CE3002 Sensors Lab

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# Circuit Diagram

Diagram

Description automatically generated

# Component List:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | Type | Description | Use | Quantity |
| 1 | 1020FC | PPG Finger Clip transducer from UFI | Transducer | 1 |
| 2 | AD625 | Instrumentation Amplifier (IA) IC | Amplification | 1 |
| 3 | IC 741 | Operational amplifier IC | Analog Signal Conditioning – in lowpass filter and level shifter | 2 |
| 4 | Trimmer | Variable Resistor 5KΩ | IA gain adjustment | 1 |
| 5 | Potentiometer | Potentiometer 10KΩ,  Round Metallic, 3-terminal | Non-inverting Adder in Level Shifter | 1 |
| 6 | Resistor | Resistor 1.2MΩ, 1/4W | Capacitive coupling for transducer | 1 |
| 7 | Resistor | Resistor 150Ω, 1/2W | Voltage divider for transducer supply | 2 |
| 8 | Resistor | Resistor 100KΩ, 1/4W | IA gain adjustment | 2 |
| 9 | Resistor | Resistor 1.6KΩ, 1/4W | Lowpass Filter | 1 |
| 10 | Resistor | Resistor 1KΩ | Non-inverting Adder in Level Shifter | 4 |
| 11 | Capacitor | Capacitor 220nF, 35V, tantalum | Capacitive coupling for transducer | 1 |
| 12 | Capacitor | Capacitor 10uF, 16V, electrolytic | Lowpass Filter | 1 |

# IC Chip Layout

Diagram, engineering drawing

Description automatically generated

# Related Work and Theory

## Plethysmograph as a Volume Change Detection Transducer

Monitoring of blood flow using plethysmograph is the measurement of volume changes that result from pulsations of blood occurring with each heartbeat.

Plethysmograph – Instruments measuring volume changes or providing outputs related to them

## Infra-Red Pulse Plethysmograph

* Infra-Red Pulse Plethysmograph (PPG) used as transducer
* Uses IR photo-electric sensor to detect and record changes in tissue blood volume frm finds, toes, ear, forehead, etc.

### Specifications

Excitation: 20mA at 6 to 9V DC nominal

Output: 5 to 50mV (typical finger application)

Output Impedance 1KΩ nominal

### Description

* Uses matched semiconductor IR emitter and receiver pair to detect small changes in the reflectivity of the subject’s skin
  + Changes are due to the inflow and outflow of blood associated with the beating of the heart.
* Use of IR light spectrum helps minimise artifacts resulting from changes in ambient light

## PPG Model 1020 Output Signal Component

Signal generated has 2 components:

* DC “baseline” or average component corresponding to the average amount of light reflected by the tissue under the transducer
* A much smaller “pulsatile” component which normally increases following the flow of blood into the tissue under the transducer, followed by the resulting decrease as blood flows out. This pulsatile blood flow correlates predominantly with the beating of the heart.

Primary application is to measure pulsatile blood flow/ volume changes in the skin of human subjects. Therefore, the average DC voltage component of the 1020 output needs to be eliminated, in order to supply just the pulsatile signal for further analysis.

## Interface – Analog to Digital Conversion and Serial Communication

* Data is fed to Arduino board
  + Board contains Atmega328P microcontroller
* On-board atmega8U2 USB-to-TTL serial chip communicates with a computer using the USB interface, via the Universal Synchronous/ Asynchronous Receiver/Transmitter (USART) protocol.
* To send/ receive, computer creates a virtual COM port
  + COM port is a name given to serial port interface on all IBM-PC compatible computers
  + Nowadays use USB port
* COM port is seen in list of devices
  + Appear as COMx
* Arduino has both digital input/output (IO) and analog I/O pins to communicate with other devices
  + 6 analog pins (A0 to A5)
  + Connected to 10-bit ADC
  + Mapping 0-5V, 1024 levels
  + Resolution of 0.0049 volts per unit
* Arduino software comes with inbuilt Serial Monitor which allows us to view the incoming data from the board, on the computer. It can also be used to send data to the board.
* To enable comms, serial lib has to be used while programming the uController
  + Baud rate needs to be specified
  + 1200 used for project

# Data Acquisition System

## Input Signal

* Amplitude: 5 – 50mVpp
* Before further analysis, analog signal conditioning is performed

## Analog Signal Conditioning

### Capacitive Coupling

Diagram, schematic

Description automatically generated

* 1020 FC produces 1 – 2V DC offset component in addition to the PPG signal
* Capacitive Coupling used to eliminate avg DC voltage in order to supply just PPG signal to amplifier
* Resistor is added between amp input and gnd to keep signal gnd referenced
* Circuit shows capacitive coupling which supplies a low frequency roll-off of 0.6Hz
  + Capacitive coupling is transfer of alternating electrical signal from one segment to the other using a capacitor, high resistance/ impedance to DC but low resistance/ impedance to AC
* Avg 1 – 2V DC offset removed due to highpass characteristic of the R-C circuit.
* Power supply of PPG is obtained using a voltage divider circuit
* Care has to be taken to make sure resistor chosen is greater than 100 times the output impedance of the 1020FC transducer (which is 1KΩ nominal) in order to prevent attenuation of desired PPG signal due to loading effect

### Amplification

* 1020FC only supplies one output signal so not necessary to use a differential amplifier
  + However, a differential amplifier can be used since it is much more common, with unused (inverting) input connected to gnd
* IA is used because it has high and balanced input impedance, high adjustable gain with low offset problem, and a high common mode rejection ratio (CMRR) which does not depend on matching of resistors
* High input impedance minimizes input signal loading effects from the finite source impedances
* IA gain is easy to adjust by selecting appropriate external resistors Rf and Rg
* IA used is AD625
* As output signal from 1020FC is ~5 – 50mVpp, amplifier circuit is designed to give gain of ~100
  + This is suitable for further analysis
  + Rf = 100Ω
  + Rg = 2.02KΩ
    - Variable resistor of 5KΩ can be used

### Filtering

Diagram

Description automatically generated

* BW of PPG is 0.6 – 10 Hz
* For low freq filtering, this corresponds to fairly high respiration rate of 36 breaths/minute, and for the high freq filtering, the max heart rate might be 240 beats/min, which corresponds to 4Hz
* Filtering PPG amplified output signal w/ lowpass filter that rolls of at 10Hz is more than enough
* Highpass filter rolls-off at 0.6Hz has been designed in the capacitive coupling for DC offset removal
* Choose closest standard capacitor value C = 10uF and closes standard resistor value R = 1.6KΩ to obtain the cutoff freq of approx. 10Hz using fc=1/(2πRC)

### Level Shifter using Non-Inverting Adder

Diagram, schematic

Description automatically generated

* ADC has range 0 – 5V DC
* To shift the dual polarity filtered and amplified PPG signal to the positive domain, a non-inverting adder is designed using an opamp.
* Vout = V1 + V2
* R is chosen as 1KΩ
* V1 is the amplified and filtered PPG signal
* V2 is set to be an appropriate fixed DC voltage using a voltage divider circuit