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# Participation of Disability People to Working and Learning Envıronments with the Help of Robots

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**Abstract:- Robots are used in different areas such as industry, hospitals, defense industry, markets and education with the developing technology. (Abdulhussein & Hadi, 2020) Robots are machines that have the capacity to do repetitive tasks quickly. (Moulay et al., 2020) In addition, since robots work with high accuracy and precision, they play an important role in minimizing human errors. (Abdulhussein & Hadi, 2020) Occupational accidents have decreased significantly, thanks to the fact that dangerous jobs are done by robots in the industry. (McGinn, 2020) In this way, the living standard of humanity has increased. (Chatterjee, 2020) The demand for robots to accompany these people is increasing day by day, especially in countries where the elderly and disabled population is increasing. (Kasaei et al., 2021) Line-following robots (LFR) can be used when people with disabilities move from one location to another. Line follower robots are vehicles that can go to the desired destination autonomously by following the line drawn on the ground. They use sensors that read the ground to reach the target. While they moves, they have the ability to stop and warn when an obstacle appears in front of them and to go around the obstacle at the same time. For example, a visually impaired person can get to know and learn about his/her surroundings by acting in the company of a line-following robot in a working environment where he/she starts to work for the first time. Thus, it can be ensured that people with disabilities are more employed in business environments. Disabled individuals participate in training activities accompanied by line-following robots, so there is no need to assign a separate staff to them. Therefore, it is important that the designs and algorithms in these robots are designed to ensure the highest level of safety for disabled individuals.At the same time, electronic elements such as microcontroller, sensor, motor driver, which are parts of the line follower robot, are used in the control of many machines we use in our daily life.The control training of LFR gives student coding and robot design skills.**

***Keywords:-*** *Arduino, ADC Converter, PID Control, IR Sensor, PWM Signal.*

## I. INTRODUCTION

The signals receiving from the environment, which we live in, are in analog type. [1]But today, many electronicsystems run as digital system. ADC (Analog-to-Digital Converter) and DAC (Digital-to- Analog Converter) modules are used to process digital signal. ADC and DAC modules are integrated into microcontroller systems, enabling control applications to be worked more efficiently and quickly.[2]The working areas of microcontrollers are expanded through these modules.[3]

The analog signal coming from the IR sensors mounted in the front of the robot should beswiftly read and converted into digital signals that the microcontroller can process for controlling of the LFR. The obtained digital signals are processed in the sensor reading program algorithm designed to generate position data to be used in PID feedback control.[4]Acquiring the position data rapidly and with the least error will provide the PID control to work more efficiently.

The values produced by the PID will be sent to the motor drivers and the power adjustment of the motors will be made according to the condition of the path followed.[5]IR sensors should be adjusted according to the light of the ambient for using in the program, which processes sensor reading.[6]Generally, LFRs are positioned on the line drawn on the ground before starting the movement. The LFR is manually or automatically moved left and right on the line, so that all IR sensors pass over the line several times. Thus, a light reference point is created for each sensor by comparing the output produced when each IR sensor comes on the line with the output produced outside the line. This process takes between 20 and 30 seconds. In addition, while the LFR is moving on the line, the reference light point of each sensor is compared with the value read at the time of movement.[7]

However, the reference light point is produced only before LFR starts motion. There may be a difference between the values read by the sensors and the light reference point created at the beginning due to factors such as sunlight and ambient lighting along the path followed by the LFR. This difference causes errors in the obtained position information and the LFR goes out of its way. In order to minimize position information errors, reading of the sensors should be processed in real time and light reference points should be determined accordingly. Reducing the duration of these processes and at the same time making IR sensor readings with the least error will save time and energy. A new method is developed in this study which enables producing real time position data obtained from the IR sensors via a program algorithm in miliseconds, while LFR moves on the line. The position data is used without any problems in the control trials in the PID system.

## II. MATERIALS AND METHODS

*A. Autonomous Line-Follower Robot Architecture*

LFR is made up of several parts. These are;

- Microcontroller
- Voltage Regulator Circuit
- Motor Driver
- Infrared Sensor Array
- Encoder
- Button – Signal Circuit
- E18-D80NK Infrared Object Detection Sensor (MZ-80)
- Motion Parts (DC motorsandWheels)
- Base Structure (Chassis)

Before creating the LFR, a suitable design for the main body (chassis) should be designed.

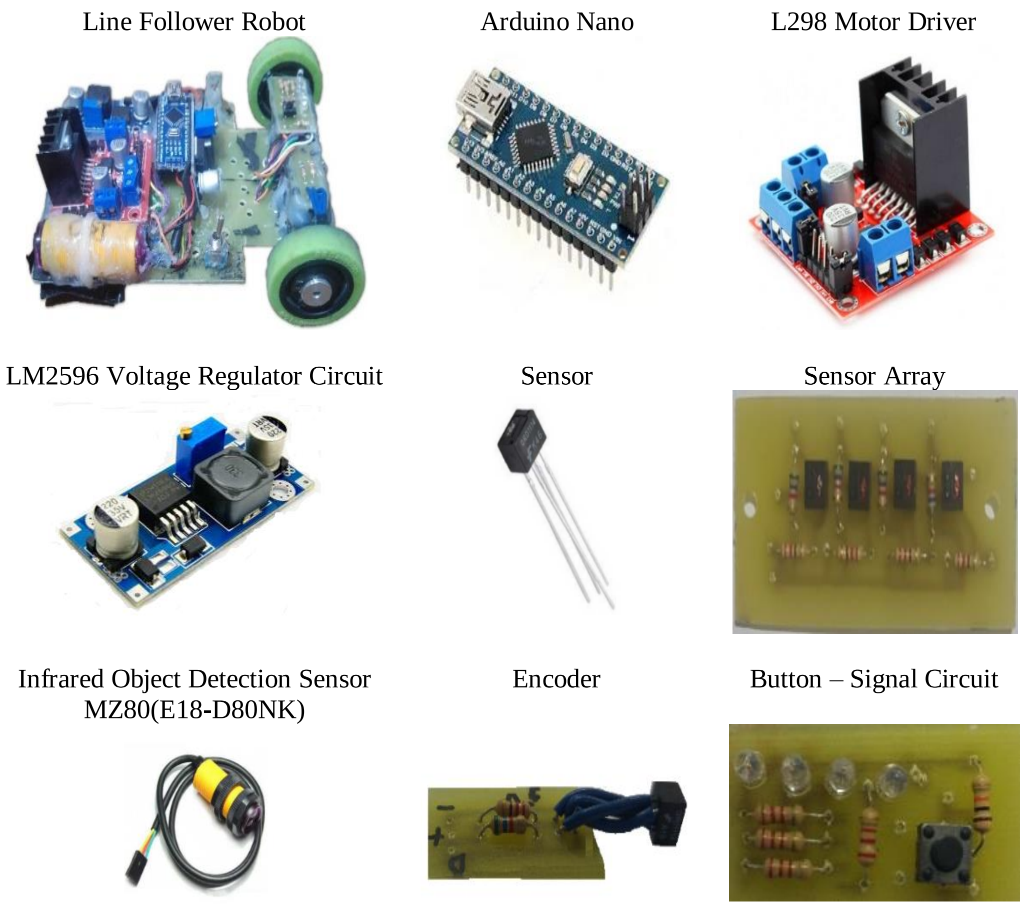


Fig. 1: Block diagram of the line-follower robot

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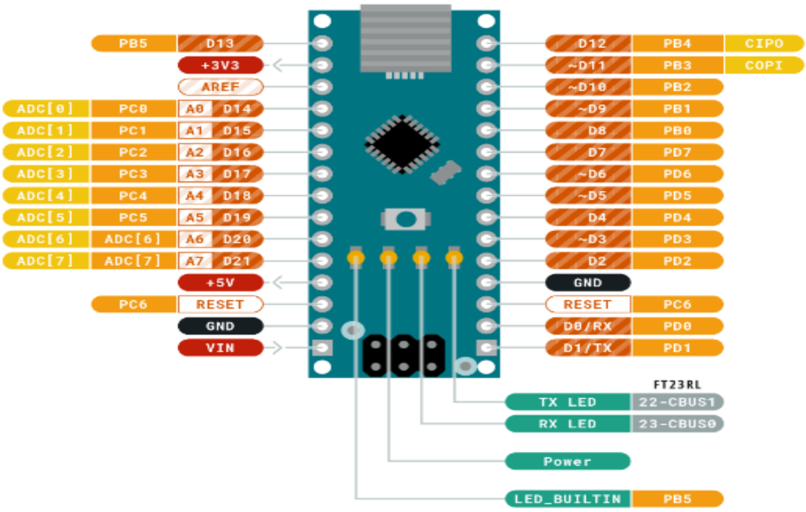


Fig. 2: Arduino nano microcontroller[8]

Arduino nano microcontroller is used to read and process signals from infrared sensors on LFR. Arduino nano microcontroller has eight ADC pins.QRD1114 sensors in the sensor array are directly connected to ADC pins without any electronic circuit. The analog datas between 0V to 5V from these sensors are captured by ADC pins. If the sensor is exactly on the white line, data value closes to 0V, if it is exactly on the black background, data value closes to 5V, are read by the ADC pins. Arduino nano has 10-bit ADC resolution capability. ADC module divides 5V,which is the highest voltage applied to the sensors, into 1024 parts which means $5/2^{10}$.Each piece is called a step and these steps range from 0-1023. The voltage value of each stepis calculated as 0.0048V and this value is multiplied by the step number in order to code digital data[9], [10] For example, if 512 value is obtained at the end of the ADC operation, this indicates that there is approximately 2.5V at the collector terminal of the sensor. As the sensor comes closer on to the white line, the voltage at the collector of the sensor will fall down, simultaneously the data value obtained at the end of the ADC operation will be reduced.[1], [3], [9]–[11]

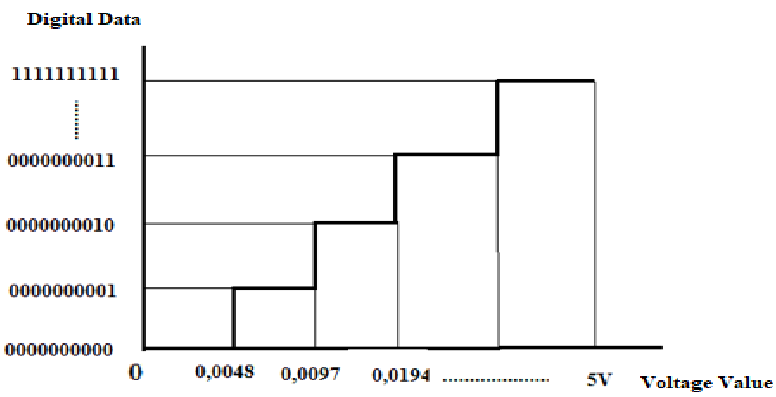


Fig. 3: 10 Bit resolution ADC step chart

IR sensors in the form of array in Figure 5, are mounted on the front of the LFR, so that they can read the line drawn on theground.QRD1114 sensor array is used in this project. The QRD1114 is formed by combining an IR LED and a phototransistor in a package.[12]

The schematic drawing of the qrd1114 sensor is shown in Figure 4. The rays emitted from the IR diode hit the ground where the LFR will move. The path, which LFR moves on, is formed by black ground and a white line can be drawn on it, or it can be created by drawing a black line on a white ground.The infrared rays hitting the gorund are absorbed by the black background and the infrared rays hitting the white line are reflected back and fall on the photosensitive base of the phototransistor, allowing the current to flow through the collector-emitter of the transistor.The current passing between the collector and emitter changes according to the intensity of the light falling on the base of the transistor[13]As the LFR moves on its way, the intensity of the light reflected and fall on the phototransistors of each sensors, approaching the white line will change. As the intensity of the reflected light increases, the current through the collector-emitter of the phototransistor will also increase.[5], [14]

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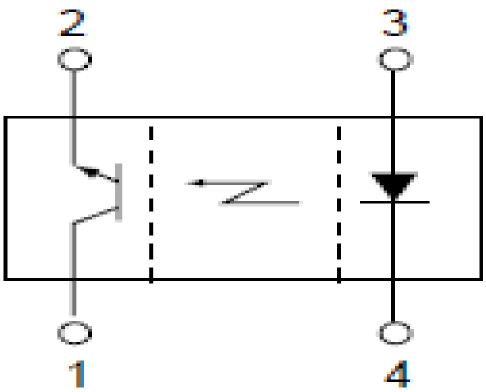

Fig. 4: (*QRD 1114*, n.d.)

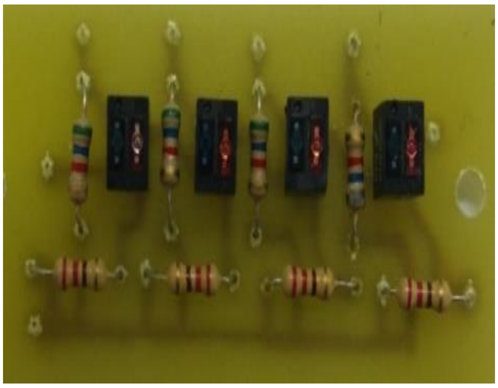
Fig. 5: Sensor Array

The datas coming from sensors are processed by the Arduino nano microcontroller according to the position of the LFR which moves through the line, the PWM signals are sent to the 12V DC motors. The maximum amplitude of the PWM signal is 5 volt which is not enough to move the motors. Therefore, it is necessary to use a motor driver to increase the amplitude of the PWM signal. In this project, L298 motor driver circuit shown in Figure 6 is used.

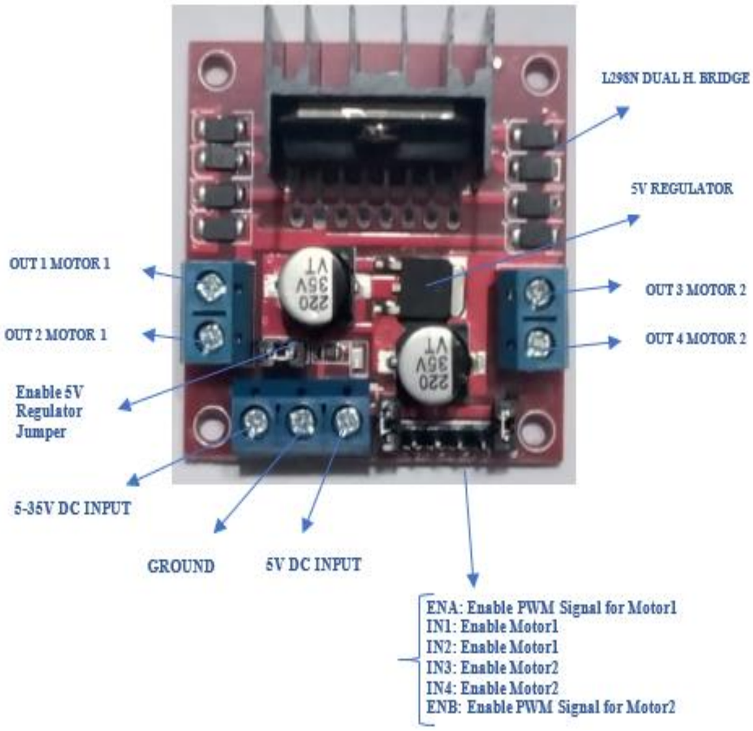

Fig. 6: L298 Motor driver circuit

LM2596 adjustable DC-DC converter regulates input voltages between 4V DC- 35V DC into the output voltage range of 1.23V DC 30V DC. Output current is 3 amps. The microcontroller and sensor arrays should be supplied with a constant voltage and current in LFR systems. The supplied voltage fluctuations may cause incorrect operation in the system. The voltage taken from the battery is reduced to 5V via 50k potentiometer on the LM2596 circuit. The circuit does not heat immediately, because it produces current up to 3 amperes. This circuit is used for 5V supplied voltage which is necessary for microcontroller and sensor array. Also, it is used for activating the motor driver.

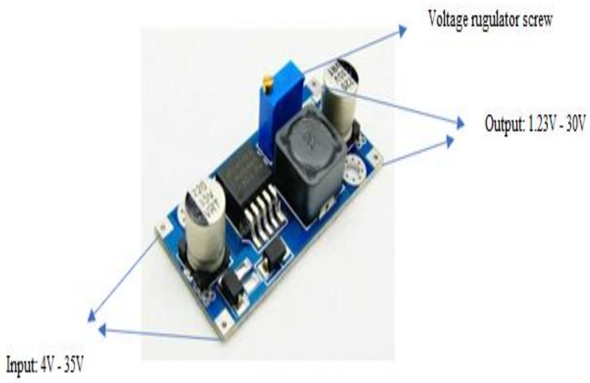

Fig. 7: Step-Down voltage regulator

E18-D80NK is an Infrared distance sensor. Its distance is between 3cm-80cm.The signal sent out from infrared sensor hits the object which is on the opposite side, and it comes back to the phototransistor. The output voltage of the sensor is in digital mode. The distance is adjusted via the potentiometer mounted on the sensor. The signal sent from E18-D80NK infrared distance sensor is modulated by the modulator. The returning signal is decoded by the demodulator to ensure that the correct signal is read.[15] The response time of the MZ80 distance sensor is 2ms.[16] The response time of the distance sensor should be as short as possible. If the response time increases, there will be delays in the PID function. This situation prevents LFR from following the line correctly. For example, the response time of the SRF05 ultrasonic sensor reaches up to 30 ms.[17] When the SRF05 ultrasonic sensor is used in LFR tests, errors occurred in the algorithm of the sensor reading program and PID algorithm, because of the signal sending time and response time of the SRF05, which are very long according to MZ80 distance sensor.

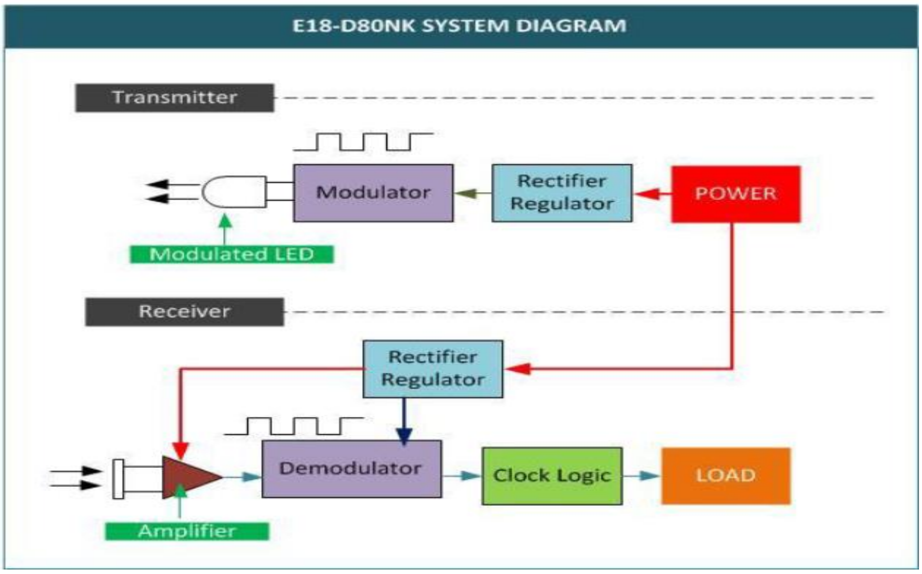

Fig. 8: E18-D80NK system diagram[15]

The encoder is a device that measures the angular position of the shaft. The main performance indicator of the encoder is its resolution, which defines the minimum angular displacement that the encoder can detect.The resolution is expressed in bits. The minumum angle that the encoder,which has N bit resolution, can detect, found by the formula of $360/2^N$. There are two types of encoders which are incremental encoders and absolute encoders. Incremental encoders are used by many systems because of their simple construction, high resolution and low cost.[18]The encoders are used to measure the speed of the robot and find the amount of distance traveled in the line follower robot systems. The encoder is mounted on the shaft of the robot and the number of infrared rays passing through the slits in the encoder's disk is read by the microcontroller using the LM393 digital output comparator. The speed or the amount of distance traveled by the LFR is determined according to the number of rays.

## III. THEORYAND CALCULATION

In this Project, the qrd1114 sensor was used in the encoder which is mounted on the motor to count the number of the turns of the wheel. The inner side of the wheel is painted in black and white colors, enabling the sensor to distinguish between black and white. The analog input of Arduino-Nano microcontroller is used to read black and white colors. After reading of the colors, the datas are obtained by using $2^{10}$ (1024) bit resolution. ADC module calculates 0.0048V each step of the ADC process, since the maximum voltage from the sensors is 5V and this voltage is divided by 10 bit resolution ($5/2^{10}$ =0.0048).Whenthe wheel rotates, the determined voltage ranges is processed by the program on the microcontroller. If the determined voltage ranges are acquired from the ADC process, the program will increase the counter value which is defined in the codes. In this way, false readings caused by ambient light are prevented. The circumference of the wheel is measured and defined as a constant number in the program to be multiplied by the counter value. Thus, the amount of distance traveled by the LFR is calculated. If this method is compared to digital readings, it will provide a faster reading and less electronic parts are used since a comporator isn't used. And also, this method will reduce the installation cost of the LFR.

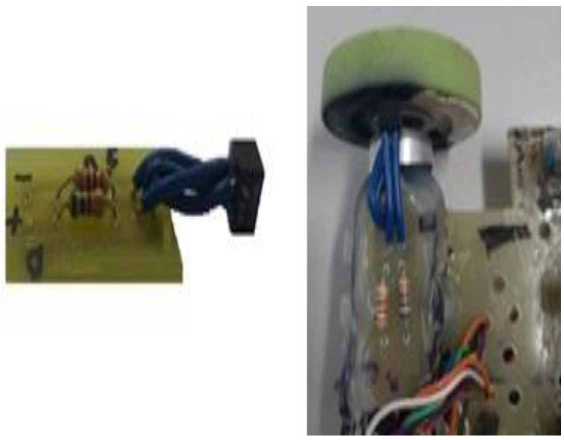
Fig. 9: QRD1114 Encoder mounted on LFR

The length of the path that the LFR will travel is determined by the button-signal circuit used in the LFR. When we press the button once, the value of the counter we use in the program is increased by one and the first led lights up. If the button is pressed twice, the counter value is incremented by two. The first and second leds light up together. The rotation number of the wheel is calculated by multiplying the counter value with a predetermined fixed number which is defined in the program. The data value obtained from encoder is multiplied by the rotation number ensure that LFR takes the path of the determined length and stops at the specified point.

When the button is pressed again after the LFR stops, the counter is reset, the leds turn off and the LFR returns to the starting point.

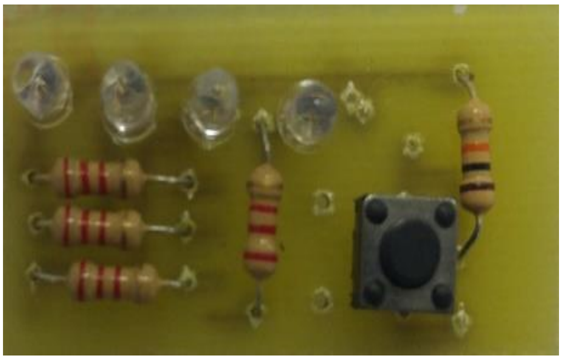

Fig. 10: Button – signal circuit

According to the electronic circuit diagram shown Figure10, 12V DC voltage is used for the motors of the LFR. 12V DC voltage is applied to the input of the LM2596 regulator and 5V voltage is obtained from its output. The supply voltages of the electronic circuits in the internal structure of Arduino Nano, qrd114, MZ80 and L298 are provided. The pins which are D2-D3-D4-D5 of Arduino are connected to the pins that are IN1, IN2, IN3, IN4 of the inputs of the L298 motor driver in order to control of rotating motors clockwise or counterclockwise directions. IN1, IN2 and OUT1-OUT-2 control MOTOR-1 rotating direction, IN3, IN4 and OUT3-OUT4 control MOTOR-2 rotating direction. The speed controls of MOTOR-1 are provided by D6-ENA and MOTOR-2 by D9-ENB. PID function in the program produces PWM values for sending ENA VE ENB pins that are used for determining the amount of power which is transferred from the battery to the MOTOR-1 and MOTOR-2.D-12 is used for reading digital data coming from MZ80.Button – Signal Circuit connected to the A4 pin is used for specifying the length of path that the LFR will travel. The A4 pin can be utilized as analog reading,but in the program it is assigned as digital reading. The number of the rotation of the wheels are counted by the encoder connected to the A7 pin which is programmed for analog reading. A0, A1, A2, A3 pins read the data values coming from sensor array containing four qrd1114 sensors in analog mode.

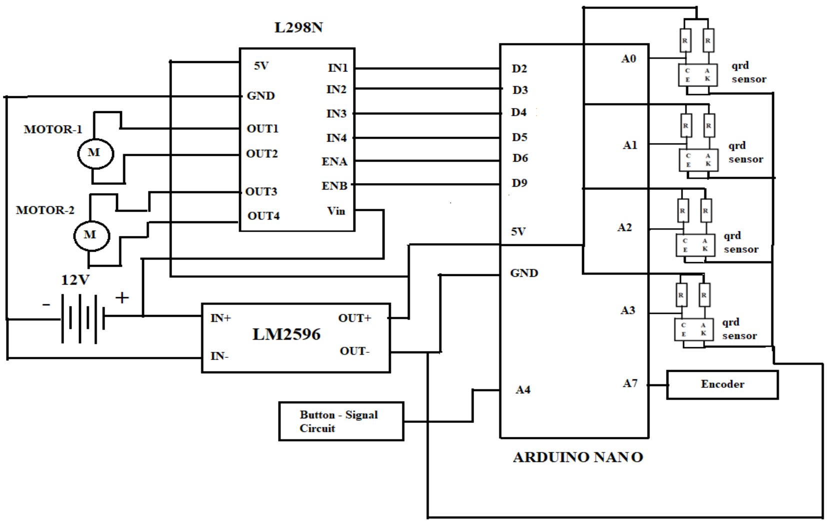


Fig. 11: LFR electronic circuit diagram

The middle point of the sensor array of the line followershould be put on its white line,where LFR follows, drawn on the ground. ADC operation is applied to the voltage values coming from the sensors.The numerical values obtained at the end of this process are registered in an array. After the largest and smallest of the values in the array are found with an algorithm.These two values are added and result is divided by two. After this calculation, a light reference point is obtained. The values in the array are evaluated by an algorithm according to the light reference point. While values below the light reference point are processed, values above the reference point are considered zero. This method changes the numeric value of the values in the array. These numerical values are multiplied bycoefficients according to the location of the sensor and results are summed up. For example, the value read from A0 ADC pin of the microcontroller is multiplied by 0, the value read from A1 ADC pin by 1000, the value read from A2 ADC pin by 2000, and the value read from A3 ADC pin by 3000. This process continues according to the number of sensors used in the sensor array.Thesensitivity of the position data increases, as the selected coefficient increases. However, the pwm outputs of the microcontroller may not completely response this signal which has high sensitivity.

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The sum of the values multiplied by the coefficients are divided by the sum of the raw values received from the ADC pins. This value is the position data.[7]

The measured values examples from ADC pins and the position datas obtained from algorithm via serial port of Arduino nano, which are sent to computer, in Table 1. Sensor values are calculated based on the light reference point. It is observerd that the error data calculated by the program is equal although the measurements,which are carried on, at different light reference point value.

The steps to be followed in calculating error data;

- The sensors of the largest and the smallest coefficients in the sensor array, are summed up and result is divided by two. The new value acquired is the midpoint of the position data value.
- Ifthe highest coefficient of s3 sensor is three thousand (3000), and the lowest coefficient of s0 sensor is zero (0).These two coefficients are added together and then divided by two. (3000+0) / 2=1500 is the midpoint of the position data.
- The error value is calculated according to the distance from the midpoint to position data obtained continuously as nagative value orpositive value.

Table 1: Sensor measurement-position and error

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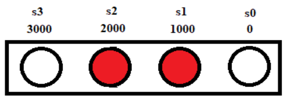
<tr><td colspan="6">
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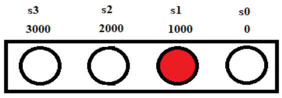
<tr><td colspan="6">
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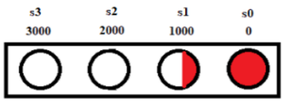
<tr><td colspan="6">
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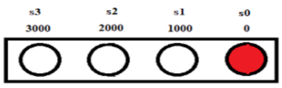
<tr><td colspan="6">
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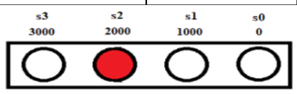
<tr><td colspan="6">
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| | | | | | | |
|---|---|---|---|---|---|---|
| reference : 527 | | | | | | error=1500-2000=-500 |
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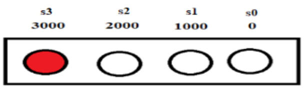
| 0 | 406 | 0 | 0 | 2000 | -500 | |
|   | | | | | | Pozitiondata: 3000<br><br>error=1500-3000=-1500 |
| reference : 520 | | | | | | |
| s3 | s2 | s1 | s0 | position | error | |
| 415 | 0 | 0 | 0 | 3000 | -1500 | |
| reference : 512 | | | | | | |
| s3 | s2 | s1 | s0 | position | error | |
| 411 | 0 | 0 | 0 | 3000 | -1500 | |

Table 2: Pseudocodes of sensor reading program

```
function readsensor(){
for(i=0; i < sensornumber; i++){
array[i]=analogread[i];
y = array[i];
rawsum = rawsum + y;
}
largestnumber = array[0];
smallestnumber = array[0];

for(k = 0;k < arraynumber; k++){
if ( array[k] > largestnumber){
largestnumber =array[k];
}
if ( array[k] < smallestnumber){
smallestnumber = array[k];
}
}
lightreferencepoint = (largestnumber + smallestnumber) / 2;
for (j = 0; j < sensornumber;  j++){
if (array[j] > lightreferencepoint){
array[j] = 0;
x = array[j] * 1000 * j;
weightsum = weightsum + x;
}
positiondata = weightsum / rawsum;
return positiondata;
}
function main ( ){
position = positiondata;
midpoint = array[last number] * 1000 / 2;
error = midpoint – position;
```

PID is a feedback control system that performs proportional, integral and differential control. PID calculates the error rate between a predetermined value and the real-time measured value from the system which is controlled. PID system is adjusted by generally applying J.G. Ziegler and N.B. Nichols method.[5], [19]The difference between the position value which iscalculatedby the algorithm and the value set as the middle point of the LFR, is the error data of the system. This data is processed with the PID algorithm and the correction result value, seen as Eq. 1, is sent to the motors from Arduino pwm output pins.

Correcion = Kp*e(t) + Ki*$\int_0^t e(t)dt$+ Kd*$\frac{d}{dt}$e(t)[19], [20] (1)

Kp: Proportional gain
Ki: Integral gain
Kd: Derivaive gain
t: time of process
e: error

The tests should be carried out in order to determine appropriate PID values which will be applied on the LFR algorithm.[6]

Table 3: Implementation of PID program in micro controller

```
function PID ( ) {
lasterror = error;
proportional = Kp * error;
derivative = Kd * (error – lasterror);
integral = (integral + error) * Ki;
correction = proportional + derivative + integral;
motor 1 = power + correction;
motor 2 = power - correction;
```

## IV. RESULTS AND DISCUSSION

In this project, reading data coming from sensors are carried out according to reference light points which are produced continuously. This method eliminates wrong data caused by the different environments which LFR moves. The position values produced by the algorithm provide controlling of motors more sensitively. If the sensors have more precision and ADC module resolution of microcontroller is increased, any system can be controlled with precision and accuracy.

## V. CONCLUSION

The position valuesare produced according to the datas coming from the sensors by using the ADC module of the microcontroller. The control of the motors are ensured by processing the position values in the PID algorithm. In this way, the LFR moved smoothly over the its course. The proximity sensor detected an obstacle while the LFR was in motion, providing the LFR to stop and resume its movement when the obstacle was removed. The aim of this project is not only to produce position value according to the datas coming from color sensors, but also to process the datas obtained from heat sensors, humidity sensors or other sensors used in the industry.The output of the system is controlled by the proposed method with the necessary control algorithms. For example; if the temperature of a furnace is provided by different heaters and the temperature inside the furnace is desired to be the same throughout the furnace, the voltage values, which is supplied to the heaters, can be adjusted with this method. As a second example; this method can be used for irrigation systems. The data values coming from humidity sensors in a field are processed to calculate PWM signals which control motors and valves that supply water. In this way, each point of field is irrigated equally with saving of water. This technologyalso will enable individuals with disabilities to gain skills to adapt to their working environments in a shorter time. In education, the training given to the students to operate the line follower robot in different environments will help the students to design different and new technological machines.

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