Stepper Motor Driver (74194)

This page features an inexpensive stepper motor driver that could be used to power slow speed projects on the layout or other hobby applications.

Based on the SN74LS194 - Bidirectional Universal Shift Register the circuit is designed to drive UNIPOLAR type stepper motors and provides only basic control functions - Forward, Reverse, Stop and Speed adjustment.

The only step angle for this driver is the design step angle for the motor.

The circuit is not complex and is cheaper than many dedicated driver/controller devices and the parts are easy to find.

For the purposes of this page the direction control function is selected by an ON-OFF-ON type toggle switch. This could be easily replaced by another method such as transistors controlled by a PC's parallel output port.

Speed control is by means of a potentiometer but the circuit could accept pulses or controls from other sources such as a push button or a simple computer interface. The direction could also be controlled by a computer interface.

This web page uses integrated circuits from the SN74LS- family of TTL devices. It is not the purpose of this page to provide detailed explanations of how these devices work and an understanding of simple logic circuits would be helpful.

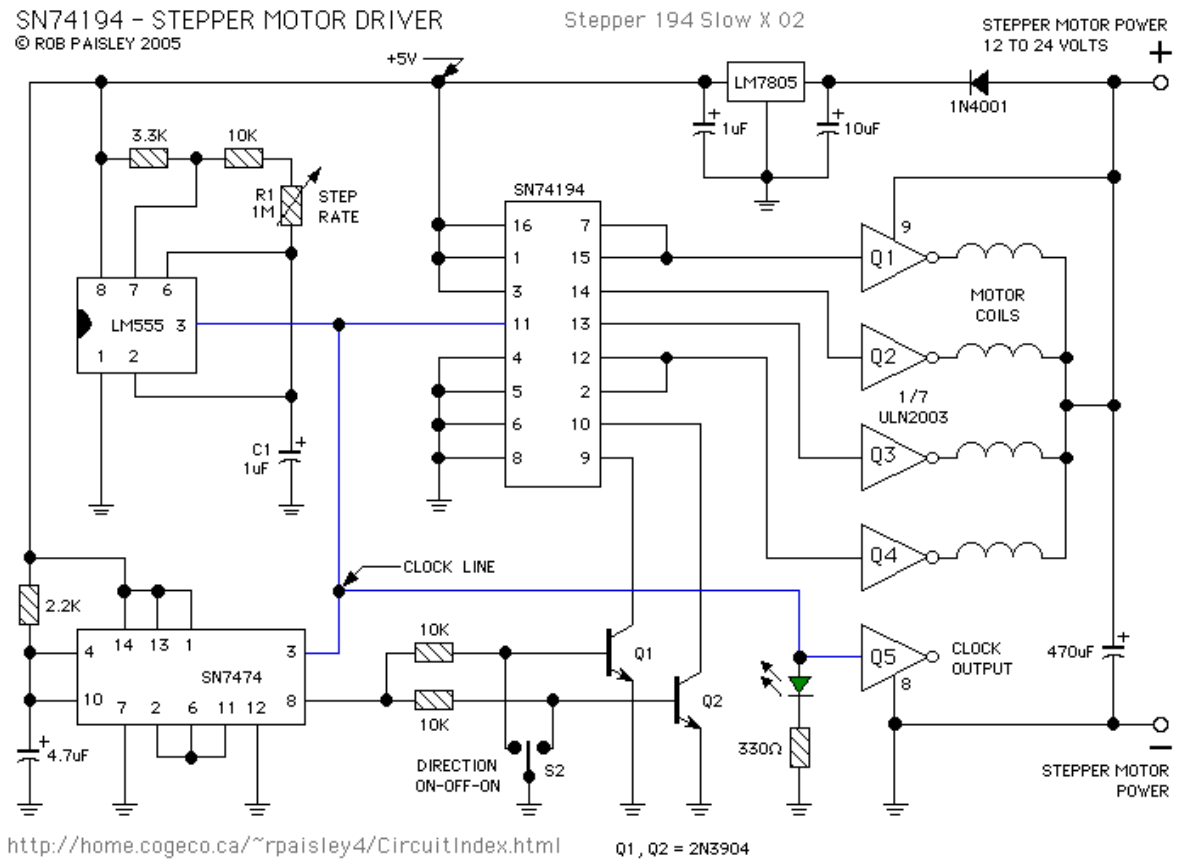
Do not be discouraged by this however as the circuit's operation is quite simple.

NOTE: - Due to the lack of error detection or correction this circuit should not be used for application that require accurate step control or positioning accuracy. The circuit is intended for hobby uses only.

Stepper Motor Driver Circuit

The following diagram is for the main circuit of the motor driver.

A testing version is shown near the end of this page. It is laid out differently and shows the SN7474 in logic block form and LED's are used to indicate the motor coils being switched.



Stepper Motor Driver circuit

The blue line on the drawing is the path that the CLOCK pulses that drive the circuit follow.

The stepper motor would not be connected as shown on the schematic as the motors usually have a common and four coil leads.

Also, the filter capacitor at the power supply to the circuit would not be connected as shown.

Stepper Motor Driver Operation

1. The 555 astable oscillator produces a series of CLOCK pulses that are fed to PIN 11 of the SN74194 integrated circuit.
2. Each time the CLOCK pulse goes positive the HIGH state at the SN74194's OUTPUT terminals, (PIN's 12, 13, 14, 15), is shifted either UP or DOWN. Refer to the "Stepper Motor Driver Waveforms" diagram.

   The direction of this shifting is controlled by switch S2. When S2 is in the center OFF position the HIGH output state will remain in its last position and the motor will be stopped.

   When the base of Q1 is LOW the shifting will be PIN 12 - 15 - 14 - 13 - 12 .etc.

   When the base of Q2 is LOW the shifting will be PIN 12 - 13 - 14 - 15 - 12 .etc.

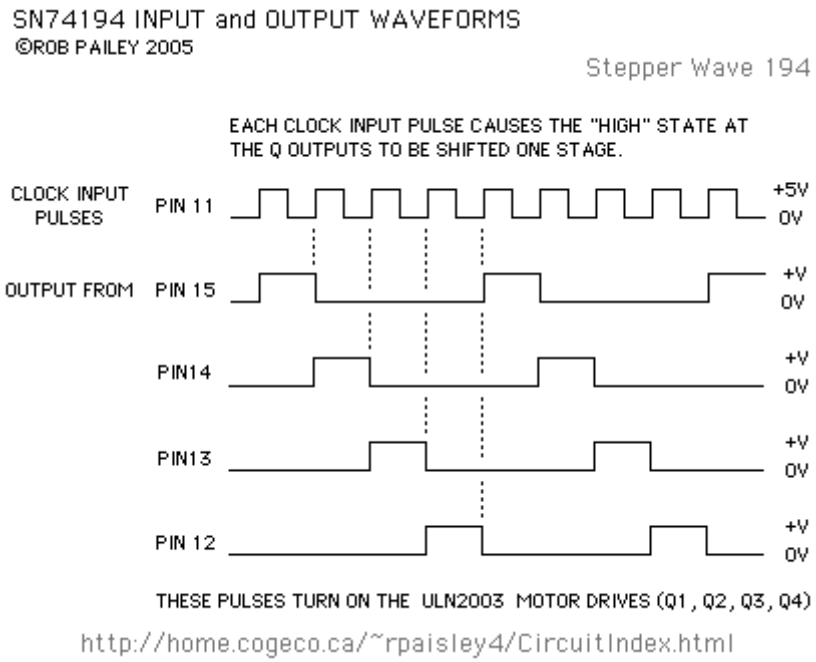
   The direction of the pulse shifting determines the direction of motor rotation.

3. The pulses from the OUTPUT's of the SN74194 are fed to four segments of the ULN2003 Driver. When a segments input is HIGH the transistor will turn ON and its OUTPUT will conduct current through one of the motors coils.
4. As the coils of the motor are turned ON in sequence the motor rotates to follow these steps. Refer to following diagrams.

Integrated Circuit Chips Used

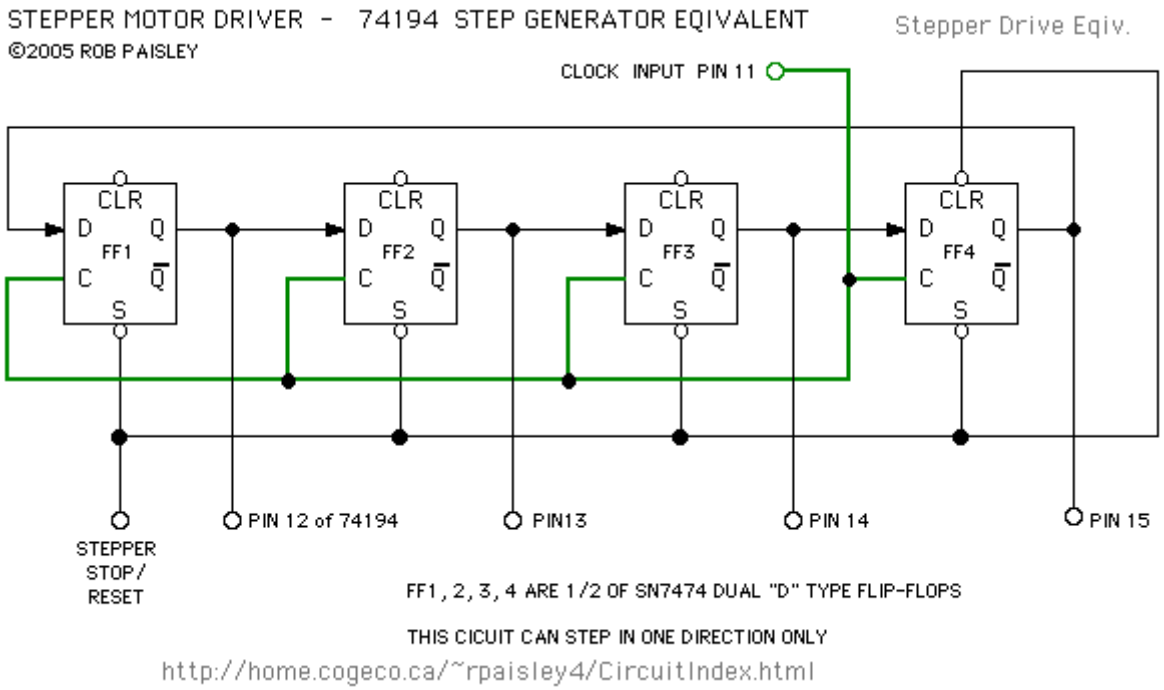
- The SN74LS194 integrated circuit is a 4-Bit Bidirectional Universal Shift Register.
- The SN74LS74 integrated circuit is a Dual 'D' Type Positive-Edge-Triggered Flip-Flops with Preset and Clear.
- The ULN2003 integrated circuit is a 7 Unit, Darlington High Current, High Voltage Peripheral Driver. Its outputs can handle currents of up to 500 milliamps and voltages up to 50 volts.
- The LM555 integrated circuit is a Timer chip configured as an astable oscillator.

The next diagram shows the basic waveforms for the stepper motor driver circuit.



Stepper Motor Driver Waveforms

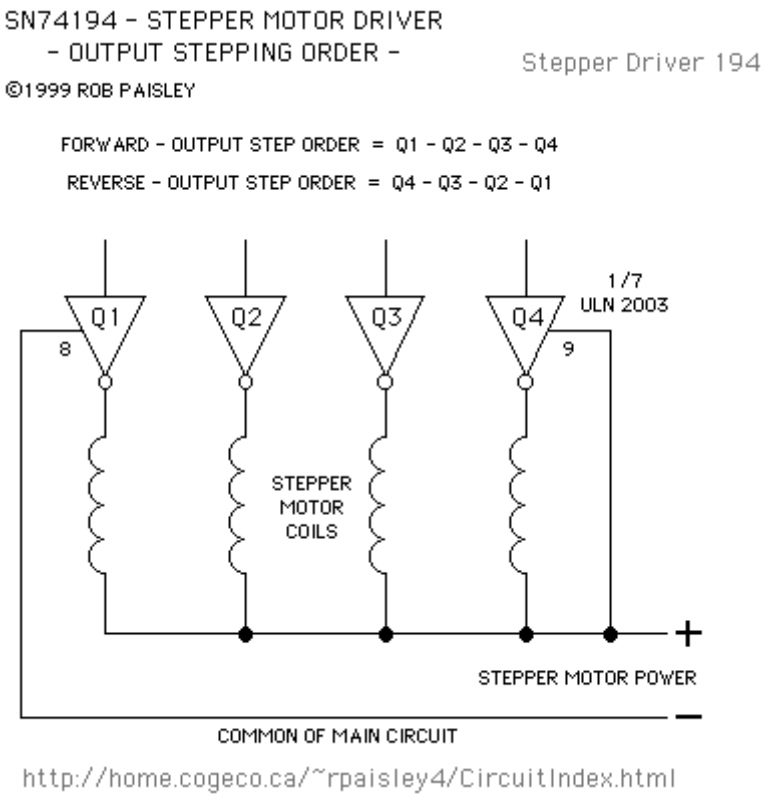
The next diagram shows a very simplified diagram of the step function of the 74194 chip.



Stepper Motor Driver Equivalent

The following diagram shows the stepping order of the inputs to ULN2003 Peripheral Driver for forward and reverse motor directions. Pin numbers are not indicated as this depends on the PCB layout.

Each positive pulse at the SN74194's - OUTPUT terminals turns ON one of the stepper motors coils.



ULN2003 Motor Driver Stepping Order

74194 Stepper Motor Driver Notes

- A printed circuit board is mentioned in the following notes. This is not available at this time but may appear in the future.
- There are some links to other stepper motor related web pages further down the page. These may be helpful in understanding stepper motor operation and control.
- With the parts values shown on the schematic and capacitor C1 being 1uF. If resistor R1 is set to "ZERO" ohms the calculated CLOCK frequency will be approximately 100Hz and the motor will make 100 steps per second. This CLOCK frequency will be slow enough for most motors to operate properly.

  The maximum RPM at which stepper motors will operate properly is quite low and the torque the motor can produce drops of rapidly as motor speed increases. Testing may be needed to determine the minimum values for R1 and C1 to produce the maximum CLOCK INPUT frequency for any given motor. Data sheets, if available, will also help determine this frequency.

  Some motors can handle higher CLOCK input frequencies. This depends largely on the construction of the motor itself.

- If R1 had a maximum resistance of 1 Megohm the calculated CLOCK frequency would be 1Hz and the motor would make 1 step per second.

  There is no minimum step speed at which stepper motors cannot operate. Therefore, in theory, the values for R1 and C1 can be as large as desired. There are practical limitations to these values though and the 555 timer data sheet should be consulted for more information.

  Provision has been made on the printed circuit board to change the values of R1 and C1 through external connections. It will also be possible to inject CLOCK pulses through these connections for external step control.

- In the above items the "calculated" minimum and maximum CLOCK frequencies are valid for the actual parts values shown. Given the tolerances of real components and the leakage currents of electrolytic capacitors the actual CLOCK rate could be lower or higher
- The Switch S1 is an option that could be used to stop the motor if desired. Closing S1 will stop the 555 oscillator thereby stopping the CLOCK input pulses.

  The switch was connected across the timing capacitor as this did not produce output noise problems and was easier to externally connect to the circuit.

  S1 could be replaced by an NPN transistor for electronic control of the CLOCK.

- The CLOCK input pulses could be supplied from other sources but any "Noise" on the CLOCK input could throw the SN74194 into a bad state. For this reason the pulses must be clean.

  It would be best to pass any external input pulses through the 555 timer chip first. This possibility has been provided for on the printed circuit board.

- The SN7474 does not have a control function but is used to provide a sub routine when power is applied to the circuit. This allows the SN74194 to "SET" its output states to PIN 15 - HIGH and PINs 12, 13 and 14 - LOW before the DIRECTION control switching transistors, Q1 and Q2, become active.

The First CLOCK pulse occurs when power is applied to the circuit (the OUTPUT of the 555 timer will go HIGH). DIRECTION control becomes active on the Second CLOCK input pulse. If a direction is selected the motor will step on the Third CLOCK pulse.

The motor may step forward, backward or not at all on the second CLOCK pulse. This is part of the output setting process.

Direction control is active when the OUTPUT at PIN 8 of the SN7474 has a HIGH state.

Logically speaking the SN7474 method used to initialize the circuit might not be the best. But at the relatively low frequencies, about 100Hz, used by this circuit it seems to work just fine. Without this sub routine the SN74194 could have all or none of its outputs in a HIGH state after power is applied to the circuit.

- The 2.2K ohm resistor and the 4.7uF capacitor connected to the SET terminals, PINS 4 and 10, of the SN7474 - FLIP-FLOP's ensures that the outputs at pins 6 and 8 go to a LOW state when power is applied to the circuit.
- When power is applied to the circuit it is possible that none, one or all of the outputs that control the motor (Q1-5) could be ON for the first CLOCK cycle. For this reason the power supply must be able to handle four times the rated motor current for short periods.

If the motor step rate is very slow this extra current draw may be lengthy.

- The Direction of the motor could be controlled by another circuit or the parallel output port of a PC. This will work as long as the voltage at the bases of Q1 and Q2 can be made lower than 0.7 volts. Additional NPN transistors may be required to achieve this result, depending on the method used.
- If the bases of both Q1 and 2 are made LOW at the same time the SN74194 will go into a RESET mode. This will cause the step sequence to stop and on the next clock pulse PIN 15 will go to a HIGH state.

Making the bases of both Q1 and Q2 LOW at the same time can be used to reset the SN74194 to its proper starting position without having to remove the circuit power.

- The controls and step generator portions of the motor driver circuit require a 5 volt regulated power supply. This supply is shown on the schematic and will be included on the printed circuit board.
- The stepper motor will have its own power requirements and as there is a great variety of motors available this page cannot hope to give information in this area. Users of this circuit will have to determine motor phasing and power requirements for themselves.

Power for the motors can be regulated or well filtered and may range from 12 to 24 volts with currents of between 150 and 500 milliamps depending on the particular motor.

- As shown on the schematic the CLOCK frequency has an output via Q5. There is no specific purpose for this but because of the way the printed circuit board is layed out it was very easy to provide this output. It should be noted that this output is not TTL compatible but is an open collector darlington that can sink up to 500 milliamps.

This OUTPUT could be used if there was a need to drive two or more motors at the same CLOCK speed. Another use could be as an feed back to a counter circuit if a specific number of steps were desired.

- A LED is connected to the output of the CLOCK that flashes at the CLOCK frequency. One step of the motor for every time the led turns ON if a direction has been selected.

The motors used to test this circuit were:

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1.      JAPAN SERVO CO.  (From an old floppy drive)
2.      TYPE KP4M4-001
3.      75 OHM / PHASE
4.      0.15 AMP / PHASE
5.      AIRPAX : LA82720-M1  (From a chart drive)
6.      24 VOLT
7.      60 OHMS / COIL
8.      7.5 DEGREES / STEP
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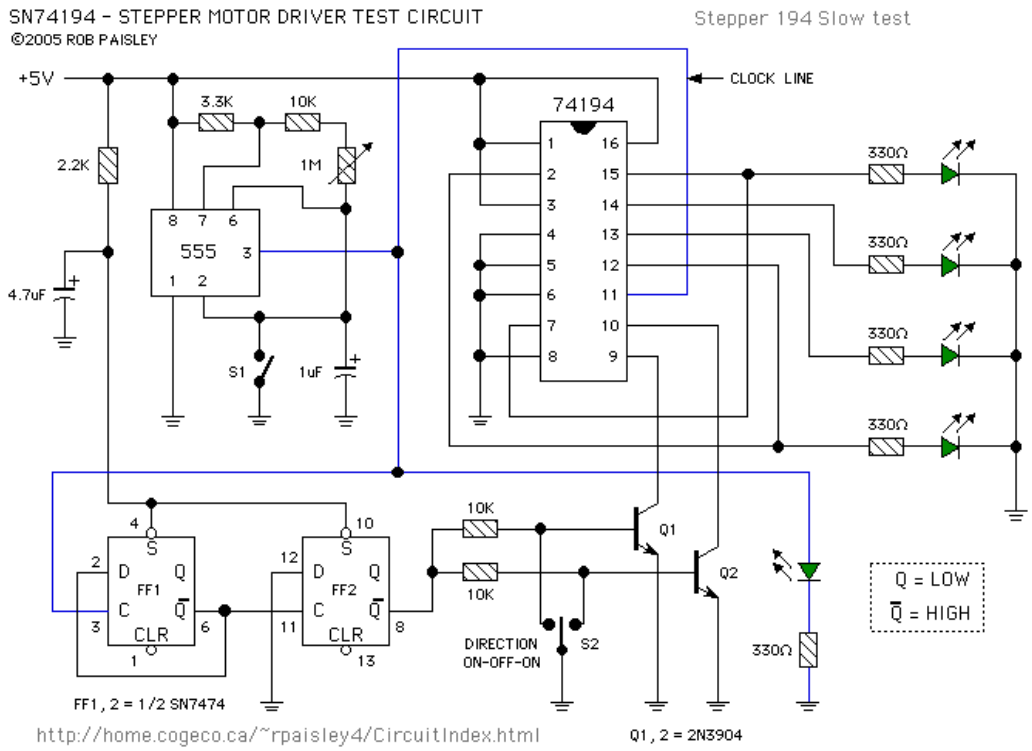
Some Stepper Motor Related Links

The following links are for stepper motor related pages and have a lot of good information on other types of driver circuits and motors.

www.cs.uiowa.edu/~jones/step/circuits.html

www.doc.ic.ac.uk/~ih/doc/stepper/control2/connect.html

Stepper Motor Driver Test Circuit



Stepper Motor Driver circuit initial testing version.

This schematic shows the SN7474 in logic block form with its two "D" type FLIP-FLOP's. This circuit was used to test the stepper motor driver circuits operation.

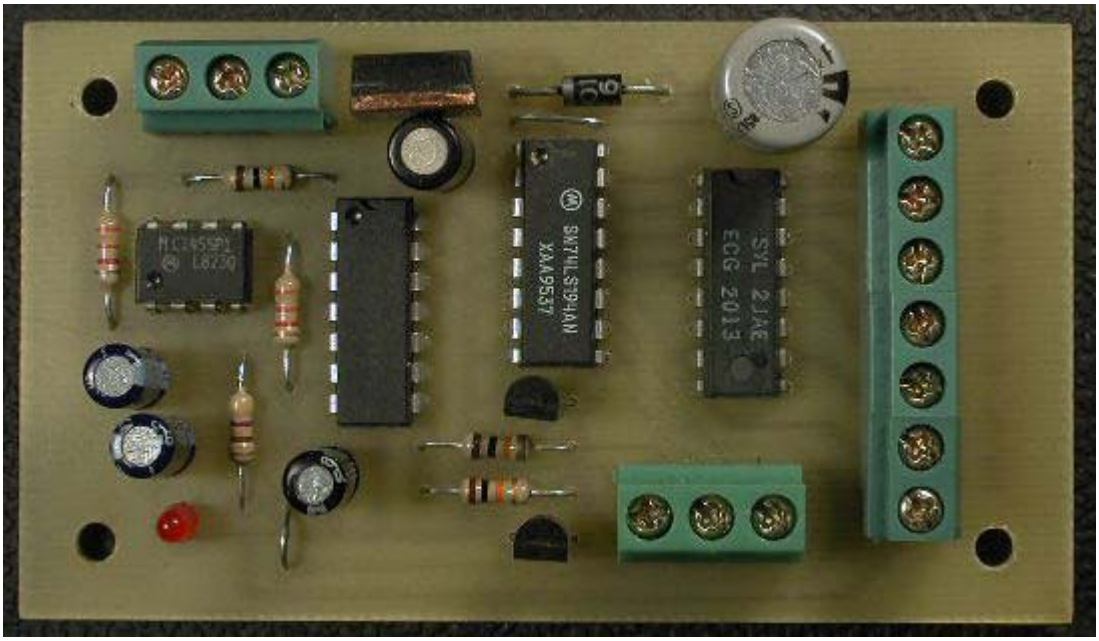
Section FF1 acts as a binary divider while FF2 acts as a RS FLIP FLOP. After one division step the FLIP FLOP is SET to Q-high.

This allows the SN74194 to "SET" its output states to PIN 15 - HIGH and PINs 12, 13 and 14 - LOW before the DIRECTION control switching transistors, Q1 and Q2, become active.

Switch S1 allows the clock to be stopped or pulsed for single step control.

The POWER (14), COMMON (7) and CLEAR (CLR) (1,13) connections of the SN7474 are not shown on the schematic diagram to make the drawing less cluttered. The CLEAR terminals are connected to the +5 volt supply.

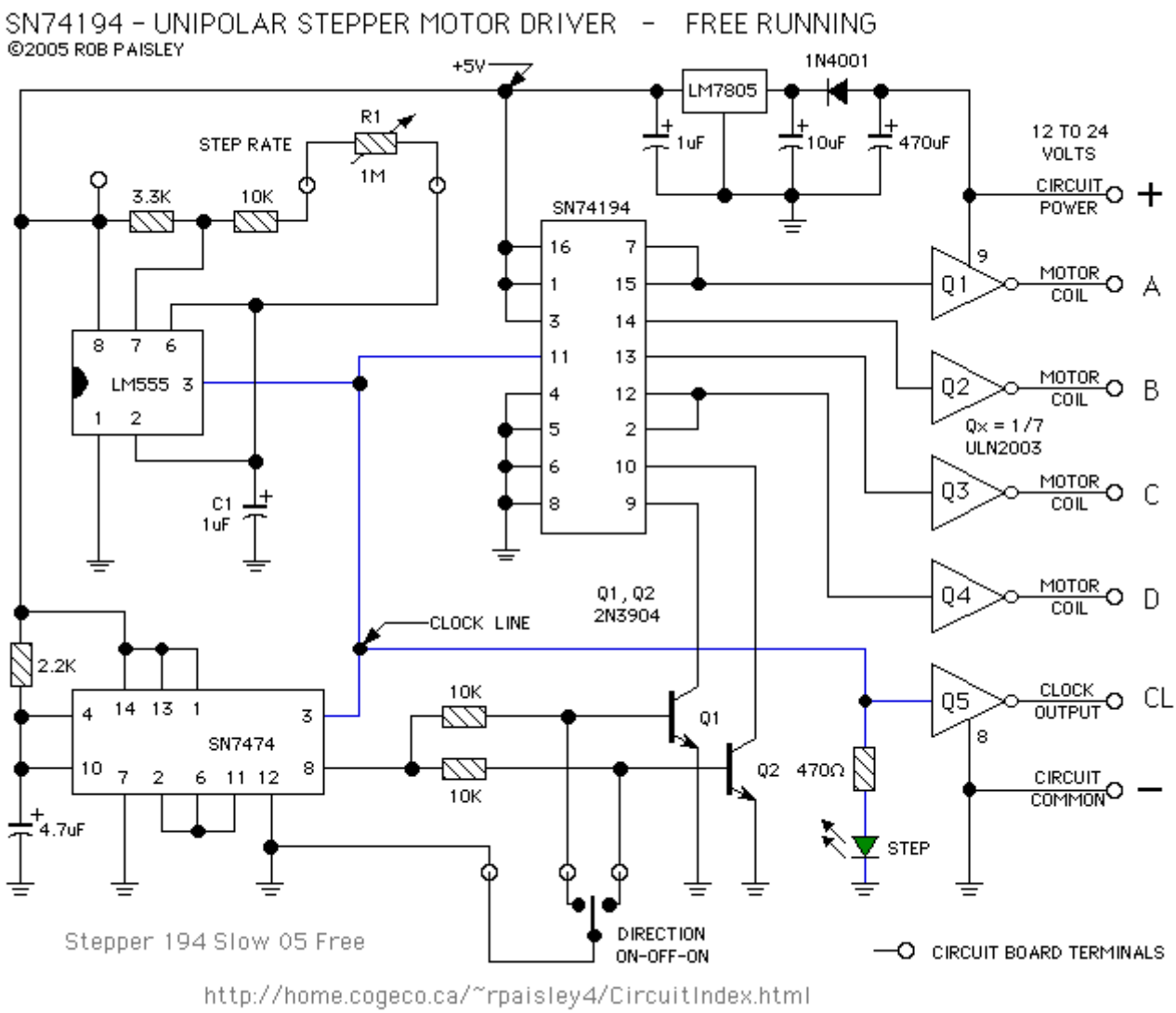
The following picture is of a printed circuit board for the Stepper Motor Driver. The terminal block positions correspond with those on the schematic shown below.



Stepper Motor Driver - Circuit Board

To lower the overall height of the circuit the tab has been removed from the 7805 regulator.

The following diagram shows the Stepper Motor Driver circuit with its circuit board's external connection terminals. The motor coils have been omitted from the diagram.



Stepper Motor Driver - Circuit Board Connections

Please Read Before Using These Circuit Ideas

The explanations for the circuits on these pages cannot hope to cover every situation on every layout. For this reason be prepared to do some experimenting to get the results you want. This is especially true of circuits such as the "Across Track Infrared Detection" circuits and any other circuit that relies on other than direct electronic inputs, such as switches.

If you use any of these circuit ideas, ask your parts supplier for a copy of the manufacturers data sheets for any components that you have not used before. These sheets contain a wealth of data and circuit design information that no electronic or print article could approach and will save time and perhaps damage to the components themselves. These data sheets can often be found on the web site of the device manufacturers.

Although the circuits are functional the pages are not meant to be full descriptions of each circuit but rather as guides for adapting them for use by others. If you have any questions or comments please send them to the email address on the Circuit Index page.