DEVICE FOR SYNCHRONIZED ROTATION

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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, and therefore this shaft is the follower. The two shafts must rotate 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.

Keywords: Synchronization Synchronized Rotation.

I 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 the joystick is for the gas pedal, backward for brake and right and left for steering. However it is really difficult 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 operate an airplane. But it is not so simple to build a driving simulator, many man powers are required to work on the project for design, computer software, and manufacturing. Because of the limited man power and financial resources, we bought a regular car simulator from Simulator System International (SSI). It has three screens to show the surrounding sceneries for the driver to see. We need 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 university library or any nearby libraries. Although we were pretty certain that synchronized motors have been used in instrumentation of large airplanes but no information is found. Anyway the existing device may not fit what we want, so we start to design the circuit all by ourselves.

II 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 direction 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 power of the motor is 93 watts with the 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 indication and relays are used for the control of motors.

2.1 Differential Amplifier

The difference of the voltage signals from the potentiometers is 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 ideal if the amplifier is very sensitive to the input voltage and the dissipation power is not very large as compared to the motor power.

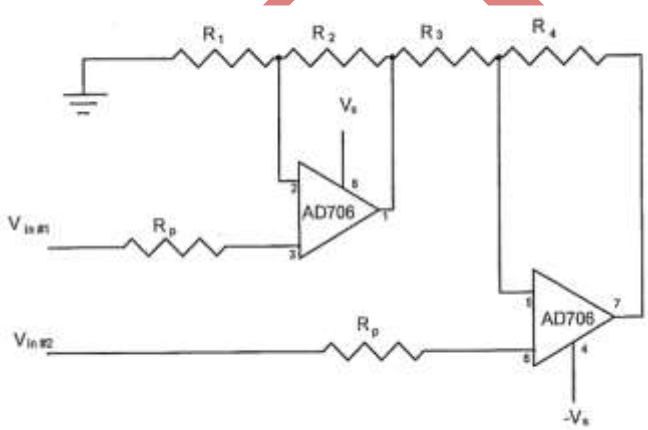

Figure 1 Differential Amplifier

The output voltage is given by

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

For R_1=R_4, and R_2= R_3.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. TC4011 is chosen for achieving this purpose. TC4011 is a 2 input positive logic NAND gate. There are four NAND gates in one IC. The specification of TC40 11 is given in Appendix. One input of the first NAND gate is connected to a fixed positive voltage, hence only a 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 resettable memory block. The switch is closed when input signal is positive. The switch opens and the output goes to high as soon as the input signal goes to negative. This is exactly we need. Two NAND gates are needed. The circuit diagram is given as follows

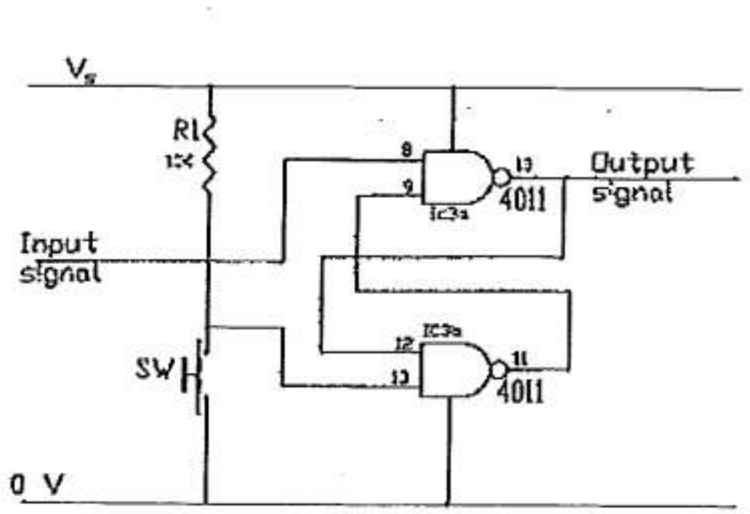

Figure 2: Negative L a t c h

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 NTC40 lIB is set to +5 vdc. This positive signal turns on the power MOSFET and makes the motor to rotate. As the output of AD706 is negative, the signal triggers the negative latch and the power MSFET in the lower branch in the diagram is turned on, consequently the motor is turning in the another direction.

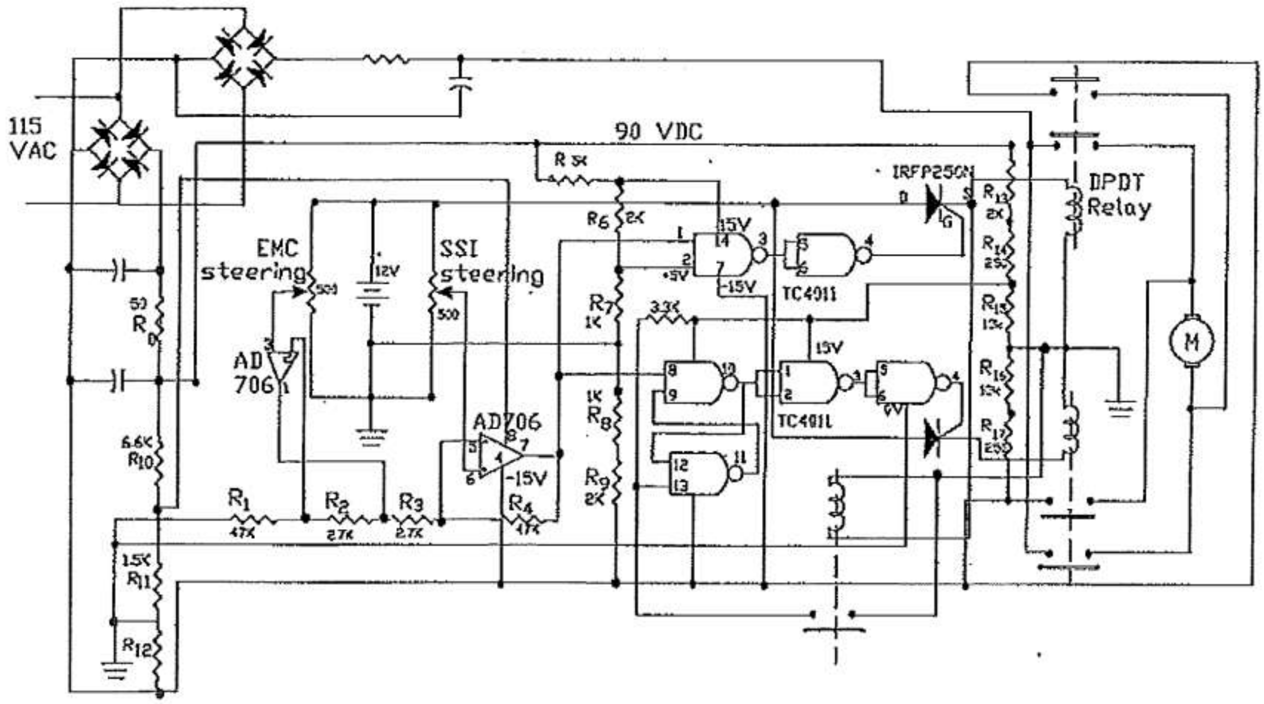

Figure 3: Circuit Diagram for Synchronized Rotation

However, when the circuit was tested, the motor will rotate back and forth rapidly as the input difference from AD706 is nearly zero. This will severely shorten the life of motor. So the circuit is modified and brief explanation is given in Section 2.6. The power supplies in the circuit are using voltage dividers. This is only for the saving of space and cost for the device.

Also we experienced that the lives of IC's are very sensitive to the voltages applied. Follow the specifications carefully is very important. This is why all the specifications are attached in Appendix.

2.6 Modified Input Circuit

To stop the rotation of the motor as the input of AD706 is nearly zero, the output of the NAND gates and the input of the power MOSFETs are disconnected. The connection of these wires is controlled by this modified input circuit as 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 output of AD706 is not strong enough to trigger the relay in this circuit so that the relays for the motor will not be turned on. Consequently the motor will not be turned on. Now the EMC steering wheel rotates approximately 45° the motor in SSI will start to rotate in the same direction. And the motor will stop as the difference between the potentiometers is within 45°. Since when we make a turn the steering wheel is usually turned more than 180°, the addition of 45° is not significant. To make a small correction on a straight road the additional 45° is a problem. If this is not acceptable, then the circuit should go back to the original one. However we tested it in our simulator, after several tries we find that is acceptable, so this circuit is kept working for our simulator.

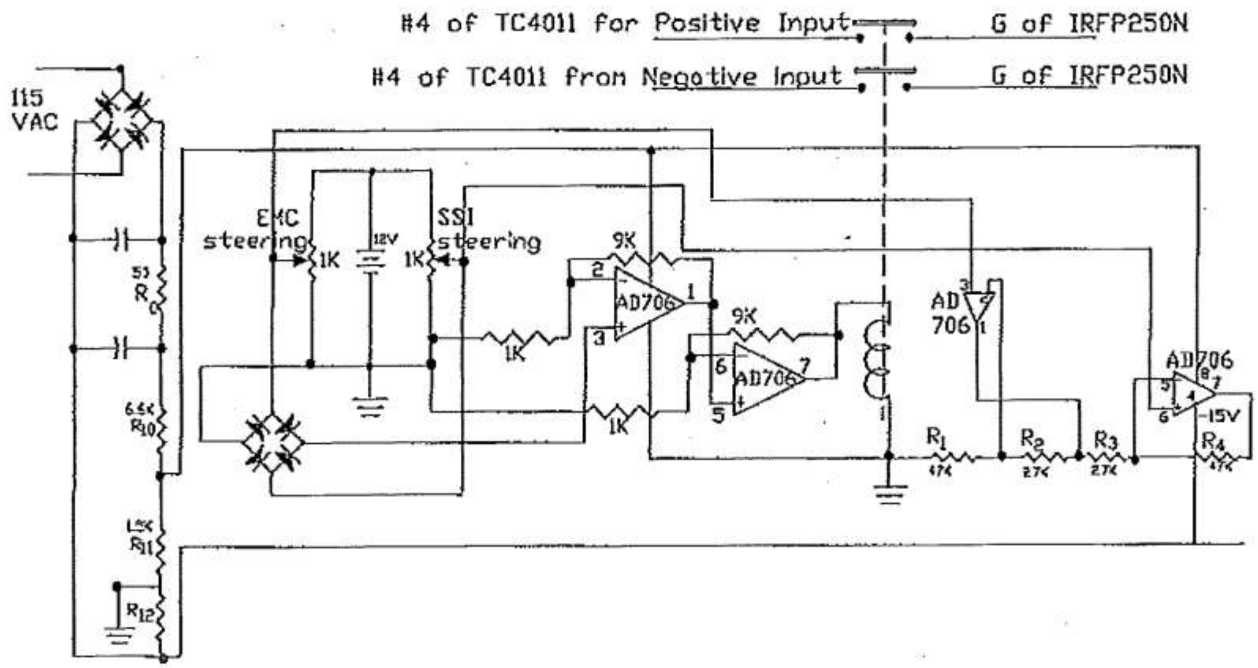

Figure 4 Modified Input Circuit

III 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 the circuit is rather simple and easy to follow, mechanical engineers can use it. Just to make the information completely presented. The specifications of all IC's are given in Appendix.

REFERENCES

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APPENDICES

AD706 - SPECIFICATION

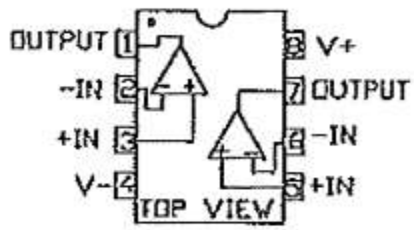

Fig. 5 Connection Diagram

Features:

High DC precision, 100 IlV max offset voltage 1.5 µV/°C max offset drift

200 pA max input bias current 0.5 µV p-p voltage noise, 0.1 to 10 Hz 750 µA supply current

Maximum Ratings:

Supply Voltage……….. 18 V Internal Power Dissipation……….650mW Input voltage……..Vs

Differential input voltage... 0.7 V Output short circuit duration…... indefinite

Operating temperature range: AD706J…. .0 to +70°C; AD706A ….._40°to +85°C

Lead Temperature (Soldering 10 sec).... 300°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 TC4011 is a quad 2 input NAND gate. The pin assignment is given below:

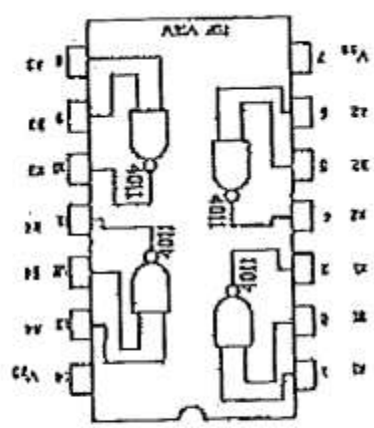

Fig. 6: Pin Connections for TC4011

Maximum Ratings:

DC Supply Voltage……..18V

Output Voltage…………18.5 V

Power Dissipation………300 mW

Input Voltage……………………..18V

DC Input Current………………..10mA

Operation Temperature Range…..-40 to 85°

Storage Temperature Range…-45 to 150°C

Note: Exceeding any of maximum ratings even briefly, lead to deterioration in IC performance or even destruction.

IRFP250N SPECIFICATION

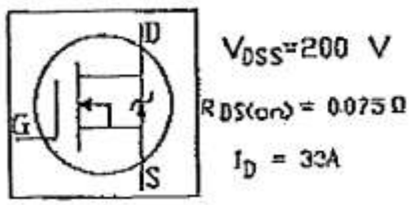

Fig.7: Schematic Diagram of IRFP250N

Maximum Ratings:

I_D Continuous Drain Current…………..30 A

Power Dissipation……………………214 W

Single Pulse Avalanche Energy……....315 mJ

Repetitive Avalanche Energy…………..21 mJ

Operating Temperature Range……..…-55 to 175°C

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

I_{DM} Pulsed Drain Current……120 A

Gate to source Voltage………20 V

Avalanche Current…………....30 A

Peak Diode Recovery…………..8.6 V/ns

Soldering Temperature (10 s)….300°C