

Opto-electronics Differential Joystick for Electronic Control of Wheelchairs and Robots

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Abstract— This paper presents an optoelectronic joystick for driving and controlling electronic wheelchair, robot or any other electronically controlled gazette. An innovative concept has been conceived and realized using light emitting diodes, photo-detectors and a sliding optical template that converts movements of joystick into variable light output depending on the position of the joystick handle. At a time two different electrical signals are generated to drive or control two independent drives or applications. The signal produced is electrical differential signal. The system works on 15 volts dc electrical supply that can be easily modified as per users requirements. The differential electrical signal produced has voltage variation between 0.1 to 14 volts. It also produces reverse action signal when reverse movement is initiated. The system is simple, stable, and reliable. It minimal tear and wear as no contact type components are used.

Index Terms— Optoelectronics; Joystick; Control Signal.

I. INTRODUCTION

Joysticks are available in many types and also in various input and output formats. Most of the joysticks that are available today have two mechanisms, which produce two axis signals depending on position of the stick. Resistive joysticks make use of two potentiometers placed on X and Y axis and produce independent signals that represent XY position. To drive and control electronic systems like wheelchairs or robots complex electronics is required using conventional joysticks. This is because, to drive two independent drives or electric motors independent driving signals or differential signals are required that moves the application in user defined direction with desired speed. Therefore, to generate this differential signal microprocessor based system is standard practice today. Although, resistive joysticks provide large voltage variations for this purpose, they suffer from wear and tear; and contact

voltages variation and also have problems related to linearity and interference. After going through the advantages and disadvantages of different types of joysticks available in the market an innovative concept has been conceived and realized. This consists of light emitting diodes, photo-detectors and a sliding optical template that convert movements of joystick into variable light output depending on the position of the joystick stick.

II MATERIALS AND METHODS

The construction of opto-electronic joystick is shown in fig. 1 bottom view. It consists of two identical base plates and one sliding template with optical window. The 'I' shaped sliding template is made up of acrylics sheet. The sliding template is fixed between two identical base plates. The small margin between fixed base plates permits it to slide between them with ease. As shown in figure, this 'I' shaped structure has two circles marked as 'A' and 'B'. They are LEDs and LDRs. LEDs along with light dependent resistors are fixed on windows 'A' and 'B' on either side of base plates. The arrow shaped sliding template has 'I' shaped window that decides transmission of light from the LEDs to reach LDRs on other side depending on the position of sliding template. The template is locked through slot 'E' that limits the movement of sliding plate in forward and reverse direction and maintains its stability over desired movements. Whereas, circular slot at front side allows circular movement of joystick handle fixed at 'D' slot. Another combination of LED and photo-detector is arranged at 'C' to detect reverse movement. These all components and base plates are aligned and fixed using four screws at the corners. Long handle stick with spring damping arrangement has been fixed at 'D'.

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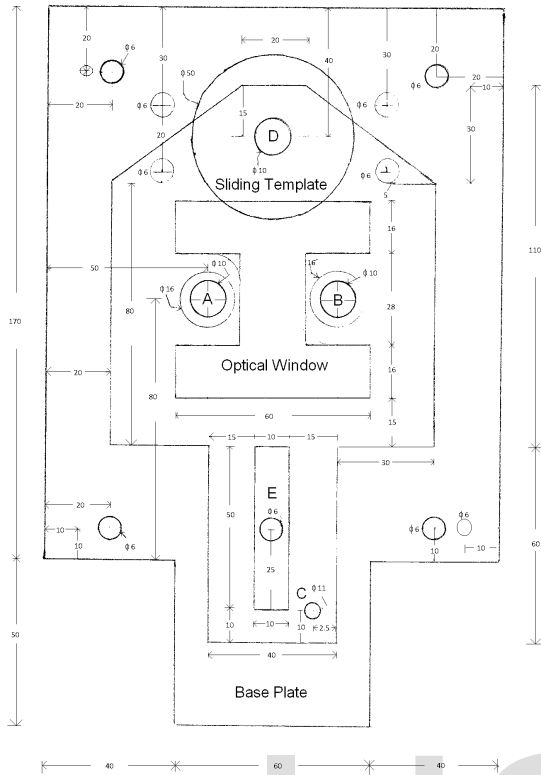


Fig. 1 Construction of Joystick

This whole assembly is finally fixed in a light proof metal container. Other components like voltage regulator, resistors and capacitor are fixed on the printed circuit board separately. The assembly is shown in photograph as Fig. 2.

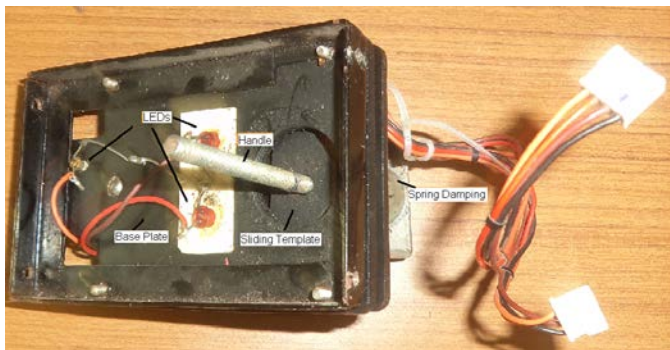


Fig. 2 Assembly of Joystick

As shown in the photograph the visible circle is the slot for joystick handle movement. The handle is fixed at the centre and has spring for damping. Two red LED visible are the light sources for two photo detectors. Two connectors provide two independent signals to control two drives.

The electronic circuit of opto-electronic joystick is shown in Fig. 3. The circuit is biased using voltage regulator IC 7815 that provides regulated voltage to the circuit components. L1 and L2 are red LEDs that work as light sources. Resistors R5 and R6 limit the current of LEDs. Counterparts of these LEDs are LDR1 and LDR2, which detect the light passing through 'I' shaped window of sliding template. They are provided biasing through R2 and R3. Junctions of LDR1 and R2; and LDR2 and R3 are the two independent outputs of joystick namely 'A0' and 'B0' that generate electrical signals proportional to joystick position. LED3 and photo-detector P1 is an arrangement to generate electrical signal 'C0' when reverse activity is initiated. The speed switch is used for speed selection. It has two positions 'A' and 'B'. When it is at 'A' position the series resistor 'R6' reduces the current fed to both the LEDs. This reduces the light output of LEDs. At position 'B' there is no resistor therefore the current is only decided by 'R5' and 'R7' only.

Overall operation of the joystick depends on intensity of the light. Therefore all operations of the joystick are contact free. This optical joystick has two work axes and it rotates around 360°. The joystick has three light emitting and three light detecting devices, and placement of these devices is done such a way that at a time three different values of control signal are generated.

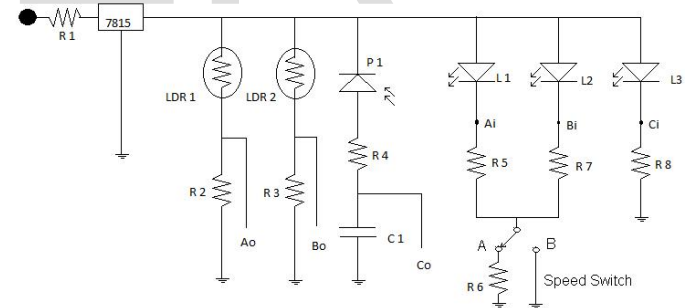


Fig. 3 Electronic Circuit of Joystick

As stated above LDR1 and LDR2 are fixed at slots 'A' and 'B' along with respective LEDs. Here, LDR1 and resistor R2 make voltage dividing network for 'A0' signal output, whereas LDR 2 and resistor R3 make another voltage dividing network that produces 'B0' signal. That means, if this joystick is used with electric wheelchair or robot then signal 'A0' drives left side motor and signal 'B0' drives right side motor.

Here, LDR1 with R2 is voltage divider network and corresponding voltage generated at 'A0' with respective to ground is given by following formula.

$$A0 = \frac{R2}{LDR1 + R2} V \dots\dots\dots (1)$$

In this circuit R2 is fixed, where as LDR1 is light dependent variable resistance. Its resistance is inversely proportional to the light falling from LED1. Depending on that light intensity, resistance of LDR1 changes and produces 'A0' signal that activates right movement.

Similarly, LDR 2 with R3 is another voltage divider network and it generates signal voltage 'B0' as shown by following formula. It activates left movement.

$$B0 = \frac{R3}{LDR2 + R3} V \dots\dots\dots (2)$$

The third opto-electronic combination using P1 photo diode and LED3 is only used to activate reverse movement. When it is activated by light entering through a slot provided for detecting reverse movement photodiode conducts and produces logic high condition that can be either used by the motor drive circuit to reverse the movements or relay network for appropriate action.

circle which is shown in between maximum reach and the handle is medium reach of the joystick handle. At rest the template is at its zero position. It closes all three light windows and doesn't allow light to reach detectors from light sources. As per fig.3, when the joystick is moved in forward direction the template moves forward and opens light windows 'A' and 'B' equally. This opening depends on the forward angle of handle. Therefore, the amount of light reaching to the detector depends on opening of light window. That means, amount of light reaching to detector is directly proportional to the forward movement. During right side movement of handle, the template moves right side; allowing left side detector to remain closed and right side detector to receive light through the window. This light reaching to the detector increases the conductivity of LDR resulting into rise in voltage at the junction of resistor and LDR. Same way, when the handle is moved towards left side, right side detector remains closed and opens left window, allowing light to reach left detector. This reduces its conductivity and produces voltage level proportional to light intensity.

The movement of joystick handles in the movement area in four quadrants and its resulting action are shown in Table 1. As mentioned in table, when the handle is in first quadrant as seen from the top, it activates left side motor resulting in to right side movements; and when it is in second quadrant it activates right side motor resulting in to left side movement. Same way, it activates right side reverse movement when the handle is in third quadrant and left side reverse movement when handle is in fourth quadrant.

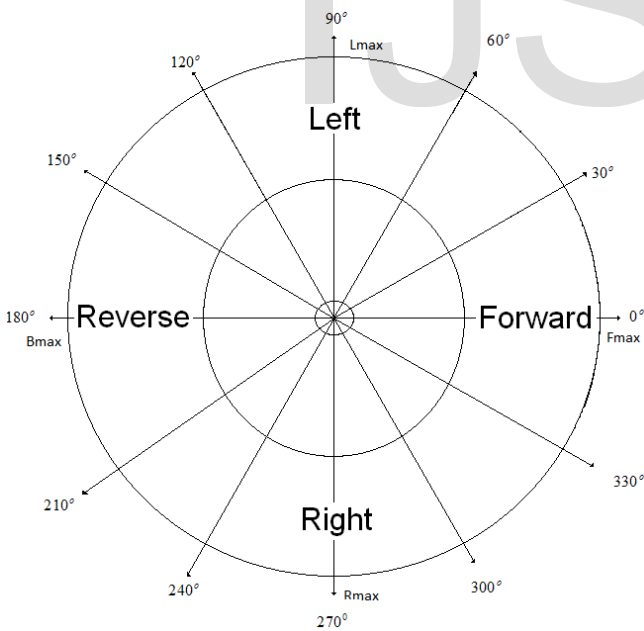


Fig. 4 Joystick Movement

Table 1 Joystick Action

Quadrant	Joystick Action	Movement
1 st	Forward + Left	Right
2 nd	Back + Left	Left
3 rd	Back + Right	Reverse-Right
4 th	Forward + Right	Reverse-Left

III RESULTS AND DISCUSSION

Results of opto-electronic joystick are recorded by referring joystick movement fig 3 and fig. 4. Output voltages are recorded at three angular positions: zero, middle and maximum. They are also recorded as Forward, Reverse, Right and Left in four quadrants at 0°, 90°, 180° and 270° respectively.

Here, right side and left side movements are presented separately. Electrical signal produced at 'A0' output due to right side joystick movement is shown in Table 2. At rest the handle is at zero and all windows are closed. Therefore, resistance of LDR is very high and the

Fig. 4 above shows the bottom view vector diagram of joystick. In this figure middle circle is joystick handle and outer circle is maximum reach of the handle and the

current is very small. Hence, voltage developed across the resistor is also very small. It is only 0.02 Volt. When the handle is moved forward or reverse direction the 'I' window also moves and light passes through the window to the LDR. The signal levels at medium and maximum positions are 8.5 and 14 volts respectively. While handle at right side, there is no variation in signal level; but when moved towards left side there is variation. The values obtained at middle and maximum level are 8.2 and 14 volts respectively. However, during reserve activity one more i.e. reverse logic signal is also produced separately by another network.

Table 2 Output Signal 'A0'

Position	Rest	Middle	Maximum
Forward	0.2 V	8.5 V	14 V
Reversed	0.2 V	8.5 V	14 V
Right	0.2 V	0.2 V	0.2 V
Left	0.2 V	8.2 V	14 V

Electrical signal produced at 'B0' output due to left side joystick movement is shown in Table 3. At rest the signal level is 0.1 volts. Just like 'A0' signal, when the handle is moved forward or reverse direction the 'I' window also moves and signal levels obtained at medium and maximum positions are 8 and 13.8 volts respectively. In contrast to 'A0' signal, here right side movement of handle produces voltage variation 7.8 volts and 13.8 volts at middle and maximum positions; and there is no variation during left side movement. The signal characteristics of both the networks are comparable.

Table 3 Output Signal 'B0'

Position	Rest	Middle	Maximum
Forward	0.1 V	8 V	13.8 V
Reverse	0.1 V	8 V	13.8 V
Right	0.1 V	7.8 V	13.8 V
Left	0.1 V	0.1 V	0.1 V

Results obtained by movement of joystick handle in 360° around the centre of joystick with middle position i.e. 50 percent mark as shown in fig. 4 are presented in Table 4 and shown graphically in fig. 5.

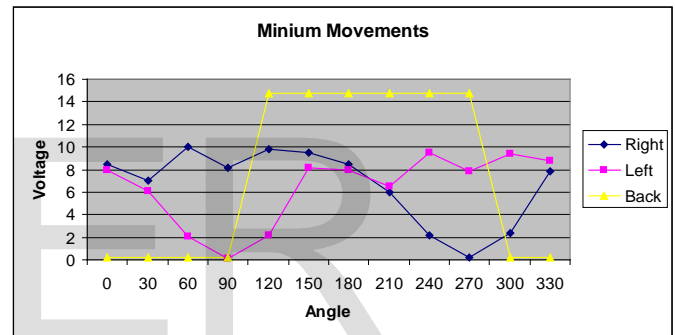
Table 4 Signal Output at Middle Position

Position Angle	A0 in Volts Right Blue	B0 in Volts Left Red	Back in Volts Yellow
0	8.5	8.	0.2
30	7.4	6.2	0.2
60	10	2	0.2

90	8.5	0.1	0.2
120	9.8	2.2	14.8
150	9.4	8	14.8
180	8.4	8	14.8
210	6	6.4	14.8
240	2.2	9.4	14.8
270	0.2	8.2	14.8
300	2.2	9.4	0.2
300	8	8.2	0.2

As shown in Table 4 and Fig. 5, when the joystick handle is moved through 360 degrees signal 'A0' varies between 0.2 volts to 9.8 volts. Similarly, the signal 'B0' varies between 0.1 volts and 9.4 volts. At 0° and 180° both the signal have almost zero output; and at 90° and 270° these signals have opposite values. The reverse or back status signal has 0.2 volts as logic '0' status and 14.8 volts as a logic '1'.

Fig. 5 Signal Output at Middle Position



This is further described using results obtained by movement of joystick handle in 360° with maximum position as shown in fig. 4.

Here, results are presented in Table 5 and shown graphically in fig. 6. In this exercise it is found that when the joystick is moved through 360 degrees signal 'A0' varies between 0.2 volts to 13.8 volts; whereas, the signal 'B0' varies between 0.1 volts and 14 volts. At 0° and 180° both the signals have almost zero output; and at 90° and 270° these signals have opposite values between 0.1 volts to 14 volts. It is clearly visible from the graph that between 0 to 180 degrees the signal 'A0' is stable around 13.8 volts and signal 'B0' is varying between 0.1 and 14 volts. Similarly, during 180 to 360 degrees signal 'A0' is varying between 0.2 and 13.8 volts; and 'B0' is stable at 14 volts.

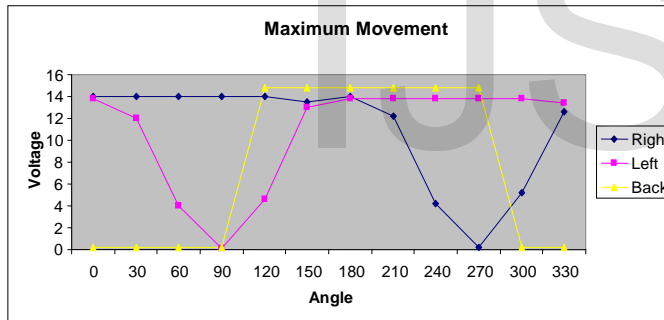
The reverse or back status signal has 0.2 volts logic '0' and 14.8 volts as a logic '1'. Switching between logic '0' and logic '1' takes between 90 and 270 degrees i.e. when handle is in second and third quadrant. This signal can be used to reverse the direction of wheelchair or

robot by initiating control in 'H' bridge circuit or relay bank.

Table 5 Signal Output at Maximum Position

Position Angle	A0 in Volts Right Blue	B0 in Volts Left Red	Back In Volts Yellow
0	13.8	14	14.8
30	13.8	12	14.8
60	13.8	4	14.8
90	13.8	0.1	14.8
120	13.8	4.2	0.2
150	13.4	8	0.2
180	13.8	12.4	0.2
210	11.8	14	0.2
240	4	14	0.2
270	0.2	14	0.2
300	4.2	14	14.8
300	12	14	14.8

Fig. 6 Signal Output at Maximum Position



IV CONCLUSION

The opto-electronic joystick produces three different control signals with minimum electronics. These three different signals can be used to drive electronic

wheelchairs, robots or any electro-mechanism that needs positional joystick. The control signals produced by this joystick have large voltage swing which is enough to drive any electronic driver or 'H' Bridges realized using MOSFETS or IGBTs. This also eliminates the need of dc amplifying circuit to enhance the signal to the desired level. Most of the joysticks produce 'X' and 'Y' signals depending on position of joystick. However, these signals need to be processed to have left and right control signals. In contrast, this joystick generates two independent differential signals directly that can be used to drive any electronic system without signal processing. The system works on 15 volts dc electrical supply that can be easily modified as per users requirements. It also produces reverse action signal when reverse movement is initiated. Non-contact concept employed here reduces the tear and wear and enhances the life considerably compare to other joysticks. As the joystick doesn't use any inductive or similar component that is susceptible to electrical interference it is free from electrical noise. And finally, it is simple, stable, low cost and reliable.

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