

Features

- **maXTouch™ Touchscreen**
 - True 12-bit multiple touch reporting and real-time XY tracking for up to 10 concurrent touches with touch size reporting
 - Up to 4.3 inch diagonal screen size supported with 10 mm “pinch” separation
- **Number of Channels**
 - Electrode grid configurations of 16 to 20 X and 10 to 14 Y lines supported (subject to a total of 30 lines)
 - Touchscreen up to 224 channels (subject to other configurations)
 - Proximity sensor up to 16 channels (subject to other configurations)
 - Up to 32 channels can be allocated as fixed keys (subject to other configurations)
- **Zero Additional Part Count**
 - 16 X by 14 Y matrix (224 channels) implementable with power bypass capacitors only
- **Signal Processing**
 - Advanced digital filtering using both hardware engine and firmware
 - Self-calibration
 - Auto drift compensation
 - Adjacent Key Suppression® (AKS™) technology
 - Grip and face suppression
 - Reports one-touch and two-touch gestures
 - Down-scaling and clipping support to match LCD resolution
 - Ultra-fast start-up and calibration for best user experience
 - Supports axis flipping and axis switch-over for portrait and landscape modes
- **Scan Speed**
 - Maximum single touch >250Hz, subject to configuration
 - Configurable to allow power/speed optimization
 - Programmable timeout for automatic transition from active to idle states
- **Response Times**
 - Initial latency <10 ms for first touch from idle, subject to configuration
- **Sensors**
 - Works with PET or glass sensors, including curved profiles
 - Works with all proprietary sensor patterns recommended by Atmel®
 - Works with a passive stylus
- **Panel Thickness**
 - Glass up to 2.5mm, screen size dependent
 - Plastic up to 1.2 mm, screen size dependent
- **Interface**
 - I²C-compatible slave mode 400 kHz
- **Dual-rail Power**
 - Interface 1.8V to 3.3V nominal, analog 2.7V to 3.3V nominal
- **Power Consumption**
 - Idle 80Hz: <1.8> mW, subject to configuration
 - One Touch Active 80Hz: 3.9 mW, subject to configuration
 - Sleep: 7.5 μW
- **Package**
 - 49-ball UFBGA 5 x 5 x 0.6 mm, 0.65 mm ball pitch
 - 49-ball VFBGA 5 x 5 x 1 mm, 0.65 mm ball pitch
 - 48-pin QFN 6 x 6 x 0.6 mm, 0.4 mm pin pitch



maXTouch™ 224-channel Touchscreen Sensor IC

mXT224

maXTouch™

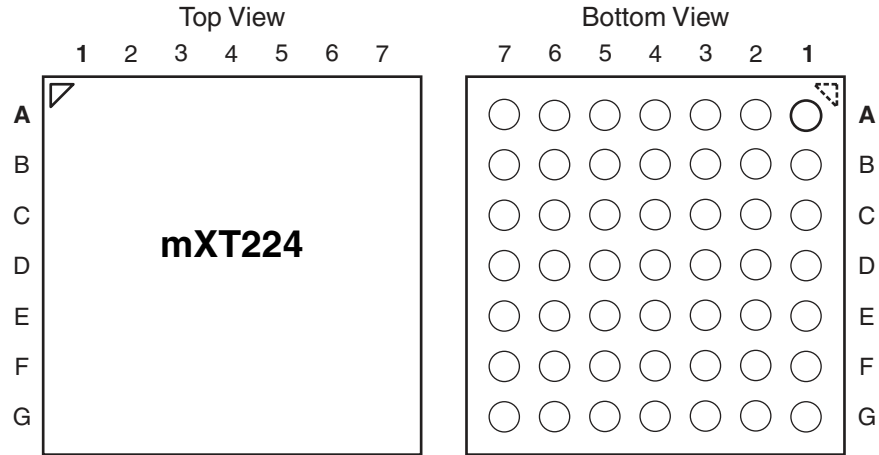
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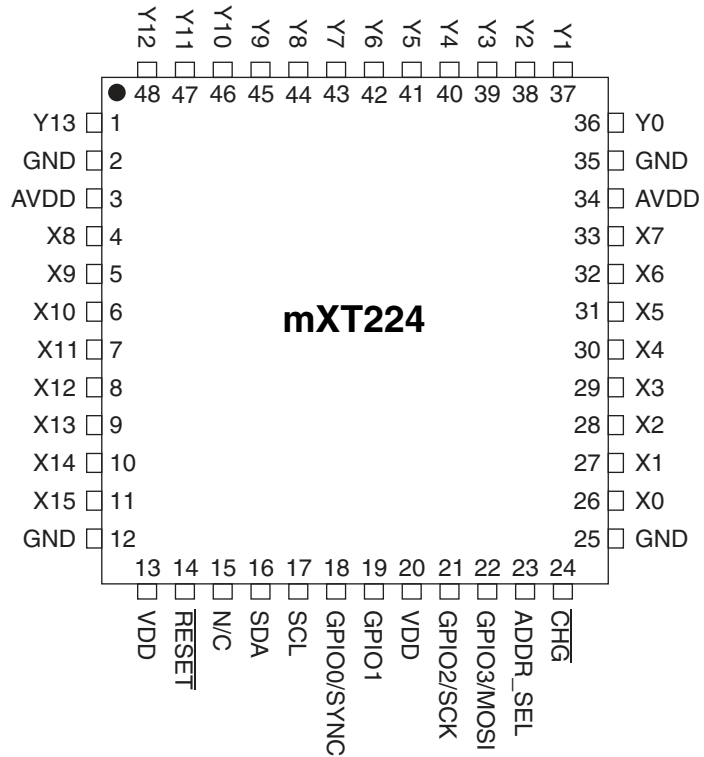
1. Pinout and Schematic

1.1 Pinout Configuration

1.1.1 49-ball UFBGA/VFBGA



1.1.2 48-pin QFN



1.2 Pinout Descriptions

1.2.1 49-ball UFBGA/VFBGA

Table 1-1. Pin Listing

Ball	Name	Type	Comments	If Unused, Connect To...
A1	AVDD	P	Analog power	–
A2	Y12	I/O	Y line connection or X line in extended mode	Leave open
A3	Y10	I/O	Y line connection or X line in extended mode	Leave open
A4	Y8	I	Y line connection	Leave open
A5	Y6	I	Y line connection	Leave open
A6	Y4	I	Y line connection	Leave open
A7	Y2	I	Y line connection	Leave open
B1	X8	O	X matrix drive line	Leave open
B2	GND	P	Ground	–
B3	Y11	I/O	Y line connection or X line in extended mode	Leave open
B4	Y9	I	Y line connection	Leave open
B5	Y5	I	Y line connection	Leave open
B6	Y1	I	Y line connection	Leave open
B7	Y0	I	Y line connection	Leave open
C1	X10	O	X matrix drive line	Leave open
C2	X9	O	X matrix drive line	Leave open
C3	Y13	I/O	Y line connection or X line in extended mode	Leave open
C4	Y7	I	Y line connection	Leave open
C5	Y3	I	Y line connection	Leave open
C6	GND	P	Ground	–
C7	AVDD	P	Analog power	–
D1	X12	O	X matrix drive line	Leave open
D2	X13	O	X matrix drive line	Leave open
D3	X11	O	X matrix drive line	Leave open
D4	GND	P	Ground	–
D5	X7	O	X matrix drive line	Leave open
D6	X5	O	X matrix drive line	Leave open
D7	X6	O	X matrix drive line	Leave open
E1	X14	O	X matrix drive line	Leave open
E2	X15	O	X matrix drive line	Leave open
E3	$\overline{\text{RESET}}$	I	Reset low; has internal 20 k Ω to 60 k Ω pull-up resistor	Vdd
E4	GPIO1	I/O	General purpose I/O	Input: GND Output: leave open

Table 1-1. Pin Listing (Continued)

Ball	Name	Type	Comments	If Unused, Connect To...
E5	X1	O	X matrix drive line	Leave open
E6	X3	O	X matrix drive line	Leave open
E7	X4	O	X matrix drive line	Leave open
F1	VDD	P	Digital power	–
F2	GND	P	Ground	–
F3	SCL	OD	Serial Interface Clock	–
F4	GPIO3/ MOSI	I/O	General purpose I/O / Debug data	Input: GND Output: leave open
F5	GND	P	Ground	–
F6	$\overline{\text{CHG}}$	OD	State change interrupt	–
F7	X2	O	X matrix drive line	Leave open
G1	N/C	–	No connection	Leave open
G2	SDA	OD	Serial Interface Data	–
G3	GPIO0/ SYNC	I/O	General purpose I/O External synchronization	Input: GND Output: leave open
G4	GPIO2/ SCK	I/O	General purpose I/O / Debug clock	Input: GND Output: leave open
G5	VDD	P	Digital power	–
G6	ADDR_SEL	I	I ² C-compatible address select	–
G7	X0	O	X matrix drive line	Leave open

I Input only
 O Output only, push-pull
 P Ground or power

I/O Input and output
 OD Open drain output

1.2.2 48-pin QFN

Table 1-2. Pin Listing

Pin	Name	Type	Comments	If Unused, Connect To...
1	Y13	I/O	Y line connection or X line in extended mode	Leave open
2	GND	P	Ground	–
3	AVDD	P	Analog power	–
4	X8	O	X matrix drive line	Leave open
5	X9	O	X matrix drive line	Leave open
6	X10	O	X matrix drive line	Leave open
7	X11	O	X matrix drive line	Leave open
8	X12	O	X matrix drive line	Leave open
9	X13	O	X matrix drive line	Leave open
10	X14	O	X matrix drive line	Leave open
11	X15	O	X matrix drive line	Leave open
12	GND	P	Ground	–
13	VDD	P	Digital power	–
14	$\overline{\text{RESET}}$	I	Reset low; has internal 20 k Ω to 60 k Ω pull-up resistor	Vdd
15	N/C	–	No connection	Leave open
16	SDA	OD	Serial Interface Data	–
17	SCL	OD	Serial Interface Clock	–
18	GPIO0/ SYNC	I/O	General purpose I/O External synchronization	Input: GND Output: leave open
19	GPIO1	I/O	General purpose I/O	Input: GND Output: leave open
20	VDD	P	Digital power	–
21	GPIO2/ SCK	I/O	General purpose I/O / Debug clock	Input: GND Output: leave open
22	GPIO3/ MOSI	I/O	General purpose I/O / Debug data	Input: GND Output: leave open
23	ADDR_SEL	I	I ² C-compatible address select	–
24	$\overline{\text{CHG}}$	OD	State change interrupt	–
25	GND	P	Ground	–
26	X0	O	X matrix drive line	Leave open
27	X1	O	X matrix drive line	Leave open
28	X2	O	X matrix drive line	Leave open
29	X3	O	X matrix drive line	Leave open
30	X4	O	X matrix drive line	Leave open
31	X5	O	X matrix drive line	Leave open
32	X6	O	X matrix drive line	Leave open

Table 1-2. Pin Listing (Continued)

Pin	Name	Type	Comments	If Unused, Connect To...
33	X7	O	X matrix drive line	Leave open
34	AVDD	P	Analog power	–
35	GND	P	Ground	–
36	Y0	I	Y line connection	Leave open
37	Y1	I	Y line connection	Leave open
38	Y2	I	Y line connection	Leave open
39	Y3	I	Y line connection	Leave open
40	Y4	I	Y line connection	Leave open
41	Y5	I	Y line connection	Leave open
42	Y6	I	Y line connection	Leave open
43	Y7	I	Y line connection	Leave open
44	Y8	I	Y line connection	Leave open
45	Y9	I	Y line connection	Leave open
46	Y10	I/O	Y line connection or X line in extended mode	Leave open
47	Y11	I/O	Y line connection or X line in extended mode	Leave open
48	Y12	I/O	Y line connection or X line in extended mode	Leave open

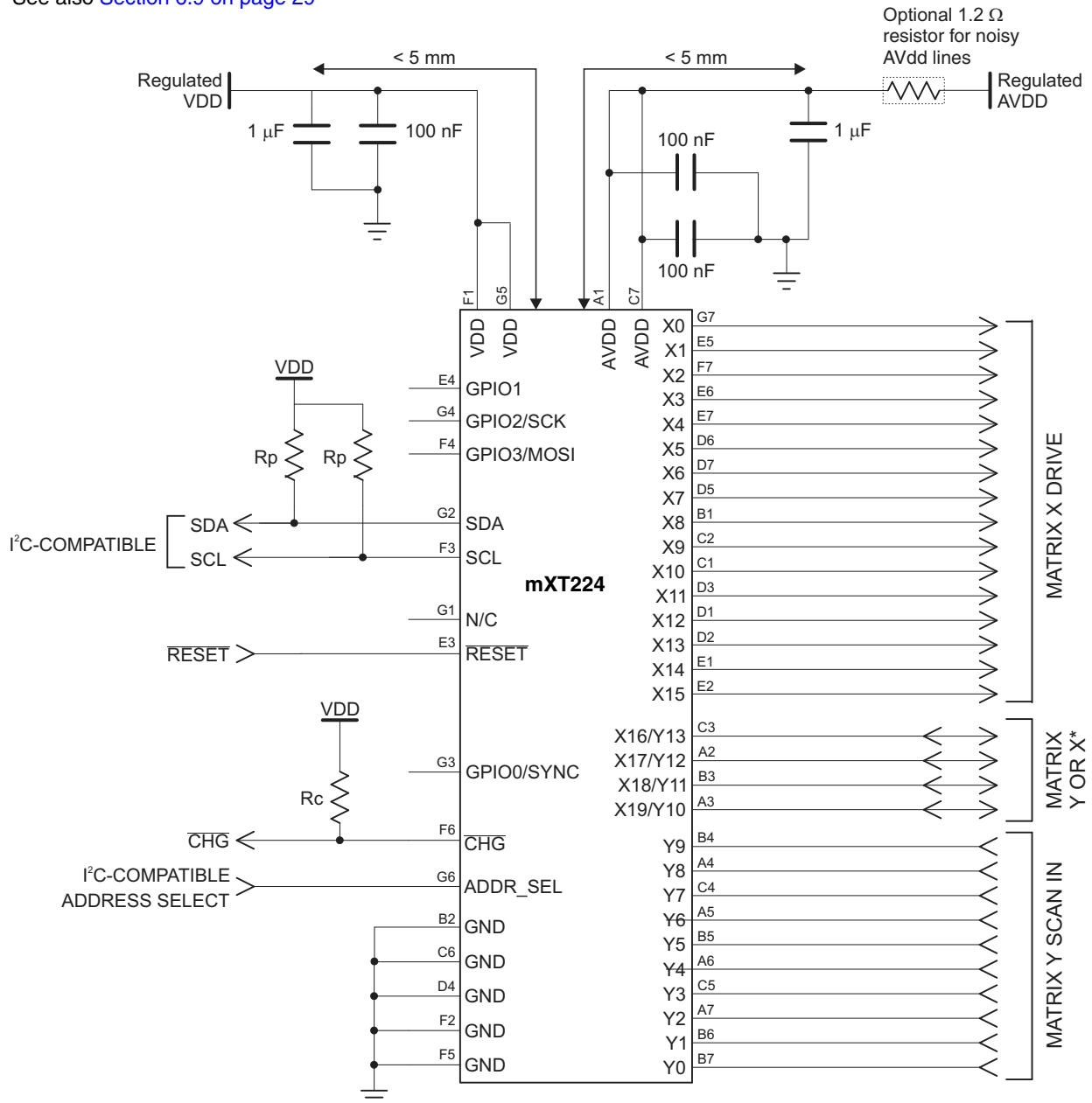
I Input only
 O Output only, push-pull
 P Ground or power

I/O Input and output
 OD Open drain output

1.3 Schematics

1.3.1 49-ball UFBGA/VFBGA

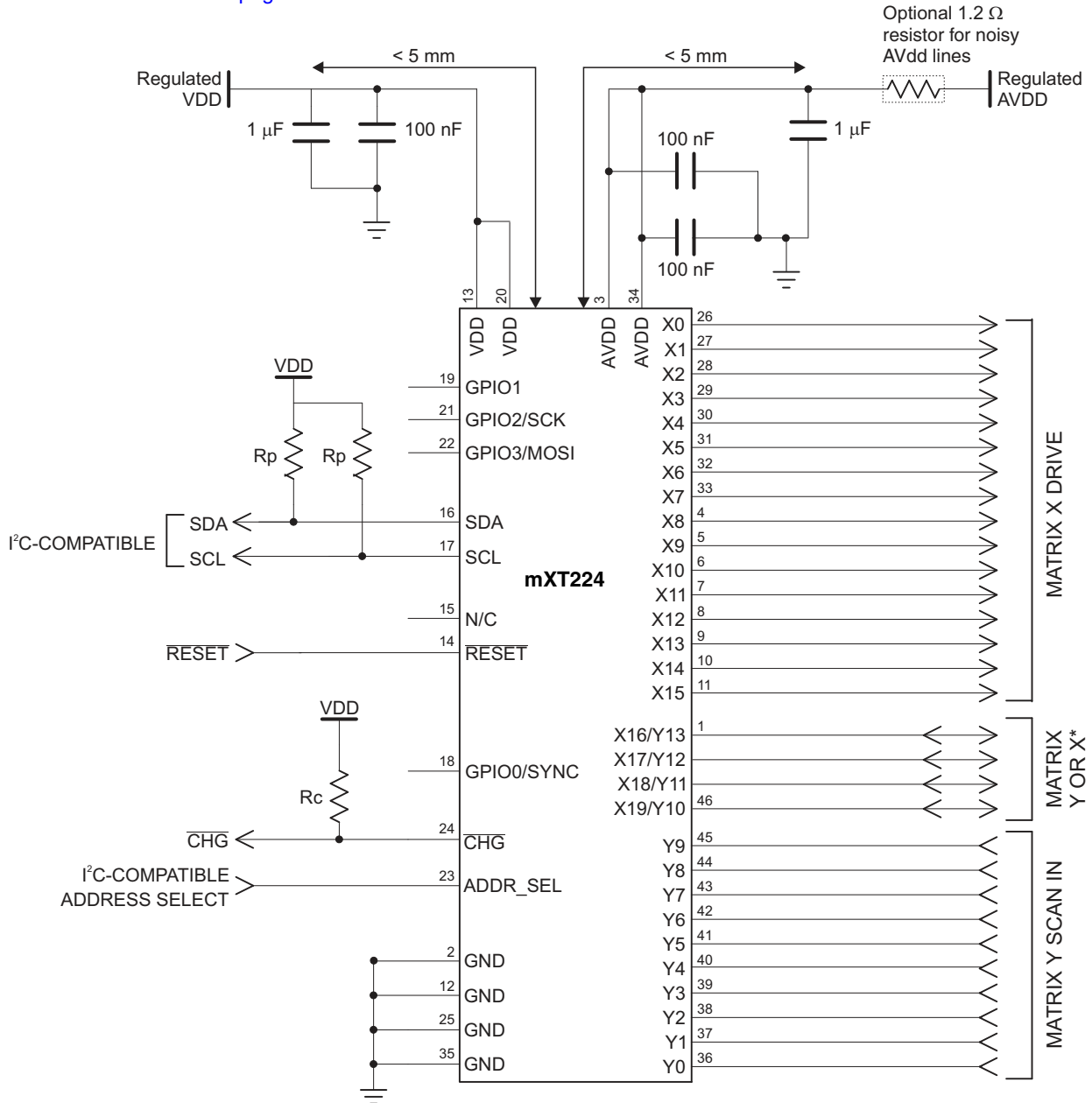
NOTE: Bypass capacitors must be X7R or X5R and placed <5 mm away from chip.
See also [Section 6.9 on page 29](#)



* NOTE: Y10 to Y13 scan lines may be used as additional X drive lines in extended mode (a 100 Ω resistor must be added to each additional line).

1.3.2 48-pin QFN

NOTE: Bypass capacitors must be X7R or X5R and placed <5 mm away from chip.
See also [Section 6.9 on page 29](#)



* NOTE: Y10 to Y13 scan lines may be used as additional X drive lines in extended mode (a 100Ω resistor must be added to each additional line).

1.3.3 Suggested Regulator Manufacturers

- Torex (XC6215 series)
- Seiko (S817 series)
- BCDSemi (AP2121 series)

2. Overview of the mXT224

2.1 Introduction

The mXT224 uses a unique charge-transfer acquisition engine to implement the QMatrix® capacitive sensing method patented by Atmel®. This allows the measurement of up to 224 mutual capacitance channels. Coupled with a state-of-the-art CPU, the entire touchscreen sensing solution can measure, classify and track a single finger touch every 4 ms if required.

The acquisition engine uses an optimal measurement approach to ensure almost complete immunity from parasitic capacitance on the receiver inputs (Y lines). The engine includes sufficient dynamic range to cope with touchscreen mutual capacitances spanning 0.5 pF to 5 pF. This allows great flexibility for use with Atmel's proprietary ITO pattern designs. One and two layer ITO sensors are possible using glass or PET substrates.

The main CPU has two powerful, yet low power, microsequencer coprocessors under its control. These combine to allow the signal acquisition, preprocessing, postprocessing and housekeeping to be partitioned in an efficient and flexible way. This gives ample scope for sensing algorithms, touch tracking or advanced shape-based filtering. An in-circuit reflash can be performed over the chip's hardware-driven two-wire interface (I²C-compatible).

The mXT224 represents a step improvement over competing technologies. It provides a near optimal mix of low power, small size and low part count with unrivalled true multitouch performance.

2.2 Understanding Unfamiliar Concepts

If some of the concepts mentioned in this datasheet are unfamiliar, see the following sections for more information:

- [Appendix A on page 37](#) for a glossary of terms
- [Appendix B on page 39](#) for QMatrix technology
- [Appendix C on page 41](#) for I²C-compatible operation

2.3 Resources

The following datasheet provides essential information on configuring the mXT224:

- *mXT224 Protocol Guide*

The following documents may also be useful (available by contacting Atmel's Touch Technology division):

- **Configuring the mXT224:**
 - Application Note QTAN0049 – *mXT224 Power and Speed Considerations*
 - Application Note: QTAN0065 – *maXTouch™ Tuning Guide*
 - Application Note: QTAN0058 – *Rejecting Unintentional Touches with the maXTouch™ Touchscreen Controllers*
 - Application Note QTAN0050 – *Using the maXTouch™ Debug Port*
 - Application Note: QTAN0059 – *Using the maXTouch™ Self Test Feature*

- **Touchscreen design and PCB/FPCB layout guidelines:**



- Application Note QTAN0054 – *Getting Started with maXTouch Touchscreen Designs*
- Application Note QTAN0048 – *maXTouch PCB/FPCB Layout Guidelines*
- Touch Sensors Design Guide (document number: 10620-AT42)
- **Bootloading:**
 - Application Note QTAN0051 – *Bootloading Procedure for Atmel® Touch Sensors Based on the Object Protocol*
- **Miscellaneous:**
 - Application Note QTAN0052 – *mXT224 Passive Stylus Support*
 - Application Note QTAN0061 – *maXTouch™ Sensitivity Effects for Mobile Devices*

3. Touchscreen Basics

3.1 Sensor Construction

A touchscreen is usually constructed from a number of transparent electrodes. These are typically on a glass or plastic substrate. They can also be made using non-transparent electrodes, such as copper or carbon. Electrodes are normally formed by etching a material called Indium Tin Oxide (ITO). This is a brittle ceramic material, of high optical clarity and varying sheet resistance. Thicker ITO yields lower levels of resistance (perhaps tens to hundreds of Ω /square) at the expense of reduced optical clarity. Lower levels of resistance are generally more compatible with capacitive sensing. Thinner ITO leads to higher levels of resistance (perhaps hundreds to thousands of Ω /square) with some of the best optical characteristics.

Long thin features, such as interconnecting tracks, formed in ITO, can cause problems. The excessive RC time constants formed between the resistance of the track and the capacitance of the electrode to ground can inhibit the capacitive sensing function. In such cases, ITO tracks should be replaced by screen printed conductive inks (non-transparent) outside the touchscreen's viewing area.

A range of trade-offs also exist with regard to the number of layers used for construction. Atmel has pioneered single-layer ITO capacitive touchscreens. For many applications these offer a near optimum cost/performance balance. With a single layer screen, the electrodes are all connected using ITO out to the edges of the sensor. From there the connection is picked up with printed silver tracks. Sometimes two overprinted silver tracking layers are used to reduce the margins between the edge of the substrate and the active area of the sensor.

Two-layer designs can have a strong technical appeal where ultra-narrow edge margins are required. They are also an advantage where the capacitive sensing function needs to have a very precise cut-off as a touch is moved to just off the active sensor area. With a two-layer design the QMatrix transmitter electrodes are normally placed nearest the bottom and the receiver electrodes nearest the top. The separation between layers can range from hundreds of nanometers to hundreds of microns, with the right electrode design and considerations of the sensing environment.

3.2 Electrode Configuration

The specific electrode designs used in Atmel's touchscreens are the subject of various patents and patent applications. Further information is available on request.

The mXT224 supports various configurations of electrodes as summarized below:

Touchscreens:	1 Touchscreen allowed 3X x 3Y minimum (depends on screen resolution) Native mode: 16X x 14Y maximum (subject to other configurations) Extended modes: 17X x 13Y, 18X x 12Y, 19X x 11Y, 20X x 10Y maximum (requires external resistors)
Keys:	Up to 32 keys allowed (subject to other configurations)
Proximity Sensors:	1 Proximity Sensor allowed occupying up to 16 channels in any configuration (subject to other configurations), 1X x 1Y minimum

3.3 Scanning Sequence

All channels are scanned in sequence by the mXT224. There is full parallelism in the scanning sequence to improve overall response time. The channels are scanned by measuring capacitive changes at the intersections formed between the first X line and all the Y lines. Then the intersections between the next X line and all the Y lines are scanned, and so on, until all X and Y combinations have been measured.

The device can be configured in various ways. It is possible to disable some channels so that they are not scanned at all. This can be used to improve overall scanning time.

3.4 Touchscreen Sensitivity

3.4.1 Adjustment

Sensitivity of touchscreens can vary across the extents of the electrode pattern due to natural differences in the parasitics of the interconnections, control chip, and so on. An important factor in the uniformity of sensitivity is the electrode design itself. It is a natural consequence of a touchscreen pattern that the edges form a discontinuity and hence tend to have a different sensitivity. The electrodes at the far edges do not have a neighboring electrode on one side and this affects the electric field distribution in that region.

A sensitivity adjustment is available for the whole touchscreen. This adjustment is a basic algorithmic threshold that defines when a channel is considered to have enough signal change to qualify as being in detect.

The mXT224 supports mixed configurations of different touch objects, each having independent threshold controls to allow fine tuning with mixed configurations.

3.4.2 Mechanical Stackup

The mechanical stackup refers to the arrangement of material layers that exist above and below a touchscreen. The arrangement of the touchscreen in relation to other parts of the mechanical stackup has an effect on the overall sensitivity of the screen. QMatrix technology has an excellent ability to operate in the presence of ground planes close to the sensor. QMatrix sensitivity is attributed more to the interaction of the electric fields between the transmitting (X) and receiving (Y) electrodes than to the surface area of these electrodes. For this reason, stray capacitance on the X or Y electrodes does not strongly reduce sensitivity.

Front panel dielectric material has a direct bearing on sensitivity. Plastic front panels are usually suitable up to about 1.5 mm, and glass up to about 3 mm (dependent upon the screen size and layout). The thicker the front panel, the lower the signal-to-noise ratio of the measured capacitive changes and hence the lower the resolution of the touchscreen. In general, glass front panels are near optimal because they conduct electric fields almost twice as easily as plastic panels.

4. Detailed Operation

4.1 Power-up/Reset

There is an internal Power-on Reset (POR) in the device. After power-up, the device takes 40 ms before it is ready to start communications. V_{DD} must drop to below 1.6V in order to effect a proper POR. See [Section 6](#) for further specifications.

The device also has a $\overline{\text{RESET}}$ pin. When this is asserted, it returns the device to its reset state. The $\overline{\text{RESET}}$ pin must be asserted low for at least 90 ns to cause a reset. After releasing the $\overline{\text{RESET}}$ pin the device takes 40 ms before it is ready to start communications. It is recommended to connect the $\overline{\text{RESET}}$ pin to a host controller to allow it to initiate a full hardware reset without requiring a power-down.

A software reset command can be used to reset the chip (refer to the Command Processor object in the *mXT224 Protocol Guide*). A software reset takes ~64 ms. After the chip has finished it asserts the $\overline{\text{CHG}}$ line to signal to the host that a message is available. The reset flag is set in the Message Processor object to indicate to the host that it has just completed a reset cycle. This bit can be used by the host to detect any unexpected brownout events. This allows the host take any necessary corrective actions, such as reconfiguration.

A checksum check is performed on the configuration settings held in the nonvolatile memory. If the checksum does not match a stored copy of the last checksum, then this indicates that the settings have become corrupted. This is signaled to the host by setting the configuration error bit in the message data for the Command Processor object (refer to the *mXT224 Protocol Guide* for more information).

4.2 Calibration

Calibration is the process by which the sensor chip assesses the background capacitance on each channel. Channels are only calibrated on power-up and when:

- The channel is enabled (that is, activated).

OR

- The channel is already enabled and one of the following applies:
 - The channel is held in detect for longer than the Touch Automatic Calibration setting (refer to the *mXT224 Protocol Guide* for more information on TCHAUTOCAL setting in the Acquisition Configuration object).
 - The signal delta on a channel is at least the touch threshold (TCHTHR) in the anti-touch direction, while no other touches are present on the channel matrix (refer to the *mXT224 Protocol Guide* for more information on the TCHTHR field in the Multiple Touch Touchscreen and Key Array objects).
 - The user issues a recalibrate command.

A status message is generated on the start and completion of a calibration.

Note that the device performs a global calibration; that is, all the channels are calibrated together.

4.3 Communications

4.3.1 Communications Protocol

The mXT224 uses an I²C-compatible interface for communication. See [Appendix C on page 41](#) for details of the I²C-compatible protocol.

The device presents data packets when internal changes have occurred. The $\overline{\text{CHG}}$ line going active signifies that a new data packet is available, thus providing an interrupt-style interface.

4.3.2 I²C-compatible Addresses

The mXT224 supports two I²C-compatible device addresses that are selected using the ADDR_SEL line at start-up. The two internal I²C-compatible device addresses are 0x4A (ADDR_SEL low) and 0x4B (ADDR_SEL high). These are shifted left to form the SLA+W or SLA+R address when transmitted over the I²C-compatible interface, as shown in [Table 4-1](#).

Table 4-1. Format of SLA+W and SLA+R

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Address: 0x4A or 0x4B							Read/write

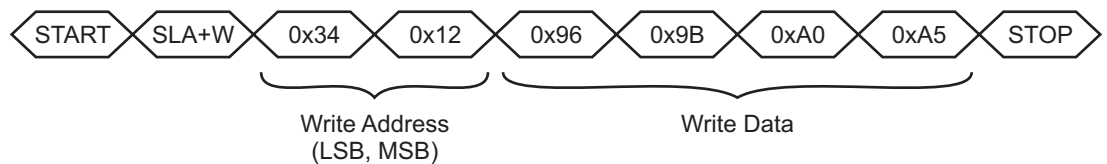
4.3.3 Writing To the Device

A WRITE cycle to the device consists of a START condition followed by the I²C-compatible address of the device (SLA+W). The next two bytes are the address of the location into which the writing starts. The first byte is the Least Significant Byte (LSByte) of the address, and the second byte is the Most Significant Byte (MSByte). This address is then stored as the address pointer.

Subsequent bytes in a multibyte transfer form the actual data. These are written to the location of the address pointer, location of the address pointer +1, location of the address pointer + 2, and so on. The address pointer returns to its starting value when the WRITE cycle's STOP condition is detected.

[Figure 4-1](#) shows an example of writing four bytes of data to contiguous addresses starting at 0x1234.

Figure 4-1. Example of a Four-byte Write Starting at Address 0x1234



4.3.4 Reading From the Device

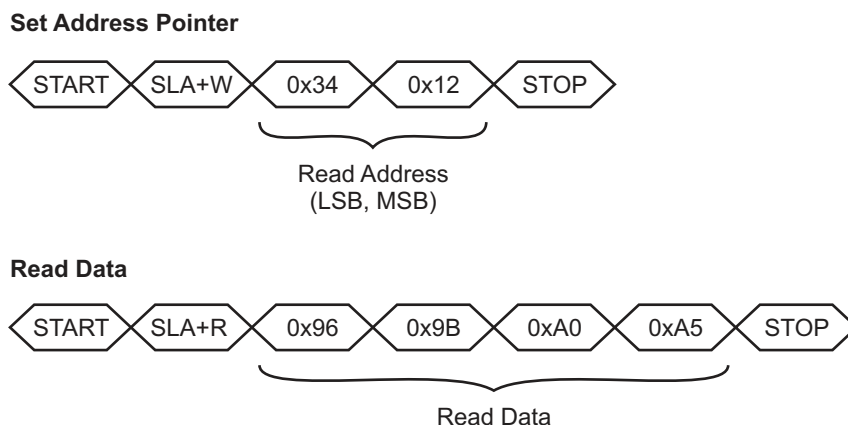
Two I²C-compatible bus activities must take place to read from the device. The first activity is an I²C-compatible write to set the address pointer (LSByte then MSByte). The second activity is the actual I²C-compatible read to receive the data. The address pointer returns to its starting value when the READ cycle's STOP condition is detected.

It is not necessary to set the address pointer before every read. The address pointer is updated automatically after every read operation. The address pointer will be correct if the reads occur in order. In particular, when reading multiple messages from the Message Processor object, the address pointer is automatically reset to allow continuous reads (see [Section 4.3.5](#)).

The WRITE and READ cycles consist of a START condition followed by the I²C-compatible address of the device (SLA+W or SLA+R respectively).

[Figure 4-2](#) shows the I²C-compatible commands to read four bytes starting at address 0x1234.

Figure 4-2. Example of a Four-byte Read Starting at Address 0x1234



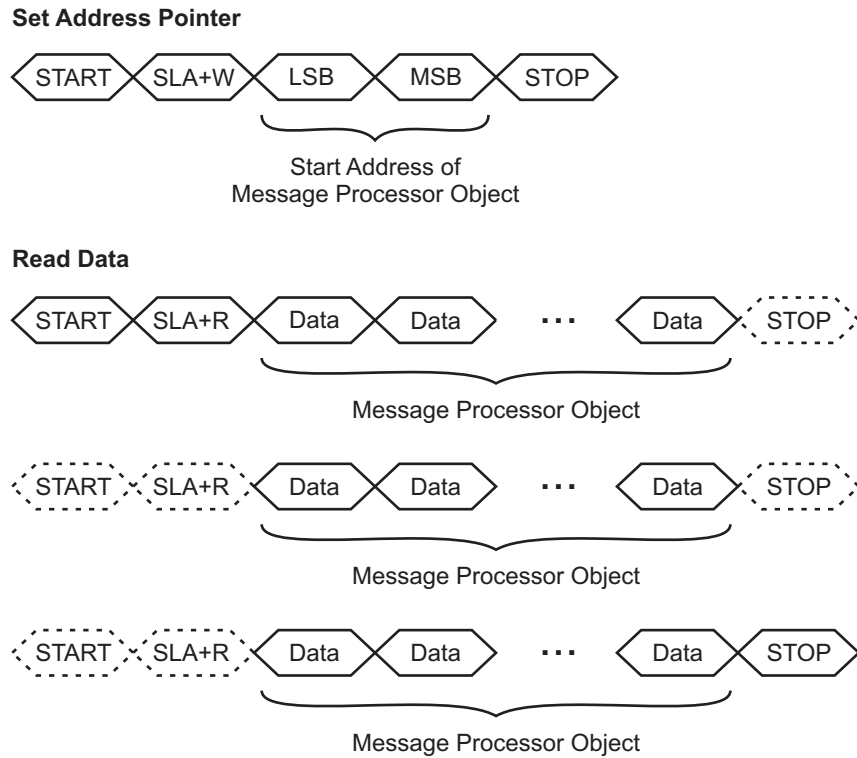
4.3.5 Reading Status Messages

Messages are stored in the device at the address of the Message Processor object. Refer to the *mXT224 Protocol Guide* for more information on how to read the Object Table to obtain the address and size of the Message Processor object.

[Figure 4-3 on page 16](#) shows how to read three messages from the device. In this case, only a single write to the address pointer is required because the address pointer is reset to its last value at the end of a multibyte read/write. If the address pointer is moved between any reads, the operation will fail. Only a single START and STOP condition is required. The START and STOP conditions between multiple reads of the Message Processor are optional and can be omitted.

If a time delay occurs between any of the reads, the message will still be read correctly.

Figure 4-3. Example of Reading the Message Processor Object



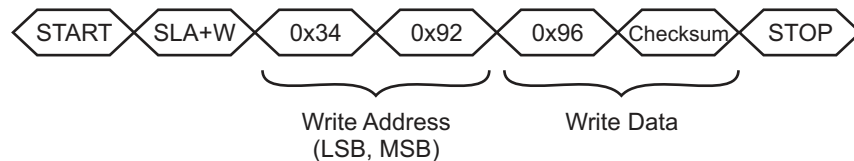
Note: Note: STOP and START conditions are not necessary between messages. The address pointer is automatically reset to the start of the Message Processor Object to allow continuous reads. Refer to the *mXT224 Protocol Guide* for more information.

4.3.6 I²C-compatible Checksum Mode

In I²C-compatible checksum mode an 8-bit CRC is added to all I²C-compatible writes. The CRC is sent at the end of the data write as the last byte before the STOP condition. All the bytes sent are included in the CRC, including the two address bytes. Any command or data sent to the device is processed even if the CRC fails.

To indicate that a checksum is to be sent in the write, the most significant bit of the MSByte of the address is set to 1. For example, the I²C-compatible command shown in [Figure 4-4](#) writes a value of 150 (0x96) to address 0x1234 with a checksum. The address is changed to 0x9234 to indicate checksum mode.

Figure 4-4. Example of a Write To Address 0x1234 With a Checksum



There are no checksums added on I²C-compatible reads except for the Message Processor object. This contains a checksum as its last byte when I²C-compatible checksum mode is enabled. To enable checksum mode, the most significant bit of the MSByte of the read address is set to 1 (refer to the *mXT224 Protocol Guide* for more information).

4.3.7 $\overline{\text{CHG}}$ Line

The $\overline{\text{CHG}}$ line is an active-low, open-drain output that is used to alert the host that a new message is available in the Message Processor object. This provides the host with an interrupt-style interface with the potential for fast response times. It reduces the need for wasteful I²C-compatible communications.

The $\overline{\text{CHG}}$ line operates in two modes, as defined by the Communications Configuration object (refer to the *mXT224 Protocol Guide*).

In Mode 0, the $\overline{\text{CHG}}$ line goes low to indicate that a message is present. It then goes high when the first message has been prepared in the output buffer and is ready to send. The STOP condition causes the $\overline{\text{CHG}}$ line to remain high if there are no more messages. Otherwise the $\overline{\text{CHG}}$ line goes low to indicate a further message. This mode allows the host to read messages until a report ID of 255 (“invalid message”) is sent. Alternatively, the host can send a STOP condition and then test the state of the $\overline{\text{CHG}}$ line.

In Mode 1, the $\overline{\text{CHG}}$ line goes low to indicate that a message is present. The $\overline{\text{CHG}}$ line remains low while there are further messages to be sent after the current message. The $\overline{\text{CHG}}$ line goes high again only once the last message has been prepared in the output buffer and is ready to be sent. In this mode the STOP condition has no effect on the $\overline{\text{CHG}}$ line state. The host can continually read the messages until the $\overline{\text{CHG}}$ line goes high.

Note that a pull-up resistor is required, typically 10 k Ω to Vdd.

4.3.8 SDA, SCL

The I²C-compatible bus transmits data and clock with SDA and SCL, respectively. These are open-drain. The I²C-compatible master and slave devices can only drive these lines low or leave them open. The termination resistors (Rp) pull the line up to Vdd if no I²C-compatible device is pulling it down.

The termination resistors commonly range from 1 k Ω to 10 k Ω . They should be chosen so that the rise times on SDA and SCL meet the I²C-compatible specifications (see [Section 6.6 on page 28](#)).

4.3.9 Clock Stretching

The mXT224 supports clock stretching in accordance with the I²C specification. It may also instigate a clock stretch if a communications event happens during a period when the mXT224 is busy internally. The maximum clock stretch is approximately 10–15 ms.

The mXT224 has an internal bus monitor that can reset the internal I²C-compatible hardware if SDA or SCL is stuck low for more than 100 – 200 ms. This means that if a clock stretch of more than 200 ms is seen by the mXT224, then any ongoing transfers with the mXT224 may be corrupted. The bus monitor is enabled or disabled using the Communications Configuration object. Refer to the *mXT224 Protocol Guide* for more information.

4.4 Operational Modes

The device operates in two modes: active (touch detected) and idle (no touches detected). Both modes operate as a series of burst cycles. Each cycle consists of a short burst (during which measurements are taken) followed by an inactive sleep period. The difference between these modes is the length of the cycles. Those in idle mode typically have longer sleep periods. The cycle length is configured using the IDLEACQINT and ACTVACQINT settings in the Power Configuration object. In addition, an Active to Idle timeout (ACTV2IDLETO) setting is provided.

Refer to the *mXT224 Protocol Guide* for full information on how these modes operate, and how to use the settings provided.

4.5 Extended Modes

The mXT224 has a total of 30 lines, which can be distributed between the X and Y lines, with limitations. In native mode these are arranged as a matrix of 16X x 14Y lines, giving 224 available channels.

In extended modes, pins Y10 – Y13 can be used as X drivers if required (see [Table 4-2](#)).

Table 4-2. Lines in Extended Modes

Y Line	Reassigned to X Line...
Y13	X16
Y12	X17
Y11	X18
Y10	X19

This allows for the permutations shown in [Table 4-3](#).

Table 4-3. Allocation of X and Y Lines

XY Matrix	Number of Channels	Highest Y Line	Mode
16X x 14Y	224	Y13	Native
17X x 13Y	221	Y12	Extended
18X x 12Y	216	Y11	
19X x 11Y	209	Y10	
20X x 10Y	200	Y9	

In extended modes, a 100Ω resistor is required in series with each extended X driver (X16, X17, X18 or X19 as applicable). The resistors should be no further than 10 mm from the chip body. They can be 0201 type or larger, 5 percent 200 ppm/°C or better.

Note that if *extended* X lines are used *solely* for keys or a proximity sensor, the series resistor should be increased. This should be no more than 1 kΩ. Some experimentation will be required to find the optimal value.

It is strongly advised to place the extended X lines at the “far end” of the touchscreen sensor; that is, at the end farthest away from the sensor’s tail connection. This means that some advantage can be gained from using the wiring resistance to act as a slew rate limiter.

4.6 Touchscreen Layout

4.6.1 Introduction

The physical matrix can be configured to have one or more touch objects. These are configured using the appropriate touch objects (Multiple Touch Touchscreen, Key Array, Proximity Sensor). It is not mandatory to have all the allowable touch objects present. Only those that you wish to use need to be enabled, as the objects are disabled by default. Refer to the *mXT224 Protocol Guide* for more information on configuring the touch objects.

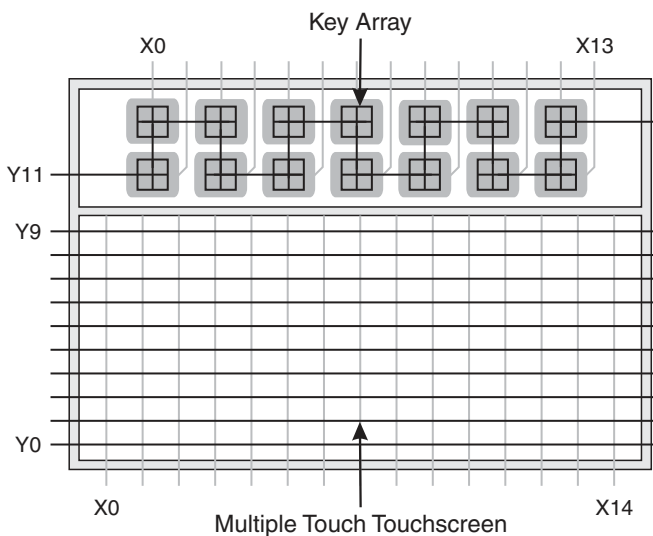
When designing the physical layout of the touch panel, obey the following rules:

- Each touch object should be a regular rectangular shape in terms of the lines it uses.
- The touch objects must not share the Y lines they use. The X lines can, however, be shared.
- The design of the touch objects does not physically need to be on a strict XY grid pattern.

4.6.2 Example Layout – A Multiple Touch Touchscreen and a Key Array

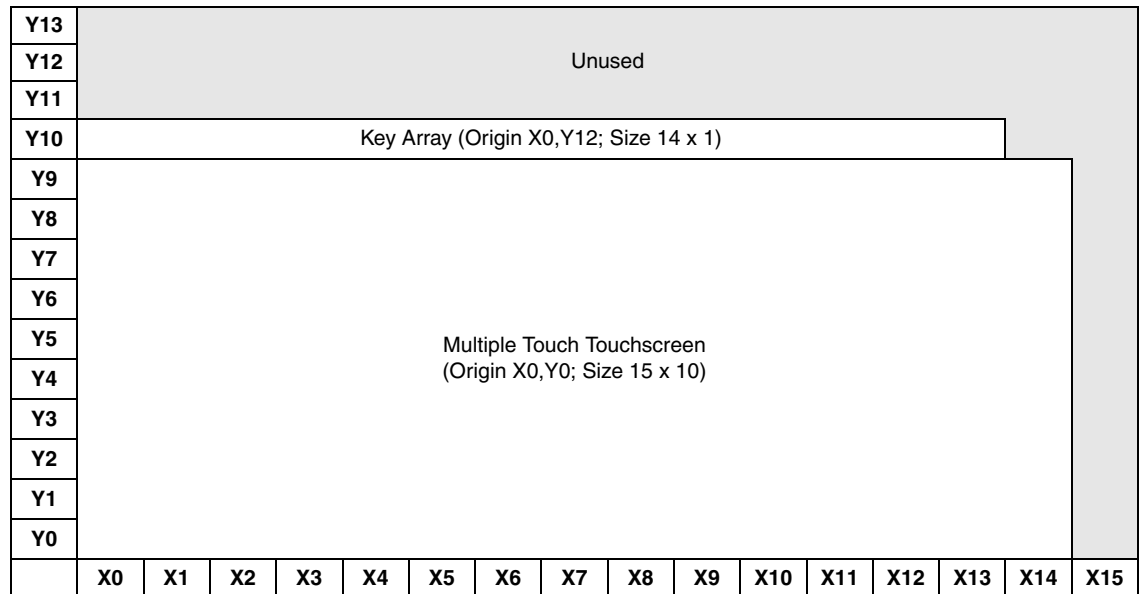
[Figure 4-5](#) shows an example layout of a Multiple Touch Touchscreen with a Key Array. Note how the touch objects do not share the same physical XY grid pattern.

Figure 4-5. Example Screen Layout (Native Mode)



The logical XY grid allocation for this layout (as configured by a Multiple Touch Touchscreen and a Key Array object) is shown in [Figure 4-6](#).

Figure 4-6. Example Touchscreen Configuration (Native Mode)



4.6.3 Example Layout – A Multiple Touch Touchscreen and a Proximity Sensor

Figure 4-7 and Figure 4-8 show an example layout of a Multiple Touch Touchscreen with a Proximity Sensor. This example uses the 18X x 12Y extended mode with Y13 and Y12 assigned to X16 and X17 respectively. Note how the proximity sensor's X and Y lines physically cover a larger area than the touchscreen, even though it logically shares X lines with the touchscreen.

Figure 4-7. Example Screen Layout (18X x 12Y Extended Mode)

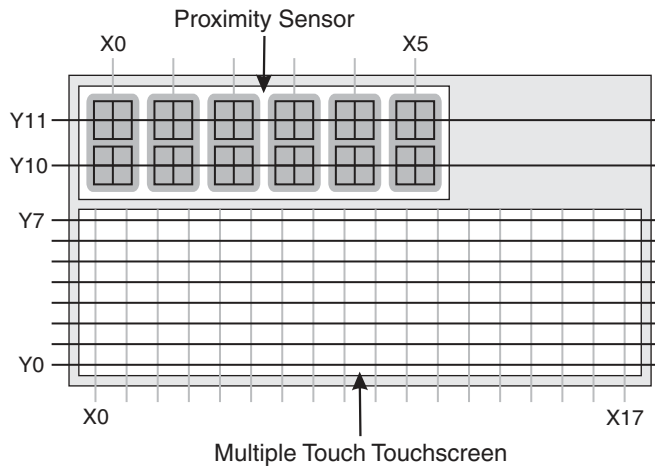


Figure 4-8. Example Touchscreen Configuration (18X x 12Y Extended Mode)

Y11	Proximity Sensor (Origin X0,Y10; Size 6 x 2)						Unused											
Y10																		
Y9																		
Y8																		
Y7	Multiple Touch Touchscreen (Origin X0,Y0; Size 18 x 8)																	
Y6																		
Y5																		
Y4																		
Y3																		
Y2																		
Y1																		
Y0																		
	X0	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17

4.7 Signal Processing

4.7.1 Adjacent Key Suppression Technology

Adjacent Key Suppression (AKS) technology is a patented method used to detect which touch object is touched when objects are located close together. A touch in a group of AKS objects is only indicated on the object in that group that is touched first. This is assumed to be the intended object. Once an object in an AKS group is in detect, there can be no further detections within that group until the object is released. Objects can be in more than one AKS group.

Note that AKS technology works best when it operates in conjunction with a detect integration setting of several acquisition cycles.

The mXT224 has two levels of AKS. The first level works between the Touchscreen and Key Array objects. The touch objects are assigned to AKS groups. If a touch occurs within one of the touch objects in a group, then touches within other objects inside that group are suppressed. For example, if a Touchscreen and Key Array are placed in the same AKS group, then a touch in the Touchscreen will suppress touches in the Key Array, and vice versa.

The second level of AKS is internal AKS within a Key Array object (note that internal AKS is not present on other touch objects). If internal AKS is enabled, then when one key is touched, touches on all the other keys within the Key Array are suppressed.

AKS is configured using the Multiple Touch Touchscreen or Key Array objects (refer to the *mXT224 Protocol Guide* for more information).

Note: If a touch is in detect and then AKS is enabled, that touch will not be forced out of detect. It will not go out of detect until the touch is released. AKS will then operate normally. This applies to both levels of AKS.

4.7.2 Detection Integrator

The device features a touch detection integration mechanism. This acts to confirm a detection in a robust fashion. A counter is incremented each time a touch has exceeded its threshold and has remained above the threshold for the current acquisition. When this counter reaches a preset limit the sensor is finally declared to be touched. If, on any acquisition, the signal is not seen to exceed the threshold level, the counter is cleared and the process has to start from the beginning.

The detection integrator is configured using the appropriate touch objects (Multiple Touch Touchscreen, Key Array, Proximity Sensor). Refer to the *mXT224 Protocol Guide* for more information. Also refer to application note QTAN0049, *mXT224 Power and Speed Considerations*, for more discussion on the touch detection integration (TCHDI) setting.

4.7.3 Digital Filtering

The mXT224 supports the on-chip filtering of the acquisition data received from the sensor. The filtering is applied to the delta values, and not to the measured signal. The filters are configured using the Noise Suppression object.

Three types of filters are supported: a Grass-cut and Accumulator Filter (GCAF), a Median Filter (MEDF) and Frequency Hopping. The GCAF rejects any samples outside preconfigured limits and then averages the remaining valid samples. The MEDF uses three sample sets: the highest and lowest sample sets are rejected, leaving the center (median) values. Frequency Hopping ensures that the sampling frequency used is not noisy.

Refer to the *mXT224 Protocol Guide* for more information on the filters and their configuration.

4.7.4 Gestures

The mXT224 supports the on-chip processing of touches so that specific gestures can be detected. These may be a one-touch gesture (such as a tap or a drag) or they may be a two-touch gesture (such as a pinch or a rotate).

Gestures are configured using the One-touch Gesture Processor and the Two-touch Gesture Processor objects. Refer to the *mXT224 Protocol Guide* for more information on gestures and their configuration.

4.7.5 Grip and Face Suppression

The mXT224 has a mechanism to suppress false detections when the user grips a handheld device or holds a mobile phone close to their face.

Grip suppression works by specifying a boundary around a touchscreen, within which touches can be suppressed whilst still allowing touches in the center of the touchscreen. This ensures that a “rolling” hand touch (such as when a user grips a mobile device) is suppressed. A “real” (finger) touch towards the center of the screen is allowed.

Maximum touch suppression works by suppressing all touches if more than a specified number of touches has been detected. This allows for the suppression of multiple touches resulting from different parts of the user’s palm.

Face suppression allows touches to be suppressed based on their size and shape. Small or narrow touches (such as from a finger) are allowed, whereas large or wide touches (such as from a face) are suppressed.

These various forms of grip and face suppression are configured using the Grip/Face Suppression object. Refer to the *mXT224 Protocol Guide* for more information.

4.8 Circuit Components

4.8.1 Bypass Capacitors

Two 100 nF bypass capacitors and one 1 μ F bypass capacitor must be used on the Vdd and supply. One 100 nF bypass capacitor and one 1 μ F bypass capacitor must be used on the AVdd supply. That is, a total of 5 ceramic X7R or X5R bypass capacitors are needed, as detailed on the schematics in [Section 1.3 on page 7](#). The PCB traces connecting the capacitors to the pins of the device must not exceed 5 mm in length. This limits any stray inductance that would reduce filtering effectiveness. See also [Section 6.9 on page 29](#).

4.8.2 PCB Cleanliness

Modern no-clean-flux is generally compatible with capacitive sensing circuits.

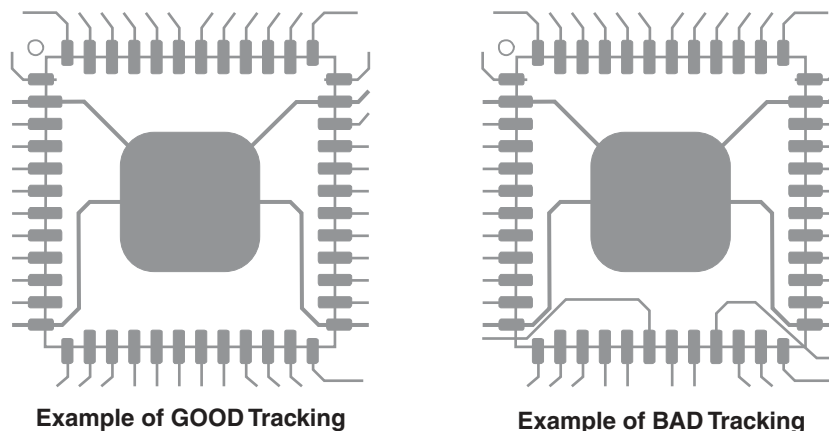


CAUTION: If a PCB is reworked to correct soldering faults relating to the mXT224, or to any associated traces or components, be sure that you fully understand the nature of the flux used during the rework process. Leakage currents from hygroscopic ionic residues can stop capacitive sensors from functioning. If you have any doubts, a thorough cleaning after rework may be the only safe option.

4.8.3 QFN Package Restrictions

The central pad on the underside of the QFN chip should be connected to ground. Do not run any tracks underneath the body of the chip, only ground. [Figure 4-9](#) shows an example of good/bad tracking.

Figure 4-9. Examples of Good and Bad Tracking



4.8.4 Supply Quality

The mXT224 has good Power Supply Rejection Ratio properties. Poorly regulated and/or noisy power can significantly reduce performance. See [Section 6.9 on page 29](#).

Always operate the mXT224 with a well-regulated and clean AVdd supply. It supplies the sensitive analog stages in the chip. Refer to QTAN0063, *maXTouch EMC Considerations*, for peak-to-peak noise requirements on this supply.

There is no separate GND return pin for the analog stages. You are advised to consider return current paths from other current consumers in the system. Try to provide a separate heavy GND return trace or flood for the mXT224 that connects at a PSU star-point or connector pin. This helps to avoid inductive transient voltages coupling into the capacitive measurements made by the chip.

Vdd is used internally to power the digital stages in the chip and is far less critical to overall performance. It is still recommended, however, that a low noise supply is used to prevent cross-talk into the analog sections.

The AVdd level used in the design must be written to the VOLTAGE field of the CTE object. Refer to the *mXT224 Protocol Guide* for more details. See also [Section 6.3.2 on page 28](#).

4.8.5 Supply Sequencing

Vdd and AVdd can be powered independently of each other without damage to the device.

Make sure that any lines connected to the device are below or equal to Vdd during power-up. For example, if $\overline{\text{RESET}}$ is supplied from a different power domain to the mXT224's Vdd pin, make sure that it is held low when Vdd is off. If this is not done, the $\overline{\text{RESET}}$ signal could parasitically couple power via the mXT224's $\overline{\text{RESET}}$ pin into the Vdd supply.

4.8.6 Oscillator

The device has an internal oscillator. No external oscillator or clock input is required.

4.9 Debugging

The mXT224 provides a mechanism for obtaining raw data for development and testing purposes by reading data from the Diagnostic Debug object. Refer to the *mXT224 Protocol Guide* for more information on this object.

A second mechanism is provided that allows the host to read the real-time raw data using the low-level debug port. Refer to QTAN0050, *Using the mXT224 Debug Port*, for more information.

There is also a Self Test object that runs self-test routines in the device to find hardware faults on the sense lines and the electrodes. Refer to the *mXT224 Protocol Guide* and QTAN0059, *Using the mXT224 Self Test Feature*, for more information.

4.10 Configuring the mXT224

The mXT224 has an object-based protocol that organizes the features of the device into objects that can be controlled individually. This is configured using the Object Protocol common to many of Atmel's touch sensor devices. For more information on the Object Protocol and its implementation on the mXT224, refer to the *mXT224 Protocol Guide*.

5. Getting Started With the mXT224

5.1 Communication with the Host

The mXT224 uses an I²C-compatible bus to communicate with the host (see [Section 4.3.1 on page 14](#)).

5.2 Establishing Contact

On power-up, the $\overline{\text{CHG}}$ line goes low to indicate that there is new data to be read from the Message Processor object. If the $\overline{\text{CHG}}$ line does not go low, there is a problem with the device.

The host should attempt to read any available messages to establish that the device is present and running following power-up or a reset. Examples of messages include reset or calibration messages. The host should also check that there are no configuration errors reported.

5.3 Using the Object Protocol

The mXT224 has an object-based protocol that is used to communicate with the device. Typical communication includes configuring the device, sending commands to the device, and receiving messages from the device. See [Section 4.10 on page 24](#) and refer also to the *mXT224 Protocol Guide*.

The host must perform the following initialization so that it can communicate with the mXT224:

1. Read the start positions of all the objects in the mXT224 from the Object Table and build up a list of these addresses.
2. Use the Object Table to calculate the report IDs so that messages from the device can be correctly interpreted.

5.4 Writing to the Device

See [Section 4.3.3 on page 14](#) for information on the format of the I²C-compatible write operation.

To communicate with the mXT224, you write to the appropriate object:

- To send a command to the device, you write the appropriate command to the Command Processor object (for example, to send a reset, backup or calibrate command). Refer to the *mXT224 Protocol Guide* for the full list of available commands.
- To configure the device, you write to an object. For example, to configure the device's power consumption you write to the global Power Configuration object, and to set up a touchscreen you write to a Multiple Touch Touchscreen object. Some objects are optional and need to be enabled before use.

Refer to the *mXT224 Protocol Guide* for more information on the objects.

5.5 Reading from the Device

See [Section 4.3.4 on page 15](#) for information on the format of the I²C-compatible read operation.

Status information is stored in the Message Processor object. This object must be read to receive any status information from the mXT224. The $\overline{\text{CHG}}$ line is asserted whenever a new message is available in the Message Processor object. This provides an interrupt-style interface. The host should always use the $\overline{\text{CHG}}$ line to be notified of messages. The host should not poll the device for messages. See [Section 4.3.7 on page 17](#) for more information on using the $\overline{\text{CHG}}$ line.

5.6 Configuring the Device

The objects are designed such that a default value of zero in their fields is a “safe” value that typically disables functionality. The objects must be configured before use and the settings written to the nonvolatile memory using the Command Processor object. Refer to the *mXT224 Protocol Guide* for more information.

The following objects must be configured before use:

- Power Configuration
 - Set up the Idle Acquisition Interval, Active Acquisition Interval and Active to Idle Timeout.
- Acquisition Configuration


The following objects should also be configured and enabled, as required:

- Touch objects: Multiple Touch Touchscreen, Key Array, Proximity Sensor
 - Enable the object.
 - Configure the origin and the number of channels it occupies. Configure the other fields in the object, as required. For example, set up the AKS group(s), specify the burst length and threshold.
 - Enable reporting to receive touch messages from the object.
- Signal processing objects: One-touch Gesture Processor, Two-touch Gesture Processor, Grip/Face Suppression, Noise Suppression
 - Enable the object.
 - Configure the fields in the object, as required.
 - Enable reporting to receive signal processing messages from the object.
- Support objects: Communications Configuration, GPIO/PWM Configuration, CTE Configuration, Self Test, User Data
 - Enable the object, if the object requires it.
 - Configure the fields in the object, as required.
 - Enable reporting, if the object supports messages, to receive messages from the object.

Refer to the *mXT224 Protocol Guide* for more information on configuring the objects.

6. Specifications

6.1 Absolute Maximum Specifications

Vdd	3.6V
AVdd	3.6V
Max continuous pin current, any control or drive pin	20 mA
Voltage forced onto any pin	-0.5V to (Vdd or AVdd)+0.5V
Configuration parameters maximum writes	10,000
 CAUTION: Stresses beyond those listed under <i>Absolute Maximum Specifications</i> may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum specification conditions for extended periods may affect device reliability.	

6.2 Recommended Operating Conditions

Operating temp	-20°C to +85°C
Storage temp	-65°C to +150°C
Vdd	1.8V ±5%
AVdd	2.7V ±5%
Vdd vs AVdd power sequencing	No sequencing required
Supply ripple + noise	See Section 6.9 on page 29
Cx transverse load capacitance per channel	0.5 pF to 5 pF
GPO current	<5 mA

6.3 DC Specifications

6.3.1 Digital Power (Vdd)

Parameter	Description	Min	Typ	Max	Units	Notes
Vdd	Operating limits	1.71		3.47	V	

Vdd = 1.8V, Ta = recommended range, unless otherwise noted

Idd	Average supply current, 80Hz, 1 touch, XSIZE=18, CHRGTIME=2 μs		0.92		mA	1.8V; see Section 6.9
	Sleep		1		μA	1.8V; see Section 6.9
Vil	Low input logic level	-0.5		0.3Vdd	V	1.8V <Vdd <3.3V
Vih	High input logic level	0.7Vdd		Vdd+0.5	V	1.8V <Vdd <3.3V
Vol	Low output voltage			0.2Vdd	V	IoL = 10 mA; 1.8V <Vdd <3.3V
Voh	High output voltage	0.8Vdd			V	IoH = -20 mA; 1.8V <Vdd <3.3V
Iil	Input leakage current		< 0.001	1	μA	
Slew rate	Minimum slew rate	1			V/100 μs	

6.3.2 Analog Power (AVdd)

Parameter	Description	Min	Typ	Max	Units	Notes
AVdd	Operating limits	2.57		3.47	V	

Note: AVdd must be stable and have a nominal tolerance in the host system of $\pm 5\%$ or better. The level configured in the VOLTAGE field of the CTE Configuration object must be within $\pm 5\%$ of the voltage applied to the device.

AVdd = 2.7V, Ta = recommended range, unless otherwise noted

Aldd	Average supply current, 80Hz, 1 touch, XSIZE = 18, CHRGTIME = 2 μ s		0.82		mA	2.7V; see Section 6.9
	Sleep		2		μ A	2.7V; see Section 6.9
Slew rate	Minimum slew rate	1			V/100 μ s	

6.4 Timing Specifications

Touches = 1, XSIZE = 18, CHRGTIME = 2 μ s

Parameter	Description	Min	Typ	Max	Units	Notes
Tlatency	80Hz	4.5	10.7	17.0	ms	Refer to application note QTAN0049 <i>mXT224 Power and Speed Considerations</i> for more information
	100Hz	4.5	9.5	14.5	ms	
	200Hz	4.5	7.0	9.5	ms	

6.5 Reset Timings

Parameter	Min	Typ	Max	Units	Notes
Power on to $\overline{\text{CHG}}$ line low		40		ms	
Hardware reset to $\overline{\text{CHG}}$ line low		40		ms	
Software reset to $\overline{\text{CHG}}$ line low		64		ms	

6.6 I²C-compatible Bus Specifications

Parameter	Operation
Addresses	0x4A or 0x4B
Maximum bus speed (SCL)	400 kHz
Hold time START condition	<600 ns (400 kHz) >4000 ns (100 kHz)
Setup time for STOP condition	<600 ns (400 kHz) >4000 ns (100 kHz)
SDA/SCL rise time	<300 ns (400 kHz) <1000 ns (100 kHz)
I ² C specification	Version 2.1

6.7 Power Consumption

Refer to application note QTAN0049, *mXT224 Power and Speed Considerations*, for more information.

6.8 Touch Accuracy and Repeatability

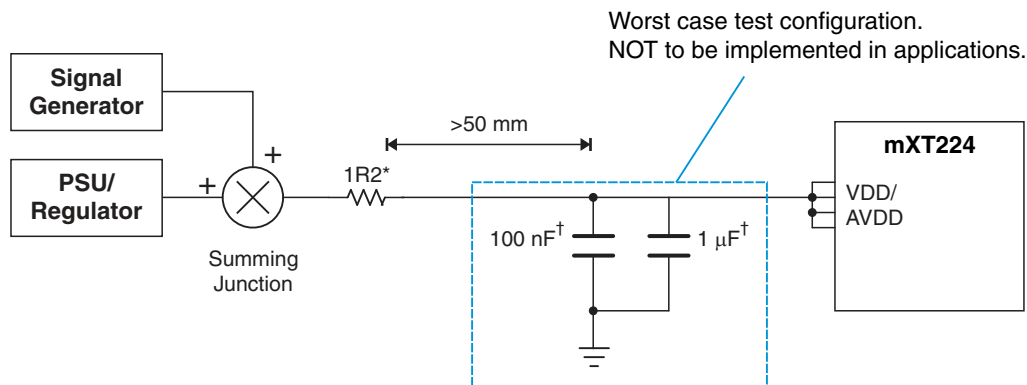
Refer to application note QTAN0064, *mXT224 Accuracy and Repeatability Considerations*, for more information.

6.9 Power Supply Ripple and Noise

See [Section 6.9.1 on page 30](#) and [Section 6.9.2 on page 31](#) for the power supply ripple and noise characterization charts.

The test circuit used for the charts is shown in [Figure 6-1](#).

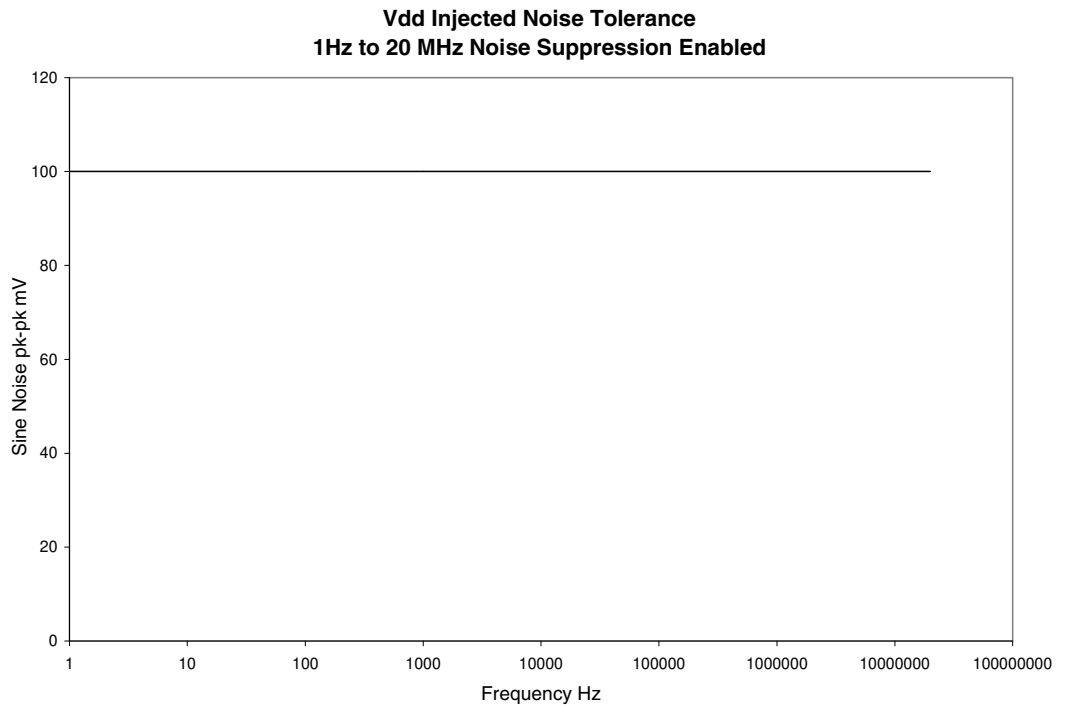
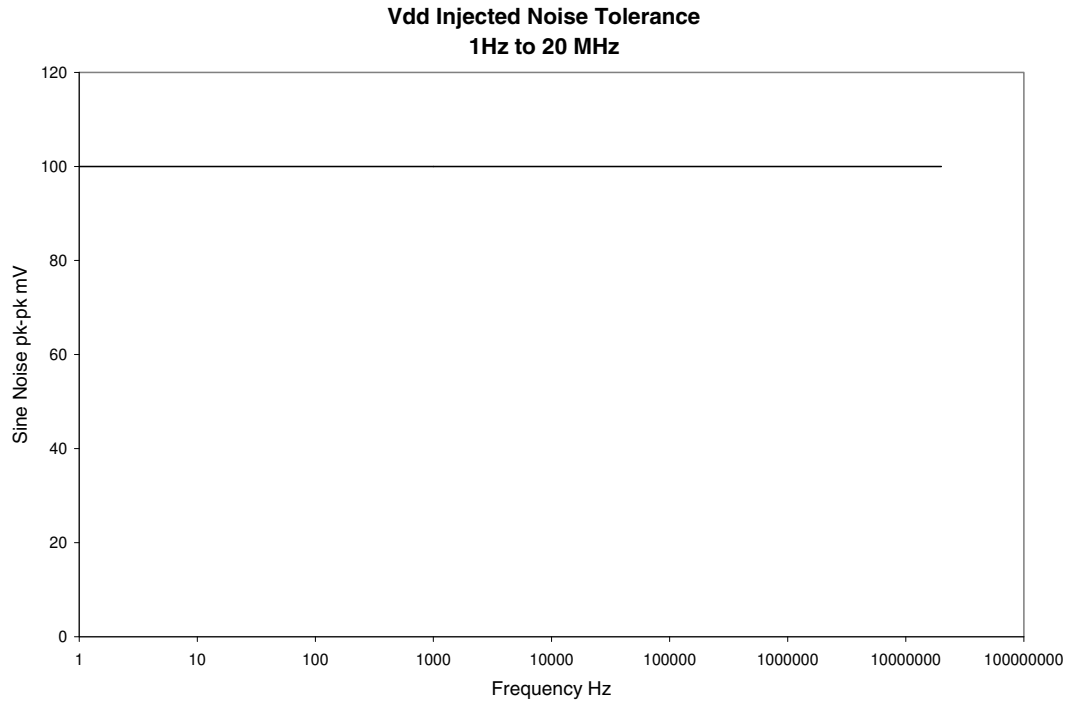
Figure 6-1. Circuit Used for Power Supply Ripple Characterization Charts



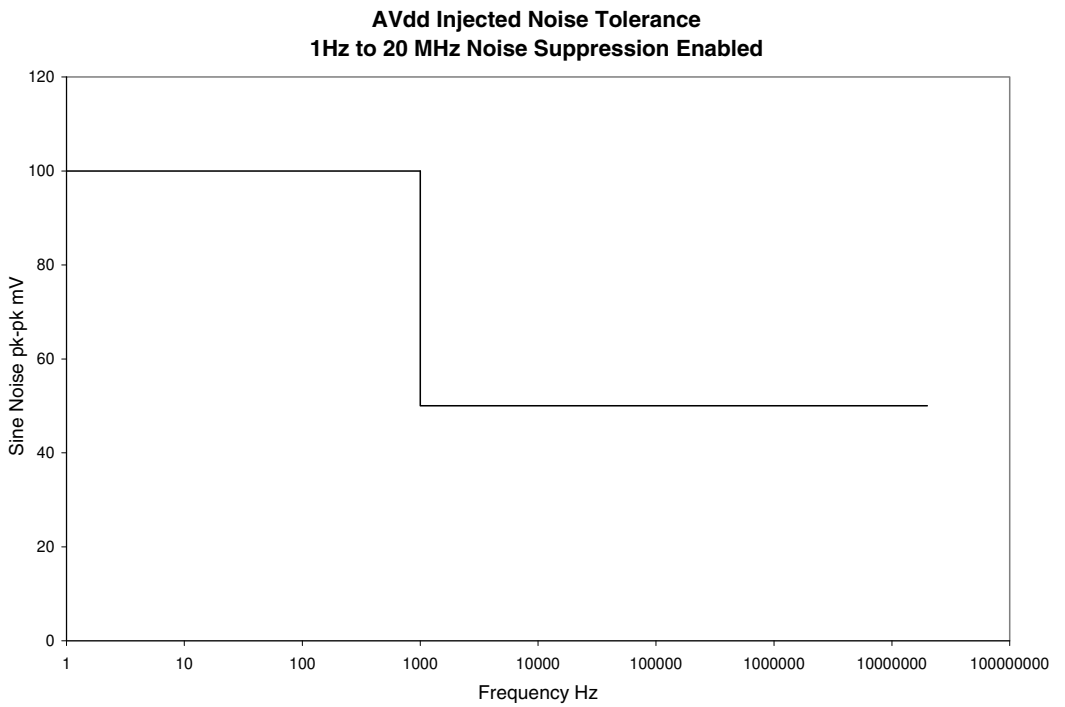
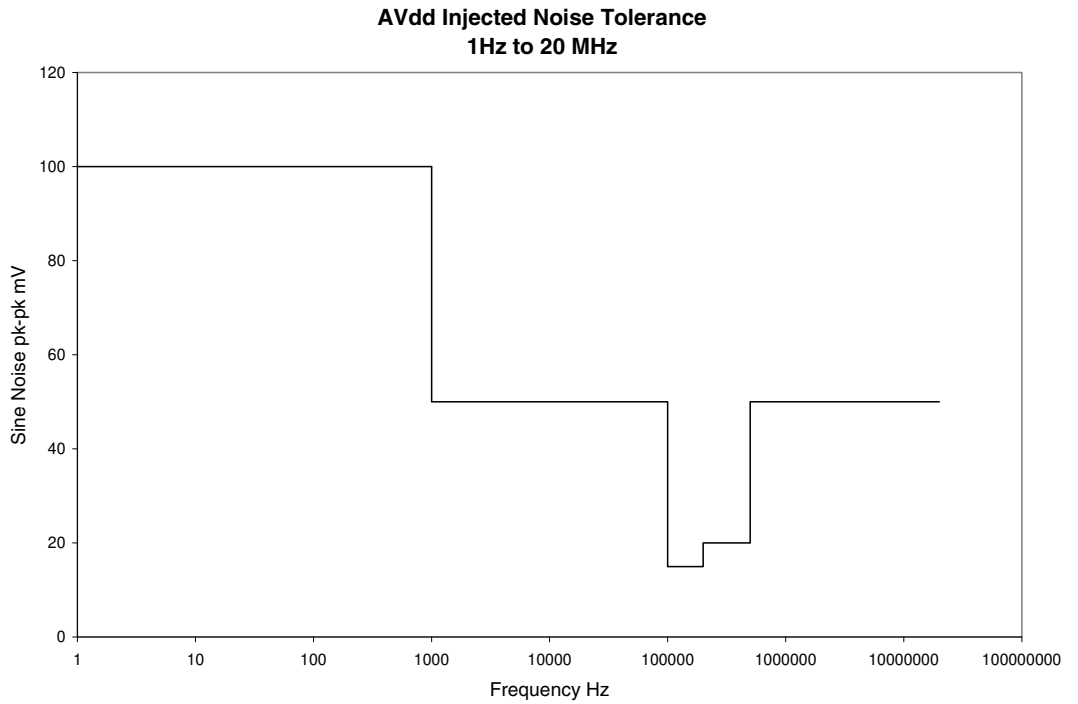
NOTES: * This series resistor models the typical impedance likely to be found due to the PSU output resistance + PCB/FPCB tracking resistances.

† Bypass capacitors are <5 mm away from the chip.

6.9.1 Digital Power (Vdd) Characterization

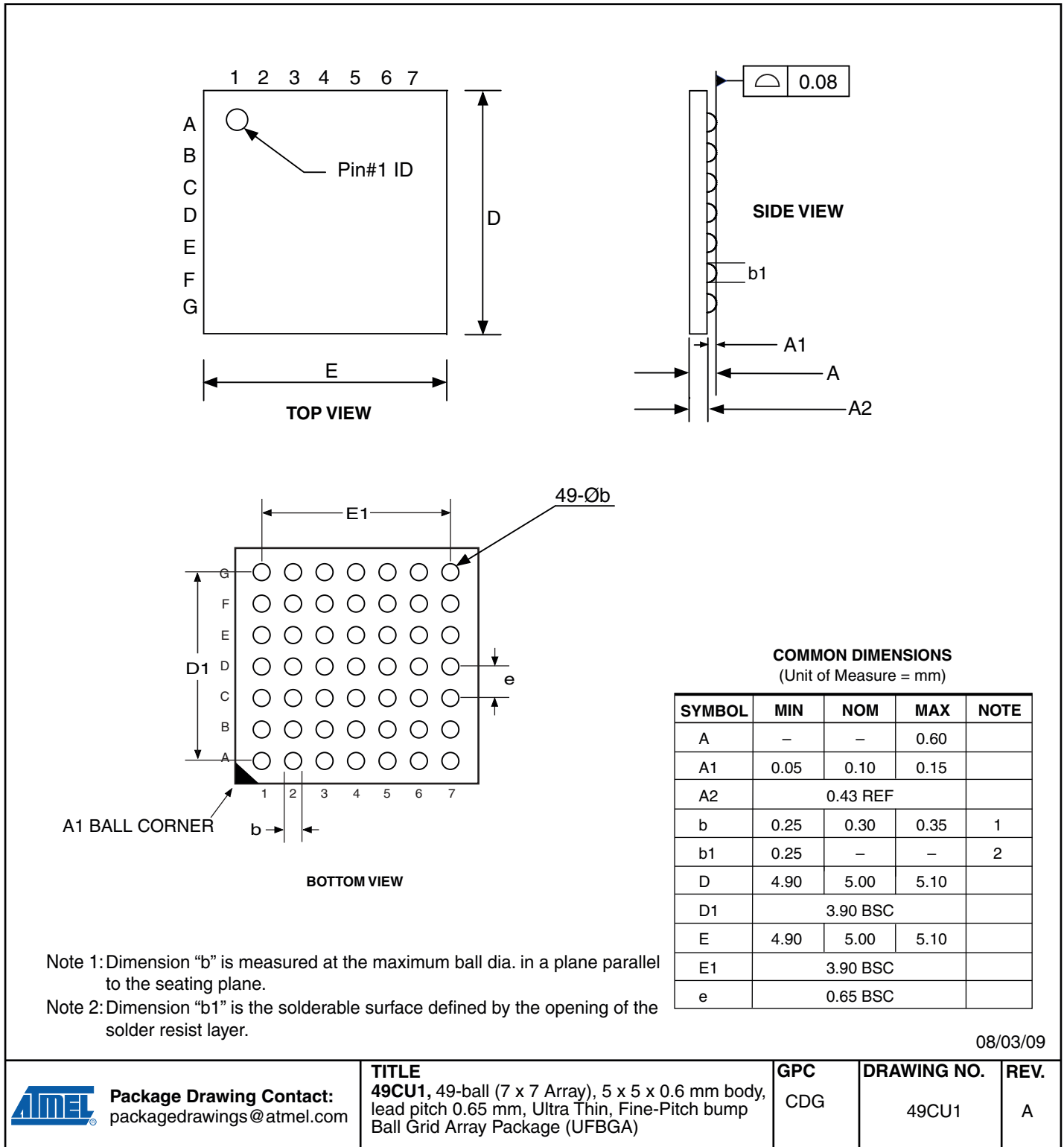


6.9.2 Analog Power (AVdd) Characterization

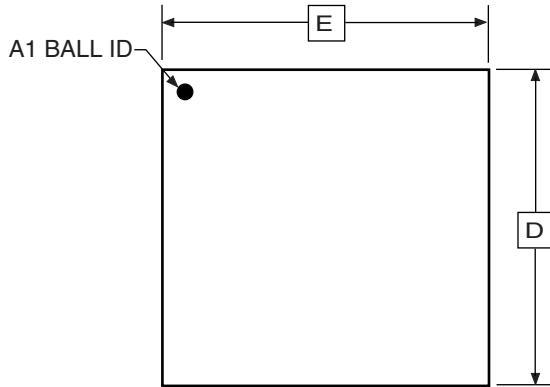


6.10 Mechanical Dimensions

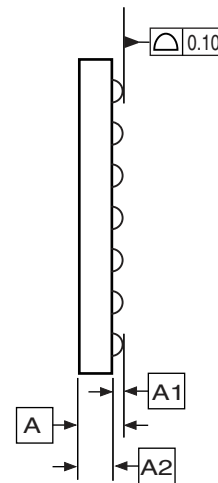
6.10.1 49-ball UFBGA (ATMXT224-CCU)



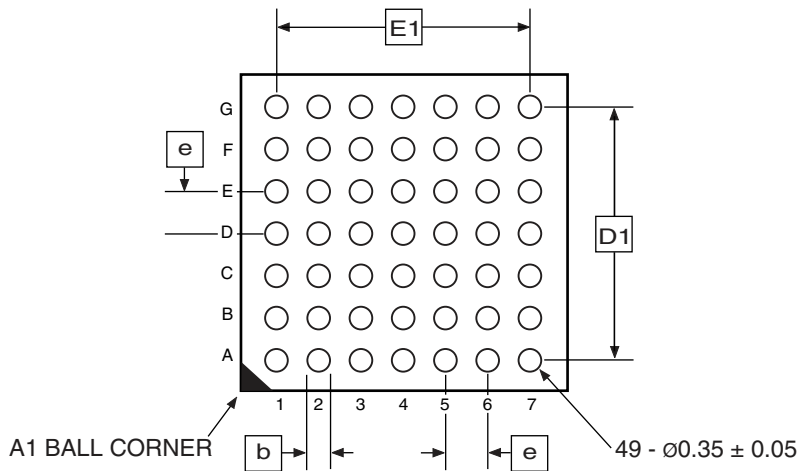
6.10.2 49-ball VFBGA (ATMXT224-CU)



TOP VIEW



SIDE VIEW



BOTTOM VIEW

COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	-	-	1.00	
A1	0.20	-	-	
A2	0.65	-	-	
D	4.90	5.00	5.10	
D1	3.90 BSC			
E	4.90	5.00	5.10	
E1	3.90 BSC			
b	0.30	0.35	0.40	
e	0.65 BSC			

3/14/08



Package Drawing Contact:
packagedrawings@atmel.com

TITLE
49C2, 49-ball (7 x 7 Array), 0.65 mm Pitch,
5.0 x 5.0 x 1.0 mm, Very Thin, Fine-Pitch
Ball Grid Array Package (VFBGA)

GPC

CBD

DRAWING NO.

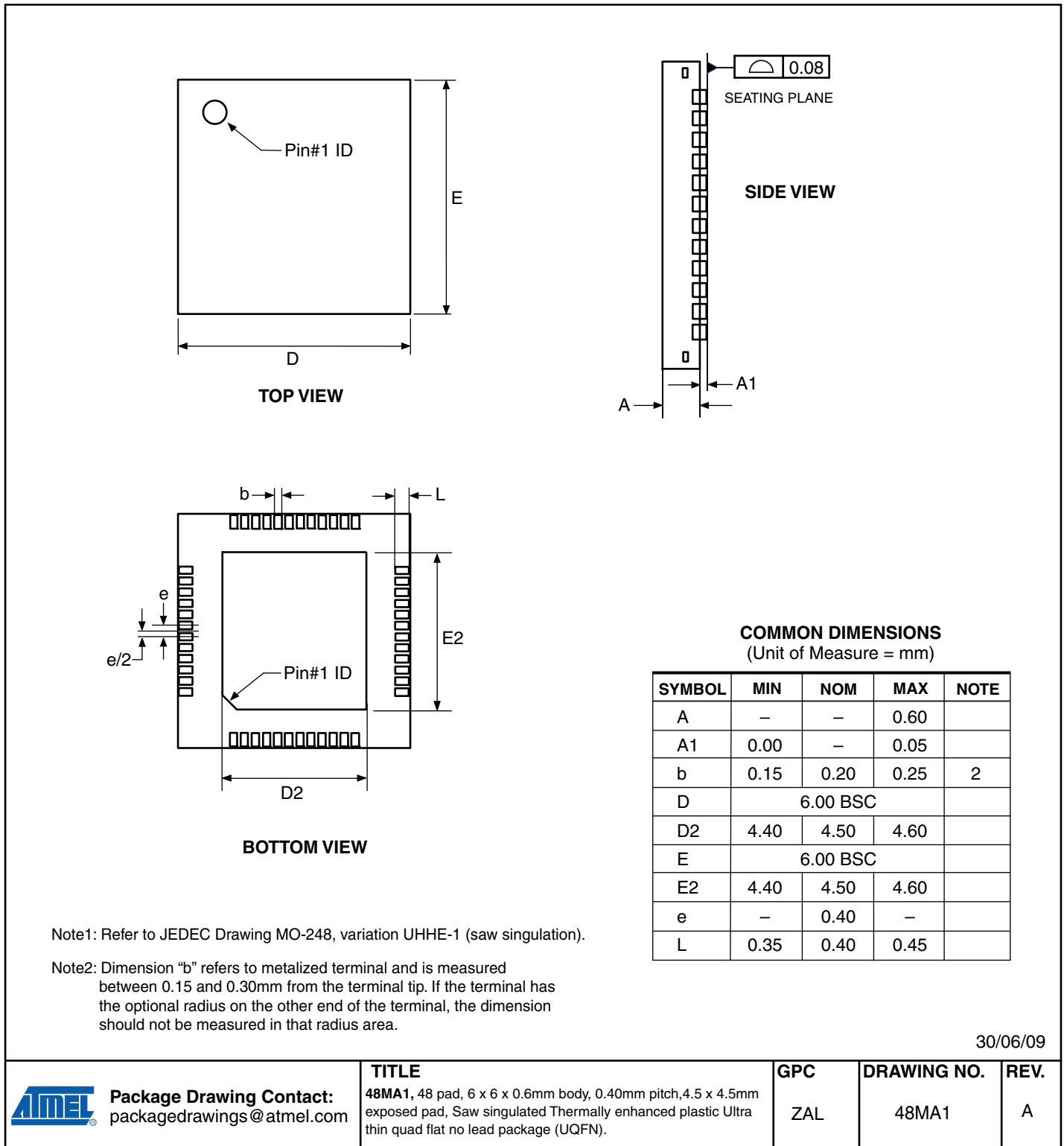
49C2

REV.

A

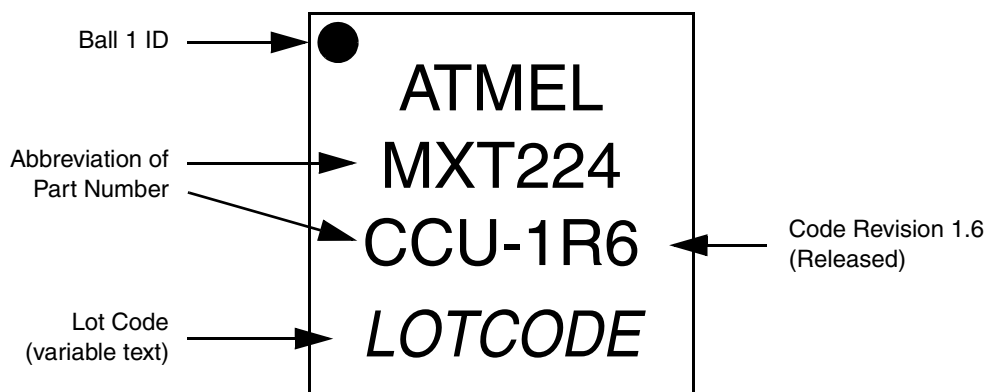


6.10.3 48-pin QFN (ATMXT224-MAH)

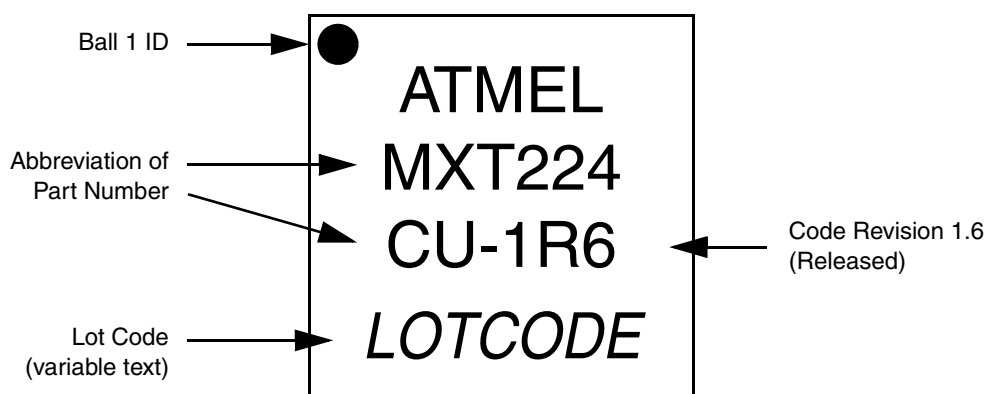


6.11 Marking

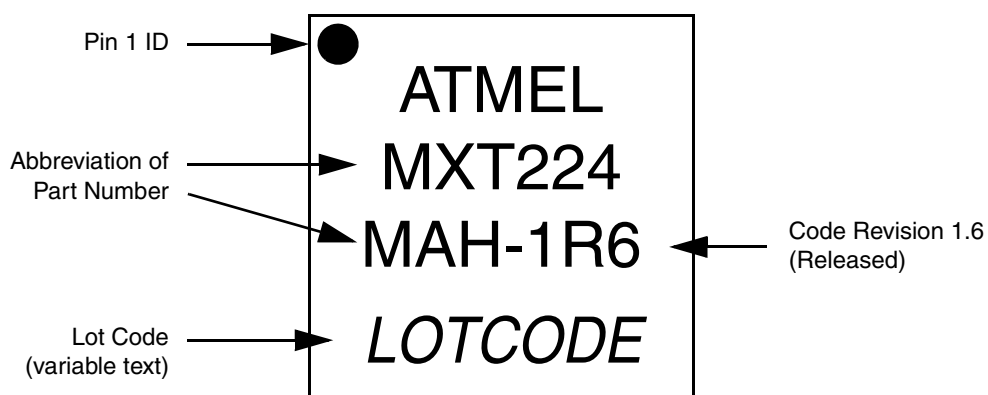
6.11.1 49-ball UFBGA (ATMXT224-CCU)



6.11.2 49-ball VFBGA (ATMXT224-CU)



6.11.3 48-pin QFN (ATMXT224-MAH)



6.12 Part Numbers

Part Number	Description
ATMXT224-CCU	49-ball 5 x 5 mm UFBGA RoHS compliant
ATMXT224-CU	49-ball 5 x 5 mm VFBGA RoHS compliant
ATMXT224-MAH	48-pin 6 x 6 mm QFN RoHS compliant

6.13 Moisture Sensitivity Level (MSL)

MSL Rating	Peak Body Temperature	Specifications
MSL3	260°C	IPC/JEDEC J-STD-020

Appendix A. Glossary of Terms

Channel

One of the capacitive measurement points at which the sensor controller can detect capacitive change.

Jitter

The peak-to-peak variance in the reported location for an axis when a fixed touch is applied. Typically jitter is random in nature and has a Gaussian⁽¹⁾ distribution, therefore measurement of peak-to-peak jitter must be conducted over some period of time, typically a few seconds. Jitter is typically measured as a percentage of the axis in question.

For example a 100 x 100 mm touchscreen that shows ± 0.5 percent jitter in X and ± 1 percent jitter in Y would show a peak deviation from the average reported coordinate of ± 0.5 mm in X and ± 1 mm in Y. Note that by defining the jitter relative to the average reported coordinate, the effects of linearity are ignored.

Linearity

The measurement of the peak-to-peak deviation of the reported touch coordinate in one axis relative to the absolute position of touch on that axis. This is often referred to as the nonlinearity. Nonlinearities in either X or Y axes manifest themselves as regions where the perceived touch motion along that axis (alone) is not reflected correctly in the reported coordinate giving the sense of moving too fast or too slow. Linearity is measured as a percentage of the axis in question.

For each axis, a plot of the true coordinate versus the reported coordinate should be a perfect straight line at 45°. A non linearity makes this plot deviate from this ideal line. It is possible to correct modest nonlinearities using on-chip linearization tables, but this correction trades linearity for resolution in regions where stronger corrections are needed (because there is a stretching or compressing effect to correct the nonlinearity, so altering the resolution in these regions). Linearity is typically measured using data that has been sufficiently filtered to remove the effects of jitter. For example, a 100 mm slider with a nonlinearity of ± 1 percent reports a position that is, at most, 1 mm away in either direction from the true position.

One-touch Gesture

A touch gesture that consists of a single touch. The combination of the duration of the touch and any change in position (that is, movement) of the touch characterizes a specific gesture. For example, a tap gesture is characterized by a short-duration touch followed by a release, and no significant movement.

1. Sometimes called Bell-shaped or Normal distribution.

Resolution

The measure of the smallest movement on a slider or touchscreen in an axis that causes a change in the reported coordinate for that axis. Resolution is normally expressed in bits and tends to refer to resolution across the whole axis in question. For example, a resolution of 10 bits can resolve a movement of 0.0977 mm on a slider 100 mm long. Jitter in the reported position degrades usable resolution.

Touchscreen

A two-dimensional arrangement of electrodes whose capacitance changes when touched, allowing the location of touch to be computed in both X and Y axes. The output from the XY computation is a pair of numbers, typically 12-bits each, ranging from 0 to 4095, representing the extents of the touchscreen active region.

Two-touch Gesture

A touch gesture that consists of two simultaneous touches. The change in position of the two touches in relation to each other characterizes a specific gesture. For example, a pinch gesture is characterized by two long-duration touches that have a decreasing distance between them (that is, they are moving closer together).

Appendix B. QMatrix Primer

B.1 Acquisition Technique

QMatrix capacitive acquisition uses a series of pulses to deposit charge into a sampling capacitor, C_s . The pulses are driven on X lines from the controller. The rising edge of the pulse causes current to flow in the mutual capacitance, C_x , formed between the X line and a neighboring receiver electrode or Y line. While one X line is being pulsed, all others are grounded. This leads to excellent isolation of the particular mutual capacitances being measured ⁽¹⁾, a feature that makes for good inherent touchscreen performance.

After a fixed number of pulses (known as the burst length) the sampling capacitor's voltage is measured to determine how much charge has accumulated. This charge is directly proportional to C_x and therefore changes if C_x ⁽²⁾ changes. The transmit-receive charge transfer process between the X lines and Y lines causes an electric field to form that loops from X to Y. The field itself emanates from X and terminates on Y. If the X and Y electrodes are fixed directly ⁽³⁾ to a dielectric material like plastic or glass, then this field tends to channel through the dielectric with very little leakage of the field out into free-space (that is, above the panel). Some proportion of the field does escape the surface of the dielectric, however, and so can be influenced during a touch.

When a finger is placed in close proximity (a few millimeters) or directly onto the dielectric's surface, some of this stray field and some of the field that would otherwise have propagated via the dielectric and terminated onto the Y electrode, is diverted into the finger and is conducted back to the controller chip via the human body rather than via the Y line.

This means that less charge is accumulated in C_s , and hence the terminal voltage present on C_s , after all the charge transfer pulses are complete, becomes less. In this way, the controller can measure changes in C_x during touch. This means that the measured capacitance C_x goes down during touch, because the coupled field is partly diverted by the touching object.

The spatial separation between the X and Y electrodes is significant to make the electric field to propagate well in relation to the thickness of the dielectric panel.

B.2 Moisture Resistance

A useful side effect of the QMatrix acquisition method is that placing a floating conductive element between the X and Y lines tends to increase the field coupling and so increases the capacitance C_x . This is the opposite change direction to normal touch, and so can be quite easily be ignored or compensated for by the controller. An example of such floating conductive elements is the water droplets caused by condensation.

As a result, QMatrix-based touchscreens tend not to go into false detect when they are covered in small non-coalesced water droplets. Once the droplets start to merge, however, they can become large enough to bridge the field across to nearby ground return paths (for example, other X lines not currently driven, or ground paths in mechanical chassis components). When this happens, the screen's behavior can become erratic.

1. A common problem with other types of capacitive acquisition technique when used for touchscreens, is that this isolation is not so pronounced. This means that when touching one region of the screen, the capacitive signals also tend to change slightly in nearby channels too, causing small but often significant errors in the reported touch position.
2. To a first approximation.
3. Air gaps in front of QMatrix sensors massively reduce this field propagation and kill sensitivity. Normal optically clear adhesives work well to attach QMatrix touchscreens to their dielectric front panel.

There are some measures used in these controllers to help with this situation, but in general there comes a point where the screen is so contaminated by moisture that false detections become inevitable. It should also be noted that uniform condensation soon becomes non-uniform once a finger has spread it around. Finger grease renders the water highly conductive, making the situation worse overall.

In general, QMatrix has industry-leading moisture tolerance but there comes a point when even the best capacitive touchscreen suffers due to moisture on the dielectric surface.

B.3 Interference Sources

B.3.1 Power Supply

See [Section 6.2 on page 27](#) for the power supply range. The device can tolerate short-term power supply fluctuations. If the power supply fluctuates slowly with temperature, the device tracks and compensates for these changes automatically with only minor changes in sensitivity. If the supply voltage drifts or shifts quickly, the drift compensation mechanism is not able to keep up, causing sensitivity anomalies or false detections.

The device itself uses the AVdd power supply as an analog reference, so the power should be very clean and come from a separate regulator. A standard inexpensive Low Dropout (LDO) type regulator should be used that is not also used to power other loads, such as LEDs, relays, or other high current devices. Load shifts on the output of the LDO can cause AVdd to fluctuate enough to cause false detection or sensitivity shifts. The digital Vdd supply is far more tolerant to noise.



CAUTION: A regulator IC shared with other logic can result in erratic operation and is not advised.

See the text underneath the schematic in [Section 1](#) for suggested regulator manufacturers.

Noise on AVdd can appear directly in the measurement results. Vdd should be checked to ensure that it stays within specification in terms of noise, across a whole range of product operating conditions.

Ceramic bypass capacitors on AVdd and Vdd, placed very close (<5 mm) to the chip are recommended. A bulk capacitor of at least 1 μF and a higher frequency capacitor of around 10 nF to 100 nF in parallel are recommended; both must be X7R dielectric capacitors.

B.3.2 LCD Drive

Switching noise from some LCDs can have a strong effect on the measurement results. Further information can be obtained on request.

B.3.3 LED Drive

LEDs and their drive circuitry can change impedance between on and off states and so present varying loads to capacitive sensors if those circuits are in close proximity. Further information can be obtained on request.

B.3.4 Other Noise Sources

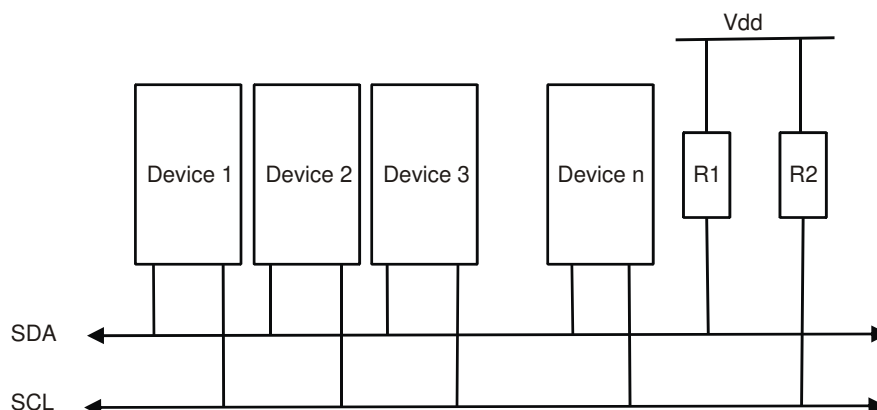
Refer to the *Touch Sensors Design Guide* (downloadable from the Touch Technology area of Atmel's website) for information.

Appendix C. I²C Basics (I²C-compatible Operation)

C.1 Interface Bus

The device communicates with the host over an I²C-compatible bus, in accordance with version 2.1 of the I²C specification. The following sections give an overview of the bus; more detailed information is available from www.i2c-bus.org. Devices are connected to the I²C-compatible bus as shown in Figure C-1. Both bus lines are connected to V_{dd} via pull-up resistors. The bus drivers of all I²C-compatible devices must be open-drain type. This implements a wired “AND” function that allows any and all devices to drive the bus, one at a time. A low level on the bus is generated when a device outputs a zero.

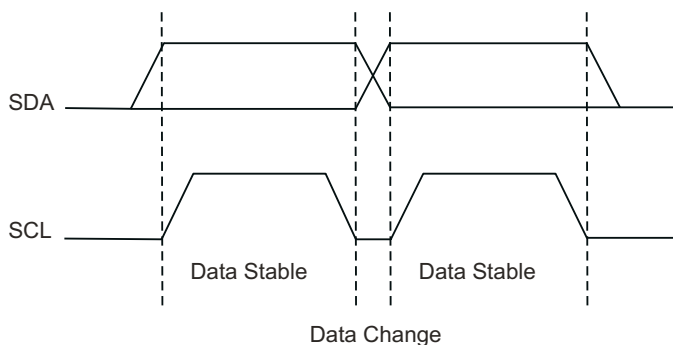
Figure C-1. I²C-compatible Interface Bus



C.2 Transferring Data Bits

Each data bit transferred on the bus is accompanied by a pulse on the clock line. The level of the data line must be stable when the clock line is high; the only exception to this rule is for generating START and STOP conditions.

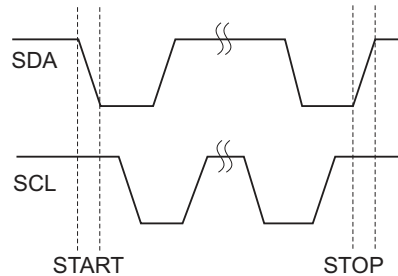
Figure C-2. Data Transfer



C.3 START and STOP Conditions

The host initiates and terminates a data transmission. The transmission is initiated when the host issues a START condition on the bus, and is terminated when the host issues a STOP condition. Between the START and STOP conditions, the bus is considered busy. As shown in [Figure C-3 on page 42](#), START and STOP conditions are signaled by changing the level of the SDA line when the SCL line is high.

Figure C-3. START and STOP Conditions

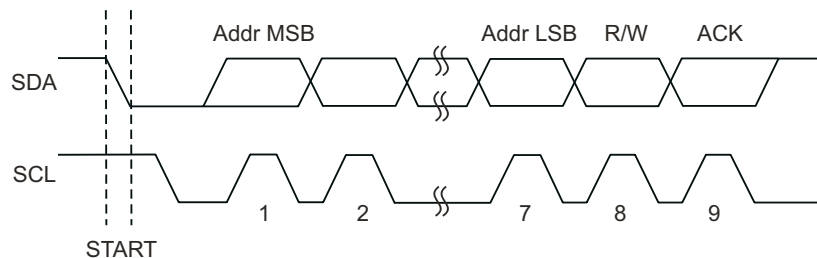


C.4 Address Byte Format

All address bytes are 9 bits long. They consist of 7 address bits, one READ/WRITE control bit and an acknowledge bit. If the READ/WRITE bit is set, a read operation is performed. Otherwise a write operation is performed. An address byte consisting of a slave address and a READ or a WRITE bit is called SLA+R or SLA+W, respectively. When the device recognizes that it is being addressed, it acknowledges by pulling SDA low in the ninth SCL (ACK) cycle.

The most significant bit of the address byte is transmitted first.

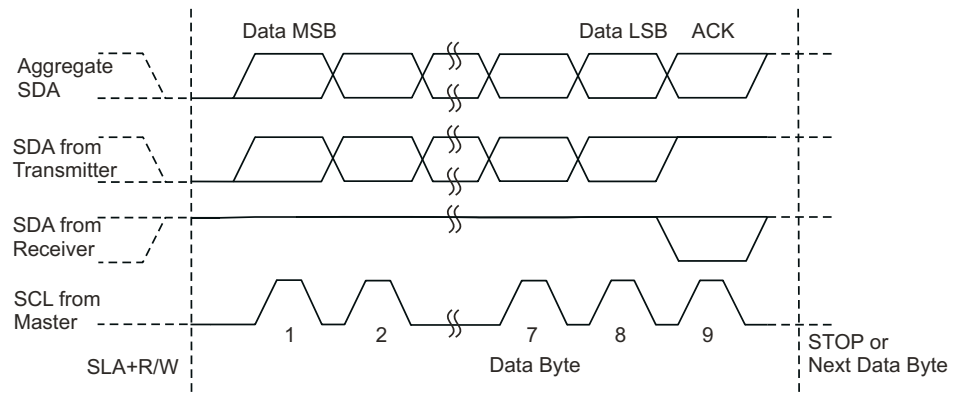
Figure C-4. Address Byte Format



C.5 Data Byte Format

All data bytes are 9 bits long, consisting of 8 data bits and an acknowledge bit. During a data transfer, the host generates the clock and the START and STOP conditions. The slave device is responsible for acknowledging the reception. An acknowledge (ACK) is signaled by the slave device pulling the SDA line low during the ninth SCL cycle. If the slave device leaves the SDA line high, a NACK is signaled.

Figure C-5. Data Byte Format

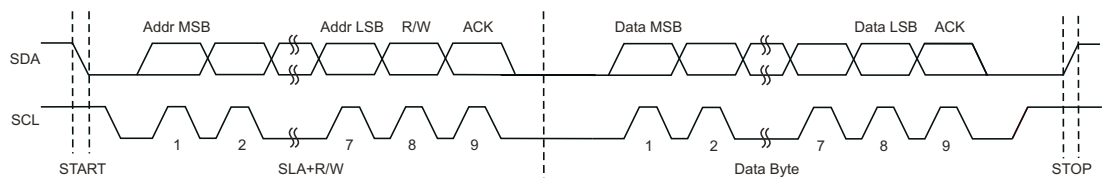


C.6 Combining Address and Data Bytes into a Transmission

A transmission consists of a START condition, an SLA+R or SLA+W, one or more data bytes and a STOP condition. The wired “ANDing” of the SCL line is used to implement handshaking between the host and the device. The device extends the SCL low period by pulling the SCL line low whenever it needs extra time for processing between the data transmissions.

Figure C-6 shows a typical data transmission. Note that several data bytes can be transmitted between the SLA+R or SLA+W and the STOP.

Figure C-6. Byte Transmission



Revision History

Revision Number	History
Revision A – February 2009	Advance information
Revision BX – May 2009	Initial release
Revision CX – June 2009	Updated for chip revision 1.1
Revision DX – July 2009	Updated for chip revision 1.2: <ul style="list-style-type: none"> • Section 4.1: Added power-up/reset timings
Revision EX – September 2009	Updated for chip revision 1.4: <ul style="list-style-type: none"> • Up to 32 keys allowed • DC specifications updated • Reset timings added to specifications • QFN package details added
Revision FX – November 2009	Updated for chip revision 1.5: <ul style="list-style-type: none"> • Updated part numbers and package markings • Section 4.3.5: I²C-compatible read operation enhanced • Updated specifications for power supply and slew rate
Revision GX – December 2009	Updated for chip revision 1.6: <ul style="list-style-type: none"> • Section 4.2: Updated description for calibration • Section 4.3.7: $\overline{\text{CHG}}$ line now operates in two modes • Section 4.8.2: Updated description for PCB cleanliness
Revision HX – May 2010	<ul style="list-style-type: none"> • Updated reset resistor values • Panel thickness revised • Minor updates to aid clarity
Revision IX – June 2010	<ul style="list-style-type: none"> • Section 1.3: Updated schematics • Section 4.8.1: Updated advice on bypass capacitors • Section 6.9: Updated test circuit

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