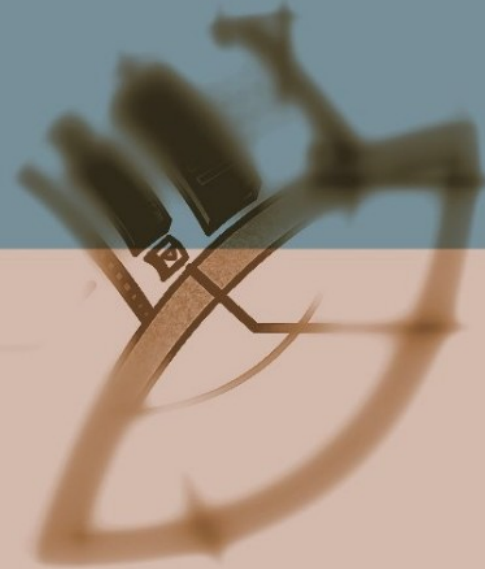


BioJoy – *The tick of which will keep you beating !*

BioJoy™ - *An interactive wearable biofeedback wristwatch for stress relief*



\$3,000,000 Funding

Minimum \$30,000 Investment

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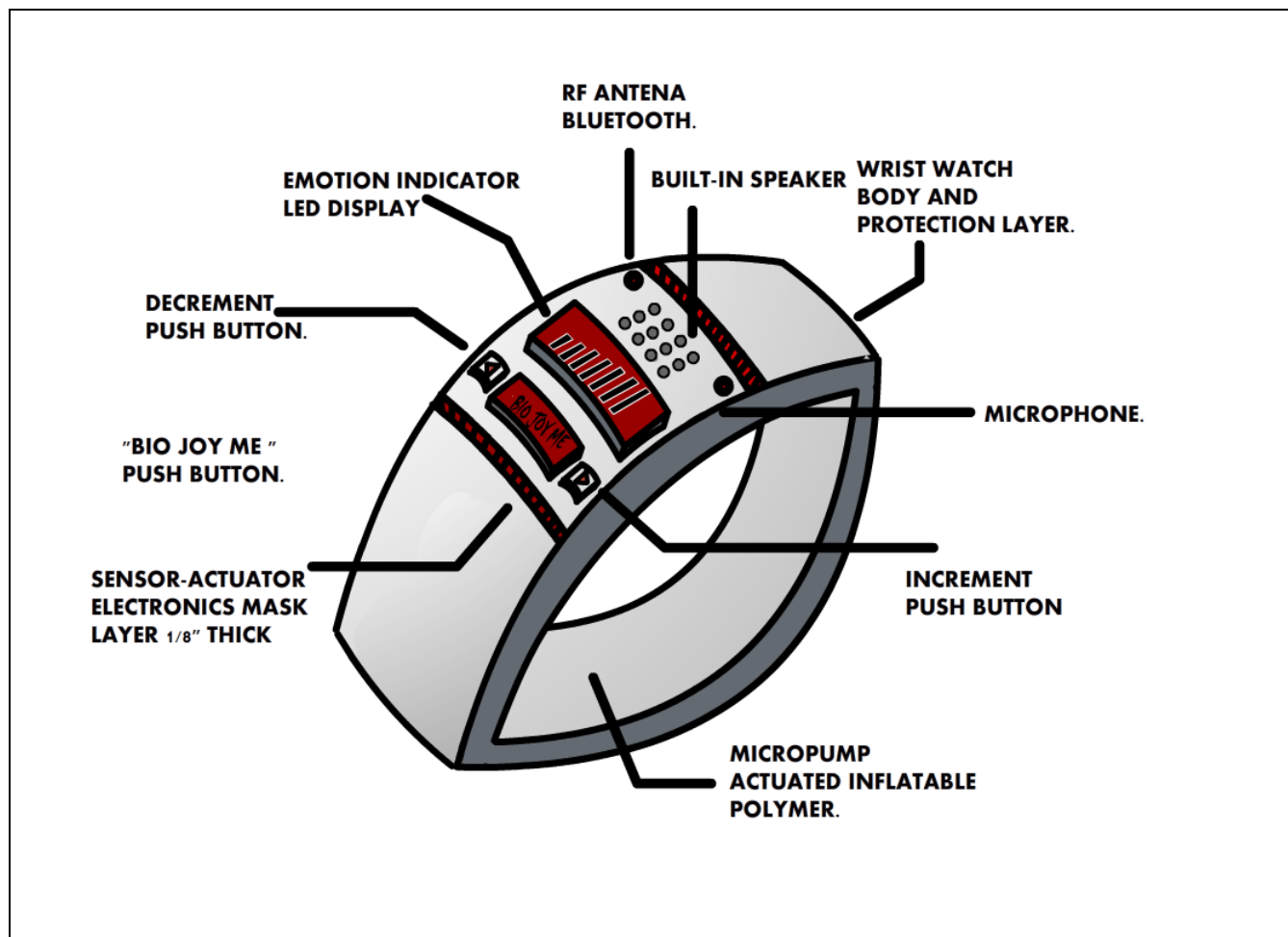
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1. The Concept

BioJoy is a **interactive wearable biofeedback wristwatch** that can help you **relieve day-to-day stress** by **monitoring your stress** levels and suggesting you **alternatives** to reduce / eliminate them within its owner's social context. It is a **wireless** Micro-Electromechanical system (MEMS) device with embedded **blood pressure** and **accelerometer** sensors whose **combined output** is a function of the **emotional state** and **well-being** of a person. The system is **neural network learning** dependent whose **efficiency of outputting** a correct emotional state value is **increased** by an **interactive feedback mechanism** from the person wearing it. This feedback system is a **measure of how good a person actually feels** as inputted by the person himself. The system can then use a combination of these **feedback values and learned preferences** [of what betters the emotional state of a person] to **suggest alternatives to stress relief** to the person through an embedded speaker at times when the stress levels reach certain values which are detrimental to the emotional well-being of the person.

2. The Product



The BioJoy wristwatch consists of the following physical and functional components:

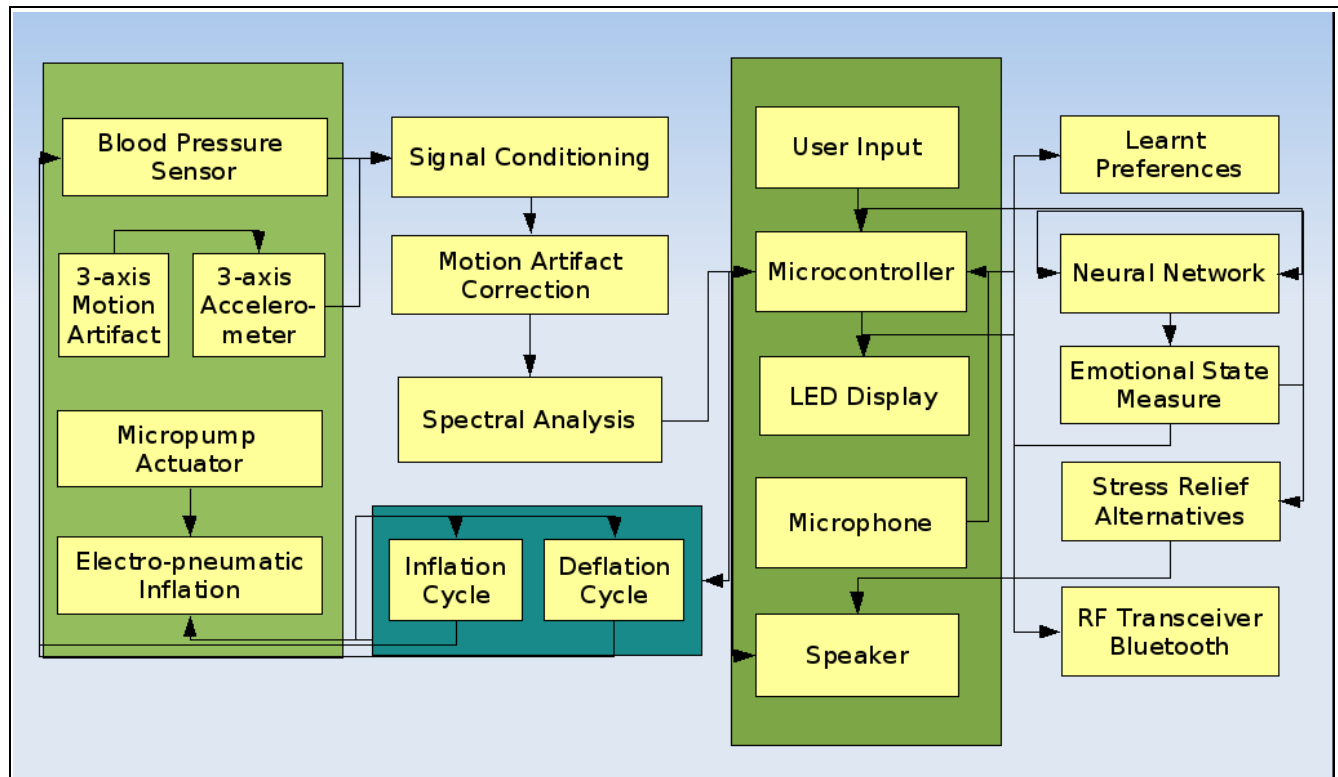
- 1] Wristwatch Body and Protection Layer** – This constitutes the primary body of the wristwatch and acts as a protection and foundation layer for other components.
- 2] Micropump Actuated Inflatable Polymer** – This consists of a microcontroller-micropump actuated polymer that allows the wrist band of the watch to be inflated to a certain pressure level for blood pressure measurement. It is during its deflation that the blood pressure sensor output is meaningful.
- 3] Sensor-Actuator Electronics Mask Layer** – This layer is 1/8th inch thick and houses the embedded blood pressure sensor, accelerometer sensor and custom electronics containing the microcontroller.
- 4] Increment-Decrement Push Buttons** – These buttons constitute the input of the user interface and allow the user to interact with the device so that he/she can help BioJoy to refine its emotional state to stress level mapping [Section 7.2]. These inputs increase/ decrease the stress-emotion bars on the LED display thereby giving a visual indication of how the user is actually feeling at the current point in time.
- 5] Emotion Indicator LED Display** – This display constitutes the output of the user interface and consists of emotion bars which are a function of the **emotional state to stress level mapping (ESLM)** of the user. It refreshes periodically to reflect the current value of ESLM and the user's current activity.
- 6] BioJoy Me Button** – This button is pushed by the user when his ESLM value is low and he/she wants BioJoy to recommend a suitable stress relief alternative that would increase the ESLM value to an appropriate level. The user then operates the input buttons [4] to cycle through the displayed alternatives and the BioJoy Me Button again to accept one of them or simply nothing to reject them.
- 7] Built in speaker** – This micro-speaker provides an audible interface to increase BioJoy's level of interactivity with the user by alerting him/her of ESLM values and to suggest stress relief alternatives.
- 8] RF Antenna / Bluetooth** – This constitutes BioJoy's wireless interface to a user's computer or for communicating with other BioJoy devices in a wireless sensor network for yet to be planned functions.
- 9] Microphone** – This component will allow the user to directly communicate with BioJoy through speech recognition software inside the microcontroller so that a friendlier user interface can augment the primary push buttons. The provision of this component will be made in BioJoy 2.0.

3. The Motivation

Developing wearable therapeutic biofeedback mechanism for stress and personal isolation relief. Many studies report significant blood pressure increase in subjects with cardiovascular problems when facing any source of mental stress. Mental stress in humans and other animals decrease cardiac electrical stability even in subjects with normal hearts. Premature ventricular contractions appear among subjects driving in heavy traffic and other stressful situations. Acute mental stress may provoke

coronary artery vasoconstriction, reduce left ventricular ejection fraction, or induce or exacerbate left ventricular wall motion abnormalities in subjects with cardiovascular disease. In particular, "anger" among subjects with cardiovascular disease may leave them vulnerable to cardiac complications.

4. Functional Block Diagram



The basic functional block diagram of BioJoy is shown in the above figure. It consists of a **blood pressure sensor** and **3-axis accelerometer** sensor. The blood pressure sensor output (oscillating signal) is a function of the emotional state measure of the person since blood pressure oscillations are related to the activity in the **autonomic nervous system (ANS)** which is known to be the central governing unit of a person's emotional state. The accelerometer sensor is employed so that the output of the blood pressure sensor is not distorted by the user's motion. The **micropump actuator** is activated by the microcontroller when a periodic emotional state measure is to be obtained by monitoring the blood pressure of the user. This activation results in **electro-pneumatic inflation** of the watch band (cuff from here on) which is an inflatable polymer that is inflated to the level of a microcontroller predetermined **systolic blood pressure** which is the peak pressure in the arteries.

It is important to inflate the cuff to this level so that blood pressure can be determined since the blood pressure sensor can then monitor the **mean arterial pressure (MAP)** during the **deflation cycle** i.e. when the pressure in the cuff gradually decreases to its initial non-inflated state. The blood pressure sensor output (electrical voltage) is thus driven by sensing the arterial pressure in the user's wrist. This output can be visualized both in the time and frequency domains as a voltage versus time and voltage versus frequency graph. The sensor output is then signal conditioned and undergoes **active motion**

artifact correction [Section 6.2.e] before it is spectrally analyzed and A/D converted after which its digital equivalent is stored in the microcontroller RAM for access by a MultiLayer Perceptron (MLP) based Neural Network [Section 7] that uses a combination of user's history (learned preferences) and new microcontroller data to determine the emotional state measure of the user and to suggest suitable alternatives for stress relief. The microcontroller is itself connected to the necessary user interface in the form of push buttons and user output in the form of an LED display and speaker to interact with the user and adapt itself.

5. The Working

1] You wear BioJoy and experience a normal day which on an average comprises of events that vary on the nature of their imparted stress. For example, working in the office for a period of 5 to 6 hours is generally considered more stressful than going out for a leisure walk.

2] While you are experiencing these various events, BioJoy is monitoring your combined emotional state in the **range of 1 to 10** but cannot yet attribute a stress measure to these events since its neural network is still in its infancy [i.e. in its training phase] and hence it has to learn from the person's input. This is because **every individual has a different emotional state to stress level mapping**. For e.g. you might be very happy and still stressed out at the same time. So you have to periodically and actively tell BioJoy when you are say certainly not, partially or completely stressed out so that BioJoy can understand that its value of 10 is actually associated with a person feeling “very” but not “completely stressed” out as it would have otherwise done in the absence of the person's interactive input. BioJoy trains its **neural network to constantly refine its emotional state to stress level mapping**.

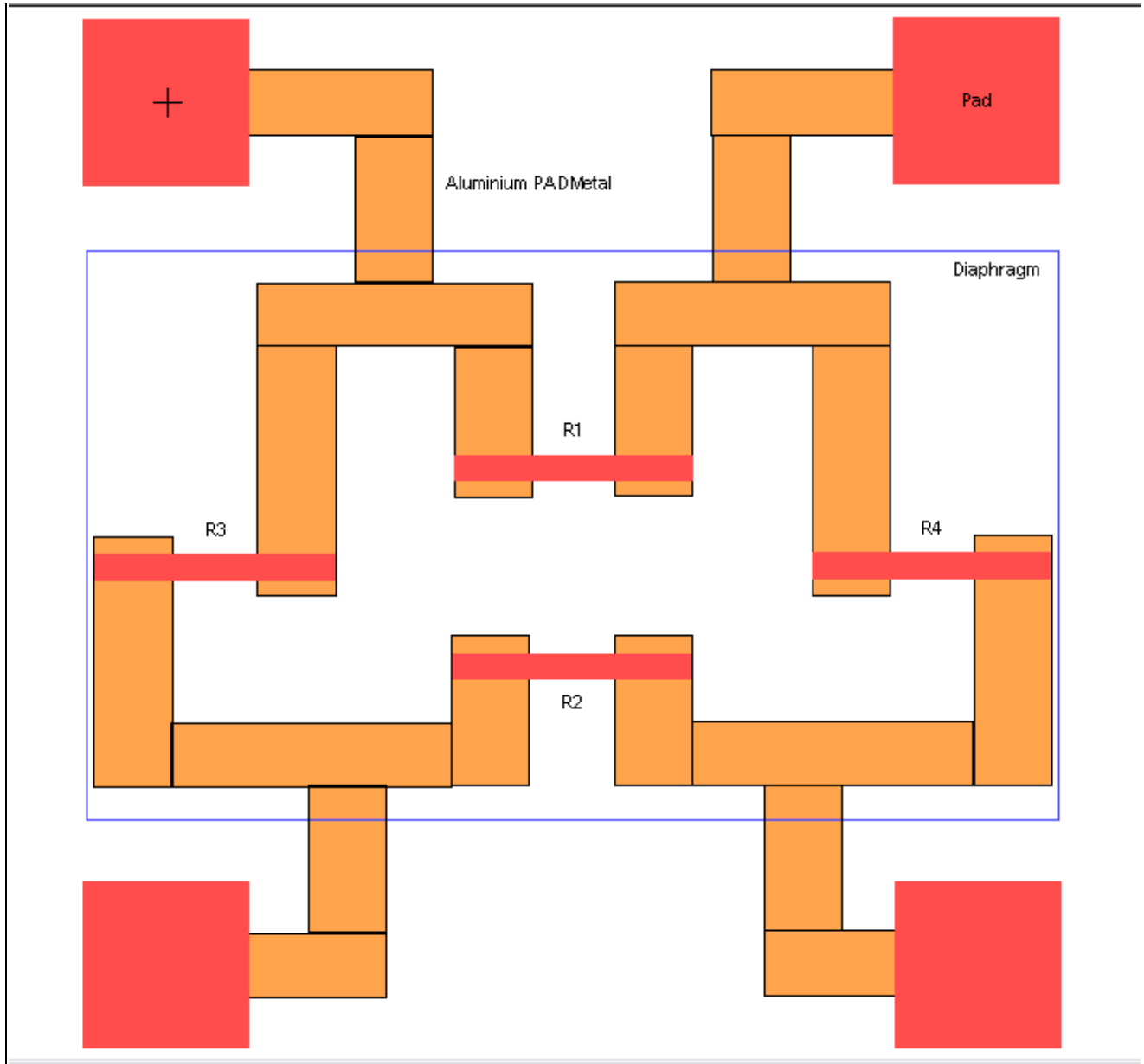
3] Over a period of say a week or ten days BioJoy's neural network is fairly well developed and it has a modestly good understanding of how its owner actually feels when it has outputted a certain value based on its blood pressure and accelerometer sensors. So now BioJoy's neural network enters the “**learning phase**” which is more geared towards **refining its emotional state to stress level mapping** than learning from the ground up as in the training phase. In this phase BioJoy comes up with a value in the range of 1 to 10 on its meter and gives its owner a chance to increment or decrement this reading to more closely resemble his correct emotional state through its embedded push buttons. If the owner thinks that BioJoy has correctly detected his state and it has a low value, then he can push the “**BioJoy Me**” button for the device to suggest a stress relieving alternative(s) through its speaker system.

For example, “John, you are hopeless. Based on your preferences and stress relieving solutions which have worked for you in the past, I find a 69% probability of you feeling better by socializing, 31% by listening to music and 0% by drinking. If you would like to include new activities you haven't tried as yet to my solution press the increment button and then the BioJoy Me button again”. Thus, BioJoy becomes increasingly smarter and more attuned to its owner's actual emotional state with the stressfully varying events of everyday.

6. Technical Description

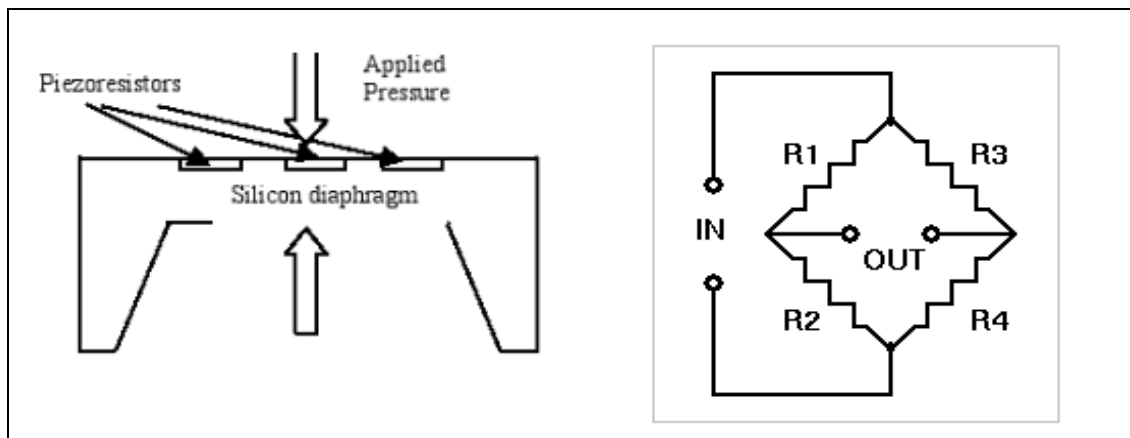
6.1 Blood Pressure Sensor

6.1.a MEMS Design / Layout



BioJoy's blood pressure sensor is a **piezoresistive pressure sensor** which uses the concept of piezoresistivity to relate the deflection and hence the pressure on the diaphragm to change in resistance of the resistors R1, R2, R3 and R4 which are embedded in the structure of the diaphragm. This sensor is fabricated using the **SOIMUMPS surface micromachining** technology where the diaphragm is created by the TRENCH mask by etching away the substrate and oxide layer. The **PADMetal Layer** is

representative of aluminum interconnects that connect the embedded resistors in a **Wheatstone Bridge configuration**. There is a certain manner in which this configuration is formed on the diaphragm to **increase pressure sensitivity**. The reason is that **deformation by applied pressure** causes **high levels of mechanical tension** at the **edges of the diaphragm**. Positioning the resistors in this area of highest tension increases sensitivity. The **SOI Mask Layer** is used for **resistors and anchors** that connect this configuration to the further stages for signal detection and conditioning. The cross sectional view of a MEMS pressure sensor with embedded piezoresistors and the silicon diaphragm is shown in the figure below. The figure also shows the typical arrangement of resistors in the Wheatstone Bridge configuration. The bridge in case of the pressure sensor is balanced when there is no pressure applied on the diaphragm. When the deflection in the diaphragm occurs then two of the resistors placed on the



diaphragm experience mechanical tension in parallel and the other two are perpendicular to the direction of current flow. Thus, the two pairs exhibit **resistance changes opposite to each other**. These pairs are located diagonally in the bridge such that applied pressure produces a bridge imbalance. Thus R1 and R4 referring to the Wheatstone bridge above experience **Transverse Stress (Sigma T)** while R2 and R3 experience **Longitudinal Stress (Sigma L)** with respect to orientation of current flow.

6.1.b Mathematical Basis

If we assume that the piezoresistors themselves have constant mechanical stresses inside them then the total resistance change ΔR is given by $\Delta R / R = \pi_T * \Delta T + \pi_L * \Delta L$ where R is the original resistance of the piezoresistors that is subject to no pressure loading. Coefficients π_T and π_L are the transverse and longitudinal piezoresistive coefficients which depend on the crystal orientation and the dopant types of the piezoresistors. If we now assume that the four piezoresistors connected in the bridge subject to a bias voltage V_b are ideally balanced and all have a resistance change ΔR then the **differential output voltage** ΔV is given by $\Delta V / V_b = \Delta R / R$. We can define the sensitivity of the pressure sensor as the voltage changing rate per unit pressure. **Sensitivity $S = (\Delta V / V_b) / P = (L/H)^2 (\alpha \pi_T + \beta \pi_L)$** where L = Diaphragm width and H = Diaphragm thickness and α and β vary only with mechanical properties i.e. Poisson ratio (ν) and Young modulus E , after the position of piezoresistors are assigned definitely.

6.1.b.1 Mathematical Modeling of the Sensor

The diaphragm is modeled as a square plate under stress. An energy-method analysis gives the load-deflection equation of the form $P = [\pi^4/6 * (E * H^3) * c1] / (1-\nu^2) * L^4$ where L = edge length of the diaphragm, c1 = displacement at the center of the diaphragm, E = Young’s Modulus, H = diaphragm thickness and ν = Poisson’s ratio.

The magnitude of the x-directed surface stress at the middle of the diaphragm edge is $\sigma_x = E * H / 2\rho x$ where the x-directed radius of curvature is given by $1/\rho x = (2\pi/L^2) * c1/2$. Thus σ_x can be expressed as $\sigma_x = 1/\pi^2 (1-\nu^2) * (L/H)^2 * P$ and because we are dealing with a plate, the y-directed stress at the center of the edge is $\sigma_y = \nu \sigma_x$

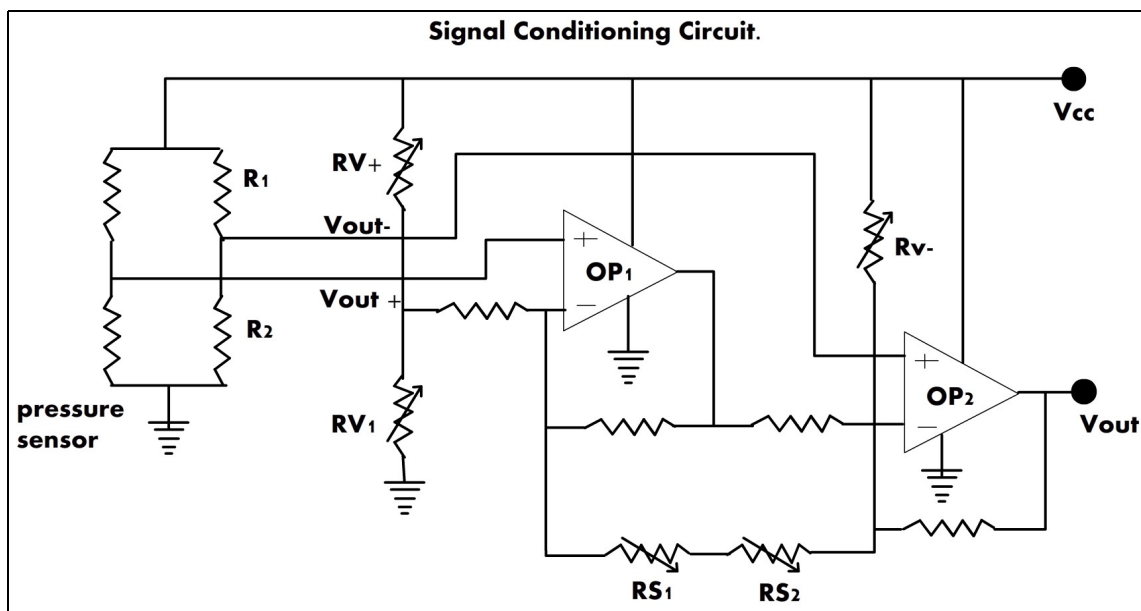
6.1.c Sensor Specifications and Performance

In view of the typical requirements of a continuous monitoring blood pressure sensor, we list the following specifications for our device that will yield to optimum results based on our analysis:

Pressure range: 10 to 115 kPa | **Temperature Range:** -10 to 70 Celsius | **Supply Voltage:** 5V +/- 0.25 V | **Offset Voltage:** 0.4V +/- 81mV | **Full Scale Pan:** 4.65 +/- 81 mV | **Diaphragm dimensions:** 1.5 mm X 1.5 mm and thickness of 20 um | **Maximum Diaphragm displacement:** Dis X – 2.44E-04, Dis Y – 4.95E-04, Dis Z – 5.77E-05 | **Temperature Coefficient of Temperature Compensation Resistors:** 1700 ppm/°C and 4700 ppm/°C | **Pressure Sensitivity:** 1.39 mV/kPa at 5 V supply voltage

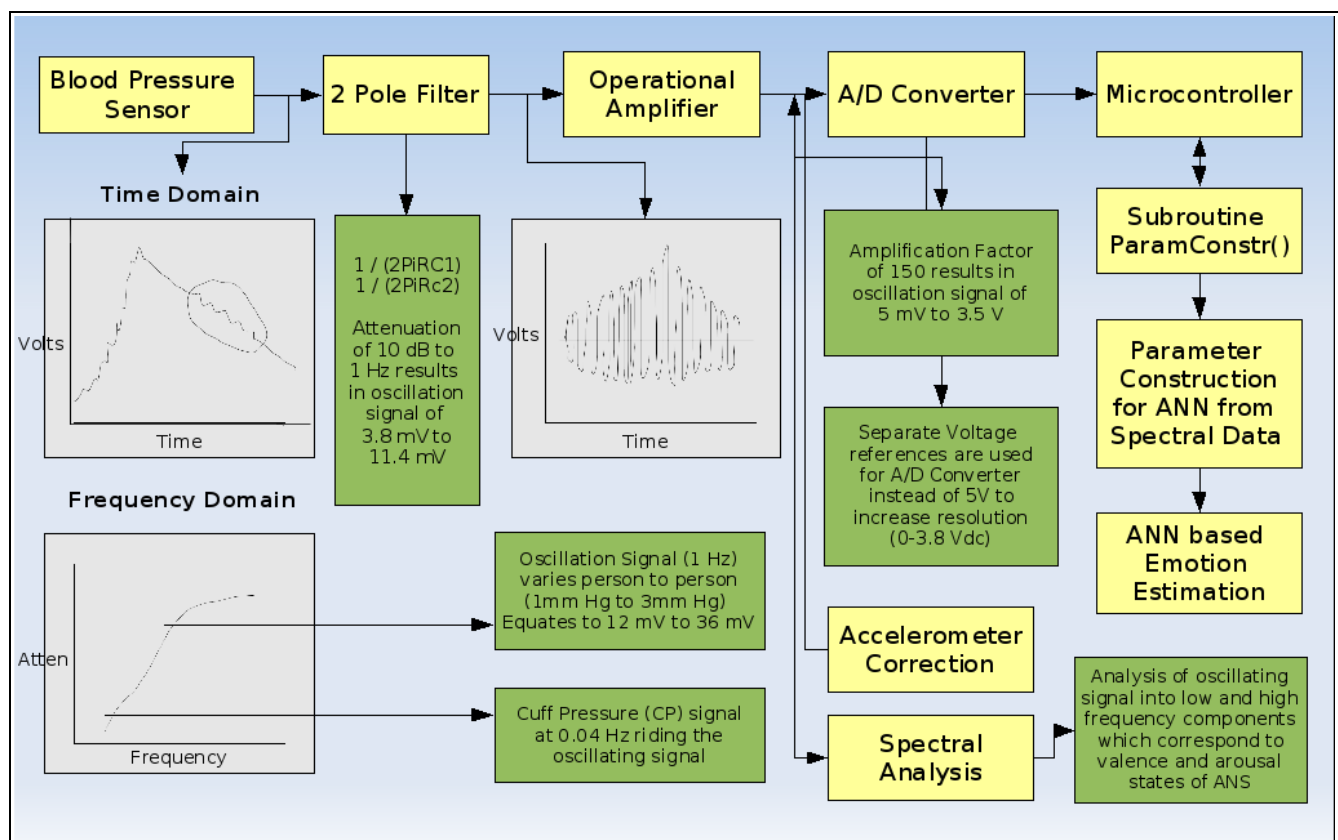
6.1.d Signal Conditioning

6.1.d.1 Internal Signal Conditioning



The signal conditioning circuitry is necessary for BioJoy's pressure sensor to calibrate and compensate offset voltage, full scale span, and temperature coefficient of offset voltage and full scale span. If the offset voltage appears, it is calibrated through trimming of RV– (for negative offset) and RV+ (for positive offset). The temperature coefficient of span and offset voltage are adjusted through trimming of RS1 and RV1, and sequentially followed calibration of full scale span through trimming of RS2. Resistors with temperature coefficient of the order of +1700 ppm/°C and +4700 ppm/°C were used for temperature compensation, depending on the value of sheet resistance R_s . The negative temperature coefficient of span from –1800 ppm/°C to –2500 ppm/°C were compensated by adding positive temperature coefficient of same value in the span.

6.1.d.2 External Signal Conditioning



The signal conditioning of the blood pressure sensor involves the following series of steps:

- 1] The microcontroller-micropump actuation causes the cuff to inflate to a predetermined systolic pressure level. The output of the sensor thus changes during the inflation and deflation cycles. During the inflation cycle, the oscillations of the user's blood pressure are absent from the sensor output and hence the sensor output reflects an increasing **cuff pressure (CP)** signal as seen in the time domain graph. During the deflation cycle, the sensor is more reflective of both the decreasing CP and the blood pressure **oscillating signal (BP)** that rides on top of CP. Since BP is alone useful for the **emotional state-stress analysis**, it has to be filtered out from the combined CP + BP signal. A frequency domain

analysis of the combined signal is thus performed to find out that **CP signal is at 0.04 Hz** riding on top of which is the **BP signal at 1 Hz**. The **2-Pole filter** is thus employed to separate the two signals.

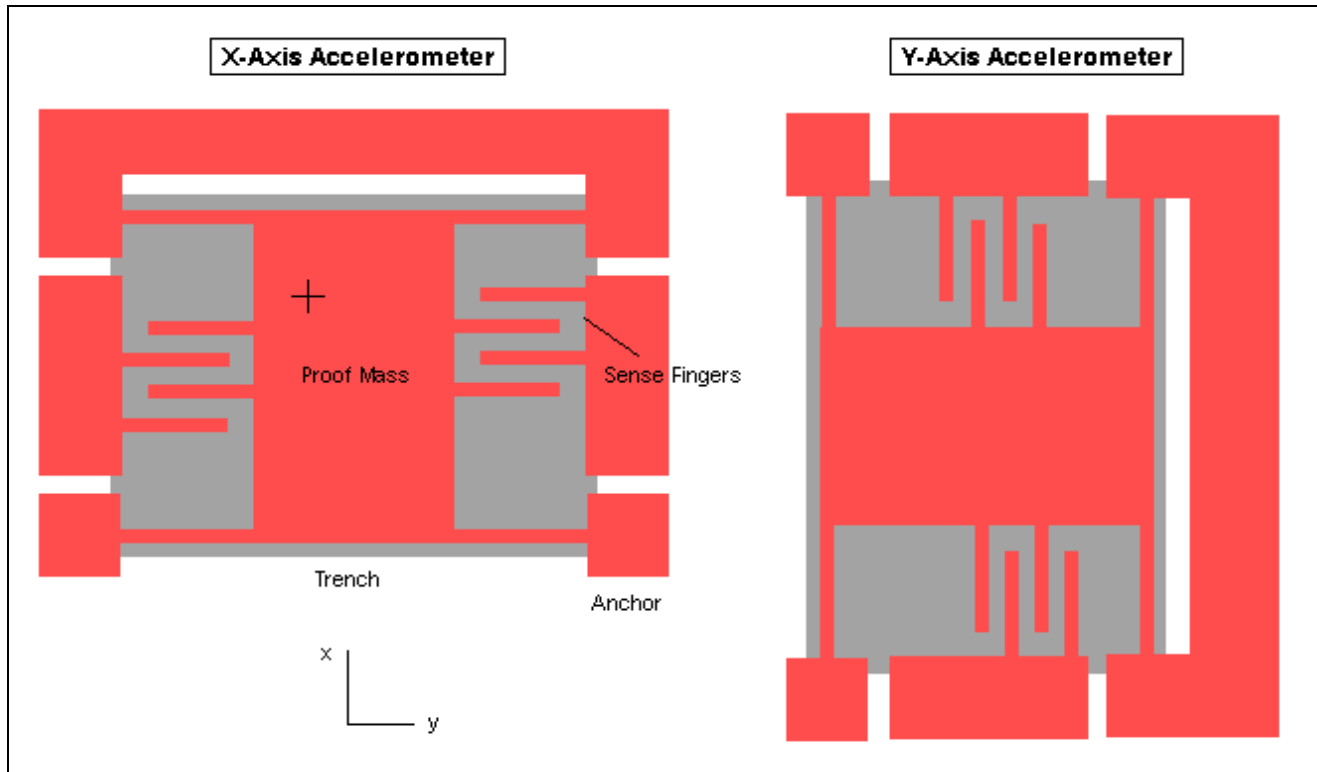
2] The 2-Pole filter has poles at $1/(2\pi RC1)$ and $1/(2\pi RC2)$ to segregate the two signals at 0.04 Hz and 1 Hz. However as the filter extracts BP from the combined signal, BP at 1 Hz undergoes an attenuation of 10 dB according to the Frequency-Attenuation characteristics of the filter. This attenuates BP with the range of 3.8 mV to 11.4 mV. It thus becomes necessary to amplify BP for efficient analysis.

3] The next stage in the signal conditioning flow involves the **operational amplifier** which an **amplification factor of 150** that boosts BP to a range of **5 mV to 3.5 V**. This amplified signal is then fed to the **A/D converter** which computes a digital equivalent of this oscillating analog BP signal. However before it is fed to the converter, **spectral analysis** is performed on the analog BP signal to compute the low and high frequency components which are related to the arousal and valence emotional states of the autonomic nervous system (ANS) [Section 7.1]. The signal is also cleaned of any **active motion artifact distortion** [Section 6.2.e] after which A/D conversion takes place.

4] In order to **increase the resolution** of A/D converter **separate voltage references** are to be used for the converter instead of the standard 5V. The voltage references thus used are **0 and 3.8 Vdc**. The range of the A/D converter is **0-300 mm Hg** which is within which the mean arterial pressure of 160 mm Hg for a normal adult lies. The converter has a resolution of approximately **1.24 mm Hg** for every count in the range of 0-255. Finally this amplified and digitally conditioned output is fed to the microcontroller which activates a subroutine **ParamConstr()** to construct suitable parameters for the ANN from digital spectral data from which ANN based Emotion Estimation can then take place [Section 7.1].

6.2 Accelerometer Sensor

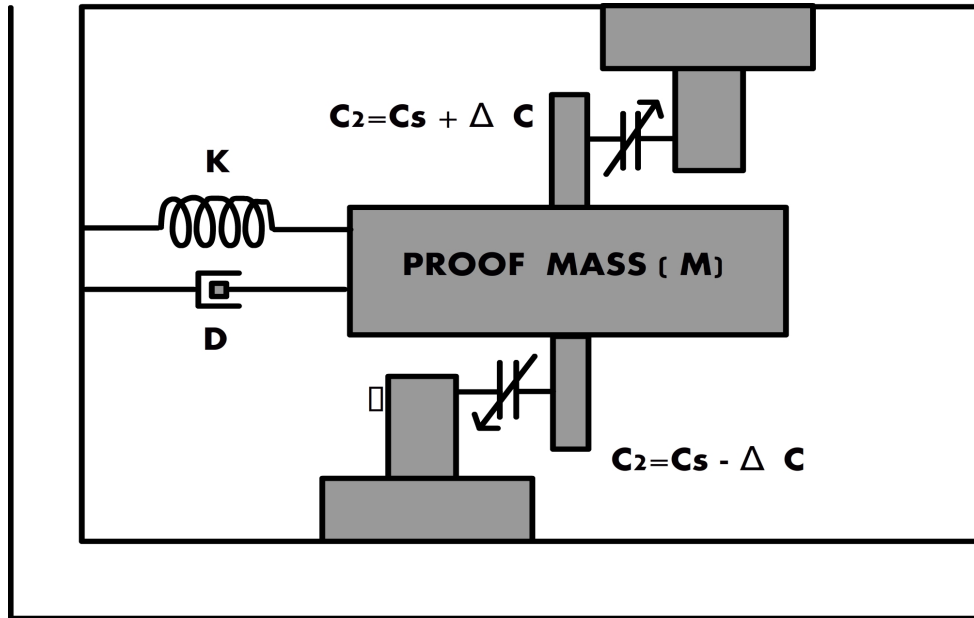
6.2.a MEMS Design / Layout



BioJoy's accelerometer sensor is currently a 2-axis capacitive accelerometer with proposed design for a single proof mass based 3-axis design. The sensor is fabricated using **Bulk SOI Micromachining** technology. The L-Edit layout of this sensor shown above has 2 accelerometers for X and Y-axis sensing with a proof mass at the center that is driven by external acceleration. The proof mass is allowed to be driven in one axis through the connected springs on the anchors of the device. The stators are fixed to the electrodes while the rotors are affixed to the proof mass and hence the relative motion between stator and rotor plates of the capacitive sense drive results in change in capacitance that is measured by an external signal conditioning circuitry to convert capacitance change to an analogous acceleration voltage. The SOI Trench layer is representative of the freed proof mass when the substrate is patterned and etched from below to allow the mass to be motioned in the lateral plane.

6.2.b Mathematical Basis

The mathematical model of the capacitive accelerometer sensor can be represented as shown in the proceeding figure which comprises of a proof mass attached to a reference frame via a spring and a damper. The inertia of the proof mass restrains the motion of this element in the presence of an external force (Ma) acting on the reference frame. The sense capacitances change with respect to the relative stator-rotor motion and can be expressed as $C_s + \Delta C$ and $C_s - \Delta C$ where ΔC is the change in capacitance induced as a result of the motion of the proof-mass and they are opposite in direction.



The equation for acceleration for the above model can be expressed as a 2nd order differential equation:

$$M \frac{d^2 x}{dt^2} + D \frac{dx}{dt} + Kx = Ma$$

where M is the proof mass, D is the damping coefficient and K is the stiffness coefficient of the spring. Using Laplace transform we can achieve to the following equation:

$$H(s) = \frac{X(s)}{A(s)} = \frac{1}{s^2 + \frac{D}{M}s + \frac{K}{M}} = \frac{1}{s^2 + \frac{\omega_r}{Q}s + \omega_r^2}$$

where $\omega_r = \sqrt{Q/M}$ is the natural frequency of the system and $Q = \sqrt{KM/D}$ is the quality factor.

Considering the effect of noise on this model, the primary mechanical noise source for the device is due to Brownian motion of the gas molecules surrounding the proof mass and the Brownian motion of the proof mass suspension or anchors. The total noise equivalent acceleration (TNEA) is given by,

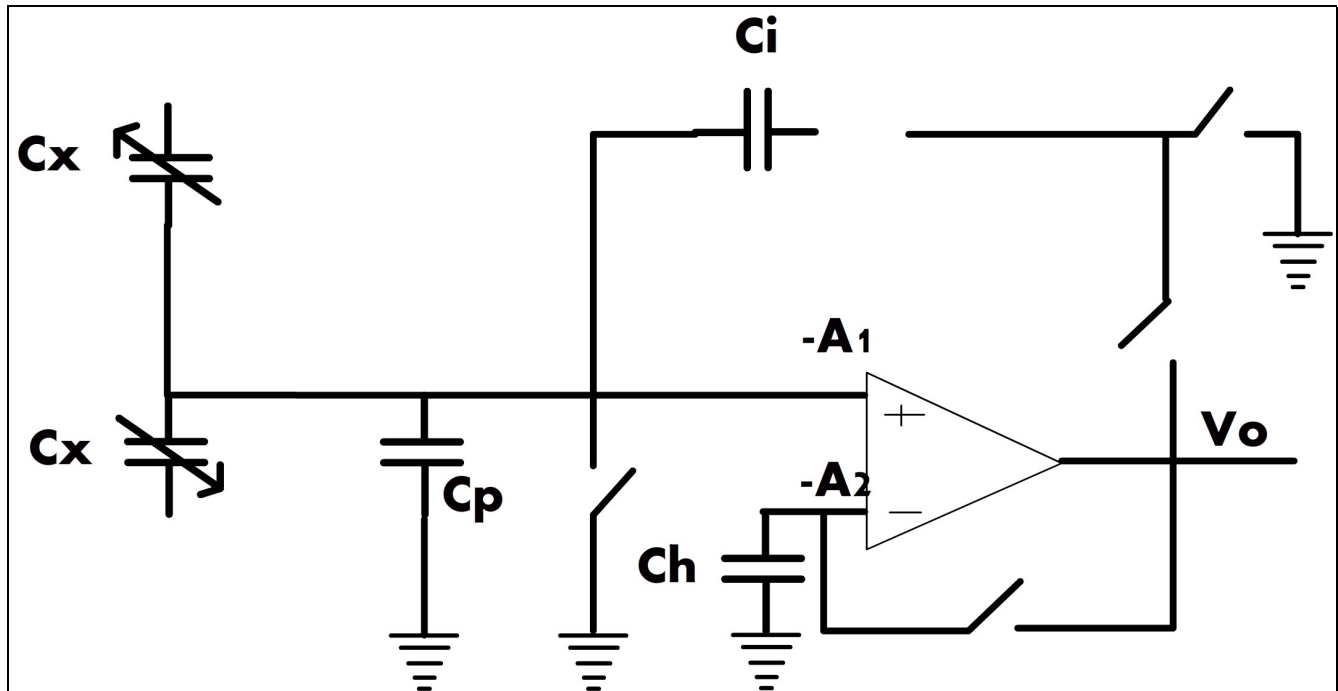
$$TNEA = \frac{\sqrt{4K_B TD}}{M}$$

where K_B is the Boltzmann thermal constant and T is the temperature in Kelvin. This above equation clearly shows that to reduce mechanical noise, the quality factor and proof mass have to be increased.

Sensitivity of the accelerometer is given by $S = (NE_0 l / w_0^2) * h/d^2$ where l and h are the length and

height of the sense electrodes, d is the initial gap spacing in between the proof mass fingers and sense electrodes, N is the total number of sense electrodes and f_0 is the resonant frequency of the sensor.

6.2.c Signal Conditioning



The above signal conditioning circuit is based on an amplifier with an auxiliary input A_2 with reduced gain and operates in two phases. First, the sense capacitors are precharged to a constant voltage. At the same time, the offset and flicker-noise of the amplifier are stored on the holding capacitor C_h . During the second phase, the voltage across the sense capacitors is changed, causing a charge that is proportional to the mismatch between the two sense capacitors to flow into node V_x . Since the amplifier input is now a virtual ground, this charge flows onto the integrating capacitor C_i unattenuated by the parasitic C_p producing an output V_o which is proportional to the position of the proof-mass.

6.2.d Sensor Specifications

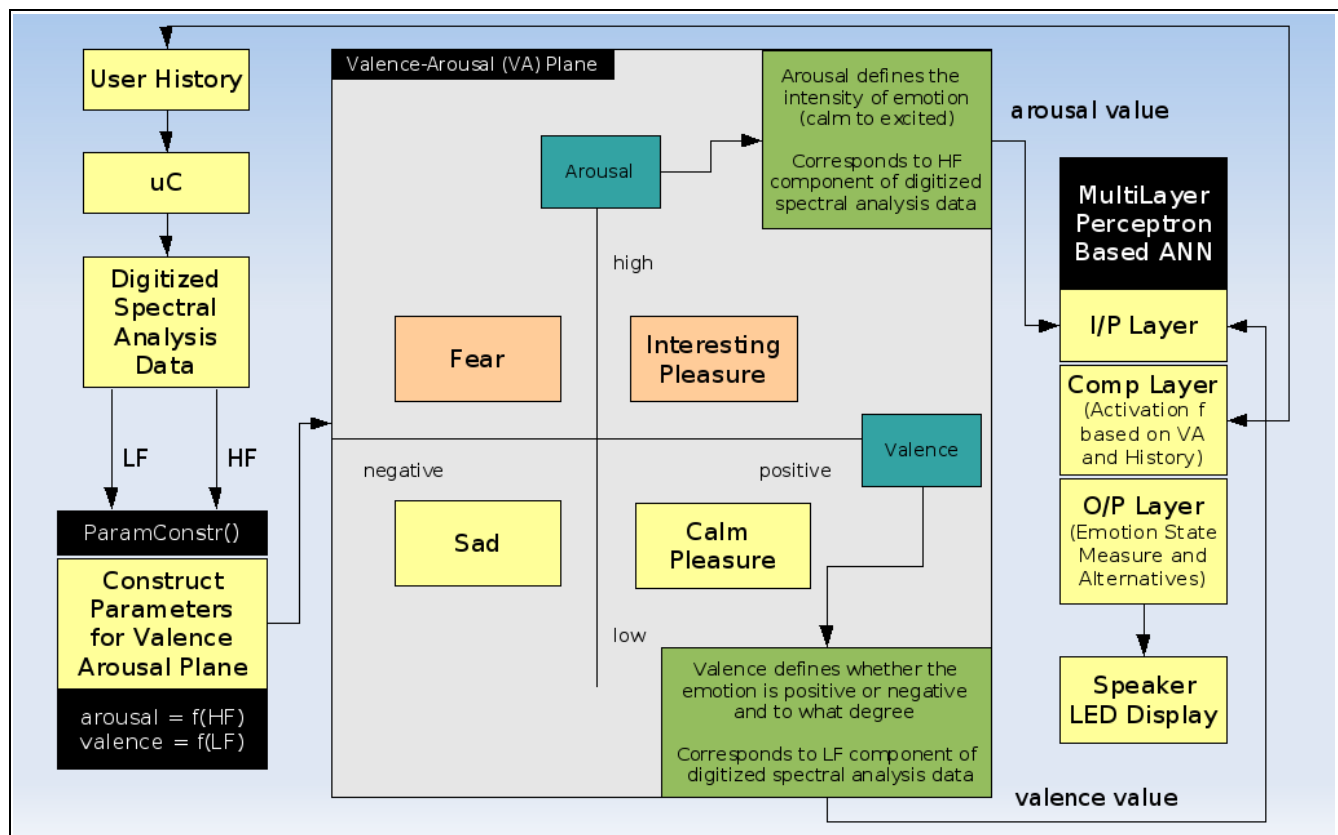
Proof Mass Dimensions: 4mm X 3mm X 40 μ m | **Proof Mass Weight:** 1.2 mg | **Sensitivity:** 0.2 pF/g
Brownian noise floor: 1 μ g/ sqrt(Hz) | **Capacitive gap:** 2 μ m | **Resonance frequency:** 1.5 kHz

Laguerre series expansion models. The filter thus is able to compute the estimated distortion w from acceleration data that is subtracted from the net distorted signal $y_0 + w$ to yield the true signal y_0 .

3] The recovered signal is finally **spectrally analyzed** to yield the **low and high frequency** components of the oscillating signal y_0 before being fed into the A/D converter and microcontroller.

7. Emotion Measurement with an MLP based adaptive Neural Network

7.1 Emotion Estimation

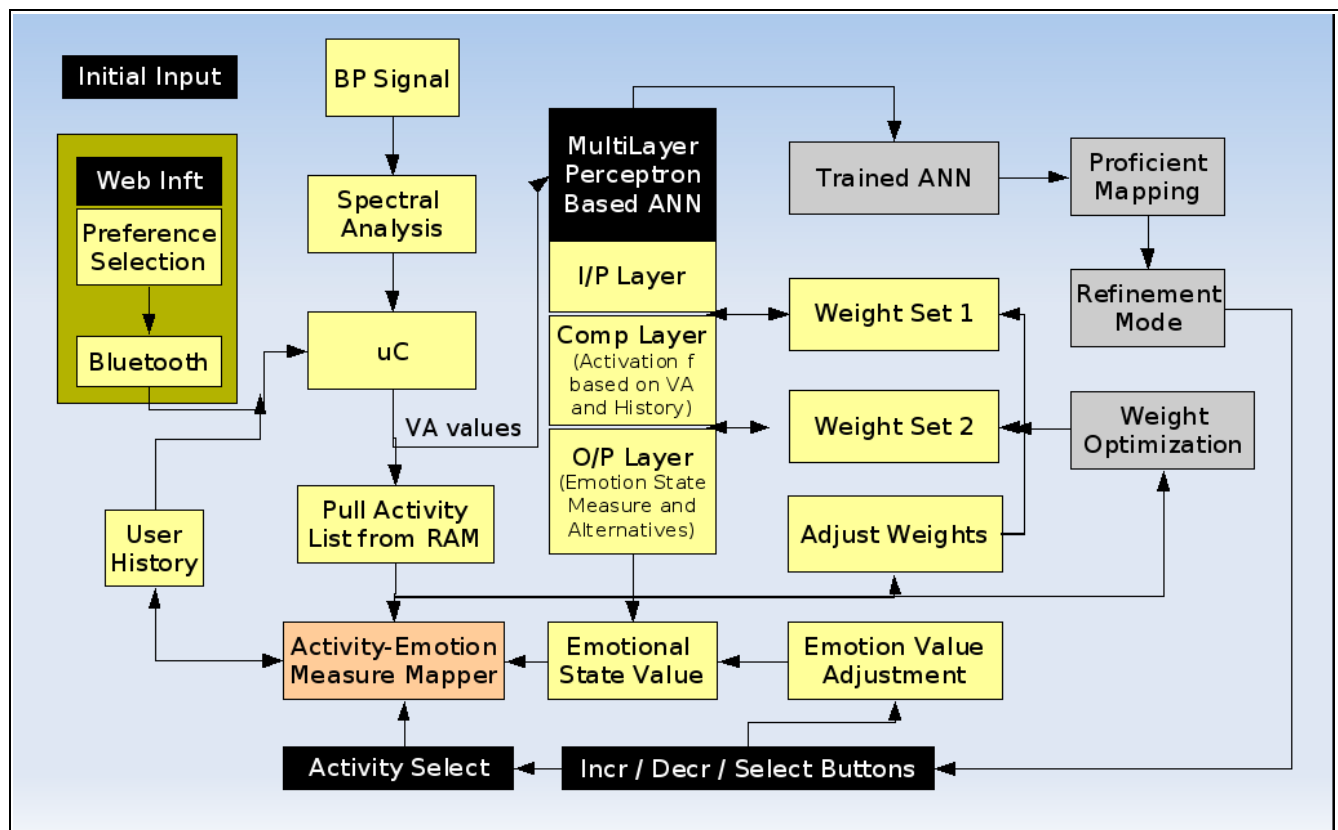


Most literature references agree to the fact that emotion can be analyzed qualitatively, but quantitative analysis is impossible. However in order for BioJoy to map the subjective nature of human emotions to an objective context, it is necessary that emotions be analyzed using an accepted mathematical concept of categorizing if not accurately measuring human emotions. A popular concept uses a valence-arousal plane to categorize / define emotions in a multi-dimensional space of emotion attributes – valence and arousal which are parameter that can be directly related to the emotional activity in the autonomic nervous system (ANS). **Valence (X-axis)** defines whether the emotion is positive or negative, and to what degree while **Arousal (Y-axis)** defines the intensity of emotion, ranging from calm (lowest value) to excited (highest value). As a deduction of using this **Valence-Arousal (VA)** plane we have four different classes of emotions that can be currently detected by BioJoy i.e. **Fear, Sad, Calm Pleasure** and **Interesting Pleasure**. For e.g. a positive measure of emotion combined with a high intensity of

emotion can be interpreted as the user feeling the emotion of Interesting Pleasure which maps to a low stress value. On the other hand, the emotion of Fear maps to a very high stress value. This valence-arousal (VA) plane is used by BioJoy's Emotion Estimation logic which involves the following steps:

1] The digitized spectral analysis data from the microcontroller is composed of the digital equivalents of the high and low frequency components of the blood pressure signal. The subroutine ParamConstr() then computes a mathematical value of arousal and valence which are functions of high frequency and low frequency components respectively. This drives the VA plane to the positive or negative and high or low domains of the X and Y axes respectively. The arousal and valence measures are then fed to the **I/P Layer** of the **MultiLayer Perceptron (MLP)** based neural network who activation function at the computational layer is based on a model of the Valence-Arousal Plane and the User's History which includes the learned preferences of the user. The user's emotional state measure and suitable alternatives are available at the **O/P Layer** of the MLP which are subsequently fed into the speaker and LED display for active notification and feedback from the user. However for the MLP to determine an **accurate measure** for the emotional state and alternatives it has to be **continuously trained** by the user both at its **inception** and **refinement** stages which is the subject of the next section on learning cycles.

6.2 Training Optimization Cycles



The training of the MultiLayer Perceptron (MLP) based ANN will be accomplished using an MLP specific learning algorithm such as **Lavenberg–Marquardt** that gives highly efficient and speedy

results since we wish to reduce the initial learning time of BioJoy as far as possible. BioJoy's MLP will learn in two stages i.e. **Training Cycle** and **Optimization Cycle**. The Training Cycle is associated with the initial 10 day phase after a user commercially procures the device from one of BioJoy Inc's distributors. During the Training Cycle, BioJoy is completely unaware of it's owner likes, dislikes and emotional state to stress level mappings. Hence certain form of seed values have to be provided by the user to help the MLP get started. This is accomplished through a web based like interface or the '**BioJoy Personalize**' Starter CD which will accompany the device. With this the user will be provided with a series of questions asking him/her about her daily routine, activity likes and dislikes [e.g. swimming, running, socializing, drinking etc] and request for a rating measure to be associated with each of these activities. For e.g. a person may rate socializing higher than drinking as thus becomes a possible stress relief indication that is fed into the system. After this initial set of seed values have been inputted by the user, he/she then uploads these values to the device's microcontroller RAM which form the basis for storing user's personal history which includes his preferences and stress relief solutions which have worked in the past. The Training Cycle of the MLP can now commence as follows:

1] Initially the LED display shows the message '**No Data**' on its LED display after the user has powered on the device. In a matter of few minutes the micropump inflatable polymer begins to inflate to the systolic level and blood pressure measurement begins during the deflation cycle. The first recorded BP signal is now available for Spectral Analysis and subsequent digitization into the microcontroller. Emotion Estimation as explained in Section 7.1 now takes place and the LED display churns out the first raw emotion bars of the user's emotional state which may be completely out of sync with the true state since the MLP is in its complete infancy i.e. it is untrained. In order to bootstrap the Training Cycle, the seed values fed in by the user and pulled from the microcontroller RAM in an activity list buffer that is then accessed by the LED driver to display the list of activities of the user.

The LED now flashes the activity 'Running' and the current raw emotion bar. If the user is 'Running' then he selects the activity to start building the '**Activity-Emotion Measure (AEM) Mapper**' which maps the activity of running to the current emotion measure. This can be interpreted as 'John feels good while he is running'. If the user is 'Swimming' instead then he cycles through the list until he can select this activity. The user is free to change the emotion measure so that he can tell BioJoy that 'I feel very good and not good alone while I am running'. This corrected AEM forms the central basis for training the MLP, a value of which is also stored in the '**User History**' buffer to be accessed by the AEM Mapper for adjusting the weights of the MLP. The AEM Mapper is thus governed by the current user adjusted **Emotional State value** and the **Activity List Data** pulled from the RAM.

2] The training of the MLP is accomplished by **refining its weights** which are multiplied with the input / processed signals at both the Input-Comp and Comp-Output Layers. It is this weighted sum of inputs at each layer which determines the value at the output layer. Hence refining weights will result in better emotional state values. The AEM Mapper pulls previously stored AEM measures from the User History buffer to adjust the weights of the MLP until the user is moderately satisfied with the mathematical results of the device such that when the LED display has 4 emotion bars high, it will usually entail that the user is sufficiently calm and relaxed. This entire process of **moderately acclimatizing** BioJoy to the user's emotional state will usually take a period of **10-12 days**. Now the Training Cycle is over and the Optimization Cycle can begin to more accurately attune BioJoy to the user's ESLM.

3] The **Optimization Cycle** unlike the Training Cycle is a **continuous refinement mode** which only ends once the user does not require the device anymore. It operates on the same principle as the training phase, except in this case, instead of starting with user inputted seed values and untrained weights, the cycle begins with sufficiently trained weights and actual ESLM measures as inputs to the Input Layer of the MLP. The difference between the Training and Optimization Cycles is the sheer magnitude of available mapped population. While the Training Cycle usually will contain only a couple hundred of these mapped entities, the Optimization Cycle will grow that population to thousands of entities. Thus after a sufficient duration of time, say 1 month or so, any new value will be more accurately mapped to one among the existing entities. This is analogous to the increased resolution of the A/D converter. However there is a theoretical limit to which this mapping population can grow and hence BioJoy can be regarded as being 'very well trained' after it has acquired anywhere in between 2000-2500 mappings. We estimate that the user will actually be so surprised with the results that BioJoy will be an indispensable stress relieving solution to the user. The user can then sufficiently depend on BioJoy to churn out a stress relieving solution just by pushing the 'BioJoy Me' button.

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