MICROCHIP

AN3433

Touchpad With Built-In Surface Gesture Recognition Using Peripheral Touch Controller

Introduction

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In the past two decades, smart gadgets led to the popularity of capacitive touch surface, or touchpad, as a Human Machine Interface (HMI) for a wide range of applications. The increase in demand for touch also led to the development of reliable, robust touch-sensing technology. Consequently, the capacitive touch interface is an essential user requirement in numerous consumer electronic, wearable, home appliances, home automation, industrial, medical, and automotive products. Many devices use capacitive touch surface as a replacement for mechanical buttons.

This application note demonstrates 2D touch surface implementation for an AVR® DA microcontroller with integrated gesture recognition using the on-chip Peripheral Touch Controller (PTC) and the Microchip Touch Library. It showcases the advanced low-power touch measurement capabilities of the AVR DA microcontroller and how to use the PTC peripheral with CPU in Standby sleep mode to minimize power consumption.

A basic Snake Game demonstrator is implemented to showcase the 2D touch surface gestures with the help of the Microchip AVR128DA48 Curiosity Nano, Curiosity Nano Touch Adapter, QT2 Xplained Pro extension board, and the Microchip Touch Library. The supplemented firmware is developed with the help of Microchip's Atmel START, and the QTouch® configurator (embedded into Atmel START) is used to configure the touch surface parameters.

View Code Example on GitHub
Click to browse repository

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1. Features

This application note features the following content:

- AVR DA PTC Overview
- 2D Capacitive Touch Surface and Gestures
- Tap and Swipe Gesture Recognition with Microchip Touch Library
- Low-Power and Robust Capacitive Sensing Using the PTC Peripheral
- I^{2}C-Based LED Multiplexer Driver for LED Matrix Display Controller
- Snake Game Application

For getting started with PIC®, AVR, SAM, and PIC32 devices and capacitive touch sensing software libraries and tools, visit https://microchipdeveloper.com/touch:start.

2. AVR® DA MCU Family Overview

The AVR DA family of microcontrollers is using the AVR CPU with hardware multiplier, running at up to 24 MHz, with 32/64/128 KB of Flash, 4/8/16 KB of SRAM, and 512 bytes of EEPROM in 28-, 32-, 48- or 64-pin packages. The family uses the latest technologies from Microchip with a flexible and low-power architecture, including Event System and SleepWalking, accurate analog features and advanced peripherals and Peripheral Touch Controller (PTC).

Note: Devices with different Flash memory sizes typically also have different SRAM and EEPROM. Refer to device-specific data sheets for more information.

2.1 Relevant Devices

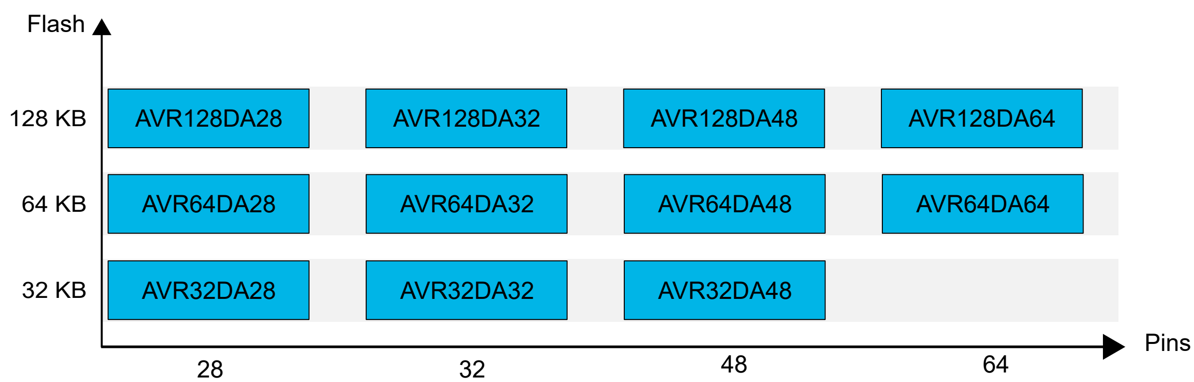
This section lists the relevant devices for this document.

2.1.1 AVR® DA Family Overview

The figure below shows the AVR® DA devices, laying out pin count variants and memory sizes:

- Vertical migration is possible without code modification, as these devices are fully pin and feature compatible
- Horizontal migration to the left reduces the pin count, and therefore, the available features

Figure 2-1. AVR® DA Family Overview



Devices with different Flash memory size typically also have different SRAM.

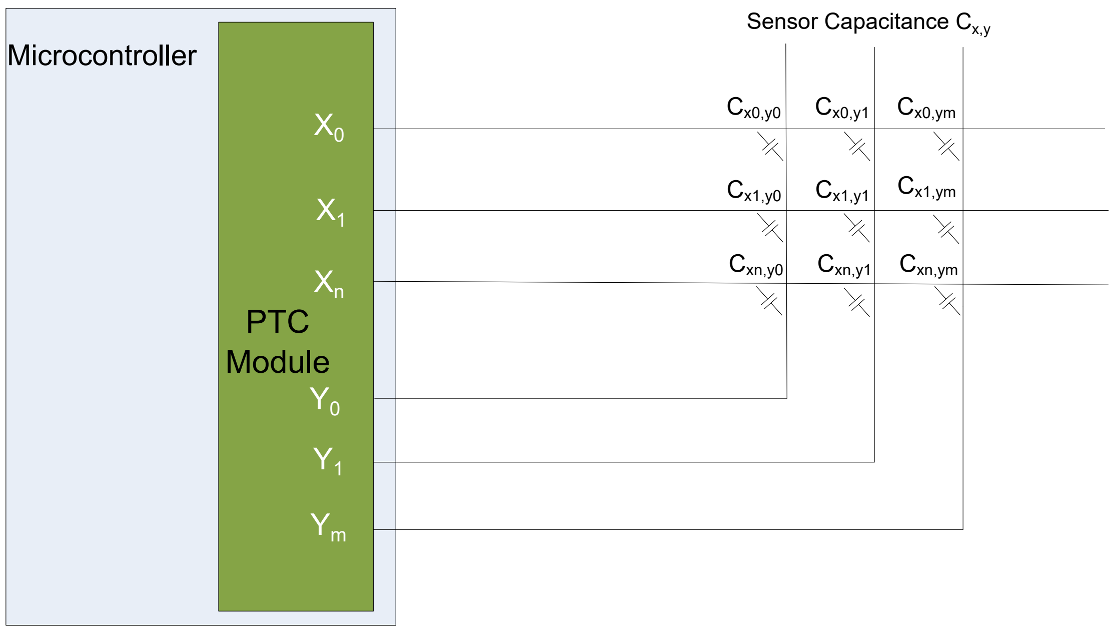
3. AVR® DA Peripheral Touch Controller

The AVR DA family of microcontrollers offers the built-in PTC module, which performs touch data acquisitions on the capacitive touch sensors autonomously without any CPU intervention.

The PTC peripheral supports both self-capacitance and mutual capacitance sensing methods for the button, slider, wheel, and 2D surface sensors. The PTC peripheral, together with Microchip Touch Library, offers an unprecedented degree of combinations for touch interface design.

Depending on the device package type and device configuration, there are up to 46 PTC channels available on an AVR DA microcontroller. 46 PTC channels can be used as up to 46 self-sensing buttons or 529 mutual sensing nodes. For more details on sense channels availability, refer to the device-specific data sheet.

Figure 3-1. Mutual Capacitance Sensor Arrangement



The PTC within the AVR DA family can be utilized by the Microchip Touch Library to deliver a robust touch experience under varying environmental conditions. The SleepWalking feature of the PTC allows it to perform touch sensing autonomously on a single, low-power sensor, with the help of the Event System.

Important:

1. To access the PTC peripheral and the Microchip Touch Library, Atmel START must be used to configure the PTC and link the library to application software. Use the Atmel START QTouch® Capacitive Sensing Library step-by-step guide for more details.
2. The Microchip Touch Library enables the use of buttons, sliders, wheels, proximity sensing, and touch surface in a variety of combinations on a single interface.

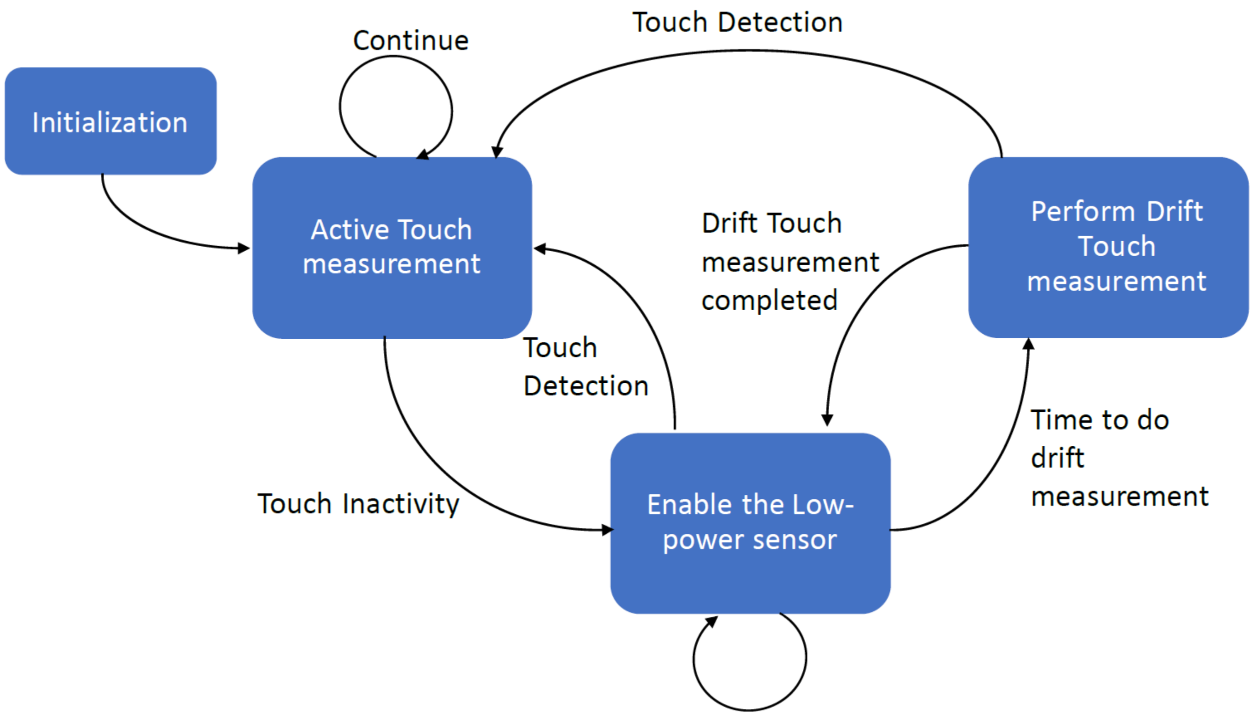
3.1 PTC Low-Power Mode

The PTC supports the Low-Power mode that utilizes the SleepWalking feature to perform touch-sensing autonomously on designated low-power sensors. The low-power touch application runs with the CPU in Standby mode. This mechanism utilizes the Event System and allows the CPU to be in sleep mode when no touch activity is being reported, thereby minimizing power consumption. The PTC generates an interrupt to wake up the CPU, as soon as a valid touch event is detected on the low-power sensor.

To implement a low-power touch application, the low-power sensor is configured as a wake-up source. Multiple channels can be lumped together to act as a single sensor, for wake-up from Low-Power mode. Once a valid touch is detected on the low-power sensor, an interrupt is issued that wakes up the CPU for further processing. The firmware switches between Low-Power mode and Active Measurement mode during the operation to keep track of capacitance changes due to variations in the environmental temperature and humidity. Thereby, Microchip Touch Library adjusts the sensor reference value to compensate for the change in the signal value by using a drifting algorithm. Typically, the drift measurement periodicity is set longer than the low-power measurement periodicity, to reduce the average power consumption.

For more details, refer to the Low-Power Sensor Design User Guide.

Figure 3-2. Low-Power Mode Event-Driven Touch Application State Machine



4. Capacitive Touch Surface and 2D Gestures

The capacitive touch surface, or touchpad, is a two-dimensional sensor formed by arranging the electrodes in rows and columns to form a matrix. The touchpad tracks finger position in both X and Y dimensions and supports single finger and multi-finger touch operations.

For optimum touch performance, the sensor design needs to be created specifically for the application and requirements. For more details on surface sensor design guidelines, refer to the AN2934-Capacitive Touch Sensor Design Guide.

4.1 2D Touchpad and Surface Gestures

The Microchip Touch Library offers on-board gesture detection for touch surfaces. It also offers dual finger gesture recognition and dual finger X/Y position reporting. Gestures are detected on the chip and reported to the host. The various gestures supported by Microchip Touch Library are:

- Tap and Hold
- Multi Taps - Single and Dual Finger
- Swipes - Single and Dual Finger
- Swipe and Hold
- Wheel and Rotations
- Pinch and Zoom

Figure 4-1. Touch Gestures

5. Application Overview

The Snake Game is implemented as a demo application to demonstrate the advanced touch capabilities and low-power mode operation of the AVR DA PTC peripheral. It uses a 2D capacitive touch surface with gesture recognition and PTC coupled with the event system as a wake-up source from the touch surface.

5.1 Basics of Snake Game

The snake game is a classic video game where the player maneuvers an onscreen snake, often represented as a line on a bordered or non-bordered screen. The snake grows in length and gets points when it eats the food, and the primary obstacle for its movement is the snake itself.

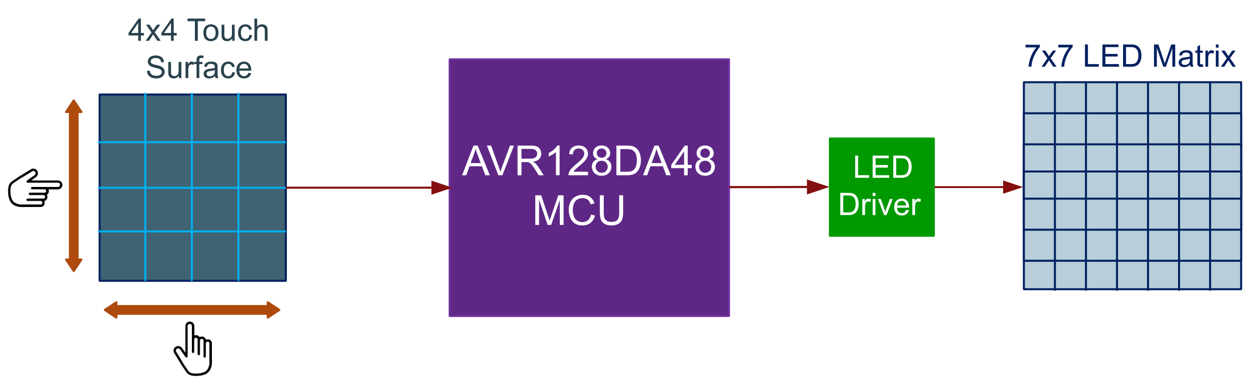
In this demo, the game has the up, down, right, and left swipe commands to steer the snake towards the food. The food is provided at random coordinates on the screen for the snake to eat. Every time the snake eats the food, its length is increased by one element. When the snake collides with itself, the game is over.

5.2 Implementation

In this demo, a 7 x 7 LED matrix is used as a display to show the snake and the food dot. A suitable LED driver/multiplexer is used to drive the LEDs via I^2C serial communication. To input the navigation commands, the demo will use a 4 x 4 capacitive touch surface that supports tap, swipe, wheel, and other 2D gestures. To change the snake's direction, the following gestures need to be used on the touch surface: Up, down, left, and right swipe. The application code is run on an AVR DA microcontroller. The built-in PTC peripheral and the Microchip Touch Library enable the easy integration of the touch surface for 2D gesture recognition.

The AVR128DA48 microcontroller is used for the demo, but it can also be realized through other microcontrollers of the AVR DA family.

Figure 5-1. Snake Game System Block Diagram



Important: Refer to the Microchip developer help at Introduction to QTouch® Project Creation for a step-by-step guide to create a touch project using Atmel START.

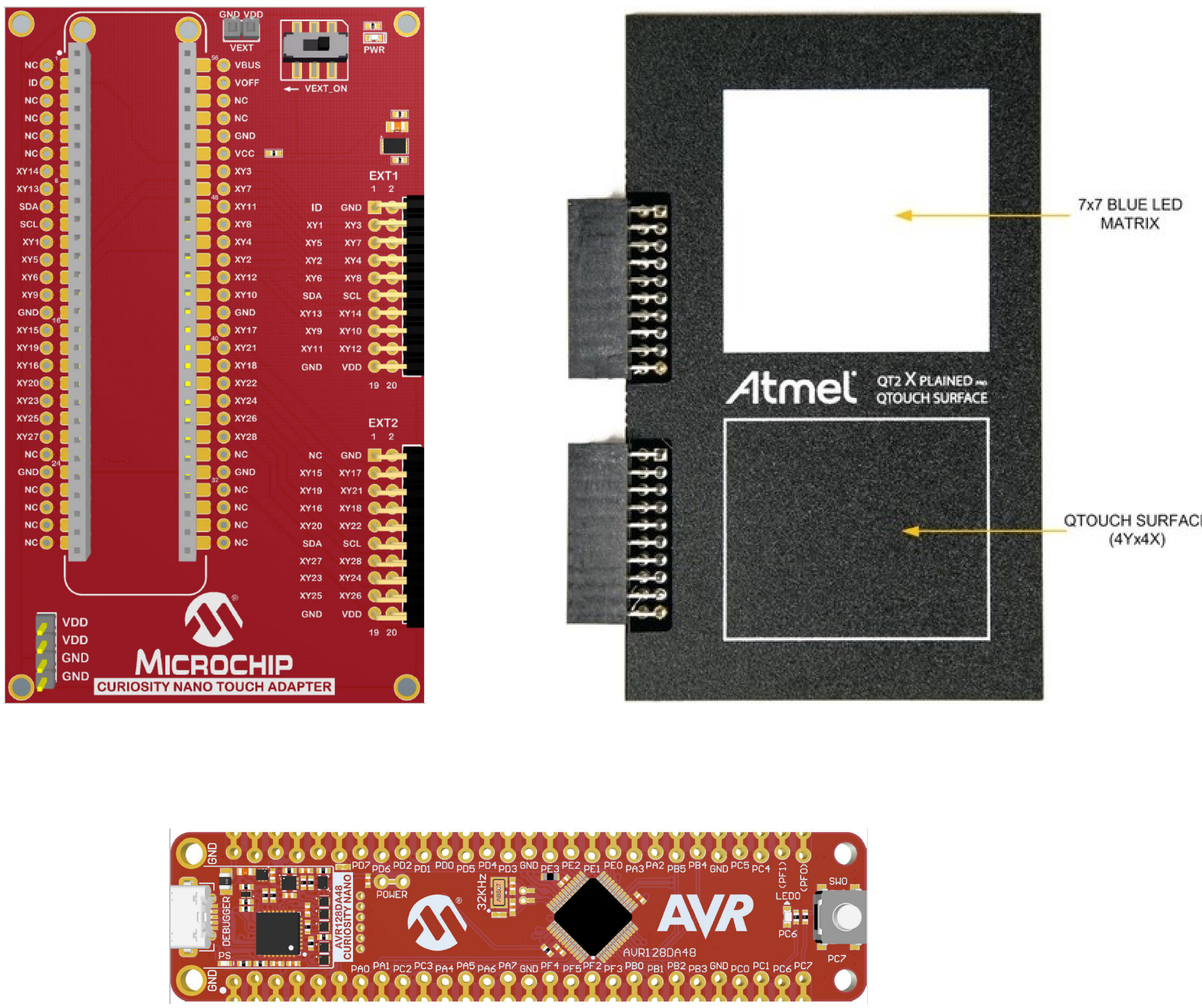
6. Hardware Overview

Development kits from Microchip are used for the snake game demo. This aids in the rapid development and deployment of the demonstration. It is encouraged to use similar boards for fast prototyping of designs.

6.1 Development Boards

- AVR128DA48 Curiosity Nano: The Curiosity Nano boards feature a variety of PIC and AVR microcontrollers, allowing rapid prototyping and easy evaluation of the design. They also offer full programming and debugging capabilities for support throughout the development process.
- QT2 Xplained Pro Extension Kit: An extension board that enables the evaluation of a mutual capacitance touch surface using the PTC module. The kit includes one board with a 4 x 4 touch surface and is accompanied by a 7 x 7 blue LED matrix for use as a display. The LED matrix is driven by an I^{2}C multiplexer LED driver.
- Curiosity Nano Touch Adapter: Each Curiosity Nano board is compatible with the Curiosity Nano Touch Adapter board. This base includes a socket that fits all Curiosity Nano boards and two Xplained headers sockets that enable effortless expansion of the design with various Microchip Touch Xplained boards. This board is used to connect the AVR128DA48 Curiosity Nano and QT2 Xplained board.

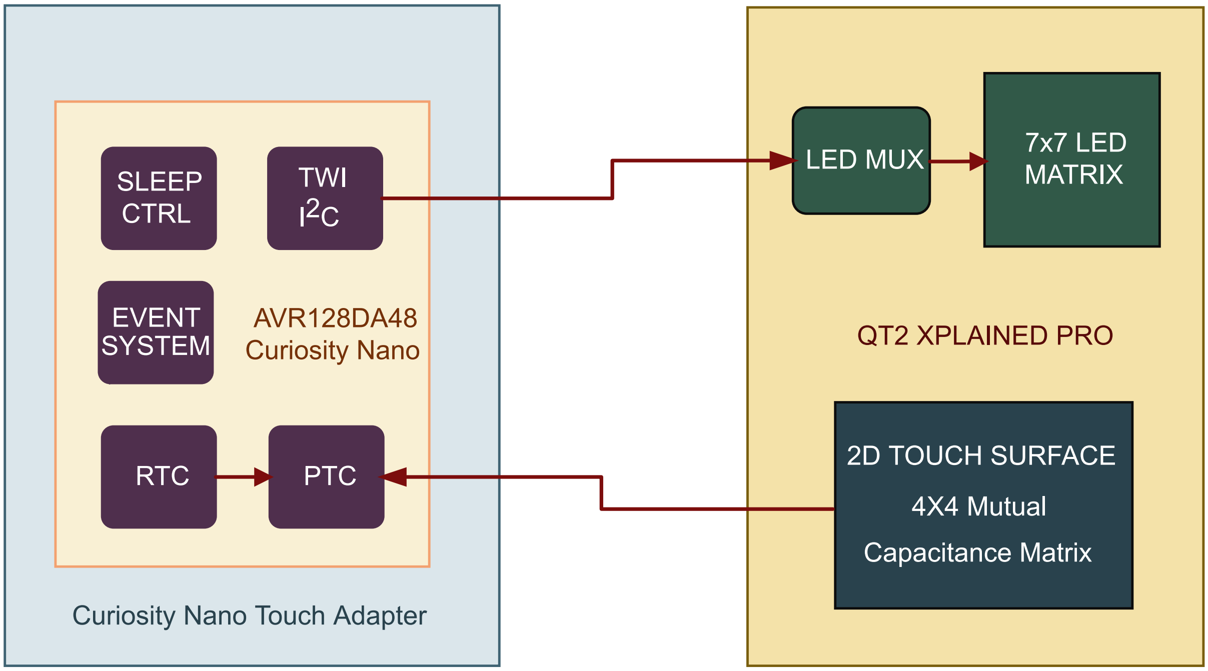
Figure 6-1. AVR128DA48 Curiosity Nano Touch Adapter Board, QT2 Xplained Board, and AVR128DA48 Curiousity Nano



6.2 Hardware Setup

The development boards used for the demo are snap-fit, and no external connections are required to realize the demo. The figure below shows the setup hardware connections after coupling all three boards.

Figure 6-2. Hardware Block Diagram



6.3 Pin Configurations

The connections configured to interface the QT2 Xplained Pro extension board are shown in the table. Apart from touch and the LED matrix, an optional USART interface on the Curiosity Nano Virtual COM port is configured to debug the touch data using the 2D Touch Surface utility.

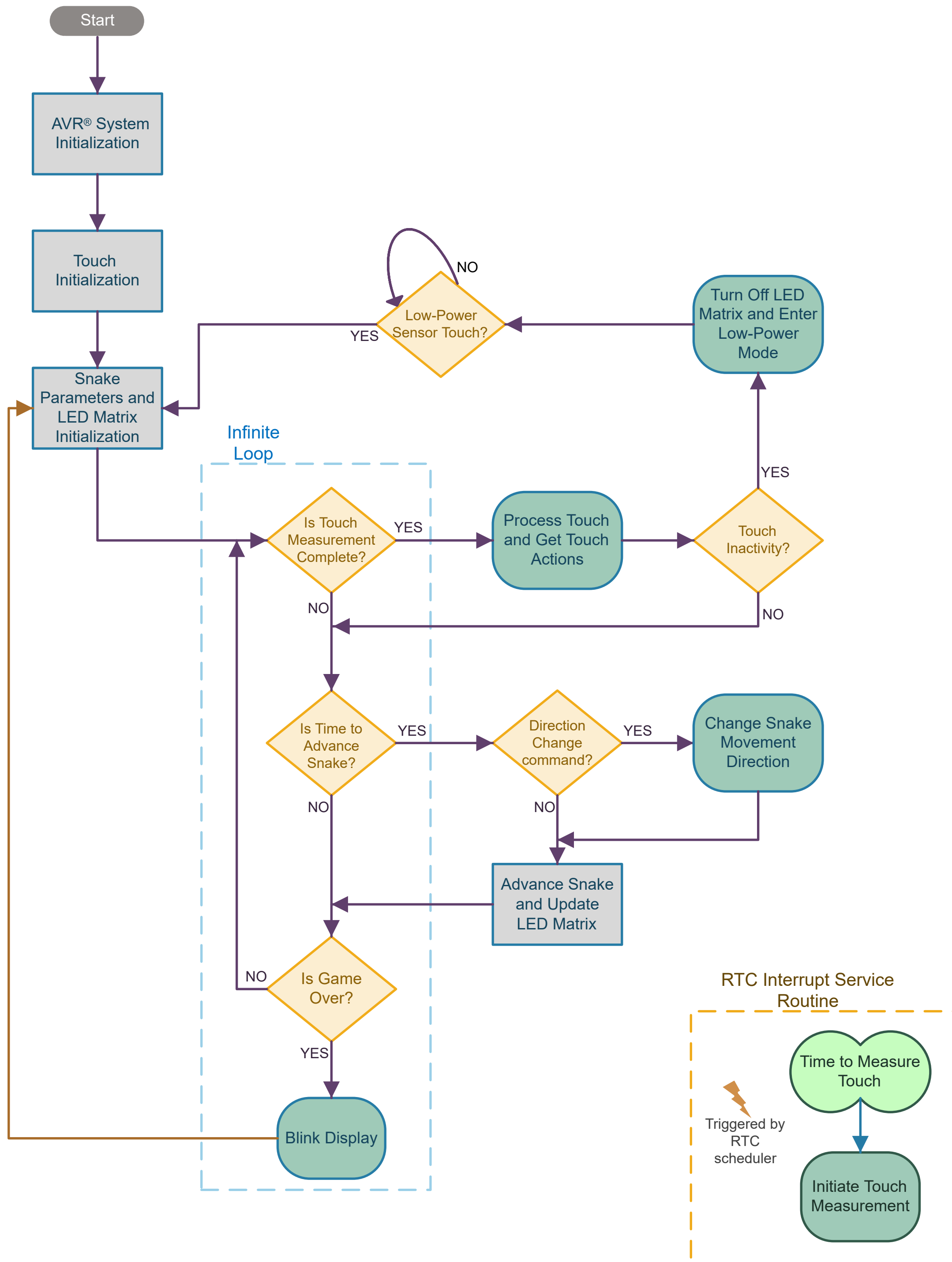
Table 6-1. Pin Details for Snake Game Demo

Serial Number	Pin Name	Port	Peripheral	Pin Function
1	SDA	PC2	TWI_0	LED Mux I^2C
2	SCL	PC3	TWI_0	LED Mux I^2C
3	X1	PD2	PTC	QT2 Touch X-line
4	X2	PD3	PTC	QT2 Touch X-line
5	X3	PA6	PTC	QT2 Touch X-line
6	X4	PD4	PTC	QT2 Touch X-line
7	Y1	PD6	PTC	QT2 Touch Y-line
8	Y2	PA5	PTC	QT2 Touch Y-line
9	Y3	PD7	PTC	QT2 Touch Y-line
10	Y4	PA4	PTC	QT2 Touch Y-line
11	Tx	PC1	USART_2	Debug UART
12	Rx	PC0	USART_2	Debug UART

7. Firmware

The application code for the demo is generated with Atmel START. Configuration of TWI, UART, and PTC peripherals, and Microchip Touch Library is done through Atmel START. The snake game algorithm and LED matrix driver application code are integrated into the firmware. The flow of the snake game demo application code is depicted in Figure 7-1.

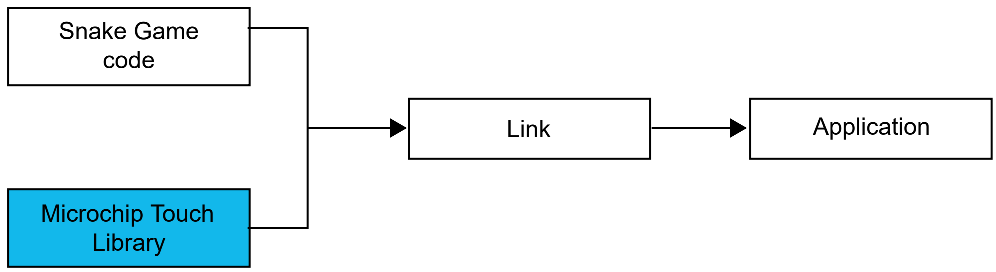
Figure 7-1. Application Flow Diagram



7.1 Microchip Touch Library

The Microchip Touch Library supports self-capacitance and mutual capacitance touch sensors on a selection of AVR, PIC, SAM, and PIC32 microcontrollers. It provides the required Application Programming Interface (API) for the PTC configuration, sensor data acquisition, and touch status update. The QTouch configurator (embedded into Atmel START) provides a seamless interface to incorporate the Microchip Touch Library into the user application.

Figure 7-2. Touch Library Usage



Note: Refer to the QTouch® Modular Library Peripheral Touch Controller User's Guide for more details.

7.2 Touch Surface Sensor Configuration

The QT2 Xplained Pro 2D surface is configured with the Atmel START for one-finger gesture detection. The various configuration parameters for sensors are shown in the table below:

Table 7-1. Touch Surface Sensor Configuration Parameters

Parameter	Value
Sensor type	Mutual capacitance
Touch measurement period	20 ms
Analog gain	1
Digital gain	2
Charge share delay	2
Filter level	16
Sensor threshold level	25
Surface resolution (Bits)	7 bits

7.3 Low-Power Touch Configuration

After the initialization of the sensors, the device starts with Active Measurement mode, by default. If there is no touch activity detected for 20 seconds, the device automatically switches to Low-Power mode. Before switching to Low-Power mode, the Event System is enabled, and the designated sensor is configured as a low-power sensor. This application demo uses all the channels lumped together, as a single node (Node_8), as a low-power sensor. This enables the microcontroller to wake-up from touch on the entire surface.

For more information on implementing the low-power touch application using PTC, refer to the Low-Power Touch Design guide. Table 7-2 shows the parameters configured for low-power touch detection.

Table 7-2. Low-Power Touch Sensor Configuration Parameters

Parameter	Value
Low-power/Auto-scan key	Lump node 8
Lump node X-lines	X21, X16, X6, X17
Lump node Y-lines	Y22, Y5, Y23, Y4
Lump node charge share delay	0
Low-power measurement period	64 ms
Touch inactivity time-out	20s
Drift measurement period	5s

7.4 Gesture Implementation

Out of all available gestures, the tap and swipe gestures are used in this application demo. The gesture configuration is as follows:

Table 7-3. Gesture Configuration Parameters

Parameter	Value
Tap time-out	200 ms
Swipe time-out	700 ms
Tap area	20
Horizontal and vertical swipe distance	30
Gesture measurement period	10 ms

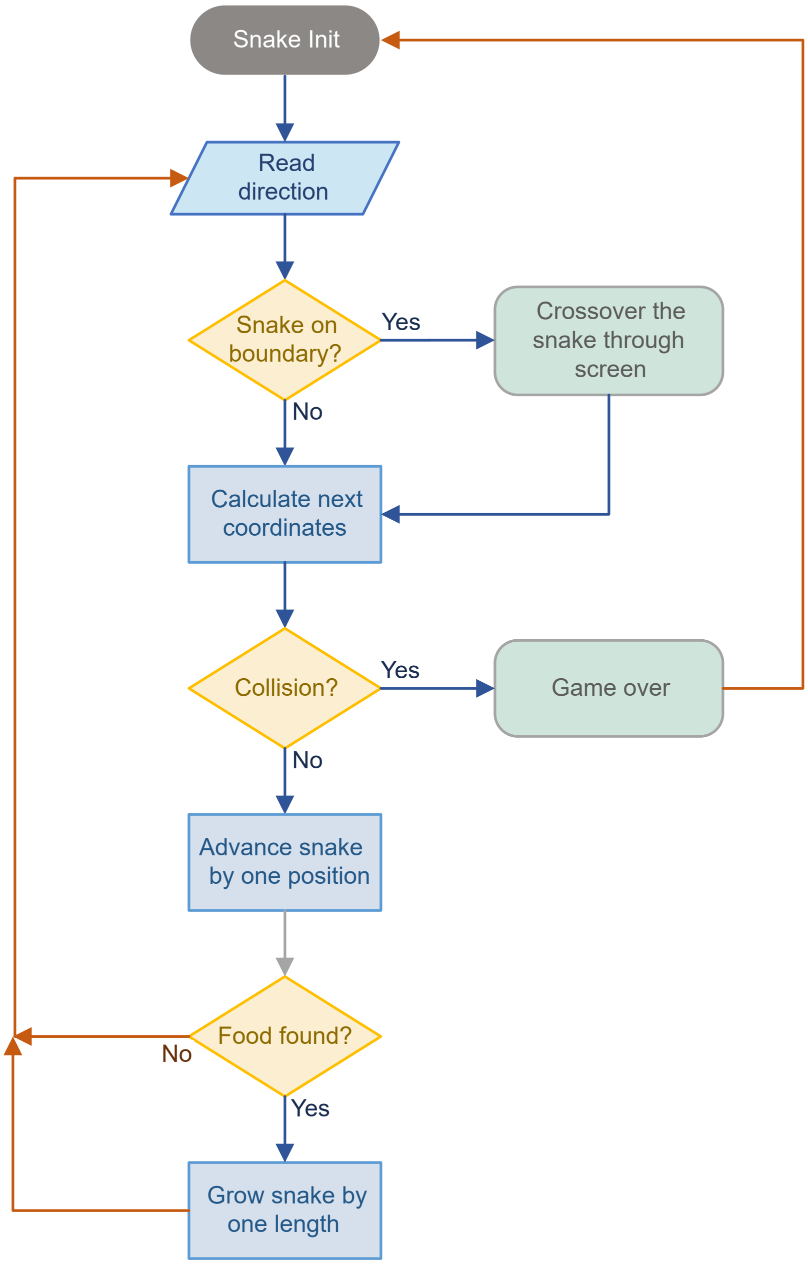
The gesture detection algorithm of the Microchip Touch Library detects valid tap and swipe gestures events (i.e., up, down, left, and right) on the touch surface. The appropriate gesture detect flag bit is set to a valid tap or swipe gesture event. The application code reads the gesture information and sets the snake direction according to the command received.

7.5 LED Matrix Driver and Snake Game Algorithm

All the LEDs on the QT2 Xplained Pro board are driven by the LED Matrix driver (IS31FL3728), which is controlled by the I^2C. For detailed instructions on how to interface the LED matrix driver, refer to the driver device data sheet at http://www.issi.com/. A suitable I^2C-based driver is implemented for the snake game demo. The led driver related code routines are available in the `LEDdriver.c` file.

A modular code is written for the snake game algorithm to demonstrate the capabilities of the touch surface. The snake algorithm related code routines are available in the `Snake.c` file. Figure 7-3 depicts the application flow for the snake game algorithm.

Figure 7-3. Snake Algorithm Flow Diagram



7.6 Software Tools

Microchip's Integrated Development Environments (IDEs), compiler, and graphical code generators are used throughout the application firmware development to provide a seamless user experience. Below are the tools used for this demo application:

- Atmel Studio 7.0.2397
- Atmel START
- AVR-Dx_DFP v1.0.21
- AVR GCC compiler

Note: For running the demo, the tool versions installed must be identical to the ones presented above or of later versions. This example is not tested with any previous versions of the tools.

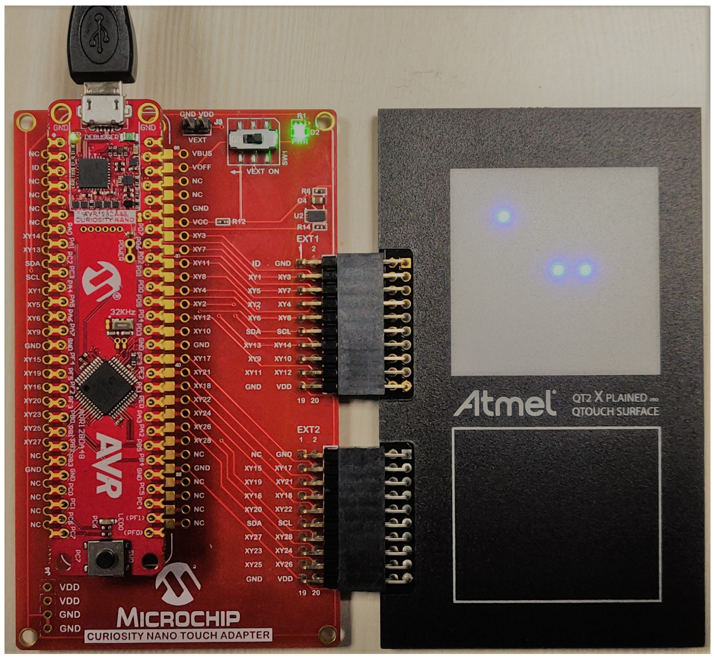
8. Demonstration Setup

The following swipe gestures can be used to steer the snake towards the food:

- Up
- Down
- Left
- Right

When the snake eats the food, its length increases. The demo goes into a Standby sleep mode if no activity is recorded for more than 20 seconds. To wake it up, a tap anywhere on the touch surface of the QT2 board is needed.

Figure 8-1. Snake Game Demo



9. Touch Surface Performance Measurement

This section provides measured data for the touch surface performance factors, such as Touch Response Time, CPU Utilization, Program and Data memory requirement, and power consumption of the touch surface solution. The measured data is only with the touch surface configuration and excluding the snake game functionality implementation.

The hardware used for measurement of the touch parameters is:

- AVR128DA48 Curiosity Nano development board
- Curiosity Nano Touch Adapter board
- QT2 Xplained Pro extension kit
- Power Debugger

9.1 Microcontroller Configuration Details

The table below details the operating conditions of the AVR128DA48 microcontroller and the peripherals configured for the snake game application.

Table 9-1. Microcontroller Configuration

Parameter	Value
Microcontroller	AVR128DA48
System Clock	24 MHz (OSCHF)
Microcontroller Operating Voltage	3.3V
RTC Clock	1 kHz (OSC32K / 32)
RTC Interrupt Period	20 ms
RTC Interrupt Period in Low-Power mode	5s
PTC Clock	2 MHz

9.2 Power Consumption

The power consumption values of the AVR128DA48 microcontroller is measured while the touch surface alone is configured and operating in active and sleep modes. Table 9-2 shows power consumption data in active and sleep modes.

Table 9-2. Touch Surface Current Consumption Data

Serial Number	State	Current
1	Active	5.7 mA
2	Low-Power without drift compensation	13 µA
3	Low-Power with drift compensation	31 µA

Note: The current consumption in Low-Power mode with drift is the average current consumed by the microcontroller during the standby period and the drift measurement period (5s).

9.3 Program and Data Memory

The table below displays the program and data memory required for the touch surface functionality with gesture implementation (excluding snake game functionality) and for various compiler optimization levels:

Table 9-3. Touch Surface Memory Consumption

Serial Number	Optimization Level	Program Memory	Data Memory
1	-O0	14510 bytes	830 bytes
2	-O1	12856 bytes	830 bytes
3	-O2	12932 bytes	830 bytes
4	-O3	13580 bytes	830 bytes
5	-Os	12874 bytes	830 bytes

9.4 Touch Response Time

Response time is the time required for the touch surface to respond to a finger touch event. This includes the time taken by the microcontroller to perform touch data acquisition on the surface sensor nodes and the post-processing of the acquired data to report a valid touch event. The number of touch events reported per second increases with lower response time.

Table 9-4. Touch Response Time

Serial Number	Touch Measurement Periodicity	Detect Integrator	Time Taken for One Measurement	Touch Response Time
1	20 ms	2	1.7 ms	5.1 ms

Note: The touch response time varies according to the Detect Integrator (DI) setting. To achieve optimum response time and touch sensitivity, the DI parameter needs to be adjusted according to the sensor design.

9.5 CPU Utilization

The time required for the post-processing phase of the touch surface measurement cycle gives the CPU utilization for touch measurement. The CPU utilization for touch detection is typically expressed as a percentage of measurement periodicity. The table below shows the CPU utilization of the touch application (excluding the snake game functionality) in active and sleep modes with different measurement period values:

Table 9-5. Touch Surface Application CPU Utilization

Serial Number	CPU State	Measurement Periodicity in Active Mode	Measurement Periodicity in Low-Power Sleep Mode	CPU Load
1	Active	20 ms	64 ms	9%
2	Sleep	20 ms	64 ms	0%
3	Active	40 ms	64 ms	5%
4	Sleep	40 ms	64 ms	0%

10. Snake Game Demo Performance Measurement

This section provides characterization data for the snake game application demo.

10.1 Microcontroller Configuration Details

The table below details the operating conditions of the AVR128DA48 microcontroller and the peripherals configured for the snake game application.

Table 10-1. Microcontroller Configuration

Parameter	Value
Microcontroller	AVR128DA48
System Clock	24 MHz (OSCHF)
Microcontroller Operating Voltage	3.3V
RTC Clock	1 kHz (OSC32K / 32)
RTC Interrupt Period	20 ms
RTC Interrupt Period in Low-Power mode	5s
PTC Clock	2 MHz

10.2 Power Consumption

Power consumption is greatly influenced by several factors, such as operating voltage, the frequency of operation, CPU active period, sleep mode, operating temperature, etc. In practical applications, usually, the microcontroller is put into sleep mode while CPU is idle and not performing any active computations. This minimizes the microcontroller's active period to a larger extent, thereby the microcontroller average power consumption is reduced.

The table below details the microcontroller power consumption for the snake game demo with the touch surface.

Table 10-2. Snake Game Demo Current Consumption

Serial Number	State	Current
1	Active	5.8 mA
2	Low-Power without drift compensation	13 μA
3	Low-Power with drift compensation	31 μA

Note:
The current consumption in Low-Power mode with drift is the average current consumed by the microcontroller during the standby period and the drift measurement period (5s). The microcontroller wakes up from Low-Power mode every five seconds for drift measurement of the sensor nodes.

10.3 Program and Data Memory

The program and data memory requirements for the application with various compiler optimization levels are shown in the table below.

Table 10-3. Snake Game Demo Memory Consumption

Serial Number	Optimization	Program Memory	Data Memory
1	-O0	22328 bytes	1216 bytes

...........continued

Serial Number	Optimization	Program Memory	Data Memory
2	-O1	16608 bytes	1216 bytes
3	-O2	16936 bytes	1216 bytes
4	-O3	18322 bytes	1216 bytes
5	-Os	16446 bytes	1216 bytes

11. References

1. AVR DA Product Family page
2. AVR128DA48 product page
3. Getting Started with Touch Using START
4. Microchip Touch Library
5. AVR128DA48 Curiosity Nano Evaluation Kit
6. QT2 Xplained Pro Extension Kit
7. Curiosity Nano Touch Adapter

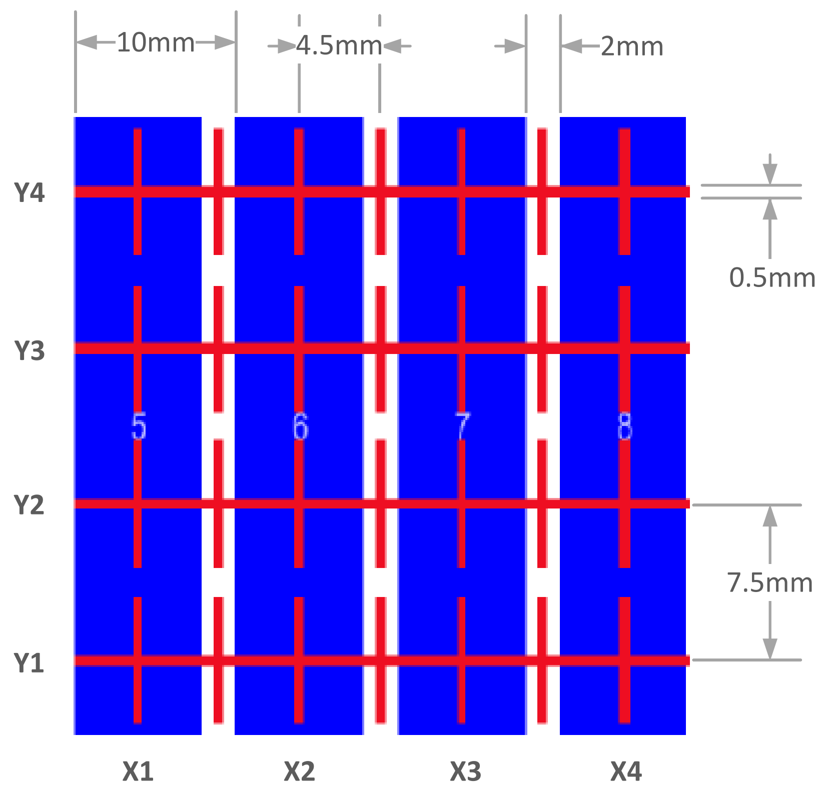
12. Appendix: QT2 Surface Sensor Design Specifications

The QT2 Xplained Pro features a 4 x 4 mutual capacitive touch surface. The sensor nodes for the touchpad are formed using the Flooded-X design layout. The QT2 Xplained Pro touchpad can be used as a touch surface, and it can also be configured as a 4 x 4 button array.

Table 12-1. Surface Design Parameters

Parameters	Value
Row pitch	7.5 mm
Column pitch	10 mm
Y-electrode width	0.5 mm
YY separation	4.5 mm
X-electrode width	8 mm
X-electrode spacing	2 mm
Front panel thickness	0.5 mm
Front panel material	Lexan (PC)

Figure 12-1. QT2 Sensor Node Arrangement



12.1 Touchpad Resolution

The resolution is the number of positions to be reported for each sensor area. Its value can range from two to 12 bits (i.e., four to 4096 positions).

The total resolution for X-axis = number of X lines x the number of positions for one sensor.

The total resolution for Y-axis = number of Y lines x the number of positions for one sensor.

Touchpad resolution (dpi) = number of sensors available in one-inch area x the number of positions for one sensor.

The number of sensors available in the one-inch area = one-inch area in mm / one sensor area in mm.

The QT2 Xplained Pro extension board is used as a touch surface in this application. On it, one sensor area is 8 mm x 8 mm, and the firmware uses a 7-bit position resolution. Using the above calculation, the touchpad resolution for the QT2 touch surface design adds up to 102 dpi.

Table 12-2 shows the position and resolution that is possible with a 4X x 4Y sensor configuration, with one sensor area of 8 mm x 8 mm and for different resolution inputs.

Table 12-2. Touch Surface DPI Calculation

Sr. No.	Resolution	X-Axis Positions	Y-Axis Positions	Touchpad Resolution (dpi)
1	6 bits	64	64	51
2	7 bits	128	128	102
3	8 bits	256	256	203

13. Revision History

Doc. Rev.	Date	Comments
B	05/2020	Updated AVR® MCU DA (AVR-DA) to AVR® DA MCU, and AVR-DA to AVR DA, per latest trademarking.
A	03/2020	Initial document release

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