

3 or 4 Cell Li-Ion Smart Battery Pack Module

FEATURE

- Complete Solution for 3-4 Cell Li-Ion battery pack
- X3100 and microcontroller control
- Built-in Gas Gauge Software
- General Purpose Microcontroller
- SMBus interface/SBS 1.1 compliant

BENEFIT

- Minimal design effort required
- Safe, accurate and flexible implementation.
- No algorithms to develop
- Custom software modules add more gas gauge capability, cell balancing, history tracking.
- Conforms to industry smart battery standards

DESCRIPTION

The XM3100 module is a complete battery pack solution that features the Xicor X3100 Lithium Ion battery protection and monitor IC. For use in battery packs consisting of 3 or 4 Lithium-Ion battery cells (10.8V or 14.4V packs) the X3100 provides over-voltage, under-voltage, and over-current protection circuitry, internal EEPROM memory, an internal voltage regulator, and drive circuitry for switching external FET devices used to control cell charge, discharge, and cell voltage balancing. The XM3100 module provides all external devices needed to control the battery pack including a preprogrammed microcontroller. This microcontroller has a System Management Bus (SMBus v.1.0) interface with operation compliant with the Smart Battery System 1.1 Standard.

The built in software on the XM3100 module provides coulomb counting algorithms that provide a basic battery

gas gauging function. Future versions of the board will offer more extensive gas gauging, cell balancing routines and pack history tracking.

The XM3100 board has outputs for a separate display board containing five LEDs and a pushbutton switch. This board is included with the XM3100. The LEDs and switch allow the battery pack user to check the state of charge without connecting the battery to the host. The LEDs turn on for a short period of time when the switch is pressed to show capacity as 10%, 30%, 50%, 70% or 90% of full charge.

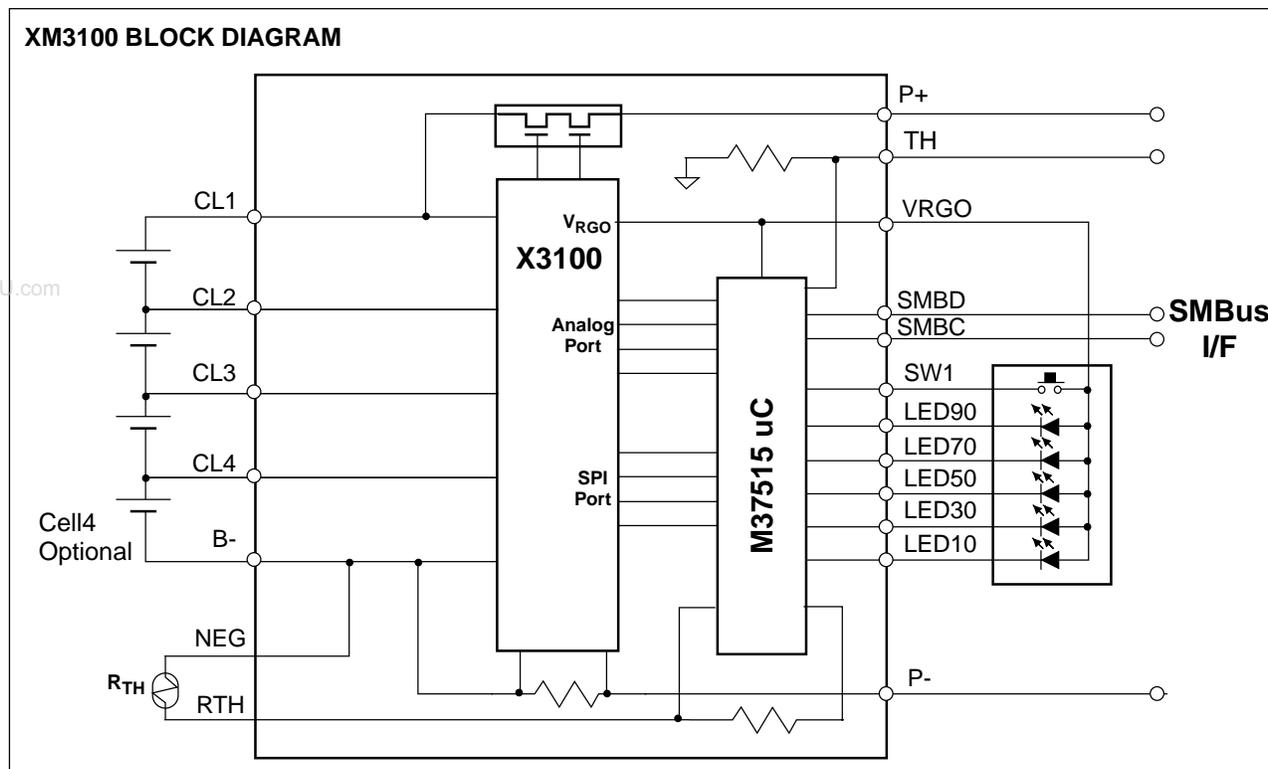
The XM3100 board can be tailored to meet specific customer requirements. The module over-voltage, over-current, and under-voltage levels are easily changed through programmable non-volatile bits. Simple capacitor changes provide different protection time-out periods. Specialized software routines can offer customized gas gauging.



Pins

CL1:	Battery Cell 1 (+)	LED10:	10-30% Capacity indicator
CL2:	Battery Cell 1 (-)/Battery Cell 2 (+)	LED30:	30-50% Capacity indicator
CL3:	Battery Cell 2 (-)/Battery Cell 3 (+)	LED50:	50-70% Capacity indicator
CL4:	Battery Cell 3 (-)/Battery Cell 4 (+)	LED70:	70-90% Capacity indicator
B-:	Battery Cell 4 (-)	LED90:	90-100% Capacity indicator
P+:	Battery Pack Positive Terminal	SW1:	Indicator LED Switch input
P-:	Battery Pack Negative Terminal	VRGO:	Regulated 5V output to display board
SMBD:	SMBus Data Line	NEG:	Negative terminal of battery (for Thermistor)
SMBC:	SMBus Clock Line	RTH:	Thermistor connection (battery pack temperature)

XM3100

**SAFETY UNIT**

The safety unit of the X3100 provides four selectable over voltage levels for the Li-ion Cells. The default threshold is set to 4.2V +/-50mV. Other selectable levels are: 4.25V, 4.3V and 4.35V. The over voltage detect time is 1 second. This can be changed by replacing a capacitor on the board. When an over voltage occurs, the charge FET is automatically turned off. When voltage drops below the over voltage threshold minus 200 mV the charge FET is automatically turned back on.

The X3100 provides four selectable under voltage levels for the battery cells. The default level is 2.25V +/-100mV. Other options are 1.95V, 2.05V, and 2.15V. The under voltage delay time is set to 1 second, but this can be changed by replacing a capacitor on the board. When the board goes into an under voltage condition, both FETs on the board turn off and the pack electronics go into a sleep mode. The unit returns to normal operation when the charger is reconnected to the pack.

The X3100 provides four selectable over current levels for the battery pack. These levels are 3.75A, 5A, 6.25A and 7.5A. These are accurate to +/-0.75A. The over

current detect time is set to 10ms, but may be changed by replacing a capacitor on the board.

SMBUS INTERFACE/SMART BATTERY SYSTEM

The SMBus interface is compliant with the SBS 1.1 specifications. The following section describes the operation of the Smart Battery Interface, features and operation. Additional details on the SBS1.1 standards are available in the Smart Battery Data Specification Revision 1.1, December 11, 1998.

Battery Commands**Manufacturer Access (0x00)**

This command is functional, so a value written using this command can be read back at a later time. However, the value written does not affect nor control the operation of the module.

Remaining Capacity Alarm (0x01)

This command sets or gets the Low Capacity Alarm Threshold. Whenever "Remaining Capacity" falls below "Low Capacity", The XM3100 sends an alarm warning message to the host. A Low Capacity setting of 0 disables the alarm.

XM3100

Remaining Time Alarm (0x02)

This command sets or gets the Remaining Time alarm value. Whenever "Average Time to Empty" falls below "Remaining Time", the XM3100 sends an alarm warning message to the host. A Remaining Time setting of 0 disables the alarm.

Battery Mode (0x03)

Battery Mode selects the various operating modes of the battery and reports on the battery's capabilities and modes and flags minor conditions requiring attention.

Table 1. Battery Mode Bits

Bit	Field	Value	Comments
0	Internal Charge Controller	1 Read Only	Internal Charge Controller Supported
1	Primary Battery Support	1 Read Only	The XM3100 supports the operation as either a primary or secondary.
2-6	Reserved		
7	Condition Flag	0 or 1 Read Only	0 = Battery O.K. 1 = Conditioning Cycle Requested.
8	Charge Controller Enabled	0 (default) or 1	Internal Charge Controller is disabled.
9	Primary Battery	0 (default) or 1	0 - Battery operating in its secondary role 1 - Battery operating in its primary role
10-12	Reserved		
13	Alarm Mode	0 (default) or 1	0 - Enable alarm warning broadcasts 1 - disable broadcasts
14	Charger Mode	0 (default) or 1	0 - Enable charge current & voltage broadcasts 1 - disable broadcasts
15	Capacity Mode	0 (default) or 1	0 = mA or mAh 1 = 10mW or 10mWh

AtRate (0x04)

The AtRate function is the first half of a two function call-set. AtRate supplies the charge or discharge value used with "AtRateTimeToFull", "AtRateTimeToEmpty" and "AtRateOK" commands. These second commands determine how long the pack can supply the requested

energy or if the pack can supply the energy for a specific period of time.

AtRateTimeToFull (0x05)

This command returns the predicted time to fully charge the battery at the previously written AtRate value.

AtRateTimeToEmpty (0x06)

This command returns the predicted time to fully discharge the battery at the previously written AtRate value.

AtRateOK (0x07)

AtRateOK returns TRUE or FALSE response indicating if the battery can deliver the previously written value of additional energy for 10 seconds.

Temperature (0x08)

This command returns the cell-packs internal temperature ($^{\circ}\text{K} \times 10$).

Voltage (0x09)

This command returns the cell pack voltage (mV).

Current (0x0A)

This command returns the current being supplied or accepted through the battery terminals (mA).

Average Current (0x0B)

The value is a one minute rolling average of the current being supplied or accepted through the battery terminals (mA).

MaxError (0x0C)

MaxError is the expected margin of error in the state of charge calculations.

RelativeStateOfCharge (0x0D)

This command returns the predicted remaining capacity expressed as a percentage of FullChargeCapacity.

AbsoluteStateOfCharge (0x0E)

This command returns the predicted remaining battery capacity expressed as a percentage of DesignCapacity.

RemainingCapacity (0x0F)

This command returns the predicted remaining battery capacity.

FullChargeCapacity (0x10)

This command returns the predicted pack capacity when it is fully charged.

XM3100

RunTimeToEmpty (0x11)

This command returns the predicted remaining battery life at the present rate of discharge (minutes).

AverageTimeToEmpty (0x12)

This command returns a rolling average of the predicted remaining battery life (minutes).

AverageTimeToFull (0x13)

This command returns a rolling average of the predicted remaining time until the battery pack reaches a full charge (minutes).

BatteryStatus (0x16)

This command returns the battery's status word which contains Alarm and Status bit flags. The bits are defined in Table 2. All of the microcontroller charge and discharge control is dictated by the Battery Status Flags, though they cannot override the X3100's protection features.

Table 2. Battery Status Bits

Status Word	Condition
Alarm Bits	
0x8000 bit15	Over Charged Alarm: Always cleared if the device is no longer charging. Set if a cell voltage exceeds 4.352V or if the X3100 OVDS flag is set.
0x4000 bit14	Terminate Charge Alarm: Always cleared if no longer charging. Set with the Over charged Alarm flag.
0x2000	Reserved
0x1000 bit12	Over Temperature Alarm: Set if the temperature exceeds 70°C and cleared below 55°C.
0x0800 bit11	Terminate Discharge Alarm: Always cleared if the current is non-negative. Set if a cell voltage is less than 2.560V or if the X3100 OCDS flag is set.
0x0400	Reserved
0x0200 bit9	Remaining Capacity Alarm: Set if Remaining Capacity drops below the alarm threshold. Cleared when the Remaining Capacity rises above the alarm threshold.
0x0100 bit8	Remaining Time Alarm: Set if the Average Time to Empty drops below the alarm threshold. Cleared when the Average Time to Empty rises above the alarm threshold.

Table 2. Battery Status Bits

Status Word	Condition
Status Bits	
0x0080	Initialized: Fixed at '1'
0x0040 bit6	Discharging: Set when the current value is negative. Cleared when positive.
0x0020 bit5	Fully Charged: Set when the X3100 OVDS flag is set cleared when the Relative State of Charge drops below 100%.
0x0010 bit4	Fully Discharged: Set when Terminate Discharge Flag is set, Cleared whe Relative State of Charge rises above 20%.
0x0000-0x000F	Reserved

Charging is allowed if all of the following are true:

- Charge Controller Enabled = 1 (Optional, set via SMBUS)
- Bit15 - Overcharged Alarm = 0
- Bit14 - Terminate Charge Alarm = 0
- Bit12 - Overtemp Alarm = 0

Discharging is allowed if all of the following are true:

- Primary Battery = 1 (Optional, set via SMBus)
- Bit11 - Terminate Discharge Alarm = 0
- Bit4 - Fully Discharged = 0

CycleCount (0x17)

This command returns the number of charge/discharge cycles the battery has experienced. A cycle is defined as an amount of discharge approximately equal to the value of DesignCapacity.

DesignCapacity (0x18)

The command returns the theoretical capacity of a new pack.

DesignVoltage (0x19)

This command returns the theoretical voltage of a new pack (mV).

SpecificationInfo (0x1A)

This command returns the version number of the Smart Battery specification that the battery pack supports. It also reports the voltage, current and capacity scaling information for the pack.

XM3100**ManufactureDate (0x1B)**

This command returns the date that the pack was manufactured.

SerialNumber (0x1C)

This command returns the pack serial number.

ManufacturerName (0x1D)

This command returns the pack manufacturer. The XM3100 is programmed to return "Xicor, Inc." but the value can be reprogrammed to meet the pack manufacturer's needs.

DeviceName (0x21)

This command returns the battery's name. The XM3100 is programmed to return the board part number, but the value can be reprogrammed to meet the pack manufacturer's needs.

DeviceChemistry (0x22)

This command returns the value "LION" to indicate that the pack supports Li-ion batteries.

ManufacturerData (0x23)

As specified in the Smart Battery Specification, this is a read only command that returns a block of data from the battery pack. It is an optional command used for reading various parameters from the pack. The XM3100 does not use this command, but enhanced software could use it to read collected battery pack history, such as the number of deep cycles, violations of temperature or current rate extremes, and discharge patterns.

Battery Charger Messages

The battery charger can set the Battery Mode bit 14 high and poll the battery pack to determine the battery charging requirements. The charger can request the battery charging current, charging voltage, and status periodically, but it must do so at intervals from 5 to 60 seconds. If the charger periodically polls the pack it can disable the pack's automatic broadcast of the charging current and charging voltage by setting the Charger Mode bit to one.

Charging Current (0x14)

When receiving this command, the XM3100 returns the the smart battery desired charging rate. This is based on the specific cells being used in the pack.

Charging Voltage (0x15)

When receiving this command, the XM3100 returns the the smart battery desired charging voltage (mV). This is based on the specific cells being used in the pack.

Battery Critical Messages

Whenever the XM3100 detects a critical condition, it beomes the master and sends an Alarm Waring message to both the Smart Battery Charger and the SMBus Host, notifying them of the critical condition.

AlarmWarning or Broadcasts (0x16)

The AlarmWarning message is sent by the XM3100, acting as a bus master device, to the charger and host. It is a warning that one or more alarm conditions exist. The alarm conditions are encoded as bit fields in the message. These bit fields match those of the battery status word. The alarm warning messages are disabled by setting the Battery Mode bit 13 high. In this case the host and charger need to poll the battery pack to determine the status.

A Broadcast (command 0x16) is sent by the battery pack to other components on the SMBus. It occurs automatically when the Battery Mode bit 14 is set low. This broadcast occurs every 30 seconds and provides the charger with values for desired charge current and voltage.

Gas Gauge

The gas gauge software on the XM3100 board consists of a simple accumulation of current based on the reading of voltage across the sense resistor. The software makes use of the current sense amplifier of the X3100 to improve the accuracy of the current reading over a wide dynamic range.

The accumulated current value is placed in a gas gauge register consistant with the SBS 1.1 specification. Other computations required for the SBS specification (such as AtRate) are computed continuously. The gas gauge does not provide routines for automatic compensation of the gas gauge value based on temperature or current rate.

Gas Gauge Calculations

There are a number of calculations associated with the gas gauge. Brief descriptions provided below give additional information about the operation of the module.

Core Parameters

- Average Current: This value is updated every 1.874 seconds. It averages 32 "fast average" current values.

XM3100

- Remaining Capacity: Every 59.97 seconds the Average current is converted to mA-h then (if positive) is added to the Remaining Capacity value and (if negative) is subtracted from the Remaining Capacity value.

Miscellaneous Parameters

These parameters are updated continuously, but the effective update rate is every 59.97 seconds, due to their dependency on the Remaining Capacity value.

- Full Charge Capacity: This is a simple comparison to Remaining Capacity. Because of the gas gauge simplicity, this value cannot exceed Design Capacity.
- Relative State of Charge: This value is Remaining Capacity divided by Full Charge Capacity.
- Absolute State of Charge: This value is Remaining Capacity divided by Design Capacity.
- Cycle Count; This is incremented on an excursion from less than 5% Relative State of Charge to greater than 90%.
- Maximum Error: This value is fixed at 5%.

Time To Commands

These parameters are updated continuously, but the effective update rate is every 59.97 seconds, due to their dependency on the Remaining Capacity value.

- Run Time to Empty: The Remaining capacity is converted to mA-min and divided by the Current value.

- Average Time to Empty: The Remaining capacity is converted to mA-min and divided by the Average current.
- Average Time to Full: The Full Charge Capacity minus Remaining Capacity value is converted to mA-min and divided by the average current.
- At Rate Commands

These parameters are updated continuously, but the effective update rate is every 59.97 seconds, due to their dependency on the Remaining Capacity value.

- At Rate O.K.: Remaining Capacity is converted to mA-10s and compared to the At Rate current. No discharge rate or temperature compensation is used.
- At Rate Time To Full: The Full Charge Capacity minus Remaining Capacity value is converted to mA-min and divided by the At Rate current.
- At Rate Time to Empty: The Remaining Capacity value is converted to mA-min and divided by the At Rate current value.

Cell Balancing

Cell balancing is not provided on this version of the module. Another version (XM3100CB) will provide the external FETs and resistors required to balance the cells and the software to control the balancing. Cell balancing is a mechanism that adjusts the voltages on the cells so they are all equal. This is usually done when the pack is fully or nearly fully charged. Cell balancing can improve the pack capacity and extend the life of the cells.

PRELIMINARY

XM3100

Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
Storage Temperature	-55	125	°C
DC Output Current		5	mA
Lead Temperature (Soldering 10 seconds)		300	°C
Battery Voltage	(B-) - 0.5	(B-) +27.0	V
Storage Temperature	-50	125	°C

of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Recommended Operating Conditions

Temperature	Min.	Max.
Industrial	-40°C	+85°C

***COMMENT**

Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and the functional operation

Supply Voltage	Limits
XM3100	6V to 24V

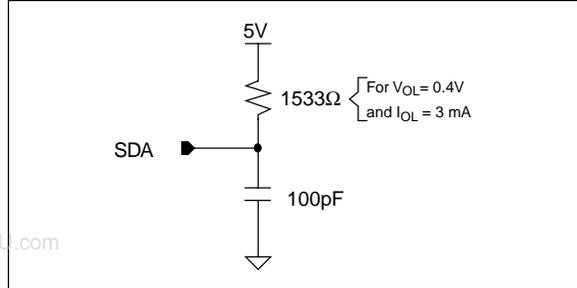
DC OPERATING CHARACTERISTICS (Over the recommended operating conditions, unless otherwise specified.)

Description	Sym	Condition	Min	Typ	Max	Unit
Vcc Supply Current (1)	Icc1	Normal Operation		4		mA
Vcc Supply Current (1)	Icc2	Power Down		300		µA
Vcc Supply Current (4)	Icc3	Sleep mode			1	µA
Cell over-voltage protection mode threshold	V _{OV}	V _{OV} =4.20V (Default) ⁽¹⁾	4.15	4.20	4.25	V
Cell over-voltage protection mode release threshold	V _{OVr}	V _{OV} =4.20V (Default) ⁽¹⁾		V _{OV} -0.2		V
Cell over-voltage detection time	T _{OV}	C _{OV} =0.1µF	0.5	1	1.5	s
Cell under-voltage protection mode (SLEEP) threshold.	V _{UV}	V _{UV} =2.3V (Default) ⁽¹⁾	2.20	2.30	2.40	V
Cell under-voltage protection mode release threshold	V _{UVr}	V _{UV} =2.3V (Default) ⁽¹⁾		V _{UV} +0.7		V
Cell under-voltage detection time	T _{UV}	C _{UV} =0.1µF	0.5	1	1.5	s
Cell under-voltage release time	T _{UVr}	C _{UV} =0.1µF	3.5	7	10.5	ms
Over-current mode Detection Voltage	V _{OC}	V _{OC} =0.1V (Default) ⁽¹⁾	0.085	0.100	0.115	V
Over-current mode Detection Time	T _{OC}	C _{OC} =1nF	5	10	15	ms
Over-current mode Release Time	T _{OCR}	C _{OC} =1nF	5	10	15	ms
Load Resistance Over-current mode Release Condition			150	250		kΩ
Cell Charge Threshold Voltage	V _{CE}	V _{CE} =1.4V (Default) ⁽¹⁾	1.30	1.40	1.50	V
Initial Charger Voltage (pack wake-up)	V _{SLR}		16.0	17.0		V

PRELIMINARY

XM3100

EQUIVALENT A.C. LOAD CIRCUIT



A.C. TEST CONDITIONS

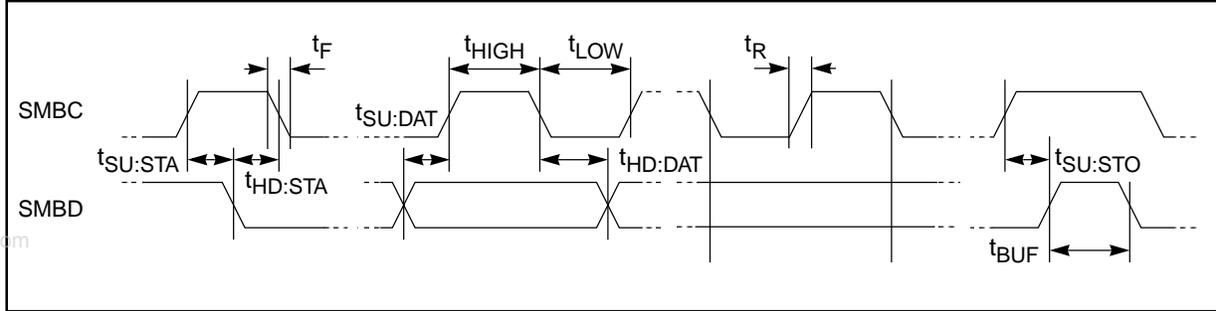
Input Pulse Levels	0.1V _{CC} to 0.9V _{CC}
Input Rise and Fall Times	10ns
Input and Output Timing Levels	0.5V _{CC}
Output Load	Standard Output Load

A.C. CHARACTERISTICS (Over recommended operating conditions, unless otherwise specified)

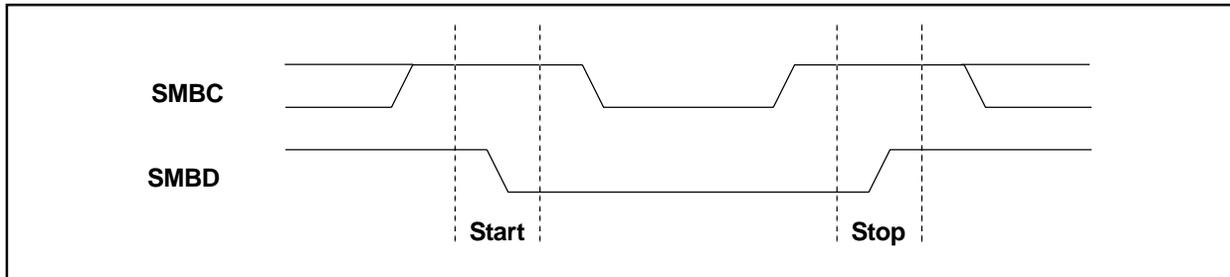
Symbol	Parameter	100kHz		Units
		Min	Max	
V _{IL}	SMBDATA, SMBCLK Input Low Voltage	-0.5	0.6	V
V _{IH}	SMBDATA, SMBCLK Input High Voltage	1.4	5.5	V
V _{OL}	SMBDATA, SMBCLK Output Low Voltage (@I _{PULLUP} max)		0.4	V
I _{PEAK}	Input Leakage		±5	μA
I _{PULLUP}	Current through pullup resistor or current source	100	350	μA
f _{SMB}	SMBus Operating Frequency	10	100	KHz
t _{BUF}	Bus free between stop and start condition	4.7		μs
t _{HD:STA}	Hold Time after (Repeated) Start condition. After this period, the first clock is generated.	4.0		μs
t _{SU:STA}	Repeated Start Condition setup time	4.7		μs
t _{SU:STO}	Stop Condition Setup Time	4.0		μs
t _{HD:DAT}	Data hold time	300		ns
t _{SU:DAT}	Data setup time	250		ns
t _{TIMEOUT}	Clock Low Timeout	25	35	ms
t _{LOW}	Clock LOW Time	4.7		μs
t _{HIGH}	Clock HIGH Time	4.0	50	μs
t _{LOW:SEXT}	Cumulative Clock Low extend time (slave device)		25	ms
t _{LOW:MEXT}	Cumulative Clock Low extend time (master device)		10	ms
t _R	Clock/Data Rise Time		1000	ns
t _F	Clock/Data Fall Time		300	ns

XM3100

BUS TIMING



VALID START AND STOP CONDITIONS



ACKNOWLEDGE RESPONSE FROM RECEIVER

