Electric-Field Contact-less Sensing System

Designer Reference Manual

MC33794 (Electric-Field Sensing IC)

APPEFIELDRM Rev. 0
09/2006

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Designer Reference Manual

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Revision History

Date	Revision Level	Description	Page Number(s)
09/2006	0	Initial release	52

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Chapter 1
Introduction

1.1 Contents

1.2 Introduction

This reference manual describes the design and features of an Electric-Field Contact-less Sensing System based on Freescale's MC33794 (Electronic Field Imaging Device).

The MC33794 is intended for cost-sensitive applications where non-contact sensing of objects is desired. When connected to external electrodes, an electric field is created. The MC33794 is intended to detect objects in this electric field. The IC generates a low-frequency sine wave, adjustable by using an external resistor, and is optimized for 120 kHz. The sine wave has very low harmonic content to reduce harmonic interference.

The MC33794 also contains support circuits for a microcontroller unit (MCU) to allow the construction of a two-chip E-field system.

MC33794 features

- Supports up to nine Electrodes and two References or Electrodes
- Shield Driver for Driving Remote Electrodes Through Coaxial Cables
- +5.0 VDC Regulator to Power External Circuit
- ISO-9141 Physical Layer Interface
- Lamp Driver Output
- Watchdog and Power-ON Reset Timer
- Critical Internal Nodes Scaled and Selectable for Measurement
- High-Purity Sine Wave Generator Tunable with External Resistor
- Response Time Tunable with External Capacitor

Typical Applications

- Appliance Control Panels and Touch Sensors
- Linear and Rotational Sliders
- Spill Over Flow Sensing Measurement
- Refrigeration Frost Sensing
- Industrial Control and Safety Systems Security
- Proximity Detection
- Touch Screens
- Liquid Level Sensing

The Electric-Field Contact-less Sensing System is based on this MC33794 device. This application is controlled by a low cost 8-bit microcontroller, the MC68HC908QB8. This E-Field demonstrator detects human touch through glass and measures the level of water in a water column. An illustration of the system configuration is shown in Figure 1-1 System Configuration.

The Electric-Field Contact-less Sensing System has the following features:

- Detecting human touch (Touchpad, Slider) and water level detection (Water pump, Water slider) using Freescale MC33794 E-Field sensor
- Freescale MC68HC908QB8 8-bit microcontroller
- Freescale MC33993 MSDI (Multiple Switch Detection Interface)
  - driving LEDs
  - interfaces directly with the microcontroller using SPI protocol
- Freescale MC33886 H-Bridge used as a water pump motor driver
- Connection with PC via RS232
- Option of installing a Dual Op-Amp to amplify weak E-Field signals
- 7-segment numeric LED display, LED Bar-Graph
- Input supply voltage +12V DC / 2A
- Audio Buzzer

Figure 1-2 Electric-Field Contact-less Sensing System shows the board layout with description of the components.

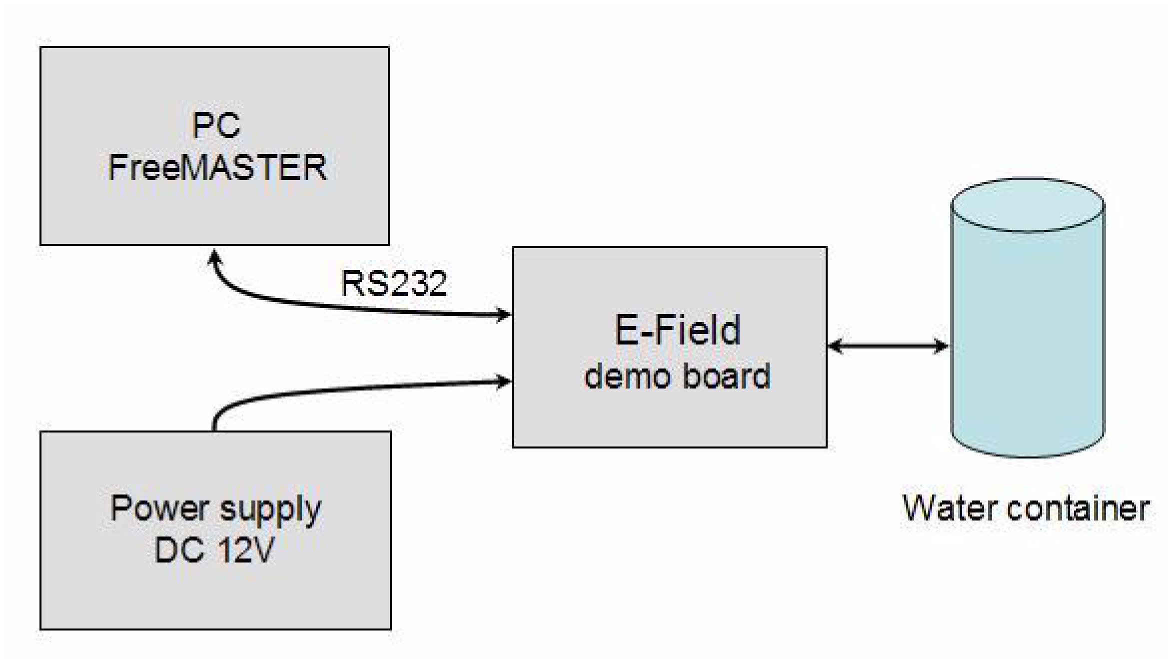


Figure 1-1. System Configuration

1.3 About this Manual

Key information can be located at the following location in this manual:

- Setup instructions are found in Chapter 6 Application Setup
- Pin-by-pin descriptions are contained in Tables 4-4 to 4-6
- For those interested in the reference design aspects of the board's circuitry, a description is provided in Chapter 5 Software

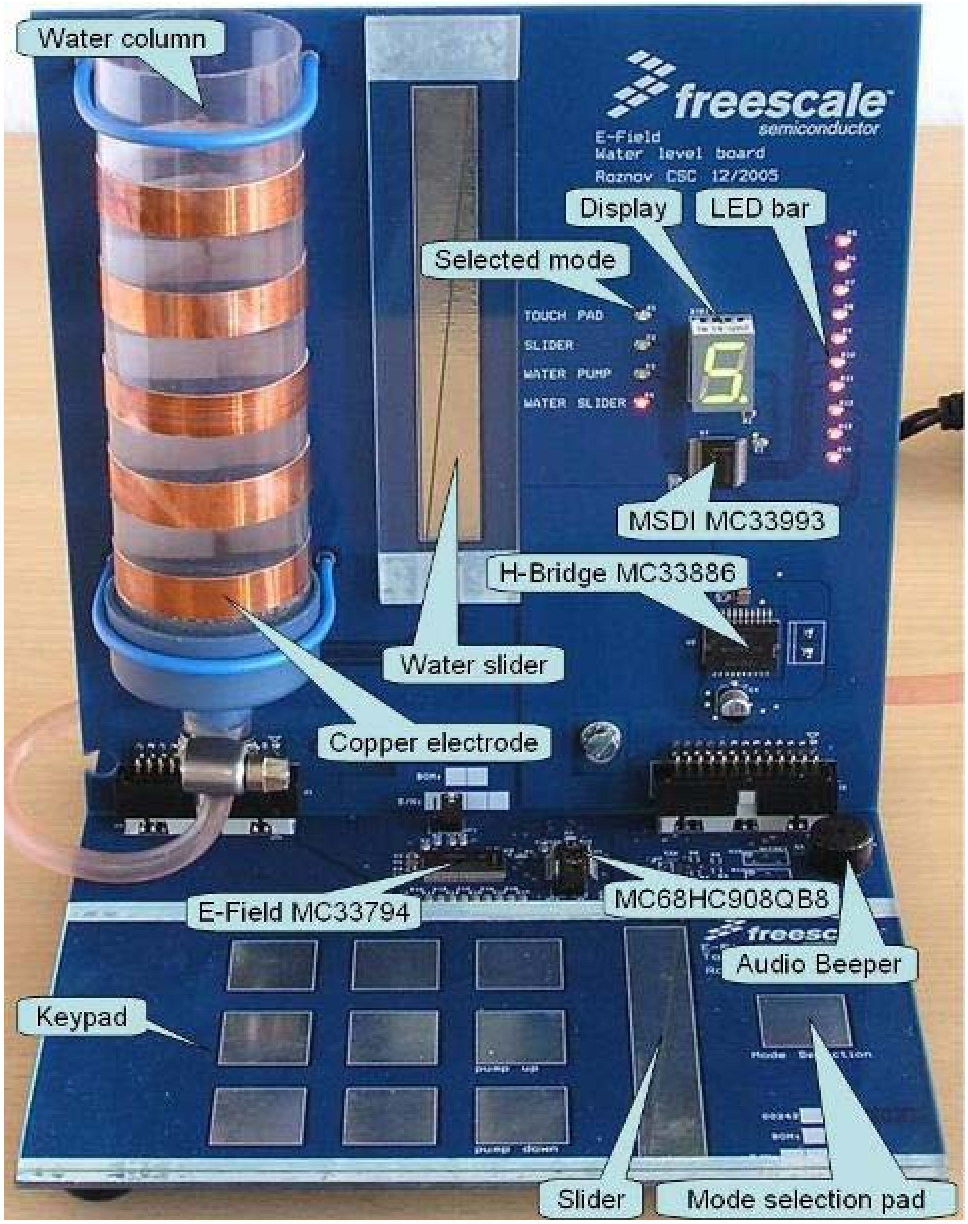


Figure 1-2. Electric-Field Contact-less Sensing System

Chapter 2
Theory

2.1 Contents

2.2 E-Field Sensing: An Alternative Solution to Control Panel Applications

Human touch can be a useful tool. Control panels, appliances, heavy machinery, toys, lighting controls, and anything that has a mechanical switch or push button requires some sort of human interaction to operate. Traditionally, push buttons are made from mechanical switches and/or multi-layer resistive touch pads that can deteriorate and become less dependable over time. This is because most of these switches require physical displacement and pressure, and are susceptible to wear-out, contact bounce, corrosion and arcing.

The MC34940/MC33794 Electric Field Imaging devices from Freescale offers an alternative to mechanical push buttons for control panel applications. The MC34940/MC33794 Integrated Circuits (IC) contain the circuitry necessary to generate a low level electric field and measure the field loading caused by objects moving into or out of the field. It is ideal for applications that require non-contact sensing, proximity detection, and three-dimensional e-field imaging. The ICs integrate support for a microcontroller and seven to nine electrodes, which can be used independently to determine the size or location of an object in a weak electric field.

With the MC34940/MC33794, membrane switches and resistive touch pads can be replaced by an array of touch pads consisting of conductive electrodes embedded beneath an insulating surface. Since it has the capability of sensing touch and proximity through the insulating surface, without direct electrical contact with the electrode metal, problems of wear, contamination, and corrosion are eliminated.

Furthermore, one of the MC34940/MC33794 key features that surpasses simple capacitive-based sensors is its on-board shield driver. Touch pads do not have to be combined and located in one centralized location. With proper shielding, coaxial cables or PCB layers can be used to connect remote touch pads up to a few meters away, while obtaining measurements as accurately as if the touch pads were directly connected to the IC. The MC34940/MC33794 does this by driving a signal on the shield of the coax, or a PCB trace, which closely follows the signal conductor voltage. The current which flows through the electric field between two conductors is proportional to the voltage difference between them. With little or no voltage difference, there is little or no current flow between the electrode conductor and the shielding trace or coax shield.

2.3 Principle of Operation

The MC33794 is intended for use in detecting objects using an electric field. The IC generates a low radio frequency sine wave. The frequency is set by an external resistor and is optimized for 120 kHz. The sine wave has very low harmonic content to reduce potential interference at higher harmonically related frequencies. The internal generator produces a nominal 5.0 V peak-to-peak output that is passed through an internal resistor of about 22 kΩ. An internal multiplexer routes the signal to one of 11 terminals under the control of the ABCD input terminals. A receiver multiplexer simultaneously connected to the selected electrode routes its signal to a detector, which converts the sine wave to a DC level. This DC level is filtered by an external capacitor and is multiplied and offset to increase sensitivity. All of the unselected electrode outputs are grounded by the device. The amplitude and phase of the sinusoidal wave at the electrode are affected by objects in proximity. A “capacitor” is formed between the driving electrode and the object, each forming a “plate” that holds the electric charge. The voltage measured is an inverse function of the capacitance between the electrode being measured, the surrounding electrodes, and other objects in the electric field surrounding that electrode. Increasing capacitance results in decreasing voltage. The value of the series resistor (22kΩ) was chosen to provide a near linear relationship at 120 kHz over a range of 10pF to 70pF. While exploring applications using E-Field products, it is always useful to approach the problem using the capacitor model.

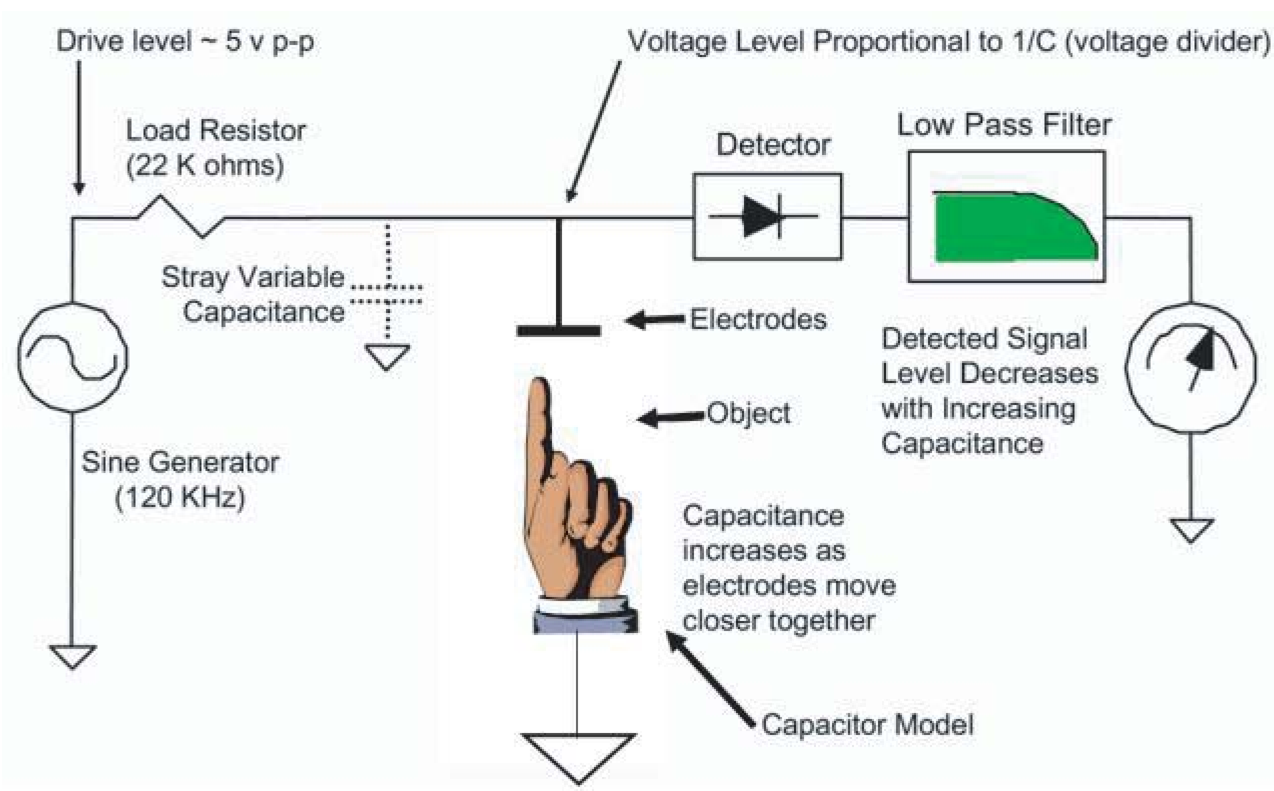


Figure 2-1. Principle of Operation

Chapter 3
System Concept

3.1 Contents

3.2 System Specification

The main goal of this demo board is to present features of the MC33794 E-Field sensor product. It is an application dedicated to sense human touch and liquid level. Every button and slider senses human touch and proximity. Water level is measured in the water column by copper electrodes fixed on the column from the outside.

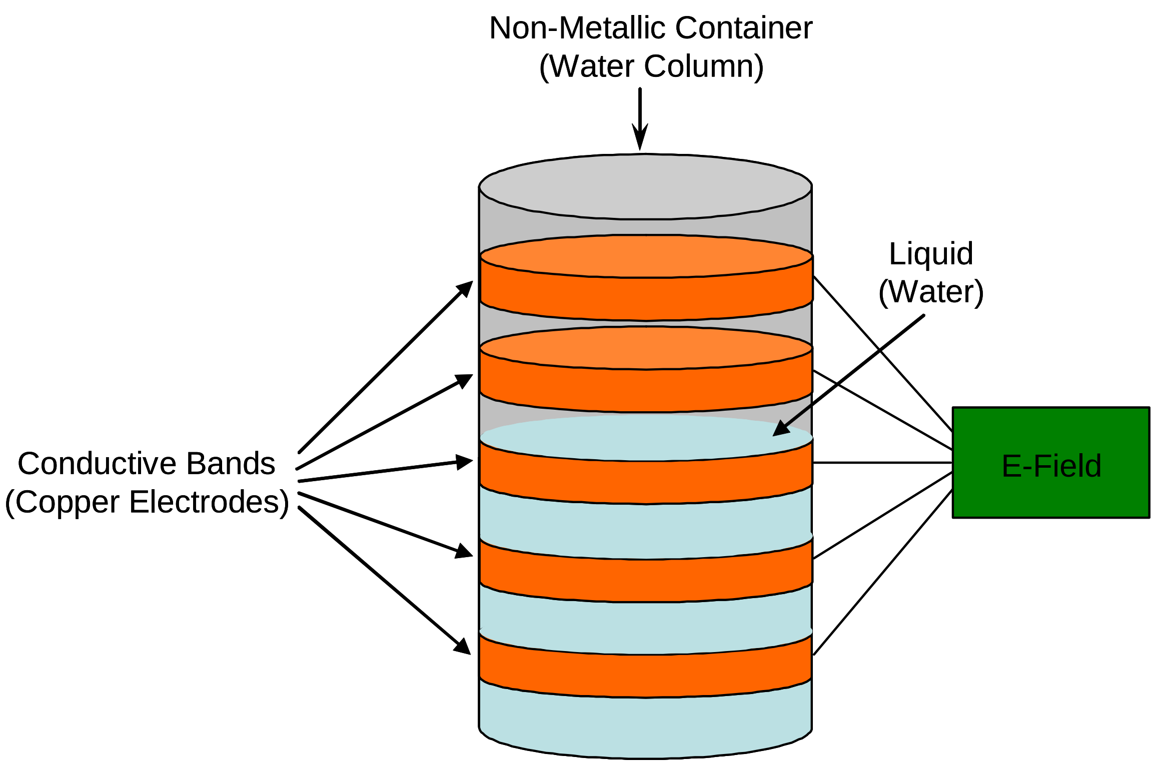


Figure 3-1. Water Column

This demo consists of two main boards: Touch Pad Board and Water Level Board. Interfacing is implemented through connectors. There is also the option of installing a Dual Op-Amp to amplify weak E-Field signals if required.

The E-Field demonstrator can work in 4 modes: Touch Pad, Slider, Water Pump and Water Slider.

A mode selection electrode is used to switch the demo to another mode.

The FreeMASTER GUI is used to bring a visual demonstration of electrode behavior during the sensing of human touch or water level.

3.3 Application Description

Figure 3-2 shows a block diagram of the application.

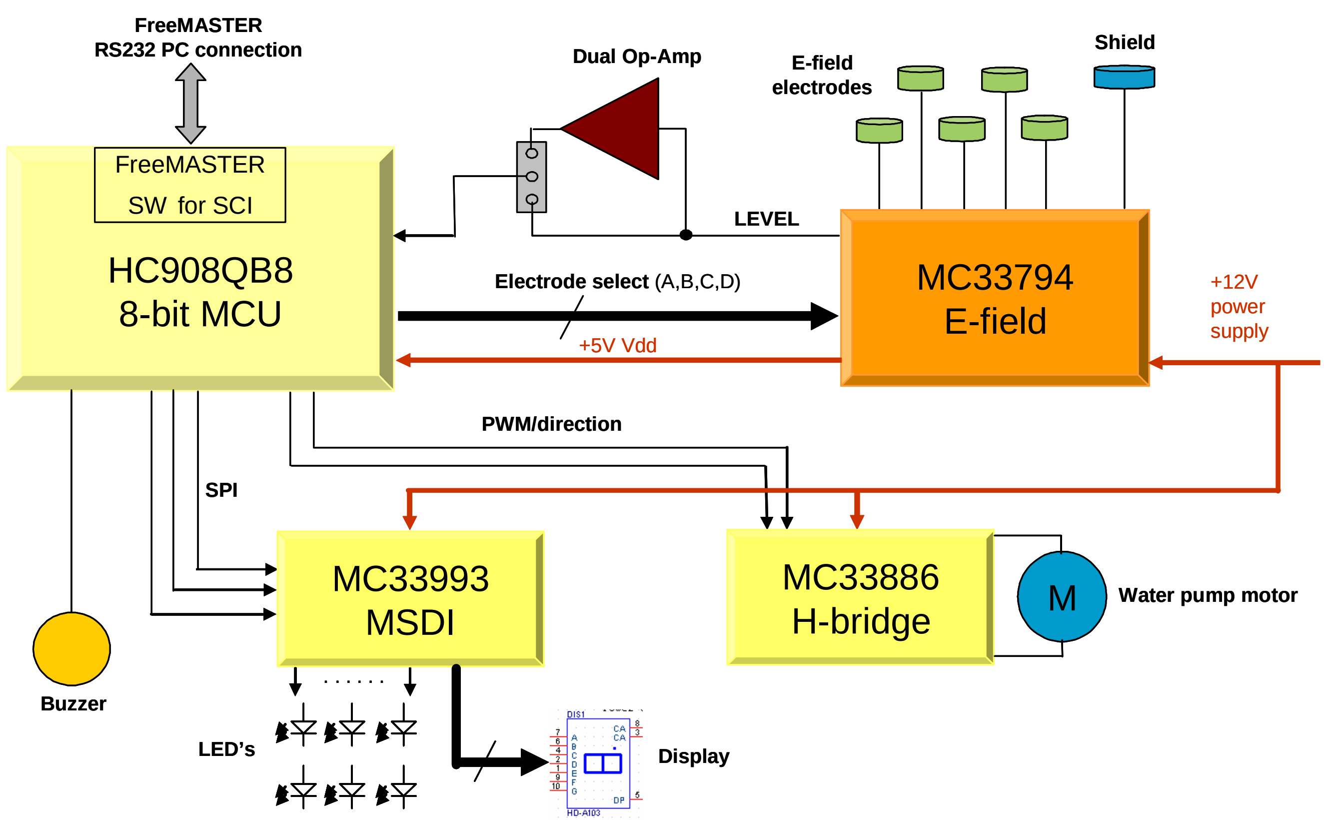


Figure 3-2. Block Diagram

The main application consists of Freescale ICs such as

- MC33794 Electric Field Sensing Device
- MC68HC908QB8 8-bit Microcontroller (8K FLASH)

- MC33993 Multiple Switch Detection Interface
- MC33886 H-Bridge

MC33794 is intended for sensing the electric field generated near the electrodes. This application uses nine electrodes (buttons and conductive bands) and one reference electrode (mode selection button). A second reference electrode pin is connected through a capacitor to the ground. Just one of these electrodes can be selected at a time for measurement. All of the other unselected electrodes are grounded by an internal switch, apart from the reference electrodes. Fringing fields were reduced by placing a copper layer connected to the SHIELD pin at the bottom and around the electrodes at the top of the PCB (Figure 3-3).

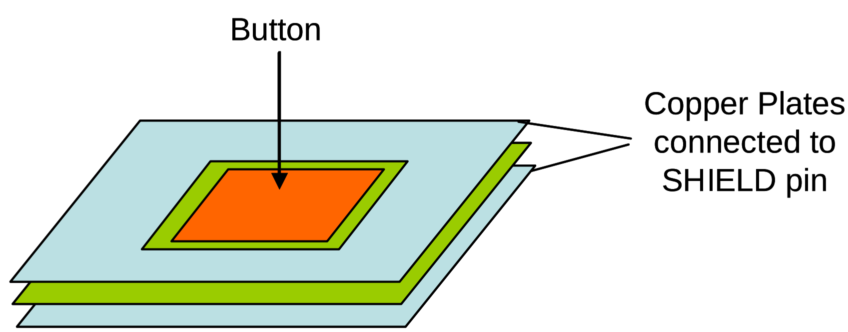


Figure 3-3. Minimizing fringing fields with SHIELD

The detected, amplified and offset representation of the signal voltage on the selected electrode is connected through the LEVEL pin to the MCU A/D convertor. Pins A, B, C, D are 5V logic pins controlled from the MCU, intended to select appropriate electrodes. The converted value is stored, read and displayed by the FreeMASTER SW using serial communication (RS232).

The application is powered by +12V DC. The power supply of +5V DC for the MCU and other devices is provided by the MC33794's +5.0V DC internal voltage regulator (Vcc).

The MSDI device (MC33993) drives the LEDs and the 7 segment display and is controlled by SPI commands from the MCU through SPI communication protocol. The LEDs and display are connected directly to the MSDI SG or SP pins.

The MC33886 is a monolithic H-Bridge. In this application it is used as a controller of the water pump DC motor. The MCU generates 6.25kHz PWM signal to drive the MC33886. The PWM duty cycle is decreased or increased by the MCU to provide the desired speed for pumping the water.

In addition, a visualization of several variables via computer has been implemented. FreeMASTER software is used for the purpose of graphical visualization, communicated via SCI protocol. The FreeMASTER SCI software is also implemented in the MCU to allow communication between the application and the PC. The communication speed is 57600Baud.

Chapter 4
Hardware

4.1 Contents

4.2 System Overview

The demo consists of two boards - *TOUCH PAD BOARD* (*TPB)* and *WATER LEVEL BOARD (WLB)*. The boards are attached to each other. Refer to Figure 6-1 and Figure 6-2.

The **TPB** contains:

- E-Field chip (MC33794)
- MCU (HC908QB8)
- RS232 connection (MAX202, DB9 female)
- Dual Op-Amp (LM358 - optional)
- Power supply jack (+12 VDC)
- Buzzer circuitry
- Buttons (keyboard, slider, mode selection button)

The **WLB** contains:

- Water column with copper electrodes
- H-Bridge (MC33886)
- MSDI (MC33993)

- Water slider
- LED Bar, 7 segment LED Display

For a block diagram, refer to Figure 3-2.

4.3 Application schematics

Figure A-1and Figure A-2 are schematics of the Touch Pad Board. Figure A-3 is a schematic of the Water Level Board.

4.4 Hardware design considerations

4.4.1 Power Supply

The board is powered by a +12 VDC external supply through jack J1 on the Touch Pad Board. An internal voltage regulator in the E-Field IC provides +5.0V DC for remaining circuits.

4.4.2 E-Field Sensor

MC33794 is powered by a +12 VDC from an external power supply. The +12V DC applied to the V_{PWR} pin is converted into the regulated voltages needed to operate the part. It is also converted into +5.0V DC to power the MCU and external devices.

The level detected from output pin LEVEL is connected directly to the MCU A/D convertor, optionally through the Dual Op-Amplifier.

A specific electrode is selected by the A, B, C, D pins Table 4-1, which are controlled from the MCU.

Table 4-1. Electrode Selection

PIN/SIGNAL	D	C	B	A
Source(internal)	0	0	0	0
E1	0	0	0	1
E2	0	0	1	0
E3	0	0	1	1
E4	0	1	0	0
E5	0	1	0	1
E6	0	1	1	0
E7	0	1	1	1
E8	1	0	0	0
E9	1	0	0	1
REF_A	1	0	1	0
REF_B	1	0	1	1
Internal OSC	1	1	0	0
Internal OSC after 22kΩ	1	1	0	1
Internal Ground	1	1	1	0
Reserved	1	1	1	1

Resistor R2 determines the operating frequency of the oscillator. R2 = 39kΩ to provide an operating frequency = 120kHz.

Electrodes (E1- E9) are used as single button electrodes on the Touch Pad Board. The slider on the Touch Pad Board is made from electrodes E6 and E7. The slider on the Water Level Board is made from E8 and E9. Five conductive bands on the water column are connected as electrodes E1- E5. The SHIELD pin is connected to the shield copper layer and is also tied to connector J3 for Water Level Board purposes. REF_A pin is used as a single (Mode Selection) electrode to switch between all modes. To avoid REF_B pin floating, this pin is connected through C19 to ground.

The VCC pin provides +5.0V DC for the remaining circuits. C4 and C5 are connected to this pin to provide a stabilized voltage.

4.4.3 Microcontroller

The system is based on an MC68HC908QB8, 8-bit, low cost microcontroller, powered by a +5V DC from the E-Field sensor. The MCU selects each specific E-Field channel, reads output from the E-Field sensor and takes appropriate action. It also sends commands to the MSDI to drive LEDs, toggle the Buzzer ON or OFF, handle interfacing with the H-Bridge (driving the water pump), and performs serial communication with the implemented FreeMASTER software via RS232.

As soon as the MCU is programmed with the serial bootloader, the MCU memory can be modified in-circuit via the serial port (see AN2295/D Developer's Serial Bootloader for M68HC08 and HCS08 MCUs).

Detected levels are fed from the E-Field to the MCU A/D channel. This A/D converter works in 10-bit resolution mode.

The PWM output from the microcontroller, combined with direction signals, drives the water pump motor through the H-Bridge.

No external crystal or oscillator is required, as the MCU runs on an internal oscillator.

Pins PTA 0, PTA1, PTA4, PTA5 select each specific E-Field channel (see Table 4-1) PTA0 = A, PTA1 = B, PTA4 = C, PTA5 = D.

4.4.4 Serial Communication

Serial communication uses the ESCI module of the QB8 microcontroller, a MAX202 and a DB9 connector. The E-Field demonstrator application implements software serial communication and FreeMASTER (formerly known as PC Master) code in order to demonstrate the sensing process. Serial communication is fully controlled by the implemented FreeMASTER software. The details are given in the separate Freescale Application notes (see AN2395 - PC Master Software Usage and AN2471 - PC Master Software Communication Protocol Specification).

4.4.5 Op-Amp

The Touch Pad Board includes footprints for Op-Amp components. This amplifier was considered to provide higher sensitivity to the signal read by the MCU A/D convertor. Measured results have shown that this Op-Amp is not necessary in this application.

4.4.6 MSDI

The 33993 Multiple Switch Detection Interface is designed to detect the closing and opening of up to 22 switch contacts. The switch status, either open or closed, is transferred to the microprocessor unit (MCU) through a serial peripheral interface (SPI).

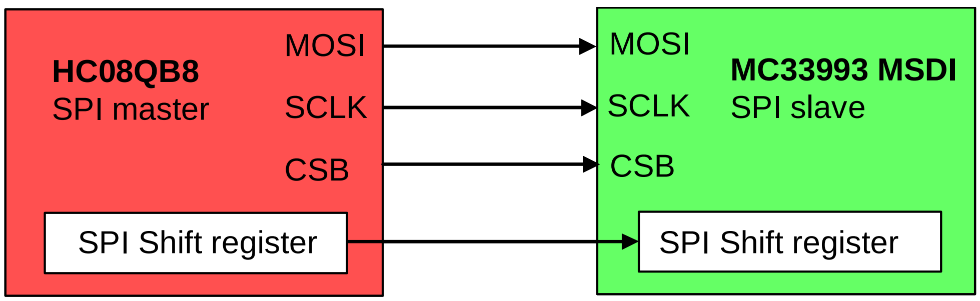


Figure 4-1. SPI communication

In this particular application, the MSDI drives LEDs D1- D14 and the seven segment display DIS1. D1 - D14 are connected to SG pins and DIS1 is connected to SP pins (SP pins are switched to the battery, SG pins are switched to the ground). In this application we use the internal configurable current sources. 2mA current sources are used for the LEDs, and 16mA current sources are used for DIS1.

The MSDI communicates with the MCU using just a three wire (MOSI, SCLK and CSB) SPI because no feedback from the MSDI is required (Figure 4-1).

4.4.7 H-Bridge

Freescale's MC33886 is a monolithic H-Bridge ideal for DC-motor and bi-directional thrust solenoid control. The 33886 is able to control continuous inductive DC load currents up to 5.0A. The water pump motor used in the E-Field demo is a 3.0A load. Output loads can be pulse width modulated (PWM-ed) at frequencies up to 10kHz.

The H-Bridge can operate in several modes but we are using just two of them (Table 4-2):

- Forward
- Reverse

Table 4-2. Truth Table

Device State	Input Conditions				Fault Status Flag	Output States	
	D1	$\overline{D2}$	IN1	IN2	$\overline{FS}$	OUT1	OUT2
Forward	L	H	H	L	H	H	L
Reverse	L	H	L	H	H	L	H

The DC motor is connected through the OUT1 and OUT2 terminals to the internal power MOSFET H-Bridge of the IC. IN1(direction) and IN2 (PWM signal) are input control terminals used to control OUT1 and OUT2 (see Figure 4-2).

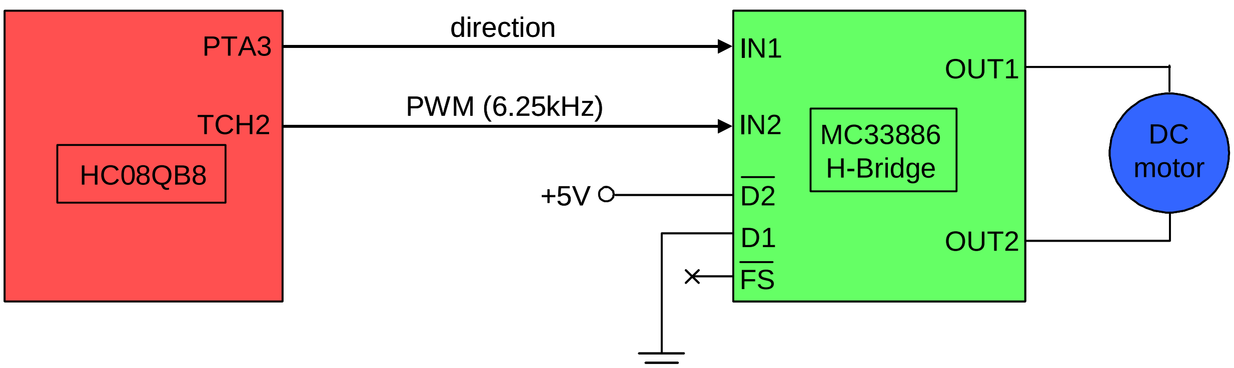


Figure 4-2. H-Bridge circuitry

4.4.8 Buzzer circuitry

The buzzer is controlled directly by a GPIO pin of the MCU (PTB7). A MOSFET transistor is used to switch the buzzer ON or OFF.

4.4.9 Jumpers

The configuration jumpers in the E-Field demonstrator are JP1 and JP2.

JP1 selects between two values of LP_CAP (Low-Pass Filter Capacitor), 10nF or 1nF. A capacitor on this pin forms a low pass filter with the internal series resistance from the detector to this pin. This pin can be used to determine the detected level before amplification or offset is applied. A 10 nF capacitor connected to this pin is recommended. More capacitance will increase the response time unnecessarily.

JP2 selects whether the input to the MCU A/D convertor is fed directly from the MC33794 output pin LEVEL or if the output signal is first amplified by the op-amp. The op-amp is not populated in this revision of the board, therefore JP2 in position 2-3 has no meaning.

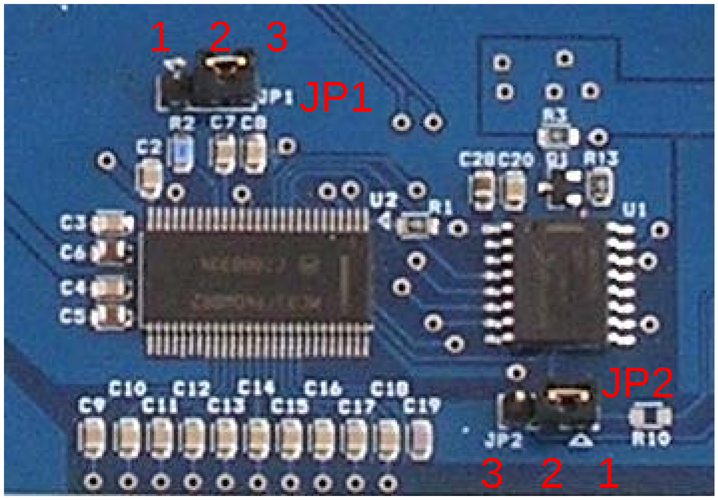


Figure 4-3. Default jumpers configuration

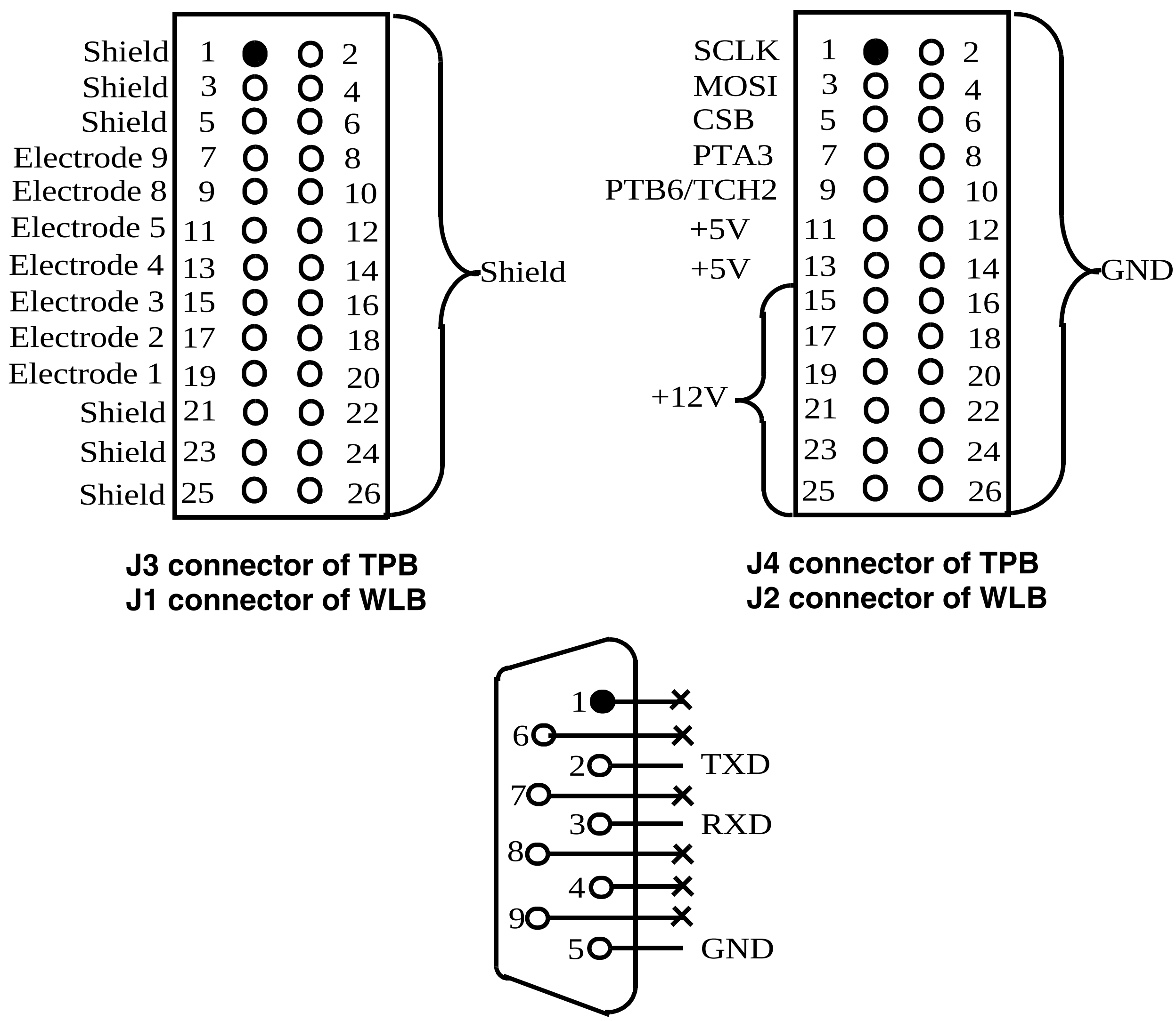
Table 4-3. Jumpers Configuration

Jumper	Position	Description	
JP1	1-2	C7 (1nF) connected to LP_CAP pin	
JP1	2-3	C8 (10nF) connected to LP_CAP pin	default
JP2	1-2	LEVEL pin connected directly to MCU	default
JP2	2-3	LEVEL pin connected through Op-Amp to MCU	

4.4.10 Connectors

The Touch Pad Board (TPB) and Water Level Board (WLB) are connected together with connectors J3, J4 on the TPB (Figure A-1, Figure A-2), and J1, J2 on the WLB (Figure A-3). J3 on the TPB matches up with J1 on the WLB. J4 on the TPB matches up with J2 on the WLB.

Electrode signals and Shield signal are grouped together on the J3 connector of the TPB and the J1 connector of the WLB. SPI signals, H-Bridge control signals, power supply and GND are grouped on the J4 connector of the TPB and on the J2 connector of the WLB. Pin assignments are shown in Figure 4-4 Connectors.



J2 connector of TPB
DB9 female

Figure 4-4. Connectors

Pin descriptions are listed in Table 4-4, Table 4-5, Table 4-6.

Table 4-4. J3 (J1) connector of TPB (WLB)

Pin #	Signal Name	Description
1-6, 8, 10, 12, 14, 16, 18, 20-26	SHIELD	Shield Driver. These pins are connected to a shield plate to cancel fringing fields.
7, 9, 11, 13, 15, 17	Electrode 9,....., Electrode 1	Electrode Connections. These are the electrode terminals.

Table 4-5. J4 (J2) connector of TPB (WLB)

Pin #	Signal Name	Description
1	SCLK	Serial Clock. SPI control clock input pin.
3	MOSI	SPI Slave In. SPI control data input pin from MCU to 33993
5	CSB	Chip Select. SPI control chip selects the input pin from MCU to 33993. Logic 0 allows data to be transferred in.
7	PTA3	Direction pin. Determines direction of the DC motor. (MCU -> H-Bridge)
9	PTB6/TCH2	PWM signal pin. Determines speed of the DC motor. (MCU -> H-Bridge)
11, 13	+5V	+5.0V DC power supply
15, 17, 19, 21, 23, 25	+12V	+12.0V DC power supply
2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26	GND	Ground

Table 4-6. J2 connector of TPB (DB9 female)

Pin #	Signal Name	Description
2	TXD	Transmit SCI Data
3	RXD	Receive SCI Data
5	GND	Ground
1, 4, 6, 7, 8, 9	NC	Not connected

Chapter 5
Software

5.1 Contents

5.2 Software Design Consideration

Electrode value reading is done by the MCU, by selecting the appropriate channel lines (**Table 4-1**) and then reading the value on the MCU A/D module. Differences from calibrated values represent changes in the electrode field, meaning the electrode might have been influenced by human touch or water level presence.

The application gives feedback to the user through the on board display, LEDs and a buzzer. The board can also be connected to the PC via an SCI port. On board Display and LEDs are managed using an MSDI device (4.4.6). SCI communication is handled by the implemented FreeMASTER Software.

5.3 Main Data Flow Chart

The general software diagram incorporates the main routine (Main) entered from reset and the interrupt service routines. The general overview of the control algorithm is described in **Figure 5-1.**

The main routine initializes the MCU, MSDI device and the FreeMASTER software, starts the TIM counter, enable interrupts, performs a delay to let things settle, reads the calibration values, tests the Buzzer and then it enters an endless loop. The endless loop contains four working modules (Touch pad, Slider, Water Pump, Water Slider). The Mode key is tested in every cycle and according to its state, the working modes are switched inside the infinite loop.

Working modes are described in flow charts from Figure 5-3 to Figure 5-6.

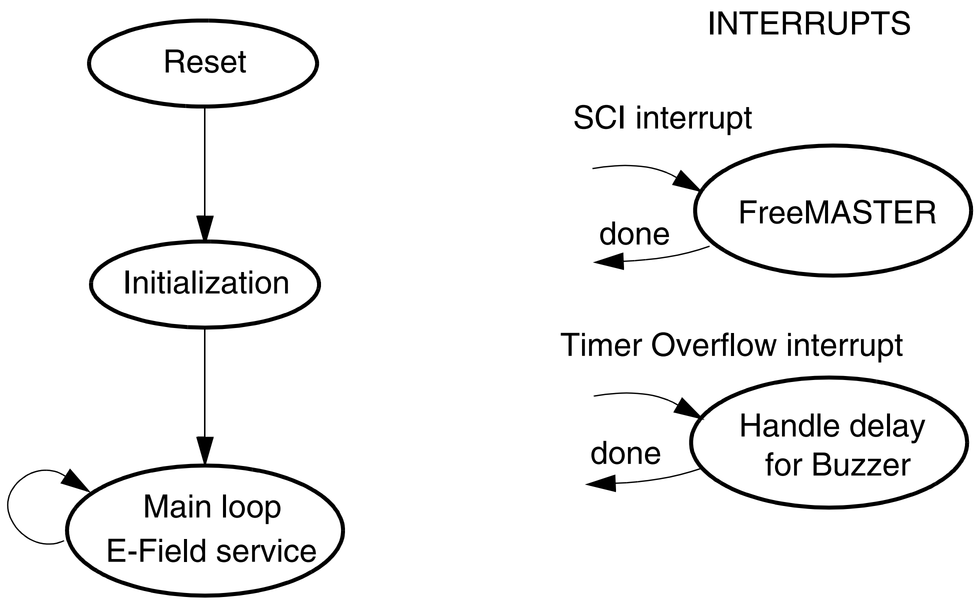


Figure 5-1. State Diagram - General Overview

The SCI interrupt services the FreeMASTER communications between the PC and MCU. The Timer Overflow interrupt handles the time delay for the Buzzer (refer to page 35).

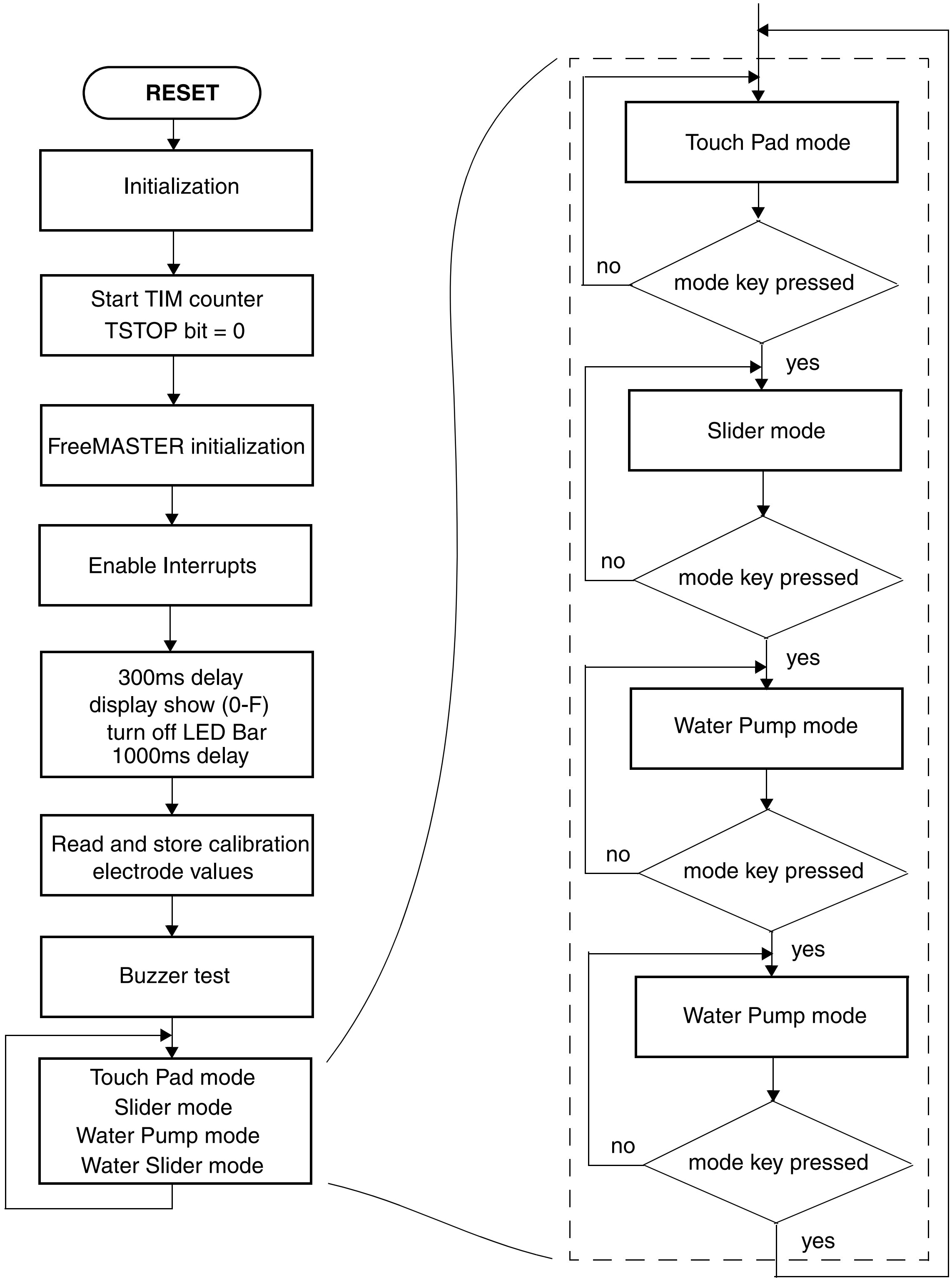


Figure 5-2. Main Data Flow Chart

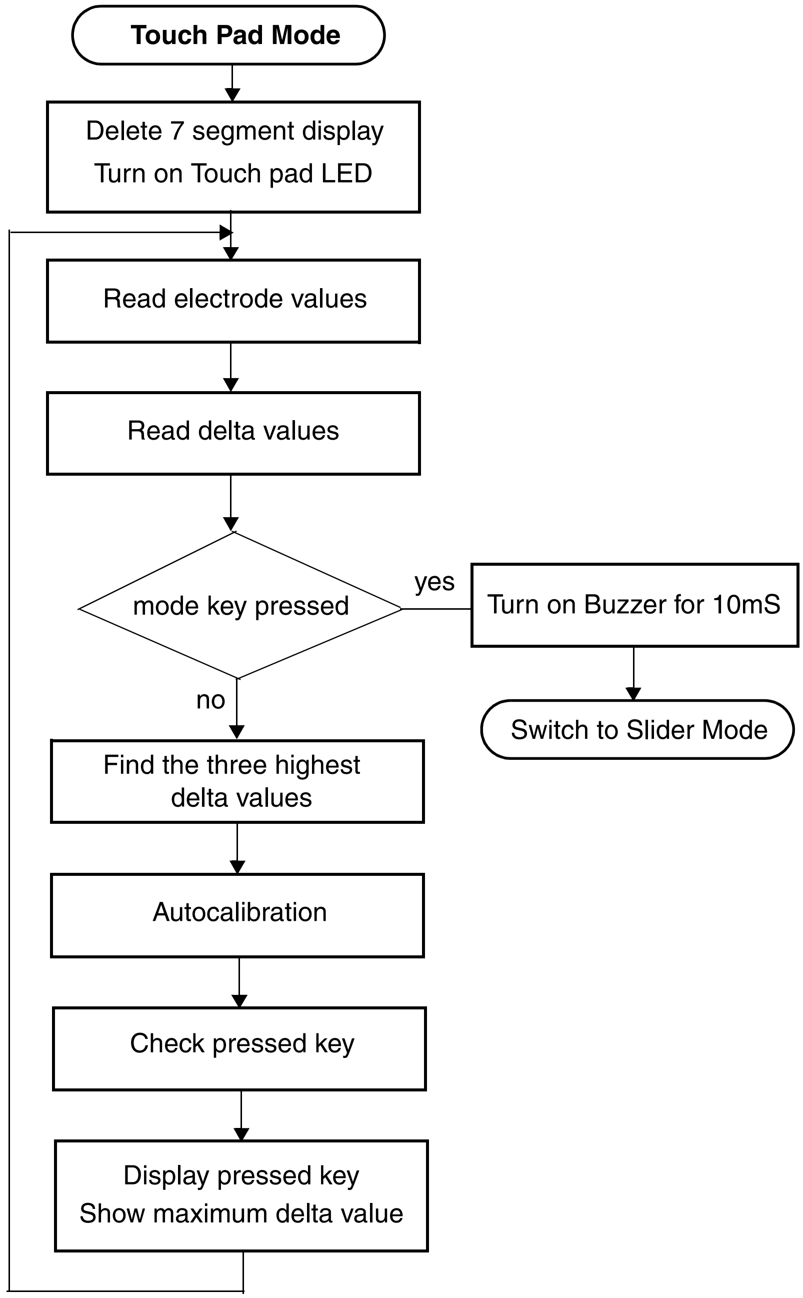


Figure 5-3. Touch Pad Mode Flow Chart

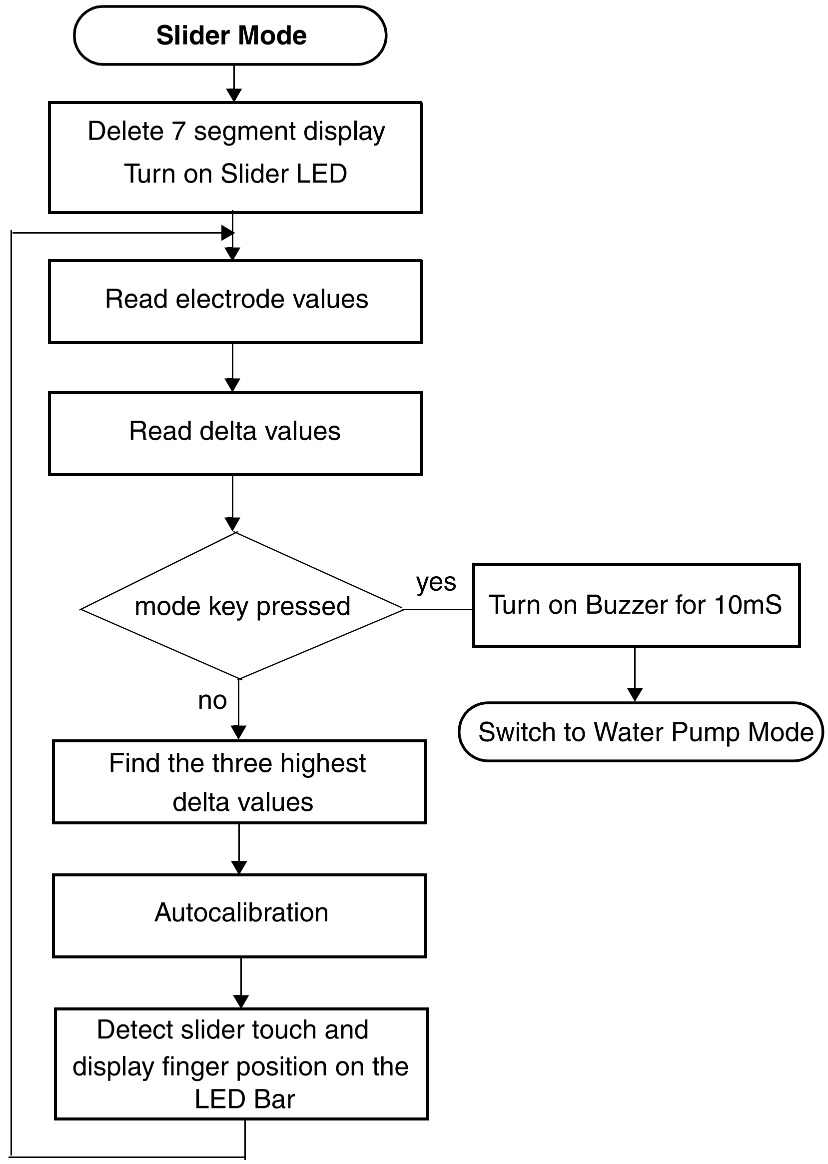


Figure 5-4. Slider Mode Flow Chart

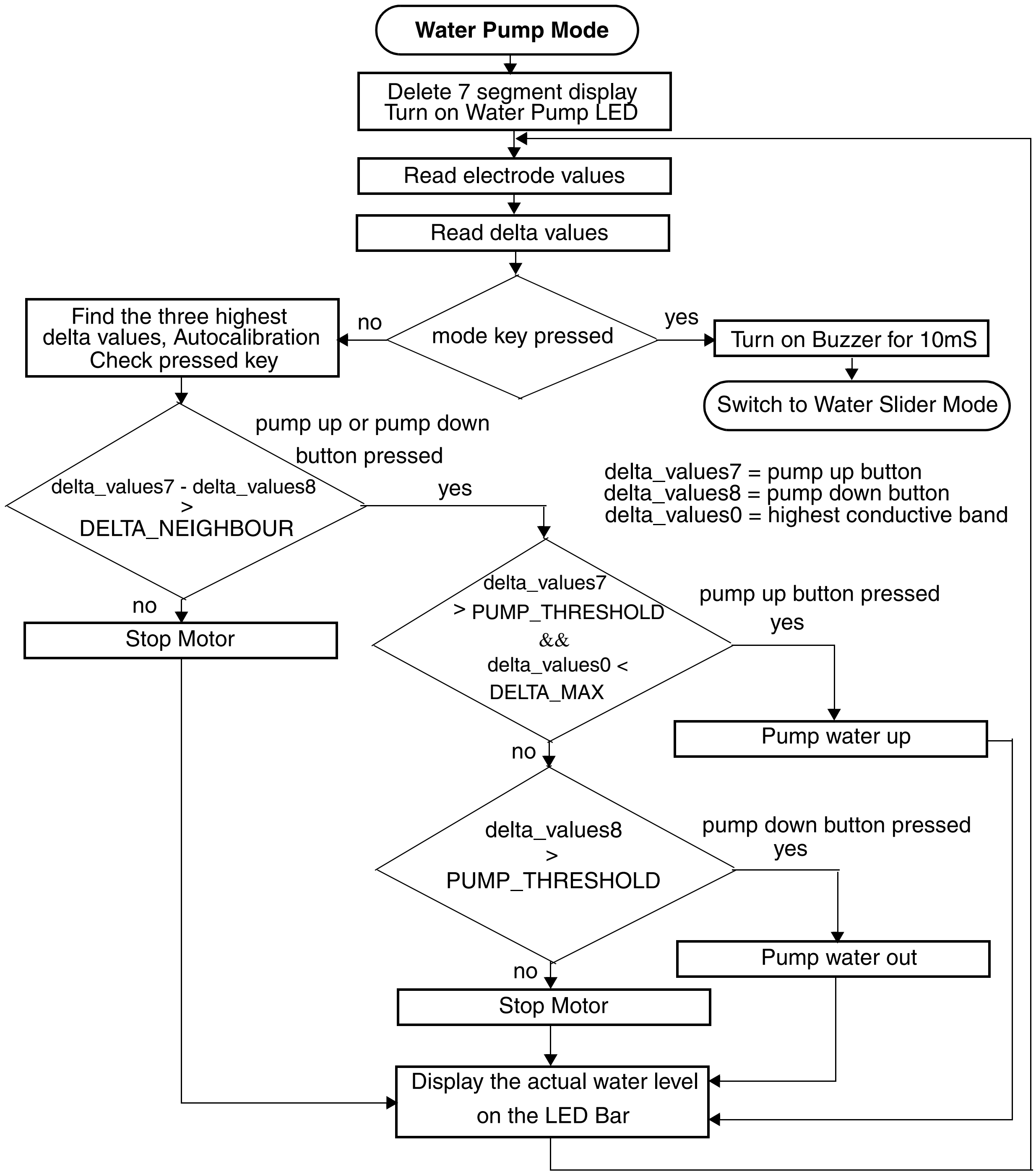


Figure 5-5. Water Pump Mode Flow Chart

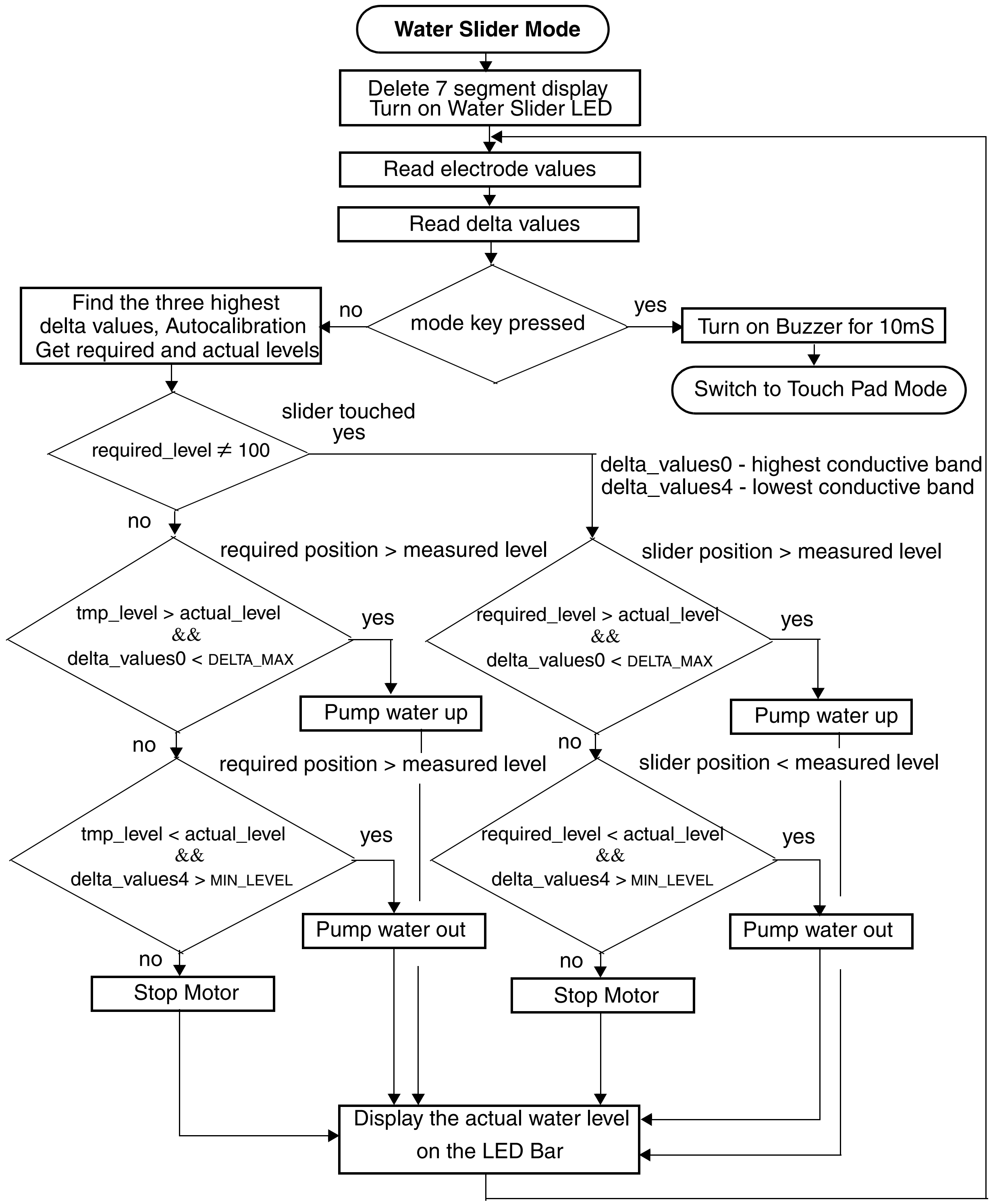


Figure 5-6. Water Slider Mode Flow Chart

5.4 Firmware Functional Description

Table 5-1. Main, Initialization, FreeMASTER Initialization

Module:	main.c	main.c	freemaster_protocol.c
Function:	main	InitPorts	FMSTR_Init
Syntax:	void main(void)	void InitPorts(void)	void FMSTR_Init(void)
Parameters:	none	none	none
Return:	none	none	none
Description:	Initializes MCU, MSDI and FreeMASTER. Gets the calibration values, scans electrodes, and takes appropriate action.	Initializes MCU (oscillator, GPIO, Timer, ADC, SPI, SCI) and external MSDI device.	FreeMASTER driver initialization (initialize communication and start listening for commands).

Table 5-2. Calibrate Electrodes, Read Values, Read Electrode

Module:	main.c	main.c	main.c
Function:	CalibrateElectrodes	ReadValues	ReadElectrode
Syntax:	void CalibrateElectrodes(void)	void ReadValues(void)	void ReadElectrode(unsigned char)
Parameters:	none	none	channel (MC33794 channel)
Return:	none	none	none
Description:	Reads each electrode value (takes 16 samples and averages the result) and stores it in the electrode's calibration register.	Scans all electrodes from 1 to NUMBER_OF_ELECTRODES using function ReadElectrode().	Reads the selected channel and places the result into RAM.

Table 5-3. Read Delta, Verify Electrodes, Display Data

Module:	main.c	main.c	main.c
Function:	ReadDelta	VerifyElectrodes	DisplayData
Syntax:	void ReadDelta(void)	void VerifyElectrodes(void)	void DisplayData(unsigned char)
Parameters:	none	none	pressed_key (pressed button)
Return:	none	none	none
Description:	Measures the difference between the current electrode value and the calibration value and stores it as the delta value in RAM. Measures the total sum of delta values.	Finds the three highest delta values .	Displays the pressed key on the 7 segment display using MSDI and a beep is generated when a button is pressed.

Table 5-4. Bar Graph, Water Bar Graph, Water Slider Graph

Module:	main.c	main.c	main.c
Function:	BarGraph	WaterBarGraph	WaterSliderGraph
Syntax:	void BarGraph(unsigned char)	void WaterBarGraph(unsigned int)	void WaterBarGraph(unsigned int)
Parameters:	led (maximum delta value)	wbar_delta (total sum of delta values)	wslider_delta
Return:	none	none	none
Description:	Routine to handle the LED Bar in Touch Pad mode. The maximum delta value is displayed.	Routine to handle the LED Bar in Water Pump mode. Displays wbar_delta.	Routine to handle the LED Bar in Water Slider mode. Displays wslider_delta.

Table 5-5. Rotate Up, Rotate Down, Stop Rotate

Module:	main.c	main.c	main.c
Function:	RotateUp	RotateDown	StopRotate
Syntax:	void RotateUp(void)	void RotateDown(unsigned char)	void StopRotate(void)
Parameters:	none	speed	none
Return:	none	none	none
Description:	Generates PWM signal for the H-Bridge to drive the DC motor (pumps water into the water tube).	Generates PWM signal for the H-Bridge to drive the DC motor (pumps water out of the water tube).	Stops the DC motor.

Table 5-6. Beep On, Beep Off, Auto Calibration

Module:	main.c	main.c	main.c
Function:	BeepOn	BeepOff	AutoCalibration
Syntax:	void BeepOn(void)	void BeepOff(void)	void AutoCalibration(void)
Parameters:	none	none	none
Return:	none	none	none
Description:	BeepOn - turn on the buzzer (PTB_PTB7 = 1)	BeepOff - turn off the buzzer (PTB_PTB7 = 0)	Tests conditions and calls the CalibrateElectrodes() function when needed.

Table 5-7. SendSPI, SendpSPI, Delay

Module:	communications.c	communications.c	delay.c
Function:	SendSPI	SendpSPI	Delay
Syntax:	void SendSPI(void)	void SendpSPI(char *)	void Delay(unsigned int)
Parameters:	none	pbuff	delay_count
Return:	none	none	none
Description:	Sends out 24 bits contained in the MSDI array to the SPI port.	Pointered version of SendSPI.	Function to wait for the desired time.

Table 5-8. GetTick, Beeper, Count

Module:	delay.c	delay.c	delay.c
Function:	GetTick	Beeper	Count
Syntax:	unsigned int GetTick(void)	void Beeper(unsigned int)	void Count(void)
Parameters:	none	delay_beep	none
Return:	ret_val	none	none
Description:	Reads and returns ***tick*** as ret_val (tick is incremented on every TIM overflow).	Turns on the Buzzer for the desired time using BeepOn().	Extra display show on the 7 segment display to let things settle at the start.

Table 5-9. Slider, Water Slider, Measure Water

Module:	slider.c	slider.c	slider.c
Function:	Slider	WaterSlider	MeasureWater
Syntax:	void Slider(unsigned int, unsigned int)	unsigned int WaterSlider(unsigned int, unsigned int)	unsigned int MeasureWater(unsigned int)
Parameters:	u_val6, u_val7	u_val8, u_val9	u_val_delta
Return:	none	wdeltaled	tmp_measure
Description:	Detects touch via the slider electrodes (E6 and E7), calculates slider value and displays the result on LED Bar.	Detects touch via the water slider electrodes (E8 and E9), calculates and returns the wdeltaled value.	Measures the current level of water and returns that level converted to the water slider range.

Table 5-10. Water Level, Verify Key, Verify Mode Key

Module:	slider.c	verify.c	verify.c
Function:	WaterLevel	VerifyKey	VerifyModeKey
Syntax:	unsigned int WaterLevel(void)	unsigned char VerifyKey(void)	unsigned char VerifyModeKey()
Parameters:	none	none	none
Return:	delta_values[4] (5th electrode delta value)	key_number[] (index of pressed key) or NO_KEY_PRESSED	MODE_KEY_PRESSED or NO_KEY_PRESSED
Description:	Reads and returns the value of electrode E5 (lowest band on the water tube). Used for pumping water out of the tube between modes (from Water pump to Water slider, and from Water Slider to Touch pad mode)	Returns the index of a pressed key if detected, otherwise returns 0.	Returns MODE_KEY_PRESSED if mode key is pressed, otherwise returns 0.

5.5 Interrupts

This application uses a TIM (Timer Interface Module) Overflow Interrupt **Figure 5-7.** The TOF (TIM Overflow Flag) bit is set when the counter reaches the modulo value programmed in the TIM counter modulo registers.

This interrupt is generated every 160µs. The variable *tick*, which is used for time delay, is incremented on every TIM Overflow interrupt. Also, the variable *beep* is tested in this interrupt routine and according to it's state the Buzzer is turned off or not.

The SCI interrupt service routine is used to provide communication with the PC. It is fully handled by the implemented FreeMASTER sotware.

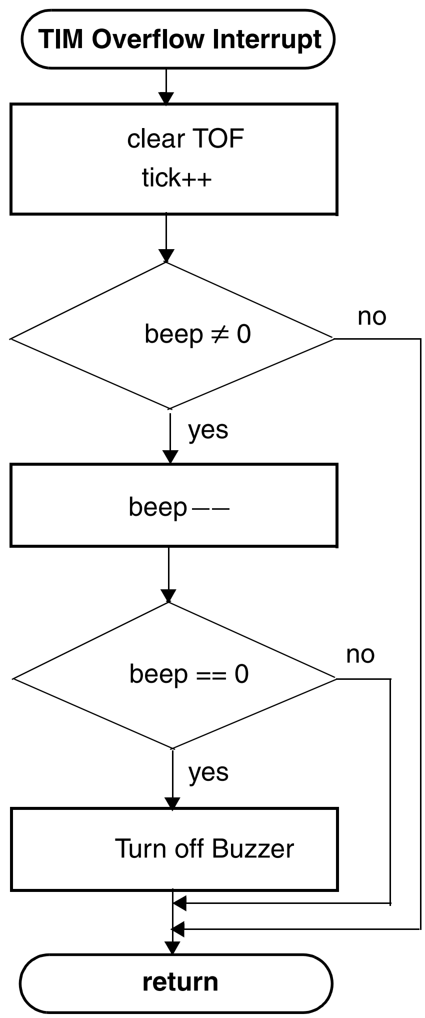


Figure 5-7. TIM Overflow Interrupt

5.6 FreeMASTER Software

The FreeMASTER software was designed to provide an application debugging, diagnostic and demonstration tool for the development of algorithms and applications. It runs on a PC connected to the controller board via an RS232 serial cable. A small program resident in the MCU communicates with the FreeMASTER software to parse commands, return status information to the PC, and to process control information from the PC. FreeMASTER software, executing on a PC, uses part of Microsoft Internet Explorer as the user interface.

The baud rate of the SCI communication for this application is 57600 baud.

A detailed description of the FreeMASTER software is provided in the dedicated *FreeMASTER for Embedded Applications* documentation.

The FreeMASTER software Control Page is illustrated in **Figure 5-8.**

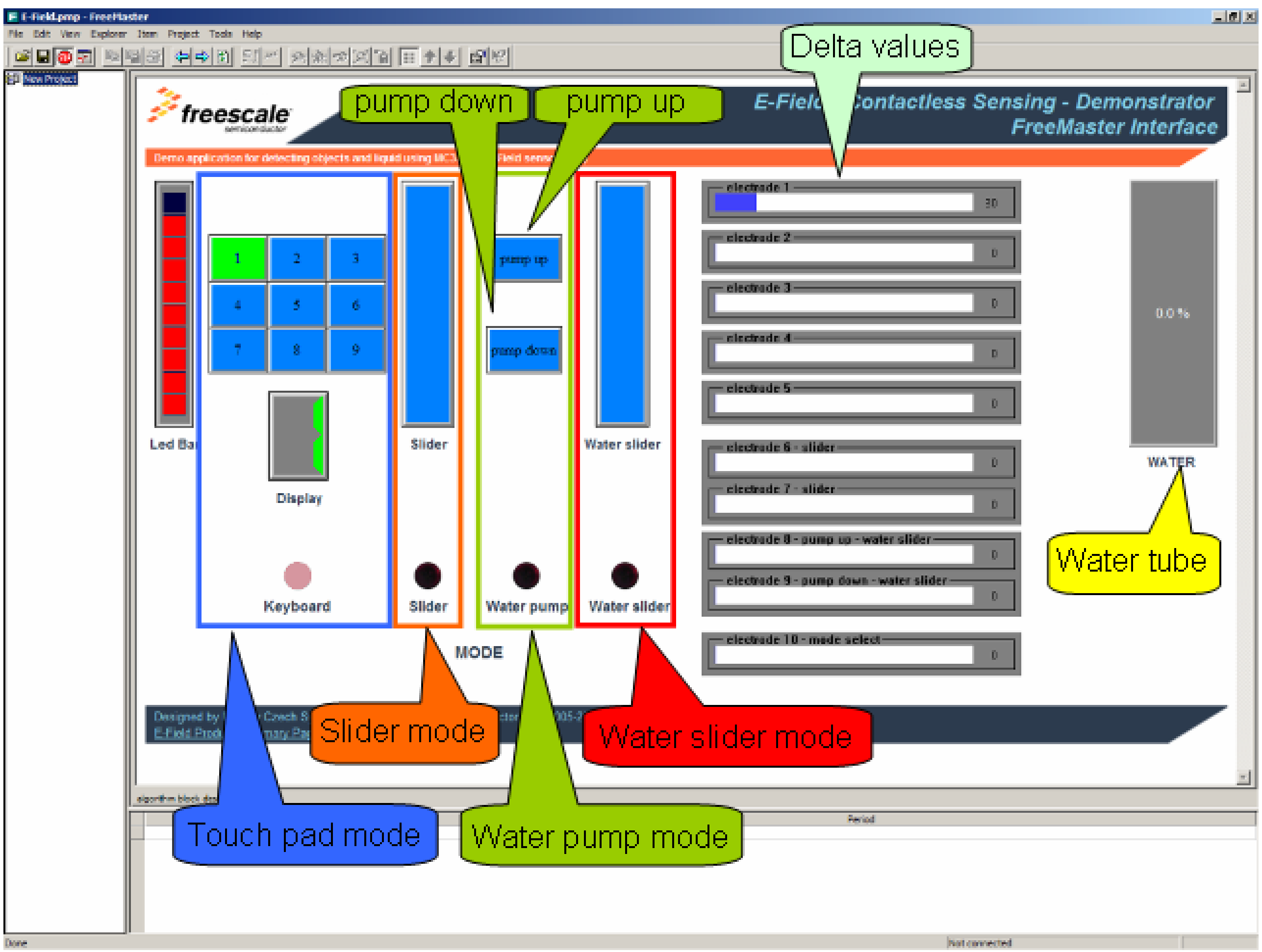


Figure 5-8. FreeMASTER Software Control Page

Chapter 6
Application Setup

6.1 Contents

6.2 Setting Up the Demo

This E-Field Demo consists of two main parts, the *Touch Pad Board (TPB)* and *Water Level Board (WLB)* **Figure 6-1.** The first step is to connect these two PCBs with each other, using connectors J3, J4 on the *TPB,* and J1, J2 on the *WLB*.

Figure 6-1. E-Field (Touch Pad Board, Water Level Board)


Figure 6-2. E-Field demo (TPB connected with WLB)

6.3 Power Supply

A DC power connector is provided on the E-Field Touch Pad Board to connect a power supply (a +12V DC switching power supply is provided with the demo). The central terminal of the power connector is positive and should be connected to +12V DC, and the second terminal should be connected to ground.

The +12V DC power supply is connected with a main outlet power cord.

6.4 Communication

On board firmware allows communication with a PC using the FreeMASTER Graphical User Interface. To use it, connect a serial cable from a communication port on your PC to the DB9 (RS232) connector on the Touch Pad Board. The female end of the cable connects to the PC and the male end to the board. The **communication speed** is **57600 Baud**.

6.5 Modes of E-Field Demonstrator

The E-Field demo can work in four modes: Touch Pad, Slider, Water Pump, Water Slider. This application starts in Touch pad mode after it is turned on. The Mode Selection Button is used to switch the demo to the next mode. The current mode is displayed on the Water Level Board LEDs D1 - D4.

Figure 6-3. Mode Selection Button

6.5.1 Touch Pad (Keyboard) Mode

This mode senses the nine electrodes arranged on the Touch Pad Board. They work as a standard keypad. After a touch is detected, the pad number will be shown on the seven segment LED display (DIS1), and on the LED Bar (LEDs D5 - D14) you will see the maximum delta value according to the proximity of the finger.

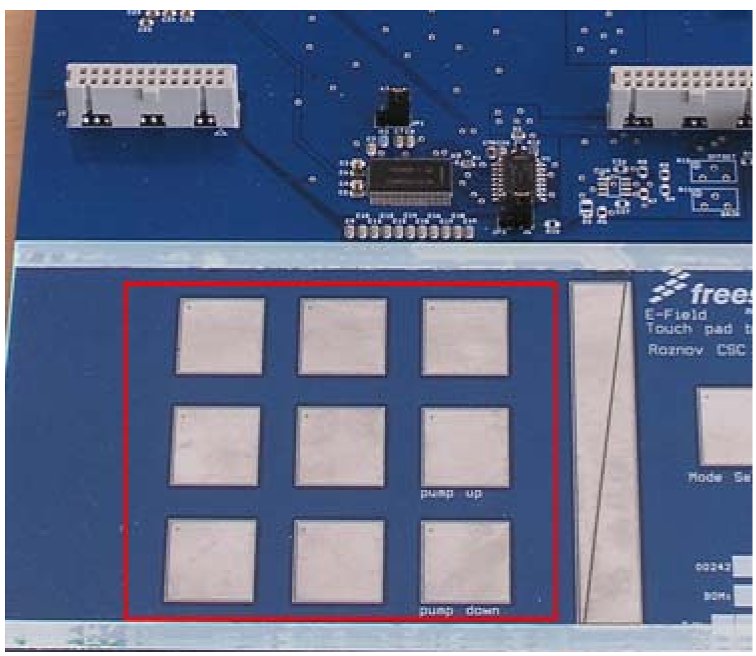


Figure 6-4. Keyboard

6.5.2 Slider Mode

This mode senses the Slider electrode, which is placed on the Touch Pad Board between the keypad and the mode selection electrode. Moving a finger along the slider, you will see the position of finger on the LED Bar. It is best to move the finger in the center of the slider to correctly activate the electrodes.

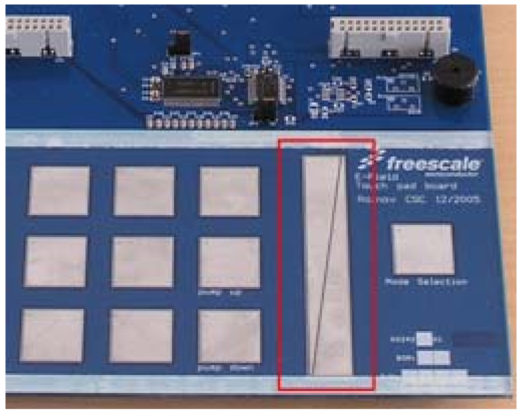


Figure 6-5. Slider

6.5.3 Water Pump Mode

In this mode, you pump water from the bottle to the Water Bar on the Water Level Board. To control the water pump, use the two electrodes: Pump Up button and Pump Down button, placed on the keyboard. The level of the water in the column is displayed on the LED Bar and the number of the electrode which is flooded is shown on the display (DIS1).

Touch and hold a finger on the Pump Up (Down) button, and the motor will pump water up (out) to the moment when the Pump Up (Down) button is released. These buttons are active only when you touch them.

If the application is switched to another mode and there is still some amount of water in the Water Bar, the water is pumped out and then, the mode changes.

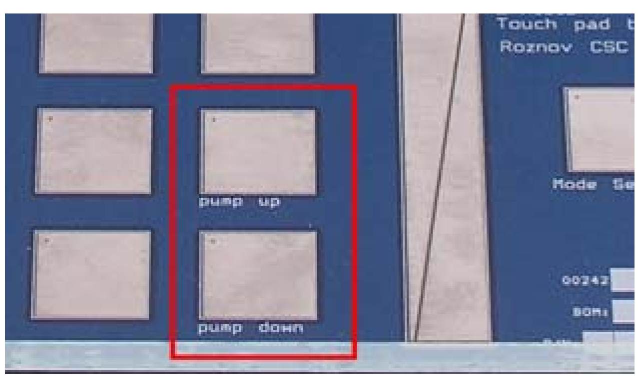


Figure 6-6. Pump Up (Down) Button

6.5.4 Water Slider Mode

Moving the finger along the Water Slider, water will be pumped up or out of the Water Bar. The Water Slider is placed on the Water Level Board near to the Water Bar. Water is pumped to the position of the finger on the Water Slider. Even if you release the Water Slider, water will flow to the last required level.

The level of water in the column is displayed on the LED Bar, and the number of electrode flooded is shown on the display (DIS1).

If the application is switched to another mode and there is still some amount of water in the Water Bar, then the water is pumped out and, after that, the mode will change.

Figure 6-7. Water Slider

NOTE: *Using modes where the water is pumped, the bottle should be approximately at the same level as the demo application, otherwise the pump is not able to pump the water.*

6.6 Demo System Setup

The following actions and cabling must be completed before the E-Field Demonstrator is started:

- connect the Touch Pad Board (connectors J3, J4) and the Water Level Board (connectors J1, J2)
- fill the plastic bottle with water and put one end of the water pump hose into the bottle
- connect the E-Field demonstrator with a serial cable to the host PC using the DB9 modem connector on the Touch Pad Board
- connect the +12V DC power supply to the power connector on the Touch Pad Board
- turn the demo on by switch SW1 (the application starts with a display show from 0 to F, then starts a calibration of the electrodes)

NOTE: *Do not touch electrodes during the calibration. The E-Field demonstrator is ready after the first beep.*

This demo has an implemented autocalibration function. Where the buzzer makes a *beep* with no touching of the demo, it means that the electrodes were calibrated.

The completed demo is shown in **Figure 6-2.**

6.7 Starting the Demo System

In order to run FreeMASTER on your computer, run the installation file ”fmaster12-38.exe” from the *FreeMASTER/freemaster_install* directory on the enclosed CD.

Once you have installed the FreeMASTER software, finished the cabling and connected the power supply, turned the demo on with switch SW1, you can start the FreeMASTER program.

6.7.1 Step 1

Start the FreeMASTER program by selecting the Windows menu sequence

Start -> Programs -> FreeMaster 1.2

When the program starts, the screen displays the main application window. If there is no project currently loaded, the window displays a welcome page, as shown in **Figure 6-8.**

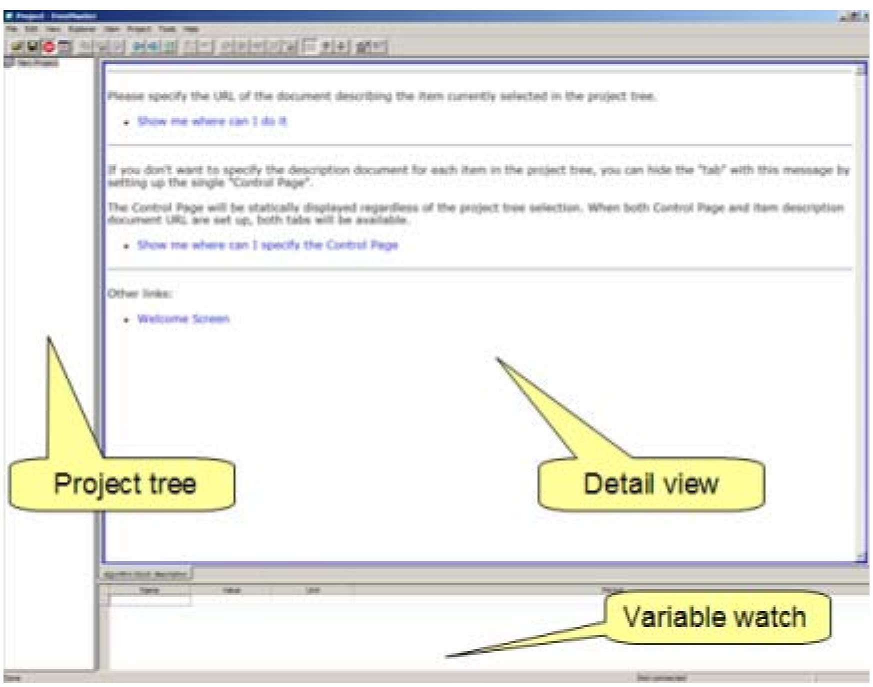


Figure 6-8. Main Window of FreeMASTER Software

The application window consists of three panes: **Project Tree**, **Detail View** and **Variable Watch**.

The Project Tree pane contains a logical tree structure of the application being monitored/controlled. Users can add project sub-blocks, Scope, and Recorder definitions to the project block, in a logical structure, to form a Project Tree. This pane provides a point-and-click selection of defined Project Tree elements.

The Detail View pane dynamically changes its contents depending on an item selected in the Project Tree. You can find detailed information about this pane in the FreeMASTER Software User Manual.

The Variable Watch pane contains a list of variables assigned to the watch. It displays the current variable values and allows you to change them (if enabled in the variable definition).

All the information related to one application is stored in a single project file with the extension ".pmp".

6.7.2 Step 2

Setup the communication for RS232.

If you are running the FreeMASTER software for the first time, you must setup the communication port and communication speed for the PC. The speed of the demo must be set to 57600 bauds.

Open the Options window by selecting the FreeMASTER software menu sequence:

Project -> Options

Select the appropriate COMx port and set up the speed to 57600 baud. See **Figure 6-9.**

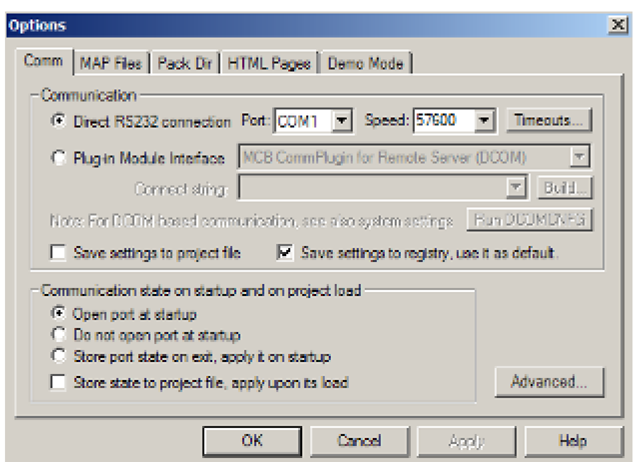


Figure 6-9. Options Window

6.7.3 Step 3

Open the FreeMASTER software project from the enclosed CD.

You can open a project by selecting the FreeMASTER software menu sequence:

File -> Open Project -> E-Field.pmp

See **Figure 6-10.**

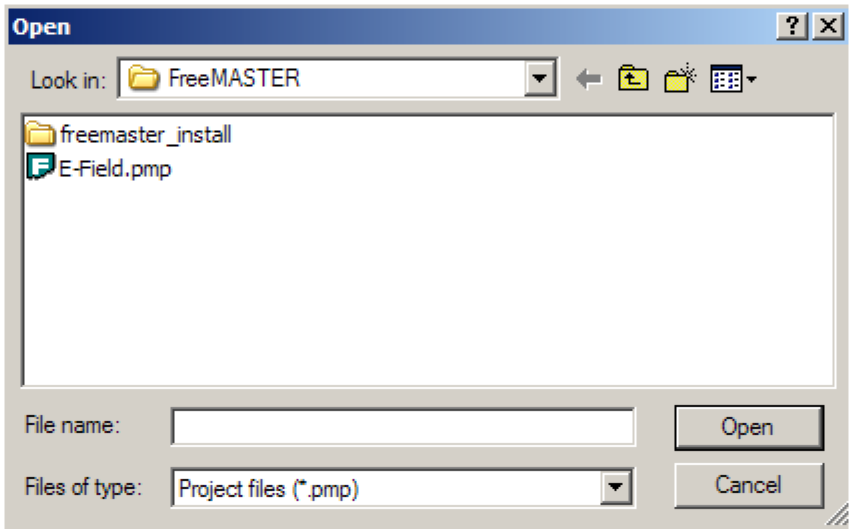


Figure 6-10. Open Project Window

If the project opened successfully, new information will be displayed on the screen. See **Figure 5-8.** The system works as follows: The FreeMASTER software communicates with the embedded application via a well-defined communication protocol. This protocol allows the PC application to issue commands and to read or modify the embedded application variables. All commands and variables used in the FreeMASTER software project must be specified within the project.

6.8 References

1. MC908QB8 data sheet

2. MC33794 data sheet

3. MC33993 data sheet

4. MC33886 data sheet

5. KIT33794DWBEVM - E-Field Imaging Device Evaluation Kit

6. Freescale Reference Manual - Touch Panel System Using the MC33794 E-Field Sensor

7. Freescale AN1985 - Touch Panel Applications Using MC34940/MC33794 E-Field ICs

8. Freescale AN2295 - Developer's Serial Bootloader for M68HC08 and HCS08 MCUs

9. Freescale AN2395 - PC Master Software Usage

10. Freescale AN2471 - PC Master Software Communication Protocol Specification

Appendix A
Electric-Field Contact-less Sensing System Schematics

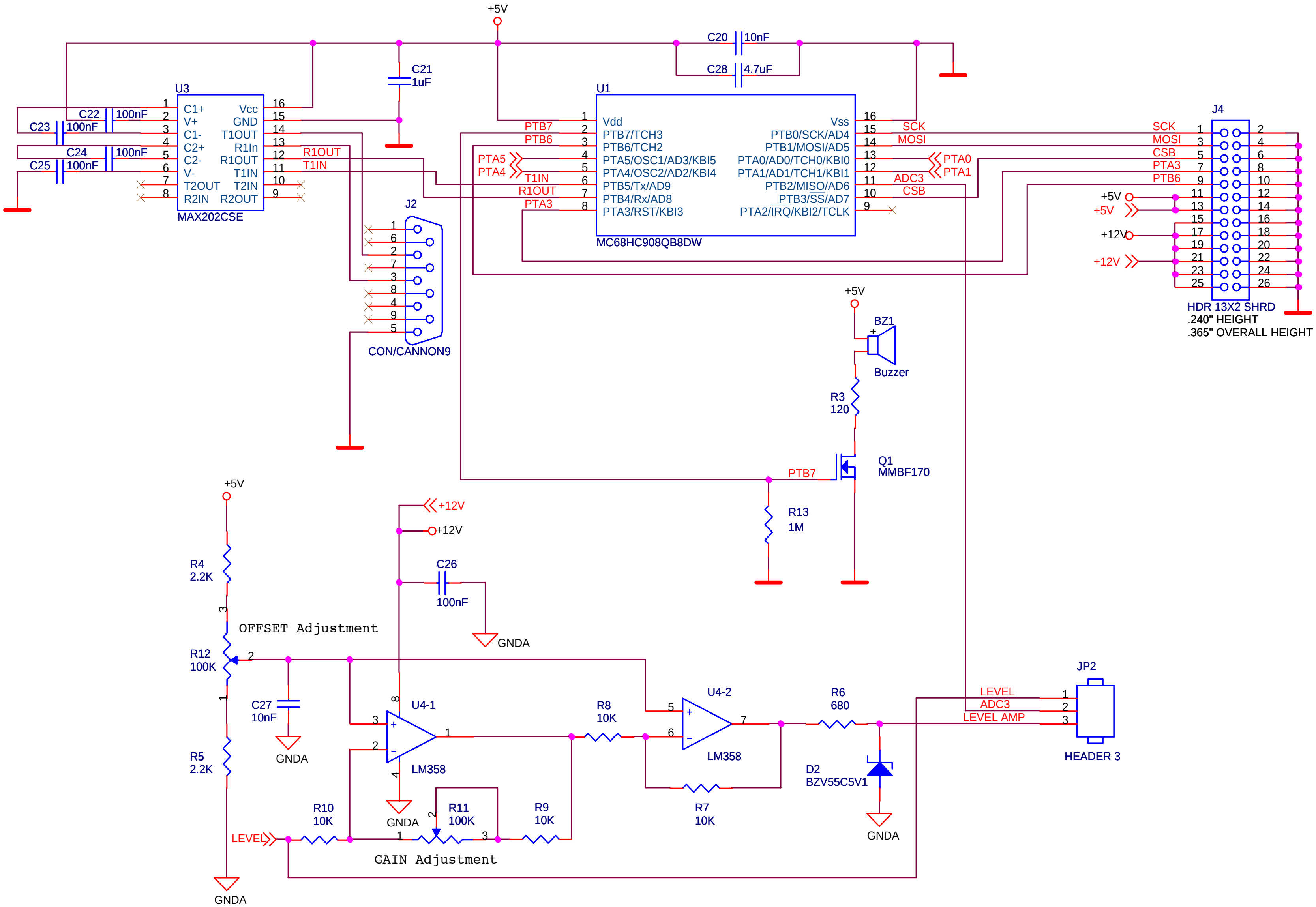


Figure A-1. Schematics "A" of Touch Pad Board

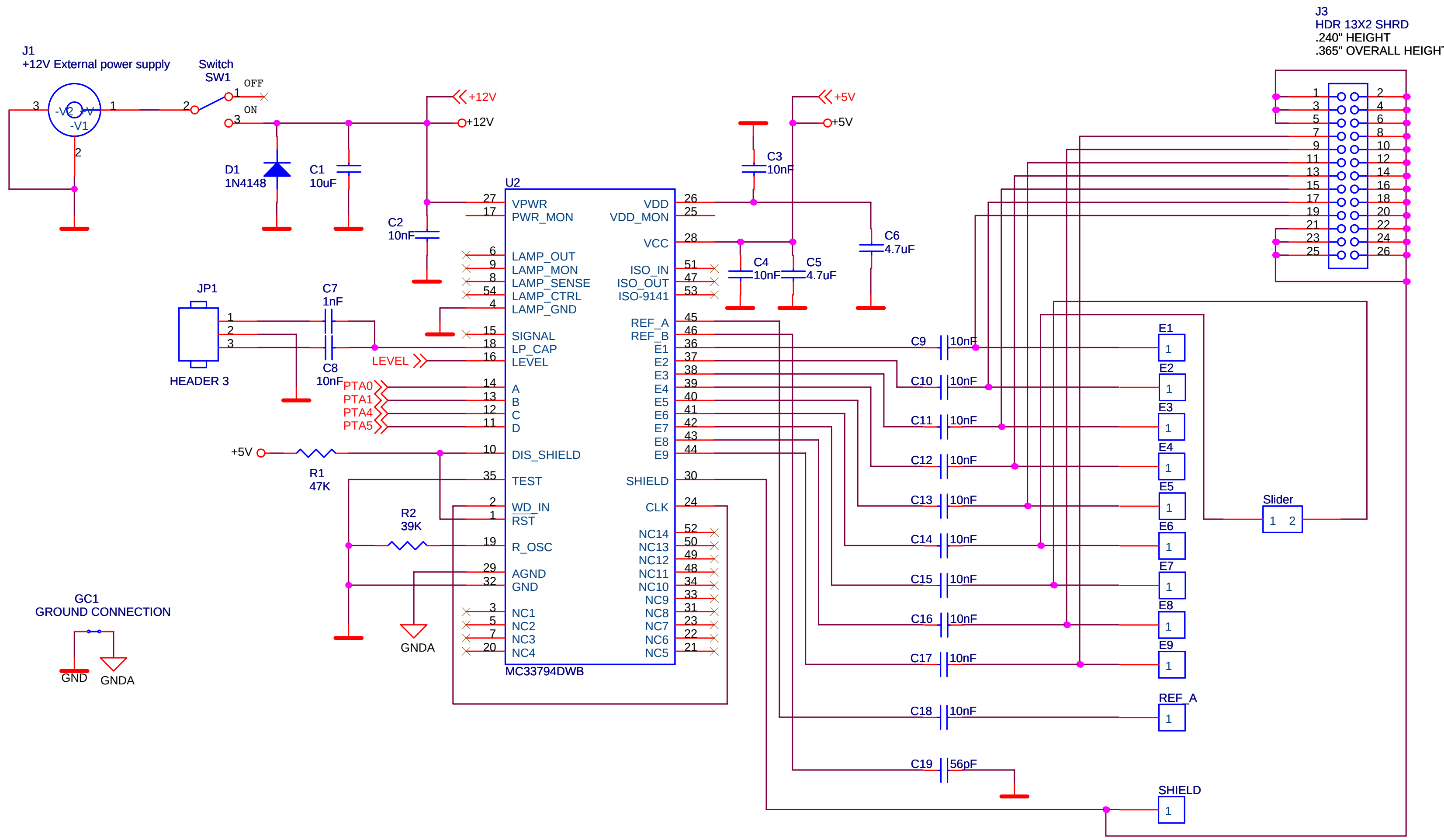


Figure A-2. Schematic “B“ of Touch Pad Board

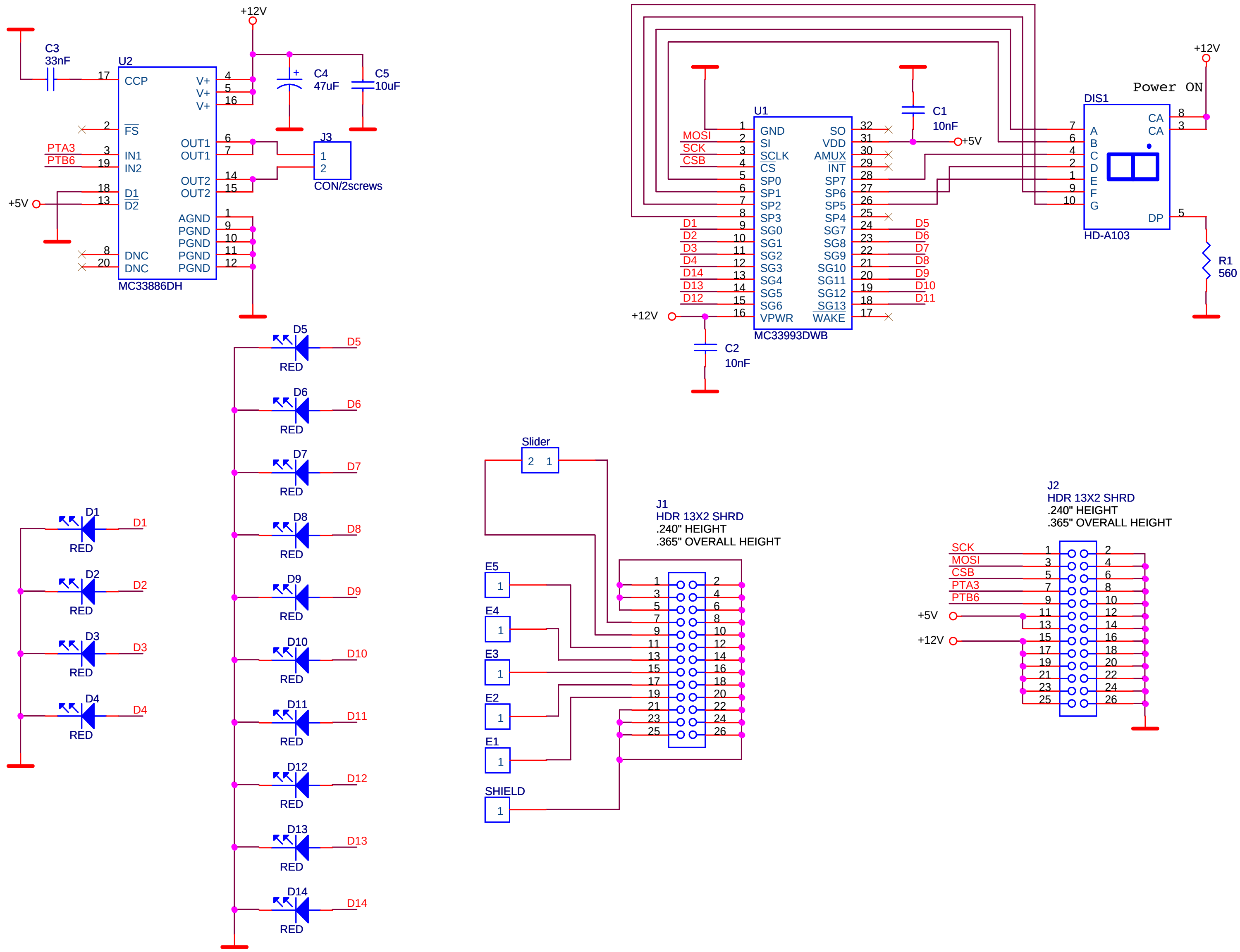


Figure A-3. Schematic of Water Level Board

Appendix B
Electric-Field Contact-less Sensing System
Bill of Material

Touch Pad Board BOM

Reference	Part Value	Description	Mfg.	Mfg. Part No.
BZ1	3-16 V/ 6mA	Buzzer	any acceptable	
C19	56 pF/ 50 V	SMD Ceramic Capacitor, 0805	any acceptable	
C7	1 nF/ 50 V	SMD Ceramic Capacitor, 0805	TDK	C2012X7R1H102K
C2, C3, C4, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C20, C27	10 nF/ 50 V	SMD Ceramic Capacitor, 0805	TDK	C2012X7R1H103K
C22, C23, C24, C25, C26	100 nF/ 25 V	SMD Ceramic Capacitor, 0805	TDK	C2012X7R1H104K
C21	1 uF/ 16 V	SMD Ceramic Capacitor, 0805	TDK	C2012X7R1C105K
C5, C6, C28	2.2 uF/ 16 V	SMD Ceramic Capacitor, 0805	TDK	C2012X7R1C225K
C1	10 uF/ 16 V	SMD Ceramic Capacitor, 1210	TDK	C3225X5R1C106M
D1	1N4148	SMD Switching Diode, SOD-80C (minimelf)	any acceptable	
D2	BZV55C5V1	5.1 V Zener Diode, SOD-80C (minimelf)	PHILIPS	BZV55-C5V1
J1	PWR Jack	Power Jack type connector 2.1mm	Elekon	K375A
J2	DB9/ female, 90°	Connector (RS232/ 9pin)		
J3, J4	Boardmount Socket	PCB socket 2x13 way	3M	8526-4500PL
JP1, JP2	1x3 Pin Header			
Q1	MMBF170	SMD MOSFET N-channel transistor, SOT23	ONSEMI	MMBF170LT1
R1	47K	SMD Resistor, 0805	any acceptable	
R2	39K	SMD Resistor, 0805	any acceptable	
R3	120	SMD Resistor, 0805	any acceptable	
R4, R5	2.2K	SMD Resistor, 0805	any acceptable	
R6	680	SMD Resistor, 0805	any acceptable	
R7, R8, R9, R10	10K	SMD Resistor, 0805	any acceptable	
R13	1M	SMD Resistor, 0805	any acceptable	

Touch Pad Board BOM

Reference	Part Value	Description	Mfg.	Mfg. Part No.
R11, R12	100K	Multi turn cermet trimmer (64Y)	VISHAY/ Spectrol	594-64Y104
SW1	Switch	Slide SPDT Top button	APEM	25136NAH
U1	MC68HC908QB 8DW	8 bit Microcontroller	FREESCALE	MC908QB8CDWE
U2	MC33794	E-Field sensor chip	FREESCALE	MC33794DWB
U3	MAX202	RS232 chip	Maxim-Dallas	MAX202CSE
U4	LM358	IC Dual OpAmp (surface mount)	ONSEMI	LM358D

Water Level Board BOM

Reference	Part Value	Description	Mfg.	Mfg. Part No.
C1, C2	10 nF/ 50 V	SMD Ceramic Capacitor, 0805	TDK	C2012X7R1H103K
C3	33nF/ 50V	SMD Ceramic Capacitor, 0805	any acceptable	
C4	47uF/ 16V	Surface Mount Electrolytic capacitor	any acceptable	
C5	10 uF/ 16 V	SMD Ceramic Capacitor, 1210	TDK	C3225X5R1C106M
D1 - D14	LED diode	Red SMD LED diode, 0805	KINGBRIGHT	KP-2012SURC
DIS1	LED display	Single digit numeric display (common anode)	KINGBRIGHT	SA52-11EWA
J1, J2	2x13 way Header	Male PCB Mounting Header, 90°	EZK	MLW26A
J3	CON/ 2screws	2 pin connector	EZK	CZM5/ 2
R1	560	SMD Resistor, 0805	any acceptable	
U1	MC33993	MSDI Device	FREESCALE	MC33993DWB
U2	MC33886	H - Bridge	FREESCALE	MC33886DH
front windshield filling unit - APO 040.01, 12V DC, manufacturer: SEV				

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