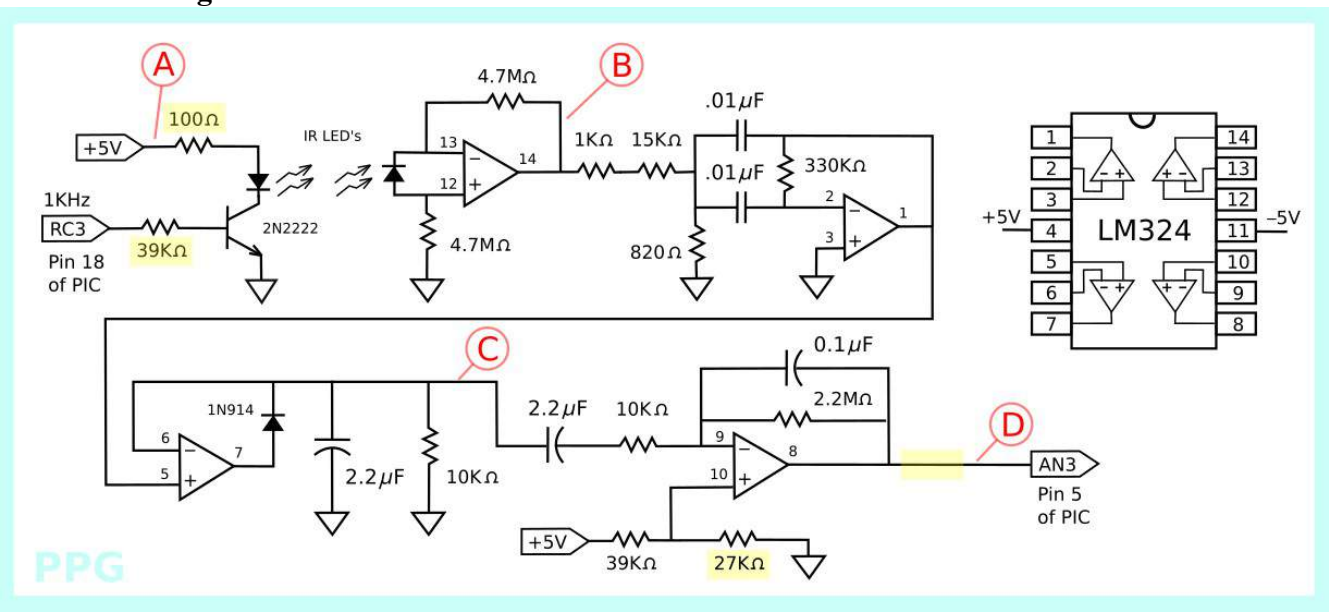
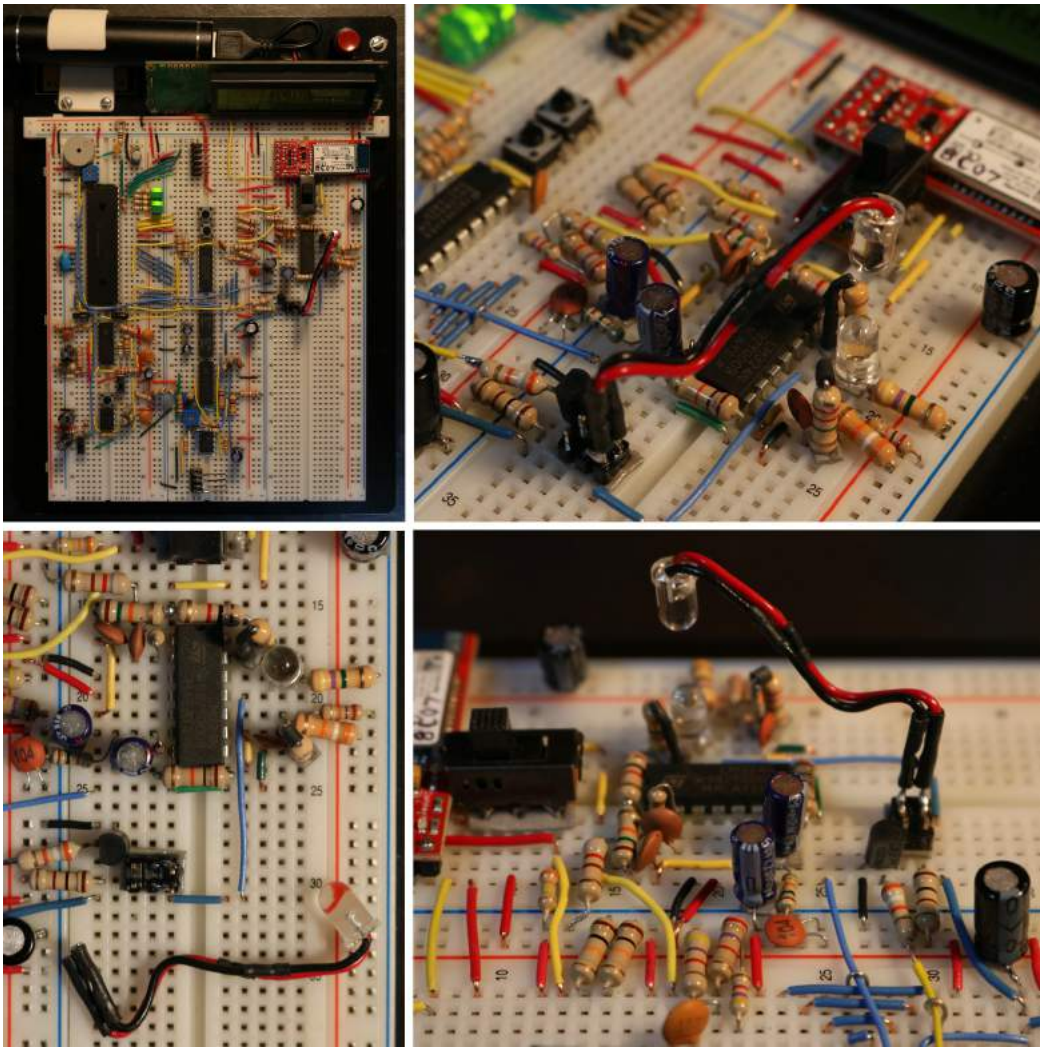
Photoplethysmogram (PPG) Circuit

BME 363 Biomedical Instrumentation Design Laboratory, University of Rhode Island

Schematic Diagram

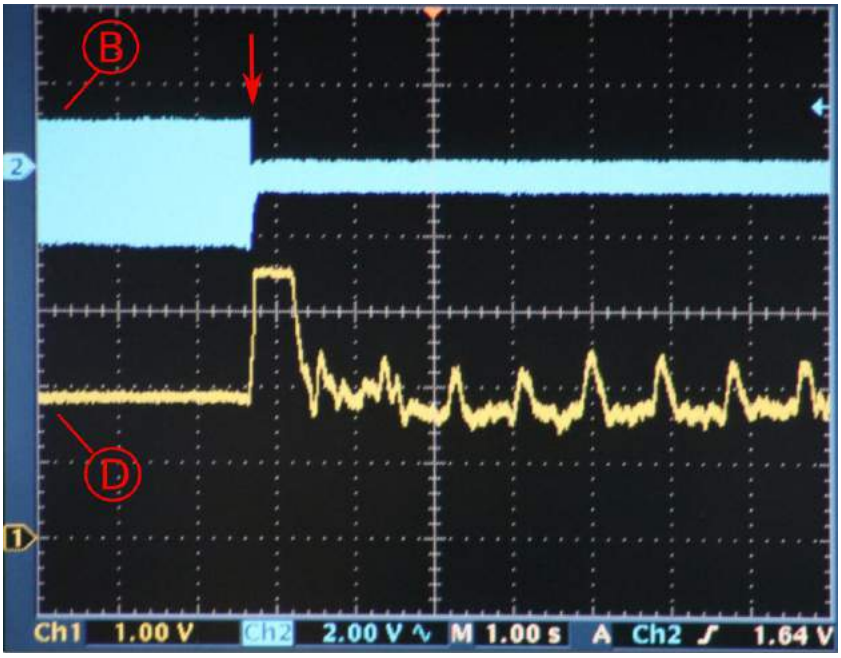


Breadboard

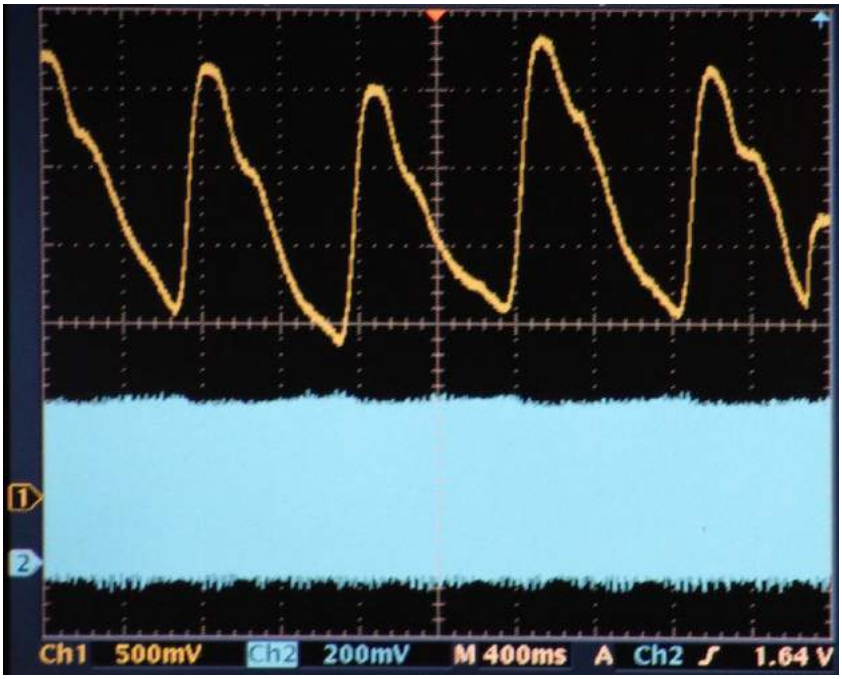


The PPG Waveforms

Channel 1 (yellow) shows the final output of the PPG signal at test point D of the schematic diagram. Channel 2 (blue) shows the 1KHz signal after the 1st stage of the LED light detector at test point B. The time scale is 1 s/block. Thus, the details of the 1 KHz are not visible. The arrow indicates when the finger was inserted. The magnitude of the 1KHz signal decreased significantly from the unblocked level, but did not diminish completely. The output at point D shows an initial saturation followed by the PPG signal. The cardiac period is about 0.9 s. The heart rate is 67 bpm.

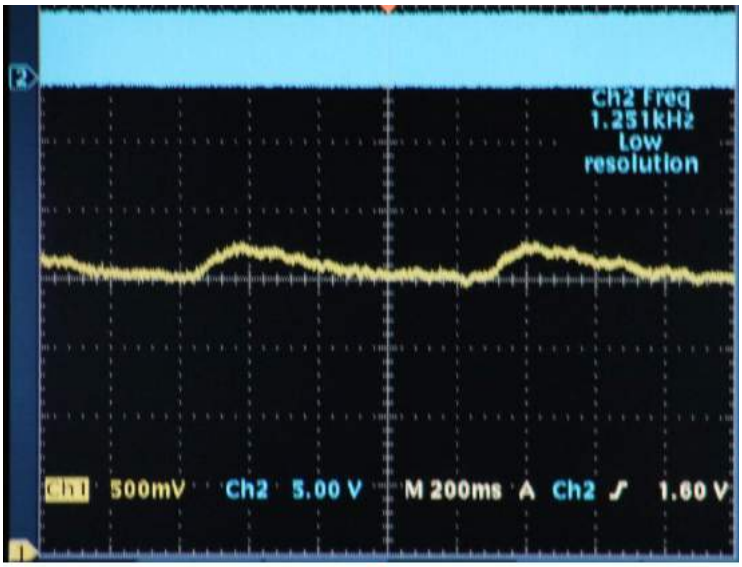


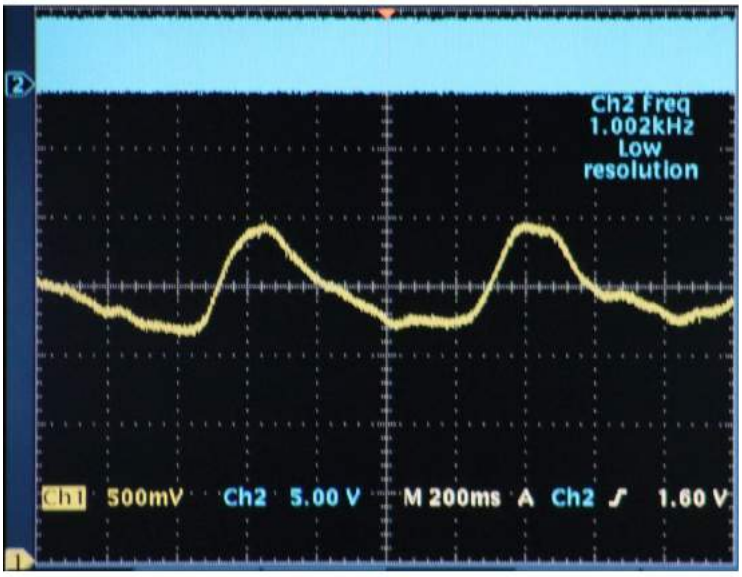
Channel 1 (yellow) shows a detailed PPG signal at test point D. Channel 2 (blue) shows the 1KHz signal at test point B. Notice that its amplitude is slightly modulated by the PPG signal. The 1 KHz signal is further processed by the band-pass filter and the amplitude demodulator to result in the PPG signal at test point D.

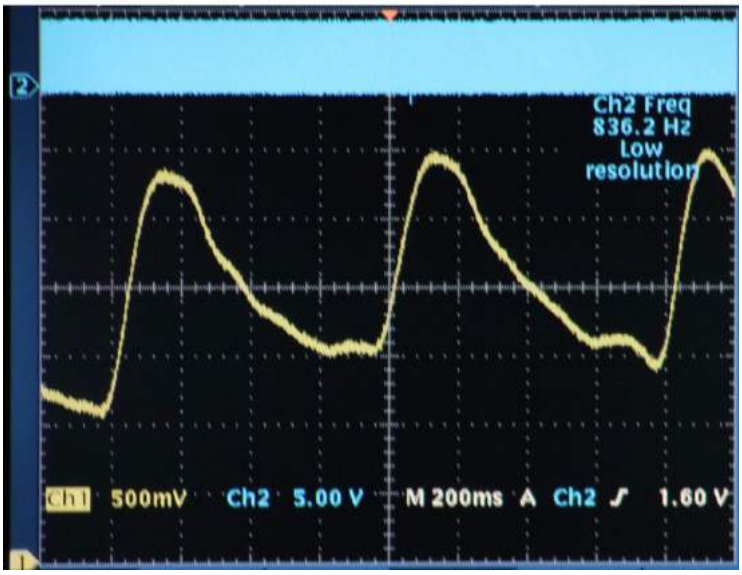


Effects of the Modulation Frequency on PPG

A square wave is generated by the PIC processor to drive the IR LED. The frequency of the square wave is centered around 1 KHz and can be adjusted via the potentiometer connected to AN2 (pin 4 of the PIC). The second stage of the light detector circuit contains a pie-filter, which is a band-pass filter centered around 1 KHz. However, this frequency may be off due to the error margins (typically 10%) of the resistors and capacitors. The PPG waveform can be affected by the frequency of the driving square wave in terms of the magnitude and noise level. As shown on the right, the frequency of the driving square wave was adjusted to 1.25 KHz (top), 1.00 KHz (middle) and 836 Hz (bottom).

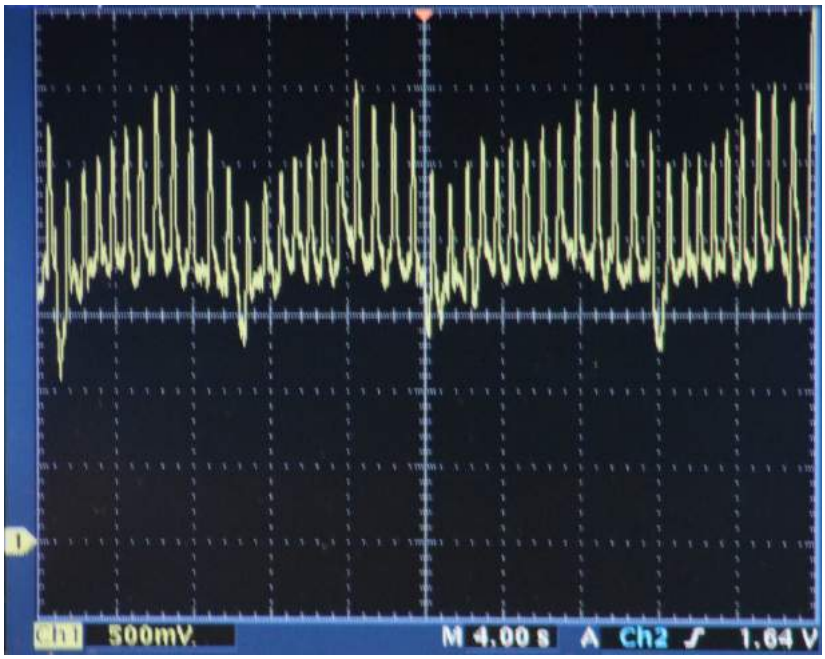




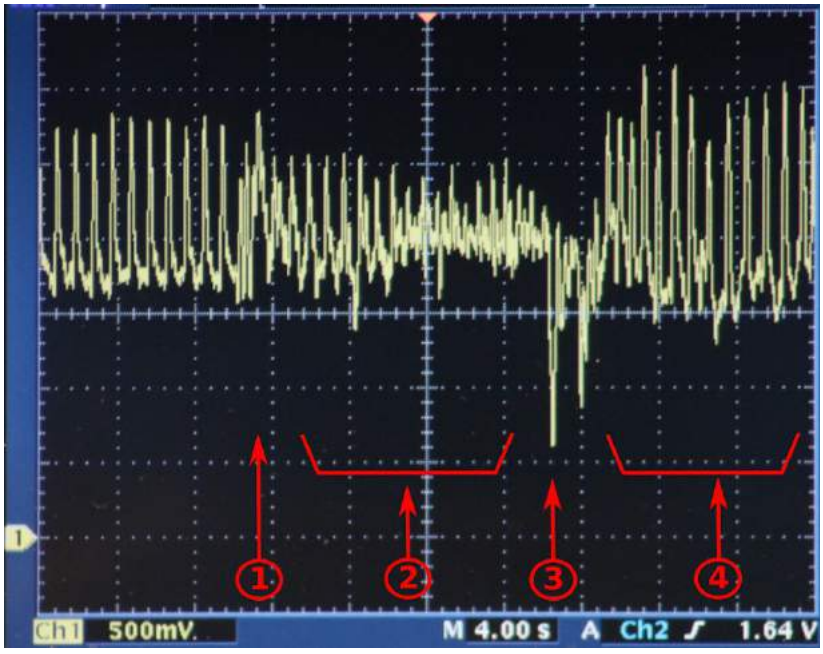


Effects of Intrathoracic Pressure on PPG

During inspiration, the chest walls expand and the diaphragm moves towards the abdomen to create a negative intrathoracic pressure (below the atmosphere pressure), which sucks the air into the lungs. The fluctuation of the intrathoracic pressure is transferred to the arterial pressure, which can also be seen in the PPG. As shown in this example, the breathing rhythm can clearly be observed. The breathing interval is about 10 s, and the breathing rate is 6 breaths per second. The typical respiratory rate for a healthy adult at rest is 12–20 breaths per minute. In general, the breathing rate decreases with age, from 30-40 at birth to 10-30 for elderly over the age of 80.



The Valsalva maneuver is the attempted forceful expiration against a closed throat for 10-15s. The intrathoracic pressure is tyipically raised to about 40 mmHg. There are four phases of the Valsalva maneuver: 1) transient rise, 2) suppressed pulses with increased heart rate, 3) transient decrease, and 4) reflex bradycardia. These four phases are observable in the PPG, as shown on the right.



PPG Waveform Display on Android

The output of the PPG circuit (test point D) is connected to the AN3 channel of the analog-to-digital converter (pin 5 of the PIC). The PIC code needs to be modified to acquire this waveform and send it to the Android device via the Bluetooth modem. As shown below, the PPG waveform was sampled at 1KHz and then decimated by 20. Thus, the waveform sent to the Android device had a sampling rate of 50 Hz.