

STEPPER MOTOR CONTROL USING 89C51 MICROCONTROLLER



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Here's a stepper motor controller based on 89C51 microcontroller to control the rotation of a DC stepper motor in clockwise and anti-clockwise directions. The controller is simple and easy-to-construct, and can be used in many applications including machine control and robotics for controlling the axial rotation in XY plane. A similar circuit can be added to control the rotation of the motor in either XZ or YZ plane.

Fig. 1 shows the block diagram of the stepper motor control system. The power supply section (in Fig. 2) consists of a step-down transformer (7.5V AC, 1A), bridge rectifier (comprising diodes D1 through D4), filter capacitors (C1 and C2) and regulator IC 7805.

We have used here an Atmel make low-power, high-performance, 8-bit CMOS microcontroller AT89C51 with 4 kB of Flash programmable and erasable read-only memory (PEROM). It has a 128x8-bit internal RAM, 32 programmable input/output (I/O) lines and two 16-bit timer/counters. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer.

By combining a versatile 8-bit CPU with Flash on a monolithic chip, Atmel AT89C51 is a powerful, highly flexible and cost-effective solution to many embedded control applications. From traffic control equipment to input devices, computer networking products and stepper motor controllers, 89C51 microcontrollers deliver a high performance with a choice of configurations and options matched to the specific needs of each application.

IC AT89C51 features:

1. 8-bit CPU with math registers A and B

2. 16-bit program counter (PC) and data pointer (DPTR)

3. 8-bit program status word (PSW)

4. 8-bit stack pointer (SP)

The control switches for the motor are connected to Reset and Port P_{0,7} pins of the microcontroller.

Circuit description

Fig. 2 shows the complete circuit of the stepper motor controller. When power supply switch S1 is closed, LED1 glows to indicate the presence of power in the circuit. Capacitor C3 connected to pin 9 (RST) provides the power-on reset to the microcontroller.

The stepper motor is connected to port pins P2.4 through P2.7 of the microcontroller (IC2) through the motor-driver circuit consisting of four Darlington pairs comprising transistors BC548 and SL100 (T1-T2, T3-T4, T5-T6 and T7-T8). Coils 1 through 4 are the

PARTS LIST

Semiconductors:

IC1	- 7805 5V regulator
IC2	- AT89C51 microcontroller
T1, T3, T5, T7	- BC548 npn transistors
T2, T4, T6, T8	- SL100 npn transistors
D1-D8	- 1N4001 rectifier diodes
LED1	- Red LED (5mm dia.)

Resistors (all ¼-watt, ± 5% carbon):

R1	- 100-ohm
R2	- 10-kilo-ohm
R3, R5, R7, R9	- 1-kilo-ohm
R4, R6, R8, R10	- 470-ohm

Capacitors:

C1	- 220µF, 25V electrolytic
C2	- 100µF, 16V electrolytic
C3	- 10µF, 16V electrolytic
C4, C5	- 33pF ceramic disk
C6	- 100µF, 16V electrolytic

Miscellaneous:

X1	- 230VAC primary to 0-7.5V, 1A secondary step-down transformer
	- 5V DC stepper motor

stepper motor coils.

When transistors conduct, 5V (V_{cc}) is applied to the coils and the currents flowing through them create magnetic fields and the motor starts rotating. The magnetic field energy thus created is stored in the coils.

When transistors stop conducting, power to the coils is cut off, the magnetic field collapses and a reverse voltage (called inductive kickback or back emf) is generated in the coils. The back emf can be more than 100 volts. The diodes connected across the coils absorb the reverse voltage spike. This voltage, if not absorbed by the diodes, may produce opposite torque and cause improper rotation of the motor and also damage the transistors. You can use virtually any type of rectifier or switching diodes of appropriate current and reverse voltage breakdown rating.

Clock and reset circuit. Two 33pF capacitors (C4 and C5) are connected to pins 18 and 19 of the microcontroller, respectively, with an 11.059MHz piezoelectric crystal (X_{TAL1}) across them. The

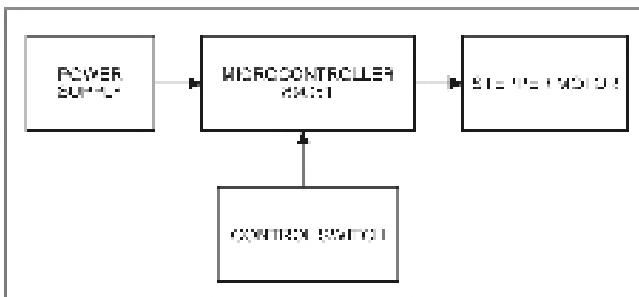


Fig. 1: Block diagram of the stepper motor control system

TABLE I
Power Consumption of Microcontrollers

IC	V _{oh}	I _{oh}	V _{oi}	I _{oi}	V _{il}	I _{il}	V _{ih}	I _{ih}	P _t
CMOS	2.4V	-60 µA	0.45V	1.7 mA	0.9V	10 µA	1.9V	10 µA	50 mW
NMOS	2.4V	-80 µA	0.45V	1.7 mA	0.8V	-800 mA	2.0V	10 µA	800 mW

clock frequency of the microcontroller depends on the frequency of the crystal oscillator used. Typically, the maximum and minimum frequencies are 1 MHz and 16 MHz, respectively, so we should use a piezoelectric crystal with a frequency in this range. The speed of the stepper motor is proportional to the frequency of the input pulses or it is inversely proportional to the time delay between pulses, which can be achieved through software by making use of instruction execution time.

The time taken by any instruction to get executed can be computed as follows:

$$\text{Time} = \frac{C \times 12}{F}$$

where 'C' is the number of cycles an instruction takes to execute and 'F' is the crystal frequency.

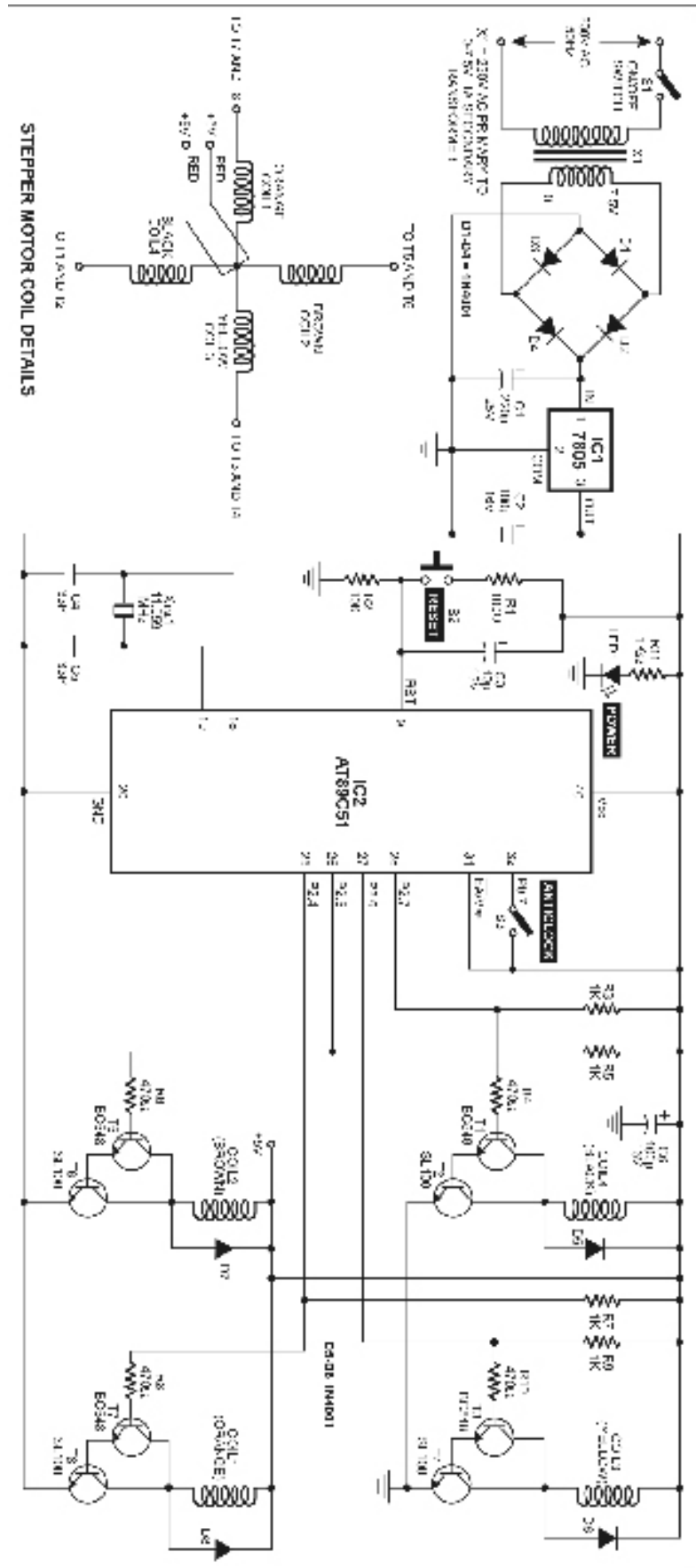
The crystal frequency in this circuit is 11.059 MHz, so the time taken to execute, say, ADD A, R1 (single-cycle instruction), is about one microsecond (μs). Use of a 6MHz crystal will bring down the instruction execution speed to 2 μs .

When power is applied, the reset input must first go high and then low. A resistor-capacitor combination (R1-C3) is used to achieve this until the capacitor begins to charge. At a threshold of about 2.5V, the reset input reaches a low level and the microcontroller begins to function normally. Reset switch (S2) allows you to reset the program without having to interrupt the power.

One major feature of 89C51 microcontroller is the versatility built into the I/O circuits that connect the microcontroller to the outside world. Ports P0 through P3 of the microcontroller are not capable of driving loads that require tens of milliamperes (mA). Logic level current, voltage and power requirement for different versions of microcontrollers are given in Table I.

Driver circuit design. The microcontroller outputs a current of 1.7 mA. To drive the coil of a stepper motor requiring a torque of 7 kg-cm, 12V DC and 2 amp/phase, we have to use a driver circuit that amplifies the current from 1.7 mA to 3 amp.

As mentioned earlier, we have used BC548 and SL100 as the driver transistors for driving a low-power rated stepper motor such as the one used in earlier 14cm (5.5-inch) floppy drives. But for a 7 kg-cm stepper motor, a driver circuit using transistors SL100 and 2N3055 would be needed to amplify the current to 2.72 amp. Typically, SL100 and 2N3055 each



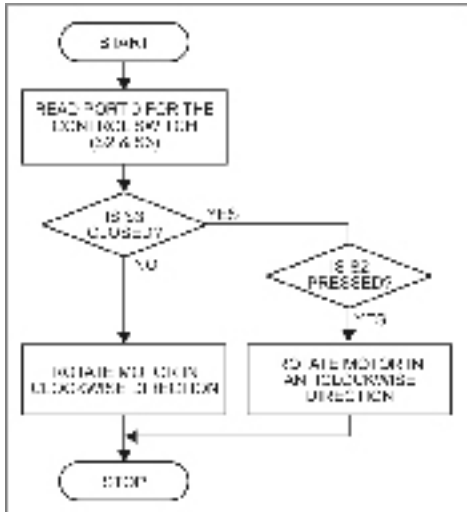


Fig. 3: Flow-chart of the program

has a gain (h_{fe}) of 40, but 2N3055 can handle larger current since it belongs to the family of power transistors. So a heat-sink is required to dissipate the heat generated.

The output gain of the Darlington pair of SL100 and 2N3055 transistors is:

$$A_{Vo} = A_{V1} \times A_{V2} = 40 \times 40 = 1600$$

$$A_{Vo} = I_o / I_{in} = 1600$$

where I_o is the output current and I_{in} is the input current of the Darlington pair.

$$I_o = 1600 \times 1.7 \text{ mA}$$

$$= 2.72 \text{ A}$$

Since the stepper motor has four coils, we need to use four Darlington pairs.

Programming

The program is written in Assembly language and compiled using ASM51 cross-assembler. The listing file is given at the end of this article. 89C51 microcontroller is programmed using Atmel's Flash programmer.

One-step rotation of the stepper motor used in this project equals 1.8° . When you program the motor for 200 steps, the motor makes one complete revolution, i.e. 360° . In the program, the line 'MOV R7, #0CAH'

defines the rotation by 202 steps. The hex number '0CAH' equals the decimal number '202.' However, one can change the number of steps in the program as per one's requirement.

The step sequence is defined by the line 'MOV A, #033H.' Table II shows the step sequence for 100 steps to energise the windings of the stepper motor in clockwise and anti-clockwise directions. The rotor of the stepper motor is in a position of minimum reluctance and maximum flux. Thus by energising the windings (represented by A1, A2, B1 and B2), the rotor takes the position accordingly. In the program, the instructions 'RR A' and 'RL A' are used for clockwise and anti-clockwise,

TABLE II
Clockwise Step Sequence of the Motor

A1	A2	B1	B2	A1	A2	B1	B2	Hex value
0	0	1	1	0	0	1	1	= 33h
0	1	1	0	0	1	1	0	= 66h
1	1	0	0	1	1	0	0	= CCh
1	0	0	1	1	0	0	1	= 99h

Anti-clockwise Step Sequence of the Motor

A1	A2	B1	B2	A1	A2	B1	B2	Hex value
0	0	1	1	0	0	1	1	= 33h
1	0	0	1	1	0	0	1	= 99h
1	1	0	0	1	1	0	0	= CCh
0	1	1	0	0	1	1	0	= 66h

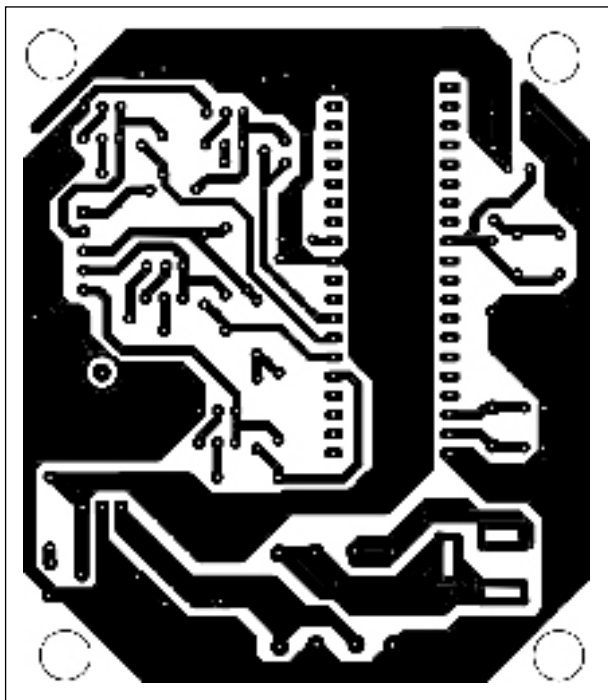


Fig. 4: Actual-size, single-side PCB for stepper motor control system using 89C51 microcontroller

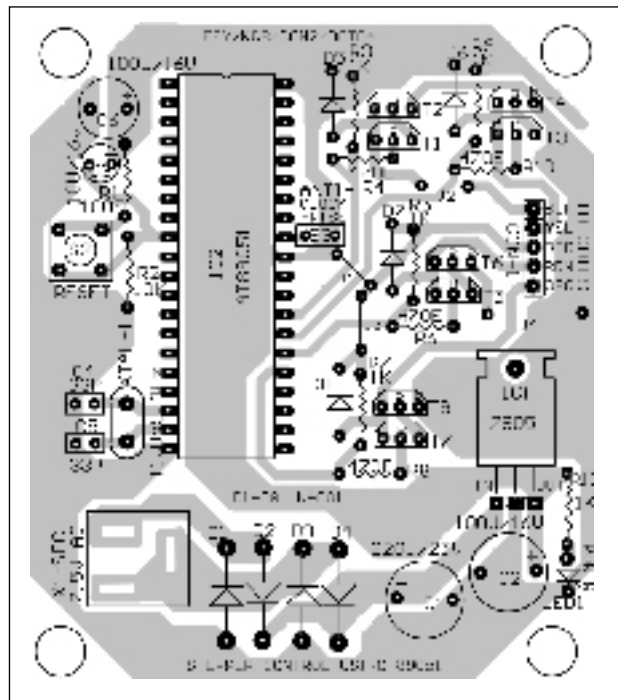


Fig. 5: Component layout for the PCB

respectively.

S1 and S3 are toggle switches, while S2 is a tactile switch. Switch S3 interfaced to pin 32 of the microcontroller determines the direction of rotation. When the switch is opened the motor rotates in clockwise direction, and when the switch is closed the motor rotates in anti-clockwise direction.

For anti-clockwise rotation of the motor, reset switch S2 is to be pressed momentarily after S3 is closed (see Fig. 3). In case you observe an abnormal motion of the motor either in clockwise or anti-clockwise direction, pressing reset switch S2 momentarily will make the motor run

smoothly.

Construction and working

You can assemble the circuit on any general-purpose PCB. An actual-size, single-side PCB for the stepper motor controller is shown in Fig. 4 and its component layout in Fig. 5.

Mount a 40-pin IC base for the microcontroller on the PCB, so you can remove the chip easily when required. Normally, six wires of different colours (two being red) are available for connection to the stepper motor. The sequence for connecting the stepper motor coils to the driver

card is shown in Fig. 2.

After you are done with the hardware part, assemble the program (stpb1.asm) using ASM51 assembler. Load the hex file generated by ASM51 into a programmer and burn it into the chip. Now put the programmed chip on the IC base on the PCB.

Switch on the power supply to the circuit using switch S1. If motor rotation is not stable, press S2 momentarily. If the motor does not move at all, check the connections.

Note. The source code and the relevant files for this article have been included in this month's EFY-CD.

STPB1.LST

```

0000      1      $MOD51
0000      2      ORG 0000H
0000 E580      3      MOV A, P0
0002 33       4      RLC A
0003 500B      5      JNC P12
0005      6
0005 7FCA      7      MOV R7, #0CAH;
0007 7433      8          MOV A, #033H;
0009 F5A0      9      P13: MOV P2, A;
000B 23       10         RL A;
000C 111B     11         ACALL DELAY
000E DFF9     12         DJNZ R7, P13
0010 7FCA     13
0012 7433     14      P12: MOV R7, #0CAH;
0014 F5A0     15          MOV A, #033H;
0016 03       16      P11: MOV P2, A;
0017 111B     17          RR A;
0019 DFF9     18          ACALL DELAY
0020      19          DJNZ R7, P11
0021      20
0022      21
0023 758910   22      DELAY: MOV TMOD, #10H
0024 7B05     23          MOV R3, #05
0025 758B08   24      Z:   MOV TL1, #8D
0026 D28E     25
0027 308FFD   26          MOV TH1, #1D
0028      27          SETB TR1
0029      28          BACK: JNB TF1, BACK
002A      29
002B C28E     30          CLR TR1
002C C28F     31          CLR TF1
002D DBEF     32          DJNZ R3, Z
002E      33          RET
002F      34
0030      35          END
0031      36
0032      37
0033      38
0034      39
0035      40
0036      41
0037      42
0038      43
0039      44
003A      45
003B      46
003C      47
003D      48
003E      49
003F      50
0040      51
0041      52
0042      53
0043      54
0044      55
0045      56
0046      57
0047      58
0048      59
0049      60
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00AA     157
00AB     158
00AC     159
00AD     160
00AE     161
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01D7     714
01D8     715
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01DA     717
01DB     718
01DC     719
01DD     720
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01DF     722
01E0     723
01E1     724
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