INVESTIGATION OF CONTINUOUS HUMAN WEIGHT MONITORING BASED ON OPTICAL FIBER SENSOR

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ABSTRAK

Measuring weight help to show the growth process for health monitoring. It is crucial to get an accurate value to determine the actual weight of human without any external load. The aim of measuring human weight is to access and monitor fluid nutrition status and monitor the effectiveness of nutritional support for the ideal body weight. There are many existing sensors type in market place used for determine the weight. However, it have many external factors interfering with the accuracy and the cost. Sometimes, it require the huge size to perform the accuracy and high cost. Currently, most of sensors are not water resistance which can affected the weighing system.the aim of this study is to study and develop a potentially low cost weightage sensor based on optical sensor using intensity modulation technique and the effect of different weight load on the optical fiber gap between the input and output fibers. An incident beam will travel between two optical fibers with a 2mm gap and it will be detected by photodetector and produce an output voltage. Data were collected from the several subject with different load. The measured value will slightly difference from the real value using the accuracy formula to obtain the lowest value of error when experiment is run. Two optical fiber are placed in parallel with each other, where light source and photodetectors are placed at respective ends of optical fiber. A type of cylinder with measurand is used as a tank or reservoir for sample, where a hole is made at each side fitting the fiber. Intensity-modulation proves to be an easy method to analyse as the output of the system is in voltage. Variation in output voltage signals the changes of light intensity at the receiving fiber undergone through the measurand. System can detect changes in load applied. In the future, sensor measurements for this method would be used to develop an advanced monitoring system where it is fully autonomous reducing the manpower needed.

ABSTRACT

Mengukur berat membantu menunjukkan proses pertumbuhan untuk pemantauan kesihatan. Ianya adalah penting untuk mendapatkan nilai yang tepat untuk menentukan berat sebenar manusia tanpa sebarang beban luaran. Tujuan mengukur berat badan manusia adalah untuk mengakses dan memantau status cecair nutrisi dan memantau keberkesanan nutrisi makanan untuk berat badan yang ideal. Terdapat banyak jenis peranti sedia ada di pasaran berfungsi untuk menentukan berat. Walau bagaimanapun, ia mempunyai banyak faktor luaran yang mengganggu ketepatan dan nilai. Kadangkala, ia memerlukan saiz yang besar untuk mendapatkan nilai yang tepat dan kos yang tinggi. Kini kebanyakan peranti bukan kalis air yang boleh menjejaskan sistem penimbang. Tujuan kajian ini adalah untuk mendalami dan menganalisi peranti pemberat yang rendah kos berdasarkan gentian optik menggunakan teknik modulasi intensiti dan kesan beban berat yang berbeza pada optik.dengan jurang gentian antara gentian kemasukan dan keluaran. Cahaya akan melalui antara dua gentian optik dengan jurang 2mm dan ia akan dikesan oleh pengesan foto dan menghasilkan keluaran didalam unit voltan. Data dikumpul daripada pelbagai subjek dengan beban yang berbeza. Nilai yang diukur akan berbeza sedikit daripada nilai sebenar menggunakan formula ketepatan untuk mendapatkan nilai ralat yang paling rendah semasa eksperimen dijalankan. Dua gentian optik diletakkan dalam selari antara satu sama lain, di mana sumber cahaya dan pengesan cahaya diletakkan di hujung gentian optik masing-masing. Sejenis silinder beserta ukuran digunakan sebagai tangki atau takungan untuk sampel, di mana lubang yang dibuat pada setiap sisi pemasangan gentian. Intensiti modulasi dibuktikan untuk menjadi satu kaedah mudah untuk menganalisis sebagai pengeluaran sistem berada dalam unit voltan. Perubahan dalam voltan pengeluaran isyarat perubahan keamatan cahaya di gentian optik penerima menandakan cahaya telah melalui bahan uji. Sistem boleh mengesan perubahan dalam bentuk tekanan. Pada masa akan datang, sensor ukuran untuk kaedah ini akan digunakan untuk membangunkan maju pemantauan sistem di mana ia adalah autonomi sepenuhnya mengurangkan tenaga kerja manusia yang diperlukan.

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LIST OF SYMBOLS

ΔI	*Change in optical power because of modulation by measurand*
Io	*Optical power reaching the detector when there is no modulation*
P	*Perturbation (measurand) Nanometre*
m	*Normalized modulation index*
%	*Percentage*

LIST OF ABBREVIATIONS

g	*Grams*
kg	*Kilograms*
mm	*Millimetre*
nm	*Nanometre*
V	*Voltage*
R1	*Resistor 1*
R2	*Resistor 2*
R3	*Resistor 3*
R4	*Resistor 4*
MM	*Multimode*
LCD	*Liquid Crystal Display*
LED	*Light Emitting Diode*
LANs	*Local Area Networks*
VCSELs	*Vertical Cavity Emitting Laser*
POF	*Plastic Optical Fiber*
IC	*Integrated Circuit*
IR	*Infrared*
DC	*Direct Current*
AC	*Alternative Current*
IRED	*Infrared Emitting Diode*
IF-E93	*Industrial Fiber Optic Inc*
PWM	*Pulse Width Modulation*
IDE	*Arduino Software*

CHAPTER 1

INTRODUCTION

1.1 Overview

Weighing scales or weighing machines are aim to measuring contraptions for determining the load or mass of an object. Knowingly the weight of an object is generally measured the use of metric units in gram (g) and kilogram (kg) increments. The weighing scale has two primary form for measure and compute the value of mass which is, the mechanical and the digital weighing scales. The mechanical scale functions as rotating dial which shows the weight. The simplicity and sturdiness over a long term has been the largest gain of this device and the primary cause to be used in locations where the device is constantly moved. The digital weighing scale is easy to operate and features a small LCD display where the weight is shown as in the market. The digital weighing scale operates on an extrinsic power supply mainly battery, and the presence of an electronic circuit makes it a very sensitive device. Presently, weighing machines to be had in the marketplace provide additional functions which includes facility to measure height, frame mass index ect in addition to the weight. Further studies are needed to identify optimal ranges of human weight gain using optical fiber to get more accuracy in recorded data.

The optical characteristics of a material can be identified by changes in output voltage when a different weight value is detected which represents the optical parameter. This sensor is practically used in remote sensing applications in this era technologies. The majority of fibre optic sensors are multiplexed over the length of a fibre by measuring the time delay as light passes along the cable or by utilising light wavelength shift for each sensor.

The purpose of this project is to develop an optical-based sensing system to investigate continuous human weight monitoring. The force from human movement of weight is detected based on the principle of intensity changes of transmitted light.

1.2 Problem Statement

In general, the weighing system is comprehensively used in any industrial application and offers a wide variety of application possibilities to fit any needed industrial scales and load cell systems. The first step in obtaining weighing accuracy for weighing system is selecting a top-quality sensor the command errors exist when it comes to weather and environment temperature. Temperature extremes one of the problem that occur in terms of weighing inaccuracies and to prevent these issue, most of load cells fabricated are temperature compensated. Nevertheless, during the weighing cycle for outdoor weight scales, if the weighing equipment experiences significant temperature variations, it can assume how temperature affected the output of the load sensor itself. it occur when the sensor exposed to low night time temperature but quickly heat up in the daytime sun. If the only major difference impacting the weighing system is the difference in temperature between summer and winter, the device can recalibrate the load cells once as the season changes to adjust for any temperature-caused some error.

Other than that, the low-cost sensors tend to lose accuracy and several sensors need huge size to generate high accuracy. The existing weightage sensors require a large shape and width compared to fiber optic sensors that are only up to 62.5mm in diameter and are not water resistant. Therefore, disruption to electronic component can occur. Contrary to that, an optical fiber is waterproof since it is made from glass (silica) or plastic. Therefore, there would be no disturbance arise.

To overcome these problems, measurement based on light intensity is found to be one of the most cost-reliable and simplest mechanisms using optical fiber for monitoring human weight. It can be determined by simulating the changes in output voltage when the input and output gaps of the fiber change based on the force of human weight.

1.3 Research Objective

- To study and develop a potentially low-cost weightage sensor based on optical sensor using intensity modulation technique.

- To study the effect of different weight load on the optical fiber gap between the input and output fiber.

- To test and analysed the sensor performance in a lab-scale environment.

1.4 Scope of Project

The scope of this project is as follows:

- Study the voltage transformation gained when various weight load is collected within 25V for 80 kg maximum for average human weight.
- The experiment is done indoor since it is commonly placed.

1.5 Expected Outcome

- An optical fiber sensor system with hardware and software implementation is designed, and successfully tested on an actual weight load system.
- This optical fiber sensing system can detect changes in voltage across various weight of load
- At the end of this project, this optical fiber sensing system will be able to measure and monitoring the weight of human weightage successfully, with minor acceptable value difference between actual and experimental readings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review will cover the different types of existing sensing systems for the weight properties measurement, focusing on those used for body weight scales. There will also be comparisons between those sensors and optical fibre sensors. This chapter also discusses the fundamentals of fibre optic sensing technologies, such as the many types of optical fibre, sensor modulation techniques, and intensity-based modulation methods.

2.2 Weight Sensor

A load cellular or weight sensor is one type of sensor or known as a transducer. The operating principle of the weight sensor relies upon at the conversion of a load into an electronic signal. The sign can be a change in voltage; modern or frequency primarily based on the load in addition to used circuit. Apparently, this sensor detects adjustments inside a physical stimulus like pressure, stress or weight and produces an output and the result will do the comparative to the physical stimulus. Hence, for a particular stable load or weight length, this sensor offers an output rate and that is comparative to the load's magnitude.

2.2.1 Strain Gauge

The primary objective of a strain gauge is to directly carry out pressure and its version with time, quantitatively. The transpose in pressure is decided through multiplying the measured strain by using the modulus of elasticity. It is one of the substantial sensors used within the geotechnical sector to measure level of stress on any structure like dams, buildings, nuclear plants, tunnels and more. The resistance of a strain gauge varies with implemented force and it converts parameters which includes pressure, strain, tension and weight. into a change in resistance that can be measured afterward.

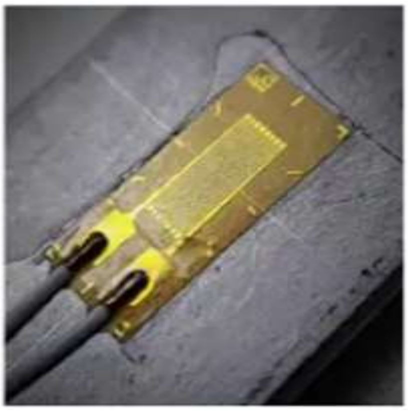

Figure 1: Strain gauge product

In practically, the change inside the strain of an item is a totally small amount that could only be measured using a Wheatstone Bridge. A Wheatstone Bridge is a network of 4 resistors with an excitation voltage, that is carried out throughout the bridge. The Wheatstone Bridge is the electrical equivalent of parallel voltage divider circuits with Rl and R2 as one in all them and R3and R4 as the other one shown in Figure 2 below.

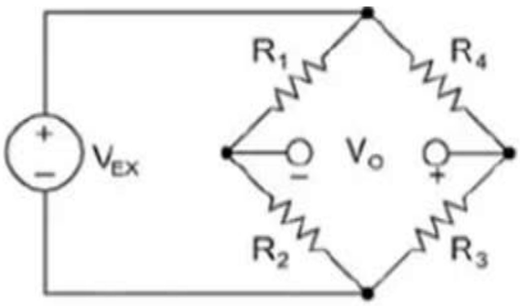

Figure 2: Wheatstone Bridge circuit

2.2.2 Pressure Sensor

An electronic pressure sensor is predicated on a physical response to applied stress, and then measuring the resulting proportional change electronically. Normally used phenomena consist of adjustments in capacitance or modifications in ohmic resistance of a strain gauge or piezoelectric element, which might be proportional to the magnitude of the deflection when stress is implemented. Critical standards inclusive of dimension range, environmental suitability, bodily length, and power requirements will have a substantial guiding impact on engineers carry out a utility particular result.

Piezoresistive sensing elements also can be arranged in a comparable bridge formation. The diagram to the proper illustrates how the sensing elements of a bridge-type stress sensor are connected to a bendy diaphragm, so that resistance modifications in step with the significance of the diaphragm deflection. The overall linearity of the sensor is depending on the stableness of the diaphragm, over the stated dimension range, as well as the linearity of the strain gauges or piezoresistive elements. Notice that, in exercise, piezoresistive factors can be organized in several ways to feel strain, as shown in the Figure 3.

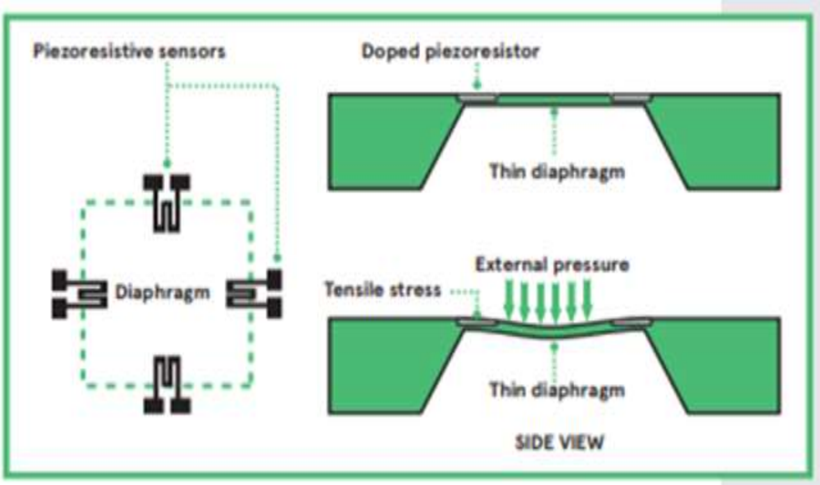

Figure 3: Piezo resistive pressure sensor operating principle

2.2.3 Optical

Considering the fact that pressure gauge and strain sensors are cumbersome, substitute and vague, they may be no longer the satisfactory preference for a weight human sensing system. Optical pressure sensors determine a change in pressure via an effect on light. Inside the best case, this will be a mechanical system that blocks the mild as the stress increases. In extra advanced sensors, the measurement of phase difference that allow very accurate and precise dimension of small strain modifications.

In an intensity-based totally optical pressure sensor, an growth in pressure will effect the source of light to be gradually blocked. The sensor then measures the change in light acquired. as an instance, within the easy mechanism proven below, the pressure moves a diaphragm and the connected opaque vane blocks greater of the light from the

LED. the fall in light intensity is detected through the photodiode and offers an instantaneous measurement of stress.

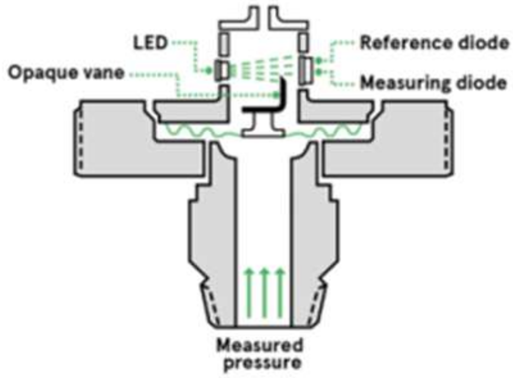

Figure 4: Pressure mechanism

A simple optical sensor like this needs a reference photodiode as shown above, which is never blocked by the vane. This allows the sensor to correct for changes in the light output due to other factors, like aging of the light source, variations in supply voltage. These mechanical systems are relatively large. Much smaller versions can be constructed with a reflective membrane and two optical fibers, one as a source of light and the other to receive the reflected light. Pressure bends the membrane and changes the amount of light reflected back to the detector. Other fiber-optic sensors use interferometry to measure changes in the path length and phase of light caused by changing pressure.

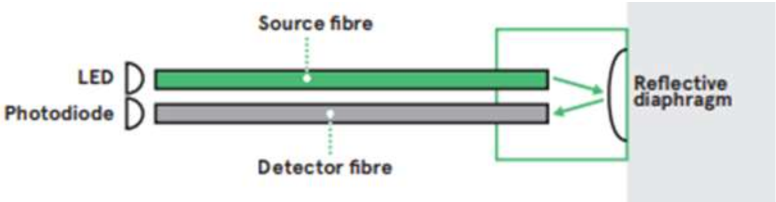

Figure 5: Optical sensor

2.2.4 Sensor Type Comparison

Each sensor type has their own advantages and limitations. Thus, a sensor type has to be chosen carefully depending on the requirements of the application. Table shows the general comparison between the different types of sensing systems for the measurement of weight properties.

Table 1: Comparison between different system types for human weight monitoring

Type	Device	Advantages	Limitation
Weight sensor	Strain gauge	• Accurate • Robust • Low cost	Strain Gauges are non-linear and they require regular calibration to avoid errors in the output readouts.
Pressure sensor	Piezoresistive	• Moderate cost • Good sensitivity • low noise • Simple electronics	• Stiff and frail • Nonlinear response • Hysteresis • Temperature sensitive
Optical	Fibers Optic	• Physically flexible • Sensitive • Fast • No interconnections • Low cost	• Fragile • Power consumption • Complex computations

2.3 Optical Fiber

Optical fibres employ tiny strands of glass or plastic to carry information or data in the form of light. The standard of information includes voice information, data information, computer information, video information, or other types of information The fundamental benefit of optical fibre over other communication mediums is that it can transfer more information over larger distances in less time. Fiber optics also has better bandwidth, less physical infrastructure, and is electrically passive.

In addition, optical fibers are unaffected by the interference of electromagnetic radiation. Fiber optic sensors are capable of measuring a wide variety of parameters to sense some quantities like temperature, pressure, vibrations, displacements, rotations or concentration of chemical species. These optical fibers are currently employed in a variety of applications other than communication, due to advancements in optical fibre technology, including medical, data transport, and industrial applications.

2.3.1 Structure of Fiber Optic

There is a lot of emphasis in the industrial sector on using optical fixer due to its ability to prevent, or at least deter, security intrusions. Optical finer also eliminates some other problems inherent in twisted-pair cable, such as near-end crosstalk (NEXT) and electromagnetic interference (EMI). While fiber optic cable itself is cheaper than an equivalent length of copper cable, fiber optic cable connectors and the equipment needed to install them have typically been more expensive than their copper counterparts. With an increased emphasis on protecting digital information, however, optical fiber has become more cost-competitive over the last few years.

A fiber optic cable consists of five main components: core, cladding, coating, strengthening fibers, and cable jacket. Core is the physical medium that carries optical signals from an associated light source to a receiving device. The core is a single continuous strand of high-purity glass or plastic with a diameter measured in microns (less than the diameter of a human hair). The bigger the core, the more light the cable can carry, which equates to a faster data transfer rate. The higher index of refraction in the core compared to the cladding, causes the effect of total internal reflection to occur, which traps light in the core and allows light to travel along the fiber by bouncing of the core/cladding interface. Coating is a plastic coating over the cladding to reinforce the fiber core, help absorb shocks, and provide extra protection against excessive cable bends. It does not have any effect on the optical waveguide properties, though. The cable jacket functions to protect against abrasion, solvents, and other contaminants. A standard fiber optic structure was depicted in Figure 6.

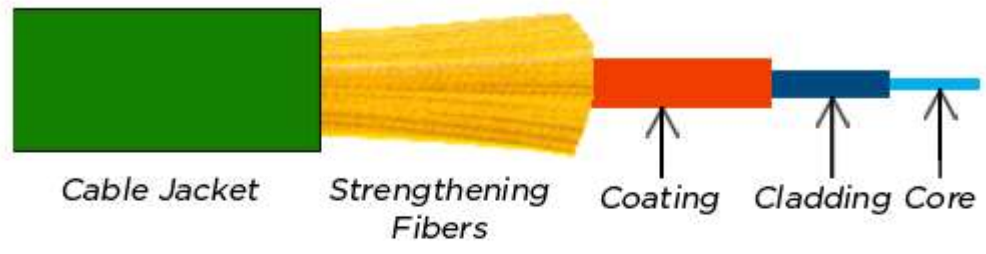

Figure 6: Fiber optic structure

2.3.2 Fiber Type

The two types of fiber are multimode and single mode. Within these categories, fibers are identified by their core composition (MM step-index or graded-index) and core/cladding diameters expressed in microns (one millionth of a meter), for example 50/125 micron graded-index multimode fiber. Most glass fibers are 125 microns in outside diameter - a micron is one one-millionth of a meter and 125 microns is 0.005 inches- a bit larger than the typical human hair.

Multimode fiber has light traveling in the core in many rays, called modes. It has a larger core (almost always 50 or 62.5 microns) which supports the transmission of multiple modes (rays) of light. Multimode is generally used with LED sources at wavelengths of 850 and 1300 nm for slower local area networks (LANs) and lasers at 850 (VCSELs) and 1310 nm (Fabry-Perot lasers) for networks running at gigabits per second or more.

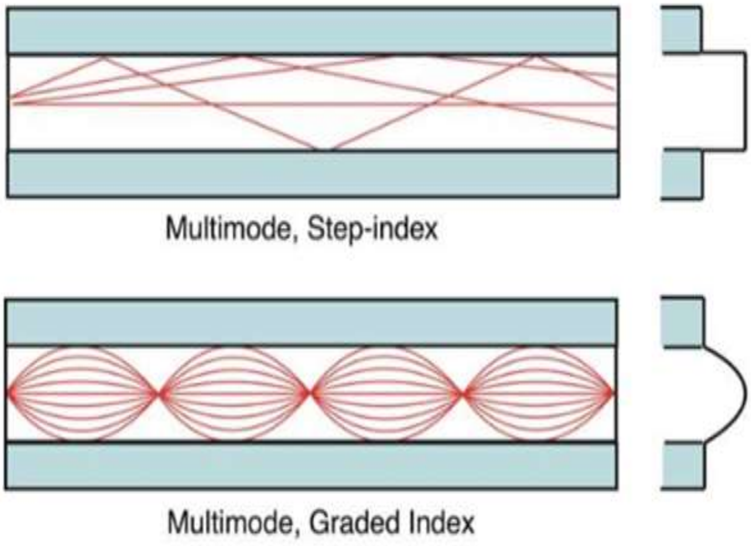

Figure 7: Fiber type for multimode

Figure 8: Fiber type for single mode

While for, Single mode fiber has a much smaller core, only about 9 microns, so that the light travels in only one ray (mode.) It is used for telephony and CATV with laser sources at l3l0 and l550 nm because it has lower loss and virtually infinite bandwidth.

2.3.3 Fiber Sizes and Types

Fiber comes in two types, single mode and multimode. Except for fibers used in specialty applications, single mode fiber can be considered as one size and type. If you deal with long haul telecom or submarine cables, you may have to work with specialty single mode fibers.

Figure 9: Size of fiber optic type

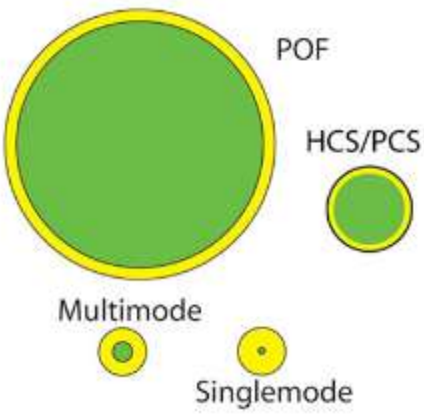

Figure 10: Type of fiber optic

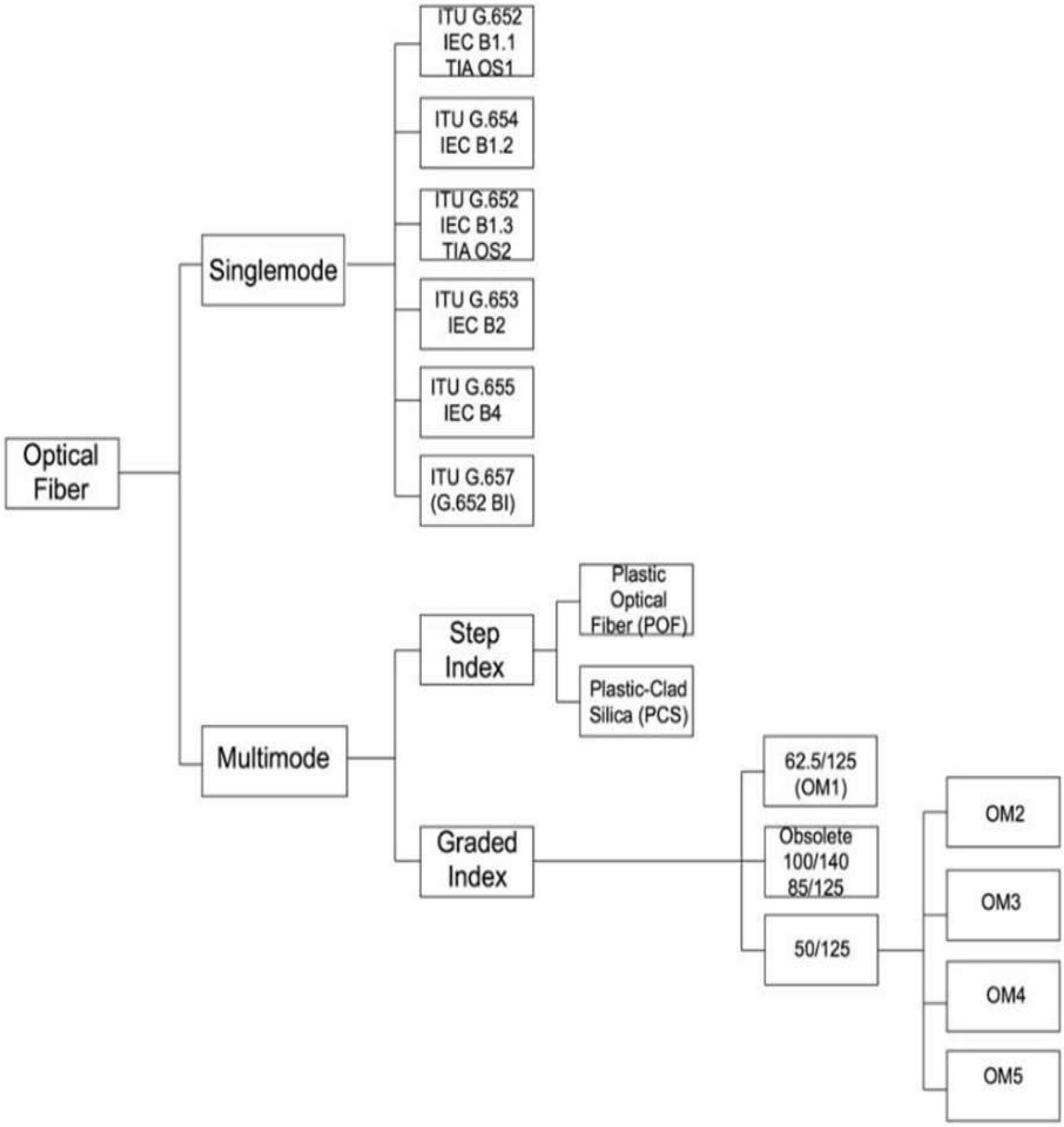

Figure 11: The optical fiber family tree

2.3.4 Fiber Types and Typical Specifications

Table 3: Multimode Graded-Index specifications

Fiber Types and Typical Specifications (OM/OS refers to TIA types, B refers to IEC types, G refers to ITU types)			
Core/Cladding	Attenuation	Bandwidth	Applications/Notes
Multimode Graded-Index			
	@850/1300 nm	@850/1300 nm	
50/125 microns (OM2, G.651.1)	3/1 dB/km	500/500 MHz-km	Laser-rated for GbE LANs
50/125 microns (OM3, G.651.1)	2.5/0.8 dB/km	1500/500 MHz-km	Optimized for 850 nm VCSELs
50/125 microns (OM4, G.651.1)	2.5/0.8 dB/km	3500/500 MHz-km	Optimized for 850 nm VCSELs, higher speed
50/125 microns (OM5)	2.5/0.8 dB/km	3500/500 MHz-km	Wideband MMF, optimized for WDM 850-950 nm VCSELs, higher speed
62.5/125 microns (OM1)	3/1 dB/km	160-200/500 MHz-km	LAN fiber
100/140 microns	3/1 dB/km	150/300 MHz-km	Obsolete

Table 2: Single Graded-Index specifications

Fiber Types and Typical Specifications (OM/OS refers to TIA types, B refers to IEC types, G refers to ITU types)			
Core/Cladding	Attenuation	Bandwidth	Applications/Notes
Multimode Graded-Index			
	@850/1300 nm	@850/1300 nm	
50/125 microns (OM2, G.651.1)	3/1 dB/km	500/500 MHz-km	Laser-rated for GbE LANs
50/125 microns (OM3, G.651.1)	2.5/0.8 dB/km	1500/500 MHz-km	Optimized for 850 nm VCSELs
50/125 microns (OM4, G.651.1)	2.5/0.8 dB/km	3500/500 MHz-km	Optimized for 850 nm VCSELs, higher speed
50/125 microns (OM5)	2.5/0.8 dB/km	3500/500 MHz-km	Wideband MMF, optimized for WDM 850-950 nm VCSELs, higher speed
62.5/125 microns (OM1)	3/1 dB/km	160-200/500 MHz-km	LAN fiber
100/140 microns	3/1 dB/km	150/300 MHz-km	Obsolete
Singlemode			
	@1310/1550 nm*		
9/125 microns (OS1 B1.1 or G.652)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Singlemode fiber, most common for Telco/CATV/high speed LANs. OS1 is a designation of TIA-568 for SM fiber cabled for premises use that has higher attenuation - 1dB/km. All SM fiber appears to be low water peak fiber.
9/125 microns (OS2, B1.2 or G.652)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Low water peak fiber. OS2 is a designation of TIA-568 for SM fiber cabled for outdoor use.
9/125 microns (B2 or G.653)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Dispersion shifted fiber
9/125 microns (B1.2 or G.654)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Cutoff shifted fiber
9/125 microns (B4 or G.655)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Non-zero dispersion shifted fiber
9/125 microns (G.657)	0.4/0.25 dB/km	HIGH! ~100 Terahertz	Bend-insensitive fiber

Table 4: Multimode Step-Index specifications

Multimode Step-Index			
	@850 nm	@850 nm	
200/240 microns	4-6 dB/km	50 MHz-km	Slow LANs & links

Table 5: POF specifications

POF (plastic optical fiber)			
	@ 650 nm	@ 650 nm	
1 mm	~ 1 dB/m	~5 MHz-km	Short Links & Cars

2.3.5 Modulation techniques

Light has several properties that can be measured such as light intensity, phase, frequency, and polarization. Optical fiber sensors detect the changes in one of these light wave properties. Optical fiber sensors can be classified based on the mechanism by which the modulation of light in the fiber is implemented. The modulation type of a sensor is determined based on the light property it senses.

Intensity modulation relies on the modulation of light amplitude. This technique detects the changes in light intensity between the input light source and the output light source. The modification or changes to the light intensity, is caused by the measured operand. Intensity modulated fiber sensors are widely used because of their accuracy, ruggedness, and contactless operation, as well as their simple and low-cost detection system. Phase modulation detects the change in phase of a coherent light wave due to the measured variable. Phase modulated optical fiber sensors are highly sensitive to environmental changes. Therefore, high resolution measurements are attainable. For frequency modulated sensors, the frequency of the light wave is the parameter that is modulated by the measured operand. Frequency modulation allows sensitive detection of moving targets. Polarization modulation detects the state of light polarization due to the influence of physical phenomena.

Intensity modulation is Intensity-based sensors are one of the first types of optical displacement measurement systems to be used. Intensity modulated type sensors are usually the simplest to set up and implement. The sensing system is relatively low cost, while still providing a sufficient accuracy level. The basic configuration of this sensing system consists of a light source, a detector and optical fibers. Optical fibers serve to transmit light from source to detector. Changes in the condition or position of the optical fiber, will cause changes to the light intensity received at the detector. The changes in light intensity are detected and calibrated in terms of the measurement desired such as temperature, pressure or angular displacement. There are various types of intensity modulated techniques such as fiber displacement, reflective, transmission loss, and evanescent.

Fiber displacement technique is where two fibers are placed in series with each other, with the light source at one end of the first fiber, and the detector at the opposite end of the second fiber. light modulation can occur due to displacement or misalignment of one fiber with respect to another. This misalignment can be axial (longitudinal), transverse or angular. For angular displacement measurement, light passing through the joint of two fibers will undergo intensity modulation, when the receiving fiber moves in an angular direction. If there is a change in the position of the second fiber relative to the first fiber at the light source end, the light intensity received at the detector end will be attenuated.

Reflective technique also one of intensity modulation. The system works starting from light beam propagated from an optical source into a transmitting fibre. At the end of the transmitting fibre, the light ray exits the fibre tip into the measurand and reflected by a mirror. The resulting reflected light ray is propagated into the tip of receiving fibre. When the light ray exits the receiving fibre, it is detected by an optical detector; photodiode. The data collected from optical detector is translated into an interpretable data that may be shown on any device. The concept works by the angle of light ray when it comes in contact with measurand; a denser measurand would result in lower intensity of ray on receiving fibre as it bents away from the normal line.

The last intensity sensor is called evanescent field sensors. It involves the phenomenon of frustrated total reflection method. It is reported that the light modulation is based on the frustrated-total-internal reflection effect caused by the variation of refractive index of the surrounding medium and the occurrence of an evanescent field at the fibre-liquid boundary. This approach is applicable for the detection of liquid level and leakage

2.4 Summary

There are many types of load detection and measurement methods that exist for the measurement of human weight. This includes sensors that are used to measure weight A sensing system can be classified by its operation principle such as vision system, or fiber optics. Each sensor type has its own set of advantages and disadvantages. A fiber optics based sensor can be designed using several modulation types, which are light intensity, phase, frequency, and polarization. The proposed optical fiber sensor will be developed to create a sensing system that is immune to electromagnetic interference, robust, and electrically passive. This optical fiber sensor will be based on the principle of light intensity modulation.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology for designing and developing a sensing system for the measurement of human weight, using optical fiber technology. The implementation of this optical fiber based system requires the use of both hardware and software integration. Hardware includes the physical system that generates the input signal, receives the modulated signal, and manipulates the properties of the received signal. The software was then used to interpret the output signal from the hardware side, and present the obtained data in the desired form. Besides that, the experimental setup for the extrinsic optical fiber sensing system is also presented.

3.2 Project Flow

The initial step in completing this research was to undertake literature studies on relevant subjects of interest. The fundamentals and fundamental concepts of fibre optics have been fully explored and comprehended. Furthermore, the different available sensing techniques that make use of fibre optics were researched. Knowledge on the essential topics was gained after comprehensive investigation, allowing us to devise appropriate techniques for carrying out this job. Regarding that, the hardware development step was accomplished but still needed to verify and reconfirm about the structure.

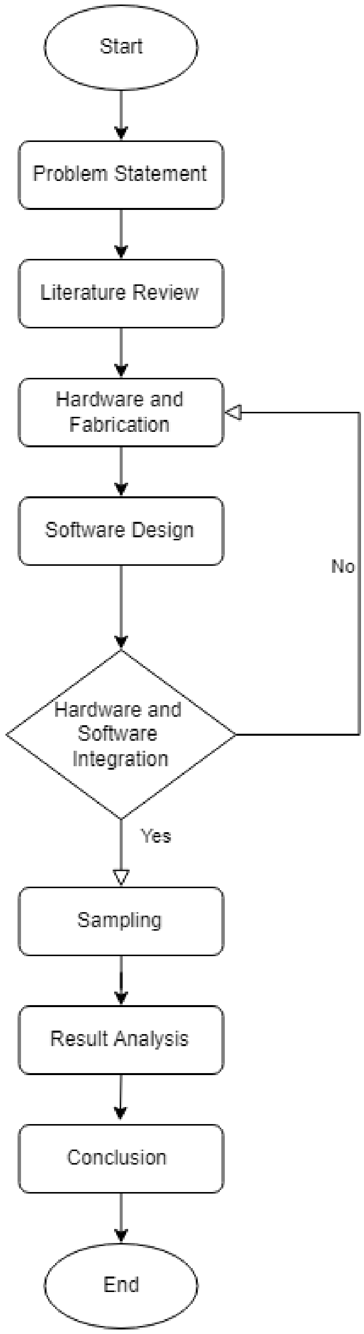

Figure 12: Progress of experiment flow chart

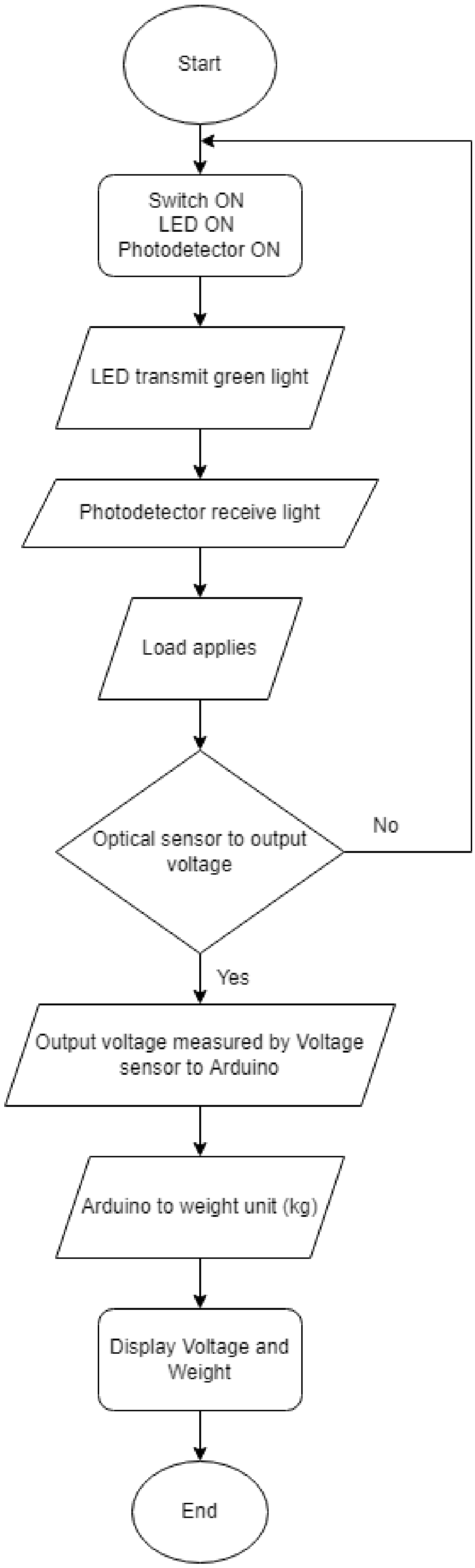

Figure 13: Flowchart of the system

3.3 Operating Principle

Light intensity is modulated when there is an external perturbation between the input and output fiber. The distance spanning across the gap is fixed at 2mm apart. When an external perturbation is applied in the sensing area, light intensity received at output fiber would fluctuates based on material characteristics. The fiber-optic cable that is connected to the amplifier allows the sensor to reach areas inaccessible to standard photoelectric sensors. To obtain a reliable data, both fiber is perpendicular to each other.

Fiber-optic through-beam mode requires two cables. One is attached to the emitter of the remote sensor and is used to guide light energy to a sensing location. The other is attached to the receiver of the remote sensor and is used to guide light energy from the sensing location back to the remote sensor. As with standard through-beam photoelectric sensing, the emitter and detector cables are positioned opposite each other. Sensing is achieved when the light beam that extends from the emitter to the receiver fiber-optic cable is interrupted.

3.4 Hardware

This project consists of several parts of hardware components or systems which include LED Driver circuit ,LED LCD, voltage sensor, fiber optic cables, photodetector, amplifier and filter circuits and a microcontroller Arduino UNO. Beside those parts mentioned, there are also other electronic components involved, namely resistors, capacitors, transistors and integrated circuit (IC). These parts or components were chosen after a considerable reviewing of available options.

3.4.1 LED Driver Circuit

Light emitting diode (LED) is an active element which over require an input to produce an output. Since a human weight requires a continuous measurement, a stable light source is needed. To maintain a stable output value, the LED must be able to receive a fixed and constant voltage on its input pin. This way, the light intensity produced by the LED is constant throughout running time regardless of fluctuation of input supply to the system. Another reason to justify the use of this voltage regulator is that it ensures the current and voltage is forward biased meaning it flows in one direction only.

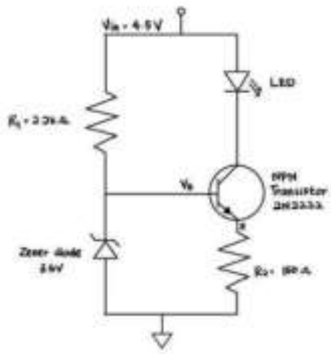

Figure 14: LED Driver Circuit

3.4.2 Light Emitting Diode (LED)

A light-emitting diode (LED) is a semiconductor device that emits visible light when electric current passes through it. The light is not particularly bright, but in most LEDs, it is monochromatic, occurring at a single wavelength. The LED output ranged from red (at a wavelength of approximately 700 nanometers) to blue-violet (about 400 nanometers). Some LEDs emit infrared (IR) energy (830 nanometers or longer). This device is known as an infrared-emitting diode (IRED). The choice of which color to be used as a light source depends on the type of fiber used and photodetector. Thus, the most suitable light source that would produce the least amount of transmission loss, is LED in the wavelength range of 530nm and 565nm. The wavelength for different types of color are presented below.

Table 6: Wavelength of different colour

LED color	Wavelength (nm)
Red	630-640
Green	520-570
Blue	430-470
Yellow	575-590

Since green light have wavelengths peak wavelength between the range of 520 nm and 570 nm, they are the best choice to use as the light source for the proposed optical fiber sensor system. The light source used in this project is the IF-E93 (Industrial Fiber Optics Inc.) green LED, as shown in Figure 15.

Figure 15: LED

In this proposed fiber optic sensor system, the type of fiber chosen is plastic optical fiber (POF). Main attributes of this optical fiber are small size, light weight, geometrical flexibility, electric and thermal insulation, chemical inertness, and immunity to electromagnetic interference. POF are generally more robust and applicable for multimode step index application compared to its counterpart, glass fiber. For this project, optical fiber used for both the input and output fiber is GH-400l by Mitsubishi Rayon, as shown in Appendix A.

3.4.3 Optical Fiber

In this proposed fiber optic sensor system, the type of fiber chosen is plastic optical fiber (POF). Main attributes of this optical fiber are small size, light weight, geometrical flexibility, electric and thermal insulation, chemical inertness, and immunity to electromagnetic interference. POF are generally more robust and applicable for multimode step index application compared to its counterpart, glass fiber. For this project,

optical fiber used for both the input and output fiber is GH-400l by Mitsubishi Rayon, as shown in Figure 16.

Figure 16: Single Input Fiber Optic

3.4.4 Photodetector

Photodetectors are electronic devices that are used for the detection of light. They convert light information (photons) into electrical signals (electrons) such as current or voltage. Different light property modulation types require the use of different photodetectors. The type of light sensor to use depends on the specific properties of the detectors. Examples of commonly used photodetectors are photodiode, photoresistor, phototransistor, and spectrometer. For the proposed optical fiber system, photodiodes are chosen for light intensity detection since they are low cost, lightweight and have fast response times.

Photodiodes are light sensitive semiconductor devices that convert light into current. A photodiode has two discrete levels of output. The photodiode is 'off' when the light intensity is exceeded, and 'on' when the light intensity is sufficient. Therefore, the use of the photodiode is suitable for applications which need to keep track of the light intensities. Photodiodes generally require a pre-amplifier to give signal gain for applications that need to detect low light power.

Figure 17: Photodetector

3.4.5 Voltage Sensor

A voltage sensor is a sensor used to calculate and display the quantity of voltage in an item. Voltage sensors can determine the AC voltage or DC voltage level. The input of this sensor is the voltage, while the output is the switches, analog voltage signal, a cutting-edge signal, or an audible sign.

Sensors are devices which could experience or become aware of and react to positive kinds of electric or optical signals. The implementation of a voltage sensor and present day sensor strategies have come to be an extraordinary desire for the conventional present day and voltage measurement techniques.

Figure 18: Voltage sensor

3.4.6 Arduino UNO

Arduino Uno is a microcontroller board based on the ATmega328P. The specification will be provided in the datasheet, Appendix E. It has l4 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a l6 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It provides a basic microcontroller functionality for applications such as serial monitor, analog read and write, portable measurements and lab-based experiments. The Arduino UNO board is interfaced with Arduino software (IDE) through a laptop, in order to provide the analog input readings to the Arduino IDE program.

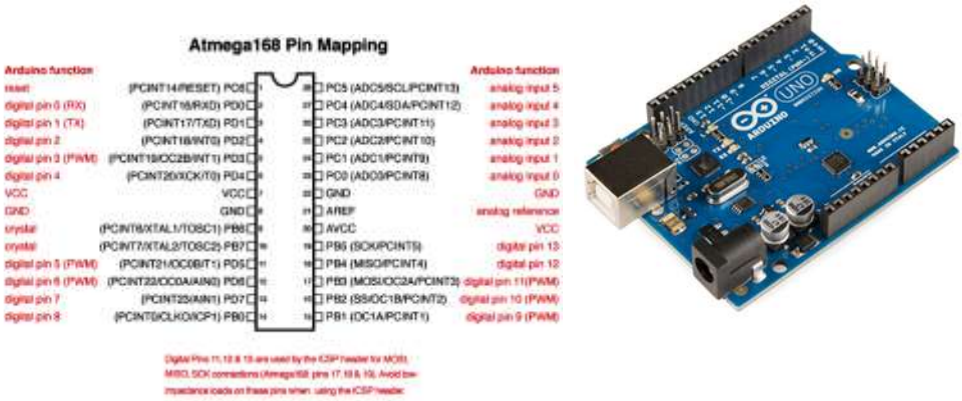

Figure 19: Arduino/Genuino UNO

3.4.7 Amplifier and Filter Circuit

The first receiver element is photodiode, which produces an electric current proportional to the received power level. Since this electric current is typically weak, an amplifier is needed to amplify it to a level that can be used by the processing system. After the signal is amplified, the signal passes through a low-pass filter to reduce the noise that is outside of the signal bandwidth. The equalization of the pulses that have become distorted as they travel through the fiber, can also be performed by the filter.

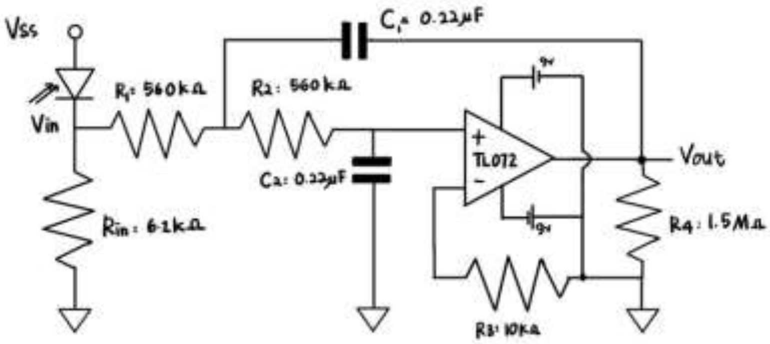

Figure 20: Signal conditioning circuit

An analog signal is digitized, low-pass filters are always used to prevent aliasing errors from out-of-band noise and interference. Analog filtering can remove higher frequency noise superimposed on the analog signal before it reaches the Analog-to-Digital Converter. This includes low-level noise as well as extraneous noise peaks. Any signal that enters the Analog-to Digital converter is digitized. If the signal is beyond half of the sampling frequency of the converter, the magnitude of that signal is converted reliably, but the frequency is modified as it aliases back into the digital output. The initial part of the circuit with the first op-amp IC performs the amplification process. The final part of the circuit with the second op-amp IC is used to filter the amplified signal. The op-amp IC used in this project for both the amplifier and filter circuits, are the TL072 model dual op-amp by Texas Instruments. The specification sheet for this op-amp is provided in Appendix B.

3.4.8 Liquid Crystal Display (LCD)

LCD is a type of flat panel display which uses liquid crystals in its primary form of operation. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it. This hardware will display the char that have been program in software.

Figure 21: LCD

3.5 Software

The software used for this project is Arduino software (IDE) for the purpose of collecting, interpreting, and determining the desired parameters. With the use of simple high level language programming, the change in load measurement for industrial automation can be determined based on the magnitude of resulting light intensity. This software presents two windows used, the coding and the serial monitor window as shown in Figure 22 below.

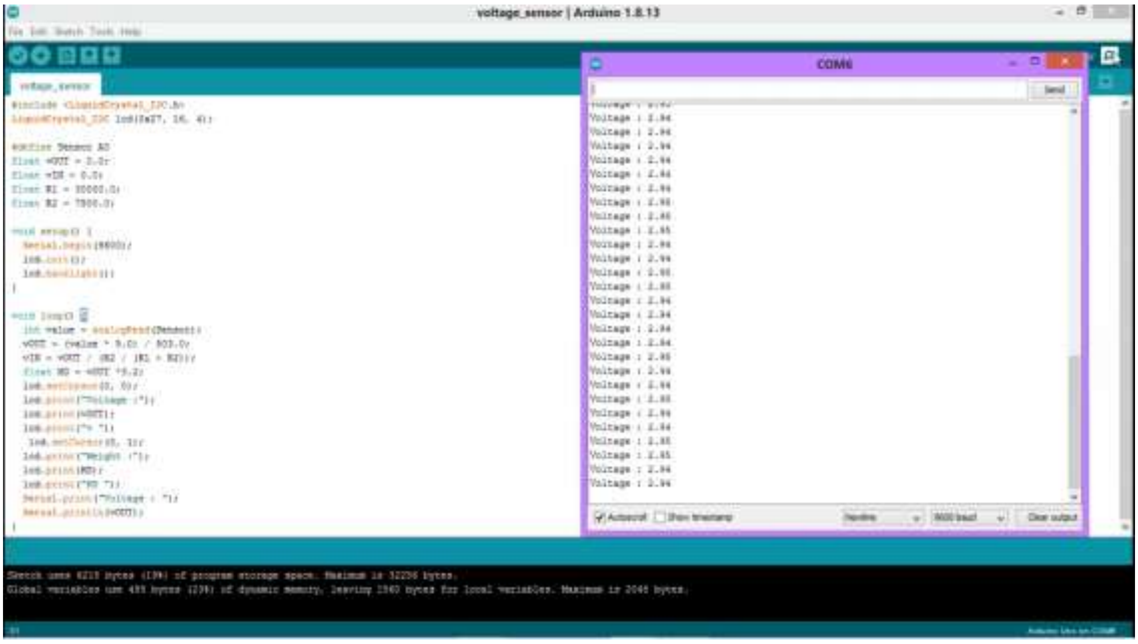

Figure 22: Arduino IDE

3.6 System Configuration

Figure 23 shows the overall configuration of the optical fiber sensing system. The LED driver circuit drives a stable input voltage of 5V to the green LED which allows it to produce a constant light intensity. The light enters the input plastic optical fiber (POF), and after being modulated due to presence of load at sensing region, the received light intensity at output fiber are then converted to its representative voltage value by the photodiode. This voltage signal is then amplified and filtered by conditioning circuit, before being fed into Arduino UNO microcontroller analog input pin, A0 which then interfaced with Arduino software (IDE) using a laptop.

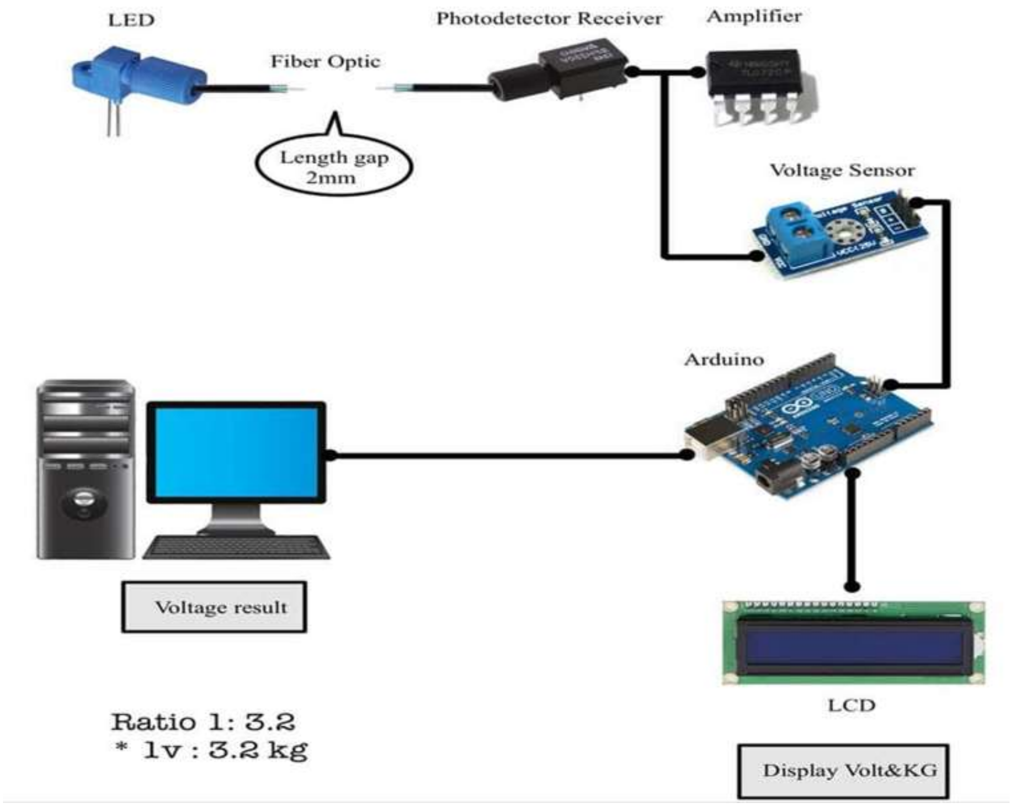

Figure 23: Human weight monitoring system configuration

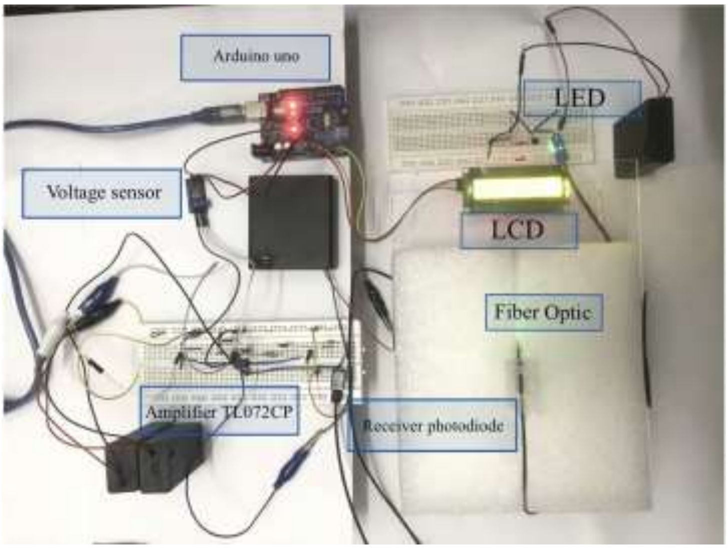

Figure 24: Human weight monitoring circuit system configuration

Figure 25: Human weight monitoring system design

Figure 26: Optical fiber displacement

The actual experimental setup of the optical fiber weight sensor system is shown in Figure 25. The designed optical fiber refractive index sensor for load was built on an acrylic base with compressed sponge to emulate testing setup for measurand. Two power sources were used to provide the required amount of voltage for the circuit, +9V and -9V for the dual supply of op-amp IC. The LED input supply voltage is acquired by stepping down from +6V to +5V by using a regulator circuit. It is also used for reverse-biasing the photodiode.

The input and output fiber holder is made by using a plastic fiber optic holder which infused together with the cylinder and connector of fiber which function as stopper on both end to make sure the maximum diameter is 2mm. The output voltage will remain at the same position while the input fiber will changes approaching the output fiber according the load applied by the subject. The stopper also serve to function as to keep the fiber in vertical position facing each other's end tip so that it is always perpendicular to the relative ground of the cylinder.

The LED driver circuit, amplifier and filter circuit are connected on a single breadboard. The system starts off with a supply of +5V for the LED through LED driver circuit and the resulting modulated output is fed into a photodiode which then is amplified first using amplifier circuit. The output signal then exits the amplifier circuit and act as an input for the filter circuit to cut off the high frequency part. The output from filter circuit is what is shown on the Arduino IDE software after being processed by Arduino UNO microcontroller using analog input pin, A0.

Since there were two signals due to having two input and output fibers, dual op-amp ICs were used. This is to reduce circuit space, and save cost. Dual-supply ICs should be supplied with both negative and positive voltage. Since the maximum output voltage for this project is less than 5 V, -9 V and +9 V were used to supply the ICs. The top rail of the breadboard is split into two positive voltages, +9V and +5V respectively while the bottom rail is split into ground and a negative voltage, -9V. The voltage sensor will sense the output voltage which replacing the multimeter function in manual technique.

3.7 Summary

This chapter focuses on the methodology for human weight monitoring by selecting the right component and designing the structure of the hardware. The hardware components for the proposed optical fiber bending sensor were discussed. Hardware components include optical light source, photodiode, the driver and Arduino Uno. lastly, the process and the system flow were presented as well.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter focuses on the experimental results obtained by application of the extrinsic optical fiber sensing system, for the measurement of human weight monitoring. The output configuration for this bending application has been carried out, and its performance in the laboratory is presented and discussed. The voltage represent the weight of subject was carried out using Arduino IDE software is also briefly described.

4.2 Intensity Modulation

As discussed in previous chapter, this modulation scheme, an applied measurand on sensing region would attenuates the intensity or amplitude of light carried by the optical fiber. The fiber optic sensor which is in this class, the normalized modulation index, m can be defined as equation 4.l below.

$$m = \frac{\Delta I}{IoP} \tag{4.1}$$

where,

ΔI = change in optical power because of modulation by the measurand

Io = optical power reaching the detector when there is no modulation

P = perturbation (measurand)

4.3 Human Weight Assessment

The human weight assessment using intensity modulated displacement fiber mechanism was conducted to determine the output sensitivity to different value of load. For the purpose of this test, quantitative analysis was implemented to obtain the average mean value of desired parameter. A total of six test is allocated for each range of average human weight. The samples called subject A, B, C, D, E and F respective the value of BMI includes the age and gender.

Prior sampling test conducted, a reference test was taken where the value load of subject B is 9.5kg. Figure shows the result obtained of output voltage, V=2,94 for load 9.42kg. Subsequently, each sample was taken and recorded in a line with marker manner and its respective the output voltage to show the linearity between distance and voltage. Figure for subject C shown that the optical fiber sensor measured the output voltage for 1.75mm length is 12.51 V, Figure for subject D is 15.94 V for 1.50mm length. Figure for subject E is 18.82 V for 1.30mm length and Figure for subject F is 21.79 V for 1.30mm length. Lastly, the overall performance of weight sensor system can be displayed below.

Figure 23: Result for subject B

Figure 24: Result for subject C

Figure 27: Result for subject D

Figure 26: Result for subject E

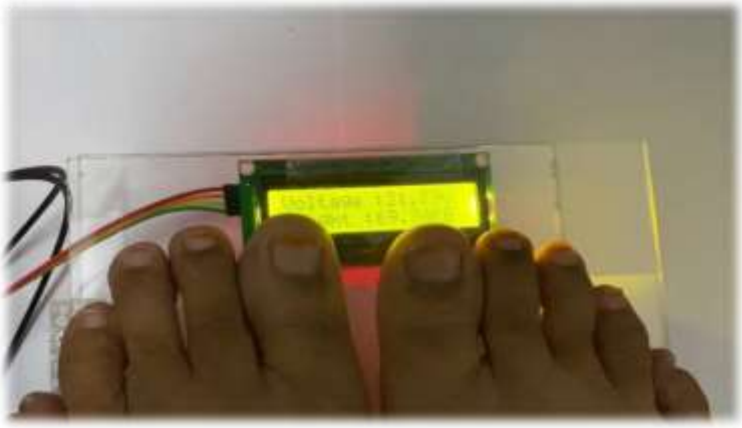

Figure 25: Result for subject F

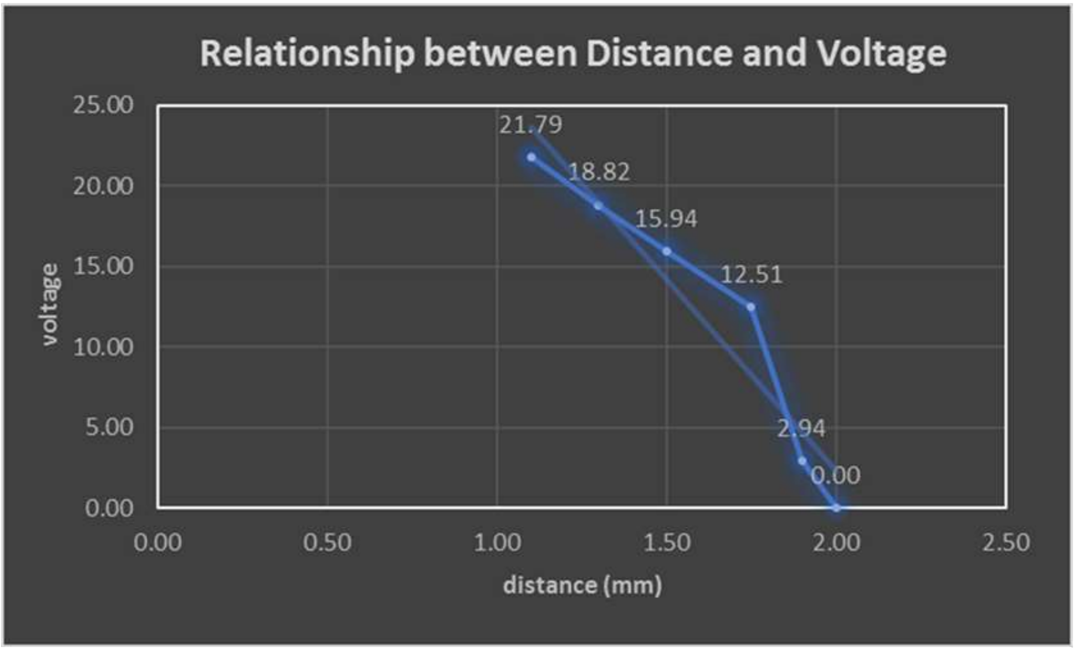

Figure 28: Linear graph for the human weight monitoring system

As can be seen from Figure 28 above, the resulting reference voltage bottommost to 2.94 V and for four consecutive samples subject C, D, E and F show an increasing trend. This is due to the sampling method conducted across the samples, when theoretically, the output voltage should increase when load applies is increases. The main cause for this occurrence was the difficulty in designing and implementing the physical aspect of the sensor hardware. The lack of proper equipment and tools to fabricate the fiber holder, results in fiber holders that non paralleled to each other making the light propagates at an angle across the sensing region. When an external force acts upon the fiber holder such as movement of the fiber when taking sample or the probe held in a certain angle, the optical fiber placed inside the fiber holder might move out of place.

Another cause that may affect the results is the distance between both fiber tips, where it is fabricated at 2mm apart, causing the load placement is not at centre part to get an accurate reading when fibers gets stucked or not attached between the fiber. The continuous reading taken by photodetector pose another problem relative to sampling action, as when sample in imbalance position, the load movement affects the measurement due to characteristic of compressed sponge is undulating. Thus, resulting in the output voltages recorded may be invalid or poor accuracy. To illustrate the linear relationship between distance and recorder voltages, these six samples exhibit a distinct load feature, which the capabilities of this optical fibre sensor may simply not be sensitive enough to detect.

In the case of subject B result, in which the accuracy shows a reading of output voltage is 2.94 V, proving the theory, when load is less than 10kg, the probability and sensitivity of compressed sponge is not suitable. This type of occurrence happens due to the compressed sponge only retaliate to load over 10kg to achieve the accuracy, however for load over 10kg, the type of sponge must fulfill the requirement of elasticity to perform the accuracy and reduce the error between measured value and real value.

4.3.1 Transmission Losses in Fiber

Ideally, the result obtained should be in sync with theoretical value. There are many external physical factors that may affect optical fiber sensor performance, loss. Extrinsically, optical fiber has a few downsides, geometrical non-uniformity at the core-cladding boundary, imperfect connection or alignment between fibers, microbending and radiation of leaky modes. Other factor that cause these losses may come from not the fiber, but from components used in the system configuration. The use of heterojunction LEDs or lasers may suggest an advantage over its counterpart, homojunction LEDs or lasers. Heterojunction means that a p-n junction is formed by a single crystal such that the material on one side of the junction differs from that on the other side of the junction. Generally, heterojunction lasers and LEDs have minimum threshold current density (10 A/mm2), high output power (10 mW) even with low operating current (<500 mA), high coherence and high monochromaticity, high stability and longer life.

4.3.2 Measurement Error

There were differences between the experimentally obtained data and the measured value of load. Based on the test run performed as shown in the above graphs, the percentage error can be determined. The formula for percentage error calculation is presented in equation 4.2:

$$\%\text{Error} = \left| \frac{Measured\ value - Real\ value}{Real\ value} \right| \times 100\% \qquad (4.2)$$

The % error for the load below 10kg is noticeably greater compared to the load over 10kg. This could be due to the misalignment between the input and output fibers at the connector segment, when the human weight assessment test was carried out. This misalignment will result in unbalanced light intensity at the output fibers.

Hence, any load measurement that is performed in that condition, will be inaccurate. The reason the error was significantly high, was partly due to the high sensitivity of the optical fiber system. A small degree of change in the alignment of the fiber, will result in considerable change in light intensity, and subsequently the output voltage. Thus, causing measurement readings that are notably different from the expected value.

4.3 Summary

The experimental results obtained using the proposed extrinsic optical fiber sensor for human weight monitoring was described. The single input and output configuration for this sensor proves to be viable to detect a change in measuring the magnitude of voltage output for human weight . The performance of the sensor when tested under laboratory-based condition was presented, and analysis on the assessment results have been carried out.

CHAPTER 5

CONCLUSION

5.1 Introduction

The main objective of this project was to design and develop an optical fiber-based on human weight monitoring properties sensor application which was based on light intensity modulation. This extrinsic optical fiber sensor was implemented on a flat surface of device to measure the human weight properties. The sensor was then tested in a laboratory-based condition in order to evaluate its performance.

5.2 Summary

The main of objective of this experiment was to design and develop an optical fiber-based properties sensor application which is based on light intensity modulation. This outward type of sensor is built upon an acrylic base and compressed sponge. The optical sensor was placed into the cylinder with mensuration of diameter for ease of measurand sampling. The sensor was later tested on an actual laboratory condition in order to evaluate its performance in accordance with its occurrence. The compressed sponge results support the suitability of using optical fibers to measure load corresponding to the maximum value. After calibration, the optical fiber sensor can be used to detect changes in voltage output when a load is applied across the sensing region. These measurements of light intensity relative to output voltage are being detected continuously in real-time using Arduino IDE software. Hence, this developed system is able to perform continuous measurement.

5.3 Recommendation

To improve the accuracy of the sensor, the optical fiber holder and the sensor's physical structure can be refined. With better hardware implementation, the hardware structure is suitable to use a casing to protect the mechanism of fiber itself and minimizing the circuit size into one complete circuit

5.4 Impact to Society and Environment

For this project, it gives more advantage and convenience to people especially in medical and personal care. Thus, the optical fiber is low cost and not to deny the flexibility of its characteristic. Computer generated is one of the specialties to improve from traditional methods. As with the previous existing device, the device requires electricity. More importantly, fiber optic LED lighting uses much less electricity than standard bulb options, making it both environmentally friendly and economical. In addition, fiber optic cables can transmit large amounts of data at very high speeds. That is why the technology is widely used in internet cables. Compared to the more traditional copper wires, fiber optic cables are lighter, more flexible and able to carry a lot more data.

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APPENDIX A
DATASHEET FOR GREEN LED IF-E93

Plastic Fiber Optic Green LED — IF-E93

5/2/06

DESCRIPTION

The IF-E93 is a high-output, high-speed, green LED housed in a "connector-less" style plastic fiber optic package. The output spectrum of the green LED is produced by a Gallium Nitride die which peaks at a wavelength of 530 nm, ideally mapping to the lowest attenuation window of PMMA plastic core optical fiber. The device package features an internal LED micro-lens, and the PBT plastic housing ensures efficient optical coupling with standard 1000 µm core plastic fiber cable.

APPLICATION HIGHLIGHTS

The high output and fast transition times of the IF-E93 make it suitable for low-cost digital data links. When coupled to PMMA plastic optical fiber, attenuation is less than .1 dB/m, as compared to .16 dB/m with commonly used 650 nm LEDs. Using standard 1 mm core plastic fiber, the IF-E93 LED is capable of distances in excess of 150 meters at data rates of 5 Mbps. The fast rise and fall times of the IF-E93 permit data rates up to 30 Mbps. The drive circuit design is simpler than required for laser diodes, making the IF-E93 a good, low-cost alternative in a variety of analog and digital applications.

TYPICAL APPLICATIONS

- Local Area Networks (LANs)
- Optical Sensors
- Medical Instruments
- Automotive Displays
- Audio Systems
- Electronic Games
- Robotics Communications
- Fiber Optic Modems
- Fluorescent Instruments
- Wavelength Multiplexing

FEATURES

- Ultra-Low Loss in Plastic Optical Fiber
- No Optical Design Required
- Mates with Standard 1000 µm Core Jacketed Plastic Fiber Cable
- Internal Micro-Lens for Efficient Coupling
- Inexpensive Plastic Connector Housing
- Connector-Less Fiber Termination and Connection
- Interference-Free Transmission from Light-Tight Housing
- Visible Light Output
- Fast Rise and Fall Times
- RoHS Compliant

MAXIMUM RATINGS

(T_A=25°C)

Operating and Storage Temperature Range (T_{OP}, T_{STG}) .... -40° to 60°C

Junction Temperature (T_J) .... 85°C

Soldering Temperature (2 mm from case bottom) (T_S) t≤5s .... 240°C

Reverse Voltage (V_R) .... 5 V

Power Dissipation (P_{TOT}) T_A=25°C .... 60 mW

De-rate Above 25°C .... 1.1 mW/°C

Forward Current, DC (I_F) .... 35 mA

Surge Current (I_{FSM}) t≤10 µs .... 150 mA

CHARACTERISTICS (T_A=25°C)

Parameter	Symbol	Min.	Typ.	Max.	Unit
Peak Wavelength	λ_{PEAK}		530		nm
Spectral Bandwidth (50% of I_{MAX})	Δλ	–	50	–	nm
Output Power Coupled into Plastic Fiber (1 mm core diameter). Distance Lens to Fiber ≤0.1 mm, 1 m SH4001 fiber, I_F=20 mA	Φ_{min}	95 -10.2	115 -9.4	135 -8.7	µW dBm
Switching Times (10% to 90% and 90% to 10%) (F=33 MHz, I_F=10 mA) *See Figure 3*	t_r, t_f	–	3.5, 16	–	ns
Capacitance (V_F=0, F=1 MHz)	C_0	–	100	–	pF
Forward Voltage (I_F=20 mA)	V_f	–	3.5	–	V
Temperature Coefficient, λ_{PEAK}	TC_λ		.17		nm/K

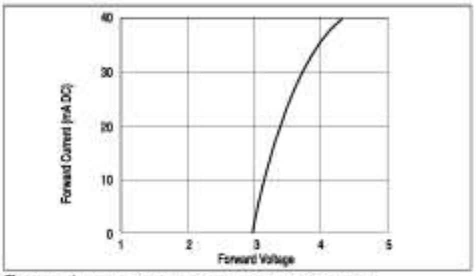


FIGURE 1. Forward current vs. forward voltage.

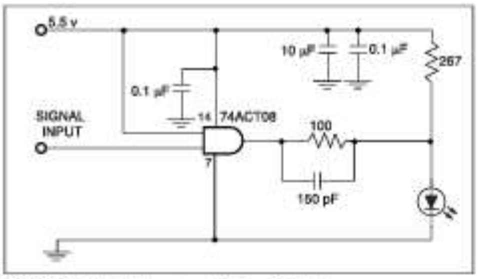


FIGURE 3. Test drive circuit (I_F = 22mA).

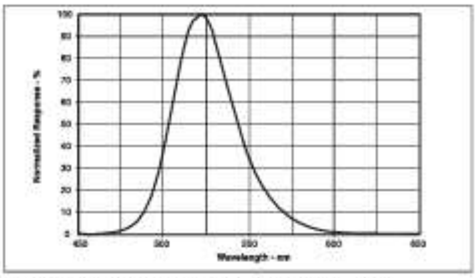


FIGURE 2. Typical spectral output vs. wavelength.

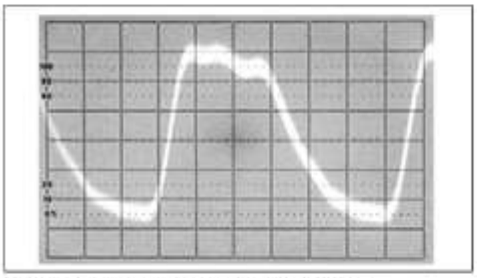
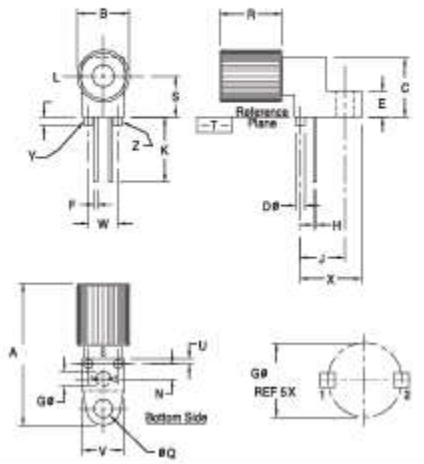


FIGURE 4. Transition times - Sweep = 5nS/div.



NOTES:
1. Y AND Z ARE DATUM DIMENSIONS AND T IS A DATUM SURFACE.
2. POSITIONAL TOLERANCE FOR D ø (2 PL): ⌖ ø 0.25 (0.010) M | T | Y M | Z M
3. POSITIONAL TOLERANCE FOR F DIM (2 PL): ⌖ 0.25 (0.010) M | T | Y M | Z M
4. POSITIONAL TOLERANCE FOR H DIM (2 PL): ⌖ 0.25 (0.010) M | T | Y M | Z M
5. POSITIONAL TOLERANCE FOR Q ø (2 PL): ⌖ ø 0.25 (0.010) M | T | Y M | Z M
6. POSITIONAL TOLERANCE FOR B (2 PL): ⌖ ø 0.25 (0.010) M | T
7. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
8. CONTROLLING DIMENSION: INCH

PACKAGE IDENTIFICATION:
- Blue housing w/ double green dot
- PIN 1. Cathode
- PIN 2. Anode

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	23.24	25.27	.915	.995
B	8.64	9.14	.340	.360
C	9.91	10.41	.390	.410
D	1.52	1.63	.060	.064
E	4.19	4.70	.165	.185
F	0.43	0.58	.017	.023
G	2.54 BSC		.100 BSC	
H	0.43	0.58	.017	.023
J	7.62 BSC		.300 BSC	
K	10.35	11.87	.408	.468
L	1.14	1.65	.045	.065
N	2.54 BSC		.100 BSC	
Q	3.05	3.30	.120	.130
R	10.48	10.99	.413	.433
S	6.98 BSC		.275 BSC	
U	0.83	1.06	.032	.042
V	7.49	7.75	.295	.305
W	5.08 BSC		.200 BSC	
X	10.10	10.88	.397	.427

APPENDIX B
DATASHEET FOR TL072 JFET OP-AMP

TEXAS INSTRUMENTS

TL071, TL071A, TL071B, TL071H
TL072, TL072A, TL072B, TL072H, TL072M
TL074, TL074A, TL074B, TL074H, TL074M

SLOS080T – SEPTEMBER 1978 – REVISED DECEMBER 2021

TL07xx Low-Noise FET-Input Operational Amplifiers

1 Features

- High slew rate: 20 V/μs (TL07xH, typ)
- Low offset voltage: 1 mV (TL07xH, typ)
- Low offset voltage drift: 2 μV/°C
- Low power consumption: 940 μA/ch (TL07xH, typ)
- Wide common-mode and differential voltage ranges
  - Common-mode input voltage range includes V_{CC+}
- Low input bias and offset currents
- Low noise: V_n = 18 nV/√Hz (typ) at f = 1 kHz
- Output short-circuit protection
- Low total harmonic distortion: 0.003% (typ)
- Wide supply voltage: ±2.25 V to ±20 V, 4.5 V to 40 V

2 Applications

- Solar energy: string and central inverter
- Motor drives: AC and servo drive control and power stage modules
- Single phase online UPS
- Three phase UPS
- Pro audio mixers
- Battery test equipment

3 Description

The TL07xH (TL071H, TL072H, and TL074H) family of devices are the next-generation versions of the industry-standard TL07x (TL071, TL072, and TL074) devices. These devices provide outstanding value for cost-sensitive applications, with features including low offset (1 mV, typical), high slew rate (20 V/μs), and common-mode input to the positive supply. High ESD (1.5 kV, HBM), integrated EMI and RF filters, and operation across the full –40°C to 125°C enable the TL07xH devices to be used in the most rugged and demanding applications.

Device Information

PART NUMBER[1]	PACKAGE	BODY SIZE (NOM)
TL071x	PDIP (8)	9.59 mm × 6.35 mm
	SC70 (5)	2.00 mm × 1.25 mm
	SO (8)	6.20 mm × 5.30 mm
	SOIC (8)	4.90 mm × 3.90 mm
	SOT-23 (5)	1.60 mm × 1.20 mm
TL072x	PDIP (8)	9.59 mm × 6.35 mm
	SO (8)	6.20 mm × 5.30 mm
	SOIC (8)	4.90 mm × 3.90 mm
	SOT-23 (8)	2.90 mm × 1.60 mm
	TSSOP (8)	4.40 mm × 3.00 mm
TL072M	CDIP (8)	9.59 mm × 6.67 mm
	CFP (10)	6.12 mm × 3.56 mm
	LCCC (20)	8.89 mm × 8.89 mm
TL074x	PDIP (14)	19.30 mm × 6.35 mm
	SO (14)	10.30 mm × 5.30 mm
	SOIC (14)	8.65 mm × 3.91 mm
	SOT-23 (14)	4.20 mm × 2.00 mm
	SSOP (14)	6.20 mm × 5.30 mm
	TSSOP (14)	5.00 mm × 4.40 mm
TL074M	CDIP (14)	19.56 mm × 6.92 mm
	CFP (14)	9.21 mm × 6.29 mm
	LCCC (20)	8.89 mm × 8.89 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Logic Symbols

6 Specifications

6.1 Absolute Maximum Ratings: TL07xH

over operating ambient temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
Supply voltage, $V_S = (V_{CC+}) - (V_{CC-})$		0	42	V
Signal input pins	Common-mode voltage (3)	$(V_{CC-}) - 0.5$	$(V_{CC+}) + 0.5$	V
	Differential voltage (3)		$V_S + 0.2$	V
	Current (3)	–10	10	mA
Output short-circuit (2)		Continuous		
Operating ambient temperature, T_A		–55	150	°C
Junction temperature, T_J			150	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Short-circuit to ground, one amplifier per package.
(3) Input pins are diode-clamped to the power-supply rails. Input signals that may swing more than 0.5 V beyond the supply rails must be current limited to 10 mA or less.

6.2 Absolute Maximum Ratings: All Devices Except TL07xH

over operating free-air temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
$V_{CC+} - V_{CC-}$	Supply voltage	–0.3	36	V
V_I	Input voltage (3)	$V_{CC-} - 0.3$	$V_{CC-} + 36$	V
I_{IK}	Input clamp current		–50	mA
	Duration of output short circuit (2)	Unlimited		
T_J	Operating virtual junction temperature		150	°C
	Case temperature for 60 seconds - FK package		260	°C
	Lead temperature 1.8 mm (1/16 inch) from case for 10 seconds		300	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) The output may be shorted to ground or to either supply. Temperature and supply voltages must be limited to ensure that the dissipation rating is not exceeded.
(3) Differential voltage only limited by input voltage.

6.3 ESD Ratings: TL07xH

			VALUE	UNIT
TL074H				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±1500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	
TL072H and TL071H				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	

APPENDIX C
DATASHEET FOR SFH250V PHOTODIODE

SFH250 and SFH250V

Receiver with analog output
for polymer optical fiber applications

Data Sheet

Lead (Pb) Free
RoHS 6 fully
compliant

Description

The SFH250 is a low-cost 650nm receiver for optical data transmission with polymer optical fiber. This Si-pin-photodiode works fine with the AVAGO transmitter SFH757. According to the intensity of the incident light the SFH250 generates an analog photocurrent. In typical applications the SFH250 is operated in reverse-biasing and is installed in series with a resistor, where the voltage tapping is taken. By increasing the reverse voltage the switching times decrease and the SFH250 can be used for transmission speeds up to 100MBd.

Components of the SFH series are optimized for easy coupling. No fiber stripping is required, only the cut fiber has to be inserted into the selected SFH component.

SFH250

The transparent plastic package has an aperture where a 2.2mm fiber end can be inserted. This very easy coupling method is extremely cost-effective.

SFH250V

The V-housing allows easy coupling of unconnectorized 2.2mm polymer optical fiber by means of an axial locking screw.

Ordering Information

SFH250

SFH250V

Type	Ordering Code
SFH250	SP000063866
SFH250V	SP000063852

Features

- Fast Switching Time
- Sensitive in visible and near IR Range
- High linearity
- 2.2mm aperture holds standard 980/1000/2200 um plastic fiber
- No fiber stripping required
- Molded microlens for efficient coupling

Plastic Direct Fiber Connector housing (V-housing)

- Locking screw attached to the connector
- Interference-free transmission by the light-tight housing
- Transmitter and receiver can be positioned flexibly
- No cross talk
- Auto insertable and wave solderable
- Supplied in tubes

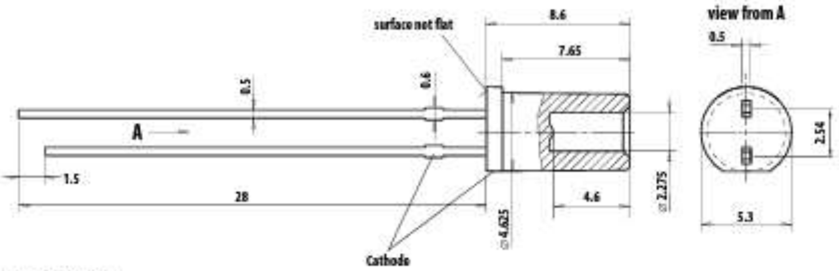
Applications

- Household electronics
- Power electronics
- Optical networks
- Light barriers

Application Literature

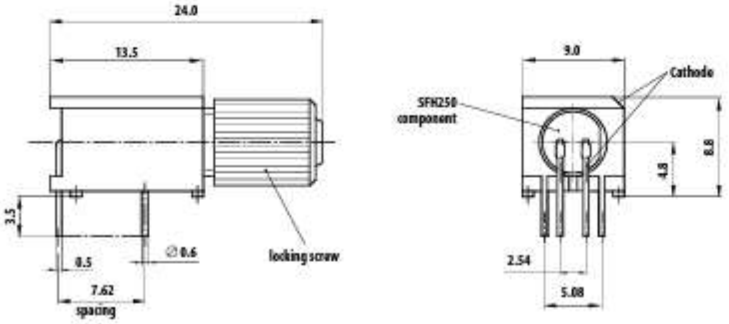
AN #	Description
5342	General information about the SFH series with Selection Guide and recommendations regarding System Planning and Mounting
5341	Information about Basic and Special Circuits for Transmitter and Receiver of the SFH series

SFH250



Dimensions in mm

SFH250V



Dimensions in mm

Package V-housing Color

SFH V-series components are color coded just like other Avago fiber optic components. The SFH757V transmitter has a white colored housing; the SFH250V and SFH551/1-1V receiver components have a black colored housing. This prevents mistakes while making connections. Product designation and date of manufacture are printed on the housing.

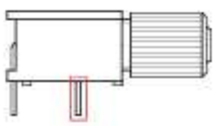
Package V-housing mounting pins

SFH V-series components have two pins that are electrically isolated from the inner circuit. The pins are only designed for mounting the V-housing to the PCB surface. This helps increase stability, which is needed during fixing the fiber end by the axial locking screw.

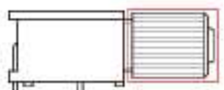
The retention force between the soldered mounting pins and the V-housing of the SFH component is about 20 N (with a vertical exertion of force). This is an approximate value.

Package V-housing axial locking screw

Components of the SFH V-series are equipped with an axial locking screw for easy coupling to the unconnectorized 2.2 mm polymer optical fiber. The force that is necessary to pull a jammed fiber out of the V-housing is typically 50 N (with a torque of 15 cNm for tightening the locking screw). This is an approximate value that is very dependent on the fiber and torque combination.



Package V-housing mounting pins



Package V-housing axial locking screw

Absolute Maximum Ratings

Parameter	Symbol	Min	Typ	Max	Unit	Notes	Figure
Operating Temperature range	T_C	-40		+85	℃		
Storage Temperature range	T_{stg}	-40		+100	℃		
Junction Temperature	T_J			100	℃		
Soldering Temperature (2mm from case bottom, t≤5s)	T_S			+260	℃		
Reverse Voltage	V_R			30	V		
Power Dissipation	P_{tot}			100	mW		
Thermal Resistance (Junction/Air)	R_{thJA}			750	K/W		
Electrostatic Discharge Voltage Capability	ESD			2000	V	1	
Electrostatic Discharge Voltage Capability	ESD			400	V	2	

Notes:

1. ESD Capability for all Pins HBM(Human Body Model) according JESD22-A114
2. ESD Capability for all Pins MM (Machine Model) according JESD22-A115

Characteristics (T_A = -40℃ to +85℃) unless otherwise specified

Parameter	Symbol	Min	Typ*	Max	Unit	Notes	Figure
Maximum Photosensitivity Wavelength	λ_{smax}		850		nm		1
Photosensitivity Spectral Range (S=80%Smax)	λS	400		1100	nm		1
Dark Current (R_L=50Ω ,V_R=5V, T_A=25℃)	I_R		1	10	nA	2	5
Capacitance (f=1MHz, V_R=0)	C_S		11		pF		5
Switching Times (R_L=50Ω, V_R=5.0V, λ=650nm) T_rise (10%...90%) T_fall (90%.. 10%)	 tr tf		 5 8	 12 16	 ns ns	 1,2	 6, 4
Switching Times (R_L=50Ω, V_R=30.0V,λ=650nm) T_rise (10%...90%) T_fall (90%.. 10%)	 tr tf		 3 4	 10 10	 ns ns	 1,2	 6, 4
Photocurrent (RL=50Ω ,Popt=10uW, V_R=5.0V, λ=650nm)	I_p	2.4	4.4		µA		2,3
Responsitivity (λ=650nm, R_L=50Ω)	R_{ip}	240	440		µA / mW	3	3
Photocurrent Temperature Coefficient (λ=650nm)	T_{ip}		-0.03		% / K		2

* Typical value = mean value at TA=25℃

Note:

1. Measured with optical input power -4dBm(mean) and pattern:"1010" at 5MBd
2. Increase with temperature
3. Not strictly linear behavior. Actual value at high optical input power could vary from the typical value.

APPENDIX D
DATASHEET FOR POF GH4001

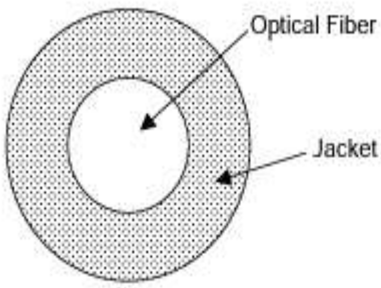
1. Scope
   This specification covers basic requirements for the structure and optical performances of GH-4001-P.

2. Structure

   Table 1

Item		Specification (GH-4001-P)			
		Unit	Min.	Typ.	Max.
Optical Fiber	Core Material	–	Polymethyl-Methacrylate Resin		
	Cladding Material	–	Fluorinated Polymer		
	Core Refractive Index	–	1.49		
	Refractive Index Profile	–	Step Index		
	Numerical Aperture	–	0.5		
	Core Diameter	µm	920	980	1,040
	Cladding Diameter	µm	940	1,000	1,060
Jacket	Material	–	Polyethylene		
	Color	–	Black		
	Diameter	mm	2.13	2.20	2.27
Approximate Weight		g/m	4		
Indication on the Jacket		–	·····ESKA PREMIER·····:Pink		

Sectional View



No. 0

3. Performances

Table 2

GH-4001-P

Item		Acceptance Criterion and/or [Test Condition]	Specification			
			Unit	Min.	Typ.	Max.
Maximum Rating	Storage Temperature	No Physical Deterioration [in a Dry Atmosphere]	℃	-55	—	+85
	Operation Temperature	No Deterioration in Optical Properties* [in a Dry Atmosphere]	℃	-55	—	+85
		No Deterioration in Optical Properties** [under 95%RH condition]	℃	—	—	+75
Optical Properties	Transmission Loss [650nm Collimated Light]	[25℃ 50%RH]	dB/km	—	—	170
		[Operation Temperature]	dB/km	—	—	190
Mechanical Characteristics	Minimum Bend Radius	Loss Increment ≦0.5dB [A Quarter Bend]	mm	25	—	—
	Repeated Bending Endurance	Loss Increment ≦1dB [in Conformity to the JIS C 6861]***	Times	10,000	—	—
	Tensile Strength	Tensile Force at 5% Elongation; in Conformity to the JIS C 6861]	N	70	—	—
	Twisting Endurance	Loss Increment ≦1dB [Sample Length : 1m Tensile Force : 4.9N]	Times	5	—	—
	Impact Endurance	Loss Increment ≦1dB [in Conformity to the JIS C 6861]	N·m	0.4	—	—

All tests are carried out under temperature of 25℃ unless otherwise specified.

* Attenuation change shall be within +/- 10% after 1,000 hours.

** Attenuation change shall be within +/- 10% after 1,000 hours, except that due to absorbed water.

*** Bend Angle +/-90° ,Bend Radius 15mm,Tension 500g

APPENDIX E
DATASHEET FOR ARDUINO UNO MICROCONTROLLER

Technical specs

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g