CHEAP-RC project

About the person:

I, a trained high-voltage electrician and computer dinosaur, have been working with electronics and computers since my training. My first microprocessor was a KIM-1 (purchased in 1976 at the tender age of 19). Apple II, IBM PC and Commodore C64 only came onto the market later. I have been working with PIC microprocessors since around 1998. As a computer dinosaur, I started with BASIC and I still use it today. BASIC existed and exists in various versions for microprocessors. I will come back to **C** as a programming language later. I also started making my own circuit boards very early on.

Since my birth, I have tried unsuccessfully to get rid of the railway virus 😊 😊.

In order to promote the spread of such projects, I provide the relevant sources (circuit diagrams, layouts, program listings, parts lists and other necessary information) for **non-commercial** use to anyone interested. Simply get in touch.

This description is a translation (with Google Translator) of an Article, I wrote for a German Magazine. So, there are some “German Words” left e.g. in pictures.

Why “CHEAP-RC”?

Cheap-RC are a translation of “Billig-RC” (the German word “Billig” means the same as Cheap, but the word “Billig” has a negative touch in this conjunction). So, I use CHEAP-RC. But “ cheap ” doesn’t mean that the system can’t do anything (quite the opposite).
To explain: The **R**adio **C**ontrol including receiver is available in the country of the "slant-eyed" inhabitants for around €20 to €25. Delivery time approx. 2 weeks. Also available from AMAZON or EBAY.

Target area:

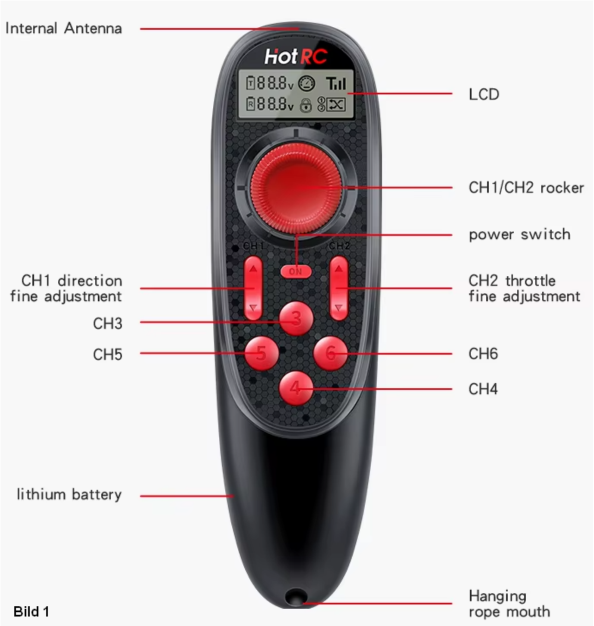
This control is intended for a small entry-level locomotive (e.g. 5-inch or 7-¼ inch) (see Foto on last page). However, that does not mean that the control cannot also be used in really large models. In order to fit into smaller models, some components were deliberately kept small (e.g. standing resistors), without limiting versatility or making it difficult to replicate. With the exception of an 8-pin IC (SMD), only wired components are used. At 98 x 73mm, the board is quite compact despite all its options. The transmitter fits comfortably in one hand and enables the model to be controlled over a distance of several hundred meters. There is also the option of local control (with cable).

Components of the control system:

The entire system consists of three components.

1.) A six-channel transmitter DS600 (Figure 1 and Figure 2)
2.) A six-channel receiver F-06A (Figure 4)
3.) A printed circuit board for preparing and outputting the control signals (Figure 5)

A motor controller for 50V and 40A has almost the same mounting holes as the board. This makes it possible to create a small, compact block for the entire system. This is sufficient for smaller models with, for example, 2 motors of 250W at **+24V**. An example of how to connect a motor controller can be found further down.



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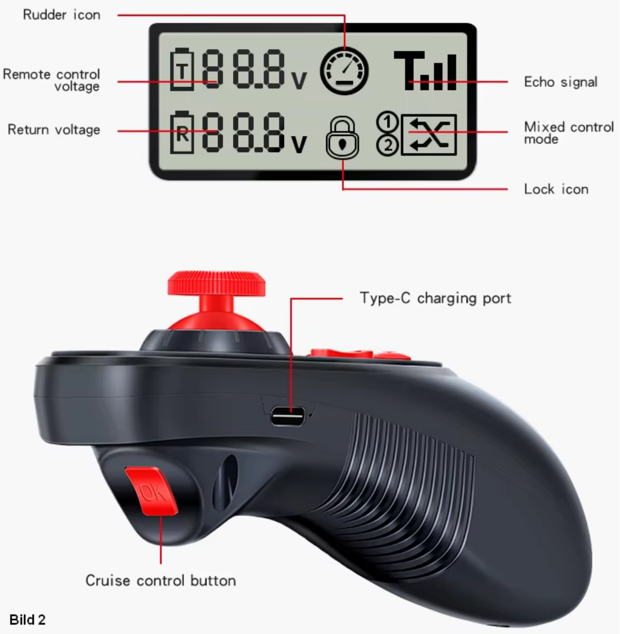

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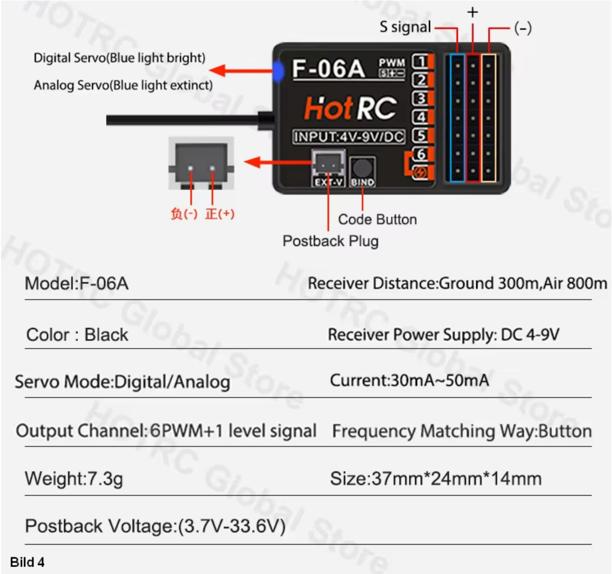

Model:F-06A	Receiver Distance:Ground 300m,Air 800m
Color : Black	Receiver Power Supply: DC 4-9V
Servo Mode:Digital/Analog	Current:30mA~50mA
Output Channel:6PWM+1 level signal	Frequency Matching Way:Button
Weight:7.3g	Size:37mm*24mm*14mm
Postback Voltage:(3.7V-33.6V)	

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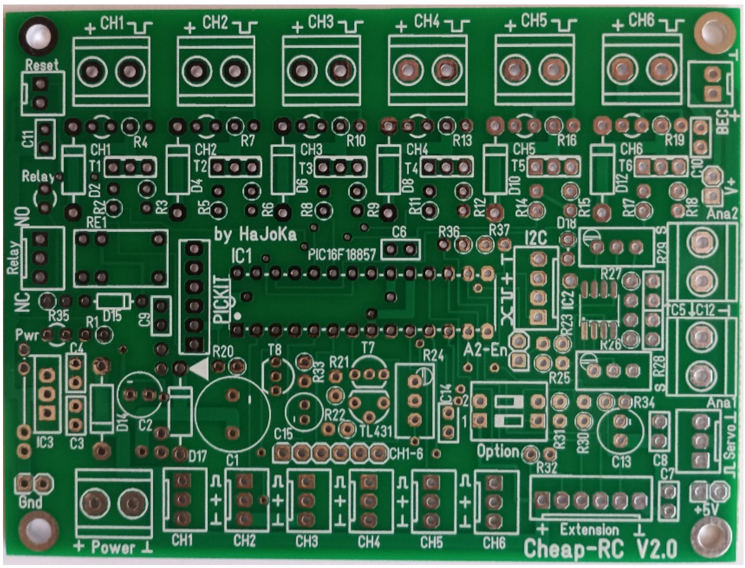


Possibilities of the board:

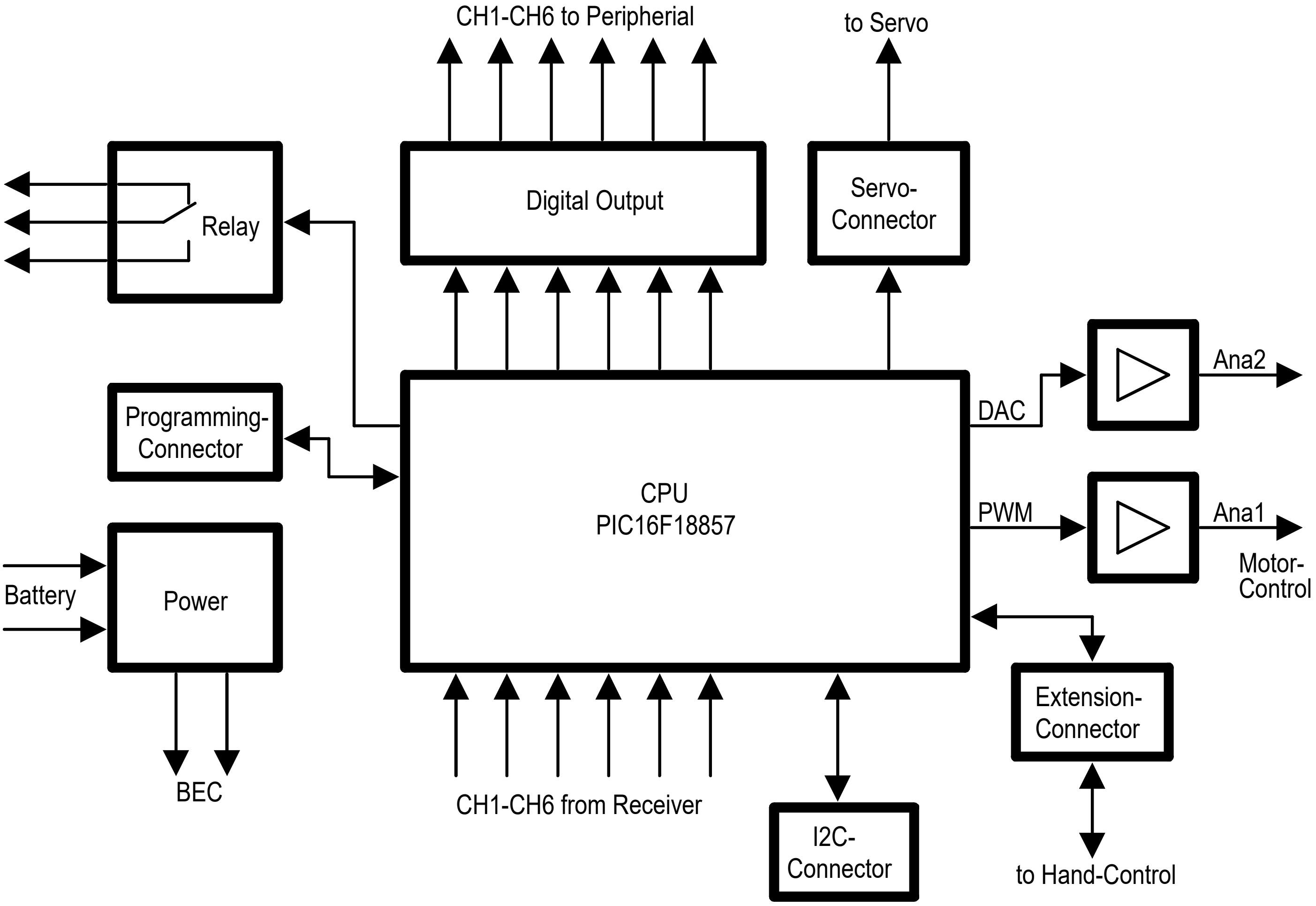
Two analog outputs (max. 10V for e.g. motor controller), six loadable digital outputs (e.g. horn, brake, sound, etc.), a relay output, an output for a RC-Servo and a connection for the power supply of the RC receiver are available as control connections. There is also a connector for local (cable) control.

The circuit is supplied with power via the POWER input. A voltage of **+12V** or **+24V can** be connected here. This voltage can be reported back via the input (Postback / Return Voltage) on the receiver. This means that the battery voltage can also be monitored during operation. A really nice extra!

The six digital outputs each switch the operating voltage (**+12V** or **+24V**) to ground (**GND**) and can handle up to 3A. However, if there is a simultaneous and large load on these outputs, the conductor tracks must be reinforced (see control system structure).

An I2C connection is also implemented. An LCD can be connected here for status or diagnostic purposes. This interface could also be used for other peripherals.

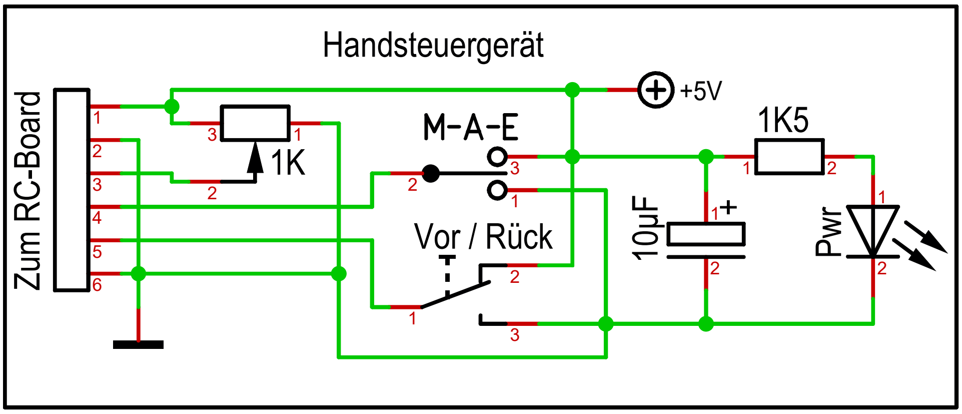
Block diagram of the board:



Extension connector (local control):

pin	function	Art	use
1	+5V	supply	
2	Remote/ Local switching	Digital Inp .	Open = Remote / Gnd = Local
3	speed	Analog	speed control
4	additional function	Analog	Horn (momentary) / Off / Brake (on)
5	direction of travel	Digital Inp .	Forward / Backward
6	GND (ground)	supply	

The local control system is relatively rudimentary. Control elements are provided for speed control, direction changeover and the horn and brake functions. The controls are a potentiometer for speed, a switch for the direction of travel and a switch (momentary-off-on) for the horn and brake. For an example of wiring, see the following image.

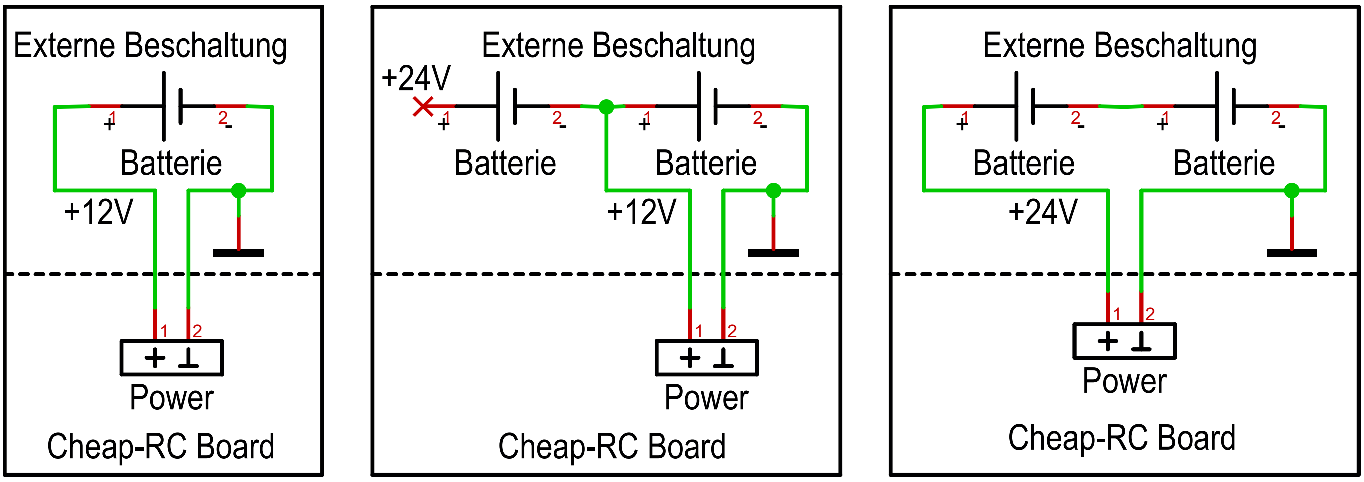


If the hand control is plugged in when the model is switched on, it switches to local control. Otherwise, the control starts in remote mode.

With the speed control (potentiometer), a digital output can be activated in the range of 0 to 5%. This can be used, for example, as a brake when stationary or as an emergency brake.

Operating voltage:

Like any electronic control, this circuit must be supplied with voltage. Some of you may notice that I mostly talk (write) about voltage. This is partly because I trained as an electrician and, more importantly, nothing happens without voltage. The cause is the voltage, current is the result of the voltage and there is resistance as the opposing factor. The honorable Mr. Georg Simon Ohm sends his regards. But that is just a side note.



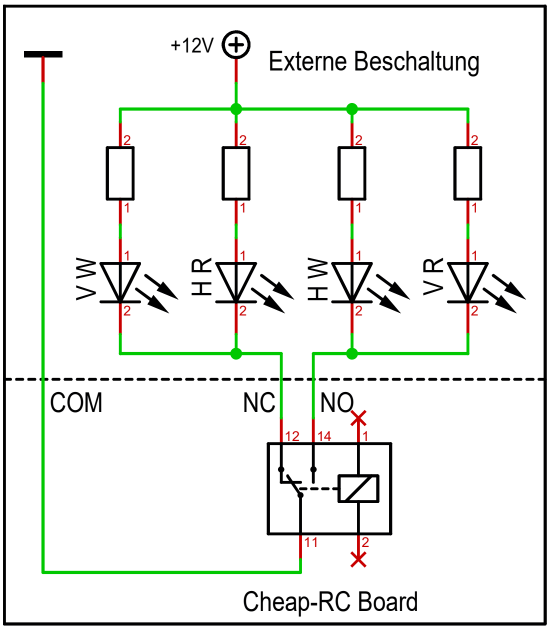
Options for supplying the board with power are listed above. Basically, it doesn't matter which version you choose. All of the board's internal functions are supplied with **+5V** and **+10.5V. These +5V** and **+10.5V are generated from the operating voltage. However, it should be noted that the digital outputs switch the operating voltage through completely. So, if peripherals for 12V are connected, the +24V** supply for these peripherals is " **extremely unhealthy** ". 🙁

BEC connection:

The BEC (**Battery Eliminator Circuit**) is used to supply power to the receiver. This means that no extra power supply or battery pack is required for the radio receiver. This also supplies any connected RC servo with power.

Here are some examples of external wiring of the connectors available on the board:

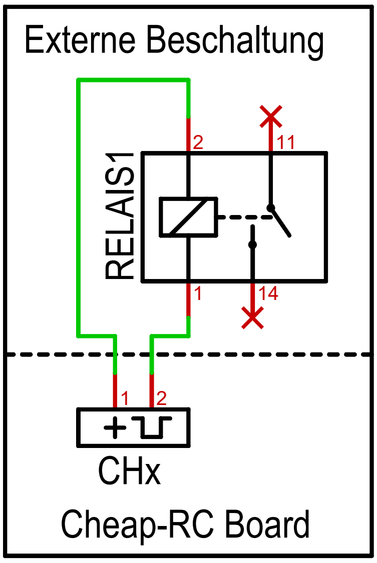
Example: lighting control

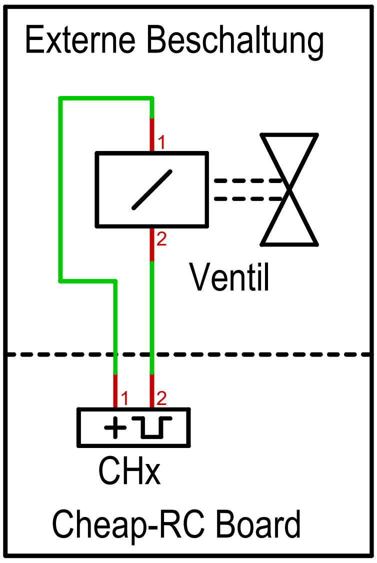


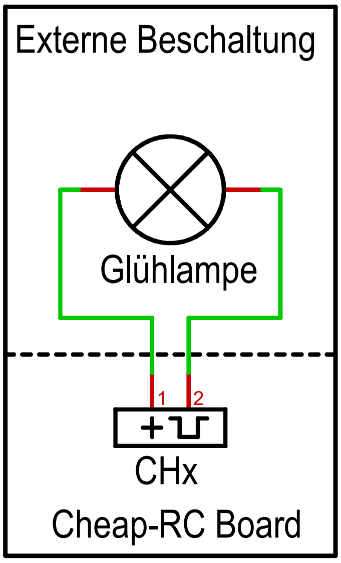
VW = Front White
HR = Rear Red
HW = Rear White
VR = Front Red

The relay contact can be used to switch the locomotive's headlights depending on the direction of travel. Of course, 2 or 3 LED resistor combinations can be connected in parallel for each group (front and rear). (**Note:** Never operate LEDs without a current limiter (resistor or constant current source). **Each** LED has its **own** current limiter. The relay output on the board can handle a maximum of 1 amp.

Examples of other peripherals:

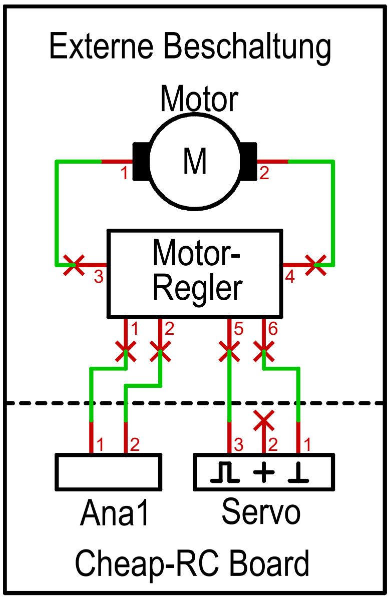






Important: All digital outputs CH1 to CH6 already have "freewheeling diodes" built into the board. Therefore, no additional diode is required for inductive loads (relays, valves). When inductive loads are switched off, very large voltage peaks can occur that can destroy other electronics.

Motor controller:



A motor controller can be controlled via two of the board connections. The motor controller is supplied with the control voltage (for the speed) from the **Ana1 connection. The direction of rotation (CW or CCW) (right or left) is controlled via the Servo connection** (depending on the type of Motor controller). The other way is to use the Relay for direction control. This can also be done for two motor controllers at the same time. To do this, simply connect the corresponding connections of the motor controllers in parallel.

Ana1 and **Ana2** connections can output an adjustable voltage of up to 10V. The load capacity is about 10mA. This is usually sufficient as a control voltage for motor controllers. The **Ana1 output** has 100 levels. **Ana2** has output with 32 levels.

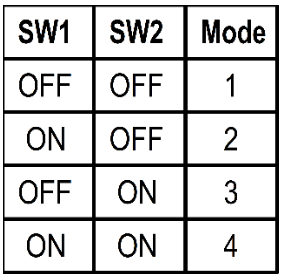
Channel assignment of the DS600 controller:

channel	Art	Description
CH1	Analog	Stick Right / Left
CH2	Analog	Stick Forward / Backward (Speed)
CH3	Digital	switching
CH4	Digital	switching
CH5	Digital	switching
CH6	Digital	moment

These are the basic functions of the radio control. This little “radio” also has some nice “gimmicks”.

If there is no use for a certain period of time, CH2 is reset to a previously set value. This would cause a model to stop, for example. After this time, the "radio" switches off (to save the battery). Here, the "radio" is operated in standard mode (no mixed mode)! The operating voltage of the model can be reported back. The " stroke distances " of the control sticks can be adjusted. And a lot more.

Option-Switch:



SW1	SW2	Mode
OFF	OFF	1
ON	OFF	2
OFF	ON	3
ON	ON	4

The control system can have several working modes. The mode is set using the 2-pin DIL switch (option switch or what I call “mouse keyboard”) on the board. This option switch is read once when the control system is switched on.

The following table shows the relationship between the input signals (Remote or Local) and the functions executed in the different modes (Mx). A detailed description would go too far at this point.

M1	M2	M3	M4	Eingang	Ausgang	Beschreibung	Beipiel / Funktion
x	x		x	CH2	Ana1	Analoge Ausgabe Ana1 bei Stick vorwärts 0%-100%	Motor CW
x	x		x	CH2	Ana1	Analoge Ausgabe Ana1 bei Stick rückwärts 0%-100%	Motor CCW
x	x		x	CH2	Relay	Relais aktiv bei Stick rückwärts	Licht für Rückwärts
x	x		x	CH2	Relay	Relais inaktiv bei Stick neutral und vorwärts	Licht für Vorwärts
x	x		x	CH2	Servo	Servo-Ausgang OFF bei Stick neutral und vorwärts (Zeitsperre)	Motor CW
x	x		x	CH2	Servo	Servo-Ausgang ON bei Stick rückwärts (Zeitsperre)	Motor CCW
x		x		CH2	CH2	Stick neutral	Bremse
x	x		x	Local	Ana1	Analog Ausgabe Ana1 bei Potentiometer ohne Bremsaktivierung	Motor Aus/An
x			x	Local	Ana1	Analog Ausgabe Ana1 bei Potentiometer mit Bremsaktivierung (CH2 Out)	Motor Aus/An
x	x	x	x	Local	Relay	Relais inaktiv bei Fahrtrichtungsschalter Vorwärts	Licht für Vorwärts
x	x	x	x	Local	Relay	Relais aktiv bei Fahrtrichtungsschalter Rückwärts	Licht für Rückwärts
x	x		x	Local	Servo	Servo-Ausgang OFF bei Fahrtrichtungsschalter Vorwärts (Zeitsperre)	Motor CW
x	x		x	Local	Servo	Servo-Ausgang ON bei Fahrtrichtungsschalter Rückwärts (Zeitsperre)	Motor CCW
x	x	x	x	Local	CH1	Handsteuerung Schalter Moment	Hupe
x	x	x	x	Local	CH2	Handsteuerung Schalter Ein	Bremse
x	x		x	CH3	CH3	CH3 Out bei CH3 (wechselfunktion)	Sound
x	x	x	x	CH4	CH4	CH4 Out bei CH4 (wechselfunktion)	Rundumlicht
x	x	x	x	CH5	CH5	CH5 Out bei CH5 (wechselfunktion)	Blinklicht
x	x	x	x	CH6	CH6	CH6 Out bei CH6 (momentfunktion)	Hupe
		x		CH2	Servo	Servo-Ausgang mit Servosignal 100%-0%-100% (Stick Vor-0-Rück)	Benzinmotor
		x		CH3	CH3	CH3 Out bei CH3 (wechselfunktion) (Wechsel nach Zeit wenn Stick neutral)	Getriebe (Vor/Rück)
		x		Local	Servo	Servo-Ausgang mit Servosignal 0%-100% (Potentiometer)	Benzinmotor
		x		Local	CH3	CH3 Out (wechselfunktion) Handsteuerung Fahrtrichtungsschalter (Wechsel nach Zeit wenn Potentiometer auf 0%)	Getriebe (Vor/Rück)
			x	CH1	Ana2	Analoge Ausgabe Ana2 bei Stick links 50%-0%	
			x	CH1	Ana2	Analoge Ausgabe Ana2 bei Stick rechts 50%-100%	
			x	CH1	CH2	CH2 Out aktiv bei Stick Links (wenn CH2 = neutral)	Bremse
			x	CH1	CH1	CH1 Out aktiv bei Stick rechts	Hupe

Structure of the control system:

First, solder the IC TS912D (the only SMD component) onto the unpopulated board. This is pretty easy to do with a fine soldering iron (pitch size 1.27mm). If other components are already mounted, it is difficult to get to them. Then solder the flat components (IC socket, diodes, block capacitors (100nF)).

A heat sink must be used for the voltage regulator (7805). However, a switching regulator module on the underside of the board (alternative 1 or 2) is better. This means that no heat sink is required, and the regulator is mechanically relatively well protected. However, the "ground clearance" (distance from already soldered components) of the board must be taken into account. Please note that if alternative 1 or 2 is used for the voltage regulator, capacitors C2, C3, C4 and diode D14 must be soldered beforehand**.** Now solder all the other components one by one.

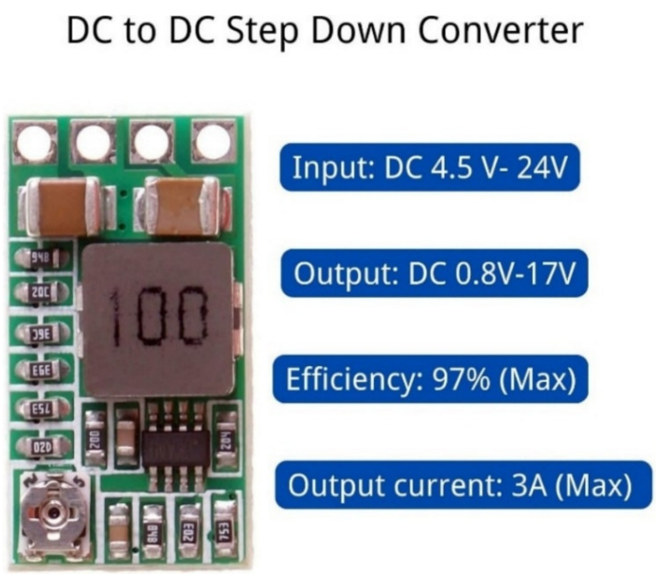
If larger loads are to be operated simultaneously with the outputs, the current-carrying conductors must be reinforced. The conductors without solder stop varnish should be coated with Solder (this is the simplest but only second-best solution). The better solution is to solder on, a bare copper wire of 0.75mm^2 or 1mm^2.

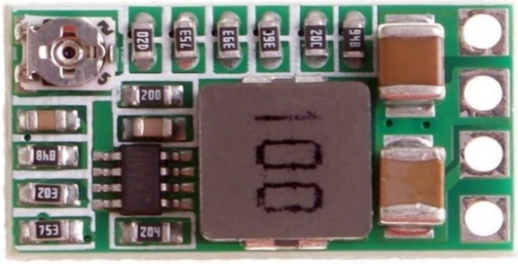
Alternative 1 for the standard linear regulator (7805):

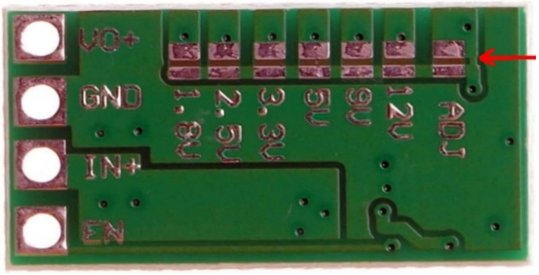
With this replacement, only the PINs **IN+**, **GND** and **VO+** are used. This controller can be inserted into the board from below using a 3-pin header. The **EN pin** remains free. The components point away from the board.

IMPORTANT: The small conductor track at **ADJ** (red arrow) must be interrupted and a blob of solder must be placed at **5V to connect it. The output voltage is then +5V**.

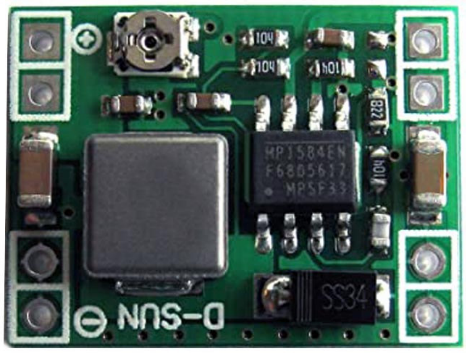
Can be used with batteries of less than 20V. Source e.g. AMAZON (brand e.g. LAOMAO) or ALI-Express.

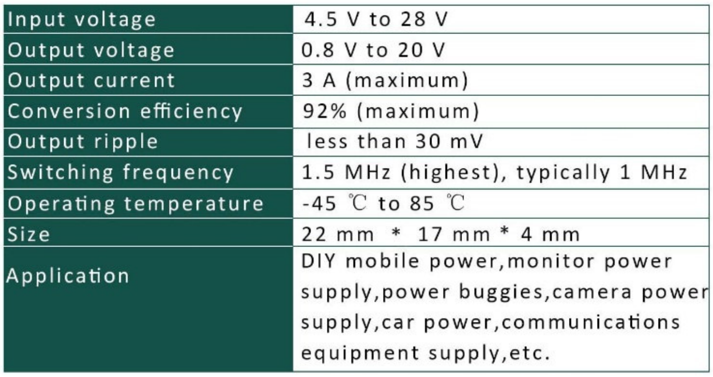




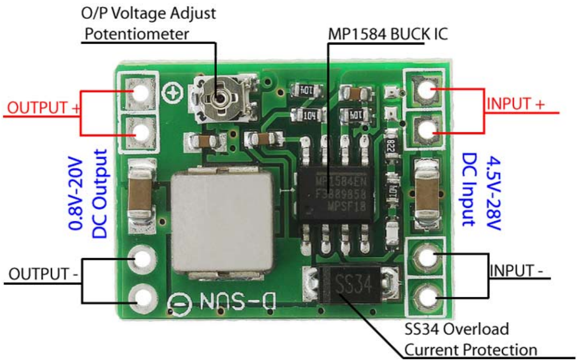


Alternative 2 for the standard linear regulator (7805):





Input voltage	4.5 V to 28 V
Output voltage	0.8 V to 20 V
Output current	3 A (maximum)
Conversion efficiency	92% (maximum)
Output ripple	less than 30 mV
Switching frequency	1.5 MHz (highest), typically 1 MHz
Operating temperature	-45 ℃ to 85 ℃
Size	22 mm * 17 mm * 4 mm
Application	DIY mobile power,monitor power supply,power buggies,camera power supply,car power,communications equipment supply,etc.



Alternative 2 can be used in systems with **12V battery voltage** as well as **24V battery voltage**. This module must be installed under the board as there is no space above. The components point downwards away from the board. Source e.g. AMAZON or ALI-Express. **Installation:** Insert four 2-pin pin strips into the board from below, insert the controller module from below **and only then** solder everything together.

In all cases, after installing the voltage regulator (7805, alternative 1 or alternative 2), check whether **+5V** is also available as a supply. After all components have been soldered, check again whether the **+5V** is available. Only then should you install the CPU (PIC16F18857).

IMPORTANT: The **+5V** is only intended for supplying the logic, the RC receiver and any RC servo that may be used. Higher current consumption is possible for the **+5V**, but should not exceed the capacity of the voltage regulator (especially 7805 => power loss => heat sink).

+10.6V using the potentiometer xx. To do this, supply the board with 12V. The **+10.6V** is necessary because otherwise the output amplifier cannot output 10V for the motor controller. On the other hand, the voltage regulation for the **+10.6V does** not work below an operating voltage of 11.5V. The analog outputs have a maximum load capacity of 10mA! But that is more than enough to control the motor controller. Many motor controllers can work with 5V control. So, the +10,6V can be reduced to 9V. Control voltage can then be adjusted to 5V.

For the LEDs, I use LEDs with 2mA operating current. Why? Standard LEDs have 20mA operating current. With 6 channels switched on, that is 12mA (6 x 2mA) compared to 120mA (6 x 20mA). The 2mA LEDs are not as bright, but are perfectly adequate for signaling on the board. FETs are used as switches for the digital outputs (CH1-CH6). These require practically no operating current and take up less space on the board. Relays, on the other hand, require power to operate. With 6 relays (30mA each or more), this can quickly add up to several hundred mA. But we want to drive and not waste or burn up battery power (power loss in the voltage regulator)! Relays can still be connected to the CH1-CH6 outputs.

Sources:

I buy most of my components from a German Distributor (Reichelt Elektronik). It is not worth buying resistors individually, for example. Even a pack of 10 is considerably cheaper. As already described, some parts come from the Far East (Ali-Express) or from AMAZON or EBAY. The circuit boards are from JLC-PCB.

Programming:

As I mentioned at the beginning, I program the PIC processors in Basic. The Basic compiler that I used to use (Mikro-Basic Pro from Mikroelektronika) is no longer supported. Fortunately, I have come across something even better, namely GCBASIC. This compiler is FREE, open source (large developer community, not a single company) and can serve three different processor families. These are Microchip PIC, AVR and LGT processors. So, unless you are dealing with absolutely CPU-specific things, you can serve three different processors with one program.

Speaking of loading: In order to get the program into the processor, you need a programming device. All three families are "*in-circuit* serial programming" device. This means that the CPU can programmed in the circuit. So, there is no constant processor "out-programming-in" as it was common in the past. There is a suitable connector for PICKIT3 (also PICKIT4 and PICKIT5) on this board.

For the PIC processors, I use PICKIT3 as a programming device. If someone knows about programming PICs, they might say: The PICKIT3 is old and doesn't know any newer processors. That's true. But there is a small additional PC software for PICKIT3 that makes it possible to program the latest PICs (such as the

PIC16F18857 on this board). This additional software + PICKIT3 costs less than half of a new PICKIT 4 or 5. So it's " cheap " here too. (PICKIT3 approx. €22 depending on the supplier)

GCBASIC (similar to Arduino libraries) has libraries for almost all processor functions and components (LCD, thermal sensor, IO expander, etc.). This means you don't have to delve into the deepest depths of the processor registers. An integrated development environment, or IDE for short, is also included. **The whole** thing is supported by a number of demo programs. This makes working very comfortable.

I have never become friends with **C as a programming language. For fans of C,** I would recommend the tools from Microchip (some of which are also free). Together with the PIC microprocessors, this is a complete product line (compiler, processors and programming device (PICKIT3, 4 and 5)). Microchip's support is very good.

PCB design and manufacturing:

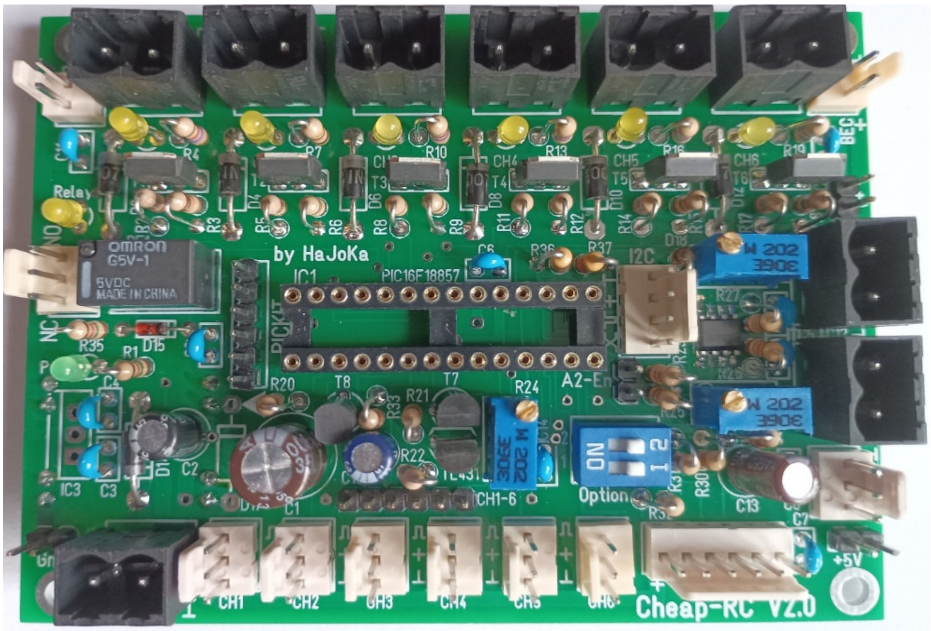
Since many years I use a software called TARGET 3001! to design circuit boards. It is developed by a German company. There is a free trial version (TARGET Discover) for small projects (boards). This version is limited to 250 pins/pads. But otherwise, it is fully functional (including saving, printing and Gerber files for production!). It is also available in English and it can handle “Eagle”-Files.

Just for your information: The CHEAP-RC board uses just only 305 pins/ pads!

So, you can see that you can create nice projects with the free "trial version". For larger projects you could create two or more boards with the "trial version" and then connect them together. This is then free. Or you can purchase a full version for a fee (e.g. TARGET 3001! Light (approx. €76)).

I have the circuit boards manufactured by JLC-PCB. The only "flaw" with JLC-PCB is that they don't manufacture single boards. There are always a batch of at least 5. But for 5 double-sided, plated-through and printed circuit boards I pay (for example CHEAP-RC) just over €12 including shipping. However, the delivery time is 14 days (2 days production and 12 days shipping). Even if I only need one board, this is considerably cheaper than boards from Europe.

With these low prices, I no longer have to mess around with chemicals at home and drill lots of small holes that aren't even connected through. Not to mention the silk screen top and bottom.



“Ich habe fertig” (a speech on TV of Giovanni Trappatoni (Soccer-Trainer))

This is what it looks like when it is completely assembled.

End credits:

I hope that reading this was interesting and that it has perhaps inspired one or more people to build this control system or something similar. Approaching such projects is not “rocket science”. I am happy to answer any questions (or criticism or suggestions).

Hans-Joachim (Hajo) Kaps

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https://www.Dampfbahn-Leverkusen.com

One small locomotive with Driver and Guest on our Track system in Leverkusen: