GLOLAB

Two Wire Stepper Motor Positioner

Introduction

A simple and inexpensive way to remotely rotate a display or object is with a positioner that uses a stepper motor to rotate it. The motor is driven by a circuit mounted near the motor and by a control circuit at a remote location. Power for the motor and its driver circuit and for the signals that control the speed and direction of the motor are all carried over a single two conductor cable. This is a device that will remotely position an object on command to any desired rotation at an adjustable speed in small steps. The object can then be left in that position until a different rotation is desired or it may be continuously rotated in steps.

How it works

Motors

Almost any two phase (sometimes called four phase) unipolar stepper motor with a voltage rating of from 9 to 24 volts and a current rating of 900 milliamps or less may be used. A unipolar motor has two center tapped windings with six leads and has its voltage and either its current or resistance marked on the nameplate. Another motor characteristic is its stepping angle which is also marked on the nameplate. An angle of 1.8 degrees or less is preferred because each step is smaller but 7.5 degrees or even more can be used. Although many surplus motors come without a wiring diagram, you can easily find the correct connections with an ohmmeter. Figure 1 is a diagram of a typical stepper motor. The winding resistance will be a few hundred ohms or less. To find the center tap first measure between any two leads. If you measure an open circuit try again until you get a reading and then record its value. Number these leads 1 and 2. Connect the meter to lead 1 and a lead other than 2 until you get another reading and then number it 3. If this value is the same as the 1-2 value then lead number 1 is the center tap. If it is twice the 1-2 value then lead number 2 is the center tap. Make a note of which lead is the center tap as this lead will be connected to the +V power. Repeat the above procedure for the remaining leads numbering them 4, 5 and 6 to find the center tap of the second winding. The motor voltage is not very critical. A lower than rated voltage may be used with a resulting lower torque. You should expect your stepper motors to run very warm or even hot because power is applied to two windings at all times. You may have seen specifications or applications that use a resistor in series with the center tap of each winding. Their purpose is to maintain a more constant torque at high speeds and are not necessary for low speed operation. When resistors are used, a higher than rated voltage is applied and the excess voltage is dropped across the resistor. At high speed as the motor impedance increases more voltage drops across the motor and less across the resistor to maintain a more constant torque. A constant current driver circuit would do the same thing.

Control circuit

Figure 2 is a diagram of the control circuit built on a 1.45 X 1.8 inch PC board. IC1 is an LMC555 CMOS timer that generates a 200 microsecond wide clock pulses to step the motor and control its speed. The speed can be varied by changing the pulse repetition rate with R1. The negative going clock pulses at pin 3 of IC1 drive the gate of Q1, an IRL530N power FET that momentarily turns OFF and disconnects the driver board from ground. These power interruption sends pulses to the motor driver circuits that cause the motor to step. Motor speed is controlled by the rate of the interruptions and direction is controlled by the polarity of the voltage applied to the driver circuit through interconnect lines L1 and L2. Bipolar MPSA05 NPN transistor Q2 and MPSA55 PNP transistors Q3 and Q4 invert the pulse from pin 3 and pull the drain of Q1 UP when it is OFF. Pushbutton S2 starts and stops the motor by turning the clock on and off. Toggle switch S1 sets its direction by switching polarity. Power for the motor is provided by DC wall transformer T1 and filter capacitor C2. Five volt regulator IC2 and filter capacitor C3 supply power to IC1.

Driver circuit

Figure 3 is a diagram of the motor driver circuit built on a 1.7 X 2.2 inch PC board. The motor is driven by four IRL530N power FETs having very low ON resistance of 0.1 ohms resulting in very little voltage drop and almost no heat. These FETs have a logic level gate threshold making them ideal for use in circuits powered by 5 volts. They were also chosen for their specifications of 60 volts at 15 amperes. FETs Q2, Q3, Q4 and Q5 are driven by CD4013 dual D type flip flop IC3A and IC3B, each having dual phase outputs that latch either Q2 or Q3 ON and either Q4 or Q5 ON, depending on the state of the flip flops. Current flows through one half of each motor winding at all times. Each flip flop has its data input cross coupled to the other flip flop's output through a CD4070 exclusive OR gate in IC4. The cross coupling between flip flops causes them to change state alternately when simultaneously triggered. The sequence of change, IC3A before IC3B or IC3B before IC3A, is controlled by the exclusive OR circuits that feed data into pins 5 and 9 of IC3. This sequence change controls the direction of the motor. A DOWN or UP level passing from L1 through D3 to direction control pins 2 and 6 of IC4 determines weather it will invert or non-invert the data applied to its input pins 1 and 5.

Both the clock and the direction control data are carried to the driver board over the same wires that power the motor. If L1, figure 3 is positive then the motor will rotate left when IC3 is triggered by a clock pulse. If L2 is positive then the motor will rotate right. The motor steps when the voltage across L1 and L2 goes DOWN and then goes UP again producing a clock pulse. The UP transition feeds through D4 or D5 and R8, depending on the polarity of L1, L2, into clock input pins 3 and 11 of IC3. Zener diodes D4 and D5 serve the dual purpose of coupling the clock pulses into IC3 and acting as a transient voltage suppressor. High voltage spikes caused by switching, that may appear across L1, L2 will pass through the forward conduction of one of these diodes and through the reverse zener breakdown of the other, thus clamping the L1, L2 voltage to a maximum of about 33 volts. C4 delays the rise of the clock pulse so it arrives later than the direction control pulse at IC4. D2 improves the discharge of C4 through R9. Power is supplied to the motor and the circuits through bridge rectifier BR1 which rectifies the L1, L2 input into a positive output. Power for IC3 and IC4 also passes through 5 volt regulator IC5 and is further filtered by C6. D6 clamps inductive spikes from the motor.

Some unpredictable motion may occur when the direction is changed. This is caused by a pulse or pulses that are generated when the polarity is switched. These pulses appear to the circuits as clock pulses. This is usually not objectionable when the positioner is used to rotate a display or similar object.

Construction

Control Board

Install all resistors, D1, IC2 and all capacitors except C2. Install a jumper made from an excess resistor lead, the IC socket, terminal block, Q1 - Q4 and IC2. Install C2, the wires for R1, S1, S2 and T1. Connect the wires to R1, S1 and S2. Solder the leads from a DC wall transformer to the PC board holes marked +V and -V. Use a transformer with a voltage rating similar to that of the stepper motor and a current rating a little more than twice the motor current rating. Plug IC1 into its socket being careful to handle it as a static sensitive device and your control board is complete. The control board may be mounted in a suitable enclosure with R1, S1 and S2 accessible from the top or front.

Driver Board

Install all the resistors, capacitors, diodes and IC5, then two jumpers made from excess resistor leads. Next install the IC sockets and terminal block. Insert and solder power FETs Q2 through Q5 being very careful to handle them as static sensitive devices. Plug IC3 and IC4 which are also static sensitive devices into their sockets and your driver board is complete.

Installation

Most stepper motors have a 1/4 inch diameter shaft. You can mount a flat faced knob on the motor shaft using the knob set screw to hold it in place. The object to be rotated can be attached to the knob using a self-adhesive Velcro fastener. You can keep the motor from rotating more than 360 degrees if this is desirable by using a long screw as a mechanical stop in one of the motor mounting holes. Another long screw used in place of a knob set screw will stop against it. If the knob slips on the motor shaft, file a small flat on the shaft for the set screw to rest against. If you have access to a machine shop even better mounting schemes can be devised including weather protection for outdoor use.

Solder the motor center tap leads to the holes marked +V on the PC board and the remaining leads to the holes marked A, B, C and D as shown in the schematic. Be sure that the leads from one winding connect to A and B. The leads of the other winding should connect to C and D. Mount the driver circuit board near the motor. The current rating of the motor used is limited by the 2 ampere current rating of bridge rectifier BR1.

Although stepper motors that run on 9 to 24 volts can be used, care must be taken when using a 24 volt wall transformer, that the voltage applied to the control board never exceeds 30 volts. Many transformers supply more than their specified voltage when unloaded or lightly loaded. When using a 24 volt transformer, be sure that the motor is connected and the L1, L2 terminals are interconnected before applying power. Voltages in excess of 30 volts may damage regulator ICs, capacitors and diodes. Power to the stepper motor should be maintained to keep the object pointed in the desired direction. Stepper motors have a small amount of holding torque with no power applied but wind or other forces could overcome this torque and cause the object to move.

A positioner has been run with 500 feet of 22 gauge wire connecting the control and driver boards while using a 16 volt 200 milliamp motor. Heavier gauge wire is preferred for lower voltage drop and should be used for greater distances or larger motors.

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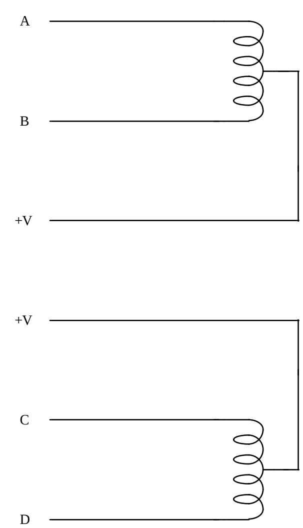
Stepper Motor Camera Positioner



STEPPER MOTOR

FIGURE 1

Glolab Corporation
134 Van Voorhis
Wappingers Falls, NY 12590
http://www.glolab.com
email kits@glolab.com
fax (914) 297-9772

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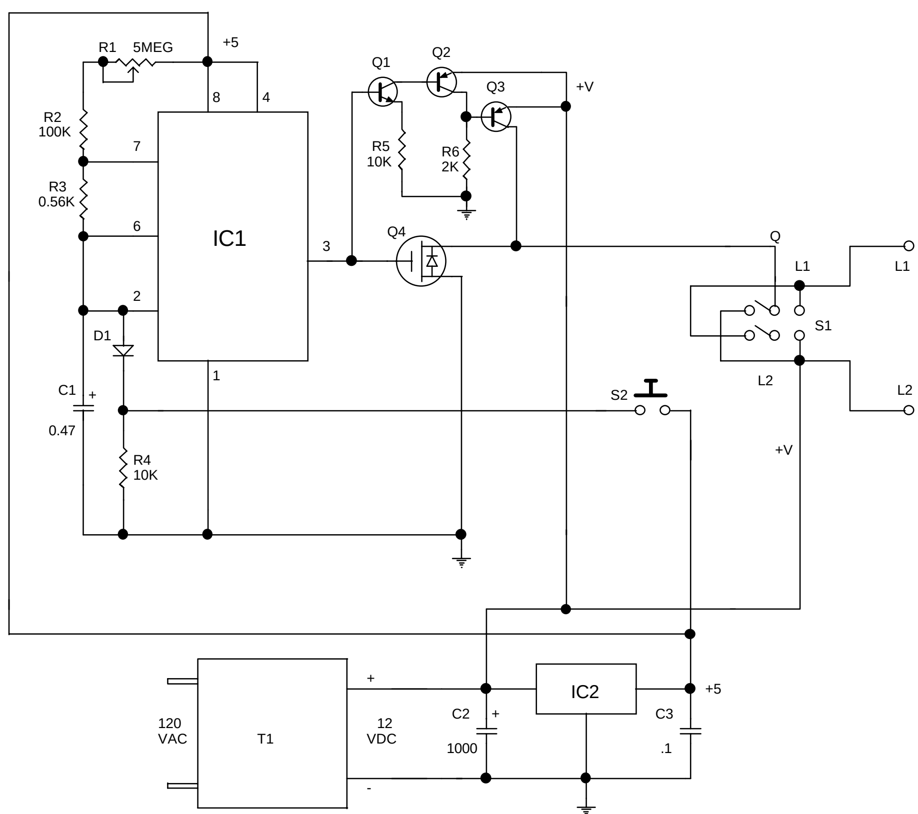
Two Wire Stepper Motor Positioner



TWO WIRE STEPPER MOTOR POSITIONER FIGURE 2

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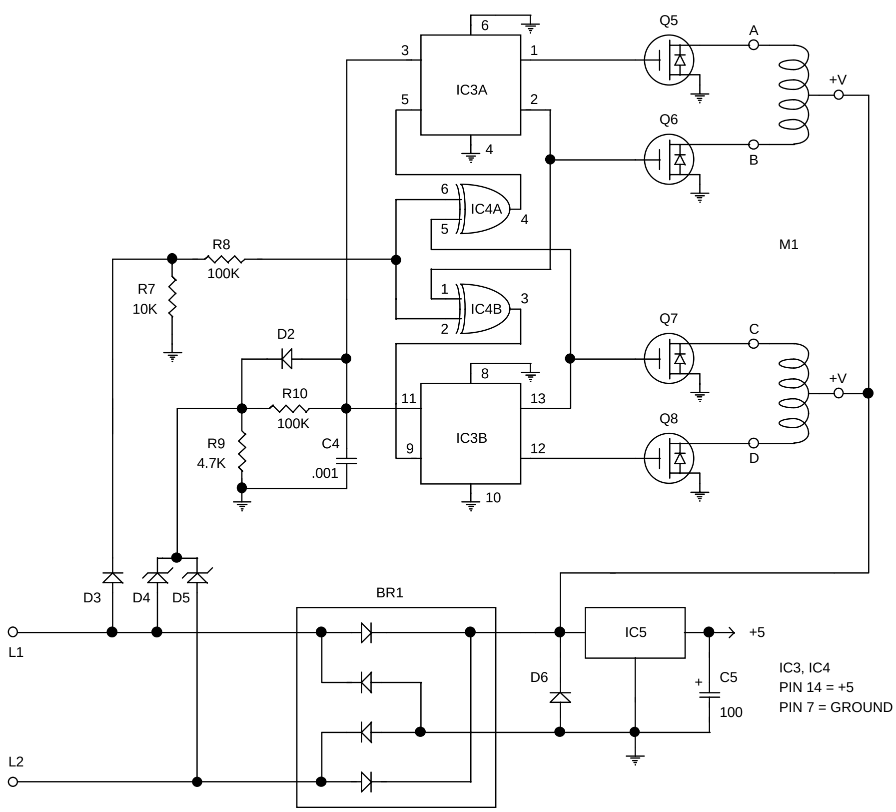
Two Wire Stepper Motor Positioner



TWO WIRE STEPPER MOTOR POSITIONER

FIGURE 3

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TWO WIRE STEPPER MOTOR POSITIONER PARTS LIST

DESCRIPTION	SOURCE	PART NUMBER
R1 - 5MEG potentiometer	Mouser	31VA605
R2, R8, R10 - 100K 1/8 watt 5%	Digi-key	
R3 - .56K 1/8 watt 5%	Digi-Key	
R4, R5, R7 - 10K 1/8 watt 5%	Digi-Key	
R6 - 2K 1/8 watt 5%		
R9 - 4.7K 1/8 watt 5%	Digi-Key	
C1 - .47 MFD 35 volt tantalum	Mouser	581-0.47K35V
C2 - 1000 MFD 35 volt electrolytic	Mouser	539-SKR35V1000
C3 - .1 MFD 50 volt metalized film	Digi-Key	
C4 - .001 MFD 50 volt metalized film	Digi-Key	P4513
C5 - 100 MFD 16 volt electrolytic		
D1, D2, D3 - 1N914 silicon diode	Mouser	610-1N914
D4, D5 - 1N4752 zener diode	Mouser	1N4752
D6 - 1N4004 rectifier	Mouser	
Q1 - MPSA05 NPN transistor	Mouser	
Q2, Q3 - MPSA55 PNP transistor	Mouser	
Q4, Q5, Q6, Q7, Q8 - IRL530N hexfet	Digi-Key	IRL530N
BR1 - 2 AMP 400 volt bridge rectifier	Mouser	583-RC204
IC1 - LMC555 CMOS timer	Jameco	126797
IC2, IC5 - 78L05 5 volt regulator	Jameco	51182
IC3 - CD4013 dual D flip flop	Jameco	12677
IC4 - CD4070 quad exclusive or	Jameco	13258
M1, M2 - two phase unipolar 24 volts		
T1 - DC or AC adapter transformer to match motor	Jameco	117321
IC socket - 1 eight pin	Digi-Key	A9308
IC sockets - 2 fourteen pin	Digi-Key	A9314
Terminal blocks - 2 two position	Digi-Key	ED1975
S1 - momentary N/O push button switch	Mouser	101-0461
S2 - double pole double throw toggle switch	Circuit Specialists	
Hookup wire - 24 gauge 24 inches	Digi-Key	
Control printed circuit board		
Driver printed circuit board		