Controlling small bipolar step motors using SN754410

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1. Introduction

Right – we already dealt with step motors (Application note 018). Nevertheless there are good reasons to return to this topic. One of them being, we built a discrete solution for the motor output stage then, now we are attempting a more elegant solution with an H-Bridge IC SN754410, which we have already tested successfully with small DC-Motors (Note 059). A further reason for the fresh start is that we want to head for bipolar step motors this time, which are simpler in their construction, cost less and are available in many DIY-boxes, for example in old disk drives (Figure 2). In addition we want to try out a battery-friendly variation with small step motors. As you remember common step motors are often quite large, mostly running on 12V or more and also use up a lot of current. This makes a battery operation much more difficult. The current consumption is already an obstacle under ordinary conditions, i.e. when operating the motor, but in particular when it comes to a standstill. First of all it is even higher due to the missing mutual induction and secondly the drive is not at all productive. This is where we wish to work on new concepts. The aim is to develop a position drive for battery operation, which, as described in the previous note, only uses current when the position is to be changed.
But first of all we will deal with to the motor itself and its adjustment to a drive system.

2. Motor and drive transmission

Our motor is supposed to be be small, should already work with a battery voltage of about 5 V (e.g. 4 NiCd- or NiMH-cells) and manage with currents under 200 mA. The P5341 step motor (Figure 1) is perfectly suitable for applications with smoothly operating transmissions, where the focus is not on speed or power which is ideal for slow settings of video cameras or focussing drives. Unfortunately it takes some time to find it. The following source only delivers to resellers:

Source for the P5341 motor: http://www.kemo-electronic.com/p5341_d.html

Further possibilities for the procurement of such small step motors are old disk drives, which are often left about. Their head positioning motor is usually a bipolar step motor and fulfils our requirements.
When “recycling” keep in mind that these motors generally only have one bearing inside, the second one is integrated outside at the end of the axle in the cast casing, as shown in figure 2. If you wish to use such a motor, you should saw a piece out of the frame with the bearing and the motor fastening and fully use this construction.

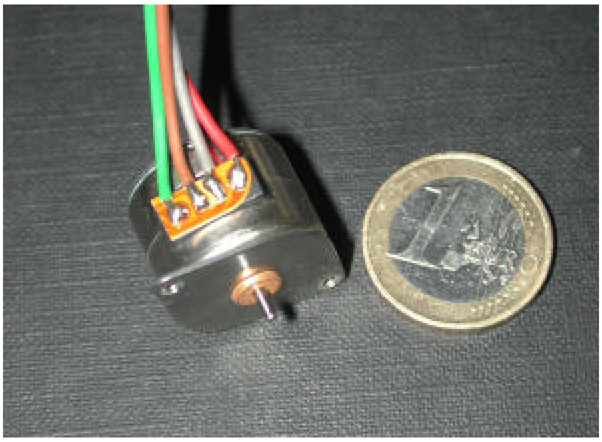


Fig. 1 Miniature step motor P5341

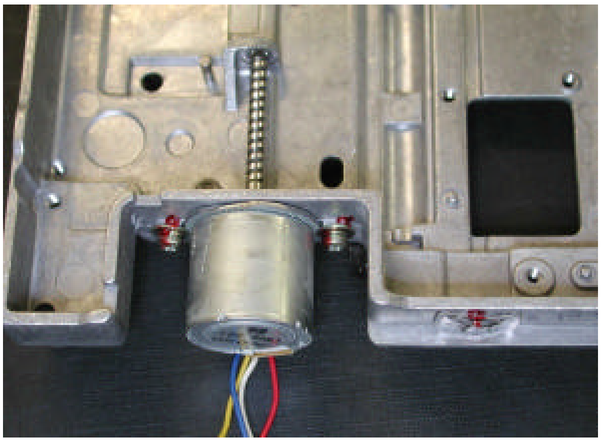


Fig. 2 An alternative source for small bipolar step motors are old disk drives.

In order to integrate such a step motor in a positioning drive, a transmission is required first. The author has good experience with Tamiya transmission construction kits which are difficult to find in Germany. An address in the USA, which also supplies Germany, is

Pololu: http://www.pololu.com/products/tamiya/index.html - gearboxes

Our motor fits perfectly to the transmission construction kit #70093, with small changes in the motor reception and respective adaption of the driving pinion to the motor axle (Figures 3 and 4). The 3 eligible gear reductions 16.6:1, 58.2:1 and 203.7:1 allow a far-reaching adaptation to different tasks.

Fig. 3 You can fit the pinion to the motor shaft using a small metal capsule or a heat-shrinkable sleeve

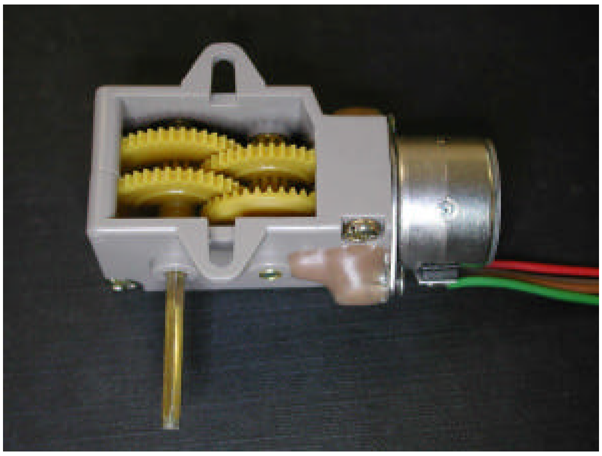


Fig. 4 Example for using a Tamiya transmission construction kit (Tamiya #70093)

3. Circuitry

First of all, we want to control a bipolar step motor. If you read note 018, you will know that such motors have (electrical) two coils and generally manage with 4 connections. Additional center taps could also make a unipolar operation possible, but then such a motor would have 6 connections. For its operation a bipolar step motor requires a control, which can change polarity for each winding. Hence, it would be best to implement this using a bridge circuit. Do you remember note 059 concerning the so-called H-bridge for DC motors? This is also required for bipolar step motors. The SN754410, which was used as an example in note 059 is principally suitable for our current task - it is the H-bridge driver for both windings of our step motor. So how will we control our step motor? There are several principles to choose from, which all have advantages and disadvantages:

- The simplest method is to directly control both coils via the 4 SN754410 inputs, which logically pass on the input signal directly to the power outputs. This principle manages to do without any further logic and has the advantage that the controlling unit, in our case the BASIC-Tiger®, is exactly "informed" about the respective condition of the current flowing to the coil. This is important when an exact positioning is required and no steps are allowed to be lost. A disadvantage is that the BASIC-Tiger® hardly has time for other operations but dealing with the changing bit patterns for the coil hook-up during motor operation. It is also disadvantageous that all actions which happen in the meantime (Information to the LCD, various calculating operations and task switches) have an influence on the running of the motor. This can be heard during practical operation! Last but not least we will need at least four port lines.

- Somewhat simpler would be to use an additional logic, which calculates the bit patterns for the coils itself and, for example, expects only one cycle and a directional signal or rather two different cycles for forward and reverse from BASIC-Tiger®. For example you will find such a solution in application note 018. The advantages are that BASIC-Tiger® simply counts forwards or backwards and only two port lines are required. One disadvantage should not be withheld. As the logic only supplies the coils via cycles there is an uncertainty at the start (RESET, Power ON) – what was the last combination of current flow to the coils? If the new cycle begins with a completely different combination, there will be undefined motor jumps at the start. This is no proper solution for exact positioning systems. In practice it will help you to use initialization phases, during which the drives are often set to 0 by a limit switch. Once operating such a step motor is supplied with current even during breaks and thus exactly holds its position.

- Even simpler to deal with are hybrid variations with usually highly complex ICs, which bring the performance part as well as a rather costly logic part. Such ICs enable micro step operation (for this a quasi sinusoidal control is generated), chopper operation (the operating current is phased and therefore reduced specifically during standstill) as well as a simple control via a single phase.

We chose the first variation, as it allows us in a simple way to implement a “memory” for the current flow situation of the last step. If all involved components are switched off during movement breaks (motor, bridge-IC, BASIC-Tiger®), the step count and the last combination of coil switching can be secured in the Flash. Once the operation is started this data is available again and the exact position is retained. The only precondition is that no mechanical power adjusts the drive (for example manually or wind). If such influences are unavoidable then self-inhibiting transmissions, for example worm gears, must be used.

The circuit concept is already clear. 4 BASIC-Tiger® outputs (L80 – L83) deliver the bit pattern to the SN754410 inputs, where they are laid directly via the accompanying outputs against both coils, logically unchanged but their performance appropriately enhanced. Both SN754410 Enable-inputs can switch the output pairs to high-impedance and hence drastically reduce the power consumption. The SN754410 can cope with such small motors without cooling and protective diodes at the outputs. With bigger motors and/or higher operation voltages or currents the manufacturer recommends appropriate cooling measures as well as additional external protective diodes (Schottky!), which have been marked as an option by a broken line in the circuit diagram. Please use cables with a wider diameter for Vcc2, GND and the motor connections as shown in figure 5 below. In particular the GND connections serve as cooling for the SN754410, which is why they are to be laid out as extensive as possible. The cable colours for the motor and its driver are meant for the motor P5341.

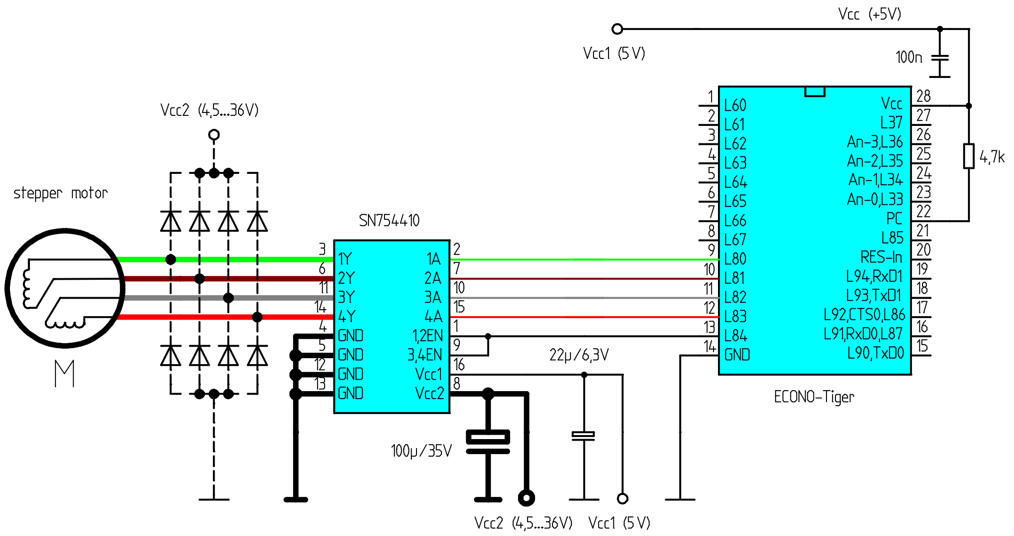


Fig. 5 the simple connection of a small step motor via the SN754410 to an ECONO-Tiger®. Only the circuit parts relevant for the step motor are depicted.

Table 1 serves for better understanding of the whole step motor driver. The bit pattern on the BASIC-Tiger®, the polarities of the coil connections as well as the gradual rotation of the rotor is depicted schematically for the 4 steps in full-step operation.

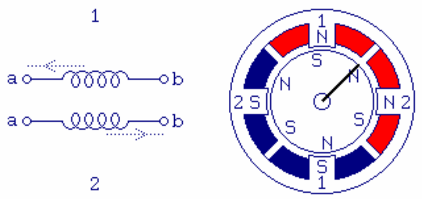
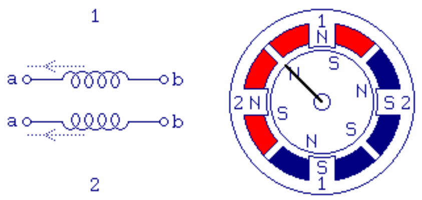
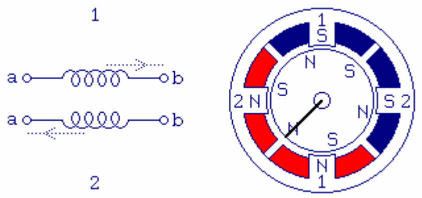
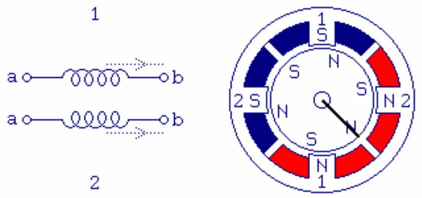
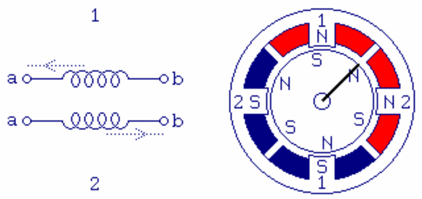
Step no.	Bit pattern L80-L83	Outputs 754410				Graphical depiction of the sequence of events in the motor, the motor in this example has four full steps per complete rotation.
		1Y	2Y	3Y	4Y	
		Coil 1		Coil 2		
		a	b	a	b	
0	0110	-	+	+	-	
1	0101	-	+	-	+	
2	1001	+	-	-	+	
3	1010	+	-	+	-	
0 (next cycle)	0110	-	+	+	-	

Table 1 Sequence of events during full-step operation. Pieces of the motor graphics were taken from the highly informative web site of Douglas W. Jones and changed accordingly (http://www.cs.uiowa.edu/~jones/step/)

4. BASIC-Tiger® software STEP01.TIG

Once the circuit is finished, we will examine its function using the BASIC-Tiger® program STEP01.TIG. An initial test should make the motor start running into one direction with a random number of steps (1 to 65536), once switched on. The program guarantees a slow start via appropriate breaks as well as a slowing down once the final destination has been reached. Following a short stop it will turn to the other direction. The number of steps is equal in both

directions and the motor must stop in the same position after it has reversed. If it does this we are almost there.
At the end of each movement the software outputs the reached position and the number of loops on a possibly connected display. This does not work well during movement, because the required times needed to operate the display would disturb the motor controlling.

Nevertheless– something remains to be done. We planned to develop a battery-run driver, which does not use up any power during the work breaks. How do we achieve this? Quite simple by using the power supply circuit from application note 060. There we had exactly the same type of problem! Nonetheless we are now using 4 cells (because the chosen motor simply runs better with 4.8 V). In order to start we again require a few keys and a CD4078. As we may need a display for certain applications (for example, in order to display the reached position of our actuation), there are only few port lines remaining for this purpose with the ECONO-Tiger® , namely L85, L86 and L87. The last two are only then free when we are not using serial communication. At least one key and one lock output of the BASIC-Tigers® are required in order to realise the principle of the voltage connection with a key, as noted in note 060. If more keys are required for operation of the system it is also possible with the ECONO-Tiger® to fall back on the extended port system with the possibility of a complete keyboard. However, with these additional keys it is not possible to switch on the operation voltage!

And what happens when it is switched off? Perhaps you have heard somewhere that step motors must always remain “under steam” in order to keep a reached position. And, you may have also heard, the first step after switching on is more or less coincidental. We have something to counter this! When switching off, we “remember” the achieved number of steps each time in Flash, read it in again when switching on and set the step motor in the same way as it was set when switching off. The STEP01.TIG software demonstrates that, following each forward movement the ENABLE inputs of the SN754410 are switched to inactive. Thus the current from the Vcc2 source is reduced to ca. 2 mA. The position of the motor is written into the Flash and after a short waiting time read out again. If you minimise outside influences on the actuation, say using a worm gear, the motor will continue running exactly where it stopped when it was switched off. You can carry out a simple duration test by coupling a small mechanical tape counter mechanism directly to the motor (figure 6). With STEP01.TIG you can now carry out many thousand steps (variable “ende”) and that many thousand times (variable “q”), if you wish. Check the end positions over and over again during the breaks. You will realise that the step motor driver really does keep its position without any holding current. Thus the path is cleared for this elegant variation.

Depending on the application you will now find your solution one way or the other. If required, perhaps use a TINY- or BASIC-Tiger® or one of the many extension modules for more complicated applications, where you need more I/O pins.

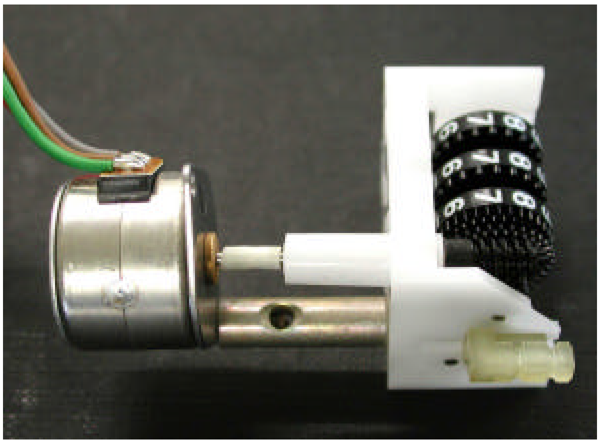


Fig. 6 This is how you can test the repetitive exactness of your motor depending on different parameters (STEP01.TIG)

Have fun stepping!