AAAA LCD Clock Demo User's Guide

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AAAA LCD CLOCK DEMO USER'S GUIDE

Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXA", where "XXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the AAAA LCD Clock Demo User's Guide. Items discussed in this chapter include:

- About this Guide
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support
- Document Revision History

ABOUT THIS GUIDE

Document Layout

This document describes how to operate the AAAA Clock Demo Board and details on its features. The manual layout is as follows:

Chapter 1. Introduction – an overview of the AAAA Clock demo and its features

Chapter 2. Operating Instructions – how to set the time and other settings

Chapter 3. Bill of Materials – a brief description of the power supply

Chapter 4. Optional Features – a brief description of the capacitive sense

Appendix A. Schematic Diagram – schematics for the AAAA Clock Demonstration Board.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">Arial font:</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>PICDEM LCD 2 User’s Guide</td></tr>
<tr><td>Emphasized text</td><td>...is the only compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><td>A menu selection</td><td>select Enable Programmer</td></tr>
<tr><td>Quotes</td><td>A field name in a window or dialog</td><td>“Save project before build”</td></tr>
<tr><td>Underlined, italic text with right angle bracket</td><td>A menu path</td><td><u>File>Save</u></td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click OK</td></tr>
<tr><td>A tab</td><td>Click the Power tab</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">Courier font:</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td><code>#define START</code></td></tr>
<tr><td>Filenames</td><td><code>autoexec.bat</code></td></tr>
<tr><td>File paths</td><td><code>c:\mcc18\h</code></td></tr>
<tr><td>Keywords</td><td><code>_asm, _endasm, static</code></td></tr>
<tr><td>Command-line options</td><td><code>-Opa+, -Opa-</code></td></tr>
<tr><td>Bit values</td><td><code>0, 1</code></td></tr>
<tr><td>A binary number</td><td><code>‘b00100, ‘b10</code></td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td><code>file.o</code>, where <code>file</code> can be any valid filename</td></tr>
<tr><td>0xnnnn</td><td>A hexadecimal number where n is a hexadecimal digit</td><td>0xFFFF, 0x007A</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td><code>mcc18 [options] file [options]</code></td></tr>
<tr><td>Curly brackets and pipe character: { | }</td><td>Choice of mutually exclusive arguments; an OR selection</td><td><code>errorlevel {0|1}</code></td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td><code>var_name [, var_name...]</code></td></tr>
<tr><td>Represents code supplied by user</td><td><code>void main (void)
{...
}</code></td></tr>
</table>

RECOMMENDED READING

This user's guide describes how to use the AAAA Clock Demo. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Readme Files

For the latest information on using other tools, read the tool-specific Readme files in the Readmes subdirectory of the MPLAB® IDE installation directory. The Readme files contain update information and known issues that may not be included in this user's guide.

The following documents are comprehensive references for the AAAA Clock Demo:

"Capacitive Touch Using Only an ADC (CVD)" AN1298

"Design Practices for Low-Power External Oscillators" AN1288

"PIC16F1933 Data Sheet"

"MCP9701A Data Sheet"

"MCP1624 Data Sheet"

"Energizer Data Sheet" (http://data.energizer.com/PDFs/E96.pdf)

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- **Emulators** – The latest information on Microchip in-circuit emulators.This includes the MPLAB ICE 2000 and MPLAB ICE 4000.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 2.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM simulator, MPLAB IDE Project Manager and general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 and PRO MATE® II device programmers and the PICSTART® Plus and PICkit™ development programmers.

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- Distributor or Representative
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- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://support.microchip.com

DOCUMENT REVISION HISTORY

Revision A (October 2010)

- Original version of this document.

Chapter 1. Introduction

The AAAA LCD Clock Demo demonstrates how a PIC® microcontroller can run from a single AAAA 1.5V battery. An MCP1624 boost controller is used, which is capable of starting with an input voltage as low as 0.65V to boost a single AAAA battery up to 3.3 volts. Also included are capacitive sense buttons for configuring the clock, an MCP9701A analog temperature sensor, a custom LCD and the ability to measure the battery voltage. The design also has the option for an external buzzer and auto shut-down by means of additional components, but these are not part of the standard assembly.

The clock displays time, temperature and battery voltage. The PIC16F1933 uses the 32.768 KHz crystal to clock the internal timer, which then generates the interrupt that causes the device to wake from Sleep. This interrupt updates the time, runs the capacitive sensors and samples the voltage and temperature. While the microcontroller is awake, it runs using the internal 500 KHz oscillator, executing instructions quickly and allowing more time in Sleep.

Please note that this demo board is not intended to be an extreme low-power demonstration. Changes can be made to the hardware and source code that will improve the overall power consumption and extend the battery life. For example, utilizing low-power modes on the LCD drive, reducing the sample rate of the capacitive sensors until an initial touch is sensed, sampling temperature less often, optimizing code to run faster and sleep longer will reduce power consumption to extend battery life.

Pads for connection to a PICkit™ 2 or PICkit 3 programmer have been included for users who wish to modify or write new firmware. The source code is available at http://www.microchip.com/AAAA.

The following features have not been implemented in the demo board, but are additional possible projects:

- Add an audible alarm using a Piezo buzzer and drive it using the PWM
- Implement auto power-down on the power supply
- Take the current demo source code and, while keeping the same functionality, reduce the current consumption as much as possible by only changing the code
- By using the auto power-down on the power supply, attempt to reduce the overall current consumption even more without changing the functionality

Some hints and tips are found later in this document.

Chapter 2. Operating Instructions

The following instructions are for version 1.04 of the firmware as shipped, which varies slightly from the instructions on the packaging.

2.1 LCD LAYOUT

The LCD has five different zones that we use. They are highlighted in the image below.

FIGURE 2-1: LCD ZONES

1. The battery level indicator is shown on the top left. When empty, the battery should be replaced.
2. The top right has a single seven-segment digit that is used to indicate AM , PM , Temperature , Battery Voltage or a 10 second count if in 24 hour mode.
3. On the right side, F3 and F4 are used to show when a capacitive button has been pushed.
4. In the right bottom corner is the Microchip Technology Inc. logo, which blinks every second.
5. The remainder of the display is a four-digit, seven-segment display which displays the time, temperature or battery voltage.

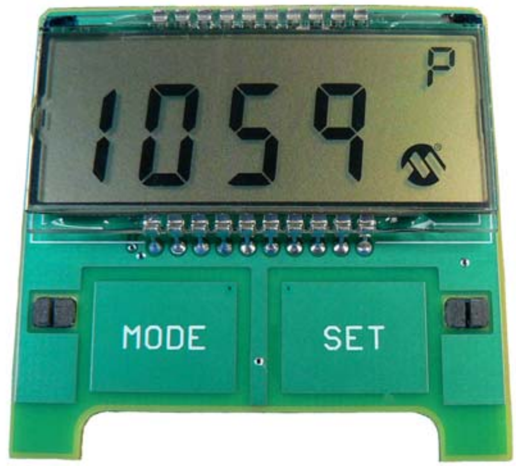
2.2 INITIAL POWER UP

On insertion of an AAAA battery (Energizer E96), the display will show the following:

1. Firmware version (1.04)
2. Temperature in Centigrade
3. Battery voltage in Volts
4. The time of 12:00A
5. This sequence then repeats from 2

2.3 SETTING TIME AND FORMATS

FIGURE 2-2: MODE AND SET BUTTONS



1. To enter the setup, press and hold the MODE button. After approximately 3 seconds, the hours should start flashing. Release the MODE button.
2. You can now set the hours by pressing and holding the SET button.
3. Press MODE until the minutes are flashing, then release the button.
4. You can now set the minutes by pressing and holding the SET button.
5. Press MODE until the A, P or 0 is flashing, then release the button.
6. You can now choose between AM, PM and 24 hour modes
7. Press MODE until the temperature is displayed and the C or F is flashing, then release the button.
8. You can now select between Centigrade C and Fahrenheit F by pressing SET.
9. Pressing MODE will now return you to the normal display.

2.4 ADDITIONAL INFORMATION

2.4.1 Boost Supply

The MCP1624 is a compact, high-efficiency, fixed frequency, synchronous step-up DC-DC converter. It provides an easy-to-use power supply solution for applications powered by one battery, making it ideal for this demonstration.

Low-voltage technology allows the regulator to start-up without high in-rush current or output voltage overshoot from a low 0.65V input. High efficiency is accomplished by integrating the low resistance N-Channel Boost switch and the synchronous P-Channel switch. All compensation and protection circuitry are integrated to minimize external components. For standby applications, the MCP1624 operates and consumes only 19 µA while operating at no load. Output voltage is set by a small external resistor divider.

Testing the AAAA LCD Clock Demo shows that the power supply would keep running well below 0.65V. However, it is not recommended to run an alkaline battery at less than 0.6V since the battery could corrode and potentially leak. An optional circuit can be used to prevent current drain below 0.6V, which is described later in this user's guide.

For more information, please refer to the MCP1624 data sheet.

2.4.2 Capacitive Sense

This demonstration uses the Capacitive Voltage Divider (CVD) method for its simplicity of operation and relatively low power consumption.

The AAAA LCD Clock Demo board runs the capacitive touch as part of the interrupt routine every time the processor wakes from Sleep. In v1.04, this interrupt occurs eight times per second giving enough samples to have a responsive button press without consuming excessive amounts of power. Power consumption could be further reduced by sampling at a slower rate until the first user touch is made.

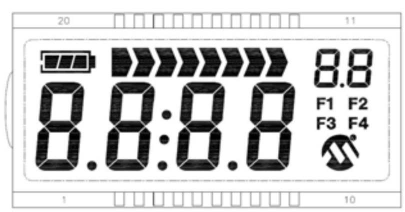
For detailed information about CVD, please refer to AN1298 “*Capacitive Touch Using Only an ADC (CVD)”*.

2.4.3 LCD

The PIC16LF1933 has a built-in multiplexed LCD peripheral driving the custom LCD used. There are modes available that allow lower power consumption. However, these are not used in this demo, so it is possible to reduce the power consumption further. Source code to do this may be provided at a later date.

The LCD layout is shown in Figure 2-3.

FIGURE 2-3: LCD LAYOUT



Because of the limited pins on the part used, the chevrons and one of the smaller 7-segment digits are not implemented, so only 48 out of the 64 segments are used in this demo.

The full data sheet for this display can be downloaded from http://www.microchip.com/AAAA.

This display is multiplexed in a 4x16 configuration with a total of 64 segments.

Driving conditions for the LCD are 1/4 Duty, 1/3 Bias, 3.3V.

The files `lcd.c` and `lcd.h` configure the LCD driver, map the individual LCD segments and create a basic character set that is used in the clock demo. This simple LCD driver can easily be modified for use with other LCD displays and PIC microcontrollers.

The LCD controller is configured to use the medium power reference, which gives a better contrast ratio and runs off the 32.768 KHz external oscillator. There are more power efficient modes that can be used, but the contrast on the LCD will be reduced.

One of the LCD controller options shares the time between the higher power reference and the low power reference. This reduces the average power consumption while still maintaining good contrast. For details, see the PIC16F1933 Data Sheet section *26.4.3 “Automatic Power Mode Switching”*, since it explains in detail how this mode operates and can reduce power consumption.

2.4.4 Crystal Capacitor Calculation

The 32.768 KHz crystal for keeping time requires careful selection of the load capacitors. If the incorrect values are used, the time can be incorrect by minutes in a day. Using a 20 ppm crystal, the clock should be able to achieve an accuracy of +/- 1.73 seconds per day (10.51minutes/year) or better.

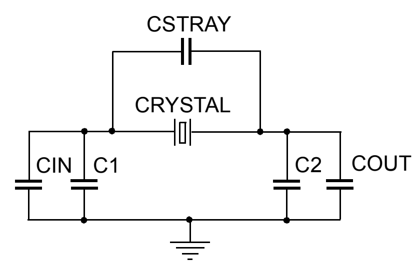
To achieve this, the following information is needed:

1. The expected total capacitance loading on the crystal, usually given in the crystal's data sheet.
2. The total capacitance of the PCB and Microcontroller on the oscillator pins.

On the AAAA Clock Demo board, an Abracon ABS13-32.768 KHz-T crystal was used. From its data sheet, this crystal requires an effective loading capacitance (CL) of 12.5 pF. Measuring the Capacitance of the OSC pins on the PIC16F1933 was around 1 pF. The stray capacitance of the PCB was measured around 1 pF.

The equivalent circuit is shown in Figure 2-4.

FIGURE 2-4: EQUIVALENT CIRCUIT



CL is the total load capacitance that the crystal sees. From this circuit, the calculation is as follows:

EQUATION 2-1:

$$CL = \frac{(CIN + C1)\ x\ (COUT + C2)}{CIN + COUT + C1 + C2} + CSTRAY$$

We need to solve for C1 and C2. Since we want C1 = C2, and since CIN = COUT, we can use the following calculation:

EQUATION 2-2:

$$CL = \frac{(C1 + CIN)\ x\ (C1 + CIN)}{(C1 + CIN)\ x\ 2} + CSTRAY$$

$$CL - STRAY = \frac{C1 + CIN}{2}$$

$$C1 + CIN = (CL - CSTRAY)\ x\ 2$$

$$C1 = ((CL - CSTRAY)\ x\ 2) - CIN$$

$$C1 = ((12.5 - 1)\ x\ 2) - 1$$

$$C1 = C2 = 22pF$$

This is a standard value capacitor which was then fitted to the board and tested over a 72 hour period. Compared to an accurate clock, the time shift over the 72 hours was less than 1 second, which is well within the 20 ppm specified for the crystal.

For more information, please read "*Design Practices for Low-Power External Oscillators*" *(AN1288)*.

2.4.5 Temperature Sensor

An MCP9701A analog temperature sensor is used on this board. The default software only allows for temperatures greater than zero degrees Centigrade.

The 10-bit ADC is used with the 2.048V internal voltage reference. The MCP9701A uses 19.5 mV / °C and 0°C offset of 400 mV. To save power, the following sequence is performed:

1. Power up the MCP9701A and the internal 2.048V reference.
2. Delay to allow outputs to stabilize.
3. Sample the ADC.
4. Power down the MCP9701A.

Calculating the temperature is done as follows:

1. Take the 10-bit result and multiply it by two (left shift by one bit). The resulting value is now mV due to using the 2.048V reference.
2. Subtract 400 mV from the result.
3. Multiply by 10 since we are doing integer math only.
4. Divide by 195 (19.5 mV per °C x 10 = 195)
5. The result is now in °C (Tc)

To convert to °F (Tf), the standard formula is:

EQUATION 2-3:

$$Tf = (9 / 5) \text{ x } Tc + 32$$

Since 9/5 = 1.8 and we are using integer math, the following calculation can be used:

EQUATION 2-4:

$$Tf = ((18 * Tc) /10) + 32$$

The source code differs slightly because an additional x10 has been used after calculating °C. This was done to shift the resulting value one digit to the left so that  or  could be displayed to the right of the temperature.

Using an MCP9700 temperature sensor would have simplified the math, since it uses 10 mV/°C. Since the LSB is 2 mV, this gives 5 LSBs per °C. The MCP9701 uses 19.5 mV/°C, which gives close to 10 LSBs per °C. This is ideal if we want to display 1/10°C on the display.

Chapter 3. Bill of Materials

TABLE 3-1: BILL OF MATERIALS

Qty	Part	Value	Manufacturer	Manufacturer Part#	Digikey Part#
	CAPACITORS				
3	C1,C4,C9	0.1µF	Generic X7R		490-1524-2-ND
2	C2,C3	22 pF	Generic COG		445-1273-2-ND
1	C5	4.7µF	Generic Y5V		PCC2474TR-ND
1	C6	10 µF	Generic Y5V		445-1593-2-ND
	RESISTORS				
1	R1	100K	Generic 5%		RMCF1/16100KJRTR-ND
1	R2	976K 1%	Generic 1%		311-976KHRCT-ND
1	R3	562K 1%	Generic 1%		311-562KHRTR-ND
1	R4	10K	Generic 5%		RMCF1/1610KJRTR-ND
2	R5,R8	4.7K	Generic 5%		RMCF1/164.7KJRTR-ND
1	R11	1K	Generic 5%		RMCF1/161KJRTR-ND
1	C8	0R	Populate C8 with 0R		RMCF1/160RTR-ND
	INDUCTORS				
1	L1	4.7µH	Murata	LQM21FN4R7M70L	490-4028-2-ND
	LCD				
1	LCD1	Custom	Focus Displays		
	SEMICONDUCTOR				
1	U1	PIC16LF1933	Microchip	PIC16LF1933-I/SO	
1	U2	MCP9701AT	Microchip	MCP9701AT-E/TT	
1	U3	MCP1624	Microchip	MCP1624T-I/CHY	
	CRYSTAL				
1	Y2	32.768 KHz	ABRACON	ABS13-32.768KHZ-T	535-9165-2-ND
	MISC				
1	B2	AAAA	Energizer	UM6	
1	AAAA Battery	AAAA Battery	Energizer	E96	

Chapter 4. Optional Features

Appendix A. "Schematic Diagram" shows additional options to program the clock, add a piezo buzzer and an auto power-down option.

4.1 PROGRAMMING PORT

The programming port is based on the PICkit™ 3 header. To program the AAAA Clock demo, there are two options for connecting to the board using a PICkit 3.

Option 1: Using a 0.1"x6-way pin header, insert it into the PICkit 3 and hold onto the surface mount pads to program the part. The plastic stand will need to be removed to do this, and it is not 100% reliable. Pogo pins would improve reliability.

Option 2: Solder a 0.1"x6-way pin header to the surface mount pads. Use hot glue to secure the header to the board to prevent it from breaking tracks. This method is more difficult to implement, but is more reliable if you intend to connect to the programmer on a regular basis. The hot glue is a crucial step; if it is missed, the pads will delaminate and break connection after a few uses.

4.2 THE PIEZO BUZZER

Connector J4 can be used to connect a disc type piezo buzzer to add an audible alarm option. This pin is connected to RC6, which is the PWM output channel P3A. It is possible to add code to set the time for an alarm, and then use PWM to drive the Piezo to generate a suitable alarm sound.

Please note that if the auto power-down circuit is used, you cannot add the piezo buzzer.

4.3 AUTO POWER-DOWN

Since running a single cell battery below 0.6V risks battery leakage, there is an option to add a self-booting and auto power-down circuit. Remove the resistor in C8's position and then add C8, R9 and R10, as shown in the schematic in Appendix A.

The theory behind this circuit is that when a fresh battery is inserted, the voltage at pin 2 on the MCP1624 spikes to 1.5V because of capacitor C8. The MCP1624 then starts and remains running long enough to pull the EN pin high through R9. The PIC16LF1933 checks the battery on a regular basis and, if the voltage on the battery drops below a specific threshold (for example 0.63V), it then pulls the EN pin on the MCP1624 Low, which turns the power supply off.

It may also be possible to use this feature to shut off the regulator for short periods of time to let the output voltage drift down a little, then re-enable it to boost back up. This may help reduce the overall power consumption by reducing the average quiescent current used by the regulator itself. This would only be effective when the circuitry the regulator is supplying is in its minimum current draw mode. Larger capacitance on the 3.3V rail may extend the time that the regulator can be off.

Please note that none of the above has been tested.

4.4 ENERGIZER AAAA (E96) BATTERY

The AAAA Clock Demo uses the Energizer E96, which is smaller than an AAA.

At the time of document publication, the AAAA was a very new release of battery which is ideal for products that need a smaller diameter, for example laser pointers, LED flashlights and other pen size devices.

- Max Diameter: 8.3 mm (0.327")
- Max Length: 42.5 mm (1.673")
- Typical Weight: 6.5 grams (0.2 oz)
- Nominal Capacity: 600 mA/H @ 10 mA (continuous discharge down to 0.8V)

For the Energizer E96 data sheet, refer to: http://data.energizer.com/PDFs/E96.pdf.

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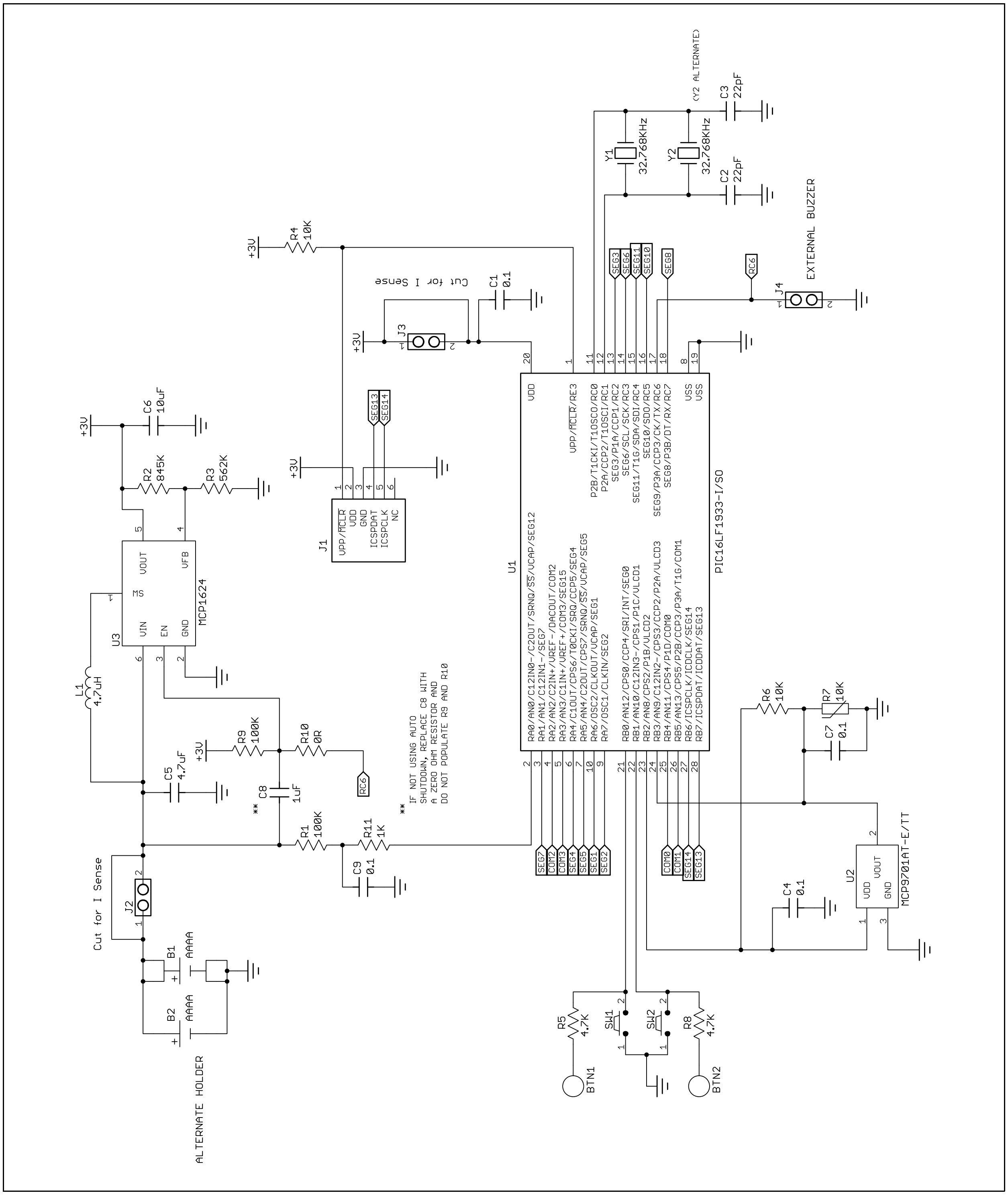
Appendix A. Schematic Diagram

FIGURE A-1: SCHEMATICS



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