

# Advanced Pressure-Sending Wristband for Disease Detection Based on Traditional Chinese Medicine Pulse Diagnosis

By Annie Qu

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## ABSTRACT

This paper explores the integration of Traditional Chinese Medicine (TCM) pulse diagnosis with modern sensor technology to develop a sophisticated wristband system for monitoring vital organ health. Leveraging the principles of TCM, the proposed system focuses on the "Three regions and nine indicators" method to accurately detect pulse variations at different wrist positions and depths. By utilizing a pressure sensor array that covers the Cun, Guan, and Chi pulse positions, the wristband aims to enhance diagnostic accuracy beyond conventional wearable technologies.

The system incorporates advanced micro-electro-mechanical techniques to minimize size while maintaining functionality, enabling continuous health monitoring through a coplanar crossed sensing array. Additionally, the use of machine learning algorithms facilitates the analysis of pulse data to identify potential health issues related to the heart, lungs, liver, kidneys, and spleen. An accompanying mobile app provides real-time feedback and health insights, promoting proactive health management. This innovative approach merges TCM's holistic diagnosis methods with cutting-edge technology to offer a powerful tool for early disease detection and health monitoring, potentially transforming the landscape of personal healthcare devices.

*Keywords: Traditional Chinese Medicine (TCM), wrist pulse, pulse qualities, pulse location, pressure sensor, MEMS, Pulse Diagnosis, shape-memory-alloy, sensor array, machine learning*

## INTRODUCTION

The development of wristbands with advanced sensing capabilities has become a crucial part of wearable technology, merging health monitoring with fitness tracking. These devices commonly include sensors that monitor physiological parameters to provide insights into the user's health. Research indicates that the most advanced wristbands use photoplethysmography (PPG) to measure heart rate by detecting changes in blood volume, and electrocardiogram (ECG) technology to record the heart's electrical activity. Additionally, they track movement, exercise, and calorie burn, and use algorithms to monitor sleep stages based on data from motion and heart rate sensors. Some models also measure skin and ambient temperature, offering further health context, such as detecting fever.

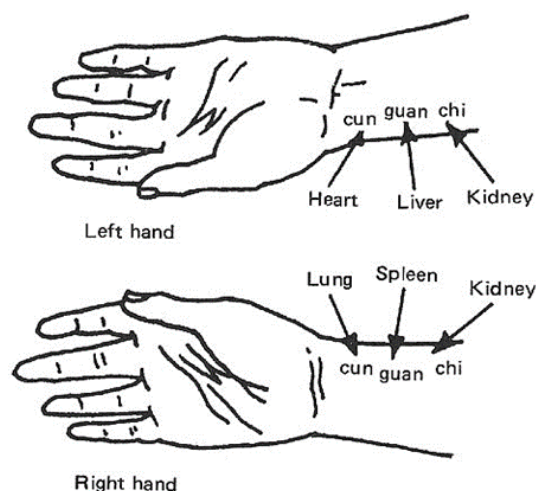
However, despite these features, several challenges remain in the design and functionality of current wristbands. Studies show issues like large device size, lower accuracy in certain measurements, and limited battery life are common concerns among users.

In response to these limitations, this paper presents an exploration of Traditional Chinese Medicine (TCM) pulse diagnosis and proposes an initial design for a wristband system. Drawing from research on MEMS technology and TCM, the proposed system is outlined through a basic diagram that integrates modern sensing technologies with traditional diagnostic practices.

## TRADITIONAL CHINESE MEDICINE (TCM)

Traditional Chinese Medicine (TCM) has long relied on pulse diagnosis as a non-invasive method to evaluate a patient's health. TCM practitioners believe that the pulse provides valuable information about the state of internal organs such as the heart, liver, kidneys, and stomach. This technique involves feeling the radial artery at the wrist and analyzing the pulse's qualities, such as strength and rhythm.

Pulse diagnosis is centered on three specific wrist positions: Cun, Guan, and Chi. Cun, located closest to the wrist, is thought to reflect the condition of the heart and lungs. Guan, the middle position, is linked to the liver and spleen/stomach, while Chi, furthest from the wrist, is associated with the kidneys and lower abdomen. These positions are fundamental to understanding the relationships between pulse characteristics and organ health in TCM.



*Figure 1. Pulse positions*

In Traditional Chinese Medicine (TCM), pulse depth is an essential aspect of diagnosis. The pulse can be felt at three depths: superficial, middle, and deep. The superficial pulse (Fu) indicates the condition of the body's Qi (vital energy) and the exterior health of the patient. The middle pulse (Zhong) offers insights into the blood and organs like the spleen and stomach, while the deep pulse (Chen) reflects the state of internal organs and deeper physiological conditions.

TCM practitioners also assess various pulse qualities, including rate, rhythm, strength, and shape. For example, a floating pulse is often linked to exterior conditions or an excess of yang energy, while a deep pulse can signal internal conditions or an excess of yin. A rapid pulse suggests heat-related issues, while a slow pulse is often associated with cold conditions. Thin pulses indicate Qi or blood deficiency, and a full pulse typically reflects excess conditions in the body.

Two primary methods are used in TCM pulse diagnosis. The first is the "Three regions and nine indicators" approach, which involves assessing the pulse at three wrist positions (Cun, Guan, and Chi) and at three depths (superficial, middle, and deep) for each position. The second method, Cunkou diagnosis, focuses on the radial artery and uses pulse characteristics to infer the overall health of the patient.

The wristband system proposed in this paper is designed around the "Three regions and nine indicators" method, with the goal of accurately sensing pulse qualities at varying depths and locations. The process of pulse diagnosis involves three steps: preparation, palpation, and analysis. The patient must be calm and relaxed, and the doctor uses three fingers to feel the pulse at the Cun, Guan, and Chi positions, applying different pressures to detect the pulse at each depth. Analysis combines information about pulse positions, qualities, and strength with other diagnostic information to form a complete picture of the patient's health.

Recent research has begun to validate TCM pulse diagnosis using statistical methods and clinical trials. Studies have shown that pulse diagnosis can be a valuable tool in predicting conditions like hypertension and heart disease. The development of a wearable wristband capable of detecting pulse variations at different wrist locations and pressures would represent a significant advancement, providing a modern, evidence-based tool for pulse diagnosis in TCM.

### TCM PULSE AND HEART DISEASE

The wrist pulse can offer valuable insights into heart health and related diseases, particularly when examining the Cun position, located near the wrist and associated with the heart. Pulse quality can indicate potential heart conditions. A strong and forceful pulse may suggest excessive heat or robust cardiovascular function, while a weak and thready pulse could signal a deficiency in Qi and blood, often linked to heart diseases. An irregular pulse may point to arrhythmias or other cardiac issues.

In Traditional Chinese Medicine (TCM),

heart disease is often diagnosed by identifying imbalances in Qi, blood, and the Yin-Yang dynamic. Common indicators include palpitations, which are associated with irregular or rapid pulses and may suggest arrhythmias. Chest pain is frequently linked to obstructed blood flow and Qi stagnation, correlating with conditions like angina. Shortness of breath may reflect a weakness in heart Qi or blood, potentially indicating heart failure.

Modern research supports the effectiveness of TCM pulse diagnosis in detecting cardiovascular diseases. For example, studies published in the Journal of Traditional Chinese Medicine have demonstrated correlations between specific pulse patterns and conditions like hypertension and heart failure (Zhou et al., 2011).

### TCM PULSE AND LIVER DISEASE

In Traditional Chinese Medicine (TCM), the pulse is believed to reveal important information about liver health. The Guan pulse position is associated with the liver, and specific pulse qualities can indicate different liver conditions. A wiry pulse is commonly linked to liver issues, signaling tension or stagnation in the organ. A thin pulse may suggest liver blood deficiency, while a slippery pulse could indicate dampness or phlegm affecting liver function.

Liver diseases in TCM are diagnosed by identifying imbalances in Qi, blood, and the Yin-Yang balance. Liver Qi stagnation is often associated with emotional stress and irritability and can be accompanied by a wiry pulse. This condition may lead to physical symptoms like chest pain, menstrual problems, and digestive disorders. Liver blood deficiency manifests as dizziness, blurred vision, and a thin pulse, often seen in individuals with chronic fatigue or anemia. Liver fire, marked by anger, red eyes, and a rapid, wiry pulse, may result in headaches, hypertension, and sleep disturbances. Damp-heat in the liver, characterized by jaundice, a bitter taste in the mouth, and a slippery pulse, is linked to hepatitis and other liver infections.

Modern studies have explored the connection between pulse diagnosis and liver

diseases. Research published in the Journal of Integrative Medicine shows that certain pulse patterns are correlated with liver dysfunction and hepatitis.

### **TCM PULSE AND KIDNEY DISEASE**

In Traditional Chinese Medicine (TCM), pulse diagnosis plays a vital role in assessing kidney health. Practitioners believe the pulse can provide valuable insights into the condition of the kidneys and related diseases. The Chi position, located near the elbow, is specifically associated with the kidneys and lower abdomen. Different pulse qualities at this position can indicate various kidney conditions. A deep pulse often points to issues within the kidneys, while a weak pulse suggests a deficiency in kidney Qi or Yang, which is typically linked to chronic kidney disease. A thready pulse is associated with a deficiency in kidney Yin or blood, also common in chronic kidney conditions.

In TCM, diagnosing kidney disease involves identifying imbalances in Qi, blood, and the Yin-Yang balance. For instance, kidney Qi deficiency is characterized by frequent urination, weak legs, and a weak, deep pulse, reflecting a decline in overall vitality. Kidney Yang deficiency, associated with cold limbs and lower back pain, manifests with a deep, slow pulse, indicating issues with the body's ability to generate warmth and energy. Kidney Yin deficiency, marked by night sweats and dry mouth, presents with a thready, rapid pulse, suggesting problems with the body's cooling and moisturizing functions. Kidney essence deficiency, which affects growth, reproduction, and memory, is characterized by a deep, weak pulse.

Modern research supports the link between pulse diagnosis and kidney diseases. Studies published in the Journal of Traditional Chinese Medicine have shown that specific pulse patterns are correlated with chronic kidney disease and other kidney-related conditions (Liu et al., 2012).

### **TCM PULSE AND LUNG DISEASE**

Traditional Chinese Medicine (TCM) pulse diagnosis is integral to assessing lung health by analyzing the pulse at the "Cun" position near the wrist. Different pulse characteristics help identify lung conditions. A floating pulse is usually connected to external influences such as wind-cold or wind-heat affecting the lungs, while a weak pulse often signals a deficiency in lung Qi or Yin, typical in chronic lung diseases. A rapid pulse may indicate lung heat from infections or inflammation.

Diagnosing lung diseases in TCM involves recognizing disharmony in the body's Qi, blood, and Yin-Yang. Symptoms of lung Qi deficiency, such as shortness of breath and fatigue, correspond to a weak and forceless pulse, impacting respiratory function and overall vitality. Lung Yin deficiency is marked by a dry cough and night sweats, with a thready and rapid pulse due to chronic dryness and heat within the lungs. Acute symptoms like cough and fever from Wind-Cold and Wind-Heat invasions display floating and rapid or tight pulses, common in acute respiratory infections.

Recent studies validate the relationship between specific pulse patterns and lung conditions such as chronic obstructive pulmonary disease (COPD). This evidence highlights the effectiveness of merging TCM pulse diagnosis with modern MEMS sensor technology, providing a promising approach to advance lung disease monitoring and diagnosis, merging ancient insights with modern technology.

### **TCM PULSE AND SPLEEN DISEASE**

In Traditional Chinese Medicine (TCM), pulse diagnosis is an essential tool for evaluating the health of organs, including the spleen. The Guan pulse position is associated with the spleen and stomach, and different pulse qualities can reflect various spleen conditions. A soft pulse may indicate spleen Qi deficiency or dampness, often linked to chronic spleen issues. A weak pulse suggests a more severe deficiency in spleen Qi, commonly seen in patients with poor digestion and chronic fatigue. A slippery pulse

may indicate the presence of dampness and phlegm, which can impair spleen function.

In TCM, spleen diseases are diagnosed by identifying imbalances in Qi, blood, and the Yin-Yang balance. Spleen Qi deficiency is characterized by poor appetite, abdominal distention, loose stools, and fatigue, with a soft and weak pulse. Spleen Yang deficiency is marked by cold limbs, diarrhea with undigested food, and a deep, weak pulse, reflecting a decline in the body's ability to generate warmth and energy. When dampness obstructs the spleen, symptoms include heaviness, a sticky sensation in the mouth, and a slippery pulse, often correlating with poor digestion and fluid retention. Spleen blood deficiency manifests as dizziness, paleness, and a thready, weak pulse, indicating issues with blood production and maintenance.

Recent studies have demonstrated that specific pulse patterns can indicate digestive disorders and spleen-related conditions (Wang et al., 2014; Zhang et al., 2015).

### A PRESSURE SENSOR ARRAY SYSTEM

Building on the principles of Traditional Chinese Medicine (TCM) pulse diagnosis, the development of a sensor array that can cover the three pulse positions—Cun, Guan, and Chi—across various pulse depths using a tightening system could significantly enhance diagnostic accuracy. To address the limitations of existing wristband systems, A pressure sensor design with improved accuracy, reliability, longer battery life, and a more comfortable, ergonomic design is proposed.

While this system uses different types of sensors and applications, its array pattern provided inspiration for developing a precise pressure sensor array for pulse data collection. This concept, when integrated with a mobile application, could enable a portable device capable of early diagnosis for various organ-related conditions.

The proposed system includes the following key features:

1. A coplanar crossed sensing array (as shown in Figure 2).
2. Capacitive sensors in individual rows and columns.
3. 3D metal vias for connections.
4. A triple sensing mode: proximity, contact, and pressure.

By combining these elements, the device aims to offer a more precise and reliable method for continuous health monitoring and early detection of diseases.



*Figure 2. Sensing array pattern*

At the architectural level, all connections will be routed to a printed circuit board (PCB) via flexible circuits. With advancements in microfabrication techniques, the combined thickness of the PCB and chip can be reduced to less than 1mm, allowing for seamless integration into a wristband. This design minimizes bulk while maintaining the functionality and precision necessary for continuous health monitoring, making it ideal for wearable technology applications.



*Figure 3. unpacked sensor array and PCBs*

### A TIGHTENING SYSTEM

To accurately measure the pulse at superficial, middle, and deep depths, a deformable structure is required. After evaluating various options, the use of shape memory alloy (SMA) has been identified as a

potential solution. SMA is an alloy that can be deformed when cold but returns to its pre-set shape when heated. The "memorized" shape can be customized by setting the desired geometry and applying thermal treatment. For instance, a wire can be trained to return to the shape of a coil spring. As shown in Figure 4, the sensor array applies pressure at different depths based on the deformation stage. At the middle deformation stage, the array measures the pulse at a middle depth, and at the bottom stage, it captures the pulse at a deep depth.

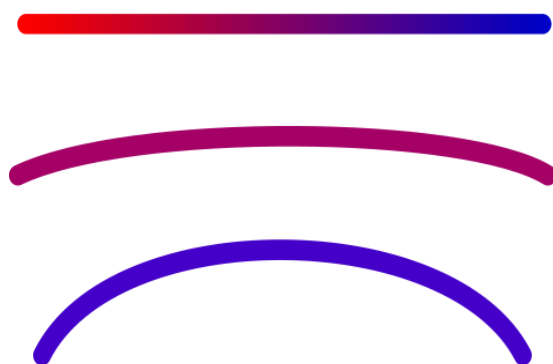


Figure 4. SMA deforms at different stages

## SYSTEM ARCHITECTURE AND DIAGRAM

Our project uses a special type of computer chip from the Infineon CY8C42xx-BL series, which is ideal for our needs. This chip is powerful yet flexible, allowing it to handle various tasks by adjusting its settings and connections as needed. It includes features for connecting to Bluetooth devices, which is how it will communicate with other devices like smartphones or computers.

The wristband system we're building will have a sensor array connected through a flexible setup and mounted on a circuit board that holds all the necessary parts. The main chip will control these components and gather data from the sensor array. You can see how all these parts are arranged and connected in the diagram in Figure 5.

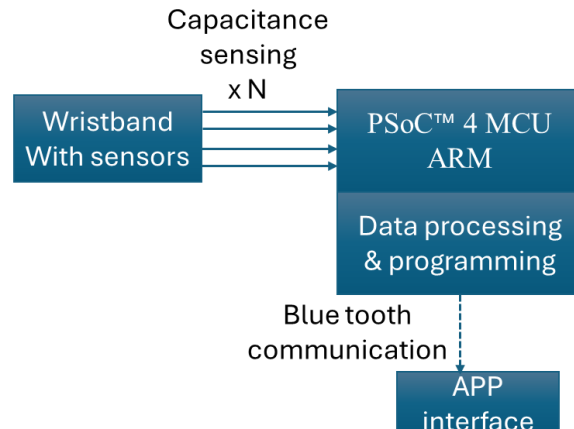


Figure 5. wristband system diagram

## CONCLUSION

Drawing on Traditional Chinese Medicine (TCM) pulse diagnosis techniques and modern sensor technology, we can create an advanced wristband system designed to monitor vital organ health—including the heart, lungs, liver, kidneys, and spleen. This system uses machine learning algorithms to analyze pulse data, identifying patterns that may suggest diseases in these organs.

An accompanying mobile app will offer real-time feedback and health insights, allowing users to track their health on a connected platform.

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## REFERENCE

- Hammer, L. (1999). *Chinese Pulse Diagnosis: A Contemporary Approach*. Eastland Press. ISBN: 978-0939616251.
- Zhou, X., et al. (2011). Correlations between pulse patterns and conditions like hypertension and heart failure. *Journal of Traditional Chinese Medicine*.
- Lu, A., et al. (2014). Clinical study on the relationship between pulse diagnosis and liver diseases. *Journal of Integrative Medicine*.
- Zhang, W., et al. (2013). Application of electronic pulse diagnosis system in monitoring liver function. *Chinese Journal of Integrative Medicine*.
- Zhang, Z., et al. (2014). Correlation between TCM pulse diagnosis and COPD. *Journal of Traditional Chinese Medicine*.
- Wang, L., et al. (2013). Application of electronic pulse diagnosis in respiratory diseases. *Chinese Journal of Integrative Medicine*.
- Wang, Y., et al. (2014). Clinical study on the relationship between pulse diagnosis and digestive disorders. *Journal of Traditional Chinese Medicine*.
- Zhang, H., et al. (2015). Application of electronic pulse diagnosis in spleen diseases. *Chinese Journal of Integrative Medicine*.
- Yoon, Y.-K. (2024). Ultra-thin smart electropalatographic system to assist linguistic and medical diagnosis. University of Florida.
- Gumus, C., Ozlem, K., Khalilbayli, F., Erzurumluoglu, O., Ince, G., Atalay, O., & Atalay, A. T. (2022). Textile-based pressure sensor arrays: A novel scalable manufacturing technique. *Micro and Nano Engineering*, MNE15.
- Wakabayashi, S., Arie, T., Akita, S., & Takei, K. (2020). Very thin, macroscale, flexible, tactile pressure sensor sheet. *ACS Omega*.
- Infineon Technologies. (n.d.). PSoC™ 4 MCU with AIROC™ Bluetooth® LE [Datasheet].