SESSION 3226

LASER OPERATED UTILITY CART

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Abstract

The objective of this undergraduate student project was to design a laser remote-controlled utility cart. The intent was to design and build the cart from discrete electronic components and mechanical parts utilizing a multitude of engineering disciplines the Engineering Technology program offered at the University of Maryland Eastern Shore.

The cart was required to perform the following motions; going forward, going in reverse, turning right, turning left and stopping. These motions were remote-controlled by laser light aimed at five different photoresistors embedded in the rear section of the cart.

Completion of a project required:

1. **Designing and constructing a laser controlled electronic circuit to operate the cart.**

2. **Designing and constructing a mechanical frame, assembling a drive mechanism to utilize an electrical DC motor to move the cart and a stepper motor to steer it.**

The electronic controlling circuit was designed and constructed on a prototype board so that students could modify or trouble shoot any malfunction section easily. The control circuit consisted of a laser switching circuit, clock generator, pulse sequencing circuit and relays to deliver high current to the DC and stepper motors.

The cart was assembled out of pine and blast wood to keep the weight down to a minimum. The cart's rear axle was coupled to the shaft of a DC motor with high torque that could move the cart forward and backward. Steering was done by a stepper motor in order to have better control during turning.

Introduction

Design of the laser operated utility car was a project in our ETEE 486 Design Technology course in the electrical engineering technology program. In this course students were expected to utilize their theoretical background to design an innovative project.

The main objective of this project was the use of laser as a means of controlling and operating the cart remotely. This method might have a potential application for guiding a real vehicle. The rear section of the cart had a housing for five photoresistors, each photo resistor was intended for moving the cart in a predetermined direction, when the laser light was aimed at the photoresistor. There was a photoresister strictly for each of the following actions; going forward, going reverse, turning right, turning left and stopping.

The completion of the project required students to design an electrical controlling circuit on prototype board; and to design and construct a mechanical frame, and a drive mechanism to move the cart and steer it.

Electrical Controlling Circuits

The controlling circuit was designed from discrete components and was assembled on two breadboards. These breadboards were located on top of the car for mobility. The five photoresistors embedded in the rear section of the car were used as the light (optical) switch. The photoresistors were recessed into wood and the inner diameter of the cavity painted black to reduce the environmental light reflection. A red ruby laser was used in this project. When laser light shined on a photoresistor, its resistance dropped from few hundreds of kilo Ohm to 1.3k Ohm. This drop of resistance was used in a comparator circuit shown in Figure 1 to generate 5 volts for the controlling circuits. The controlling commands for motion; forward, reverse, left, right and stops were produced by dedicate photoresistors located in the rear section of the cart for desired actions.

The control circuit shown in Figure 2 accepted the triggered outputs from the light switches and processed them accordingly. The stop, going forward, and going reverse signals were controlled through a 74279 set/reset latch. The forward and reverse were tied to reset and set respectively to allow a logic low or high to determine the rotation of rear wheels. Stop was used to terminate the power to the rear driving motor and to reset the circuit whenever forward or reverse was activated.

The left and right signals were used to produce a logic high or low respectively for biasing the NPN transistor during the process shown in Figure 3. The transistor acted as a current amplifier allowing it to operate an SPST relay. The relay allowed a clock signal to be fed into the pulse sequencing circuit ultimately to drive a stepper motor for precision steering.

The pulse sequencing circuit shown in Figure 4 generated a series of pulses necessary to operate a stepper motor. This was accomplished by applying a clock signal to a cascade JK Master/Slave Flip-Flop arrangement, to generate a multi-phase clock signals. During a positive transition of the clock signal the first JK-FF output was toggled. The second JK-FF was gated such that it would only toggle every other period with respect to the first. The signals were decoded to generate a pulse sequence. Since the stepper motor was a four-pole motor, only four individual pulses were necessary. The angular rotation of the motor was controlled by an inverter that enabled a NAND (7400) while disabling the

other NAND producing the pulse sequence to change from Pulse A,B, C, and D to D,C,B then A.

The front steering drive circuit was composed of a four-pole stepper motor allowing precise angular displacement in 7.5 degree increments. The individual poles of the stepper motor were connected in series with the collector of NPN transistors for current amplification allowing the motor to be operated by a standard TTL level signal. The motor was operated by a pulse present at the base of the transistor, which would tun on the transistor allowing 12V DC voltage across each motor's pole with the necessary current to drive the motor. A diode was placed in parallel with each motor's pole to reduce transients produced by the motor's inductor caused by driving pulses.

The rear drive circuit incorporated the use of relays, due to a need for low contact resistance. The SPST relay acted as a circuit breaker terminating the field in the DC motor. The DPDT relay was a polarity inverter, changing positive 12V DC to negative 12V DC, to reverse the rear wheel rotation. Transistors used as switches to activate the relays allowing a reliable interface to preceding TTL circuitry. A 1k Ohm potentiometer was placed in series with the motor to allow manual adjustment of the motor's initial torque and terminal angular velocity.

The clock generator circuit shown in Figure 6 was structured around an LM555 timer ship. The components were chosen to allow a range of frequencies between 40 and 80 Hz. These frequencies were chosen because they were found to provide optimum steering at high and low velocity. The clock duty cycle had no effect on steering due to the pulse sequencer being an edge triggered device.

To power the system a 12V DC dry cell battery was used allowing ample current necessary to drive the associated motors. However, the 5V DC power supply was designed by using an LM7805 voltage regulator with built-in ripple suppression, which powered the TTL chips. The power supply has an on/off indicator and was fused for 3 amps of current.

Mechanical Drive Mechanism

The cart body was made of 1/4 inch pine blast wood shaped like a trapezoid with sides of 12, 10, 12 and 4 inches. The 10 inch long piece was the rear section and the 4 inch long piece was the front of the cart. The front wheel was coupled directly to the shaft of a stepper motor passing through a yoke for ease of steering. The rear axle had a gear reduction box and was coupled to a DC motor. To balance the weight of the cart a brace was used to transfer some of the weight from the center of the cart to the rear axle. Figures 7 and 8 show the side and top view of the designed cart.

Conclusion:

The cart functioned as anticipated however, problems were encountered. The initial problem was with the front steering assembly, being made of a dense metal (iron), it had a

high moment of inertia. This caused the wheel to run more than desired when pulsed. A yoke type of assembly was incorporated which in turn reduced its weight and ultimately its moment of inertia.

Another problem was excessive weight of the cart itself. Initially the body made from wood weighing 4.051 lbs, caused the cart to have trouble starting. An adjustment of the 1k potentiometer temporarily overcame this, however, the problem was rectified by building another body of blast pine wood using thinner design. The new body weighed 1.20 lbs., ultimately resulting in a 30% weight reduction of the cart.

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BIOGRAPHICAL INFORMATION

Mohammad Fotouhi is an associate professor of Electrical Engineering Technology at the University of Maryland Eastern Shore. He received his Ph.D. in Power System Engineering from the University of Missouri-Rolla, M.S. from Oklahoma State University and B.S. from Tehran Polytechnic College. He has been conducting a practical research on growth and characterization of diluted magnetic semiconductor since 1986. He is a member of Etta Kappa Nu Honor Society and IEEE. He was Chairman of Student and Industry Relations and Host Committee member of IEEE Conferences on: Power System Computer Application (PICA ‘91), and Power Engineering Society, Winter Meeting, (PES ‘95) both held in Baltimore, Maryland.