
MXG3141 3D Gesture Controller Data Sheet

Introduction

The MXG3141 is a companion Integrated Circuit (IC) to the mXT2912TG or mXT2113TG device, enabling cost-effective and high-performance 2D/3D capacitive touch and gesture solutions for the designer.

Microchip's MXG3141 is a 3D gesture and motion-tracking controller based on Microchip's patented GestIC® technology – suitable for consumer, industrial, and automotive applications. It enables robust user interfaces with natural hand and finger movements, utilizing the principles of electrical near-field sensing. Implemented as a low-power, mixed-signal configurable controller, the MXG3141 provides a compelling set of smart functional features, such as gesture recognition, while using adaptive working frequencies for robust performance in noisy environments. Microchip's on-chip Colibri Gesture Suite obsoletes processing needs at the host and reduces system power consumption, resulting in low software development efforts for short time to market success.

MXG3141 Applications

- Automotive Applications
- IoT
- Audio Products
- Notebooks/Keyboards/PC Peripherals
- Home Automation
- Medical Products

Power Operation Modes

- Processing mode: 31 mA, typical

Key Features

- Automotive Qualification AEC Q100 Grade 1
- Recognition of 3D Hand Gestures
- Proximity
- Built-in Colibri Gesture Suite (running on-chip)
- Advanced 3D Signal Processing Unit
- Detection Range: 0 to 10 cm, typical
- Receiver Sensitivity: <1 fF
- Channels Supported:
 - Five receive (Rx) channels
- On-chip Auto-Calibration
- Low-Noise Radiation Due to TX Signal Shaping in the Touchcontroller
- Noise Susceptibility Reduction:
 - On-Chip analog filtering

- On-Chip digital filtering
 - Automatic frequency hopping
- Enables the Use of Low-Cost Electrode Material Including:
 - Printed circuit board
 - Conductive paint
 - Conductive foil
 - Laser Direct Structuring (LDS)
 - Touch panel ITO structures
- Field Upgrade Capability
- Operating Voltage: $V_{DD} = 3.3V \pm 5\%$
- Industrial Operating Temperature Range:
 - $40^{\circ}C$ to $+85^{\circ}C$
- Extended Operating Temperature Range:
 - $40^{\circ}C$ to $+125^{\circ}C$

Peripheral Features

- I²C for Configuration and Sensor Output Streaming

Packages

Part Number	Available Package	Pins	Contact/Lead Pitch	Dimensions
MXG3141	UQFN	48	0.4	6x6x0.5

Note: All dimensions are in millimeters (mm), unless otherwise specified.

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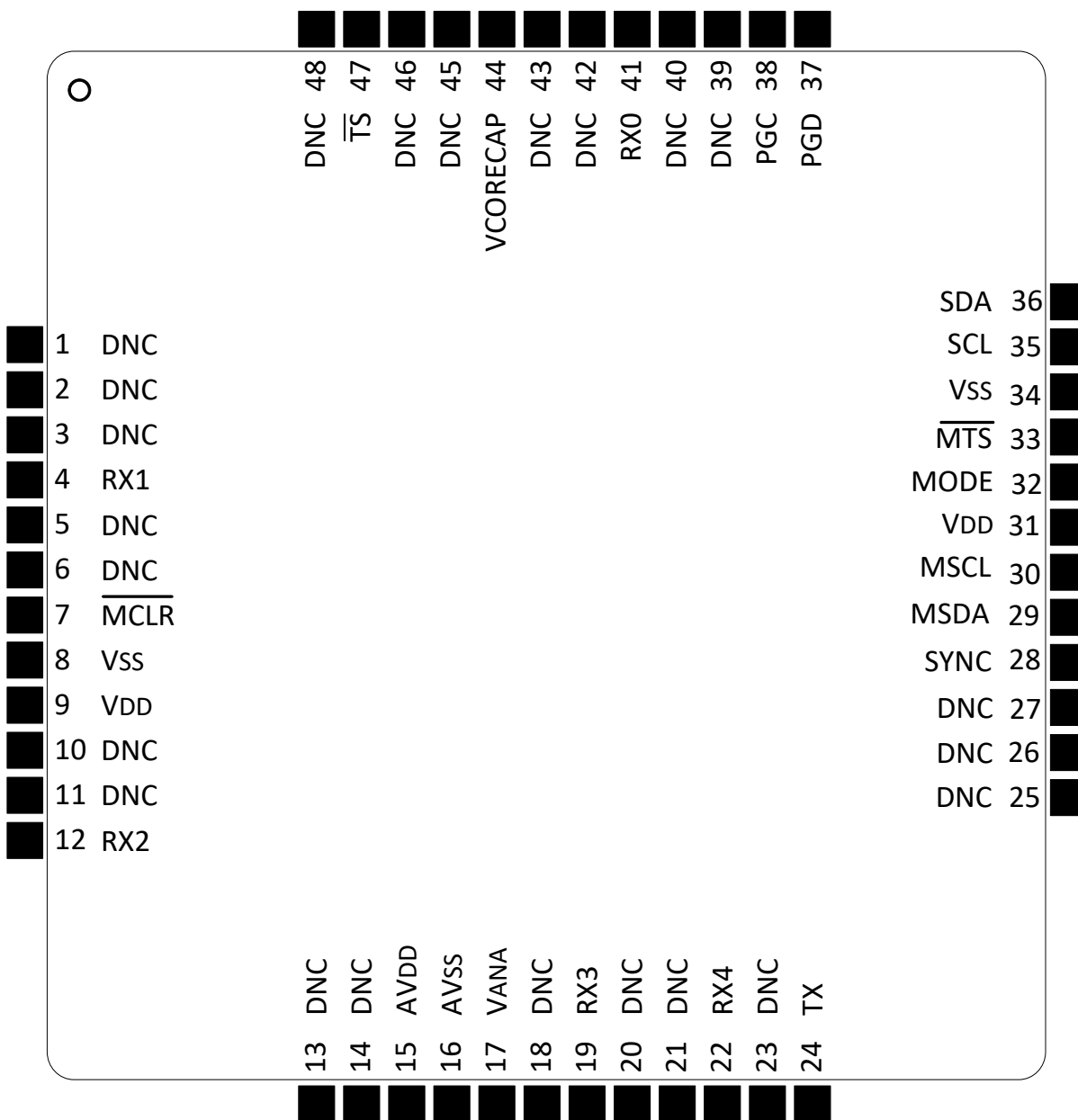
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1. Pin Diagram

1.1 48-Pin Diagram

Figure 1-1. 48-Pin Diagram UQFN



Note: Exposed pad must be connected to V_{SS}.

Related Links

[2.1 48-Pin Allocation and Pinout Description Table](#)

2. Pin Allocation Table

2.1 48-Pin Allocation and Pinout Description Table

Pin Name	Pin Number	Pin Type	Buffer Type	Description
DNC	1	—	—	Reserved. Do not connect
DNC	2	—	—	Reserved. Do not connect
DNC	3	—	—	Reserved. Do not connect
RX1	4	I	Analog	Analog GestIC® input channel 1: Receive electrode connection.
DNC	5	—	—	Reserved. Do not connect
DNC	6	—	—	Reserved. Do not connect
MCLR	7	I	ST	Master Clear (Reset) input. This pin is an active-low Reset to the device.
V _{SS}	8	P	—	Ground reference for logic and I/O pins. This pin must be connected at all times.
V _{DD}	9	P	—	Positive supply for peripheral logic and I/O pins.
IS1	10	I	ST	Reserved. Must be connected to V _{SS} .
IS2	11	I	ST	Reserved. Must be connected to V _{SS} .
RX2	12	I	Analog	Analog GestIC® input channel 2: Receive electrode connection.
DNC	13	—	—	Reserved. Do not connect
DNC	14	—	—	Reserved. Do not connect
AV _{DD}	15	P	—	Positive supply for analog modules. This pin must be connected at all times.
AV _{SS}	16	P	—	Ground reference for analog modules.
V _{ANA}	17	P	—	Positive supply for analog front end.
DNC	18	—	—	not connected
RX3	19	I	Analog	Analog GestIC® input channel 3: Receive electrode connection.
DNC	20	—	—	Reserved. Do not connect
DNC	21	—	—	Reserved. Do not connect
RX4	22	I	Analog	Analog GestIC® input channel 4: Receive electrode connection.
DNC	23	—	—	Reserved. Do not connect
TX	24	O	—	Touch Controller TX trigger signal.
DNC	25	—	—	Reserved. Do not connect
DNC	26	—	—	Reserved. Do not connect
DNC	27	—	—	Reserved. Do not connect
SYNC	28	O	—	Gesture device synchronization pulse (every 1 ms).
MSDA	29	I/O	ST	Reserved. Connect a 10 kΩ pull-up to V _{DD} .
MSCL	30	I/O	ST	Reserved. Connect a 10 kΩ pull-up to V _{DD} .
V _{DD}	31	P	—	Positive supply for peripheral logic and I/O pins.
MODE	32	I	ST	Gesture devices scan mode: High: 2D touch device measuring; Low: Gesture device measuring
MTS	33	O	—	Reserved. Connect a 10 kΩ pull-up to V _{DD} .
V _{SS}	34	P	—	Ground reference for analog modules.
SCL	35	I/O	ST	Synchronous serial Clock input/output for I ² C.
SDA	36	I/O	ST	Synchronous serial Data input/output for I ² C.
PGD	37	I/O	ST	Programming Data line, connect to test pin in application.
PGC	38	I/O	ST	Programming Clock line, connect to test pin in application.
DNC	39	—	—	Reserved. Do not connect

MXG3141

Pin Allocation Table

.....continued

Pin Name	Pin Number	Pin Type	Buffer Type	Description
DNC	40	—	—	Reserved. Do not connect
RX0	41	I	Analog	Analog GestIC® input channel 0: Receive electrode connection.
DNC	42	—	—	Reserved. Do not connect
DNC	43	—	—	Reserved. Do not connect
V _{CORECAP}	44	P	—	Capacitor for Internal Voltage Regulator.
DNC	45	—	—	Reserved. Do not connect
DNC	46	—	—	Reserved. Do not connect
TS	47	O	ST	Transfer Status. MXG3141 message ready interrupt. Connect a 10 kΩ pull-up to V _{DD} .
DNC	48	—	—	Reserved. Do not connect

Legend: Analog = Analog input, P = Power, ST = Schmitt Trigger input with CMOS levels, I/O = Input/Output, — = N/A



Important: Exposed pad must be connected to V_{SS}.

3. Theory of Operation: Electrical Near-Field (E-Field) Sensing

Microchip's GestIC technology is a 3D sensor technology that utilizes an electric field (E-field) for advanced proximity sensing. It allows realization of new user interface applications by detection, tracking and classification of a user's hand gestures in free space.

E-fields are generated by electrical charges and propagate three-dimensionally around the surface, carrying the electrical charge.

Applying direct voltages (DC) to an electrode results in a constant electric field. Applying alternating voltages (AC) makes the charges vary over time and the field. When the charge varies sinusoidally with frequency 'f', the resulting electromagnetic wave is characterized by wavelength $\lambda = c/f$, where 'c' is the wave propagation velocity — in vacuum, the speed of light. In cases where the wavelength is much larger than the electrode geometry, the magnetic component is practically zero and no wave propagation takes place. The result is quasi-static electrical near field that can be used for sensing conductive objects such as the human body.

Microchip's GestIC technology uses transmit (Tx) frequencies in the range of 100 kHz, which reflects a wavelength of about three kilometers. With electrode geometries of typically less than fourteen by fourteen centimeters, this wavelength is much larger in comparison. GestIC systems work without wave propagation.

In case a person's hand or finger intrudes in the electrical field, the field becomes distorted. The field lines are drawn to the hand due to the conductivity of the human body itself and shunted to ground. The three-dimensional electric field decreases locally. Microchip's GestIC technology uses a minimum number of four receiver (Rx) electrodes to detect the E-field variations at different positions to measure the origin of the electric field distortion from the varying signals received. The information is used to track movements and to classify movement patterns (gestures).

The two following figures show the influence of an earth-grounded body to the electric field. The proximity of the body causes a compression of the equipotential lines and shifts the Rx electrode signal levels to a lower potential that is measured.

Figure 3-1. Equipotential Lines of an Undistorted E-Field

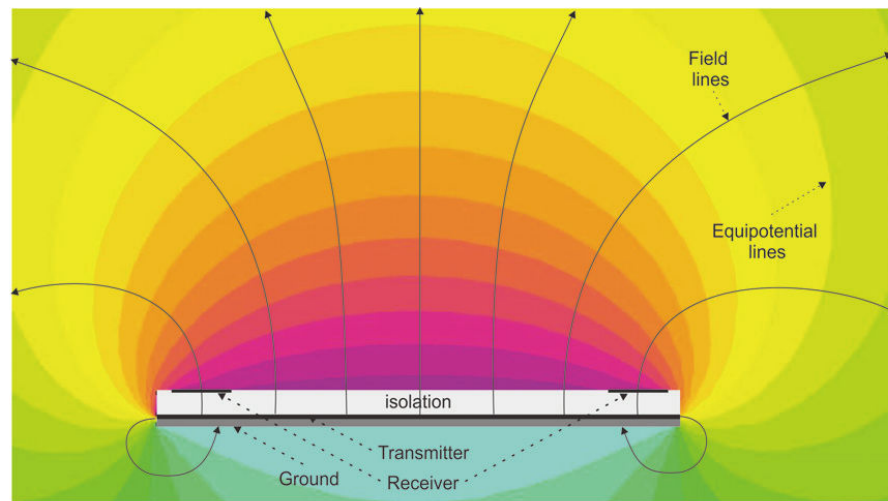
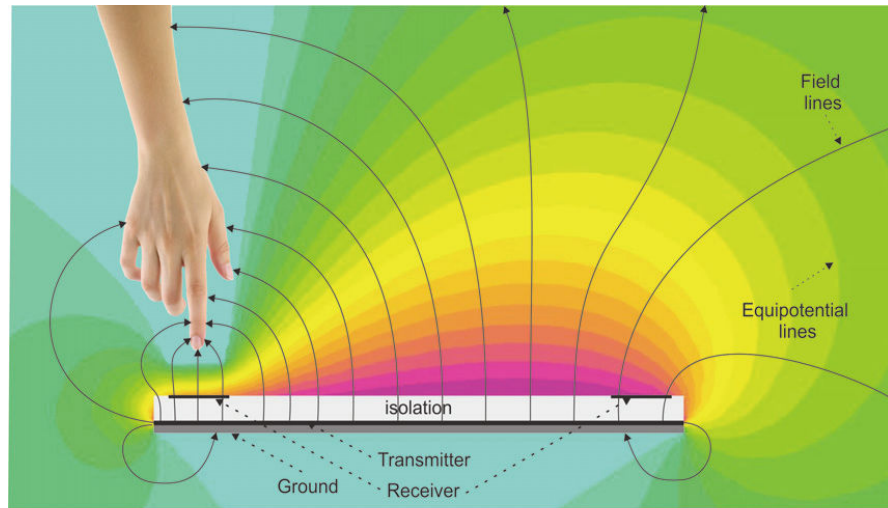


Figure 3-2. Equipotential Lines of a Distorted E-Field



3.1 GestIC® Technology Benefits

- GestIC E-field sensors are not impacted by ambient influences such as light or sound since these have a negative impact on the majority of 3D technologies.
- GestIC technology allows gesture processing on-chip – no host processing needed. Algorithms are included in the Colibri Gesture Suite, which runs on-chip and is provided by Microchip.
- The GestIC technology has a high immunity to noise, provides high update rates and resolution, low latency, and is also not affected by clothing, surface texture or reflectivity.
- A carrier frequency in the range of 40-100 kHz is utilized by the GestIC with minimal impact on the regulated radio frequency range.
- Usage of thin low-cost materials such as electrodes allow low system cost at slim industrial designs.
- The further use of existing capacitive sensor structures such as a touch panel's Indium tin oxide (ITO) coating allow additional cost savings and ease the integration of the technology.
- Electrodes are invisible to the user's eye since they are implemented underneath the housing surface or integrated into a touch panel's ITO structure.
- GestIC works centrally over the full sensing space. Thus, it provides full surface coverage without any detection blind spots.
- mXT2912TG/mXT2113TG drive the transmitter electrodes for E-field generation. The benefit is an overall low-power system and optimized radiated EMC emissions.
- Since GestIC is basically processing raw electrode signals and computes them in real time into preprocessed gestures, it provides a highly-flexible user interface technology for any kind of electronic devices.

4. Feature Description

4.1 GestIC Library

MXG3141 is provided with a GestIC Library loader (bootloader) that is stored on the chip's Flash memory. Activating this loader, a GestIC Library can be flashed on the MXG3141 via I²C using, for example, an embedded host controller or Microchip's programmer utility. The GestIC Library includes:

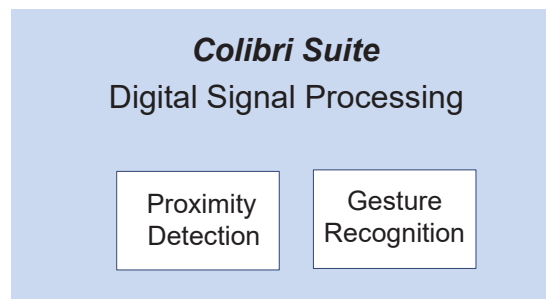
- Colibri Suite: Digital Signal Processing (DSP) algorithms and feature implementations
- System Control: MXG3141 hardware control

4.1.1 Colibri Suite

The Colibri Suite combines data acquisition, digital signal processing, and interpretation.

The Colibri Suite functional features are illustrated below and described in the following sections.

Figure 4-1. Colibri Suite Core Elements



4.1.1.1 Gesture Recognition

The Colibri Suite's gesture recognition model detects and classifies hand movement patterns performed inside the sensing area.

Using advanced stochastic classification based on Hidden Markov Model (HMM), industry best gesture recognition rate is achieved.

Flick Gestures

Figure 4-2. Flick Gestures



A flick gesture is a unidirectional gesture in a quick flicking motion. An example may be a hand movement from West to East within the sensing area, from South to North, etc.

Hold and Presence Gestures

Detection of a hand within a configurable detection area. After the hand is detected as being present in this area, a timer will be started. If the hand stays within the detection area until a certain timer value is reached, the Presence gesture is detected. The timer value is configurable. The Presence gesture is typically used for lighting up back-lights, as if the hand is in the detection area and does not move; a second timer is started.

Presence and Hold gestures are triggered upon a timeout in a defined status flag. If a Status flag is active during a certain amount of time, after its last rising edge, the corresponding gesture is triggered.

The status flags that can trigger one of these gestures are:

- **Hand Presence** flag is active while the user's hand is in the sensing space
- **Hand Inside** flag is active while the user's hand is in the sensing space approximately centered above the sensor
- **Hand Hold** flag is active while the hand is not moving and one of the above status flags is active; the selection depends on ActiveOutside.

The behavior of the status flags and corresponding gestures can be adjusted to suit a specific application.

The Gesture and Presence/Hold State visualization windows offer immediate feedback upon adjustment.

The adjustable parameters are:

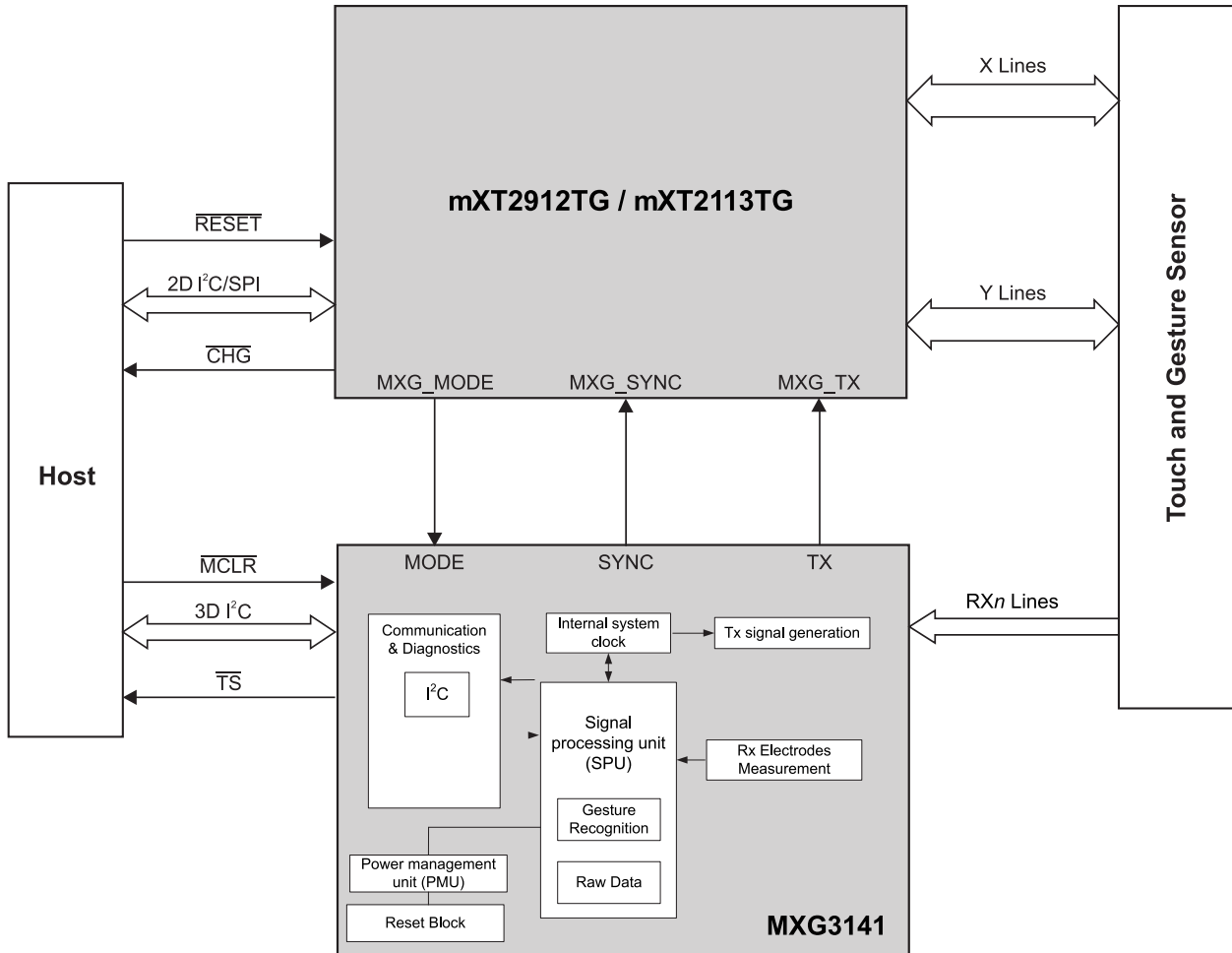
1. **ActiveOutside**
 - Chooses if Hand Hold flag and Presence gesture can be active when the user is outside the sensor, but still in sensing space.
 - ActiveOutside checked (default) means that Hand Presence is required to set Hand Hold and that Presence Duration starts counting on the rising edge of Hand Presence status flag.
 - ActiveOutside unchecked means that Hand Inside is required to set Hand Hold and that Presence Duration starts counting on the rising edge of Hand Inside status flag.
2. **Presence Duration**
 - This is the time during which the selected status flag must be active to trigger a Presence gesture. This time starts counting on the last rising edge of the selected status flag. The gesture is only triggered once for each rising edge of the flag.
3. **Hold Duration**
 - This is the time during which the Holding Hand flag must be active to trigger a Hold gesture. This time starts counting on the last rising edge of the Holding Hand flag. The gesture is only triggered once for each rising edge of the flag.
4. **Hold Tremble Threshold**
 - This value specifies how much the hand can move and still be considered as holding. For high values, the hand can move while the Hand Hold flag is still high. For low values, only a slight movement is necessary to clear the Hand Hold flag.

5. System Architecture

MXG3141 is a mixed-signal configurable controller. The entire system solution is composed of the following main building blocks (see diagram below):

- MXG3141 Controller
- GestIC® Library
- External Electrodes
- mXT2912TG/mXT2113TG Host Controller

Figure 5-1. mXT2912TG / mXT2113TG + MXG3141 Controller System Architecture



5.1 MXG3141 Controller

The MXG3141 features the following main building blocks:

- Low-Noise Analog Front End (AFE)
- Digital Signal Processing Unit (SPU)
- Communication Interfaces

The host mXT2912TG/mXT2113TG device provides the transmit signal to generate the E-field. MXG3141 conditions the analog signals from the receiving electrodes and processes these data digitally on the SPU.

Related Links

[6. Functional Description](#)

5.2 GestIC® Library

The embedded GestIC Library is optimized to ensure continuous and Real-Time Free-Space gesture recognition and motion tracking concurrently. It is fully-configurable and allows required parametrization for individual application and external electrodes.

5.3 External Rx Electrodes

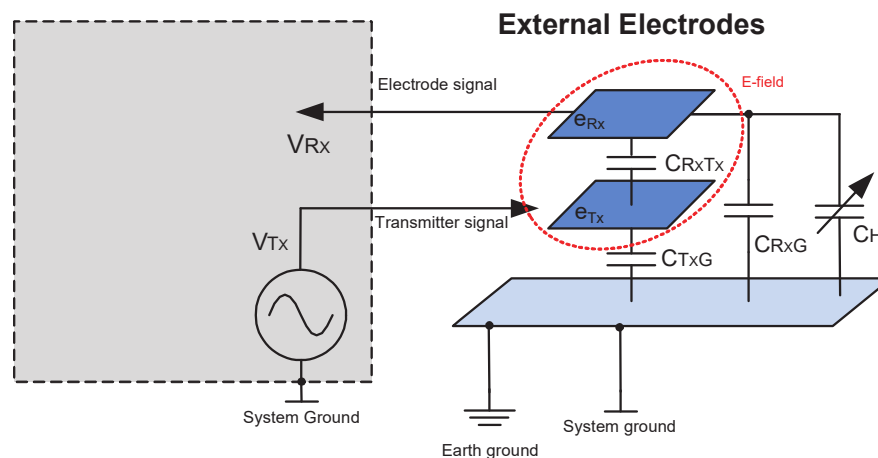
Rx electrodes are connected to the MXG3141. An electrode needs to be individually designed following the guide lines from AN2574, “2D3D Electrode Design Guide” (DS00002574), for optimal E-field distribution and detection of E-field variations created by a user.

5.3.1 Electrode Equivalent Circuit

The gesture recognition capabilities of a GestIC system depend on the electrode design and their material characteristics.

A simplified equivalent circuit model of a generic GestIC electrode system is illustrated in the following figure:

Figure 5-2. Electrodes Capacitive Equivalent Circuitry Earth Grounded



V_{Tx} Tx electrode voltage

V_{Rx} MXG3141 Rx input voltage

C_H Capacitance between receive electrode and hand (earth ground). The user's hand can always be considered as earth-grounded due to the comparable large size of the human body.

C_{RxTx} Capacitance between receive and transmit electrodes

C_{RxG} Capacitance of the receive (Rx) electrode to system ground + input capacitance of the MXG3141 receiver circuit

C_{TxG} Capacitance of the transmit (Tx) electrode to system ground

e_{Rx} Rx electrode

e_{Tx} Tx electrode

The Rx and Tx electrodes in a GestIC electrode system build a capacitance voltage divider with the capacitances C_{RxTx} and C_{RxG} which are determined by the electrode design. C_{TxG} represents the Tx electrode capacitance to system ground driven by the Tx signal. The Rx electrode measures the potential of the generated E-field. If a conductive object (e.g., a hand) approaches the Rx electrode, C_H changes its capacitance. This minuscule change

in the femtofarad range is detected by the MXG3141 receiver. The equivalent circuit formula for the earth-grounded circuitry is described in the following equation:

Equation 5-1. Electrodes Equivalent Circuit

$$V_{RxBuf} = V_{Tx} \times \frac{C_{RxTx}}{C_{RxTx} + C_{RxG} + C_H}$$

A common example of an earth-grounded device is a notebook, even with no ground connection via power supply or ethernet connection. Due to its larger form factor, it presents a high earth-ground capacitance in the range of 50 pF and thus, it can be assumed as an earth-grounded GestIC system. For further information on sensor designs with earth-grounded as well as non-earth-grounded devices, see AN2574, “2D3D Electrode Design Guide” (DS00002574).

A brief overview of the typical values of the electrode capacitances is summarized in the table below:

Table 5-1. Electrode Capacitances Typical Values

Capacity	Typical value
C_{RxTx}	10...30 pF
C_{RxG}	10...30 pF
C_H	<1 pF



Important: Ideal designs have low C_{RxTx} and C_{RxG} to ensure higher sensitivity of the electrode system. Optimal results are achieved with C_{RxTx} and C_{RxG} values being in the same range.

5.3.2 Standard Electrode Design

The MXG3141 electrode system is typically a coplanar 2D and 3D design. Up to five comparably smaller Rx electrodes are included in the design, providing the spatial resolution of the GestIC system. The Rx electrodes are typically arranged in a frame configuration as shown in the electrode diagrams below.

The frame defines the inside sensing area.

Larger dimensions yield higher sensitivity of the system.

For more information on sensor design, as well as the function of the center electrode, see AN2574, “2D3D Electrode Design Guide” (DS00002574).

The electrode shapes can be designed solid or structured. In addition to the distance and the material between the Rx and Tx electrodes, the shape structure density also controls the capacitance C_{RxTx} and thus, the sensitivity of the system.

Figure 5-3. Frame Shape Electrodes (NSWE) - Front View

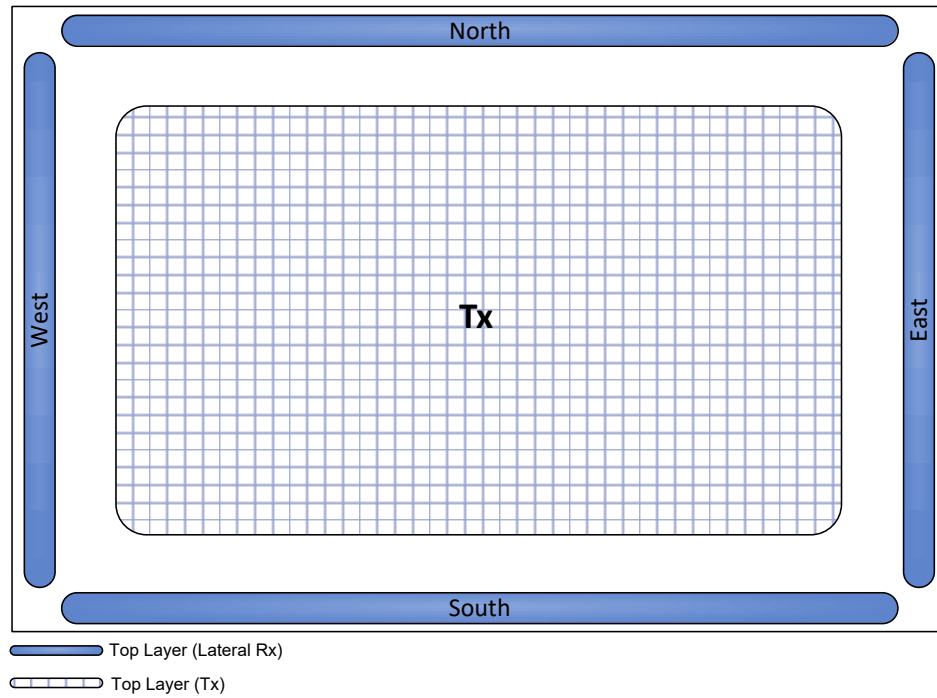
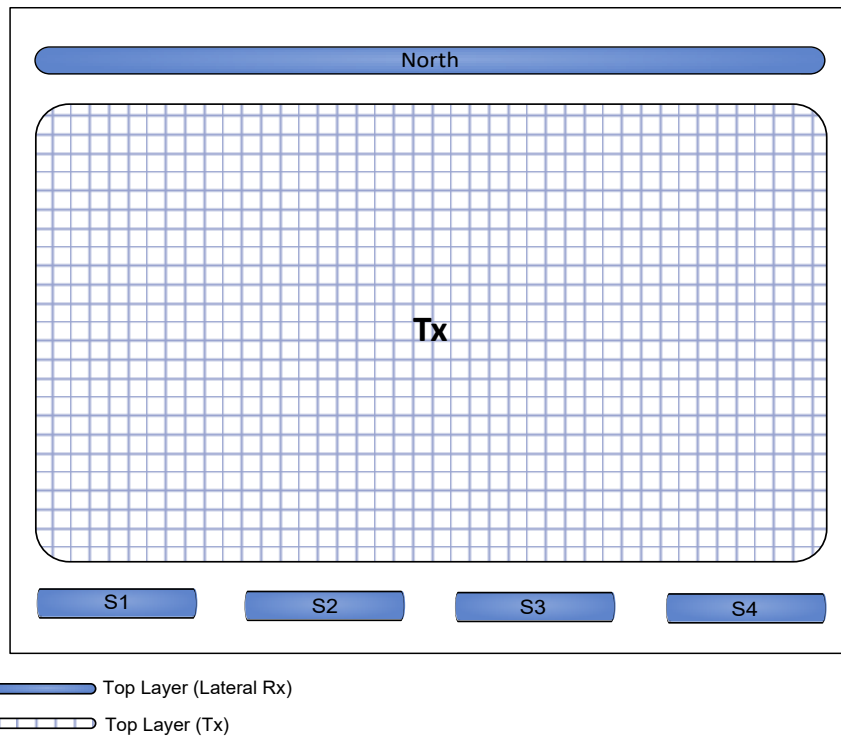


Figure 5-4. South-Side and North-Side Electrodes (4S1N) - Front View



The choice whether to use 'Frame' or '4S1N' style depends on various factors. Please refer to '*AN2574 - 2D/3D Electrode Design Guide*' for proper 2D/3D sensor design.

Related Links

[4. Feature Description](#)

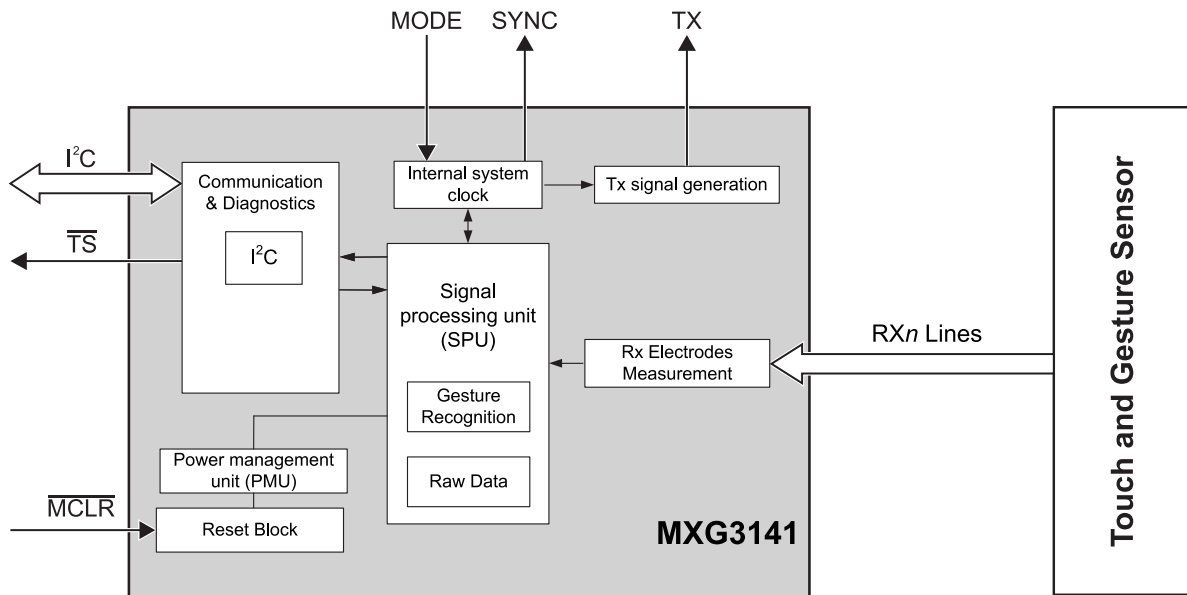
6. Functional Description

Microchip's MXG3141 configurable controller uses up to five E-field receiving electrodes. Featuring a Signal Processing Unit (SPU), a wide range of 3D gesture applications are being preprocessed on the device, which allows short development cycles as no host processing is needed.

The MXG3141 offers one enhanced I²C interface and a dedicated Transfer Status line ($\overline{TS}$) for data exchange with a host controller. GestIC sensing electrodes are driven by a low-voltage signal with a frequency in the range of 100 kHz, which allows their electrical conductive structure to be made up of any low-cost material. Even the reuse of existing conductive structures, such as a display's ITO coating, is feasible. Overall, this makes the MXG3141 a very cost-effective system solution.

The following block diagram provides an overview of the main building blocks of MXG3141. These blocks will be described in the following sections.

Figure 6-1. MXG3141 Controller Block Diagram



6.1 Reset

The Reset block combines all Reset sources. It controls the device system's Reset signal (SYSRST). The following is a list of device Reset sources:

- $\overline{MCLR}$: Host Clear Reset pin
- SWR: Software Reset available through GestIC Library Loader
- Power-on Reset (POR)
- Brown-out Reset (BOR)
- Watchdog Timer Reset (WDTR)

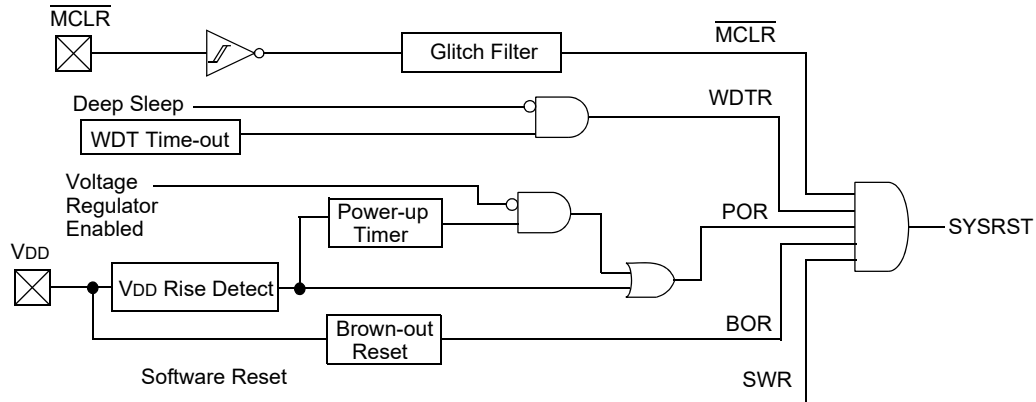
A simplified block diagram of the Reset block is illustrated in the following figure.

A pull-up resistor of 10 k Ω must be connected at all times to the $\overline{MCLR}$ pin.

It is recommended to have a dedicated MXG3141 reset line and avoid to share the same one used for maXTouch / RESET. This separation is required to avoid interference between tuning tools (e.g.: maXTouch Studio and Aurea).

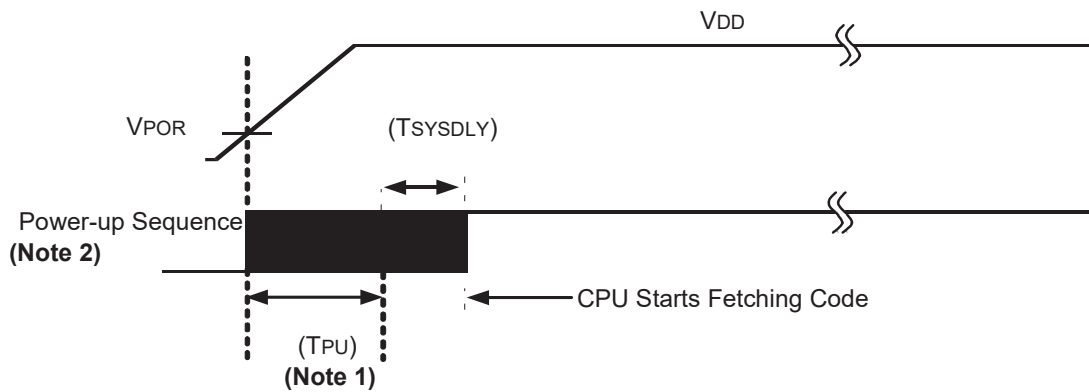
Note: GestIC 3D detection operation starts after Reset regardless of the MODE pin status. As a consequence, if a hand is placed on the sensor at start-up, this could result in false gesture detection when the hand is removed. The host system must take this into account.

Figure 6-2. System Reset Block Diagram



Timing Diagrams for POR and BOR are shown below:

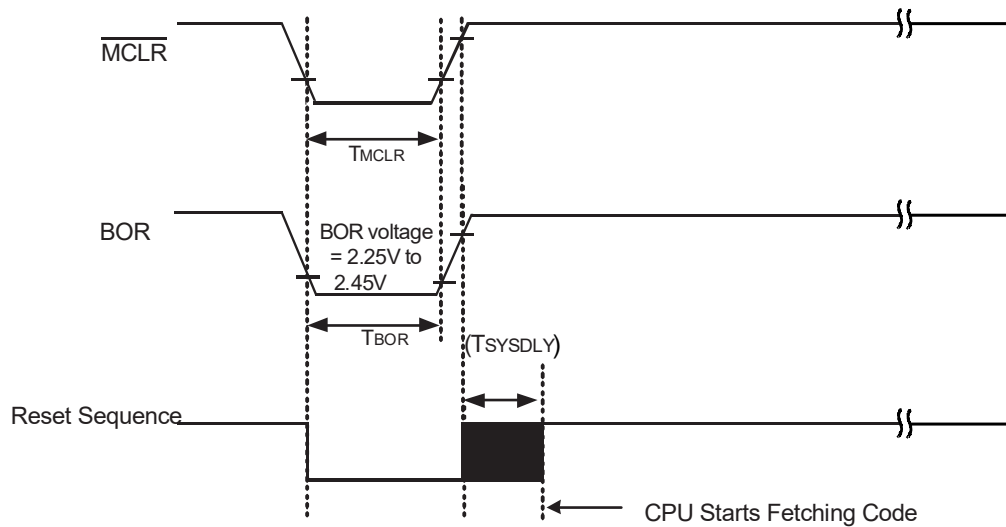
Figure 6-3. Power-on Reset Timing



Notes:

1. The power-up period will be extended if the power-up sequence completes before the device exits from BOR ($V_{DD} < V_{DDMIN}$).
2. Includes interval voltage regulator stabilization delay.

Figure 6-4. Brown-out Reset Timing



It is recommended to have a dedicated MXG3141 reset line and avoid to share the same one used for maXTouch / RESET. This separation is required to avoid interference between tuning tools (e.g.: maXTouch Studio and Aurea). **Note:** GestIC 3D detection operation starts after Reset regardless of the MODE pin status. As a consequence, if a hand is placed on the sensor at start-up, this could result in false gesture detection when the hand is removed. The host system must take this into account.

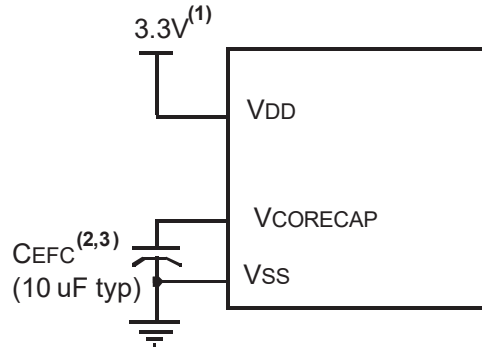
6.2 Power Management Unit (PMU)

6.2.1 Basic Connection Requirements

The device requires a nominal 3.3V supply voltage. The following pins need to be connected:

- All V_{DD} and V_{SS} pins need connection to the supply voltage and decoupling capacitors
- **V_{CORECAP}**: The devices' core and digital logic are designed to operate at a nominal 1.8V, which is provided by an on-chip regulator. The required core logic voltage is derived from V_{DD} and is outputted on the $V_{CORECAP}$ pin. A low-ESR capacitor (such as tantalum or ceramic) must be connected to the $V_{CORECAP}$ pin. This helps to maintain the stability of the regulator.
- **AV_{DD}**: Analog voltage references for the ADC needs to be connected to the supply voltage and a decoupling capacitor
- **V_{ANA}**: Analog supply for GestIC analog front end must be connected to the supply voltage

Figure 6-5. Connections for V_{CORE} Regulator



Notes:

1. These are typical operating voltages.
2. It is important that the low-ESR capacitor is placed as close as possible to the V_{CAP} pin.
3. The typical voltage on the V_{CAP} is 1.8V.

6.2.2 Decoupling Capacitors

The use of decoupling capacitors on power supply pins, such as V_{DD}, V_{SS} and AV_{DD} is required.

Consider the following criteria when using decoupling capacitors:

- **Value and type of capacitor:** SMD X7R ceramic capacitors with the value indicated in 'Reference Schematic' section and nominal voltage of 10...25V X7R are recommended. The capacitors should be a low Equivalent Series Resistance (low-ESR) capacitor and have resonance frequency of 20 MHz or higher.
- **Placement on the printed circuit board:** The decoupling capacitors should be placed as close to the pins as possible. It is recommended that the capacitors be placed on the same side of the board as the device. If space is constricted, the capacitor can be placed on another layer on the PCB using a "via"; however, ensure that the trace length from the pin to the capacitor is within 6 mm in length.
- **Handling high-frequency noise:** If the board is experiencing high-frequency noise, upward of tens of MHz, add a second ceramic-type capacitor in parallel to the above described decoupling capacitor. The value of the second capacitor can be in the range of 0.01 μ F to 0.001 μ F. Place this second capacitor next to the primary decoupling capacitor. In high-speed circuit designs, consider implementing a decade pair of capacitances as close as possible to the power and ground pins. For example, 0.1 μ F in parallel with 0.001 μ F.
- **Maximizing performance:** On the board layout from the power supply circuit, run the power and return traces to the decoupling capacitors first and then to the device pins. This ensures that the decoupling capacitors are first in the power chain. Equally important is to keep the trace length between the capacitor and the power pins to a minimum, thereby reducing PCB track inductance.

Related Links

[8.5 Reference Schematic](#)

6.3 Transmit Signal Generation

The transmit "electrode" is constructed from the mXT2912TG/mXT2113TG X-lines and Y-lines that provide a bandwidth limited square wave signal for the Tx signal generation.

6.4 Receive (Rx) Channels

There are five RX input pins to be connected to receiving electrodes. Every pin feeds a dedicated ADC.

To simplify layout, the association between logical electrodes (e.g. "West", "East", etc...) and physical pin (RX0...RX4) can be freely performed in software.

Note: When only four electrodes are required in the application, it is recommend to use RX channels RX1...RX4, while RX0 can be left disconnected.

6.5 Analog-to-Digital Converter (ADC)

As outlined in the previous section, each Rx channel features a dedicated ADC with a trigger derived from the internal clock. ADC samples are synchronous with twice the Tx transmit frequency.

6.6 Signal Processing Unit (SPU)

The MXG3141 features a Signal Processing Unit (SPU) to control the hardware blocks and process the advanced DSP algorithms included in the GestIC Library. It provides filtered sensor data and recognized gestures to the application host. The host combines the information and controls its application.

6.7 Parameters Storage

The MXG3141 provides an embedded 128 kB Flash memory which is dedicated to the GestIC Library and storage of the individual configuration parameters. These parameters have to be set according to the individual electrode design and application.

Related Links

[9. Development Support](#)

7. Interface Description

The MXG3141 supports an I²C interface in Client mode. For further information on the I²C interface as well as a list of the I²C commands, see "MGC3140/MXG3141 - GestIC Library Interface Description User's Guide" (DS40001875).

It is recommended to use two separated I²C interfaces for mXT2912TG/mXT2113TG and GestIC to allow for best performances.

7.1 I²C Client Mode

7.1.1 I²C Hardware Interface

A summary of the hardware interface pins is shown below:

Table 7-1. Interface Pins

Pin	Function
SCL	Serial Clock to Host I ² C
SDA	Serial Data to Host I ² C
$\overline{\text{TS}}$	Transfer Status Line
Note: Inter-IC control signals (MODE, SYNC and TX) are described in the mXT2912TG / mXT2113TG data sheet.	

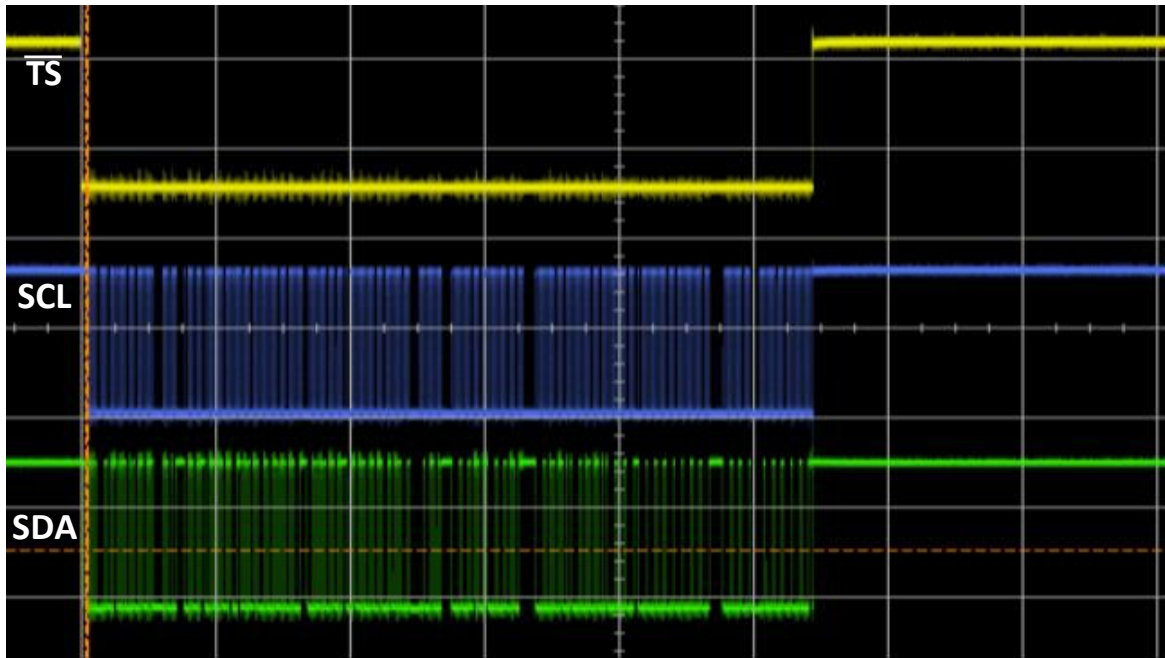
The MXG3141 requires a dedicated Transfer Status line ($\overline{\text{TS}}$). The MXG3141 (I²C Client) uses this line to inform the host controller (I²C Host) that there is data available which can be transferred. The $\overline{\text{TS}}$ line is electrically open-drain and requires a pull-up resistor of typically 10 k Ω from the $\overline{\text{TS}}$ line to V_{DD}. The $\overline{\text{TS}}$ Idle state is high.

The MXG3141 uses an internal I²C message buffer. If after a read operation there are remaining messages in the buffer, the $\overline{\text{TS}}$ will only go high for a short-time period and then be driven low again.

Table 7-2. Usage of $\overline{\text{TS}}$ Line

Device	$\overline{\text{TS}}$ Line	Status
Released (H)	High	No new pending message from the device
Asserted (L)	Low	New message from device available; Host can start reading I ² C message

Figure 7-1. Example for $\overline{TS}$ Line Indication and Following Read Operation



Note: The $\overline{TS}$ line handling of the MXG3141 is different to MGC3x30 devices. With the MXG3141, there is no need for the host to assert the $\overline{TS}$ line.



Important: Usage of $\overline{TS}$ line is **compulsory**. Trying to read the MXG3141 internal message buffer without waiting for $\overline{TS}$ signal, as specified above, could lead to corrupted data and abnormal interface behavior. Consequently, an appropriate dedicated input port must be planned on the host processor. The $\overline{TS}$ line must be dedicated to MXG3141 and cannot be shared with the maXTouch /CHG line.

7.1.2 I²C Message Buffer

The MXG3141 has an internal First-In First-Out (FIFO) I²C message buffer for a total of five messages. After a I²C message read process is started by the host, the message will be deleted from the buffer. Also, if the I²C transfer of a message is read by the host and the transfer is interrupted, the message will be deleted. For further information, refer to “MGC3140/MXG3141 - GestIC Library Interface Description User’s Guide” (DS40001875).

7.1.3 I²C Addressing

The MXG3141 Device ID 7-bit address is: 0x42 (0b1000010).

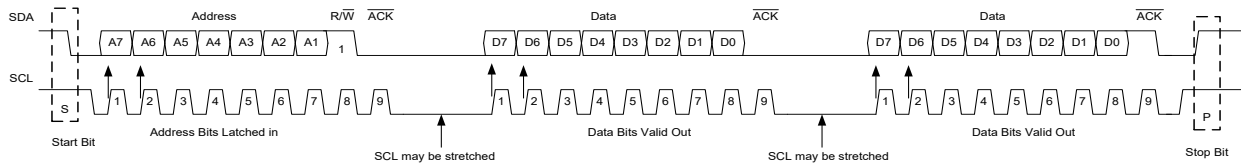
7.1.4 Timing Descriptions

I²C Clock - The I²C clock operates up to 400 kHz.

I²C Host Read Bit Timing

Host read is to receive gesture reports and command responses from the MXG3141. The timing diagram is shown below:

Figure 7-2. I²C Host Read Bit Timing Diagram



- Address bits are latched into the MXG3141 on the rising edges of SCL.
- Data bits are latched out of the MXG3141 on the rising edges of SCL.
- ACK bit:
 - MXG3141 presents the ACK bit on the ninth clock for address acknowledgment
 - I²C host presents the ACK bit on the ninth clock for data acknowledgment
- The I²C host must monitor the SCL pin prior to asserting another clock pulse, as the MXG3141 may be holding off the I²C host by stretching the clock.

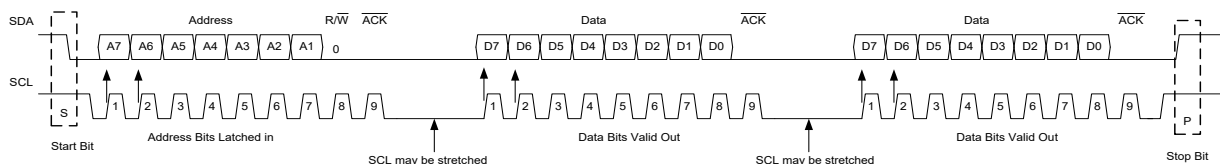
I²C Communication Steps

1. SCL and SDA lines are Idle high.
2. I²C host presents Start bit to the MXG3141 by taking SDA high-to-low, followed by taking SCL high-to-low.
3. I²C host presents 7-bit address, followed by a R/W = 1 (Read mode) bit to the MXG3141 on SDA, at the rising edge of eight host clock (SCL) cycles.
4. MXG3141 compares the received address to its Device ID. If they match, the MXG3141 acknowledges (ACK) the host sent address by presenting a low on SDA, followed by a low-high-low on SCL.
5. MXG3141 host monitors SCL, as the MXG3141 may be clock-stretching, holding SCL low to indicate that the I²C host should wait.
6. I²C host receives eight data bits (MSB first) presented on SDA by the MXG3141, at eight sequential I²C host clock (SCL) cycles. The data is latched out on SCL falling edges to ensure it is valid during the subsequent SCL high time.
7. If data transfer is not complete, then:
 - I²C host acknowledges (ACK) reception of the eight data bits by presenting a low on SDA, followed by a low-high-low on SCL.
 - Go to Step 5.
8. If data transfer is complete, then:
 - I²C host NACK's reception of the eight data bits and a completed data transfer by presenting a high on SDA, followed by a low-high-low on SCL.

I²C Host Write Bit Timing

I²C host write is to send supported commands to the MXG3141. The timing diagram is shown below:

Figure 7-3. I²C Host Write Bit Timing Diagram



- Address bits are latched into the MXG3141 on the rising edges of SCL.
- Data bits are latched into the MXG3141 on the rising edges of SCL.
- ACK bit:
 - MXG3141 presents the ACK bit on the ninth clock for address acknowledgment

- MXG3141 presents the ACK bit on the ninth clock for data acknowledgment
- The host must monitor the SCL pin prior to asserting another clock pulse, as the MXG3141 may be holding off the host by stretching the clock.

I²C Communication Steps

1. SCL and SDA lines are Idle high.
2. I²C host presents Start bit to the MXG3141 by taking SDA high-to-low, followed by taking SCL high-to-low.
3. I²C host presents 7-bit address, followed by a R/W = 0 (Write mode) bit to the MXG3141 on SDA, at the rising edge of eight host clock (SCL) cycles.
4. MXG3141 compares the received address to its Device ID. If they match, the MXG3141 acknowledges (ACK) the I²C host sent address by presenting a low on SDA, followed by a low-high-low on SCL.
5. I²C host monitors SCL, as the MXG3141 may be clock stretching, holding SCL low to indicate the I²C host should wait.
6. I²C host presents eight data bits (MSB first) to the MXG3141 on SDA, at the rising edge of eight host clock (SCL) cycles.
7. MXG3141 acknowledges (ACK) receipt of the eight data bits by presenting a low on SDA, followed by a low-high-low on SCL.
8. If data transfer is not complete, then go to Step 5.
9. Host presents a Stop bit to the MXG3141 by taking SCL low-high, followed by taking SDA low-to-high.



Important: The Stop condition after an I²C data transmission is generated by the host controller after the data transfer is completed. Thus, it is recommended to verify the number of bytes to be read in the message header (Size field). Host must send the Stop condition as soon as the exact number of bytes specified in the message header has been received. Failing to do so could result in abnormal interface operation.

8. Application Architecture

The standard MXG3141 application architecture is shown in [Figure 5-1](#).

8.1 ESD Considerations

The MXG3141 provides Electrostatic Discharge (ESD) voltage protection up to 4 kV (HBM) and Charge Device Model (CDM) 750V on corner pins; 500V on all other pins. Additional ESD countermeasures may be implemented individually to meet application-specific requirements.

8.2 Power Supply Considerations

Power rail must be supplied by a stable linear regulator with low output noise. For best performances, it is recommended to use the same regulator powering the maXTouch device.

8.3 High-Frequency Noise Immunity

In order to suppress irradiated high-frequency signals, the five Rx channels of the chip are connected to the electrodes via serial 10 k Ω resistors, as close as possible to MXG3141. The 10 k Ω resistor and the MXG3141 input capacitance are building a low-pass filter with a corner frequency of 3 MHz.

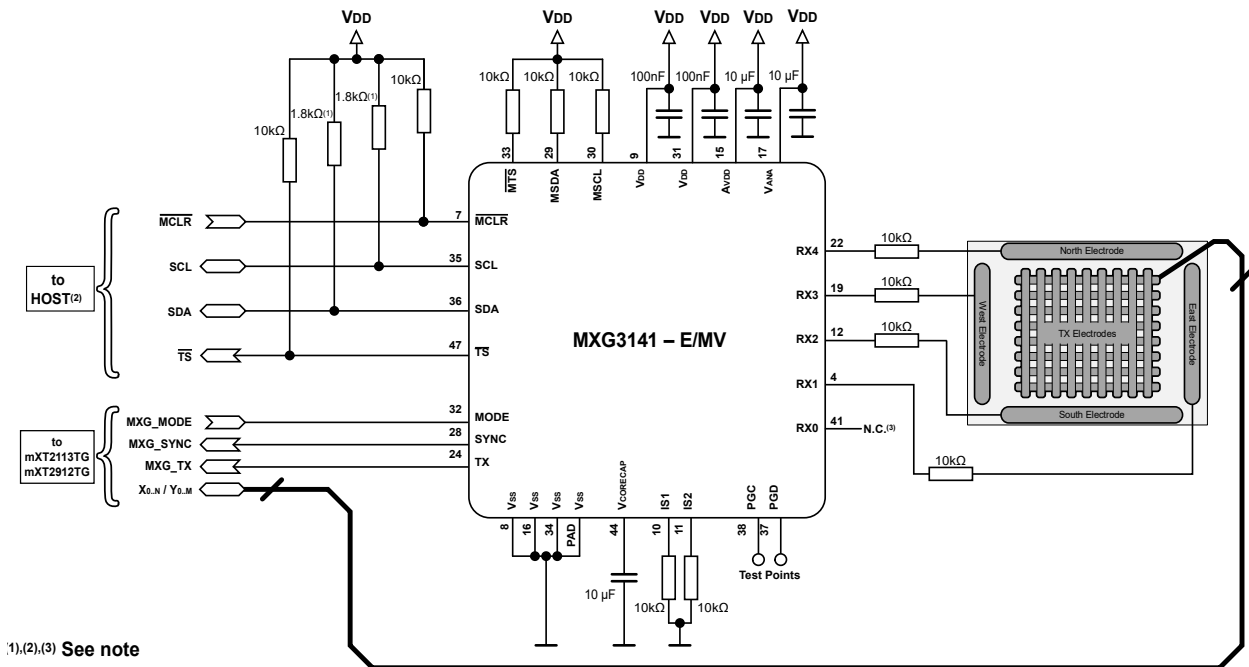
8.4 RF Emission

The mXT2912TG/mXT2113TG Tx drive signals are shaped to reduce emissions in the relevant frequency bands. The slope of the Tx signal is randomized using, among others, dithering techniques while the sampling point is kept constant for further reduction of emission. The respective reference schematic is shown in [Figure 8-1](#). For further support on reduction of RF emission, contact your local Microchip representative.

8.5 Reference Schematic

This is the reference application schematic for the MXG3141 device:

Figure 8-1. Reference Schematic



^{1),(2),(3)} See note

Notes:

1. The values of the pull-up resistors will be chosen to ensure SCL and SDA rise and fall times meet the I²C specification. The value required will depend on the amount of capacitance loading on the lines.
2. It is recommended to provide a 2 mm pitch connector for the "GestIC I²C to USB" interface (EV91M41A) and the ability for the host to keep MCLR line in high impedance state while the interface is connected.
3. See paragraph 6.4 for details on RX0...4 pins assignment.

8.6 Sensor Style

The MXG3141-Library supports two different sensor types:

- Frame style sensor - one electrode on each side
- 4S1N

8.7 Layout Recommendation

This section provides a brief description of layout hints for a proper system design.

The PCB layout requirements for MXG3141 follow the general rules for a mixed signal design. In addition, there are certain requirements to be considered for the sensor signals and electrode feeding lines.

A two layer PCB layout is sufficient to enable analog and digital signals to be separated from each other to minimize crosstalk. The individual electrode feeding lines should be kept apart as far as possible from each other.

V_{DD} lines should be routed as wide as possible.

MXG3141 requires a proper ground connection on all V_{SS} pins, including the exposed pad.

PCB RX_n feeding lines are extremely sensitive to external electric fields. They must be kept as short and straight as possible. Track width must be the minimum allowed by the process used. RX_n tracks must be kept at least 2 mm distant from any other kind of signal (power supply, analog, digital) and must not cross over other signals. Keep a minimum of 1 mm between every RX_n line. To avoid strong signal attenuation, ground planes below RX_n lines must be completely avoided if possible. And they must be kept at a minimum of 1.2 mm distance.

9. Development Support

Contact your Microchip local representative for up to date information on development support for MXG3141.

9.1 Aurea Software Package

The Aurea evaluation software comes in aid to customers supporting debug of 2D/3D systems. Aurea provides visualization of 3D gestures and allows for logging of 3D sensor data.

9.2 Configuration and Programming

Aurea software cannot be used for the parametrization or programming of MXG3141.

Please contact your Microchip local representative for GestIC configuration and production programming alternatives.

9.3 GestIC® Hardware References

PCB schematics and layouts are available from the mXT2912TG/mXT2113TG and MXG3141 Evaluation Kit Board Designs. 3D sensor design guidance is available within application note AN2574, “*2D3D Electrode Design Guide*” (DS00002574).

10. Electrical Specifications

10.1 Absolute Maximum Ratings^(†)

Parameter	Rating
Ambient temperature under bias	-40°C to +125°C
Storage temperature	-65°C to +150°C
Voltage on pins with respect to V _{SS} • on V_{SS} pin:	-0.3V to +4.0V



Notice: (†) Stresses above those listed under “*Absolute Maximum Ratings*” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure above maximum rating conditions for extended periods may affect device reliability.



Notice: (†) This device is sensitive to ESD damage and must be handled appropriately. Failure to properly handle and protect the device in an application may cause partial to complete failure of the device.

10.2 Recommended Operating Conditions

Parameter	Rating
Operating temperature	-40°C to +125°C
Storage temperature	-65°C to +150°C
V _{DD}	3.3V ± 5%
V _{ANA}	3.3V ± 5%
A _{VDD}	3.3V ± 5%

10.3 I/O Characteristics

DC Input Characteristics			Operating temperature: -40°C ≤ TA ≤ 125°C			
Characteristic	Symbol	Pin Function	Min	Max	Units	Conditions
Input low voltage	V _{IL}	Rx pins	V _{SS}	0.2 V _{DD}	V	
		SDA, SCL	V _{SS}	0.3 V _{DD}	V	
Input high voltage	V _{IH}	Rx pins	0.65 V _{DD}	V _{DD}	V	
		SDA, SCL	0.65 V _{DD}	5.5	V	
Input leakage current	I _{IL}	Rx pins		±1	uA	V _{SS} ≤ V _{pin} ≤ V _{DD}
		MCLR		±1	uA	V _{SS} ≤ V _{pin} ≤ V _{DD}

Note: Parameters are characterized, but not tested.

DC Output Characteristics			Operating temperature: $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$			
Characteristic	Symbol	Pin Function	Min	Max	Units	Conditions
Output low voltage	V_{IL}	Tx, SDA, SCL, SYNC		0.4	V	$I_{OL} \leq 10 \text{ mA } V_{DD} = 3.3\text{V}$
Output high voltage	V_{IH}	Tx, SDA, SCL, SYNC	1.5 ⁽¹⁾		V	$I_{OH} \geq -14 \text{ mA } V_{DD} = 3.3\text{V}$
			2.0 ⁽¹⁾		V	$I_{OH} \geq -12 \text{ mA } V_{DD} = 3.3\text{V}$
			2.4 ⁽¹⁾		uA	$I_{OH} \geq -10 \text{ mA } V_{DD} = 3.3\text{V}$
			3.0 ⁽¹⁾		uA	$I_{OH} \geq -7 \text{ mA } V_{DD} = 3.3\text{V}$

Note:

- Parameters are characterized, but not tested.

10.4 Current Consumption

Operating mode	Current Consumption mA
	Typical
Processing mode	31

10.5 Timing Characteristics

10.5.1 Power-on and Reset Timing

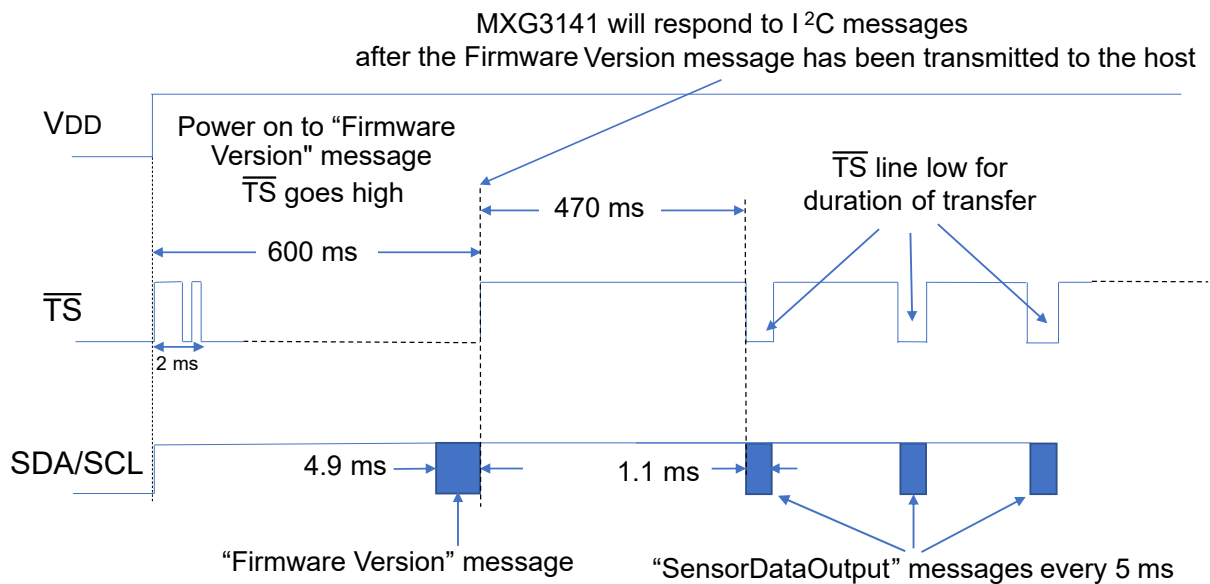
Table 10-1. Power-on and Reset Parameters

Characteristic ⁽¹⁾	Parameter Symbol	Operating temperature: $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$			
		Min	Typical ⁽²⁾	Max	Units
Power-up period: Internal voltage regulator enabled	TPU	—	400	600	us
System delay period: Time required to reload device configuration fuses plus clock delay before first instruction is fetched	TSYSDLY	—	1.2	—	us
MCLR minimum pulse width	TMCLR	2	—	—	us
BOR pulse width	TBOR	—	1	—	us

Notes:

- These parameters are characterized, but not tested in manufacture.
- Data in Typical column is at 3.3V, 25°C, unless otherwise stated.

Figure 10-1. Power-on Timings



Note: Indicated timings are typical values and could vary depending on the installed firmware and actual configuration. Timings after release of MCLR are similar to above. The Bootloader mode can be entered in the first 600 ms after Reset and will be aborted about 400 ms after the latest message not recognized by the bootloader itself (see 'MGC3140/MXG3141 Library Interface Guide' - DS40001875C document for a description of commands available in Bootloader mode).

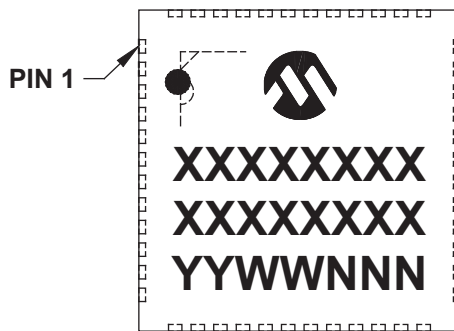
11. Packaging Information

Package Marking Information

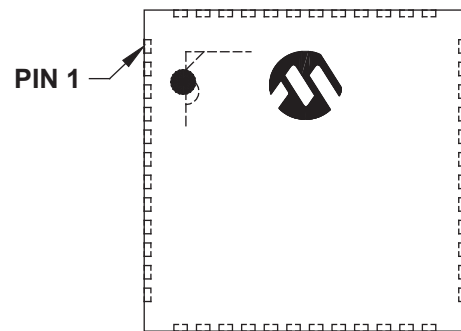
Legend:	XX...X	Customer-specific information or Microchip part number
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

48-Lead UQFN (6x6x0.5 mm)



Example

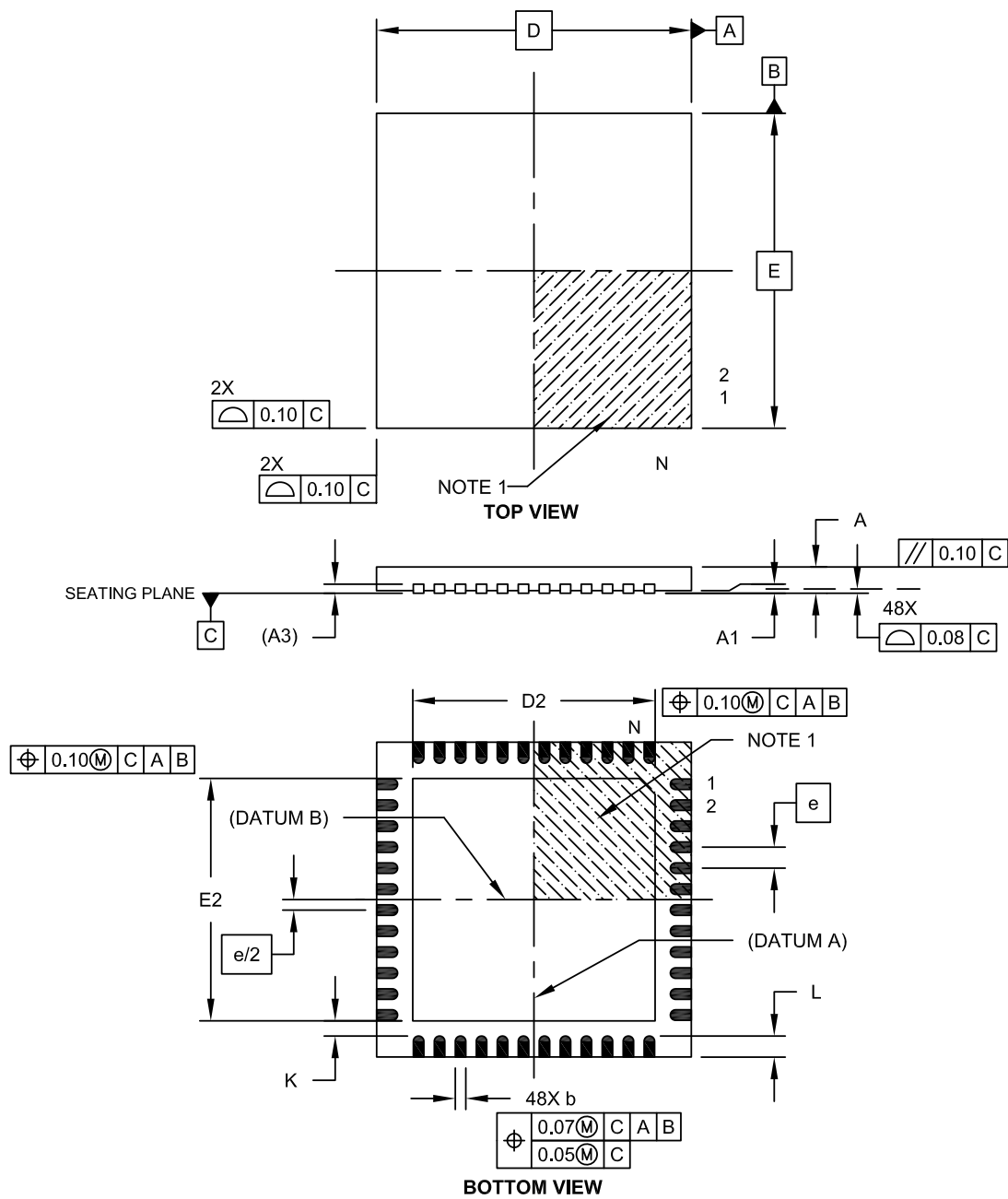


11.1 Package Details

The following sections give the technical details of the packages.

48-Lead Plastic Ultra Thin Quad Flat, No Lead Package (MV) – 6x6x0.5 mm Body [UQFN]

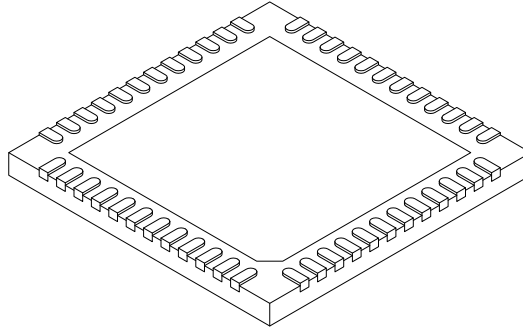
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/package3>



Microchip Technology Drawing C04-153A Sheet 1 of 2

48-Lead Plastic Ultra Thin Quad Flat, No Lead Package (MV) – 6x6x0.5 mm Body [UQFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



		Units	MILLIMETERS		
Dimension Limits			MIN	NOM	MAX
Number of Pins	N		48		
Pitch	e		0.40 BSC		
Overall Height	A		0.45	0.50	0.55
Standoff	A1		0.00	0.02	0.05
Contact Thickness	A3		0.127 REF		
Overall Width	E		6.00 BSC		
Exposed Pad Width	E2		4.45	4.60	4.75
Overall Length	D		6.00 BSC		
Exposed Pad Length	D2		4.45	4.60	4.75
Contact Width	b		0.15	0.20	0.25
Contact Length	L		0.30	0.40	0.50
Contact-to-Exposed Pad	K		0.20	-	-

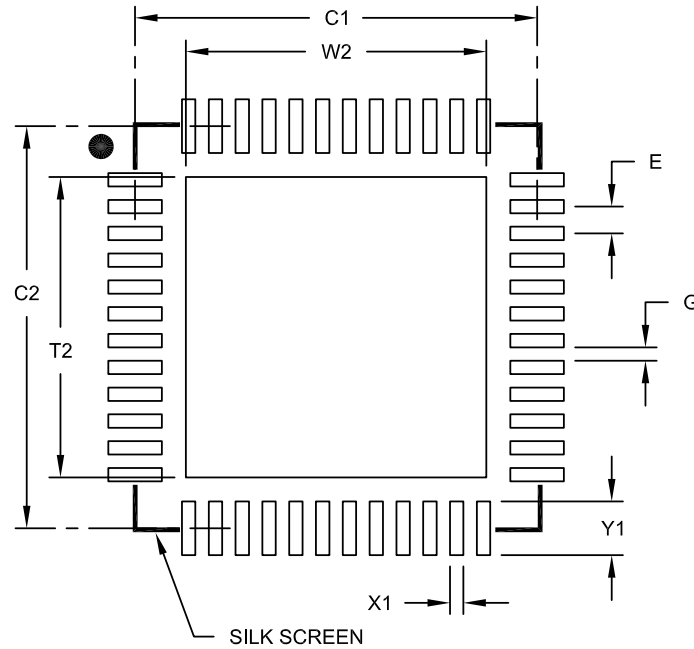
Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated.
- Dimensioning and tolerancing per ASME Y14.5M.
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-153A Sheet 2 of 2

48-Lead Ultra Thin Plastic Quad Flat, No Lead Package (MV) - 6x6 mm Body [UQFN] With 0.40 mm Contact Length

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.40 BSC		
Optional Center Pad Width	W2			4.45
Optional Center Pad Length	T2			4.45
Contact Pad Spacing	C1		6.00	
Contact Pad Spacing	C2		6.00	
Contact Pad Width (X28)	X1			0.20
Contact Pad Length (X28)	Y1			0.80
Distance Between Pads	G	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2153A

12. Appendix A: Revision History

Revision C (03/2021)

Updating master/slave terminology; other minor corrections.

Revision B (08/2019)

Updated chapter 4. Feature Description, 4.1 Gesture Definition, chapter 4.1.1.3 Presence Detection, chapter 5.3.2 Standard Electrode Design, and chapter 6. Functional Description. Added new chapter 4.2 and chapter 8.6. Removed section 6.4.3 and Table 7-4. Updated Table 2.1 and Table 6-1. Updated Figure 5.1, Figure 5-2, Figure 6-1, and Figure 8-1.

Revision A (12/2017)

Initial release of this document.

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Product Identification System

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.
 Device [X]⁽¹⁾ -X /XX
 Tape Temperature Package
 and Reel Range

Device:	MXG3141	
Tape & Reel Option:	Blank	= Tube
	T	= Tape & Reel
Temperature Range:	I	= -40°C to +85°C (Industrial)
	E	= -40°C to +125°C (Extended)
Package	MV	= 48-lead UQFN 6x6x0.5mm
Pattern	QTP, SQTP, Code or Special Requirements (blank otherwise)	

Orderable Part Number	Firmware Revision	Industrial/Automotive	Description
MXG3141-E/MVVAO (supplied in tubes)	1.0.AA	Automotive	48-pin UQFN48 6x6x0.5 RoHS compliant Automotive grade; suitable for automotive characterization
MXG3141-I/MVVAO (supplied in tubes)		Automotive	
MXG3141T-E/MVVAO (supplied in tape and reel)		Automotive	
MXG3141T-I/MVVAO (supplied in tape and reel)		Automotive	
MXG3141-E/MV (supplied in tubes)		Industrial	48-pin UQFN48 6x6x0.5 RoHS compliant Industrial grade, PPAP requests are not supported
MXG3141-I/MV (supplied in tubes)		Industrial	
MXG3141T-E/MV (supplied in tape and reel)		Industrial	
MXG3141T-I/MV (supplied in tape and reel)		Industrial	

Examples:

- MXG3141-E/MV: Extended temperature, UQFN package.
- MXG3141-I/MV = Industrial temperature, UQFN package

Note:

1. Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

Microchip Devices Code Protection Feature

Note the following details of the code protection feature on Microchip devices:

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- Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable." Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

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ISBN: 978-1-5224-7744-0

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