Lab 8. Stepper Motor Controller

Overview of this Session

In this laboratory, you will learn:
- To continue to use an oscilloscope
- How to use a Step Motor driver chip.

Introduction

- This lab is focused around the control of a stepper motor. You will be using the SAA1042 Step Motor Driver chip to implement the various stepping sequences.

Background

In lecture you learned how a step motor works and how you can manipulate the phases to make the rotor move. The phases of the step motor must be energized in a specific order for this to work. Luckily the SAA1042 chip knows how to sequence the phase properly. All you have to do is tell it which direction and which stepping sequence you want (full or half).

IMPORTANT:

Take a look at the pin out. There are four places where ground must be attached. Since the step motor uses a lot of current, the chip needs to have the ability to sink that current. **Make sure you hook up all five GND pins to ground**.

The SAA1042 has three power pins. One pin powers the logic (Vcc); the other two power the step motor through the chip. The other two power the step motor. Hook all three to 12 volts.
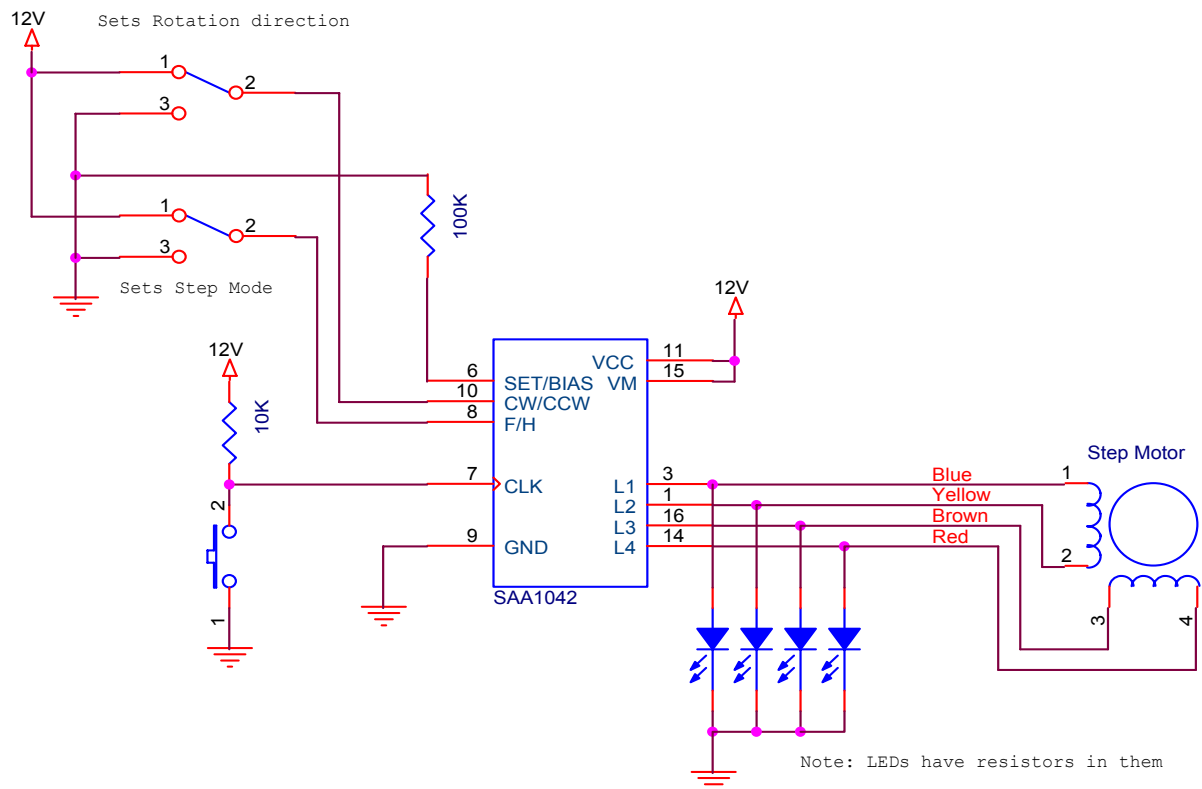
PIN CONNECTIONS

(Top View)
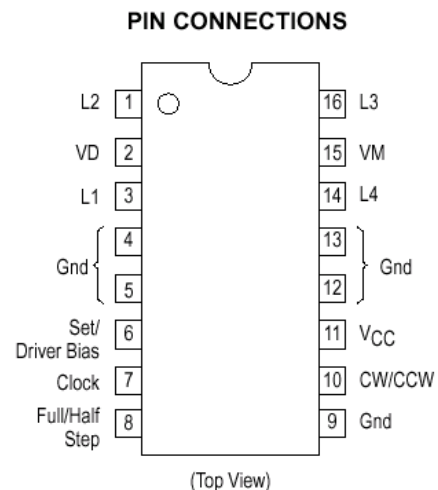
Before applying power, check the circuit twice. Incorrect power connections will destroy the chip and perhaps melt the breadboard.

Oscilloscope Measurements

8.1   Connect the signal from the function generator to the oscilloscope and determine the type of signal present, the frequency, amplitude, and the DC offset.

PART 1: Manual Clocking for Rotation

Build this circuit.

12V Sets Rotation direction

1
2
3

100K

1
2
3

Sets Step Mode

12V

12V

6
10
8

SET/BIAS
CW/CCW
F/H

VCC
VM

11
15

10K

7 CLK

L1
L2
L3
L4

3
1
16
14

Blue
Yellow
Brown
Red

Step Motor

1

2

2

9 GND

SAA1042

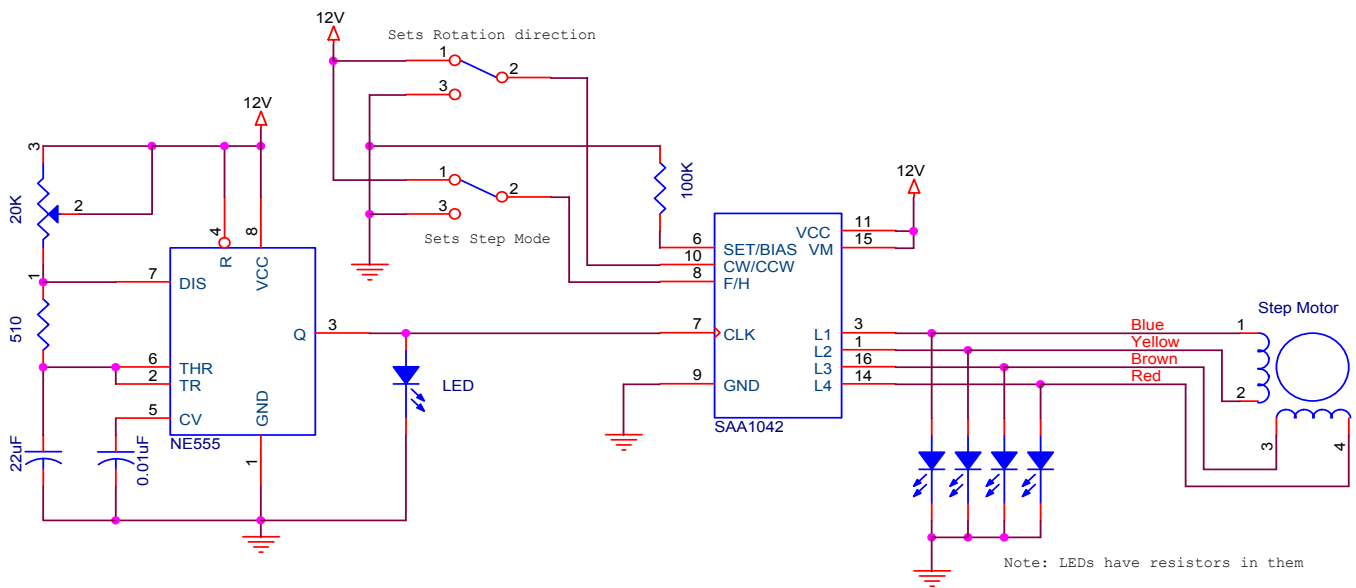Note: LEDs have resistors in them

3 4

Pressing the button should advance the step motor. However, due to circuit 'bounce' the SAA1042 may try to advance the motor twice or more even if the motor is not capable of doing this quickly enough. If this is the case, try using a function generator to supply the clock pulses. Set the function generator to create a 1 Hz square wave with a 6 volt amplitude and a 3 volt DC offset.

8.2   Once you have built the circuit, use the pushbutton to advance the step motor, step by step. Record the light pattern. Are you in full stepping mode?

8.3   Change the stepping mode half stepping. Change the direction also. Feel the step motor. Try to rotate the shaft by hand while its energized. Advance it another half step and try to move it again. Any difference?

PART 2: Timer initiated clocking

Build this circuit

12V

Sets Rotation direction

12V

Sets Step Mode

100K

12V

20K

510

DIS 7

THR 6
TR 2

CV 5

NE555

R 4 VCC 8

Q 3

GND 1

22uF   0.01uF

LED

SET/BIAS 6
CW/CCW 10
F/H 8

CLK 7

GND 9

SAA1042

VCC 11
VM 15

L1 3
L2 1
L3 16
L4 14

Step Motor

Blue   1
Yellow
Brown
Red   2

3   4

Note: LEDs have resistors in them

The TA will supply you with a 555 circuit. You will have to adapt it to be wired as shown above. If you used a function generator before, the 555 simply replaces it.

8.4   Place the step motor drive to be in Full stepping mode and adjust the frequency (by turning the pot) from a slow speed to a fast speed.

8.5   What happens when the CLK frequency gets too high?

8.6   At what frequency does the stepper motor fail? How fast is the motor turning at this frequency? See the next page on how to calculate the motor speed.

8.7   Put the driver chip into half stepping mode.

8.8   What is the highest frequency that will still make the step motor work? How fast is the motor turning at this frequency?

8.9   Why do you think there is any difference?

<u>HOW TO CALCULATE MOTOR SPEED</u>

From the data sheet for your motor find the number of degrees per step, N.

From the scope determine the frequency, F.

$$Motor\,Speed = \frac{N\,degrees}{1\,step} \; x \; \frac{F\,cycles\,(steps)}{1\,second} \; x \; \frac{1\,revolution}{360\,degrees} \; x \; \frac{60\,seconds}{1\,minute}$$

$$= \frac{Revolutions}{Minute}$$

Stepper Motor Driver

The SAA1042 drives a two–phase stepper motor in the bipolar mode. The device contains three input stages, a logic section and two output stages. The IC is contained in a 16 pin dual–in–line heat tab plastic package for improved heatsinking capability. The center four ground pins are connected to the copper alloy heat tab and improve thermal conduction from the die to the circuit board.

- Drive Stages Designed for Motors: 6.0 V and 12 V: SAA1042V
- 500 mA/Coil Drive Capability
- Built–In Clamp Diodes for Overvoltage Suppression
- Wide Logic Supply Voltage Range
- Accepts Commands for CW/CCW and Half/Full Step Operation
- Inputs Compatible with Popular Logic Families: MOS, TTL, DTL
- Set Input Defined Output State
- Drive Stage Bias Adaptable to Motor Power Dissipation for Optimum Efficiency

PIN CONNECTIONS

(Top View)
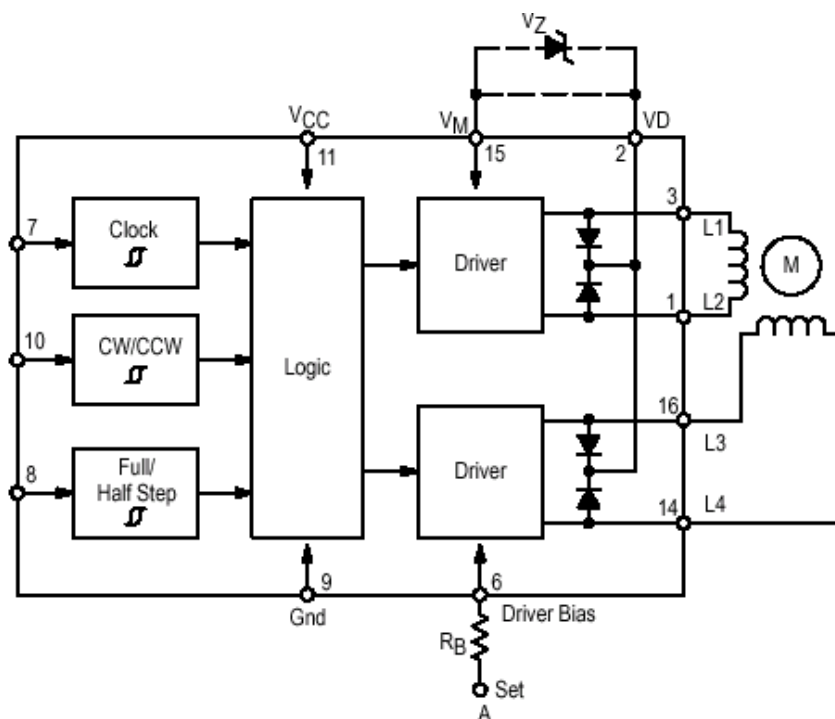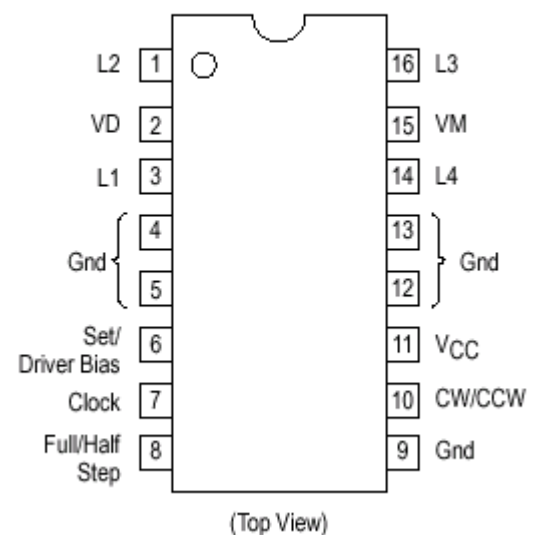
SAA1042
INPUT/OUTPUT FUNCTIONS

Clock — (Pin 7) This input is active on the positive edge of the clock pulse and accepts Logic '1' input levels dependent on the supply voltage and includes hysteresis for noise immunity.

CW/CCW — (Pin 10) This input determines the motor's rotational direction. When the input is held low, (OV, see the electrical characteristics) the motor's direction is nominally clockwise (CW). When the input is in the high state, Logic '1', the motor direction is nominally counter clockwise (CCW), depending on the motor connections.

Full/Half Step — (Pin 8) This input determines the angular rotation of the motor for each clock pulse. In the low state, the motor will make a full step for each applied clock pulse, while in the high state, the motor will make half a step.

V_D — (Pin 2) This pin is used to protect the outputs (1, 3,14, 16) where large positive spikes occur due to switching the motor coils. The maximum allowable voltage on these pins is the clamp voltage (V_{clamp}). Motor performance is improved if a zener diode is connected between Pin 2 and 15, as shown in Figure 1.

The following conditions have to be considered when selecting the zener diode:

$$V_{clamp} = V_M + 6.0 \text{ V}$$
$$V_Z = V_{clamp} - V_M - V_F$$

where: V_F = clamp diodes forward voltage drop (see Figure 4)

V_{clamp}: ≤ 20 V for SAA1042V ≤ 30 V for SAA1042AV

Pins 2 and 15 can be linked, in this case $V_Z = 0$ V.

Set/Bias Input — (Pin 6) This input has two functions:
1) The resistor R_B adapts the drivers to the motor current.
2) A pulse via the resistor R_B sets the outputs (1, 3, 14, 16) to a defined state.

The resistor R_B can be determined from the graph of Figure 2 according to the motor current and voltage. Smaller values of R_B will increase the power dissipation of the circuit and larger values of R_B may increase the saturation voltage of the driver transistors.

When the "set" function is not used, terminal A of the resistor R_B must be grounded. When the set function is used, terminal A has to be connected to an open–collector (buffer) circuit. Figure 7 shows this configuration. The buffer circuit (off–state) has to sustain the motor voltage (V_M). When a pulse is applied via the buffer and the bias resistor (R_B), the motor driver transistors are turned off during the pulse and after the pulse has ended, the outputs will be in defined states. Figure 6 shows the Timing Diagram.

Figure 7 illustrates a typical application in which the SAA1042 drives a 12 V stepper motor with a current consumption of 200 mA/coil. A bias resistor (R_B) of 56 kΩ is chosen according to Figure 2.

The maximum voltage permitted at the output pin is $V_M + 6.0$ V (see Maximum Ratings table), in this application $V_M = 12$ V, therefore the maximum voltage is 18 V. The outputs are protected by the internal diodes and an external zener connected between Pins 2 and 15.

From Figure 4, it can be seen that the voltage drop across the internal diodes is about 1.7 V at 200 mA. This results in a zener voltage between Pins 2 and 15 of:

$$V_Z = 6.0 \text{ V} - 1.7 \text{ V} = 4.3 \text{ V}.$$

To allow for production tolerances and a safety margin, a 3.9 V zener has been chosen for this example.

The clock is derived from the line frequency which is phase–locked by the MC14046B and the MC14024. The voltage on the clock input is normally low (Logic '0'). The motor steps on the positive going transition of the clock pulse.

The Logic '0' applied to the Full/Half input (Pin 8) operates the motor in Full Step mode. A Logic '1' at this input will result in Half Step mode. The logic level state on the CW/CCW input (Pin 10), and the connection of the motor coils to the outputs determines the rotational direction of the motor.

These two inputs should be biased to a Logic '0' or '1' and not left floating. In the event of non–use, they should be tied to ground or the logic supply line, V_{CC}.

The output drivers can be set to a fixed operating point by use of the Set input and a bias resistor, R_B. A positive pulse to this input turns the drivers off and sets the logic state of the outputs.

After the negative going transition of the Set pulse, and until the first positive going transition of the clock, the outputs will be:

L1 = L3 = high and L2 = L4 = low, (see Figure 6).

The Set input can be driven by a MC14007B or a transistor whose collector resistor is R_B. **If the input is not used, the bottom of R_B must be grounded.**

The total power dissipation of the circuit can be determined from Figures 3 and 5:

$$P_D = 0.9 \text{ W} + 0.08 \text{ W} = 0.98 \text{ W}.$$

The junction temperature can then be computed using Figure 8.

Lab 8 Example Answer Sheet

Name:_____   Section Number:_____

TA init:_____   Date:_____

8.1   Draw the waveform shown on the oscilloscope. What is the name of this waveform? What is the amplitude, frequency, and DC offset? Show all your calculations.

8.2   Record the light pattern, which represents the phases that are energized. Record the step mode. Is the light pattern correct for full stepping?

8.3   With the mode set to half stepping: Is there a difference in torque with a single phase on as opposed to having two phases on?

8.5   What happens when the CLK frequency gets to high?

Lab 8 Example Answer Sheet

Name:_____   Section Number:_____
TA init:_____   Date:_____

8.6   What is the frequency at which the motor fails to rotate properly? What is the rotational speed at this frequency? Show your calculations.

8.8   In half stepping mode, what is the highest frequency at which the motor will rotate properly? What is the rotational speed at this frequency? Show your calculations.

8.9   Why is there a difference between full and half stepping maximum speeds?