Bi-Directional Current and Power Monitor

Features

- Senses Bus Voltages From 0 V to 36 V
- High-Side or Low-Side Sensing
- Reports Current, Voltage, and Power
- High Accuracy
- Configurable Averaging Options
- 16 Programmable Addresses
- Operates from 2.7-V to 5.5-V Power Supply
- 10-Pin, MSOP Package

Applications

- Power Management
- Servers
- Telecom Equipment
- Computing
- Test Equipment

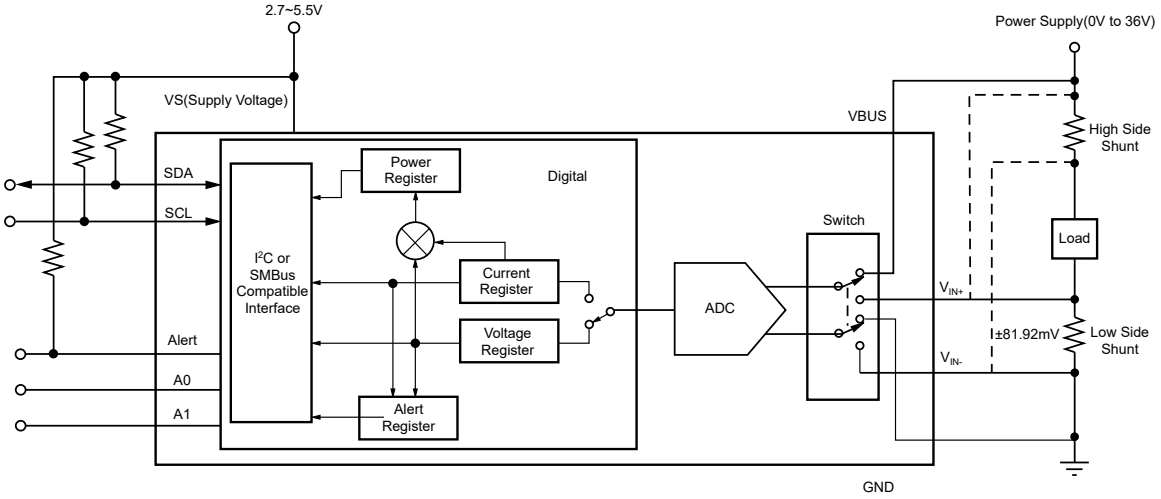
Description

The TPA6270X is a current and power monitor, with I^2C or SMBUS-compatible interface. The device monitors both a shunt voltage drop and bus supply voltage.

The TPA6270X common mode input voltage can vary from 0 V to 36 V.

The TPA6270X features up to 16 programmable addresses on the I^2C-compatible interface.

Functional Block Diagram



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Revision History

Revision	Notes
Rev.A.0	Released version.

Pin Configuration and Functions

TPA6270X
MSOP10 Package
Top View

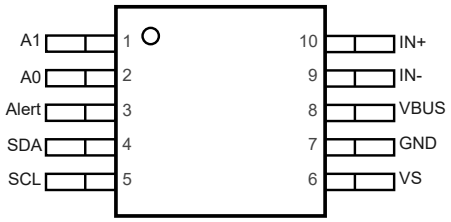


Table 1. Pin Functions: TPA6270X

Pin No.	Name	I/O	Description
2	A0	Digital input	Address pin. Connect to GND, SCL, SDA, or VS.
1	A1	Digital input	Address pin. Connect to GND, SCL, SDA, or VS.
3	Alert	Digital output	Multi-functional alert, open-drain output.
7	GND	Analog	Ground.
10	IN+	Analog input	Connect to the supply side of the shunt resistor.
9	IN–	Analog input	Connect to the load side of the shunt resistor.
5	SCL	Digital input	Serial bus clock line, open-drain input.
4	SDA	Digital I/O	Serial bus data line, open-drain input/output.
8	VBUS	Analog input	Bus voltage input.
6	VS	Analog	Power supply, 2.7 V to 5.5 V.

Specifications

Absolute Maximum Ratings

Cover operating free-air temperature range (unless otherwise noted) (1)

Parameter		Min	Max	Unit
V_{VS}	Supply Voltage		6	V
Analog Inputs, IN+, IN–	Differential (VIN+ – VIN-) (2)	–40	40	V
	Common-Mode (VIN+ + VIN-) / 2	–0.3	40	
V_{VBUS}		–0.3	40	V
V_{SDA}		GND – 0.3	6	V
V_{SCL}		GND – 0.3	VVS + 0.3	V
I_{IN}	Input Current into any Pin		5	mA
I_{OUT}	Open-Drain Digital Output Current		10	mA
T_J	Junction Temperature		150	°C
T_{stg}	Storage Temperature Range	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) IN+ and IN– may have a differential voltage between –40 V and 40 V. However, the voltage at these pins must not exceed the range from −0.3 V to 40 V.

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Value	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1), all pins	±2	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2), all pins	±1.5	kV

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Recommended Operating Conditions (1)

Parameter		Min	Typ	Max	Unit
V_{CM}	Common Mode Input Voltage		12		V
V_{VS}	Operating Supply Voltage		3.3		V
T_A	Operating Free-Air Temperature	−40		125	℃

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
MSOP10	171	42.9	°C/W

Electrical Characteristics

All test conditions: T_A = 25°C, V_{VS} = 3.3 V, V_{IN+} = 12 V, V_{SENSE} = (V_{IN+} – $V_{IN–}$) = 0 mV, and V_{VBUS} = 12 V, unless otherwise noted.

Parameter		Test conditions	Min	Typ	Max	Unit
INPUT						
	Shunt Voltage Input Range		–81.9175		81.92	mV
	Bus Voltage Input Range (1)		0		36	V
CMRR	Common-Mode Rejection	0 V ≤ VIN+ ≤ 36 V	120	140		dB
V_{OS}	Shunt Offset Voltage, RTI (2)			±2.5	±10	µV
	Shunt Offset Voltage, RTI (2) vs Temperature	–40°C ≤ TA ≤ 125°C		0.025		µV/°C
PSRR	Shunt Offset Voltage, RTI (2) vs Power Supply	2.7 V ≤ VS ≤ 5.5 V		5		µV/V
V_{OS}	Bus Offset Voltage, RTI (2)			±1.25	±5	mV
	Bus Offset Voltage, RTI (2) vs Temperature	–40°C ≤ TA ≤ 125°C		5		µV/°C
PSRR	Bus Offset Voltage, RTI (2) vs Power Supply	2.7 V ≤ VS ≤ 5.5 V		0.1		mV/V
I_B	Input Bias Current			10		µA
	VBUS Input Impedance			830		kΩ
	Input Leakage (3)	(IN+ pin) + (IN– pin), Power-down mode		1		µA
DC ACCURACY						
	ADC Native Resolution			16		Bits
	1 LSB Step Size	Shunt voltage		2.5		µV
		Bus voltage		1.25		mV
	Shunt Voltage Gain Error			0.02%	0.15%	
	Shunt Voltage Gain Error Vs Temperature	–40°C ≤ TA ≤ 125°C		10		ppm/°C
	Shunt Voltage Linearity			1		LSB
	Bus Voltage Gain Error			0.02%	0.15%	
	Bus Voltage Gain Error vs Temperature	–40°C ≤ TA ≤ 125°C		10		ppm/°C
	Bus Voltage Linearity			1		LSB
t_{CT}	ADC Conversion Time	CT bit = 000		140		µs
		CT bit = 001		204		
		CT bit = 010		332		
		CT bit = 011		588		
		CT bit = 100		1100		µs

Parameter		Test conditions	Min	Typ	Max	Unit
		CT bit = 101		2116		
		CT bit = 110		4156		
		CT bit = 111		8244		
SMBus						
	SMBus Timeout (4)			28		ms

(1) While the input range is 36 V, the full-scale range of the ADC scaling is 40.96 V.
(2) RTI = Referred-to-input.
(3) Input leakage is positive (current flowing into the pin) for the conditions shown at the top of this table. Negative leakage currents can occur under different input conditions.
(4) SMBus timeout in the TPA6270X resets the interface any time SCL is low for more than 28 ms.
(5) Test Levels: (A) Tested at final test. Over-temperature limits are set by characterization and simulation. (B) Set by characterization and simulation. (C) Typical value only for information, provided by design simulation.

Electrical Characteristics (continued)

All test conditions: T_A = 25°C, V_{VS} = 3.3 V, V_{IN+} = 12 V, V_{SENSE} = (V_{IN+} – $V_{IN–}$) = 0 mV, and V_{VBUS} = 12 V, unless otherwise noted.

Parameter		Test conditions	Min	Typ	Max	Unit
Digital Input/Output						
	Input Capacitance			3		pF
	Leakage Input Current	0 V ≤ VSCL ≤ VVS , 0 V ≤ VSDA ≤ VVS, 0 V ≤ VAlert ≤ VVS , 0 V ≤ VA0 ≤ VVS , 0 V ≤ VA1 ≤ VVS		0.1		μA
V_{IH}	High-Level Input Voltage		0.7×VVS			V
V_{IL}	Low-Level Input Voltage				0.3×VVS	V
V_{OL}	Low-Level Output Voltage, SDA, Alert		0		0.4	V
	Hysteresis			150		mV
Power Supply						
	Operating Supply Range		2.7		5.5	V
IQ	Quiescent Current			600	950	μA
	Quiescent Current, Power-Down (Shutdown) Mode			2	20	μA
V_{POR}	Operating Supply Range			2.2		V

Typical Performance Characteristics

All test conditions: T_A = 25°C, V_{VS} = 3.3 V, V_{IN+} = 12 V, V_{SENSE} = (V_{IN+} – $V_{IN–}$) = 0 mV and V_{VBUS} = 12 V, unless otherwise noted.

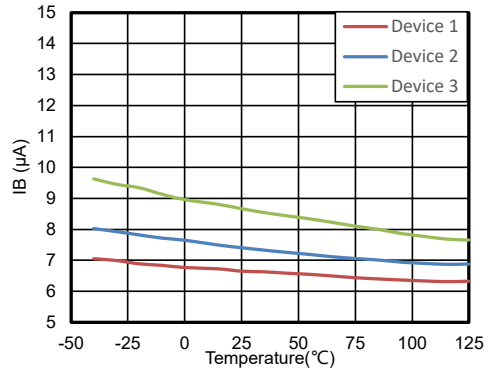


Figure 1. Ib VS Temp

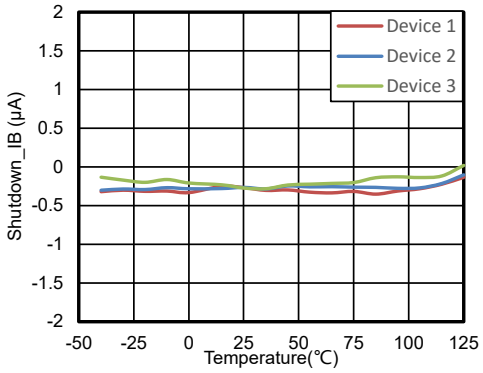


Figure 2. Shutdown Ib VS Temp

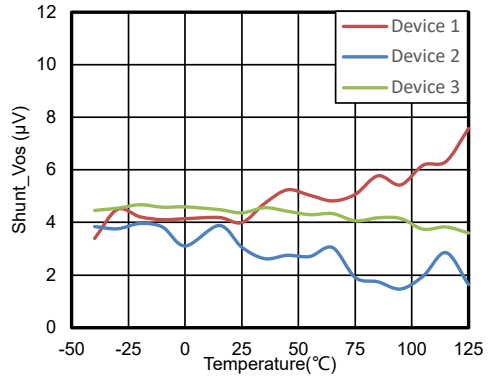


Figure 3. Shunt Vos VS Temp

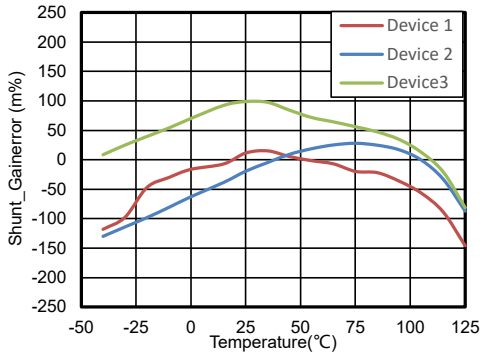


Figure 4. Shunt Gain VS Temp

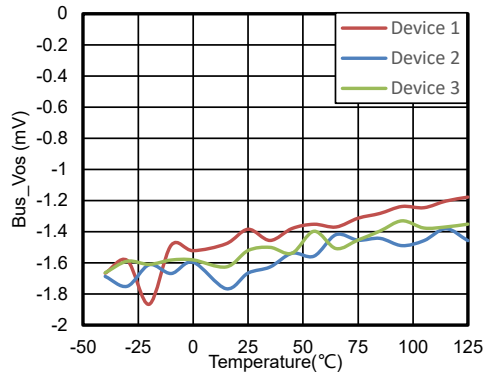


Figure 5. Bus Vos VS Temp

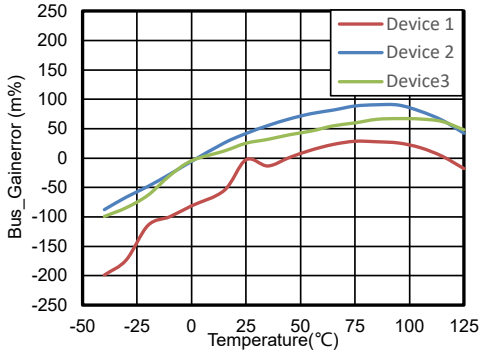


Figure 6. Bus Gain VS Temp

Detailed Description

Overview

The TPA6270X is a digital current sense amplifier with an I2C- and SMBus-compatible interface. It performs two measurements on the power-supply bus: The differential shunt voltage created by load current flowing through a shunt resistor measured at the IN+ and IN– pins. The power supply bus voltage is measured at the VBUS pin.

There is no special requirement for power supply sequencing since power supply and input voltages are independent of each other.

Functional Block Diagram

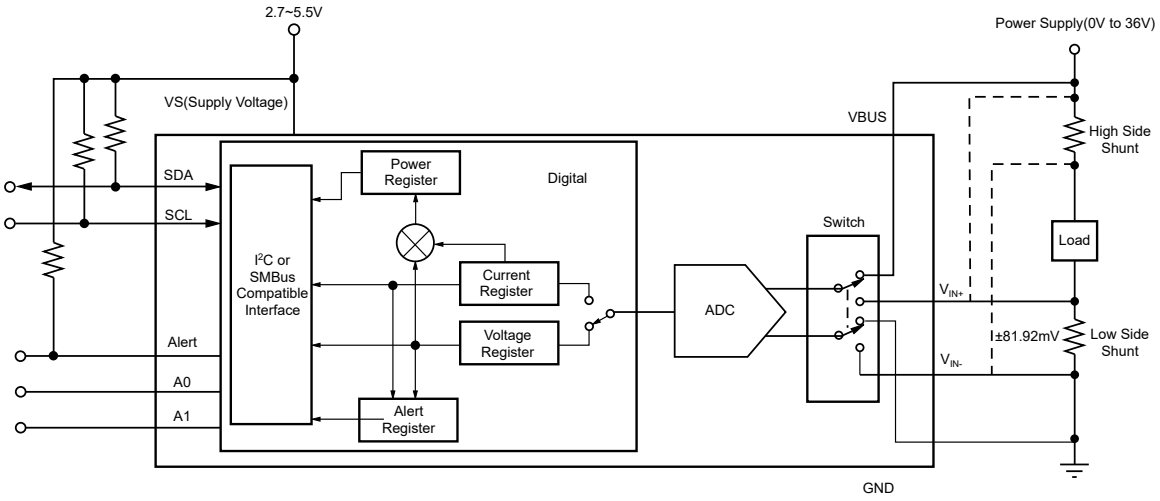


Figure 7. Functional Block Diagram

Feature Description

Programming

Table 2 lists the steps for configuring, measuring, and calculating the values for current and power for this device.

Table 2. Calculating Current and Power

Step	Register name	Address	Contents	Dec	Lsb	Value
Step 1	Configuration Register	00h	4127h	—	—	—
Step 2	Shunt Register	01h	1F40h	8000	2.5 μV	20 mV
Step 3	Bus Voltage Register	02h	2570h	9584	1.25 mV	11.98 V
Step 4	Calibration Register	05h	A00h	2560	—	—
Step 5	Current Register	04h	2710	10000	1 mA	10 A
Step 6	Power Register	03h	12B8h	4792	25 mW	119.82 W

I^2C Address

The device has two address pins, A0 and A1. The device samples the state of pins A0 and A1 on every bus communication. The following table lists the pin logic levels for each of the 16 possible addresses.

Table 3. Address Pins and Slave Address

A1	A0	Slave Address
GND	GND	1000000
GND	VS	1000001
GND	SDA	1000010
GND	SCL	1000011
VS	GND	1000100
VS	VS	1000101
VS	SDA	1000110
VS	SCL	1000111
SDA	GND	1001000
SDA	VS	1001001
SDA	SDA	1001010
SDA	SCL	1001011
SCL	GND	1001100
SCL	VS	1001101
SCL	SDA	1001110
SCL	SCL	1001111

Register Map

Table 4. Register Set Summary

Pointer Address	Register Name	Function	Power-on Reset		Type (1)
HEX			Binary	Hex	
00h	Configuration Register	All-register reset, shunt voltage and bus voltage ADC conversion times and averaging, operating mode.	01000001 00100111	4127	R/W
01h	Shunt Voltage Register	Shunt voltage measurement data.	00000000 00000000	0000	R
02h	Bus Voltage Register	Bus voltage measurement data.	00000000 00000000	0000	R
03h	Power Register (2)	Contains the value of the calculated power being delivered to the load.	00000000 00000000	0000	R
04h	Current Register (2)	Contains the value of the calculated current flowing through the shunt resistor.	00000000 00000000	0000	R

Table 5.

Pointer Address	Register Name	Function	Power-on Reset		Type (1)
Hex			Binary	Hex	
05h	Calibration Register	Sets full-scale range and LSB of current and power measurements. Overall system calibration.	00000000 00000000	0000	R/W
06h	Mask/Enable Register	Alert configuration and Conversion Ready flag.	00000000 00000000	0000	R/W
07h	Alert Limit Register	Contains the limit value to compare to the selected Alert function.	00000000 00000000	0000	R/W
FEh	Manufacturer ID Register	Contains unique manufacturer identification number.	0101010001001001	5549	R
FFh	Die ID Register	Contains unique die identification number.	0010001001100000	2260	R

Table 6. Configuration Register (00h) (Read/Write) Descriptions

BIT NO.	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	RST	—	—	—	AVG 2	AVG 1	AVG 0	VBU SCT2	VBU SCT1	VBU SCT0	VSH CT2	VSH CT1	VSH CT0	MOD E3	MOD E2	MOD E1
POR VALUE	0	1	0	0	0	0	0	1	0	0	1	0	0	1	1	1

Table 7. AVG Bit Settings[11:9] Combinations

AVG2 D11	AVG1 D10	AVG0 D9	Number OF Averages (1)
0	0	0	1
0	0	1	4
0	1	0	16
0	1	1	64
1	0	0	128
1	0	1	256
1	1	0	512
1	1	1	1024

(1) Shaded values are default.

Table 8. VBUSCT Bit Settings [8:6] Combinations

VBUSCT2 D8	VBUSCT1 D7	VBUSCT0 D6	CONVERSION TIME (μS)
0	0	0	140
0	0	1	204
0	1	0	332
0	1	1	588
1	0	0	1100
1	0	1	2116
1	1	0	4156
1	1	1	8244

Table 9. VSHCT Bit Settings [5:3] Combinations

VSHCT2 D5	VSHCT1 D4	VSHCT0 D3	CONVERSION TIME(1)
0	0	0	140
0	0	1	204
0	1	0	332

VSHCT2 D5	VSHCT1 D4	VSHCT0 D3	CONVERSION TIME(1)
0	1	1	588
1	0	0	1100
1	0	1	2116
1	1	0	4156
1	1	1	8244

Table 10. Mode Settings [2:0] Combinations

MODE3 D2	MODE2 D1	MODE1 D0	MODE (1)
0	0	0	Power-Down (or Shutdown)
0	0	1	Shunt Voltage, Triggered
0	1	0	Bus Voltage, Triggered
0	1	1	Shunt and Bus, Triggered
1	0	0	Power-Down (or Shutdown)
1	0	1	Shunt Voltage, Continuous
1	1	0	Bus Voltage, Continuous
1	1	1	Shunt and Bus, Continuous

Table 11. Shunt Voltage Register (01h) (Read-Only) Description

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	SIGN	SD14	SD13	SD12	SD11	SD10	SD9	SD8	SD7	SD6	SD5	SD4	SD3	SD2	SD1	SD0
POR VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 12. Bus Voltage Register (02h) (Read-Only) Description

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	—	BD14	BD13	BD12	BD11	BD10	BD9	BD8	BD7	BD6	BD5	BD4	BD3	BD2	BD1	BD0
POR VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 13. Power Register (03h) (Read-Only) Description

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	PD15	PD14	PD13	PD12	PD11	PD10	PD9	PD8	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0
POR VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 14. Current Register (04h) (Read-Only) Register Description

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	CSIGN	CD14	CD13	CD12	CD11	CD10	CD9	CD8	CD7	CD6	CD5	CD4	CD3	CD2	CD1	CD0
POR VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 15. Calibration Register (05h) (Read/Write) Description

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	—	FS14	FS13	FS12	FS11	FS10	FS9	FS8	FS7	FS6	FS5	FS4	FS3	FS2	FS1	FS0
POR VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 16. Mask/Enable Register (06h) (Read/Write)

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	SOL	SUL	BOL	BUL	POL	CNVR	—	—	—	—	—	AFF	CVRF	OVF	APOL	LEN
POR VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SOL: Shunt Voltage Over-Voltage

Bit 15

Setting this bit high configures the Alert pin to be asserted if the shunt voltage measurement following a conversion exceeds the value programmed in the Alert Limit Register.

SUL: Shunt Voltage Under-Voltage

Bit 14

Setting this bit high configures the Alert pin to be asserted if the shunt voltage measurement following a conversion drops below the value programmed in the Alert Limit Register.

BOL: Bus Voltage Over-Voltage

Bit 13

Setting this bit high configures the Alert pin to be asserted if the bus voltage measurement following a conversion exceeds the value programmed in the Alert Limit Register.

BUL: Bus Voltage Under-Voltage

Bit 12

Setting this bit high configures the Alert pin to be asserted if the bus voltage measurement following a conversion drops below the value programmed in the Alert Limit Register.

POL: Power Over-Limit

Bit 11

Setting this bit high configures the Alert pin to be asserted if the Power calculation made following a bus voltage measurement exceeds the value programmed in the Alert Limit Register.

CNVR: Conversion Ready

Bit 10

Setting this bit high configures the Alert pin to be asserted when the Conversion Ready Flag, Bit 3, is asserted indicating that the device is ready for the next conversion.

AFF: Alert Function Flag

Bit 4

While only one Alert Function can be monitored at the Alert pin at a time, Conversion Ready can also be enabled to assert the Alert pin. Reading the Alert Function Flag following an alert allows the user to determine if the

Alert Function was the source of the Alert.

When the Alert Latch Enable bit is set to Latch mode, the Alert Function Flag bit clears only when the Mask/Enable

Register is read. When the Alert Latch Enable bit is set to transparent mode, the Alert Function Flag bit is cleared following the next conversion that does not result in an Alert condition.

CVRF: Conversion Ready Flag

Bit 3

Although the device can be read at any time, and the data from the last conversion is available, the Conversion

Ready Flag bit is provided to help coordinate one-shot or triggered conversions. The Conversion Ready Flag bit is set after all conversions, averaging, and multiplications are complete. Conversion Ready Flag bit clears under the following conditions:

1.) Writing to the Configuration Register (except for Power-Down selection)

2.) Reading the Mask/Enable Register

OVF: Math Overflow Flag

Bit 2

This bit is set to '1' if an arithmetic operation results in an overflow error. It indicates that current and power data may be invalid.

APOL: Alert Polarity bit; sets the Alert pin polarity.

Bit 1

1 = Inverted (active-high open collector)

0 = Normal (active-low open collector) (default)

LEN: Alert Latch Enable; configures the latching feature of the Alert pin and Alert Flag bits.

Bit 0

1 = Latch enabled

0 = Transparent (default)

When the Alert Latch Enable bit is set to transparent mode, the Alert pin and Flag bit reset to the idle states when the fault has been cleared. When the Alert Latch Enable bit is set to Latch mode, the Alert pin and Alert Flag bit remains active following a fault until the Mask/Enable Register has been read.

Table 17. Alert Limit Register (07h) (Read/Write) Description

ddBIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	AUL15	AUL14	AUL13	AUL12	AUL11	AUL10	AUL9	AUL8	AUL7	AUL6	AUL5	AUL4	AUL3	AUL2	AUL1	AUL0
POR VALUE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 18. Manufacturer ID Register (FEh) (Read-Only) Description

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
BIT NAME	ID15	ID14	ID13	ID12	ID11	ID10	ID9	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0
POR VALUE	0	1	0	1	0	1	0	1	0	1	0	0	1	0	0	1

Table 19. Die ID Register (FFh) (Read-Only) Description

BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4f	D3	D2	D1	D0
BIT NAME	DID11	DID10	DID9	DID8	DID7	DID6	DID5	DID4	DID3	DID2	DID1	DID0	RID3	RID2	RID1	RID0

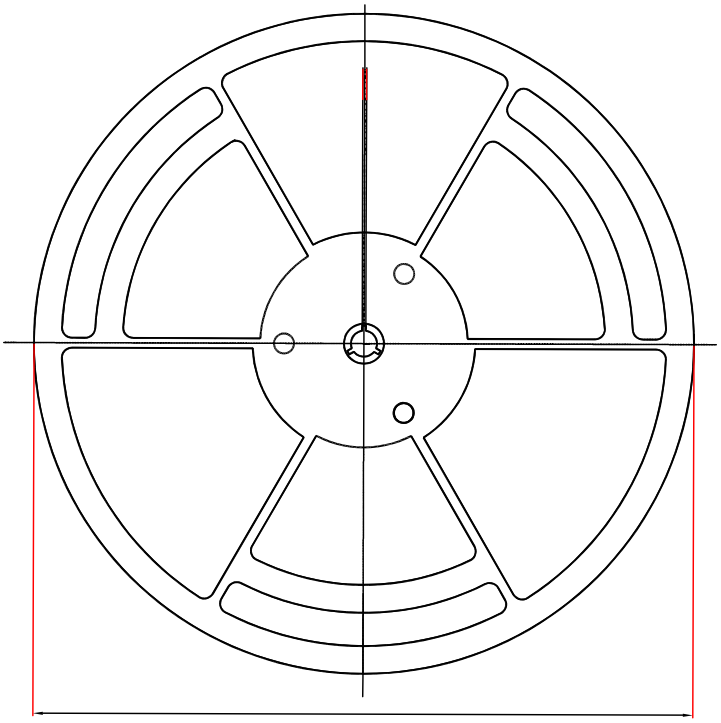
BIT #	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4f	D3	D2	D1	D0
POR VAL UE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

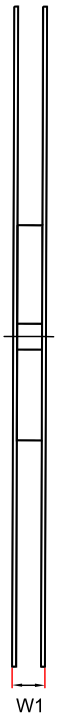
The device can not accept a stop command immediately after a start operation. If the customer wants to reset I2C communication, 9 clocks could be sent to TPA6270X after a start operation, to make sure the device is quite to default mode, and then wait for a new I2C start operation.

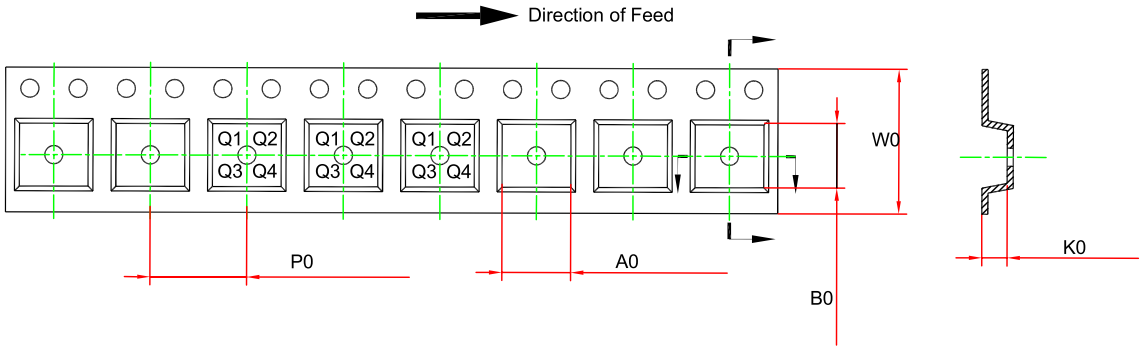
SMBUS alert function is supported to respond to the SMBus Alert Response address (0001 100) when an alert occurs. But be aware when the master is accessing the address if the device doesn't have an alert, the device will still acknowledge to address but without following response.

I^2C Data hold time should be at least 10nS for a proper start function is recognized.

Tape and Reel Information





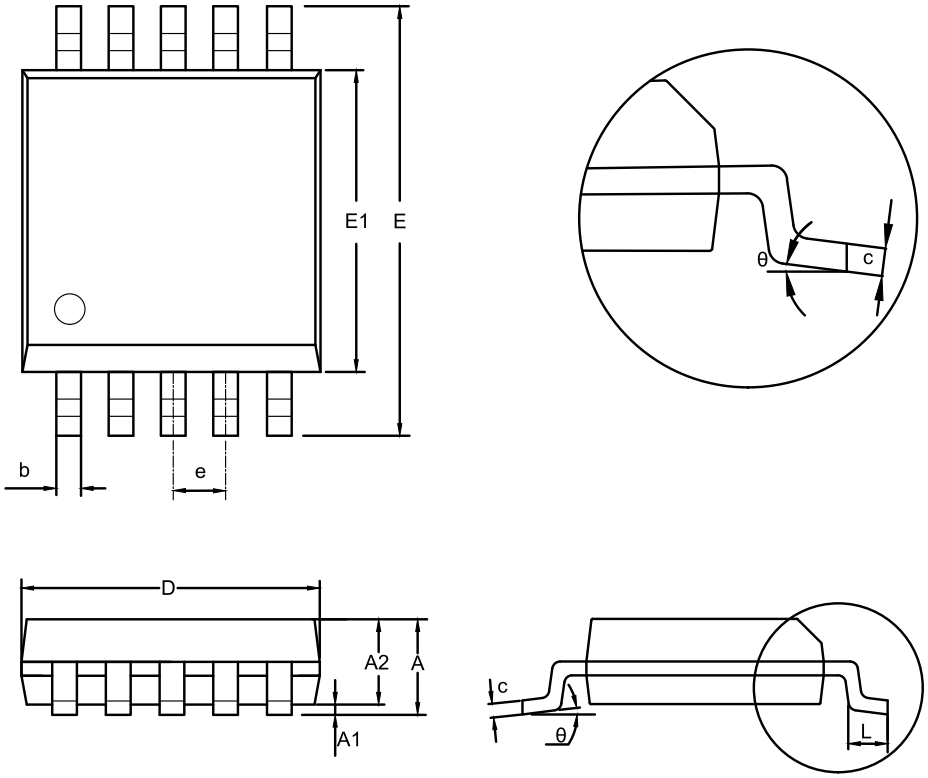


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA6270X-VS2R-S	MSOP10	330.0	17.6	5.30	3.30	1.40	8.0	12.0	Q1

Package Outline Dimensions

MSOP10

Package Outline Dimensions VS2(MSOP-10-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.050	0.150	0.002	0.006
A2	0.750	0.950	0.030	0.037
b	0.180	0.280	0.007	0.011
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.500 BSC		0.020 BSC	
L	0.400	0.800	0.016	0.031
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA6270X-VS2R-S	−40 to 125°C	MSOP10	6270	MSL2	Tape and Reel, 3000	Green

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