# SMART WORKWEAR FOR SAFER WORK

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softserve

Safety remains a burning issue for employers and workers that work in harsh environments. Environmental hazards (physical or chemical) and health issues (loss of attention under stress or heart attacks) remain some of the highest risks. For better protection, workers must constantly wear personal protective equipment (PPE). However, workers tend to eschew these protocols for various reasons:

- Lack of risk awareness. Workers have no real-time information about a hazardous environment. This decreases workers' motivation to follow safety rules. It is especially important for health problems, where unsafe behavior leads to occupational diseases over the course of months or years.
- Overconfidence. Experienced workers often overestimate their own ability to assess conditions and, therefore, do not use PPE.
- Macho culture. A workplace culture based on assertiveness, competitiveness, and boldness decreases workers' attitudes toward safety issues. It has emerged in a so-called "Texas period" , where minor accidents and procedure defiance were almost a badge of honor.

As reported recently by the US Department of Labor, the top most frequently cited **OSHA standards violated in 2018** include:

- Fall protection
- Hazard communication
- General scaffolding requirements
- Respiratory protection
- Control of hazardous energy, lockout/tagout
- Ladders
- Powered industrial trucks
- Fall protection, training requirements
- General machine guarding requirements
- Eye and face personal protective and lifesaving equipment

Training and diligence are very helpful for to reducing workplace accidents and injuries, but when it comes to bringing workers home safe, it is not enough. Embedded technologies integrated into smart workwear or as standalone devices enable the continuous monitoring of dangerous conditions.

## Smart workwear

Based on IoT edge trends and current market analysis, research suggests workwear with an integrated wearable device allows workers to:

- Continuously monitor environmental conditions, alarming workers and their neighbors about risky and critical situations, without interrupting for measurement or for using additional standalone or mobile tools.
- Continuously monitor vital signs and behavior, alerting the closest coworker that help is needed. This monitoring enables small teams and self-employed workers to continue working without having to constantly be in one another's line of vision.

Investigating solutions, SoftServe's R&D team built several smart workwear prototypes, focusing on smart workwear jackets. The team built each smart workwear jacket prototype with an embedded device and sensors, researched algorithms for detecting workers' instant health issues and unsafe behavior ("man down" accident, heart attack), and implemented algorithms in firmware and android software. Results had in-field tests and measurements to verify performance parameters (distance, power consumption, working time, detection of accidents).

The next sections will provide a more detailed description of the system architecture and the results achieved.

# IMPLEMENTING A SMART WORKWEAR SYSTEM

Construction workers are the target audience of the designed smart workwear jacket. The smart workwear jacket's system aims to inform a worker, a neighboring worker, or a supervisor of any issues in real-time and with minimal configuration.

We separated two main use cases for the smart workwear system:

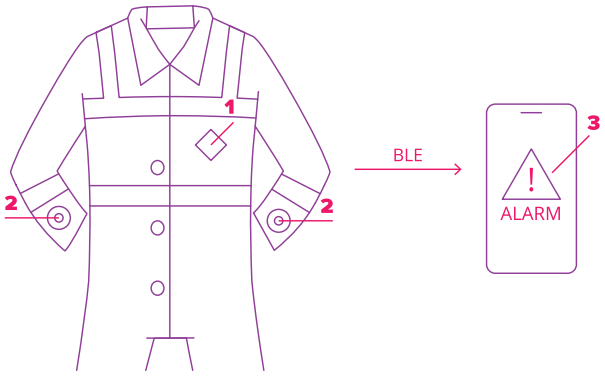



**Figure 1. "Supervisor-controlled"**

**1** Module with microcontroller unit (MCU) and basic environmental and motion sensors

**2** ECG senses location

**3** Mobile phone receives alarms via Bluetooth

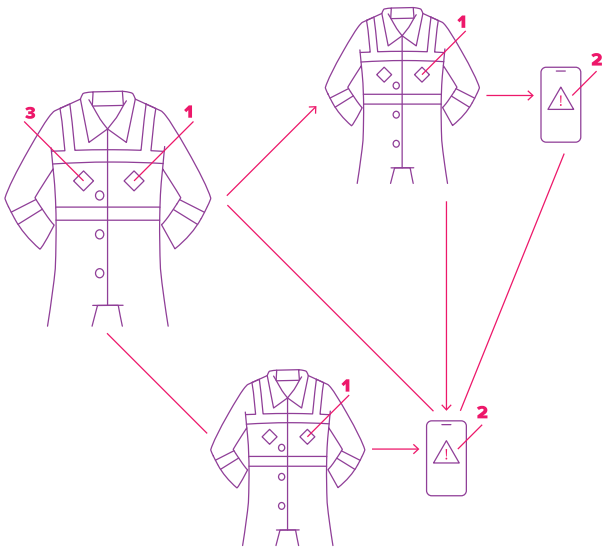



**Figure 2. "Mesh Network"**

**1** Basic modules, with MCU as part of mesh network

**2** Mobile phones (part of mesh network)

**3** Additional alarm module for alerts from neighbors like "Replace mobile phone"

In the case of **Figure 2,** there is at least one actor in the system that has a smartphone and can check the status of each individual within the mesh network of the connected workwear. The mesh network can also connect to the selected individual to gather detailed telemetry data.

The smartphone's availability is optional. Smart workwear units connected in the mesh network send alarm messages directly to the endangered worker's nearest neighbors, with the aim of preventing accidents. The unit uses the same transport (BLE radio) as for communication with a smartphone.

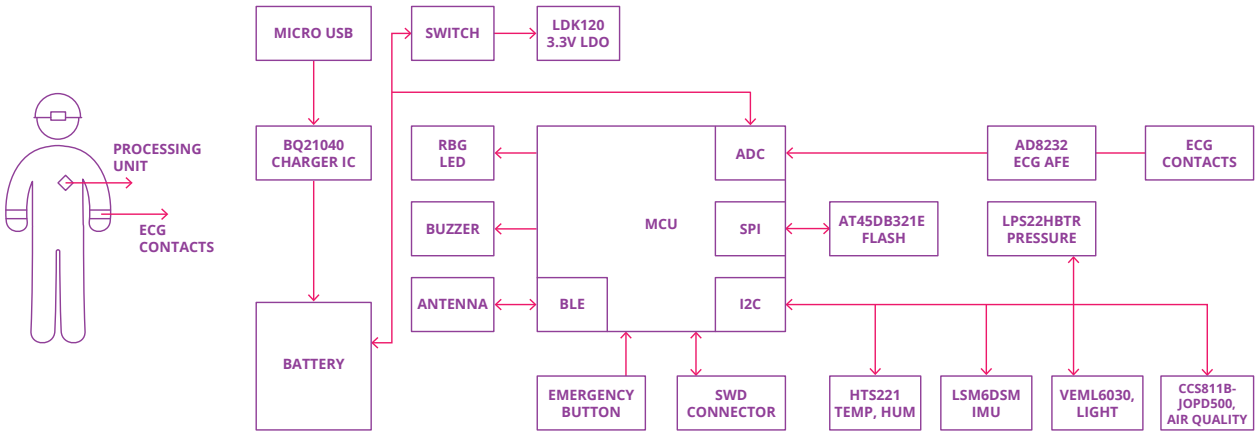



**Figure 3. Workwear top-level system diagram**

All units in the system are built around the top-level architecture from Figure 3, which consists of several elements. The MCU is Cortex-M0 processor with BLE radio support and there is a set of sensors on the board:

- Temperature, humidity for monitoring environmental conditions (HTS221).
- Inertial measurement unit (IMU) accelerometer, gyroscope for monitoring body position, movement and fall detection (LSM6DSM).
- A pressure sensor for altitude monitoring (LPS22HBTR), which can also be used for navigation purposes.
- A light sensor to track UV light influence (VEML6030).
- Air quality sensors (CCS811B-JOPD500)
- ECG analog front-end (AD8232)

Sensors share the I2C bus, but the ECG analog front-end has its own output that is sampled by a 12-bit ADC inside the main controller.

The ECG analog front-end (AD8232) gets an ECG signal from the contacts on the hands. The ECG contacts are made from conductive rubber with small resistance. The device's printed circuit board (PCB) is in a plastic case in the front pocket of the jacket, the ECG contacts header is also routed to this pocket. The Flash IC uses an SPI interface to store historical data.

The system is powered from a rechargeable LiPo battery (6EB401230, 3.7V 100mA). The battery charger (IC bq21040) charges the battery from a USB port, and a low dropout voltage regulator (LDK120) provides a stable power supply (3.3V, 200 mA) for all system elements. A user can get visual feedback from an RGB LED, or red-green-blue LED light, that indicates the internal system state. Additionally, there is "panic button" on the PCB for emergency notification alerts. The button is implemented as a capacitive sensor on the top side of the plastic case. The buzzer supplements LED alerts indication with "SOS" signal.

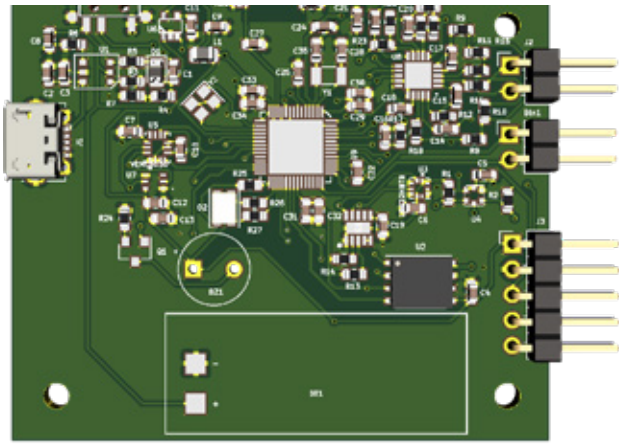


**Figure 4. Workwear PCB prototype 3-D view**

# FIRMWARE DETAILS

There are a number of firmware components in the MCU responsible for communication. These firmware components acquire data from sensors, sample analog signals, and control the RGB LED. The figure below shows their interconnection.

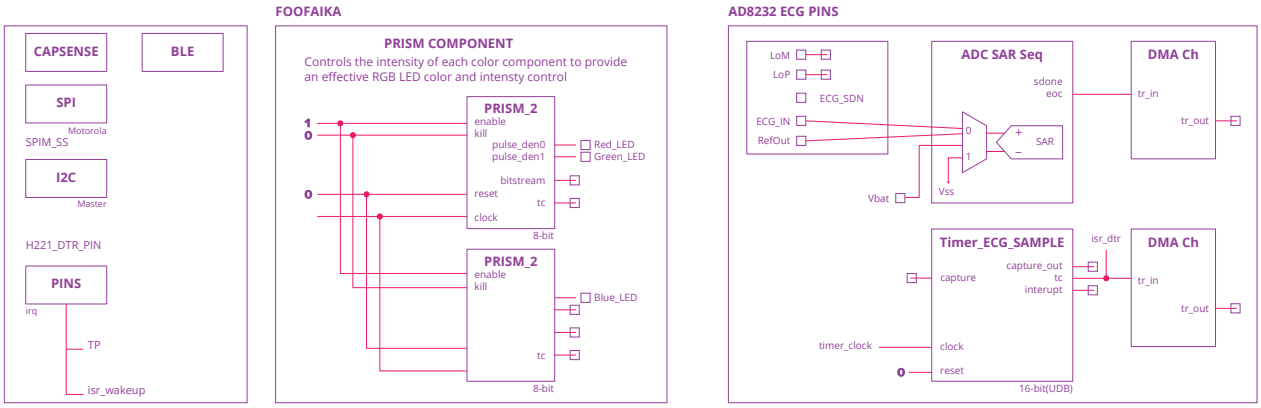



**Figure 5. Component utilization in MCU (CY8C4248LQI)**

The Bluetooth low energy (BLE) component is configured for a custom client/server profile support.

One of two use cases is possible for the BLE device:

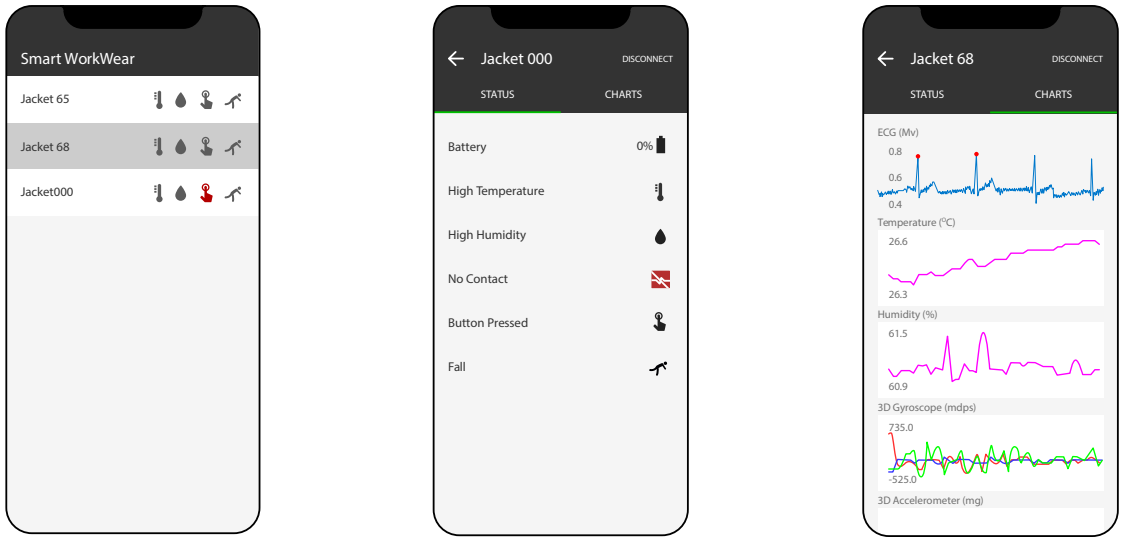
- The BLE device is connected to a smartphone. The BLE device acts as a general attribute (GATT) server, providing a set of services to the smartphone with custom characteristics (a system status, a sensor data stream, an ECG stream, a battery level). A smartphone gets these characteristics as notifications. Simultaneously, it broadcasts status, temperature, and humidity to the nearest devices.

- The BLE device is not connected to a smartphone within an initial advertising interval. The BLE device is configured as a GATT client that scans nearby Bluetooth devices for the same “workwear” name in the advertising packet. Upon detection, it checks the neighbors’ statuses and updates its own advertising package, if there is a need to spread this data. The system continues to broadcast the advertising packet.

The 12-bit SAR ADC has two channels to measure ECG analog signal (differential), as well as the battery charge level (single ended). The ADC sampling rate is 10,000 SPS; and the transfer over the BLE notification packet sends 100 samples of ECG signals every 500 milliseconds. For this purpose, we use a timer configured to get a sample every five milliseconds to feed the buffering for notifications.

# SOFTWARE DETAILS

Reading the data from the smart workwear jacket is easy with the developed Android application. Visualizing data from the sensors, the application has three main views:




**Discovery Mode** **Connected Status** **Connected Raw Data**

**Figure 6. Smart WorkWear Android Application**

The “Discovery Mode” view appears at the application’s start-up; it has a list of discovered jacket devices and their statuses broadcasted in advertising packets. Each jacket has an associated ID that can be changed.

Clicking on one of the list elements brings the user to the “Connected Status” view. The Connected Status view under “Status” shows a battery charge level, a connection status, and alerts. And clicking “Charts” brings users to the “Connected Raw Data” view, the raw data stream that has a set of charts to refer to ECG, temperature, humidity, a magnetometer, and an accelerometer.

The heart rate detection algorithm is based on the Pan-Tompkins “Real-Time QRS Detection Algorithm.” This algorithm reliably recognizes QRS complexes based upon the digital analyses of the slope, amplitude, and width. The set of filters in the algorithms is used to pass an ECG bandwidth of 5-15 Hz, reducing false detections caused by the various types of interference present in ECG signals, muscular noise, 50Hz wall supply, and others. This allows the reliable identification of R-peaks for calculating heart rate.

Motion artifacts are a significant challenge for ECG processing, but the SoftServe R&D team has experience using a “de-noising” technique to eliminate friction that is already planned into the further stages of this research. Currently, we only detect heart rate using standard algorithms, but research suggests that detecting cardiovascular diseases and emotional state using ECG signal processing can be perfected.

## CONCLUSION

Usage of these smart workwear jackets in groups working in harsh environments will improve worker safety and monitoring. Using sensor technology, these jackets alert fellow workers to impending accidents—allowing time for the endangered worker to be saved by another—and alerting supervisors to health and environmental concerns and conditions in general. Such technology will be used to decrease risk due to accidents and health, and improve the lives of workers overall.

Explore the value of smart workwear solutions with SoftServe—**contact us today**.

# ABOUT US

SoftServe is a digital authority that advises and provides at the cutting-edge of technology. We reveal, transform, accelerate, and optimize the way enterprises and software companies do business. With expertise across healthcare, retail, media, financial services, software, and more, we implement end-to-end solutions to deliver the innovation, quality, and speed that our clients' users expect.

SoftServe delivers open innovation—from generating compelling new ideas, to developing and implementing transformational products and services.

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