Speed Controller for Brushed Motor With Polarity Reversal (Relay)

Assembly and Operating Instructions

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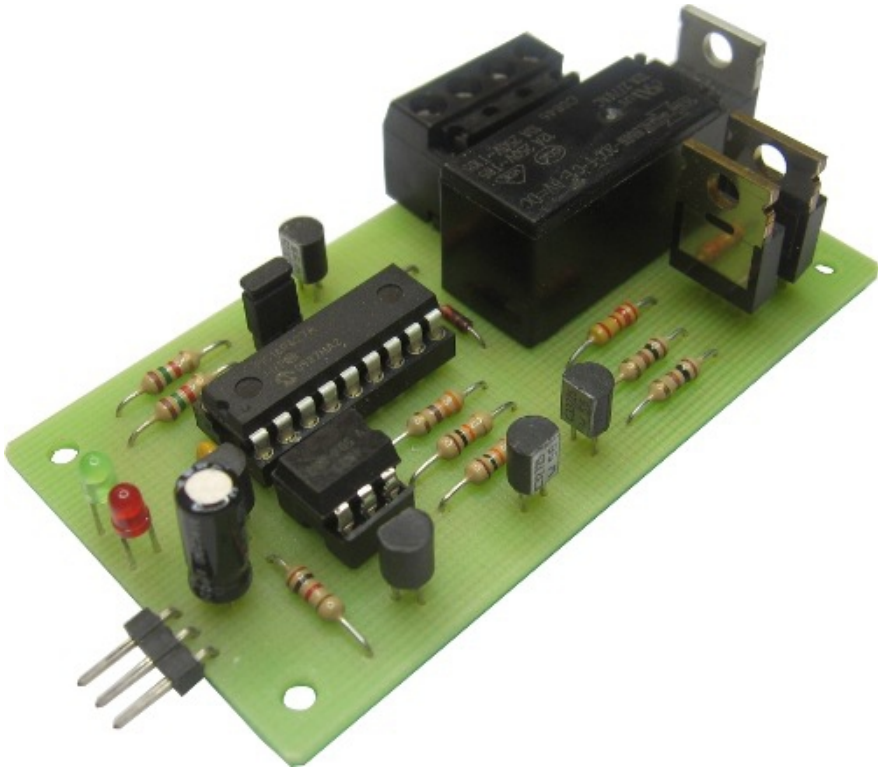

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1 introduction

This speed control is used for stepless control of the speed of a brushed electric motor.
The engine speed varies proportionally with the position of the throttle control on the transmitter when it is moved above or below the center position.
When the knob is in neutral position, The motor is stopped. It then changes speed to the maximum forward or reverse speed whenever the throttle control is moved to the full up or down position. This motor speed control thereby makes it possible to move the vehicle forward or back without the need for a forward/reverse switch

1.1 ESC and Heat

Controlling an electric motor's speed is usually associated with electrical losses. These losses show up as heating of the controlling transistors in the ESC. Losses serve no useful purposes and are therefore unwanted. On the one hand, heat must be dissipated, on the other hand, this waste of energy reduces the running time of the model. Energy losses through heat are part of the equation for energy consumed from the supply battery and therefore the discharge rate of the battery. External cooling of the ESC indicates poor efficiency.

The motor that will be connected to this speed control must not consume more power than the speed controller is capable of supplying, otherwise the controller will be destroyed. The higher the current carrying capacity of an ESC is, the lower is the the risk of overloading the ESC.

Low power loss can be achieved by supplying the power transistors with a square wave in the kHz range (several thousand times per second) with variable pulse-pause ratio (PWM or Pulse Width Modulation) The operation of this speed control is described in Chapter 4.

The unit presented in this document has the following features:

- Current carrying capacity max. 15 A
- Clock frequency of 2.5 kHz or 9 kHz
- Precise control through 250 speed levels per direction of travel
- fail safe: the motor is switched off in case of faulty input signal
- Starting protection of the motor when switching on the power supply
- High stability due to galvanic isolation of control and power stage
- Learning the neutral and maximum position through setup procedure

Printed circuit boards with solder mask and embossed print, programmed microcontroller or complete kits are available on request from the author.
The board layouts are available as PDF files(Exposure Template)and the firmware for programming the Microcontroller is available as a download from http://cp-elektronik.de. The firmware is also free and information about the programming serviceis also available at the website.

2 assembly instructions

2.1 General information

To reproduce this circuit basic knowledge about the use of the components is required. In addition, you should do a few electronic exercises such as soldering

General Information Continued.....

- Work carefully and pay attention while soldering and wiring.
- Take your time for each connection and make sure that there are no cold solder joints.
- Use a controllable soldering station or a small soldering iron for soldering with a capacity of max. 30 watts with a small solder tip.
- For some components, attention must be paid to the correct polarity or orientation. These are all mentioned in the text.
- Semiconductors are heat sensitive. Do not leave heat on a pin for too long (max. 5 seconds). If necessary, allow the component lead to cool off if you need to try making the solder connection again

The following assumes that you already have a board and all the necessary Components on hand.

2.2 Building the Speed Conrol

2.2.1 List of Parts

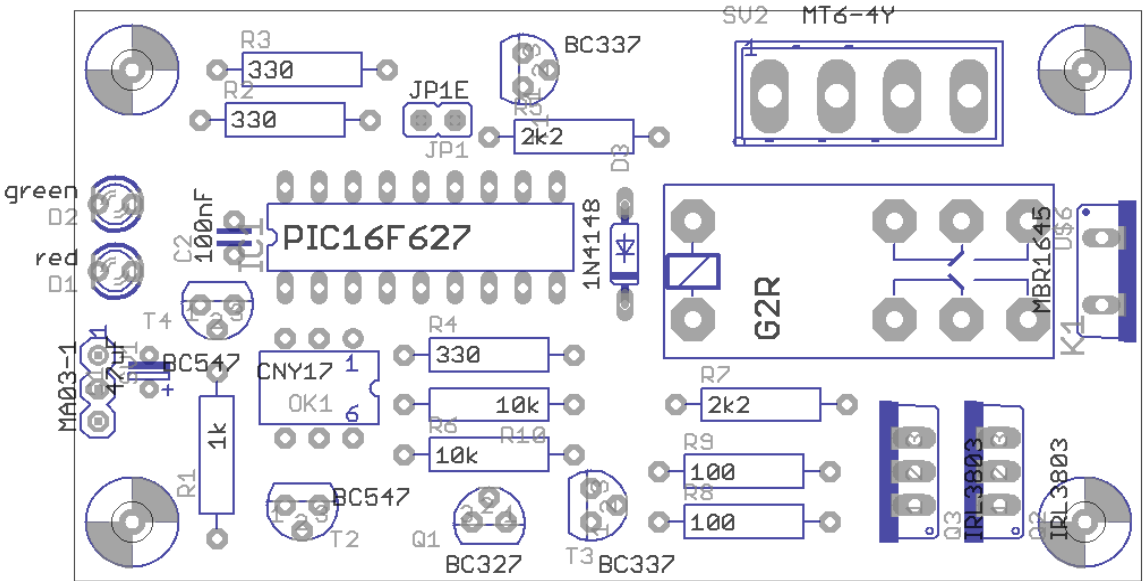
First, you will want to gather all the necessary parts. A table has been provided (Pg 5) which lists all of the parts needed to build this project.
The designation of the components embossed on the printed circuit board is the same as the designation of the components on the schematic wiring diagram
(Fig. 3).

Quantity	Designation	Description	Component/Part No
1	C1	Electrolytic Capacitor	100 µF 25v
1	C2	Disc Capacitor	100 nF
1	D1	LED 3mm	Red
1	D2	LED 3mm	Green
1	D3	silicon Universal diode	1N4148
1	D8	Shotty Diode	MBR1645 (16A 45V)
1	IC1	Microcontroller 18 pin DIL	PIC16F627A
1	Socket	18 Pin IC Socket PC Mount	Digi-Key AE9995-ND
1	JP1	Header 2-PIN	Digi-Key A106753-ND
1	JP1	Shunt	Digi-Key A106575-ND
1	K1	General Purpose Power Relay DPDT PCB mount 8A Contacts	G2RL-2 Omron JQX-115F-06 Futurlec RT424 Tyco
1	OK1	Opto Coupler	4N27, CNY17, 1L47
1	Socket	6 Pin IC Socket PC Mount	
1	Q1	Transistor	BC3327
1	Q2, Q3	Transistor N-Channel MOSFET	IRL3803
1	R1	Resistor 1/4w	1K Ω
3	R2, R3, R4	Resistor 1/4w	330 Ω
2	R5, R7	Resistor 1/4w	2.2k Ω
2	R6, R10	Resistor 1/4w	10K Ω
2	R8, R9	Resistor 1/4w	100 Ω
1	SV1	Header 3-pin	Digi-Key A106753-ND
1	SV2	Term Strip 4 Posn PC Mount	TER-404 All Electronics
2	T1, T3	Transistor	BC337
2	T2, T4	Transistor	BC547

2.3 Assembly of the printed circuit board
Insert the leads of the components through the holes on the circuit board and solder them ton the foil side. Observe correct orientation of diodes, leds and polarized capacitors. Refer to (Fig. 1) and on the silkscreen on the board. This layout shows the component side of the board.

2.3.1 Resistances
Begin the build by mounting resistors. They are the easiest because orientation of these components does not matter.

Figure 1: PCB Layout for the ESC



- R1: 1k Ω, Color: Brown – Black - Red – Gold
- R2, R3, R4: 330 Ω, Color: Orange – Orange – Brown - gold
- R5, R7: 2,2 k Ω , Color: Red – Red – Red – Gold
- R6, R10: 10K Ω, Color: Brown – Black – Orange – Gold
- R8, R9: 100 Ω, Color: Brown – Blak – Brown – Gold

2.3.2 Flyback diode for the relay

Now mount D3. The diode has a small glass body and is marked with a line one end. This is the Cathode end and must oriented so that the line points toward R4 / R7. Its function is to suppress the pulse caused by the collapsing magnetic field of the relay coil when it becomes de-energized.

2.3.3 ceramic capacitor

Now mount the 100nF capacitor C2. There is no concern for orientation of this component

2.3.4 PIC Microcontroller

Mount the 18 pin socket for the Microcontroller so that the notch on one end of the socket is pointing toward the ceramic capacitor (C2) that you just mounted (2.3.1). **Proper orientation is very important**

When it is time to insert the Microcontroller, it is very important to insert it so that the notch on the end of the IC maches the notch on the socket for this IC.
The six-pin socket for the Optic Coupler (OK1) must be oriented so that the notch on the socket is pointing at R4 / R6. After completion of all work, the programmed PIC Microconroller and the Optic Coupler can be inserted in their respective sockets observing that they are correctly oriented with their notched aligned with the notches on their sockets.

Note

If you cannot find a six-pin socket for the Optic Coupler, you can use an 8-pin socket by cutting off pins 4 and 5.

2.3.5 Jumpers

Mount the 2-pin header JP1 to accept the jumper. This option will be used when it comes time for setting up the ESC.

2.3.6 LEDs

Now look at the red LED D1 and the green LED D2. The connecting legs of the LED are not the same length; There is also a flat spot on the case of the LED and is nearest the shorter leg. This lead on both LEDs is called the Cathode and must be orientated to the outside edge of the circuit board. The longer connecting leg points in the direction of the PIC microcontroller.

2.3.7 Transistors

The transistors have three connection legs (base, collector and emitter). The outline for each transistor is embossed onto the circuit board. Note one side of each of the transistors is flat. Mount the transistors so that they match their outlines on the board.. **Also ensure that the proper transistor is being mounted in its correct spot.** Mount one transistor at a time. Double check your work before soldering it into place.

2.3.8 Electrolytic Capacitors

These are polorized units and must be oriented correctly otherwise, they will be damaged when power is turned on. Note that one lead is shorter than the other – this is the NEGATIVE lead. Usually the case for this type of capacitor is marked with a “-” symbol for this lead and a “+” symbol for the positive lead. In this case, the negative (-) lead points to the red and green LEDs.

2.3.9 MOSFETs

The MOSFET power transistors have three connection legs and a housing of plastic with one side made of metal. A hole for fastening to a heatsink is provided If heat sink cooling is required. Using this speed control up to and not exceeding 15 A, the 2.5-kHz firmware version does not require any cooling, so solder the transistors as they are supplied oriented with the metal side of the housing pointing in the direction of R7 / R9.

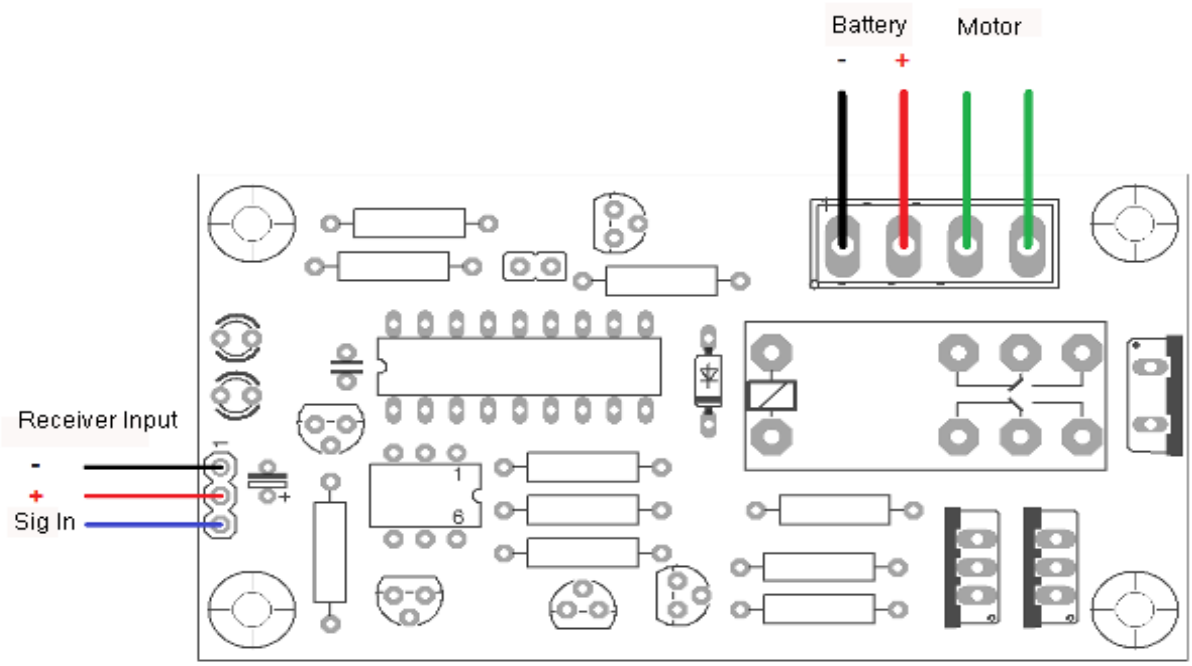
2.3.10 Schottky diode

This diode dissipates the motor current during the power-down phases of the power transistors. It must be able to handle the entire motor current. Its case is similar to the MOSFETs, but contains only two connecting legs - an Anode leg and a Cathode leg. Pay attention to the orientation of this unit - the metal side of the case points to the outside edge of the PCB.

2.3.11 Relays and motor connection

mount the reversing relay and the four-pin barrier strip which is used to connect the battery and the motor to the circuit board. The screw terminal openings to insert wires should face to the outside edge of the circuit board.

Figure 2: Speed Control Connections



2.3.12 Connection cable

Use a commercially available servo cable to connect to the receiver Contact strip SV1. The color scheme for ribbon connection cables is usually red for +5 V, black for GND and white for the signal line. Figure 2 shows how the servo cable is connected to the decoder.

2.3.13 Inserting the ICs

Gently push the programmed microcontroller into the 18-pin. Observe alignent of the notch that it matches the notch on the socket
If the connecting pins of the PIC are too wide slightly and do not align easily with the socket, adjust them slightly by holding the IC so that all pins along one side are against a flat surface. Apply a bit of pressure so that the pins bend slightly and are close to right angles to the body of the IC. Repaet for the other side. He IC should now more easily fit into the socket.

Also mount the optocoupler in its socket, following the procedure above if the pins seem to be spread too wide. Observe the orientation of notches on the IC and its socket.
NOTE:
Should you have problems finding a six-pin socket for the optic coupler, you can use a standard eight-pin socket. Remove pins 4 and 5 before soldering to the circuit board.

3 Notes on operation

3.1 Setup and commissioning

The red LED is extinguished if there is no error condition.
If the red LED lights up permanently, there is an issue with the receiver signal. Make sure the transmitter is switched on. Also check the cable connection to the receiver and the soldering at R1, T4 and Pin 6 of the PIC.
Before using the speed controller the first time, it has to be adapted to the throttle control and "learn" the center position und full up position. To do so, proceed as follows:

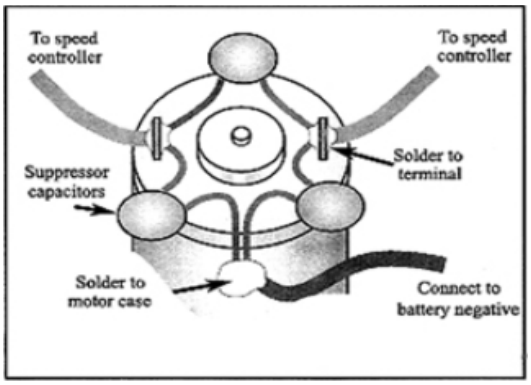
- Turn off the receiver and the speed controller
- Remove the jumper JP1 to enter setup mode
- Make sure the throttle control and the trim adjustment (-> those tiny things for fine tuning the center position) is in center position
- Switch on the transmitter
- Switch on receiver / speed controller
- The red LED will flash for 5 secs. Don't move the throttle control out of the center position during this period of time
- If the red LED is extinguished, the center position was stored in the permanent memory of the controller. Data in the permanent memory is retained even if the power is switched off.
- After 5 sec, the green LED begins flashing. Move the throttle control to the full up position and hold this position, until the green LED is extinguished (again 5 secs).
- When the green LED is exinguished, the full up position is stored and the setup procedure is done
- Remove the receiver power supply for about 30 secs to give the capcitors time to fully discharge.
- Replace JP1 again to enter operation mode

You may repeat the setup procedure if another channel or another receiver is employed. Nevertheless, the setup procedure can be repeated at any time.

3.2 Connection of motor and battery

3.2.1 Radio Interference

Please make sure the motor is radio-interference-suppressed (e.g. use suppressor capacitors for this). Sparking at the brushes inside of the motor can cause severe RFI (Radio Frequency Interference) which can affect the receiver and cause erratic operation of the speed control and servos. Suppresser capacitors should be fitted as shown in the accompanying image. One capacitor of 10nF is soldered between the motor connections and a 100nF capacitor from each motor connection soldered directly to the case of the motor.



Connect the battery Supply and the Motor (as shown in picture 2).
Verify that the Transmitter is switched on.
When the receiver is switched on, the green LED lights up for approx 2 sec. For safety reasons, the throttle control has to be in the center position and must not be moved during this time. If the green LED extinguishes, the motor output is activated and the controller is ready for operation.

Move the throttle control slowly forward. The motor will now start. In neutral position
the motor will stop. Move the control knob slowly back.
The relay should activate (noticeable clack) and the motor changes direction.
If the motor runs in the wrong direction, the motor connections can be reversed
Never interchange the connections of the supply battery!
If the relay picks up when you move the knob forward, activate
the corresponding channel servo-reverse in the transmitter and then run a new setup (3.1).
Note that the controller is the most heavily loaded when operating in the partial load range. If the Schottky diode does heat up during operation, attach a heat sink with one M3 screw for better heat dissipation.
Also, when using the 9 kHz firmware version, the two power transistors may heat up. In this case, Fit each power transistor with a heat sink and M3 screw.
When I designed the PCB, the PCBs are manufacured in a way that
the printed board tracks carrying the motor current are not covered with solder resist. This enables the tracks to be reinforced with bare copper wire or solder. Usually, when the PCB etched in a do-it-yourself process, there is no solder resist.

Another method of increasing the current carrying capacity is reinforcing the printed board tracks carrying the motor current by soldering bare copper wire (preferred) or solder tin.

4 Operation of the cruise control

The circuit diagram of the cruise control can be seen in Figure 3. The heart of the control unit is a 16F627A microcontroller. T4, R1 and R10 build an inverter stage to increase level of the the receiver input, which is connected to port B0 of the controller.

At the outputs A0 and A1 are two LEDs for displaying error conditions and setup procedure progress. The polarity reversal relay is controlled via the output B4 and the driver transistor T1.

The current carrying capacity is mainly limited by the carrying capacity contacts of the relay, this is 12 A for the specified relay, the copper foil traces on the circuit board and the size of the wire feeding the motor. This should be sufficient for most model boats, but racing boats may demand more current carrying capacity. As the relay is usually operated in a no current condition (center position), we can assume 15 A without decreasing the relay lifetime too much.

The PWM signal appears at pin B3 to control the motor via the optocoupler CNY17 and the inverter stage T2. Q1 and T3 form a “totem pole driver circuit” for MOSFETs IRL 3803.

R8 / R9 (100 Ohm) are a compromise from the demand for reduced power dissipation and low emission of radio interference signals. Fast switching (steep rising/falling edges) reduces power dissipation but increases emission of radio interference signals. If there is no interference with reception even over larger distances, the gate resistors could be reduced to 47 Ohm.
The Schottky diode MBR 1645 carries the current induced in the motor during the switch off phases of the MOSFETs in the motor back EMF.
The optocoupler ensures galvanic isolation of the control and power section. Nevertheless, make sure the motor is radio-interference-suppressed (e.g. use suppressor capacitors for this).

The controller can be operated with a driving voltage between 6 V and 12 V. In general, however, it is recommended to use 12 V as the driving voltage. A small current is easier to handle and the
Power loss at the power transistors, supply lines and in the motor is reduced clearly, as it grows in proportion to the square of the current. Given equal engine power, the power loss with 6 V driving voltage is 4 times higher than with 12 V.

5 feedback

If you have any suggestions for errors, ambiguities or suggestions for improvement for this manual
Please write me an E-Mail to info@cp-elektronik.de

Figure 3: ESC Schematic Diagram