Piano and Dimming Light Using Ultra Low-End MCU and Electric-Field Sensor

Designer Reference Manual

RS08
Microcontrollers

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Piano and Dimming Light Using Ultra Low-End MCU and Electric-Field Sensor

Designer Reference Manual

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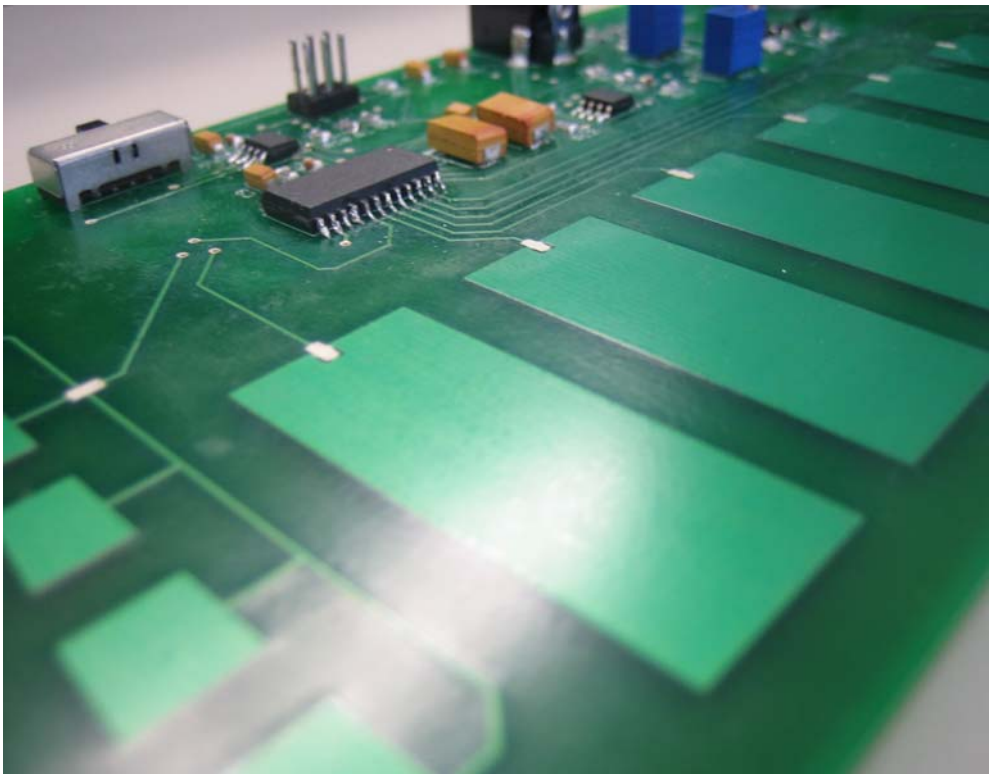

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The following revision history table summarizes changes contained in this document. For your convenience, the page number designators are linked to the appropriate location.

Revision History

Date	Revision Level	Description	Page Number(s)
07/2006	0	Initial release	N/A

Chapter 1
Designer Reference Manual Usage Notes

Chapter 2
Hardware Description

Chapter 3
Firmware Description

Appendix A BOM and Schematics

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Chapter 1
Designer Reference Manual Usage Notes

1.1 Intended Application Functionality

This reference design demonstrates the application of Freescale's MC9RS08KA2 microcontroller and the MC34940 electrical field. This demonstration shows the connection between MC9RS08KA2 and the electrical-field sensor.

This demonstration can play seven musical notes (C, D, E, F, G, A, B) and be heard in a buzzer. A switch can change a piano function to a dimmer-light function with one electrode divided into five parts of varying intensity. One electrode connects to the electrical field when the demonstration works on a dimmer function. When the demonstration works in piano function, the electrical field is connected to seven electrodes.

The MC9RS08KA2 PADL reference design is intended for the toy industry and for use in some lighting devices (for example, lamps).

1.2 Quick Start

The demonstration shows the connection between the MC9RS08KA2 ultra low-end, 8-bit microcontroller and the MC34940, an electrical-field imaging device.

1.2.1 System Requirements

This demonstration needs only a 12 V DC external power supply to work properly.

1.2.2 MC9RS08KA2 PADL Setup

The MC9RS08KA2 PADL demonstration requires no setup. The board is distributed with the application loaded in the MC9RS08KA2 flash memory. Changing between functions depends on the switch position. Figure 1-1 and Figure 1-2 are pictures of the reference design board.

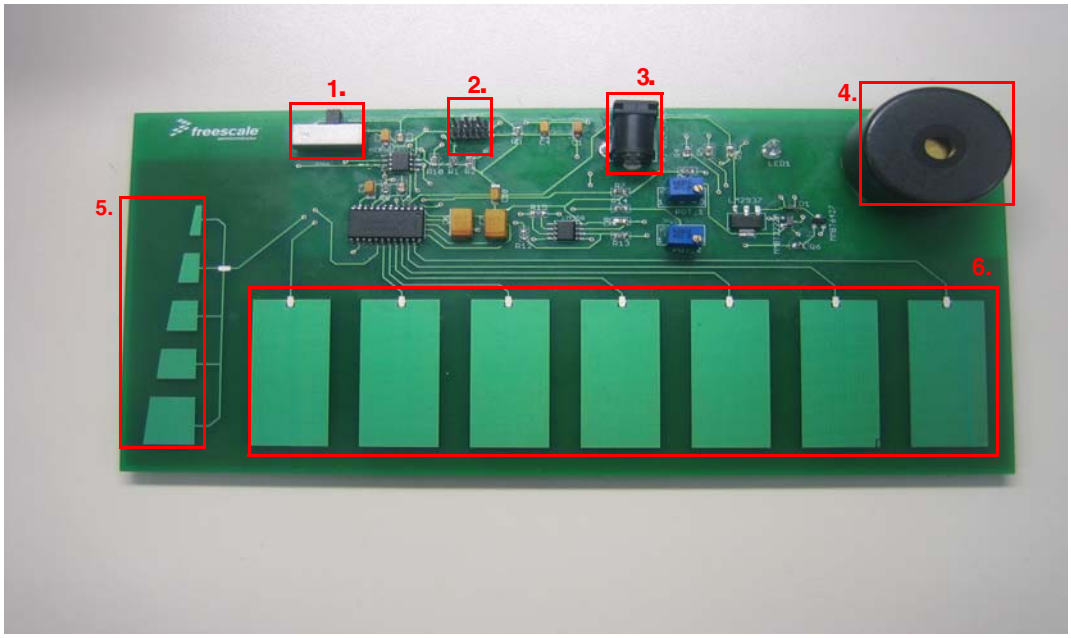

Figure 1-1. MC9RS08KA2 PADL Board (Front)

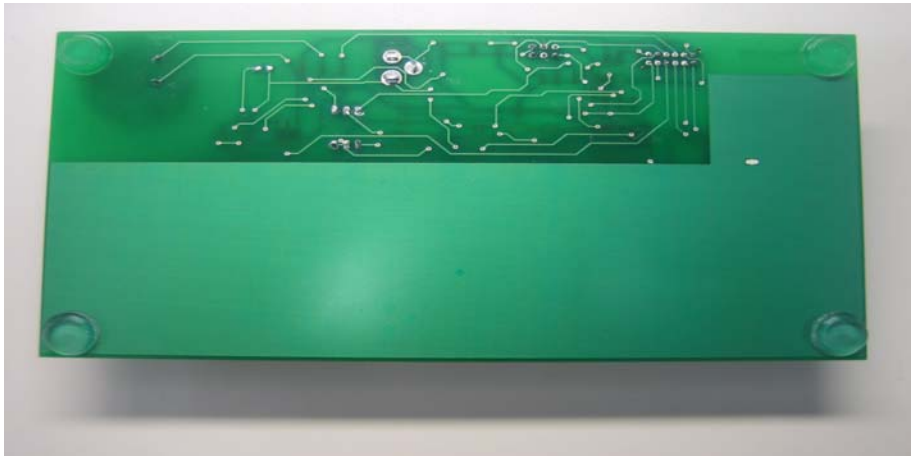

Figure 1-2. MC9RS08KA2 PADL Board (Back)

1. Switch — Selects between piano and dimmer light.
2. BDM connector
3. Power supply
4. Buzzer
5. Dimmer electrodes
6. Piano electrodes

To run the demonstration:

1. Put the switch in position 1 or position 2.
   a. Position 1 selects dimming mode.
   b. Position 2 selects piano mode.
2. Connect the 12 V DC power supply to the demo board.
3. Start pressing the electrodes.

Chapter 2 Hardware Description

2.1 Introduction

This section describes the module design and features.

Figure 2-1 shows the basic blocks of each reference design component.

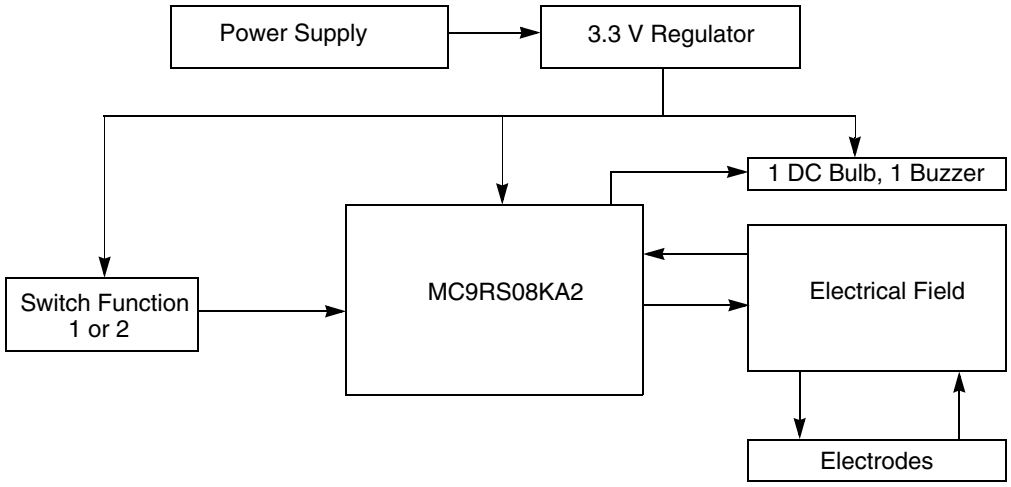

Figure 2-1. MC9RS08KA2 PADL Building Block

This demo has two functions (both use the electrical-field sensor):

- Piano
- Light dimmer

2.1.1 Piano Function

In the piano function, MC9RS08KA2 is connected to the electrical field (MC34940), the seven electrodes (from the seven different musical notes), and a buzzer (Figure 2-2).

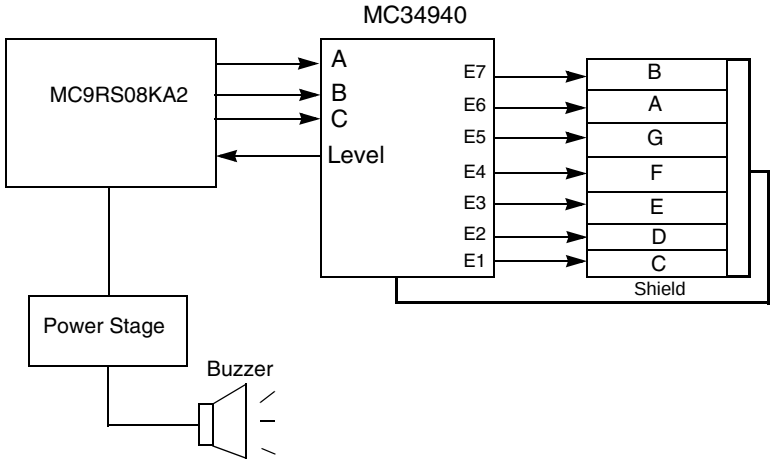

Figure 2-2. MC9RS08KA2 PADL Function 1 Logic Diagram

2.1.2 Dimmer Light Function

When the demo runs in dimmer light function, the MC9RS08KA2 MCU is connected to an electrical field and DC bulb. The electrical field is also connected to a divided electrode. Figure 2-3 shows the logic block diagram for function 2.

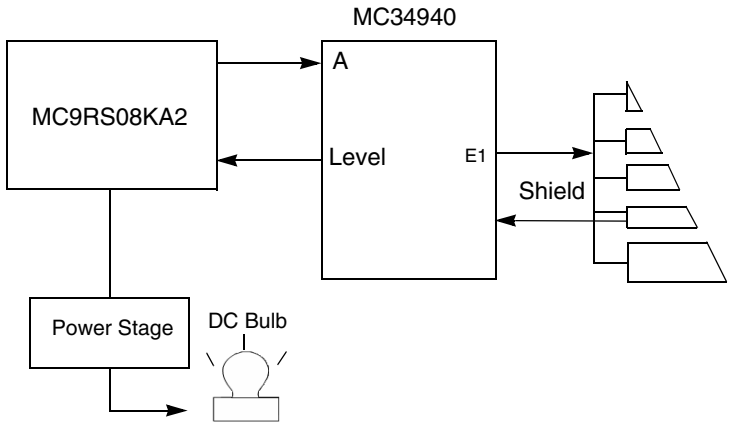

Figure 2-3. MC9RS08KA2 PADL Function 2 Logic Diagram

2.2 Technical Data

This section provides technical details of the MC9RS08KA2 PADL and components in this reference design.

2.2.1 MC9RS08KA2 Microcontroller Unit

The MC9RS08KA2 is the control unit for the PADL and part of the RS08 family.

MC9RS08KA2 features:

- 8-bit RS08 CPU
  – Analog comparator (ACMP)

  - Keyboard interrupt (KBI)
  - Pending interrupt indication
  - Background debug mode (BDM)
- Reset, clock, COP watchdog
- 6-bit port with digital filtering and programmable rising- or falling-edge trigger
- Memory
  - 2K flash EEPROM
  - 63 bytes RAM

MC9RS08KA2 functions:

- Controls the MC34940 (electrical field)
- Generates the pulse width modulation (PWM) for the dimming light and musical notes
- Switches between PADL functions
- Processes data

2.2.2 Electrical-Field Imaging Device (MC34940)

MC34940 is a sensor that detects objects in an electrical field. In this demonstration, it detects the user's hands.

Features:

- Supports up to nine electrodes and two references or electrodes
- Shield driver for driving remote electrodes through coaxial cables
- Lamp driver output
- Watchdog and power-on reset timer
- High-purity sine wave generator tunable with external resistor

Function:

- Relays electrode status to microcontroller

2.3 MC9RS08KA2 PADL Reference Design Architecture

2.3.1 MC9RS08KA2

The MC9RS08KA2 controls the application.

The application occupies these modules:

- General-purpose input/output pins (GPIO)
- Analog comparator (ACMP)
- Modulo timer (MTIM)

2.3.2 Electrical Field (MC34940)

The MC34940 generates a low radio frequency sine wave with nominal 5 V peak-to-peak amplitude. An internal multiplexer routes the signal to one of seven terminals under the ABC input terminals. A receiver multiplexer connected to the selected electrode simultaneously routes its signal to a detector that converts the sine wave to a DC level. The DC level is filtered by an external capacitor, and that value is multiplied so the value offset is less sensitive to objects near the signal.

A capacitor is formed between the driving electrode and the object, each forming a plate that holds the electrical charge. The voltage measured is an inverse function of the capacitance among the electrode being measured, the surrounding electrodes, and other objects in the electrical field surrounding the electrode. Increasing capacitance decreases voltage.

The basic building block for these devices is found in Figure 2-4 and shows its connections and functionality, the shield module, and the electrode select.

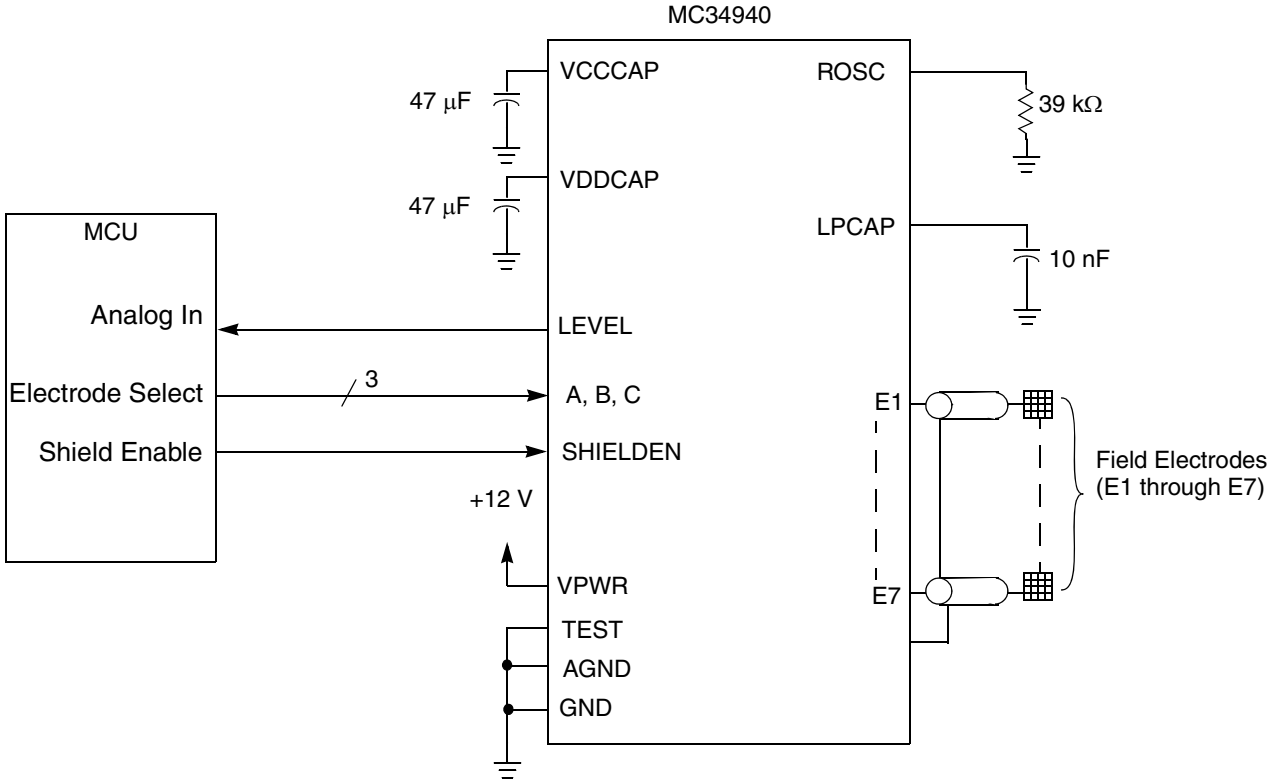

Figure 2-4. Electrical-Field Building Block

2.4 Board Layout

The detailed layout, schematic, and bill of materials (BOM) of the MC9RS08KA2 PADL reference design are shown in this section.

2.4.1 PADL Components Board

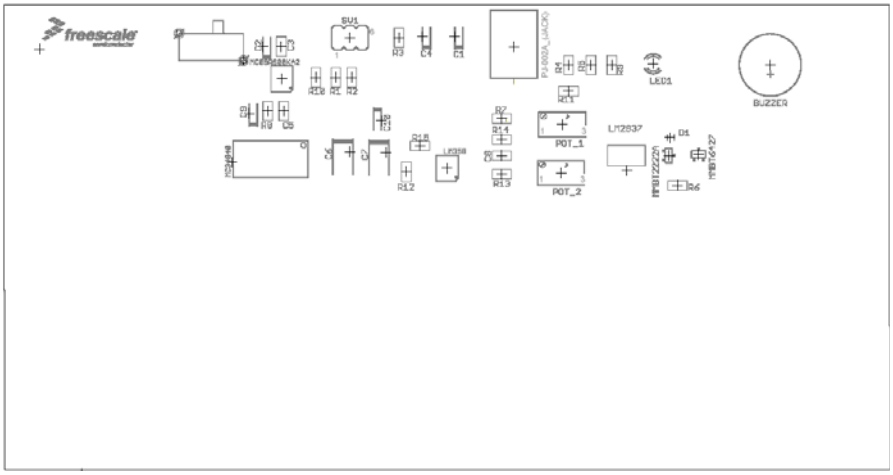

Figure 2-5. PADL Component Side

2.4.2 General Layout Explanation

The circuit board layout considerations are dominated by:

- Minimizing size
- The need to conduct high currents into the module, to the power drivers, and then out of the module

2.4.3 PCB Board Size

The circuit board size is 7.1 x 3.8 inches.

2.4.4 Component Placement

Before laying out the PCB, components were placed on the PCB. Figure 2-6 shows the separated main blocks. Low-level analog, digital circuitry, and high-current switches were separated to maintain signal integrity.

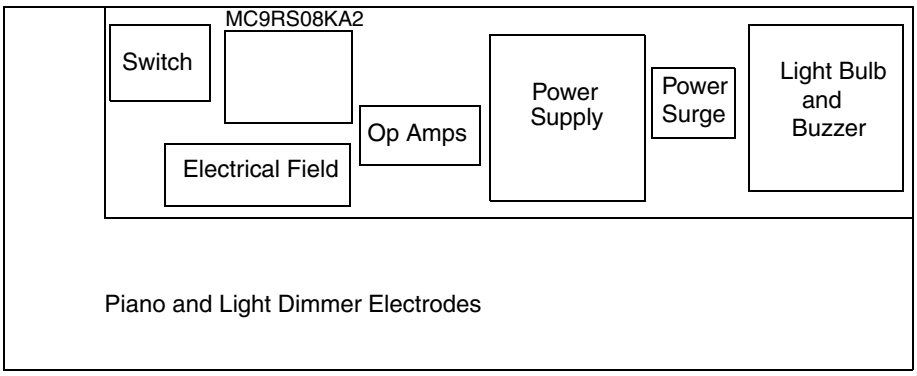

Figure 2-6. PADL Board and Main Blocks

- BDM Connector—Near the MC9RS08KA2 microcontroller.
- Power Stage Block—Digital devices are separated from the high-current management blocks.
- Electrical-Field Footprints—Electrodes must be near the electrical-field electrodes to avoid parasite capacitance.
- Via Dimensions and Spacing—Electrode spacing is 244 mil. The electrode width is 636 mil, and the electrode height is 1476 mil. The vias spacing is 35 mil.

2.4.5 Layout Layers

2.4.5.1 Top Layer

The low-analog and digital signals are separated from battery and high current traces to avoid interference between the signals; the signals from the piano and dimmer electrodes are near the electrical-field device.

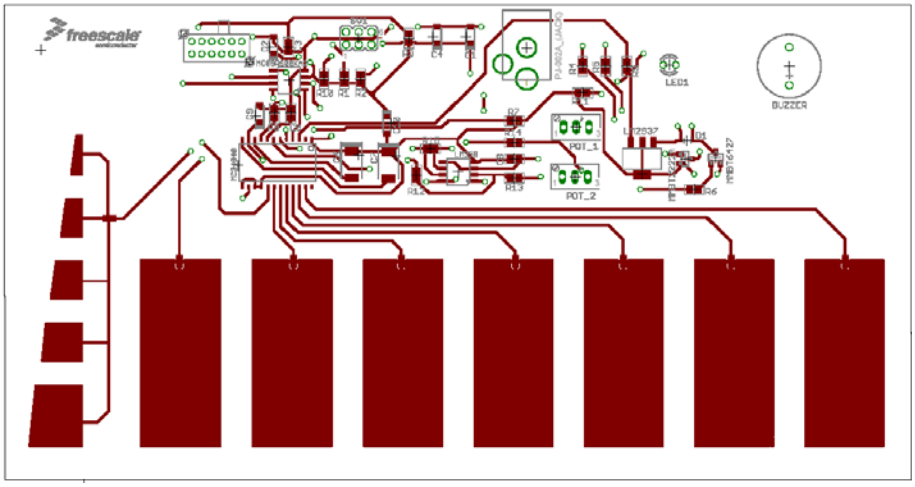

Figure 2-7. Top Layer

2.4.5.2 Bottom Layer

Similar to the top layer, the low-analog and digital signals are separated from battery and high current traces to avoid interference between the signals (Figure 2-8).

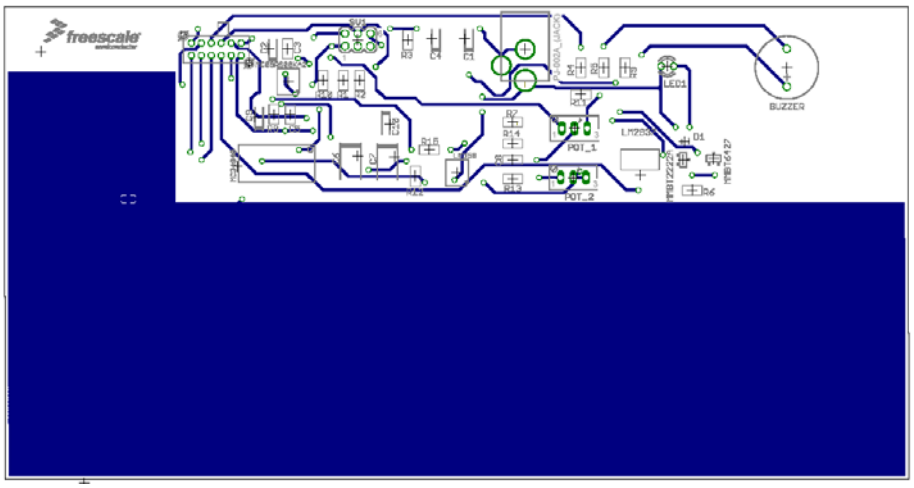

Figure 2-8. Bottom Layer

Chapter 3 Firmware Description

3.1 Introduction

This section describes MC9RS08KA2 PADL firmware.

3.1.1 Firmware Basics

This project was written using the CodeWarrior™ V 5.1 development tool. The application source file for this demo was written in assembly language.

3.1.2 Application Basics

The application demonstrates how to connect the MC9RS08KA2 to the MC34940.

3.2 Project Introduction

This section introduces and describes firmware implementation of the PADL project.

3.2.1 Coding Convention

All source code was written using guidelines to make the final product more readable.

The most important guidelines:

- Variables—Begin in uppercase to distinguish between words.
- Subroutines—In uppercase only at the beginning and are underscored to distinguish between words.
- Macros—Uppercase; underscores distinguish between words.
- Tags—In the first column of every row.

3.2.2 List of Project Files

These files are required for the project:

- Project files—PADL.mcp is the CodeWarrior Project file.
- Configuration files—MC9RS08KA2.inc contains definitions. Derivative.inc contains watchdog feed macro.
- Application source files—Main.asm contains the demonstration's main application.

3.2.3 MCU Peripherals

This section briefly describes the RS08 peripherals used in the project and summarizes the necessary microcontroller resources.

The MC9RS08KA2 MCU is used in this demonstration with the SOIC 8-pin package.

3.2.3.1 GPIO Module

If the demonstration is in piano mode, the GPIO module is configured as follows:

- Outputs—PTA1 (pin 7), PTA3 (pin 2), PTA4 (pin 6), and PTA5 (pin 5).
- Inputs—PTA0 (pin 8) and PTA2 (pin 1).

PTA3, PTA4, and PTA5 are the selectors of electrodes.

PTA1 is the PWM output (this signal goes to a buzzer create a sound).

PTA2 selects between function 1 and function 2.

PTA0 goes to the level signal; it indicates whether an electrode was pressed.

If the demonstration is in dimmer mode, the GPIO module is configured:

- Outputs—PTA1 (pin 7) and PTA4 (pin 4).
- Inputs—PTA0 (pin 8) and PTA2 (pin 1).

PTA1 is needed to discharge a capacitor. This is necessary to emulate an ADC.

PTA4 is the PWM output (this signal goes to a DC bulb).

PTA0 is an input for the level signal; it goes to the ACMP.

PTA2 selects between function 1 (piano) and function 2 (dimmer).

3.2.3.2 ACMP Module

The ACMP module is configured for only the dimmer light. When the ACMP— is greater than ACMP+, an interrupt generates. With this we can determine the ADC value.

ACMP+ is located in pin number 8 (PTA0).

ACMP– is located in pin number 7 (PTA1).

3.2.3.3 MTIM Module

The MTIM module emulates the ADC. The MTIM interrupts every 1 ms; this configuration works only for function 2. In function 1, the module interrupts every 40 counts.

3.2.4 Software Interrupts

See Table 3-1 for software interrupts used in the MC9RS08KA2 PADL.

Table 3-1. Interrupts

Module	Type of Interrupt	Purpose
ACMP	Asynchronous	Verify whether ACMP– is above ACMP+
MTIM	Asynchronous	Generate PWM

3.2.5 Main Variables of the Project

These variables control module functionality:

- Var
- Times
- SensorReading
- C1
- C2
- CountsSet
- CounterClr
- CounterL
- Counts
- PCBuffer

3.2.6 Memory Usage

Table 3-3 shows software memory usage of the MC9RS08KA2 PADL.

Table 3-2. Memory Usage

Memory Type	Total Size (Bytes)	Used Memory (Bytes)	Free Memory (%)
Flash	2048	491	Approx. 77%
RAM	63	11	Approx. 82%

3.3 Firmware Implementation

This section contains the complete description of the firmware included with the board.

3.3.1 Application

When the switch is in position 1 (logic level 0), the application works on the piano demonstration. This function selects one of the seven electrodes and knows which was pressed (Figure 3-1and Figure 3-2).

The application switches three pins (PTA3, PTA4, and PTA5) from 001 to 111 (see Figure 3-1, Figure 3-2, and Table 3-3); this signal is sent to the electrical field and then selects an electrode to read the level voltage. This is the main loop from this firmware section.

NOTE

The signals A, B, and C can be switched at least 2 ms after the last changes were made.

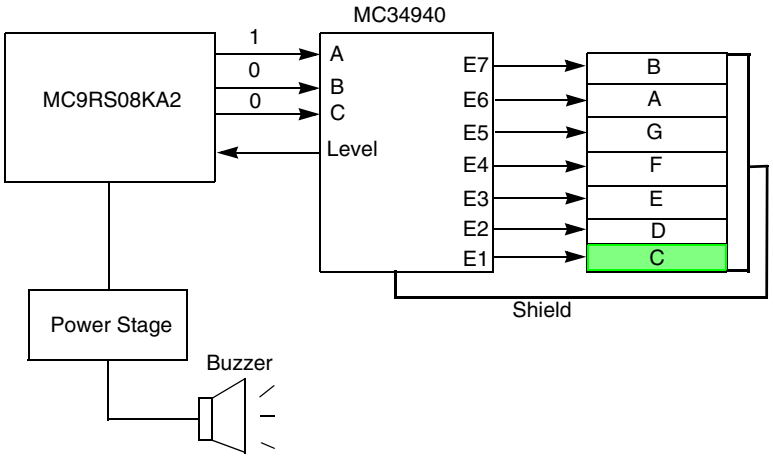

Figure 3-1. MC9RS08KA2 Piano and Dimming Switches Signals

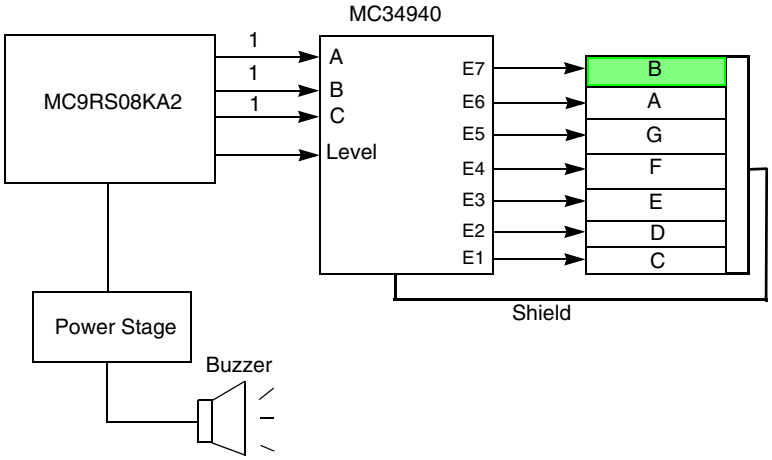

Figure 3-2. MC9RS08KA2 Piano and Dimming Switches Signals

Table 3-3. Signals Switch to Select a Pad

Microcontroller Signals			Electrical-Field Signals	
A	B	C	Selected Pad	
0	0	1	E1	C
0	1	0	E2	D
0	1	1	E3	E
1	0	0	E4	F
1	0	1	E5	G
1	1	0	E6	A
1	1	1	E7	B

After the electrode is selected, it is assigned the number of counts necessary to generate a musical note. The counts and the MTIM (configured with a prescaler of 1 and 40 counts before interrupts) generate the PWM. The PWM subroutine requires the pulse in the middle of the period (Figure 3-2). If the pulse is not generated at the middle of the period, the resulting frequency is incorrect for the required note.

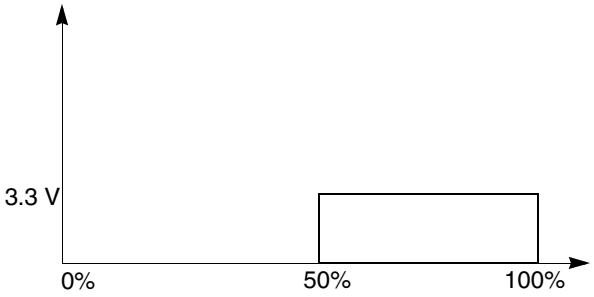

Figure 3-3. MC9RS08KA2 Piano and Dimming Light PWM

After the sound is generated, the application reads PTA2 and executes the function depending on the switch position.

If the switch changes to position 2 (logical level 1), the application works on the dimmer light. For this part of the firmware only one electrode is selected (signal A is active, signal C is set to GND). When the electrode is pressed, the ACMP detects the voltage change. Then a value is read from the ADC. This value is used to make a PWM and reveal the intensity light in a DC bulb. This application has only five light intensities.

For more information about the firmware, refer to Figure 3-3.

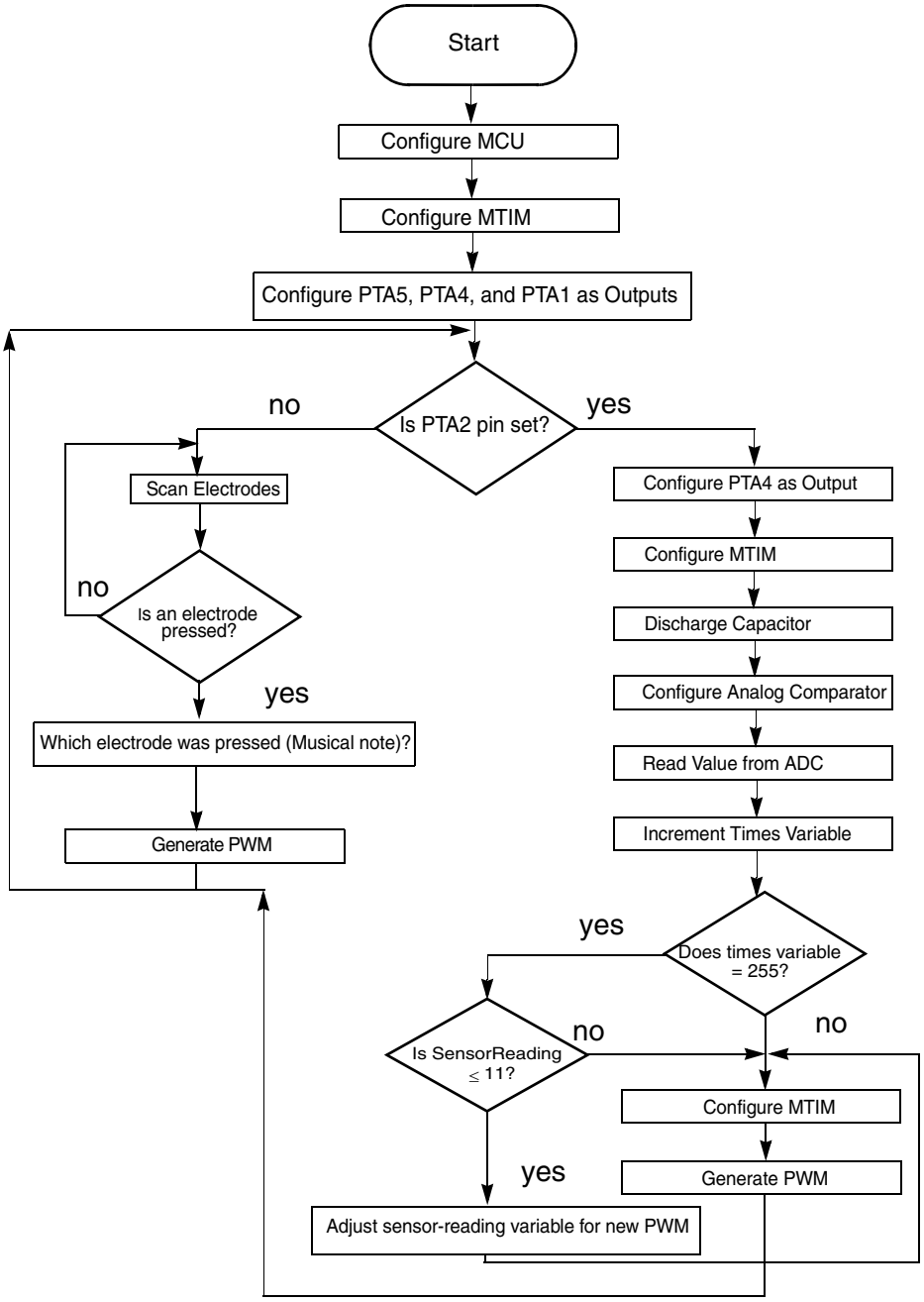

Figure 3-4. MC9RS08KA2 PADL Flowchart Diagram

Appendix A. BOM and Schematics

Table A-1. MC9RS08KA2 PADL Reference Design Bill of Materials

Item	QTY	Reference	Description	Manufacturer	Part Number
1	3	C3,C5,C8	0.01µ	KEMET	399-1158-1-ND
2	3	C1,C4,C9	0.1 µ	KEMET	399-3676-1-ND
3	2	C2,C10	10 µ	KEMET	399-3687-1-ND
4	2	C6,C7	47 µ	KEMET	7343-31(D-EIA)
5	1	R5	120 Ω	Rohm	RHM120CC-ND
6	3	R4,R6,R7	1 kΩ	Panasonic	P1.0KACT-ND
7	2	R10,R11	2.2 kΩ	Yageo	311-2.2KARCT-ND
8	1	R8	39 kΩ	Yageo	311-39.0KCRCT-ND
9	2	R2,R9	47 kΩ	Yageo	311-47KARCT-ND
10	6	R1,R3,R12,R13, R14,R15	10 kΩ	Yageo	311-10.0KCRCT-ND
11	2	NU	Pot 100 kΩ	Bourns	3266W-104-ND
12	1	NU	Lm358DR – Op Amp	3-M	296-1014-1-ND
13	1	NU	EG4208 – Switch	E-Switch	EG1914-ND
14	1	NU	MMBT6427 – NPN Darlington	Fairchild Semiconductor	MMBT6427-FSCT-ND
15	1	NU	Microcontroller	Freescale Semiconductor	MC9RS08KA2
16	1	NU	Electrical Field	Freescale Semiconductor	MC34940
17	1	NU	MMBT2222A – BJT	Fairchild	MMBT2222A-FDICT-ND
18	1	NU	B0520WS-7-F – Diode	Taiwan Semiconductor	B0520WS-FDICT-ND
19	1	NU	Buzzer	Mallory	458-1064-ND
20	1	NU	7219 – Bulb	Chicago Miniature	CM7219-ND
21	1	NU	LM2937IMP-3.3 – 3.3V Regulator	National Semiconductor	LM2937IMP-3.3CT-ND
22	1	NU	PJ-002A – DC Power Jack	CUI Inc	CP-002A-ND

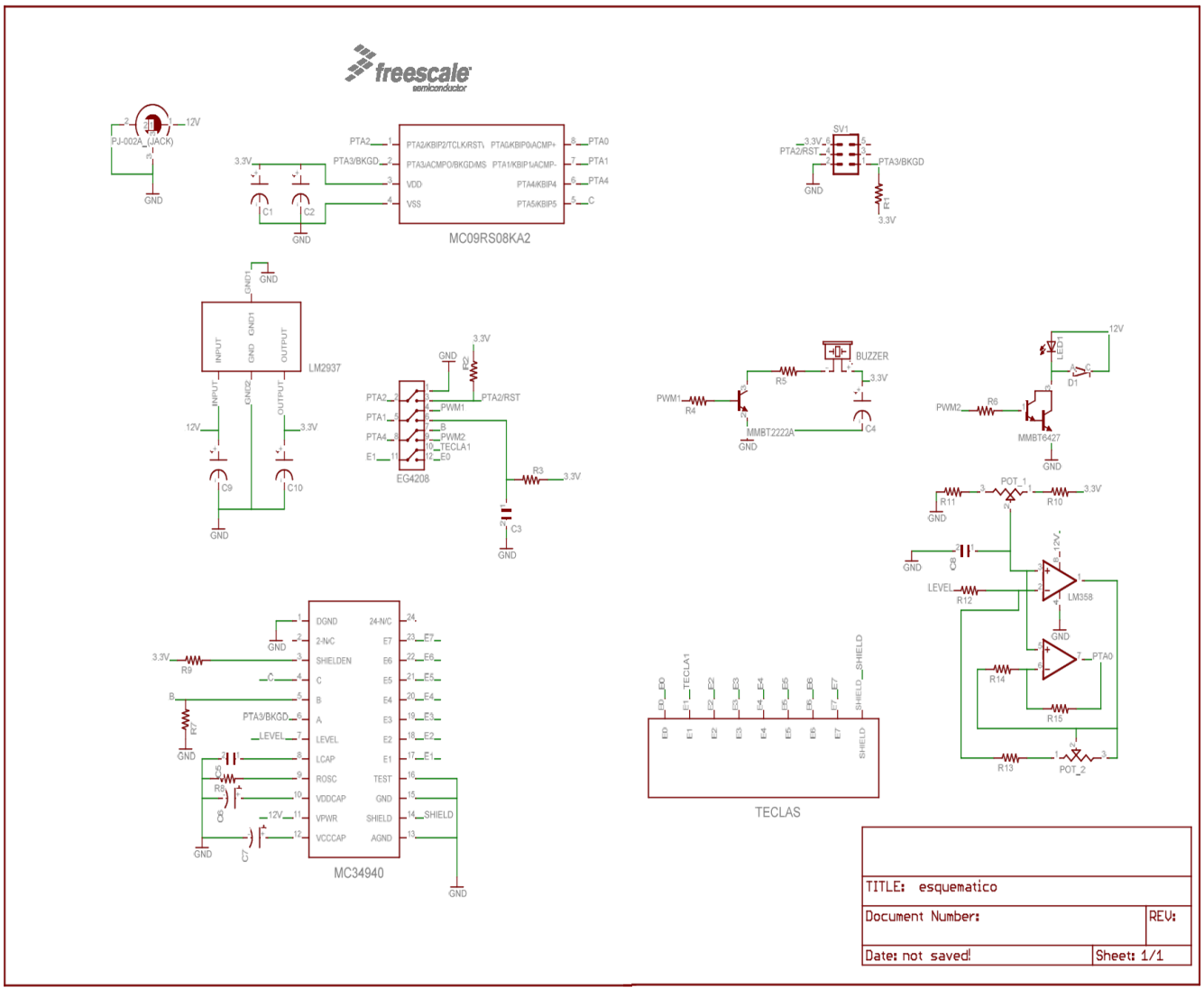

Figure A-1. PADL Block Diagram Schematic

Appendix B. Glossary

- ACMP – Analog comparator module. It provides a circuit to compare two analog inputs' voltage or one analog input's voltage to an internal reference.
- ADC – Analog to digital converter.
- Binary – Relating to the base 2 number system.
- Bit – A binary digit that has a value of logic 0 or logic 1.
- Byte – A set of 8 bits.
- DC – Direct current.
- EEPROM – Electrically erasable and programmable, read-only memory.
- Firmware – Instructions and data that control the operation of a microcontroller.
- MCU – Microcontroller unit, which is a complete computer system, including a CPU, memory, a clock oscillator, and Input/Output (I/O) on a single integrated circuit.
- PADL – Piano and dimming light.
- Port – A set of wires for communicating with off-chip devices.
- Prescaler – A circuit that generates an output signal related to the input signal by a fractional scale such as 1/2, 1/8, 1/10, etc.
- PWM – Pulse width modulation.
- Toggle – To change the state of an output from logic 0 to logic 1 or from logic 1 to logic 0.
- VBatt – Battery voltage.

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