AN1556

Blood Pressure Meter Design Using Microchip's PIC24F Microcontroller and Analog Devices

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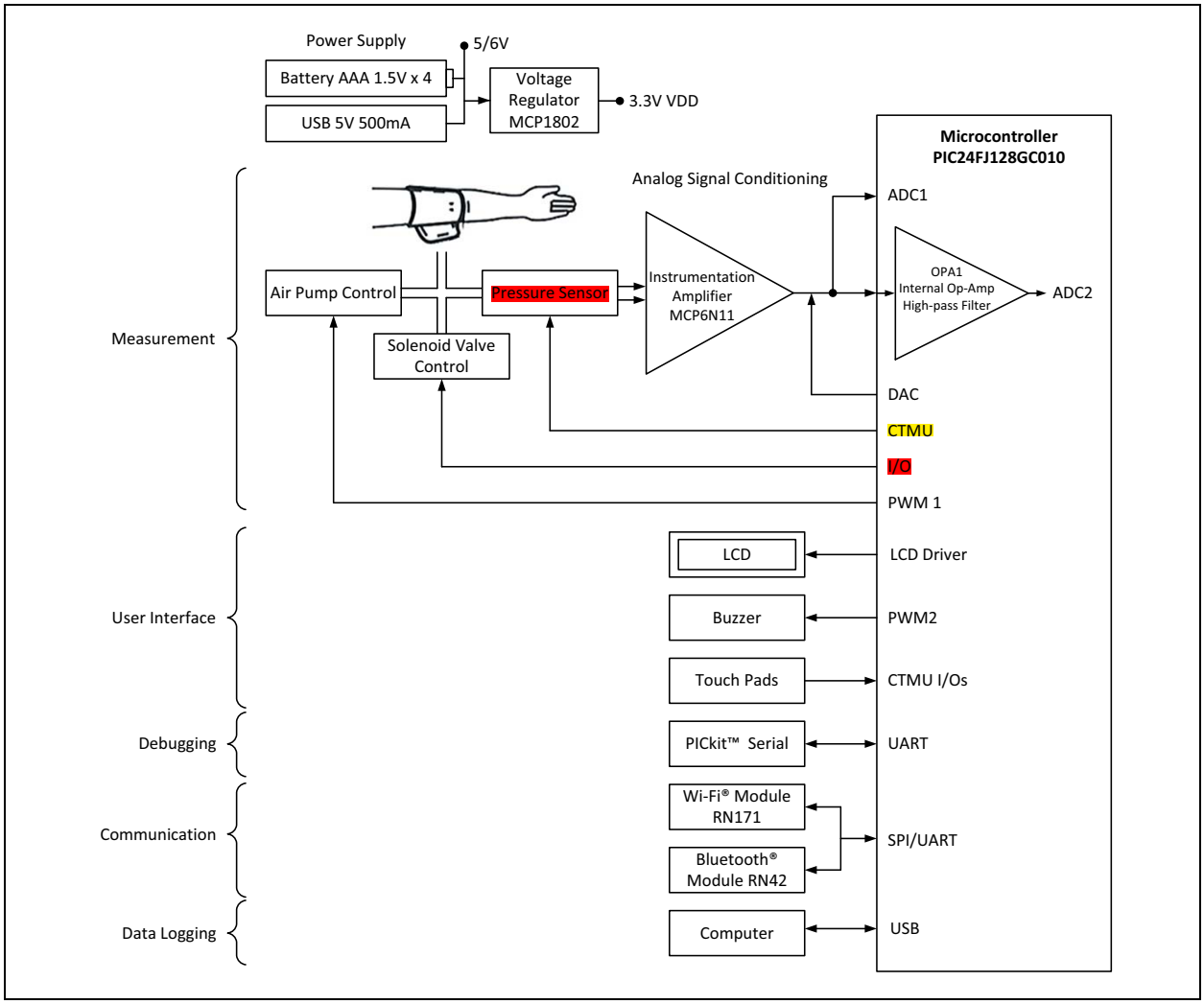
INTRODUCTION

A Blood Pressure Meter (BPM) is a non-invasive device used to measure blood pressure. This application note demonstrates the implementation of a digital blood pressure meter using Microchip's PIC24FJ128GC010 microcontroller and MCP6N11 instrumentation amplifier.

FIGURE 1: BLOCK DIAGRAM



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ANALOG FRONT-END SIGNAL CONDITIONING CIRCUIT DESCRIPTION

As shown in Figure 1, the MCP6N11-100 single instrumentation amplifier (INA) is used to condition the analog signal acquired from the Wheatstone bridge type of air pressure sensor. The overall INA gain is set at 151 V/V. The output signal of the MCP6N11 is split into two paths. One path, representing the cuff pressure, is connected to the ADC1 channel of the microcontroller. Another path is passed through a 2-pole active high-pass filter with cutoff frequencies of 0.48Hz and 4.8Hz, and a gain of 92. The high-pass filter is formed by one of the microcontroller's internal operational amplifiers. The output of the high-pass filter, representing the oscillation signal, is sent to the ADC2 channel of the microcontroller through a notch filter.

PIC24FJ128GC010 MICROCONTROLLER

The microcontroller provides a 12-bit high-speed pipeline Analog-to-Digital Converter (ADC). The cuff pressure signal and the oscillation signal are both sampled at 500 Hz by the 12-bit ADC.

As described in the previous section, the demo system uses one of the microcontroller's internal operational amplifiers to build the analog high-pass filter. It also utilizes one of the internal 10-bit Digital-to-Analog Converters (DAC) with buffered output voltage to provide an adjustable DC offset level as the bias for the operational amplifier.

Microchip's mTouch™ sensing solution is implemented in the firmware for the capacitive touch pads utilizing the microcontroller's Charge Time Measurement Unit (CTMU). Meanwhile, the air pressure sensor requires a stable supply current of 100 uA DC which is also provided by the CTMU.

The demo system utilizes the microcontroller's Pulse-Width Modulation (PWM) module to drive the air pump's motor in fast or slow speed mode. The noise generated by a running motor can interfere with the pressure measurement while inflating. The circuit design, firmware and Printed Circuit Board (PCB) layout are intended to reduce the motor noise.

The results for blood pressure and pulse rate can be sent to a Liquid Crystal Display (LCD) panel, USB interface and wireless interface. The microcontroller has an integrated LCD controller that generates the data and timing control required to directly drive a static or multiplexed LCD panel. The demo system utilizes the microcontroller's USB On-The-Go interface for data communication as well as the 5V main power source. For wireless communication, the microcontroller's SPI or UART port connects to one of Microchip's Bluetooth® module RN42 or Wi-Fi® module RN171. A real-time clock is also displayed on the LCD panel by using the microcontroller's Real-Time Clock and Calendar module that can operate in Deep Sleep mode.

POWER SUPPLY

The main input power is supplied by either four 1.5V AAA alkaline batteries or the USB's VBus line. The MCP1802 LDO converts the 5V or 6V main input voltage to 3.3V VDD.

SPECIAL FEATURES

A digital low-pass filter with a cutoff frequency of 5 Hz is implemented in the firmware. It filters the raw ADC samples acquired on the oscillation signal.

This demo system uses a custom algorithm for blood pressure calculation that was developed based upon published academic papers available in the public domain (see **Appendix D: "References"**).

MEASUREMENT TECHNOLOGY

A digital blood pressure meter measures systolic and diastolic pressures by oscillometric detection. Microchip's digital blood pressure meter demo can measure blood pressure and pulse rate during inflation. The Measurement While Inflating (MWI) principle reduces overall measuring time, which in turn reduces discomfort caused by the pressure in the cuff.

After the motor pumps the pressure up to 30 mmHg in fast mode, the motor changes to slow mode gradually and linearly inflating the cuff. When the pressure in the cuff gets high enough to just begin constricting the flow of blood, the arterial pulse becomes detectable by the pressure sensor. At this point, the waveform captured from the ADC2 channel (the output of the analog high-pass filter) starts to show the onset of the blood pressure oscillation signal (see Figure 2). The oscillation signal is then filtered by a digital low-pass filter. The Mean Arterial Pressure (MAP) is the cuff pressure which corresponds to the maximum oscillation signal. Based on the custom algorithm for blood pressure calculation, the Systolic Pressure (SYS) and the Diastolic Pressure (DIA) can be determined using the MAP value and a lookup table of empirical formulas (see Figure 3). The inflation process is automatically terminated when the pressure reaches a specified value. The Pulse Rate (PR) can be calculated based on ADC sample rate and sample numbers obtained in multiple consecutive pulses.

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FIGURE 2: RAW ADC DATA OF THE OSCILLATION SIGNAL ACQUIRED FROM THE ADC2 AT 500 SAMPLES/SECOND

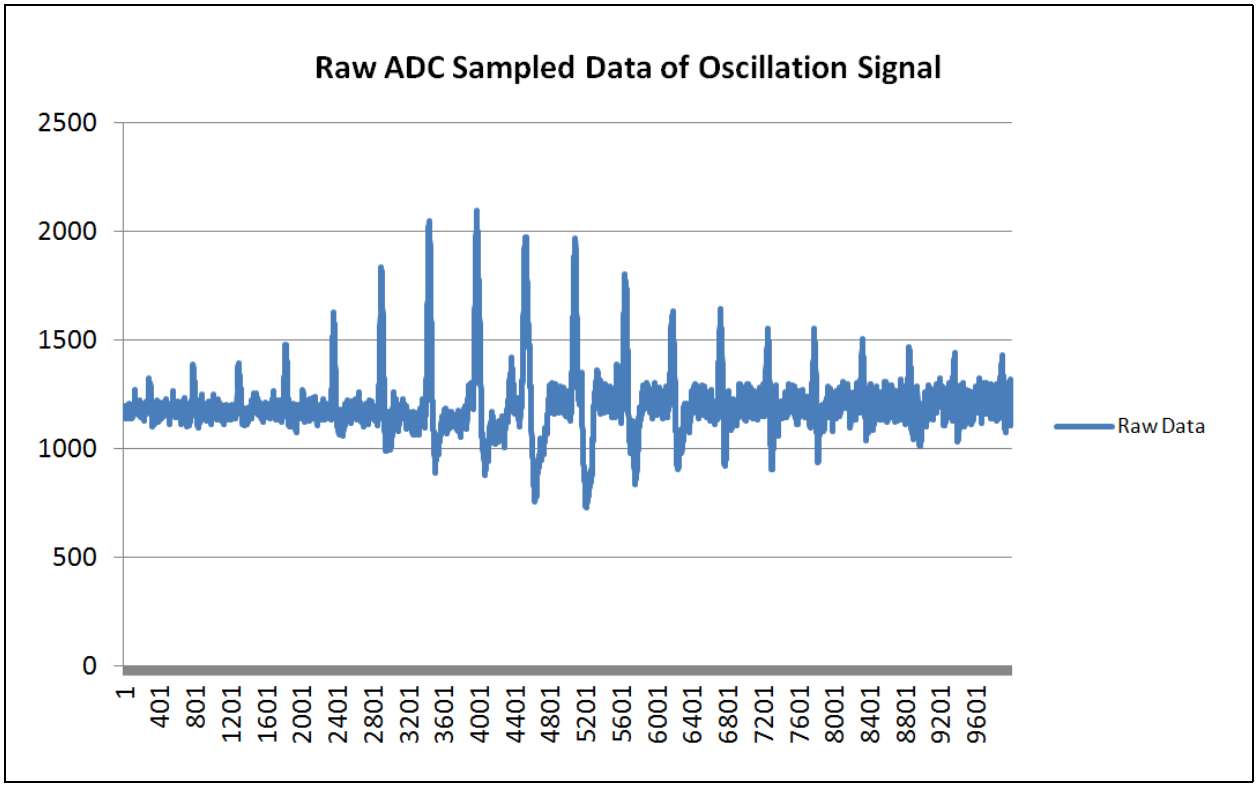
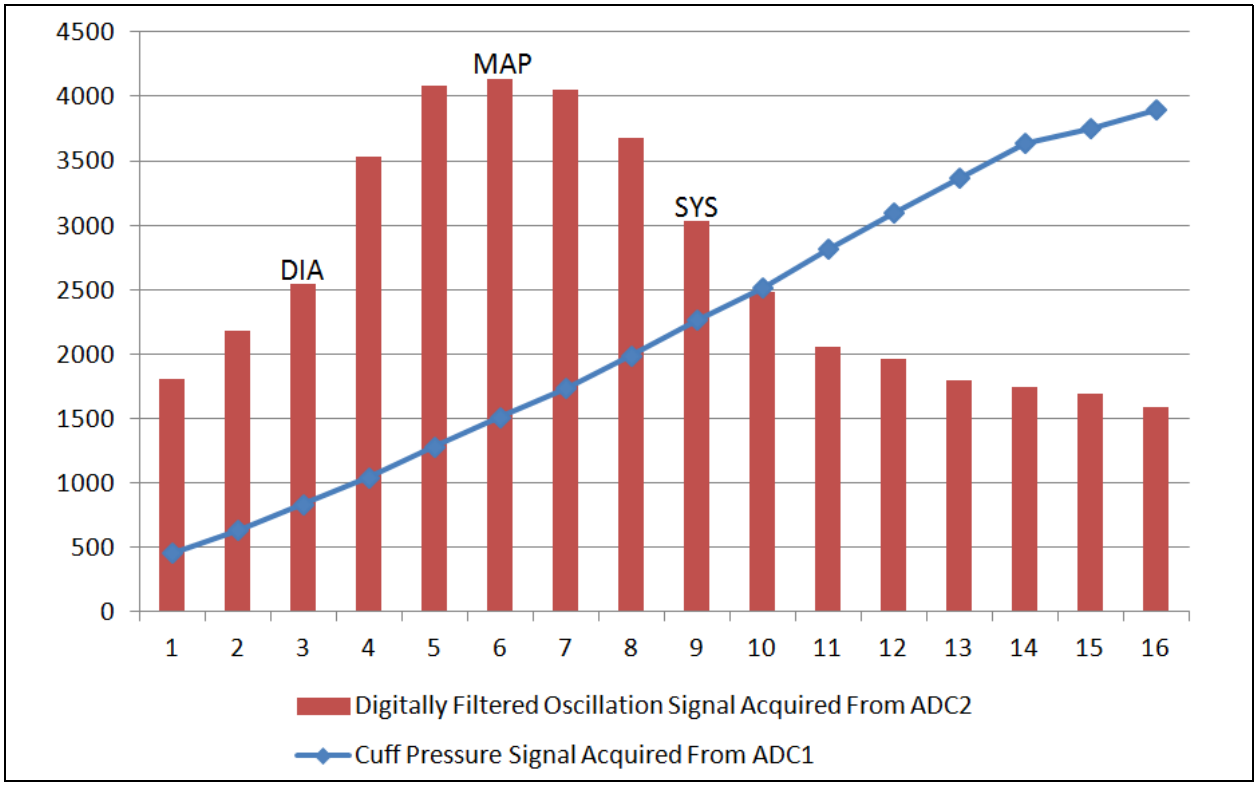


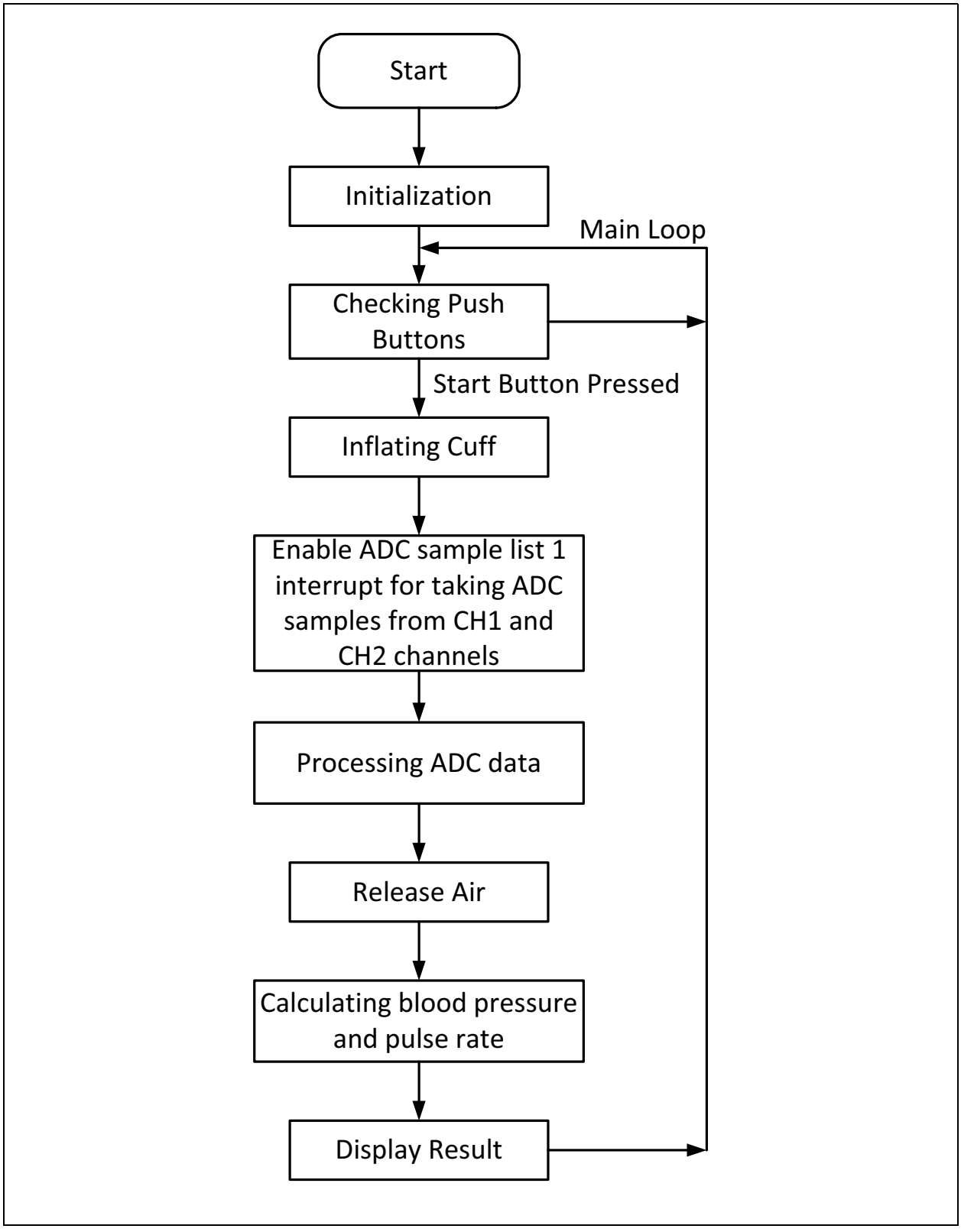
FIGURE 3: THE PLOT OF ADC DATA FOR DIGITALLY FILTERED OSCILLATION SIGNAL AND CUFF PRESSURE SIGNAL



PROGRAM FLOWCHART

Figure 4 shows the firmware process flow.

FIGURE 4: FIRMWARE PROCESS FLOWCHART



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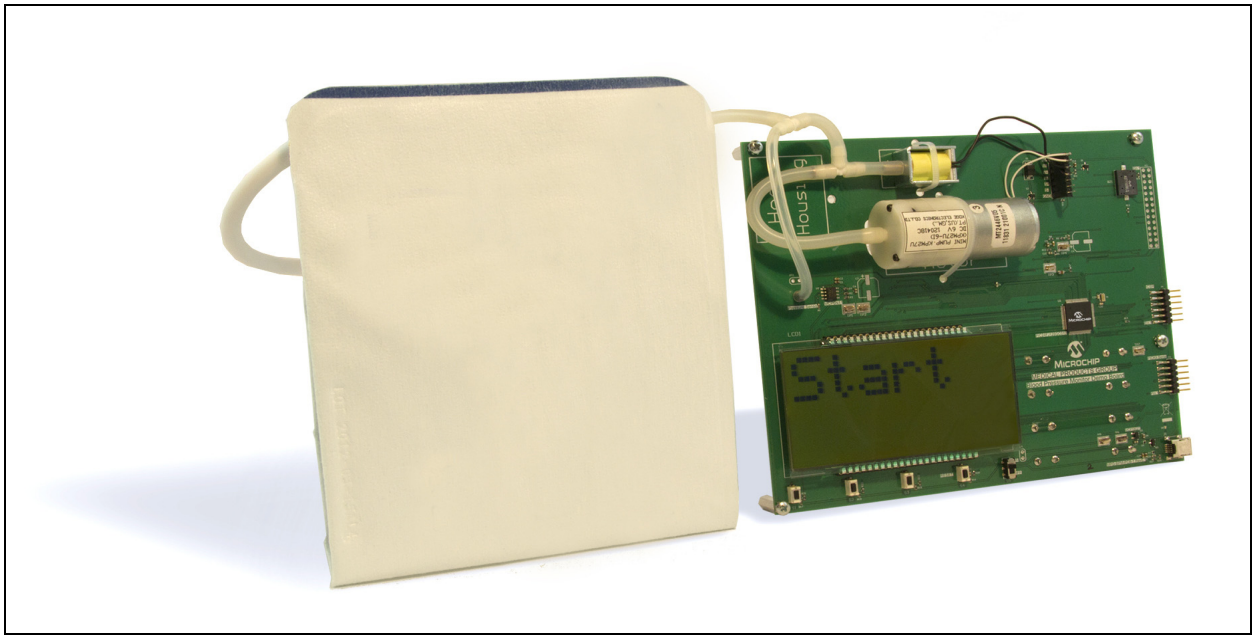
APPENDIX A: BPM DEMO BOARD

This appendix shows the BPM demo board.

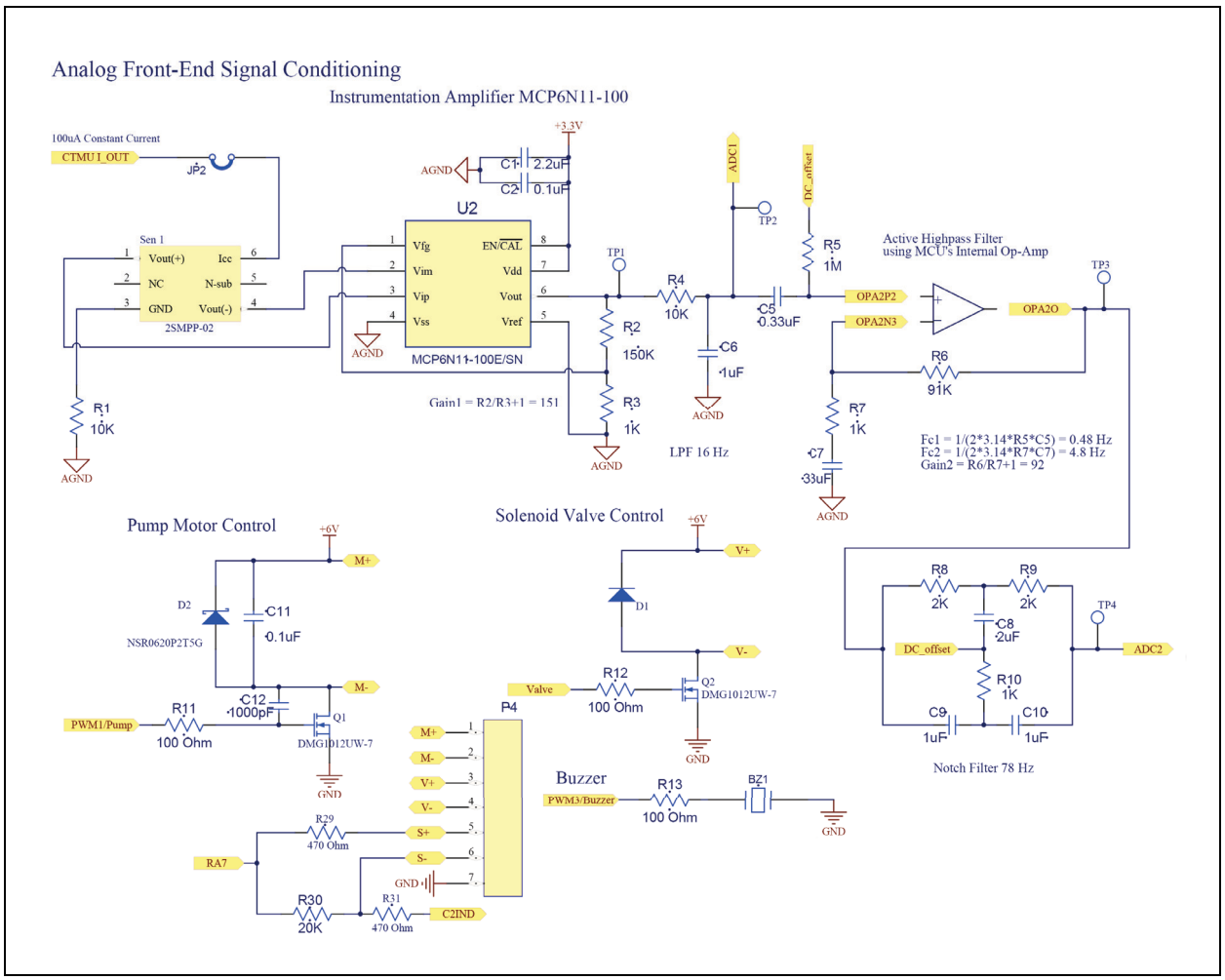
FIGURE 5: BPM DEMO BOARD



APPENDIX B: SCHEMATICS

This appendix shows the Blood Pressure Meter schematics.

SHEET 1: MICROCHIP BLOOD PRESSURE METER SCHEMATIC – ANALOG FRONT-END



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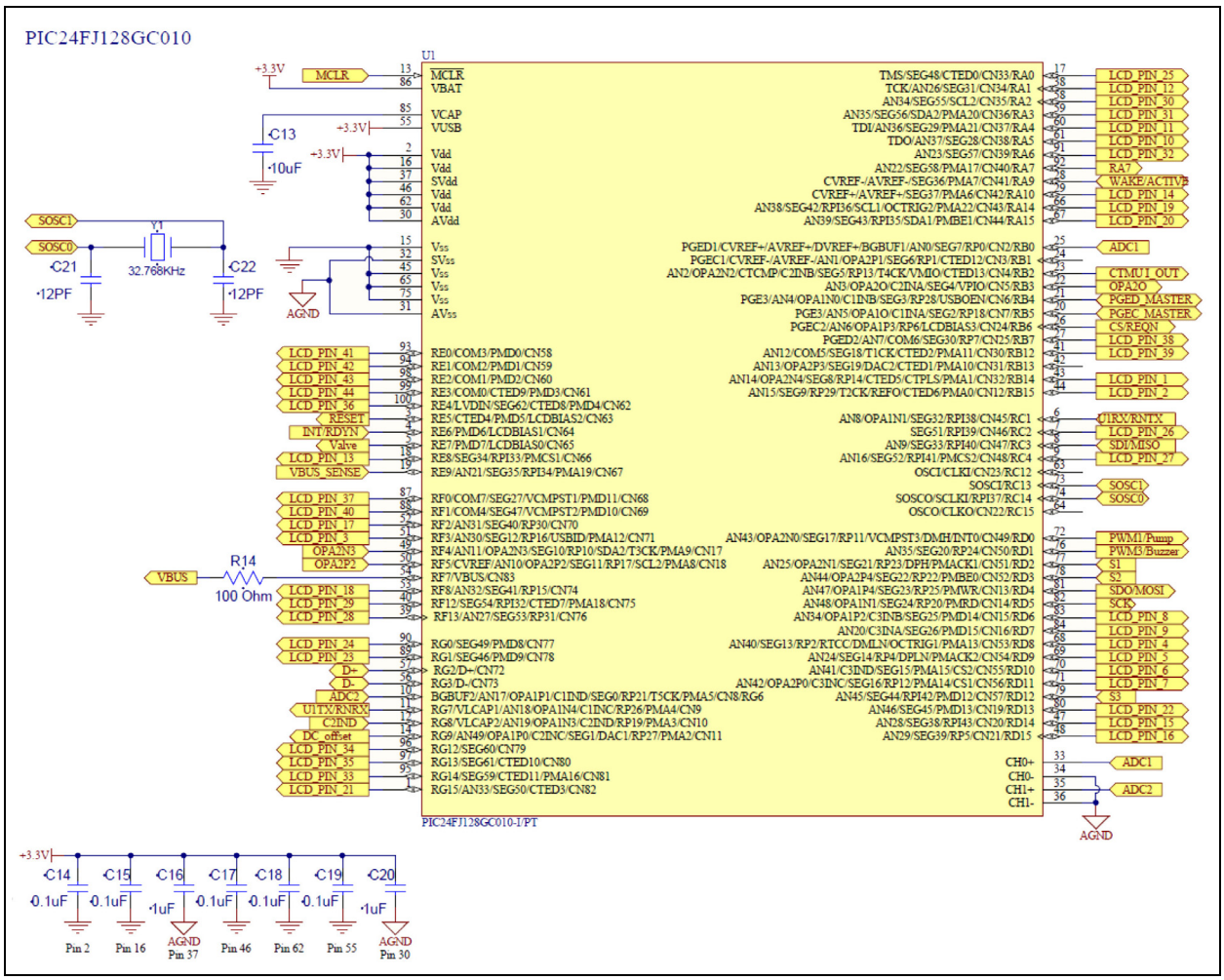
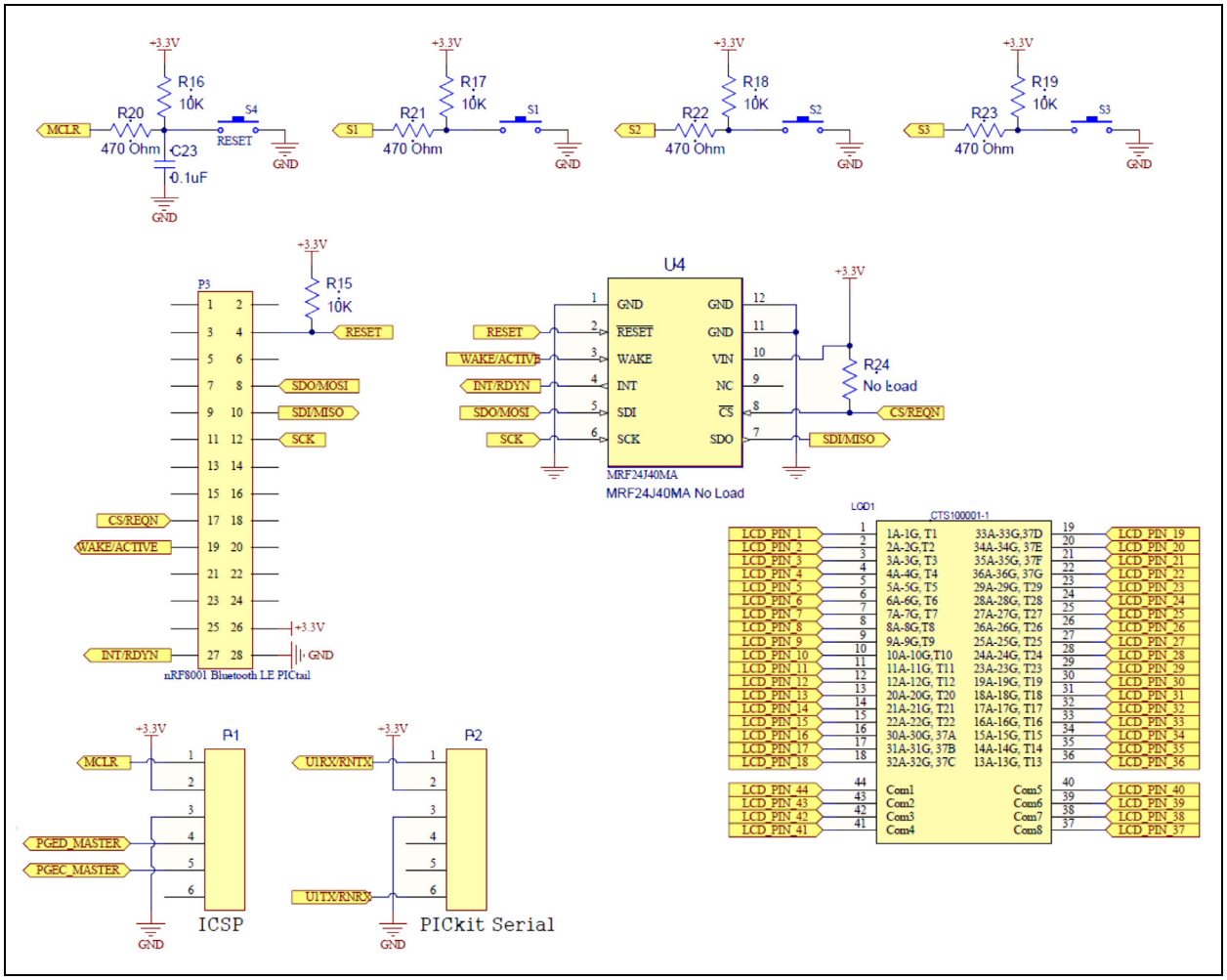
SHEET 2: MICROCHIP BLOOD PRESSURE METER SCHEMATIC – PIC24F MICROCONTROLLER



SHEET 3: MICROCHIP BLOOD PRESSURE METER SCHEMATIC – INTERFACE CIRCUITS



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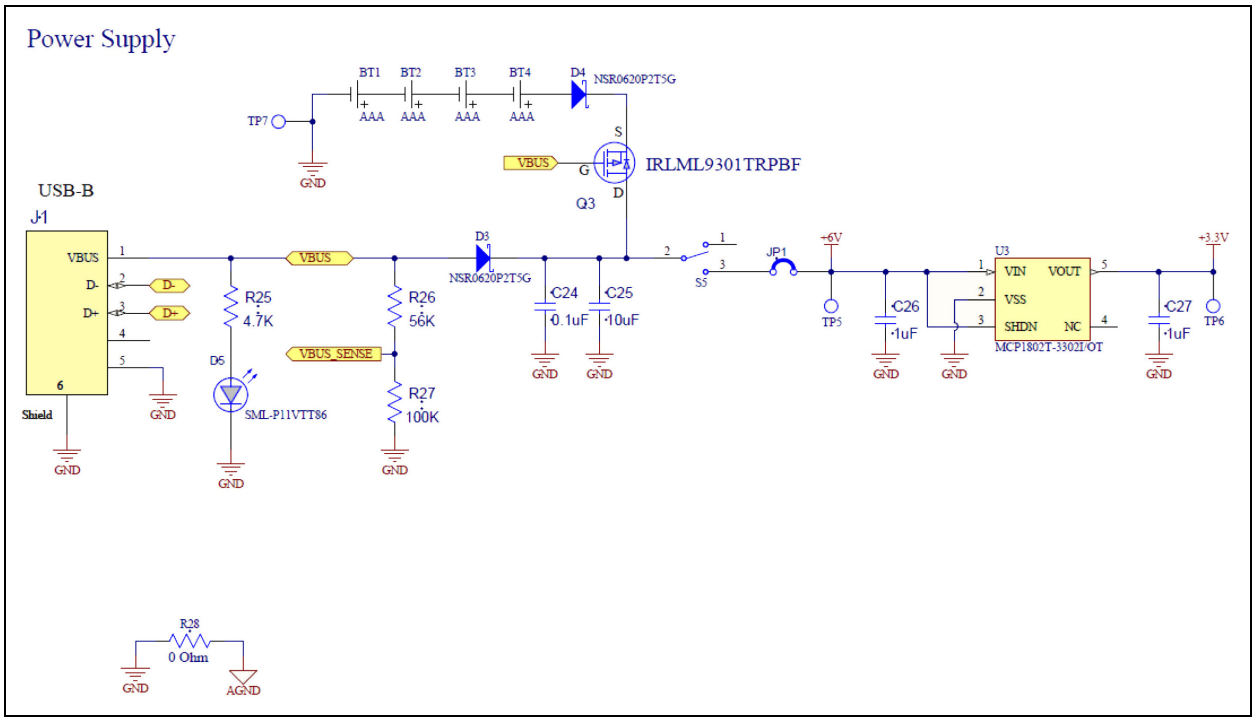
SHEET 4: MICROCHIP BLOOD PRESSURE METER SCHEMATIC – POWER SUPPLY



APPENDIX C: WARNINGS, RESTRICTIONS AND DISCLAIMER

This demo is intended solely for evaluation and development purposes. It is not intended for medical diagnostic use.

APPENDIX D: REFERENCES

Wang Wei-Wei, Pu Bao-Ming, He Bao-Yue, Li Sheng-Jin. Design and Realization of Electronic Sphygmomanometer Based on Inflation Measurement. Journal of Computer Systems & Applications, 2012,21(2):150-153,97.

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