Electrodermal Activity (EDA) and body temperature Monitoring system for patients with psychological disorder

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Abstract. In today’s world we are leading an unimaginably fast and stressful life. Hence, the number indicating psychological disorder cases has hiked like never before. Compared to physiological disorders, psychological disorders take longer time to cure and mandates long term monitoring the patient in his/her daily and personal life. Galvanic Skin Resistance (GSR), also called Electrodermal Activity (EDA) is actually measurement of variations in electrical properties of skin attributed to Sympathetic Nerve System (SNS), directly related to mental state of the subject, such as stress, drowsiness and engagement. We have put an effort in making a wearable device to monitor such important parameter. The device is designed using silver electrodes, LMT70 temperature sensor and Arduino mini pro. The device is capable of recording EDA and body temperature periodically at an interval of 5 minutes for 7 days on a single charge of 3000mAh battery of 3.3V. The data is recorded on a microSD card in CSV format.

1. INTRODUCTION
Contemporary life is much fast paced and competitive compared to life a decade before. People are driven by high ambition and virtual feeling called status. Everyone is striving for success, prosperity and glory. The hunger of success, prosperity and glory makes one exploit oneself beyond one’s capacity. Another reason for such pace of life is, the fear of failure or being left behind. This competitive life and restless struggle results in poor physical health and disturbed mental condition [1], [2]. Not only competitive culture, but our new life style and invasion of social media [3] is also responsible for the same. Most people avoid exercise and confine themselves in chair and practice wrong food habits with imbalanced diet. We need to keep our brain and all internal organs in equilibrium by resisting any kind of change that affects this equilibrium. This stable condition is called, ‘homeostasis. Any disturbance, in this condition of homeostasis is called stress [4].

Stress can be physical as well as mental [5]. Physically, stress is exploiting the physiological system of body beyond its capacity i.e. to do too much work, not to have enough sleep, not to take healthy and sufficient diet, etc. Mentally, stress is caused due to too much of worry about career, occupation, work, family or feeling of any traumatic event. Amount of such stress is different amongst male and females [5].

Stress is a type of physio-psychological pain [6], [7]. Stress is beneficial and, in a way necessary if level of stress is small. It works as catalyzing agent for improving performance or inclination towards
work. It helps in improving adaptability and mode of reaction to the situation [8]. However, stress beyond certain level can be detrimental to human body [9], causing higher probability of stroke, heart attack, and psychological disorders.

For a person suffering from stress, pharmacological therapeutic treatments although mainstay is not enough in many cases. Life skill trainers and psychologists help such people in coming out of the detrimental effects of stress to a large extent. But, the process of destressing is very slow and requires long term monitoring.

One of the ways to do so is monitoring Electrodermal Activities (EDA) and body temperature. EDA and body temperature both are direct outcome of disturbed homeostasis. Many researchers have already shown that EDA shows variations due to emotional stimuli as well as muscular stress.

Resistance/conductance of skin is controlled by subconscious part of our brain. The skin impedance is controlled by sympathetic nerve system (SNS) activity [10] [11] triggering eccrine sweat glands. The baseline value of skin resistance/conductance (basal skin resistance/conductance) varies person to person as well as time to time depending upon the average sweat gland activity and ambient conditions (temperature and humidity). But the deviation (d/dt) in the baseline value of skin resistance/conductance (galvanic skin resistance/conductance) reflects the emotional activity of a person. Sympathetic nerve system drives human behavior and emotional states at a subconscious level. Hence, skin impedance (EDA) may be considered as an indicator of emotional stimuli or physical stress [11]. The relationship between skin sympathetic nerve activity and electrodermal responses is complex [12], [13], and is highly influenced by body temperature [14].

2. MATERIALS AND METHODS

2.1. Body Temperature Measurement

Normal temperature of human body is 98.6oF/37.0oC and is controlled by thermoregulatory center in hypothalamus [15], [16]. Any deviation from this normal condition represents some psycho-physiological event that disturbs the homeostasis. Although the normal temperature is not the same for every one and same for all days, its deviation is a parameter of high medical importance.

![LMT70 Temperature sensing circuit](image)

Figure 1. LMT70 Temperature sensing circuit

Even after considering the mass of population having sign of hypothermia (lower body temperature) as well as hyperthermia (higher body temperature) the range of temperature measurement is restricted to 25°C-45°C. Therefore, the temperature sensor working in range 0-50°C is sufficient,
provided it measures temperature to accuracy of 1 decimal point of °C. We have used LMT70 RTD based precision temperature sensor with negative temperature coefficient, here. The sensor has operating voltage (2.0V-5.5V), low operating current (typically 9.2µA), wide measurement range of temperature (-55°C -150°C) and typical accuracy of measurement (±0.05°C for 20°C - 42°C) [17]. The mentioned specifications are fitting our requirement of low voltage and power operation as well as desired accuracy in the operational range. The circuit diagram for temperature sensor is shown in Fig.1 below.

The sensor as well as the signal conditioning circuit designed around LM358 (low power, low voltage rail-to-rail dual amplifier) is fed power from Arduino D5 to avoid power dissipation during non-sampling time. This mechanism energizes the circuit only for 50 milliseconds every time temperature is to be sensed and logged.

2.2. Electrodermal Activity Measurement
The electrodermal activity is deviation in skin impedance due to psycho-physiological events leading to excitation on eccrine sweat glands. Eccrine glands are present all over the body, but the density of eccrine sweat glands is maximum (2-5 times more) in glabrous (non-hairy) skin i.e. palm and sole (250–550 glands/cm²) [18] compared to non-glabrous skin. Again, the eccrine glands over non-glabrous skin are primarily responsible for thermoregulation, while those over glabrous skin respond mostly to emotional or thermal stimuli [19]. Baseline value of skin resistance/conductance may be different for different persons, but deviation in baseline values defines EDA.

Skin resistance/conductance is measured by simply measuring the relation between voltage-current passing through two electrodes placed approximately 2 inches apart on palm or on two fingers. Schematic of the circuit yielding Galvanic Skin Resistance/conductance is shown in Fig. 2. The circuit is designed around LM358 in two stages. First stage is a bandpass filter. Component values selected affirm passband of 0.5-5 Hz. This arrangement ensures deviation in skin resistance/conductance from baseline value.

2.3. Data acquisition system
The analog signals representing body temperature and EDA are conditioned and processed by the circuitry shown in Fig.1 and Fig.2 respectively. These values are recorded on a microSD card using a
data acquisition system designed using Arduino mini pro. Arduino mini pro is Atmega328 (8-bit microcontroller) based development board operating on 3.3V at 8MHz. Data acquisition system here is expected to perform following tasks:

1. To convert analog inputs from temperature and EDA sensing circuit modules.
2. To sample the analog quantities periodically at an interval of 1 second, if no significant EDA or deviation in body temperature is recorded.
3. If significant EDA or deviation in body temperature is recorded, the sampling rate will be increased to 100Hz for next 5 minutes.
4. The sampled data to be stored with timestamp in CSV (comma separated value) format on interfaced microSD card.

In order, to accomplish the tasks enlisted, the Arduino mini pro is interfaced with an RTC module and a microSD card module. Both analog modules fetching body temperature and skin resistance/conductance provide analog outputs. These modules are controlled by D5 pin of Arduino to be energized only when periodic measurement is to be carried out. Outputs from the modules are connected to respectively A0 and A1 pins of Arduino mini pro. A detailed wiring diagram of the system is shown in Fig.3 below.

![Connection diagram of data acquisition system](image)

**Figure 3.** Connection diagram of data acquisition system

The Arduino mini pro is programmed to execute the following tasks repeatedly:

1. To read timestamp from RTC module
2. To sample temperature and EDA from respective modules and convert them to digital
3. To store the timestamp, temperature and EDA on microSD card
4. To check whether any notable deviation in body temperature or EDA recorded
5. If yes, change sleep time to 10 milliseconds else sleep time is to be set 1 second
6. Finally enter in sleep mode

3. RESULT AND DISCUSSION

The system discussed above was realized and deployed on the author himself (Fig.4). The system was able of data acquisition at desired sampling rate, including higher sampling rate for specific cases. Software for data acquisition was designed such that, is prepares one data file every hour and one separate file for summary storing timestamp when the higher EDA or deviation in body temperature was recorded.
The data stored on the microSD card can be used to generate a plot of body temperature vs. time and EDA vs. time. These plots can yield ease of analysis and help speed up the diagnosis. Plots of body temperature and Skin Conductance (EDA) for some section of time are shown in Fig.4.

![Actual System realized](image_url)

**Figure 4.** Actual System realized

![Plots of tonic skin conductance, phasic skin conductance (EDA) vs. time and body temperature vs. time](image_url)

**Figure 5.** Plots of tonic skin conductance, phasic skin conductance (EDA) vs. time and body temperature vs. time

![Plots of tonic skin conductance, phasic skin conductance (EDA) vs. time and body temperature vs. time under various physio-psychological conditions: a). deep sleep, b). stress and c). excitement](image_url)

**Figure 6.** Plots of tonic skin conductance, phasic skin conductance (EDA) vs. time and body temperature vs. time under various physio-psychological conditions: a). deep sleep, b). stress and c). excitement
The results obtained are quite suitable for the analysis of physio-psychological stress. The plots are for 300 seconds only but actual recording has been carried out for 1 week. Typical plots of tonic skin conductance, phasic skin conductance (EDA) vs. time and body temperature vs. time are shown in Fig.5. Plots reveal various psycho-physiological conditions of the subject. Conditions such as deep sleep, excitation, stress etc. are distinguished easily from the plots. Example plots for such conditions are depicted in Fig.6.

4. CONCLUSION
The system is quite suitable for the physio-psychological stress analysis. Yet the automated analysis is not possible as the deviation in EDA as well as body temperature may be attributed to other physiological reasons apart from stress like illness, fever, etc. This mandates that the information recorded must be analyzed by medical personnel before reaching to any conclusion.

The system is quite reliable and performs its task quite accurately. The system is small enough to fit in a small cigarette case and weighs approximately 150gm including battery making it easily wearable. The system is quite cost effective too. Its applicability from medical point of view is to be certified by competent authority.

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