

Automated Digital Blood Pressure Meter

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ABSTRACT

The purpose of this application note is to describe an automatic digital blood pressure meter that uses a microcontroller and electronic pressure sensor to create a system that is easy to use and reduces human error in blood pressure readings.

INTRODUCTION

Blood pressure is typically measured using a sphygmomanometer and stethoscope, which are analog devices. This method of measuring blood pressure introduces human error and requires a trained user to take the measurement. Automated electronic devices have been developed to take blood pressure readings at the press of a button and can reduce error and require no training. This particular design uses a microcontroller (Microchip PIC18F4520) and pressure sensor (Freescale Semiconductor MPX5050GP). The pressure sensor is connected to an arm cuff that is pressurized around the user's arm. The resulting pressure changes in the sensor are output and split into two signals that are used to calculate the systolic and diastolic blood pressure.

MEASURING BLOOD PRESSURE

Blood pressure measurements consist of two numbers. A typical reading will look something like "120/80" (read "120 over 80") and is measured in mmHg. The first number is the systolic blood pressure, which is the pressure in the vascular tissue when the heart is pumping blood away from the heart. The second number is the pressure when the blood is flowing back to the heart, so the first number is always higher than the second.

[1] When measuring blood pressure with a sphygmomanometer and stethoscope, a cuff is inflated around the user's arm until it completely restricts the flow of blood through the arm. The operator listens with the stethoscope and can tell that the blood is no longer flowing when there is no sound in the stethoscope. Once this point is reached, the air in the cuff is slowly released, decreasing the pressure, which is read from the sphygmomanometer. When the blood resumes flowing in the arteries, it will create sound in the stethoscope. The pressure where this occurs is the systolic pressure. The pressure in the cuff is decreased more until the sound stops. This is the diastolic pressure. At the diastolic pressure, the arterial pressure is greater than the cuff pressure and no sound is heard in the stethoscope.

[2] A similar method is used in electronic systems to measure blood pressure, which is called the oscillometric method. There is an electronic pressure sensor connected to the cuff instead of a sphygmomanometer. The cuff is inflated to a pressure high enough to stop circulation to the arm and then slowly decreased. At systolic pressure, oscillations will begin in the pressure sensor output. Continuing to decrease the pressure, the diastolic pressure is read when the oscillation stops.

HARDWARE OPERATION

The pressure sensor is connected directly to the cuff, which is inflated or deflated via a motor and valve. The output of the pressure sensor is split into two signals. The PIC18F4520

has only one analog-to-digital converter (ADC) built in, but there are multiple channels so both signals can be input into one microcontroller. The first signal is input directly into the microprocessor without any amplification because the MPX5050GP pressure sensor outputs between .2V and 4.7V, which is acceptable for the microcontroller's ADC input. This signal contains both the cuff pressure signal and the oscillation signal. The second signal is put through a two-pole high-pass filter to block the cuff pressure signal and amplify the oscillation signal. It is assumed that the oscillation signal is around 1Hz (corresponding to 60 heartbeats per minute) and the cuff pressure signal is less than .04Hz. These frequencies are important when designing the high-pass filter. Figure 1 shows the filter schematic and the frequency response of the filter is shown in Figure 2. Figure 3 is the direct output of the cuff, showing the cuff pressure and region of oscillation. Figure 4 shows the filtered and amplified oscillation signal.

$$P_1 = \frac{1}{2\pi R_1 C_1} \quad P_2 = \frac{1}{2\pi R_3 C_2}$$

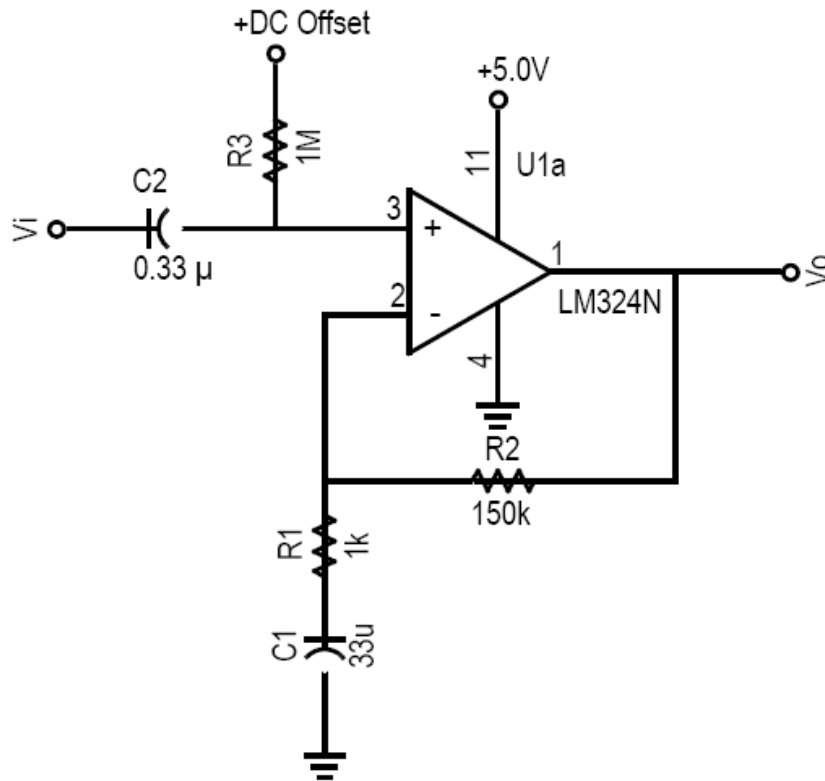


Figure 1. Oscillation Signal Amplifier [2]

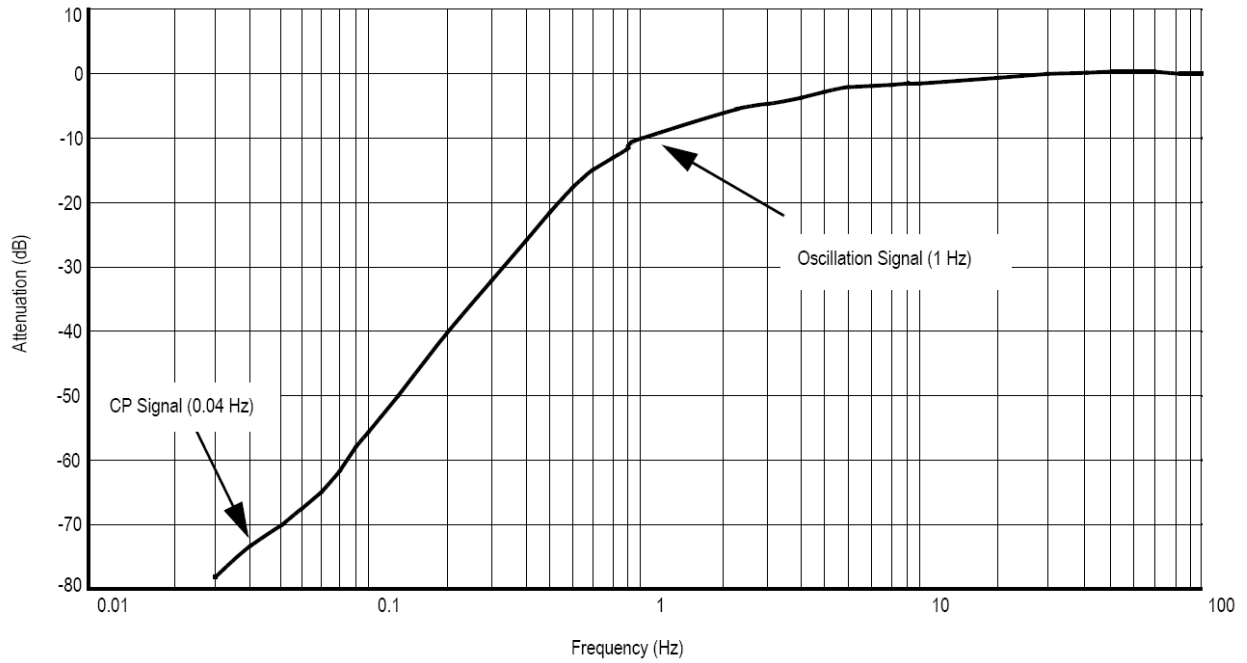


Figure 2. Filter Frequency Response [2]

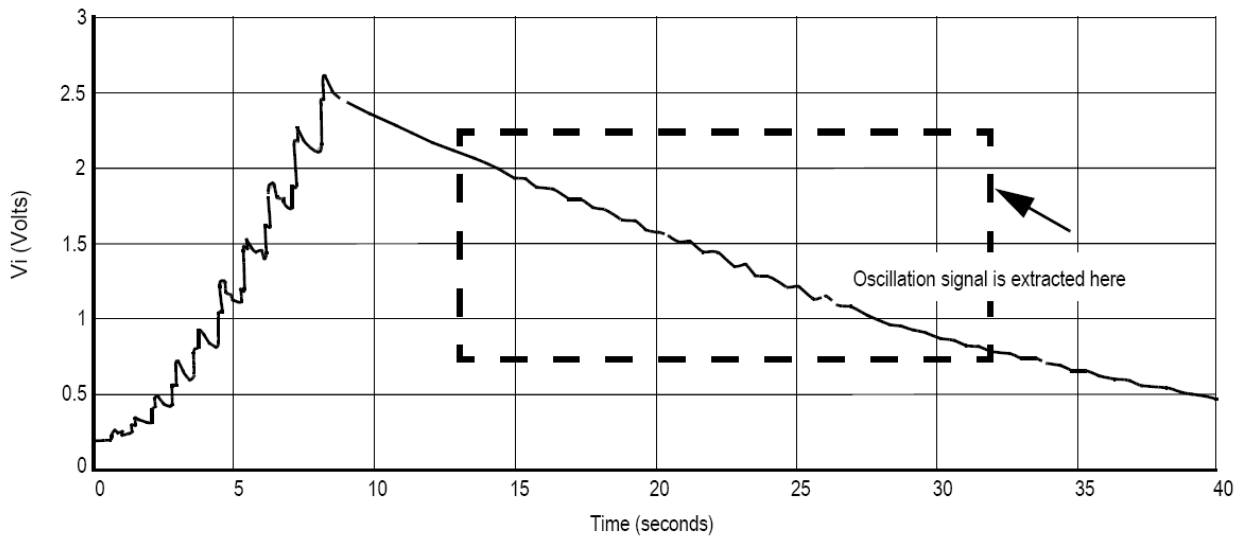


Figure 3. Output of Pressure Sensor [2]

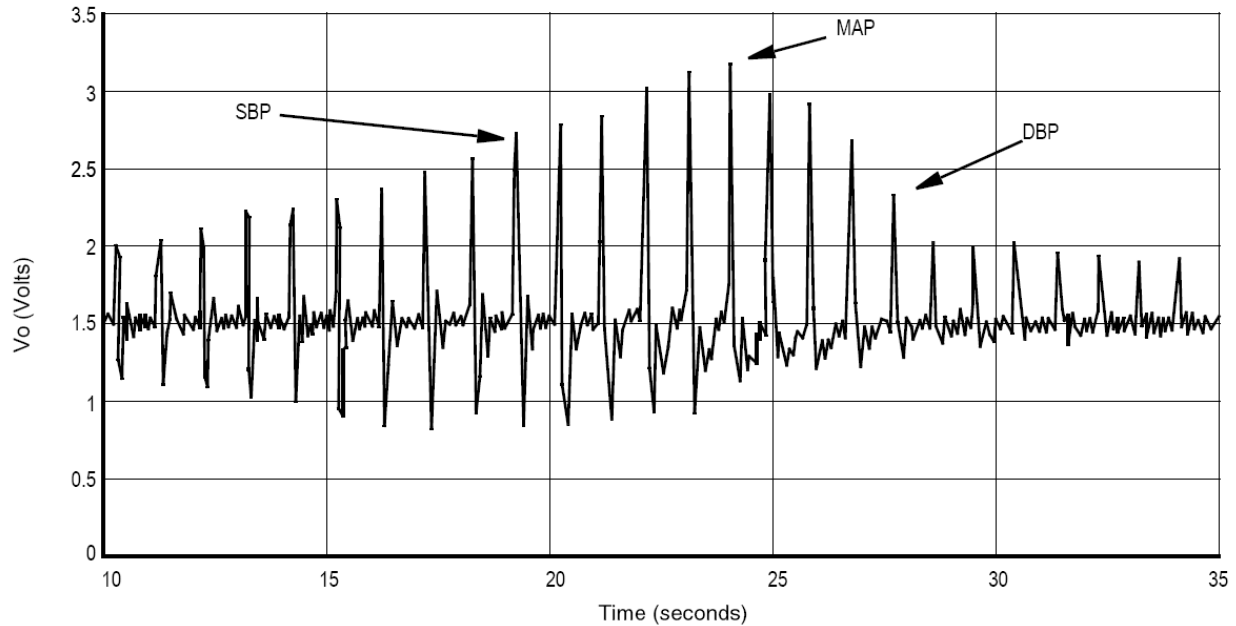


Figure 4. Filtered Oscillation Signal [2]

This signal needs to be amplified to the range of approximately 5.0mV to 3.5V [2] so that it remains within the amplifier's output range and the microcontroller's input range. The microcontroller's ADC is set from 0 to 3.8Vdc, which corresponds with 0 to 300mmHg from the pressure sensor. The ADC on the PIC18F4520 is 10 bits, so the range of the ADC is 1024 counts, or 0 to 1023. The pressure resolution is calculated below:

$$\text{Count at 0mmHg} = \frac{0.2 - 0}{3.8 - 0} \times 1023 \approx 54$$

$$\text{Count at 300mmHg} = \frac{3.8 - 0}{3.8 - 0} \times 1023 \approx 1023$$

The resolution is $1023 - 54 = 969$ counts, so the system will resolve to 0.31mmHg. The schematic of this system is shown below. It should be noted that the external clock is not included in the schematic.

REFERENCES

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<http://www.people.cornell.edu/pages/ws62/>

- [4] PIC18F2420/2520/4420/4520 Data Sheet
<http://ww1.microchip.com/downloads/en/DeviceDoc/39631a.pdf>