



Sensors and their Applications in Smart Textiles using Arduino

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Smart textiles are fabrics embedded with electronic components and sensors, adding functionality beyond traditional textiles. When these sensors are combined with microcontrollers like Arduino, they become powerful tools for building interactive and responsive projects. Arduino serves as a versatile platform for sensor integration, data processing, and controlling actuators or displays embedded in smart textiles. Its open-source nature and extensive community support make it ideal for prototyping and developing innovative solutions in wearable technology. The combination of sensors and Arduino empowers designers and engineers to create functional, responsive, and personalized smart textile applications that cater to diverse user needs and environments.

Types of Sensors used in Smart Textiles

Various types of sensors can be embedded on textile products to provide smart functions. Common types of sensors include temperature sensors, such as thermistors and temperature-dependent resistors (e.g., DS18B20), which measure ambient temperature and are used in applications like thermal regulation in smart clothing, temperature monitoring in medical garments, and climate-controlled bedding. Light sensors, including light-dependent resistors (LDRs) and photodiodes, detect ambient light levels and are employed in automatic lighting systems, solar trackers, and photography equipment. Heart rate sensors, whether optical or ECG-based, monitor heart rate and cardiac activity, finding applications in smart shirts for continuous heart rate monitoring during exercise, medical-grade garments for remote patient monitoring, and stress-tracking apparel for mental health. Gas sensors, including those that detect carbon monoxide (MQ-7), methane (MQ-4), and carbon dioxide (MQ-135), are used in air quality monitoring, industrial safety, and gas leak detection systems. The MQ-2 gas sensor, a Metal Oxide Semiconductor (MOS) type, is particularly notable for detecting gases like methane, butane, LPG, and smoke by changing the resistance of its sensing material upon gas contact. Humidity sensors, like DHT11 and DHT22, measure air moisture content and are used in weather stations, HVAC systems, and agricultural applications, while in textiles, they monitor moisture levels in sweat-sensing garments, moisture-wicking fabrics, and breathable textiles for comfort in varying climates. Pressure sensors, employing piezoresistive or piezoelectric materials, detect pressure or touch changes and are integrated into smart gloves for gesture recognition, pressure-sensitive garments for posture monitoring, and smart footwear for gait analysis. Accelerometers and gyroscopes, which detect motion and orientation changes, are used in activity-tracking apparel for step counting, rehabilitation garments for movement pattern monitoring, and wearable technology for cyclist and athlete safety. Additionally, electroencephalography (EEG) sensors measure brain activity, enabling

applications in smart headwear for cognitive monitoring, brain-computer interfaces, and neurofeedback.

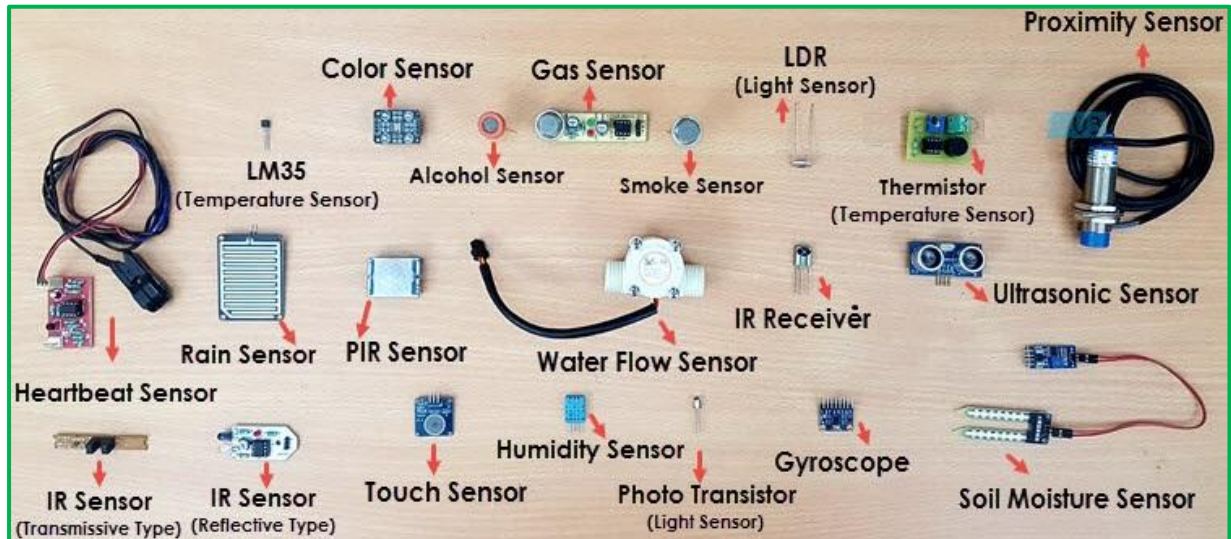


Fig. 1. Different Types of Sensors

Sensors with Arduino

Sensors are essential components in smart textiles and wearable technology, enabling interaction with the environment or the wearer. When combined with microcontrollers like Arduino, these sensors can be integrated, processed, and controlled to create highly functional and responsive textiles. For instance, temperature sensors such as thermistors and DS18B20 can be embedded in smart clothing to monitor body or environmental temperature, with Arduino processing this data to regulate heating elements, maintaining a comfortable temperature. Light sensors like light-dependent resistors (LDRs) and photodiodes can detect ambient light levels, allowing Arduino to control the brightness of integrated LEDs in smart textiles, providing adaptive lighting solutions. Heart rate sensors, whether optical or ECG-based, can be embedded into textiles to continuously monitor heart rate and cardiac activity, with Arduino transmitting this data to a mobile app or displaying it on an integrated screen. Gas sensors, including MQ-7 for carbon monoxide and MQ-135 for carbon dioxide, can monitor air quality, with Arduino analyzing the data to alert the wearer to hazardous levels or activate ventilation systems. Humidity sensors like DHT11 and DHT22 can measure moisture content in the air or within the textile, with Arduino managing moisture levels for comfort. For an example, the DHT11 can be interface with Arduino board with simple wiring as shown in the Figure 2.

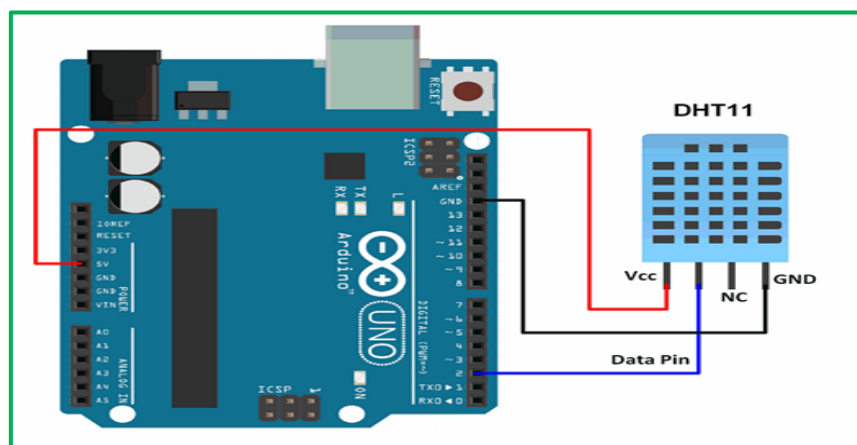


Fig. 2. Arduino with DHT11 Temperature/Humidity sensor

Pressure sensors using piezoresistive or piezoelectric materials can detect touch or pressure changes, allowing Arduino to enable applications like smart gloves for gesture recognition and pressure-sensitive garments for posture monitoring. Accelerometers and gyroscopes embedded in textiles can detect motion and orientation changes, with Arduino tracking movements for data on physical activity and safety. Lastly, electroencephalography (EEG) sensors can measure brain activity, with Arduino processing EEG data for smart headwear applications in cognitive monitoring and neurofeedback. By integrating these diverse sensors with Arduino, designers and engineers can create a wide range of smart textile applications that enhance user interaction, comfort, safety, and overall experience.

Future Trends in Smart Textiles Using Arduino

Looking ahead, the evolution of smart textiles integrated with Arduino microcontrollers promises ground-breaking advancements in wearable technology. Future trends indicate a move towards miniaturization and integration, with smaller and more comfortable sensor modules seamlessly integrated into textiles. These advancements will enable smart textiles to sense a broader array of biometric data beyond traditional parameters like temperature and motion, potentially monitoring hydration levels, muscle activity, and even emotional states. Wireless connectivity, utilizing technologies such as Bluetooth and Wi-Fi, will enhance real-time data transmission to external devices, facilitating more efficient monitoring and control. Energy harvesting technologies, like solar cells and kinetic energy harvesters, are set to mitigate power supply challenges by generating electricity from natural sources or body movement, reducing reliance on batteries. Moreover, advancements in flexible display technologies may lead to the integration of OLED or e-ink displays into smart textiles, enabling dynamic feedback and interactive interfaces. With a focus on healthcare applications, future smart textiles are poised to monitor chronic conditions, aid in rehabilitation, and optimize athletic performance through personalized feedback and analysis. Embracing AI and machine learning, Arduino-enabled smart textiles will learn user behaviours over time, offering predictive capabilities and personalized experiences. Sustainability will also play a pivotal role, driving innovations in eco-friendly materials and production processes. Ultimately, interdisciplinary collaboration among textile designers, engineers, software developers, and healthcare professionals will drive these innovations forward, paving the way for smarter, more adaptive, and sustainable smart textiles that enhance daily living across diverse fields.

Demerits of smart textiles with sensors

While smart textiles with sensors offer numerous benefits, they also come with several demerits. The integration of sensors and electronic components significantly increases production costs, making these textiles more expensive than traditional garments. Durability is another concern, as washing, stretching, and general wear and tear can damage the sensors and circuits, reducing the lifespan of the textile. Comfort can also be compromised, with added electronic components affecting the flexibility, breathability, and overall comfort of the fabric. Power supply is a critical issue, as smart textiles require batteries that need regular recharging or replacement, adding inconvenience and potentially increasing the garment's weight. Additionally, using smart textiles often requires technical knowledge for operation and maintenance, posing a barrier for some users.

The environmental impact is another drawback, with the production and disposal of smart textiles contributing to electronic waste. Reliability can be affected by external factors like humidity, temperature, and electromagnetic interference, challenging the consistent functionality of these textiles. Aesthetic limitations arise from the need to incorporate sensors and electronic components, which can restrict design options and detract from the garment's look and feel. The electronic components in smart textiles often have a shorter lifespan than

the textiles themselves, leading to potential issues with replacement and repair. Finally, navigating regulatory and standardization issues across different regions can be complex and time-consuming for manufacturers.

Conclusion

Sensors integrated into smart textiles, in conjunction with Arduino microcontrollers, enable the development of innovative applications across various domains, including healthcare, sports, fashion, assistive technology, and environmental monitoring. By combining sensors with textiles, designers and engineers can create wearable systems that seamlessly integrate into everyday life, providing comfort, functionality, and personalized experiences for users. With advancements in sensor technology and the versatility of Arduino platforms, the future of smart textiles holds immense potential for revolutionizing the way we interact with clothing and the world around us.

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