

DEVICE FOR SYNCHRONIZED ROTATION

Shuh Jing Ying, Rufael Berhane and Rajiv Dubey
*Department of Mechanical Engineering
University of South Florida
Tampa, Florida, U.S.A.*

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Abstract: This device makes two shafts rotating in synchronized angular displacement. The sensors are potentiometers. The device is designed for use in a driving simulator. The first shaft is connected to a steering wheel and controlled by a driver so this shaft is the master, the second shaft is connected to the computer software that displays the surrounding sceneries, therefore this shaft is the follower. The two shafts must be rotated in synchronized mode and accurately. Major components in this device are operational amplifiers, NAND gates, power MOFET and relays. Details in design and manufacturing are reported in this paper. This device may be used for any place that requires two shafts rotating synchronically.

1 INTRODUCTION

Electronic Mobility Control Co.(EMC) developed an Advanced Electronic Vehicle Interface Technology (AVEIT) that converted the steering wheel, gas pedal and brake pedal in a car into one joystick. Based on the EMC system, we are building a driving simulator for training disabled person to drive by using a joystick for gas, brake and steering. The forward movement of joystick is for gas pedal, backward for brake, and right and left for steering. However it is really difficulty for a person to drive a real car without going through a simulator. A simulator to be built is similar to an airplane simulator for training pilot to drive an airplane. But it is not so simple to build a driving simulator, many man powers are required to work on the project from design, computer software, and manufacturing. Because of the limited man power and financial resources, we bought a regular car simulator from Simulator Systems International (SSI). It has three screens to show the surrounding sceneries for the driver to see. We hope to build a device that can make EMC and SSI systems working simultaneously. That is the whole purpose of this project.

There are two possibilities for reaching the synchronized rotation, mechanical and electrical devices. After a length consideration the final decision was on electrical approach.

Once electrical device is chosen we looked into existing literature but to our surprise we could not find any in our library or any nearby libraries. Although we were pretty certain that synchronized motors have been used in large airplanes but no information is found. Anyway the existing device may not fit what we need.

So we start to design a circuit for our purpose and we build the device exactly as we want. The details are given in this paper. After the device is completed certainly we had quite extensive test to check out every part. However we have not reached to the point to train a disabled person actually to drive.

2 DESIGN OF THE CIRCUIT

The circuit required is to operate a motor which has enough power to rotate the steering mechanism of the SSI system. The directions of rotation can be clockwise and counterclockwise. The size of motor is chosen to be similar to the servomotor used in the EMC system. The input power of the motor is 93 watts with torque of 8.7 n-m. The motor is a geared DC motor. Because there is no precise position required in the operation analogue circuit is chosen in the design. Potentiometers are used for the position indicators and relays are used for the control of the motor.

2.1 Differential Amplifier

The difference of the voltage signals from the potentiometers are to be amplified. Positive signal will make the motor to rotate in one direction and negative signal then will rotate in the other direction. A bipolar op amp, AD706, is chosen to build a differential amplifier. The schematic circuit diagram is shown below.

It will be idea if the amplifier is very sensitive to the input voltage and the dissipation power is not very large as compared to the motor power. The output voltage is given by

$$V_{out} = (V_{in\#1} - V_{in\#2}) \left[1 + \frac{R_4}{R_3} \right]$$

for $R_1 = R_4$ and $R_2 = R_3$

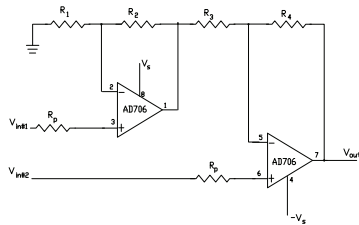


Figure 1: Differential Amplifier.

See Ref. 3 for details. The specification of AD706 is given in Appendix.

2.2 NAND Gate

Because the output voltage of AD706 is not high enough to turn on the power MOSFET to operate the relay, a NAND gate is used to further amplify the positive signal. NTC4011B is chosen for achieving this purpose. NTC 4011B is a 2 input positive logic NAND gate. There are four NAND gates in one IC. The specification of NTE4011B is given in Appendix. One input of the first NAND gate is connected to a fixed positive voltage, hence only positive signal will go through the first NAND gate. Two of the 4 NAND gates are used for amplifying the positive signals when the output of AD706 is positive. However when the output of AD706 is negative we must lead the signal to go to other branch and to make the motor to turn in another direction. A negative latch is used for that purpose.

2.3 Negative Latch

A negative latch is a resetable memory block. The output goes to high as soon as the input signal goes

to negative. This is exactly we need for the output of AD706 goes to negative.

Two NAND gates are needed. The circuit diagram is given as follows

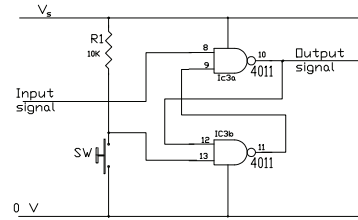


Figure 2: Negative Latch.

2.4 Power MOSFET

A power MOSFET is a specific type of Metal Oxide Semiconductor Field-Effect Transistor. It is designed to handle large power. IRFP250N is chosen for this circuit. When the voltage applied to G reaches 12 v, the switch is turned on from S to D. The specification of IRFP250N is given in appendix.

2.5 The Circuit Diagram

With some details given above, the whole circuit can be presented as shown in Fig 3. The input signals are from the potentiometers, one is connected to the EMC system and one is with SSI system. These signals go through the differential amplifier AD706. When the difference is positive, the signal goes through the upper branch in the circuit diagram because one of the inputs in the NAND gate TC4011 is set to +5Vdc. This positive signal then turn on the power MOSFET and make the motor to rotate. As the output of AD706 is negative, the signal triggers the negative latch and the power MOSFET in the lower branch in the diagram is turned on consequently the motor is turning in the another direction.

However, when the circuit was tested, the motor will rotate back and forth as the input difference of AD706 is nearly zero. This will severely shorten the life of the motor. The power supplies in the circuit are using voltage dividers. This is only for the saving of space in the device.

Also we experienced the lives of IC's are very sensitive to the voltages applied. Follow the specifications carefully, is very important. That is why all the specification are attached in appendix.

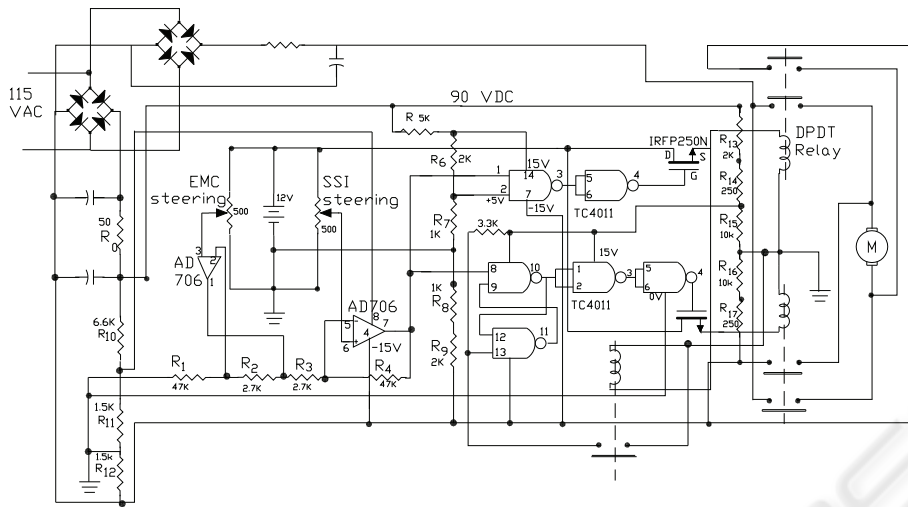


Figure 3: Circuit Diagram for Synchronized Rotation.

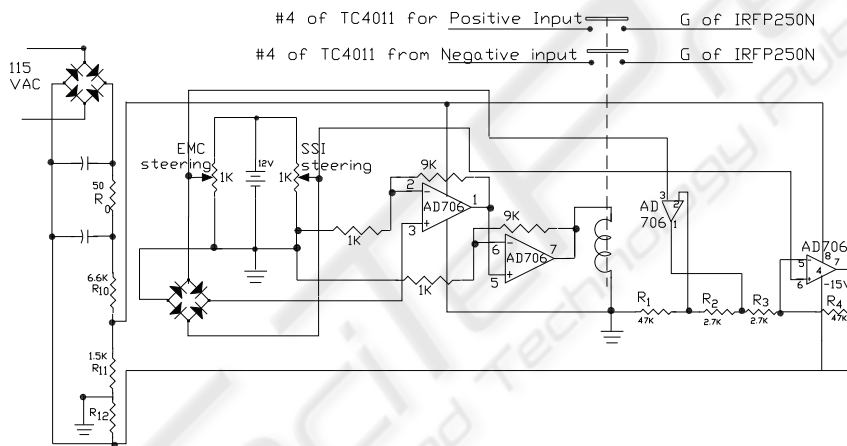


Figure 4: Modified Input Circuit.

2.6 Modified Input Circuit

To stop the rotation of the motor as the input of AD706 is nearly zero. The outputs of NAND gates and the inputs of the power MOSFETs are disconnected. The connection of these wires are controlled by this modified input circuit that is shown in Fig 4. Note that in this circuit the input to IC AD706 is through a full wave rectifier. When the signal is nearly zero, the voltage is not strong enough to trigger the relay in this circuit so that the relay in the previous diagram will not be turned on. Consequently the motor will not be turned on. Now as the EMC steering wheel rotates approximately 45°, the motor will start to rotate in the same direction. And the motor will stop as the difference between the potentiometers is within 45°. This operation is considered as perfect.

3 CONCLUSIONS

Although this device is aimed originally for the use of the synchronized rotation in a driving simulator, actually it can be used in many other places requiring a synchronized rotation. Because of this, the information presented here could be invaluable to many research workers in this community. On the other hand this circuit is rather simple and easy to follow, mechanical engineers can use it. The device has been tested extensively in the simulator and it is working perfectly well. However, the simulator has not been used for training disabled person to drive. This is considered as the next phase of our work. Just to make the information completely presented. The specifications of IC's are given in appendix.

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APPENDIX

AD706 – SPECIFICATIONS

Features:

High DC precision.

100 μ V max offset voltage

1.5 μ V/ $^{\circ}$ C max offset drift

200 pA max input bias current

0.5 μ V p-p voltage noise, 0.1 Hz to 10 Hz

750 μ A supply current

Maximum Ratings:

Supply Voltage.....18V

Internal Power Dissipation

(Total: Both Amplifiers).....650mW

Input Voltage..... V_s

Differential Input Voltage.....0.7V

Output Short Circuit Duration.....Indefinite

Storage Temperature Range.....-65 $^{\circ}$ to +125 $^{\circ}$ C

Operating Temperature Range

AD706J.....0 to +70 $^{\circ}$ C

AD706A.....-40 to +85 $^{\circ}$ C

Lead Temperature(Soldering 10sec).....300 $^{\circ}$ C

Notes:

Stresses above the maximum ratings may cause permanent damage to the device. This is a stress rating only. Exposure to max rating conditions for extended periods may affect device reliability. The input pins of this amplifier are protected by back-to-back diodes. If the differential voltage exceeds 0.7 V, external series protection resistors should be added to limit the input current to less than 25 mA.

TC4011-SPECIFICATIONS

The TC4011B is a quad 2 input NAND gate.

Maximum Ratings:

DC Supply voltage.....18 V

Input voltage.....18.5 V

Output Voltage.....18.5 V

DC input current.....10 mA

Power dissipation.....300 mW

Operation Temperature range.....-40 to 85 $^{\circ}$ C

Storage Temperature range.....-65 to 150 $^{\circ}$ C

IRFP250N-SPECIFICATIONS

Maximum Ratings:

I_D , continuous drain current.....30A

I_{DM} , pulsed drain current.....120A

Power dissipation.....214W

Gate to source voltage.....20V

Single pulse avalanche energy.....315mJ

Avalanche current.....30A

Repetitive avalanche energy.....21mJ

Peak diode recovery.....8.6V/ns

Operating temperature range.....-55 to 175 $^{\circ}$ C

Soldering Temperature (10 sec).....300 $^{\circ}$ C

Mounting Torque.....1.1 N-m (10 lbf-in)