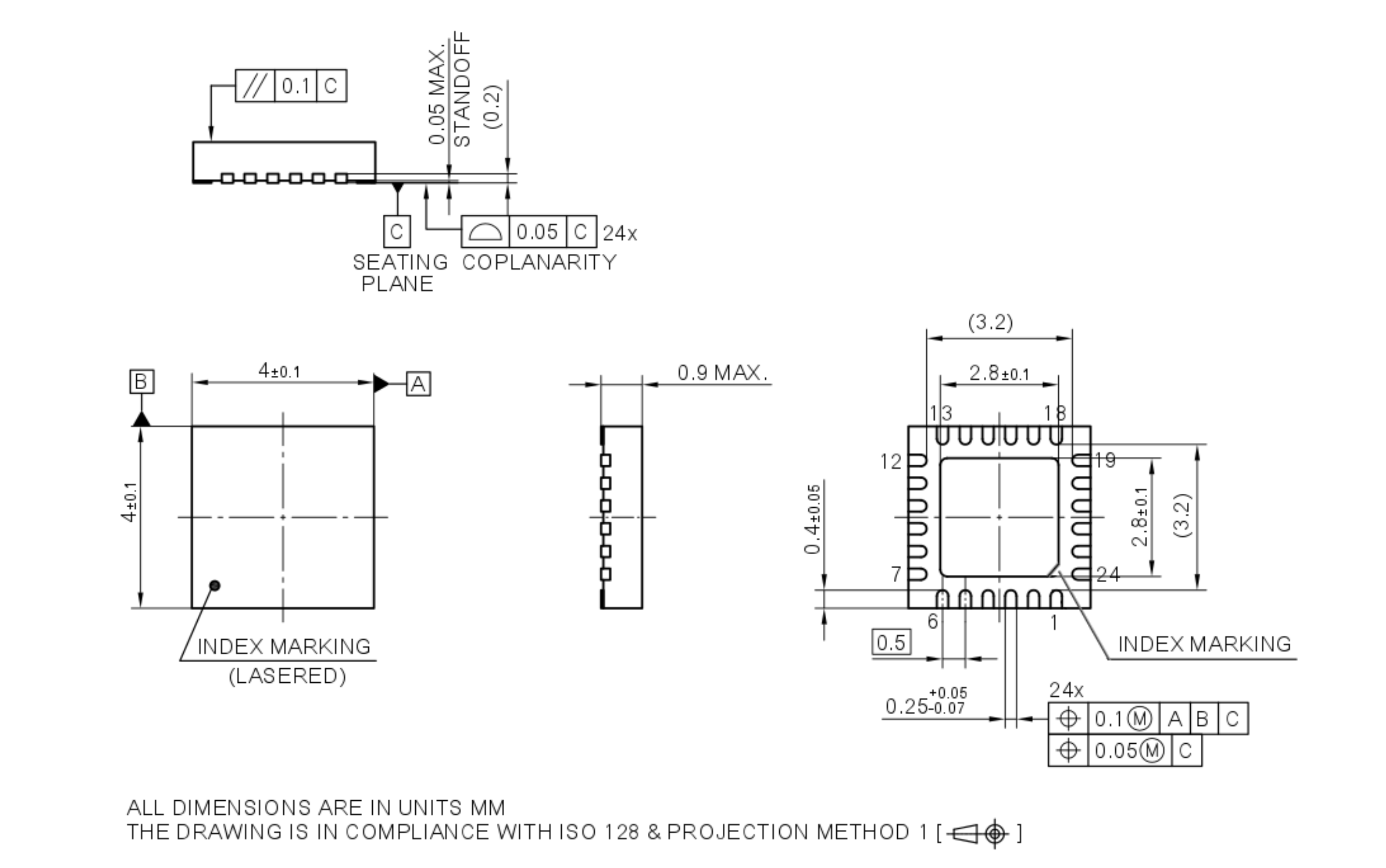

Figure 29 XDM700 package dimensions

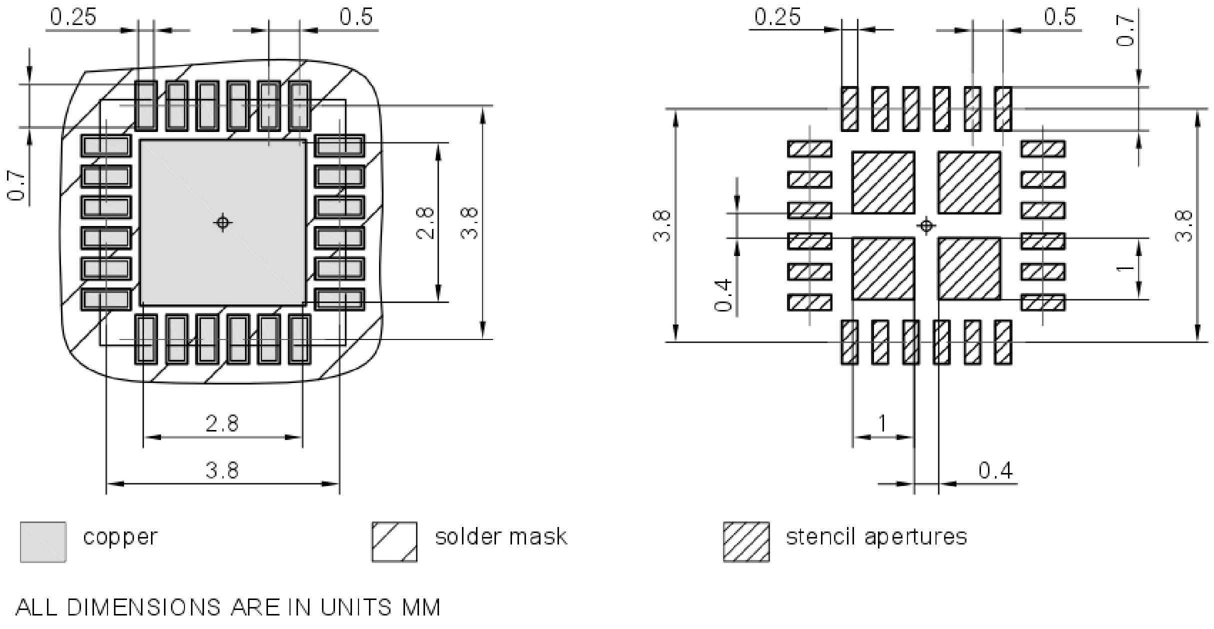

Figure 30 **XDM700 recommended footprint**

Green Product (RoHS compliant)

To meet the worldwide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e. Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020). Further information on packages: https://www.infineon.com/packages

7 Revision history

Revision	Date	Subjects (major changes since last revision)
1.0	2026-03-16	First release.

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Edition 2026-03-16

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about any aspect of this document?

Email: erratum@infineon.com

Document reference IFX-fhh1773650975088