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Design of Safety Head Gear using Electrical Sensors

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Abstract: This paper presents a prototype of digital safety helmet equipped with environmental sensorsand voltage sensor that helps to measure environmental conditions and display it real time onthe display attached within the helmet. This gives workers real time information about the any environmental situation they are in. This will not only improve the safety of the workers but also helps to improve work ethics thereby improving overall productivity.

Index Terms – Helmet, Sensors.

I INTRODUCTION:

We all know safety is one the most important aspects of any industry. safety equipment is specifically designed to help workers from getting harm that could even escalate to severe health risk or even to death. By using safety equipment workers could eliminate most of such issues. As most industries adapted to use such safety equipment, the safety of our work environment increased significantly.

But as the standers improve, we could integrate modern technology into our safety devices which will further help to improve the safety of the workers. By wearing the appropriate safetyequipment, workers can decrease the number of preventable accidents that occur on jobsites every year.

Our goal is to provide safe work place by providing better safety equipment for workers that could potentially save thousands of lives. we managed to upgrade existing head protection gearby adding sensors and other electronic devices in order to monitor the environmental conditionssuch as temperature and air quality they are working in. It is also equipped with voltage sensingdevice that can be used to measure voltage without carrying an extra device or without even have to move or fiddle around so the workers can concentrate on what they are doing without sacrificing the safety.

Types of Personal Protective Equipment

Some of the different types of personal protective equipment that can be worn to help protectagainst workplace safety risks include:

Head Protection

Head protection, such as hard hats, are specifically designed to protect your head from fallingobjects like equipment or material that could otherwise impact or penetrate you. While the most basic types of hard hats only cover your head, some hard hats can easily be equipped with extra protection, such as face shields or earmuffs. When selecting the appropriate head protection for your jobsite, make sure that the hard hat fits snuggly on your head.

Eye and Face Protection

In addition to wearing head protection, workers should also take precautions for keeping theireyes and face safe. Consider using products like full-face shields to protect your face from flying debris or safety goggles to protect your eyes when working with metal, wood, or hot temperatures.

Respiratory Protection

Wearing the proper respiratory protection can be vital in keeping your lungs in good workingcondition, especially if you are working on a jobsite with toxic substances present.
Respirators are specifically designed to protect you from paint spray and dust, as well as fromdangerous substances, such as pesticides, fumes, and other hazardous contaminants.

Hand & Skin Protection

Since the majority of work completed on a jobsite is done by hand, wearing gloves can be anessential part of providing proper hand and skin protection. Wearing gloves in the workplacecan help you avoid hazards involved in working with chemicals, glass, sheet metal, electricity, hot materials, or slippery objects.

Hearing Protection

Workers exposed to a lot of noise in the workplace should consider wearing hearing protection, such as earplugs or earmuffs, to help prevent hearing loss. When selecting the right type of hearing protection for your particular needs, it is important to note that earmuffsare more effective at reducing high-frequency noises and earplugs are more effective at reducing low-frequency noises.

Major challenges

According to international labor organization, 4,80,000 people die each year due to work related hazards in India. India with 1.25 billion population has a strong workforce of 465 million. However only 20% are covered under the existing health and safety legal framework.It is a real challenge to implement proper safety equipment on jobsites especially in India dueto lack of adequate manpower.
Safety should be considered a priority in every worksite. Accidents on the worksite can beavoided if everyone in the company is aware of the common worksite safety issues. Everybusiness has common safety standards and rarely are they all addressed. One way to avoidthis problem would be to make sure that all issues are identified and proper intervention isdiscussed.

The largest and loudest dangers rarely cause most injuries. That's because workers are safest when they're focused on the hazard, and hazard awareness is highest during complex tasks orwhen the risks are obvious.

However, workers who've been on sites for many years are prone to becoming desensitizedto smaller, ongoing, but very real hazards. Workers underestimate their chances of getting hurt performing the activities they've gotten used to carrying out on a regular basis. Being exposed to risk every day instills a belief in many workers that they're invulnerable. That canlead workers to stop thinking about the risk and that's precisely when an accident is most likely to occur.

Historical aspects

People have used personal protective equipment from at least as far back as the Middle Ages when blacksmiths wore protective hand gear and aprons or shields to keep from being burnedby the molten metal they were working with. Head gear such as hard hats protected some factory workers, miners and construction workers from objects falling on an individual's head. In many cases, the use of such PPE was considered optional and there weren't mandatory regulations for workers' protection until the advent of the Occupational Safety andhealth Administration, which stemmed from the Occupational Safety and Health Act of 1970.

Personal protective equipment (PPE) is an all-encompassing term that includes gear worn byfirefighters, soldiers, chemists, factory workers, miners, construction workers and police officers (among others), who wear in order for them to safely do their job or operate in a certain capacity safely. In theory, every time a motorcyclist dons a motorcycle helmet, he or she is putting on personal protective gear. The two major industries utilizing personal protective gear are the military and many employment industries.

a. Headgear history

One of the first things one thinks of with the word "headgear" as personal protective equipment is the hard hat. The first company to create hard hats was the Bullard Manufacturing Company, which first began manufacturing industrial head protection in the late 1800s. Prior to that time, hard hats and protective headgear did not exist. Even fifty yearsago, protective headgear as considered optional for workers.

Established in 1898, Bullard sold primarily to miners. The hat was similar to a baseball cap and was made out of hard leather with a shellac brim. The sales of hats continued past WWIat which time the hat was called the "hard-boiled hat" because of the use of steam in the manufacturing process. The Hard-boiled Hat was patented in 1919 and was made out of steamed canvas, glue and black paint.

The first designated hard hat area was created at the time of the building of the San FranciscoGolden Gate Bridge. It was created due to the presence of multiple falling rivets from the bridge which had the potential to injure workers.

In 1938, Bullard designed and created the first aluminum hard hat, considered light weight and extremely durable. The major drawback of aluminum hard hats was that such a hat was agreat conductor of electricity.

A heat-resistant fiberglass hard hat was created in the 1940's; thermoplastics replaced the more expensive hard hat in the 1950's and 60's. Thermoplastics were injected into a mold toproduce a molded hard hat.

The modern-day standard hard hat was designed in 1982. It was created because prior versions of hard hats didn't have adequate suspension. One of the most recent hard hats out ofBullard was named the 3000 R and was made from polyethylene plastic. It was lightweight, durable, moldable and non-conductive to electricity. It became the predecessor to the C30 or the standard yellow hard hat one sees at construction zones. The newest hard hats are vented as the original ones were declared to be too hot and uncomfortable.

Firefighting helmets were initially made from thick leather. They, too, evolved to become helmets of a very light weight at 25 ounces. Such helmets offer a crown pad, a soft replaceable vinyl brow pad and a limited rear brim, which limits head movement to a lesserdegree than the original brimmed hats.

Appropriate headgear

Protective headgear is an item worn by an individual which provides protection to the wearer's head or part of their head. It may or may not provide facial protection. They aredesigned to protect an individual from any one of the following hazards:

- Physical danger
- Environmental danger
- Chemical hazard
- Biological hazard
- Thermal danger
- Electrical hazards

Helmets are generally made of hard plastic materials and composites. The usual materialswith which helmets are currently made are:

- Nylon
- High density polyurethane
- Fiberglass
- Vulcanized rubber
- Polycarbonate
- Aluminum

The visors, if attached, are made from Nylon, Lexan, Steel mesh or materials which are specially gold-coated against the hazards of radiant heat. Some of the materials from whichhelmets are made are themselves heat and flame resistant.

Smart Technology PPE Improving Worker Safety

Managers across many fields seek safer equipment for workers in dangerous environments.Jobs in emergency management, firefighting, construction, oil and gas, manufacturing, andmining all require personal protective equipment (PPE).

Managers who make safety a priority continually seek the most efficient solutions to comply with and exceed the requirements of Occupational Health and Safety Administration (OSHA)regulations. Advances in smart technology are creating new ways to protect workers by enhancing PPE. Smart devices can respond to both the body of the worker and the environment to deliver crucial information to both the worker and, often, the supervisor.

What are the Benefits of Smart PPE?

Smart PPE refers to wearable pieces of equipment, such as helmets, that connect to the internet or Bluetooth and deliver safety information to the wearer or others in the field. Thesewearables collect data, adjust to conditions, and warn of hazards.

Bluetooth allows smart PPE to gather data and connect to other devices in real time, oftenusing software that integrates the information from various PPE wearables

Chips in Smart Tech Helmets Protect Workers

Smart PPE allows supervisors to track the location of their workers on large work sites in realtime if the workers wear smart tech helmets that include GPS chips.

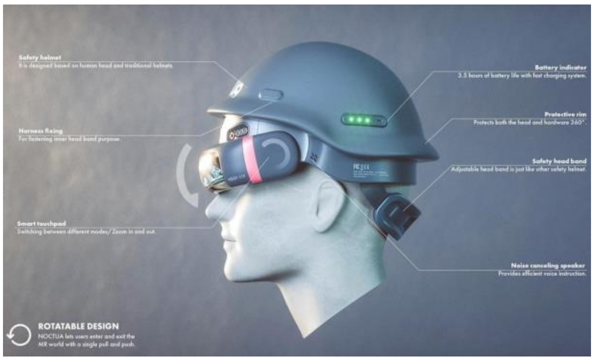

Fig 1: concept

Smart helmets use meta sensors to evaluate information and protect wearers. Smart helmets detect impact, free falls, temperature, humidity, brightness, and more. Business owners can program the chips in smart helmets many ways to improve safety. They can insert GPS tracking systems to map workers' location on large construction sites or at sparsely populatedoil refineries. Helmets can also be programmed to warn wearers if they are close to hazards with an alarm. This location information can help prevent accidents. In addition to helmets, other wearable pieces of smart tech offer additional benefits.

II.LITERATURE REVIEW

Following works are carried out by specific persons in the area of digital safety helmets

N M. Rensing, E. Weststrate, P. M. Zavracky, M. Chandler, K. R. Nobel,

S. Helfter, M. Kinsky, M. Gold & B. Martin[1]

The application of wearable computer systems to threat response, exemplified by the Multi- functional Micro-controllable Interface Module (MMIM)/Digital Military Policeman (DMP)system. The system consists of a wearable computer, eyewear interface developed by MicroOptical comprising display, camera, and audio, and software incorporating the FaceIt face recognition algorithms developed by Identix (formerly, Visionics). This system will enhance gate security at military installations by enabling guards to use automated face recognition to verify the identity of visitors and check the database of known threatening individuals automatically.

Gerald Pirkl, Peter Hevesi & Paul Lukowicz[2]

A wearable sensor system which supports construction site workers in work documentation, and access to digital information. In a standard safety helmet self-localization (IMU and LIDAR), room dimension estimation (LIDAR) and material detection (ultrasound) have beenintegrated. A combination of IR cameras retrieves temperature scans of the environment usable for leak detection and isolation checks. The camera, together with a head mounted display also supports a head movement-controlled picture-based documentation.

Brian Mullins[3]

Workplace safety is a key area that the helmet has been designed to address. "It replaces the necessity to carry auxiliary tools like tablets, books, digital cameras, laptops etc. These types of hand-carried equipment can be dangerous when a worker is performing a task at high altitudes. By having access to this information in a visual space, workers can have their handsfree to perform operations or maintain balance,"

Mayur Panchal[4]

The Smart Hard Hat has been furnished with a temperature sensor and heart rate monitor sensor to keep updated the worker with his health. By chance, if some worker finds anythingthat needs to be addressed, then this smart sensor will provide him accurate results and avoidmajor health problems. Apart from that, the SOS (Save our Soul) panic button will instantly send a signal to top level authorities about your condition, so any major health accident canbe avoided. So Smart Hard Hat ultimately leads to the trust and productivity of workers.

III .METHOD AND METHODOLOGY

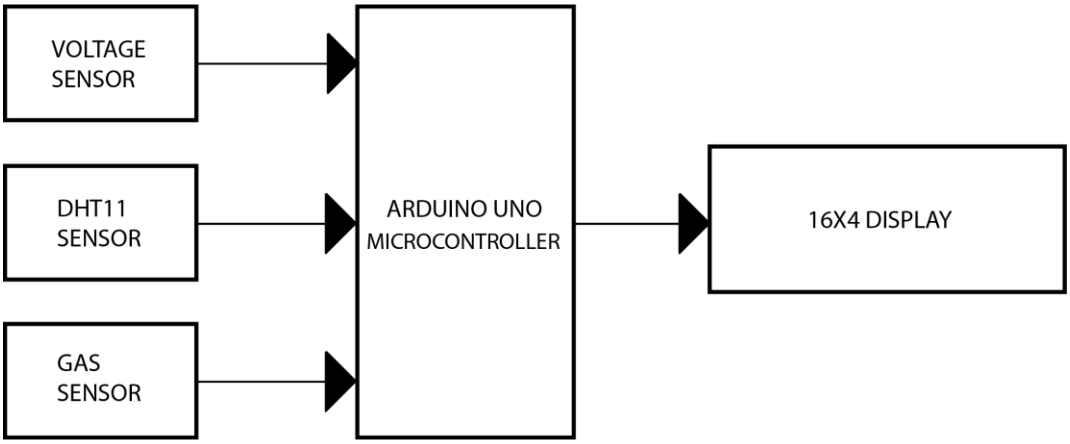

Fig 2: Block diagram

Inputs from the voltage sensor, humidity-temperature sensor (DHT11) and gas sensor connected to the inputs of the Arduino uno microcontroller the output from the controller is then connected to the 12c display adapter then connected to the 12x4 display module. Properlibraries are installed and Arduino is coded.

Voltage can be measured using the measuring probes attached to the helmet and can be readout using the display. Data from the DHT11 sensors are converted to appropriate units (degree and percentage). Data from the gas sensor is converted to graphs for easy understanding.

Hardware Requirement

a. Arduino Uno

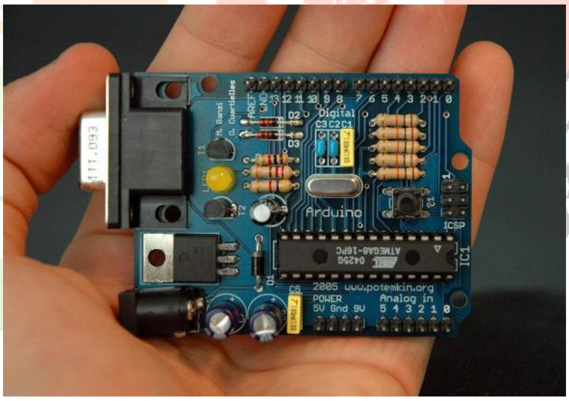

Fig 3: Arduino uno

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with setsof digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable orby an external 9-volt battery,

The Voltage Sensor is a simple module that can used with Arduino (or any other microcontroller with input tolerance of 5V) to measure external voltages that are greater thanits maximum acceptable value i.e., 5V in case of Arduino.

b. Voltage Sensor

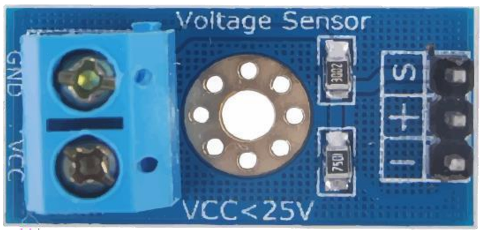

Fig 3: voltage sensor

The Arduino range of microcontrollers provides analog inputs that can be used to measurevoltage. We can use this to build a voltmeter. The analog Read function reads the voltageand converts it to a number between 0 and 1023.

The Voltage Sensor is basically a Voltage Divider consisting of two resistors with resistancesof 30KΩ and 7.5KΩ i.e., a 5 to 1 voltage divider.

Since the Voltage Sensor module is basically a voltage divider circuit, you can calculate inputvoltage using the formula

Vin = Vout * (R2/(R1+R2))

Here R1 = 30000, R2 = 7500 and Vout can be calculated from Analog Input of Arduino byusing Vout = (analog value * 5 / 1024).

c. Gas Sensor

A Typical human nose has 400 types of scent receptors enabling us to smell about 1 trillion different odors. But still, many of us do not have the capacity to identify the type orconcentration of gas present in our atmosphere. This is where Sensors comes in, there are manytypes of sensors to measure different parameters and a Gas sensor is one which comes handy in applications where we have to detect the variation in the concentration of toxic gases in orderto maintain the system safe and avoid/caution any unexpected threats. There are various gas sensors to detect gases like oxygen, Carbon Dioxide, Nitrogen, methane etc. They can also becommonly found in devices that are used to detect the leakage of the harmful gases, monitor the air quality in industries and offices etc. There are many types of Gas sensors but the MQ type gas sensors are commonly used and widely popular.

A gas sensor is a device which detects the presence or concentration of gases in the atmosphere.Based on the concentration of the

Fig 4: gas sensor

gas sensor produces a corresponding potential differenceby changing the resistance of the material inside the sensor, which can be measured as output voltage. Based on this voltage value the type and concentration of the gas can be estimated.Sensor could detect depends on the sensing material present inside the sensor. Normally these sensors are available as modules with comparators. These comparators can be set for a particular threshold value of gas concentration. When the concentration of the gas exceeds thisthreshold, the digital pin goes high. The analog pin can be used to measure the concentration of the gas.

The most commonly used gas sensor is the Metal oxide semiconductor-based gas sensor. All Gas sensors will consist of a sensing element which comprises of the following parts.

1. Gas sensing layer
2. Heater Coil
3. Electrode line
4. Tubular ceramic
5. Electrode

The ability of a Gas sensor to detect gases depends on the chemiresister to conduct current. The most commonly used chemiresistor is Tin Dioxide (SnO2) which is an n-type semiconductor that has free electrons (also called as donor). Normally the atmosphere will contain more oxygen than combustible gases. The oxygen particles attract the free electrons present in SnO2 which pushes them to the surface of the SnO2. As there are no free electrons available output current will be zero.

When the sensor is placed in the toxic or combustible gases environment, this reducing gas reacts with the adsorbed oxygen particles and breaks the chemical bond between oxygen and free electrons thus releasing the free electrons. As the free electrons are back to its initial position they can now conduct current, this conduction will be proportional the amount of free electrons available in SnO2, if the gas is highly toxic more free electrons will be available.

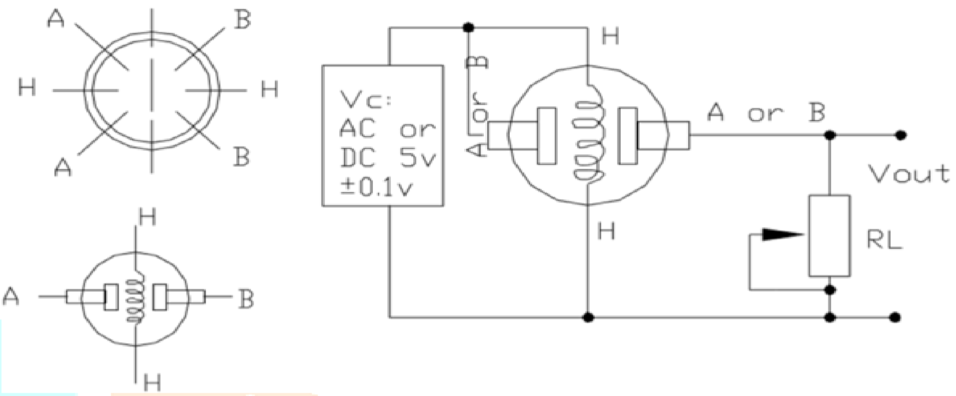

Fig 5: block diagram-gas sensor

Here A and B are the input and output terminals and H is the Heater coil terminal. The purposeof the variable resistor is to adjust the output voltage and to maintain high sensitivity.

If no input voltage is applied to the heater coil, then the output current will be very less (whichis negligible or approximately 0). When sufficient voltage is applied to the input terminal andheater coil, the sensing layer wakes up and is ready to sense any combustible gases nearby it. Initially let's assume that there is no toxic gas near the sensor, so the resistance of the layer doesn't change and the output current and voltage are also unchanged and are negligible (approximately 0).

Now let's assume that there is some toxic gas nearby. As the heater coil is pre-heated it is noweasy to detect any combustible gases. When the sensing layer interacts with the gases, the resistance of the material varies and the current flowing through the circuit also varies. This change in variation can be then observed at the load resistance (RL).

The value of load resistance (RL) can be anywhere from 10KΩ to 47KΩ. The exact value of the load resistance can be selected by calibrating with the known concentration of the gas. If low load resistance is selected then the circuit has less sensitivity and if high load resistance isselected then the circuit has high sensitivity.

d. DHT11 Sensor

DHT11 is a low-cost digital sensor for sensing temperature and humidity. This sensor can beeasily interfaced with any micro-controller such as Arduino, Raspberry Pi etc. to measure humidity and temperature instantaneously.

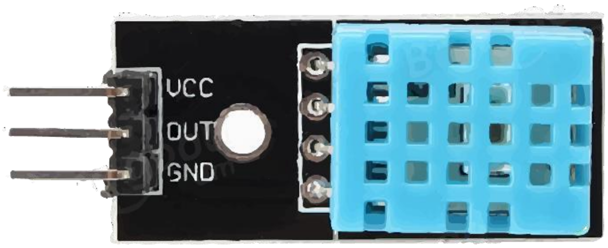

Fig 6: dht11 sensor

DHT11 sensor consists of a capacitive humidity sensing element and a thermistor for sensing temperature. The humidity sensing capacitor has two electrodes with a moisture holding substrate as a dielectric between them. Change in the capacitance value occurs with the changein humidity levels. The IC measure, process this changed resistance values and change them into digital form.

The temperature range of DHT11 is from 0 to 50 degree Celsius with a 2-degree accuracy. Humidity range of this sensor is from 20 to 80% with 5% accuracy. The sampling rate of this sensor is 1Hz. i.e., it gives one reading for every second. DHT11 is small in size with operatingvoltage from 3 to 5 volts. The maximum current used while measuring is 2.5mA.

The DHT11 Sensor is factory calibrated and outputs serial data and hence it is highly easy to set it up. The connection diagram for this sensor is shown below.

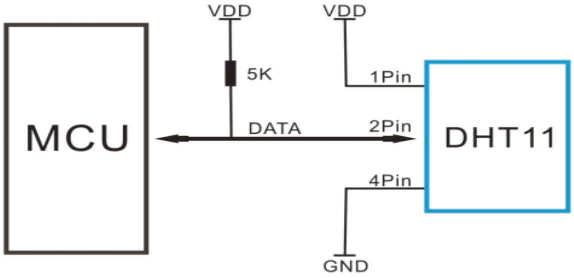

Fig 7: block diagram-dht11 sensor

e. Safety work helmet

Fig 8: work helmet

f. Display holder

Fig 9: display holder

A smart phone holder is repurposed and used as Arduino 16x4 display holder by slightstructural modification and attaching it directly on to the helmet.

g. I2c LCD Adapter Module

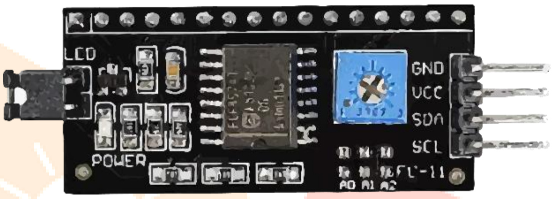

Fig 10: i2c module

I2C Module has an inbuilt PCF8574 I2C chip that converts I2C serial data to parallel data forthe LCD display. These modules are currently supplied with a default I2C address of either 0x27 or 0x3F. The module has a contrast adjustment pot on the underside of the display. Thismay require adjusting for the screen to display text correctly.

- Operating Voltage: 5V
- Backlight and Contrast is adjusted by potentiometer
- Serial I2C control of LCD display using PCF8574
- Come with 2 IIC interface, which can be connected by Dupont Line or IIC dedicatedcable
- Compatible for 16x2, 20x4, 16x4 LCDs
- With this I2C interface module, you will be able to realize data display via only 2wires.

h. LCD Display 16x4

Fig 11: display

The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones,calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations, etc

- The operating voltage of this LCD is 4.7V-5.3V
- It includes four rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight
- Every character can be built with a 5×8-pixel box
- The alphanumeric LCDs alphabets & numbers
- Is display can work on two modes like 4-bit & 8-bit
- These are obtainable in Blue & Green Backlight
- It displays a few custom generated characters

i. Voltage measuring probes

Fig 12: voltage measuring probes

Voltage measuring probe is a one-meter-long wire with pins attached to its end used to measure voltages/current by attaching it to the multimeter. Here this probe is connected to thevoltage sensor which is secured inside the helmet along with microcontroller and other sensors.

IV.RESULTS AND DISCUSSIONS

The equipment is tested to detect harmful chemicals & combustible gas. It can show the userreal time environmental conditions such as temperature and humidity which is important forensuring the safety of the worker and could avoid skin burns or potential death.

This device is also equipped with voltage measuring sensors so that the workers can ensure ifthere is any possibility of getting shock by some accident or it could be used as real time voltage measuring device depending up on the industry.

CONSTRUCTION

Initially all the sensors which includes voltage sensor, gas sensor and temperature sensors areconnected to Arduino to its appropriate pins as shown in picture below.

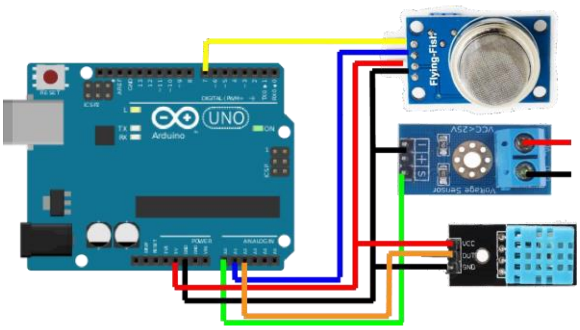

Fig 13: sensor assembly

Arduino is powered on through an external USB power source 5v & 2.5A. A 16x4 LCD display is connected to a 12c display adapter then the adapter is connected to the Arduinopins as shown in the image below.

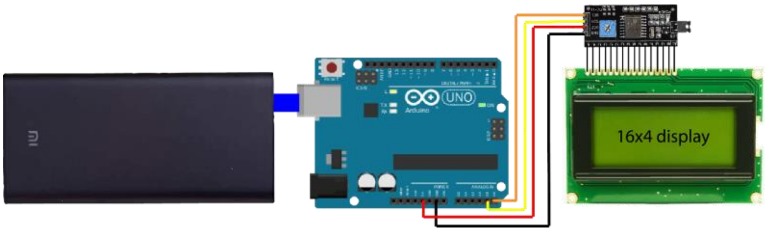

Fig 14: display assembly

Proper libraries are installed and coded the Arduino. Now everything is assembled inside a work safety helmet using appropriate adhesion techniques. Since human eye needs at least 15-25 cm for proper vision, display have to be set up at least 25 cm away from the eyes, (thiscan be resolved by using proper concave lens in front of the display) so a repurposed mobile holder is used to attach the display as shown below.

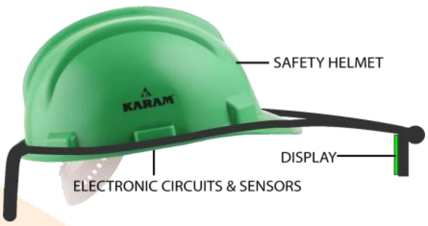

Fig 15: electronics assembled inside work helmet

Voltage measuring pen probe is then attached along both sides of the helmet which is thenconnected to voltage measuring sensor that is secured inside the helmet. This measuring probe is used to measure voltage by attaching its end to an electronic circuit or devices.

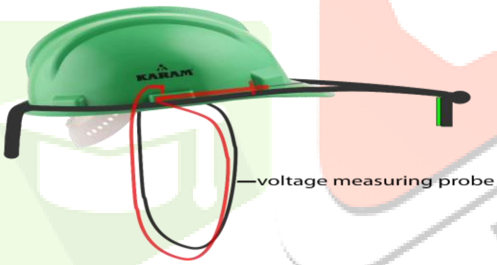

Fig 16: electronics assembled inside work helmet

a. Applicable only on selected industries

Though safety helmets are used in almost all industries, this device can only be used in specific niche industries where the workers are exposed to harmful chemicals, extreme temperature / humid environment or if the workers are at risk of getting shock because ofclose contact with electronic devices where built-in voltmeter will come in handy.

b. Battery

Build in battery works great for wireless operations but this means we have to constantly check, recharge/replace batteries to make sure it is operable. Exposing battery to high temperature risks overheating battery that could even lead to explosion in extreme scenario.

c. No proper weather proofing

There is no proper water proofing which means it could damage when exposed to moistureand no proper heat shield means it could over heat while exposed to high temperature.

V. CONCLUSION

Safety is quintessential in every aspect of life including the workplace. As per the NationalSafety Council, a worker is injured at their workplace every 7th second. So proper safety features at the workplace can help save numerous lives. Therefore, taking proper safety precautions before taking on any task which includes risks to physical safety. Adding moresafety features on existing safety devices will only ensure more safety and could help to eliminate many potential accidents.

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2.Gerald Pirkl, Peter Hevesi & Paul Lukowicz - A wearable sensor system which supports construction site workers in work documentation, and access to digital information

3.Brian Mullins - founder and CEO of DAQRI, a Los Angeles-based enterprise augmentedreality company. Workplace safety is a key area that the helmet has been designed to address.

4.Mayur Panchalb - The Smart Hard Hat has been furnished with a temperature sensorand heart rate monitor sensor to keep updated the worker with his health.