Automatic Running-i

for internal combustion model engines

Part 2: the test bench, actuators and detectors

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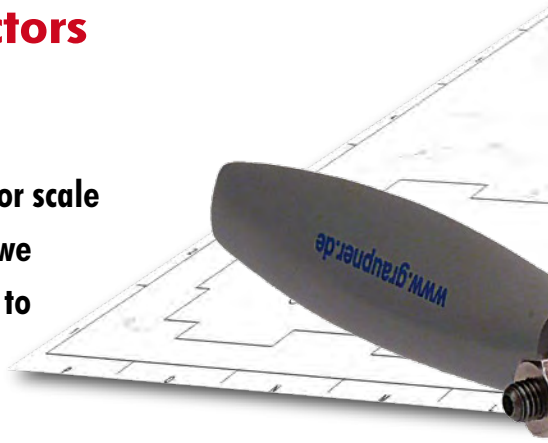


Last month, we began constructing a running-in bench for i/c engines for scale models with the description and wiring of the electronics boards. Now we need to build a chassis capable of housing our new boards, the engine to be run-in, and all the essential accessories.

Building the boards led us to make intensive use of the soldering iron and measuring instruments in our electronics lab.This month, the saw, drill, and screwdrivers are coming to the fore. To get the best out of these boards, it's vital to have a bench that is perfectly suited to this very specific activity of running-in model engines.

Throughout this article we'll be guiding you step-by-step through building your version of the bench. We have checked that the components used are readily available commercially. Most of them can be replaced without any problem by equivalents, depending on what you may already have, and your needs.

After describing the chassis of the bench, we'll tackle fitting, testing, and adjusting all the bench's actuators and detectors.

Before getting down to things, we strongly advise you to read the inset about the basic precautions relating to using model i/c engines.

The bench…

…has been specially designed for our application by experienced model enthusiasts (**Figure 1**) — the plans for this bench are available for download [1]. The base of the bench, the chassis, is made entirely from 10 mm plywood. The bench is compact enough that you can put it away on a shelf between two running-in sessions. This chassis takes the engine, the fuel tank, the electronics boards, and all the neces-

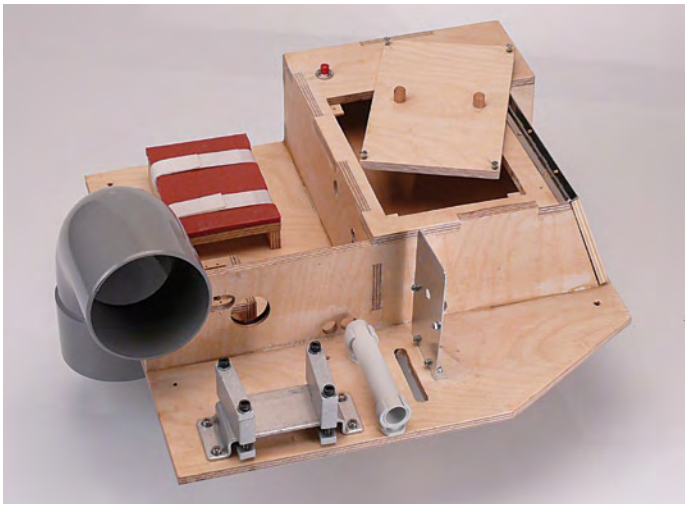


Figure 1. The prototype of our bench, without fittings.

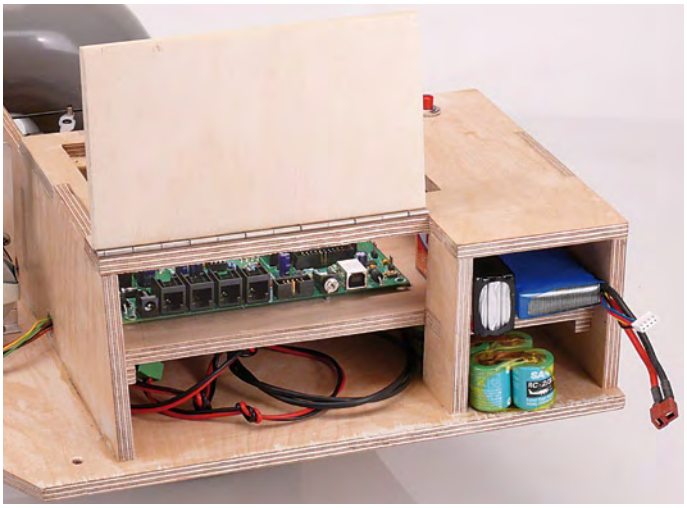
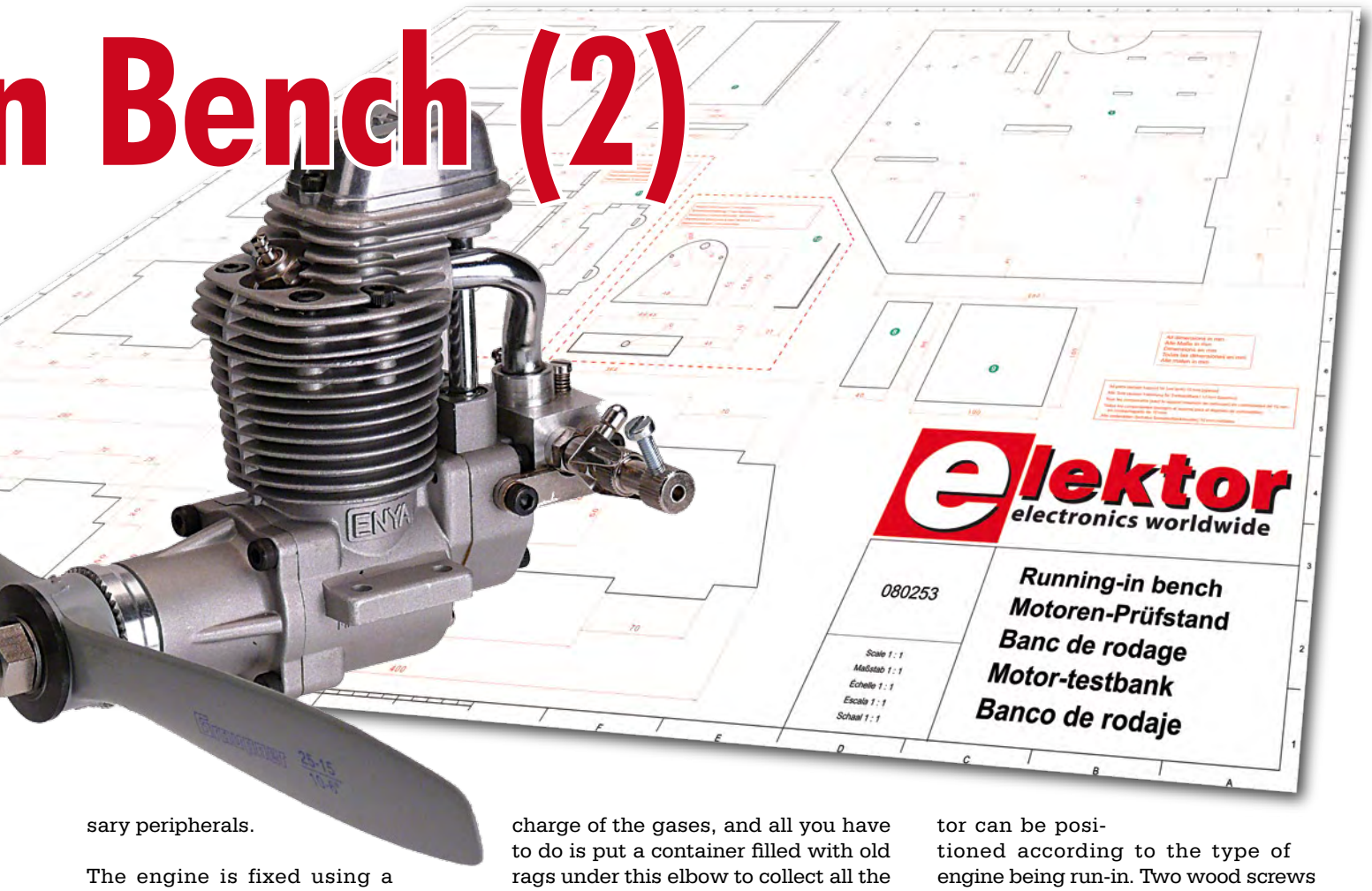


Figure 2. The compartments for the electronics, batteries, and cables.

n Bench (2)



sary peripherals.

The engine is fixed using a robust aluminium mount specially designed for the purpose. You'll have no problem finding this sort of accessory in model shops or on the Internet. This mount is able to take most single-cylinder engines up to 20 cc. It is of course possible to make do without a mount of this type, but in all cases, make sure you have a solid fixing, and secure the engine fixings with thread locking compound (Loctite, etc.) or using self-locking nuts.

The fuel tank is slightly raised to meet the height requirements (see box). It may be necessary to adapt the fuel tank mount to the dimensions of your particular tank.

The strange plastic elbow on the left of the bench, you'll no doubt have guessed, is used to channel the oil-laden exhaust gases that the engine emits during running-in. This simple, cheap arrangement proved highly effective during our trials. The large diameter of the tube means that it doesn't in any way affect the discharge of the gases, and all you have to do is put a container filled with old rags under this elbow to collect all the oil given off and thus avoid polluting the environment, at the same time making cleaning up after each running-in session a lot easier.

Let's talk safety!

Contrary to what their appearance might lead us to think, model engines are not toys. Their considerable power and the presence of the propeller makes them potentially dangerous, and every year there is a regrettably large number of serious accidents, particularly to people's hands. If you are new to modelling, seek advice and help from an experienced model-maker during your trials. They will be able to guide you and perhaps avoid an accident. If you are an experienced model-maker, but new to electronics, then ask the advice of an experienced electronics hobbyist who will help you build, test, and wire up your bench. And if you are familiar with both fields, then think like two people and check your board and all the electrical connections and mechanical tightening three times before carrying out your first trials. Under no circumstances may either the authors or Elektor be held liable for accidents following use of this board.

To the right of the engine, there's enough space for the speed detector and for the richness-setting motor. Behind the engine, behind the partition we find a little mount, designed for a 'standard' size servo. This actuator can be positioned according to the type of engine being run-in. Two wood screws are used to fix this mount onto the bench's chassis.

A special two-level compartment is set aside for the electronics boards and possible batteries (**Figure 2**). The CBRM board [2] has its own 'tailor-made' space in the top of this compartment. Connecting the bench's detectors and actuators to the board really is child's play. A few judiciously placed holes, approx. 16 mm diameter, (see photo) let you thread the cables through easily with their connectors. The compartment below the board is designed for storing the cables between sessions. Amongst others, you'll probably want to store a USB cable, a DSC cable, the pocket terminal cable, and maybe a cigar-lighter plug. The second pair of compartments has been designed to hold the batteries that allow the bench to operate in a stand-alone fashion. In the top part, you can fit a 5- or 6-cell NiMH battery, or a 2s or 3s LiPo (Lithium Polymer) battery. A capacity of 1500 mAh

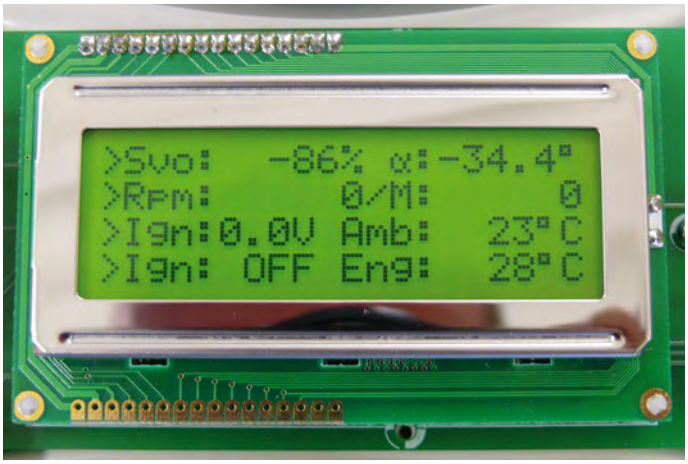


Figure 3. The display once the bench is powered up.

Figure 4. The engine mounted and fitted with a propeller.

is enough to operate the bench for several hours. The battery for heating the glow-plug or for the electronic ignition will go into the bottom compartment. Wrap your batteries in foam to wedge them in place and protect them from engine vibrations, thereby avoiding their falling off the bench.

Once the woodwork is finished, don't forget to apply a coat of cellulose varnish to your chassis to protect the wood from the fuel and the oil it contains. With the help of the photos, drill the holes for the cables, glue on the 100 mm diameter PVC elbow, and fit the engine and fuel tank mounts. Don't fix the servo mount for the time being.

Functional testing software

The next step consists of fitting, connecting up, and then testing the operation of the actuators and detectors. But before starting, 'flash' the CBRMtest_sensors.hex software [2], then fit the board to the bench. Connect up the pocket terminal, power up the board and check that the software starts up correctly. The terminal display should look like **Figure 3**.

The first line of the display shows the current position of the servo. By turning the encoder knob, the servo moves through an angle of 80° (from −100% to +100%). By pressing the push-button alongside the first line, the display changes and the encoder knob now acts on the stepper motor. The first line of the display now shows the current position of the motor and the position set for it to go to. The current position updates as the motor rotates.

The second line of the display permanently shows the engine speed.
The third line permanently shows the board supply voltage and the glow-plug supply voltage. As a safety precaution, if the board supply voltage drops below 6 V, the servo is set to the 0% position and the program hangs in this condition.

The start of the fourth line indicates the state of the glow-plug: on or off. The glow-plug can be turned on or off by operating the push-button alongside the fourth line. The end of the line shows the engine temperature.

Fitting the engine to be run-in

When seen from the front, most engines have their throttle controls on the left and the richness screw (or needle-valve) on the right. If this is not the case, it may be possible to turn the carburettor to achieve this situation. Fix the engine firmly to the mount, taking care that the exhaust comes within the discharge elbow (**Figure 4**). When everything is properly in place, connect a

Figure 5. The throttle servo in its mount.

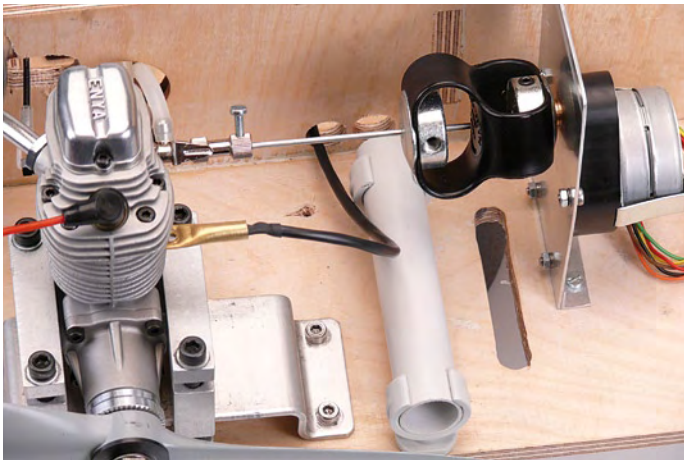


Figure 6. Connecting the stepper motor.

2 mm clevis with its rod to the throttle control and feed it through the oblong opening you've made in the partition behind the engine. It will also be very helpful to fit your engine with a new, good-quality glow-plug. You'll fit the propeller and its cone just at the moment of starting the tests.

Throttle control

Fit the servo into its mount using the rubber grommets and spacers supplied with the servo (rounded part downwards. Fit a piece of 'choc-block' to the servo rod (see **Figure 5**). This is probably the most effective and practical way of connecting the control rod to the throttle servo. Position and fix the mount in such a way that all the moving elements are correctly aligned and operate without any tight spots. Connect the servo to the board via K5, then set it to the neutral position (i.e. 0%) using the pocket terminal encoder. Position the servo rod in such a way that it is perpendicular to the servo, then fit the rod screw.

By turning the encoder knob, you'll be able to check that the control functions gently and operates over the whole travel of the throttle control for a control variation between approx. −100% and +100%. The butterfly valve should open as the control increases, by turning the encoder clockwise. If this is not the case, position the configuration jumper JP4 so as to invert the sense in which the servo acts. Adjust the position of the choc-block on the servo rod to arrive at a suitable travel.

Richness setting

The fuel mixture (richness) screw must be capable of being operated over several turns during the running-in. In this situation, a servo, whose travel is limited to around 120 degrees, i.e. a third of a turn, is not at all suitable for the task. What's more, the richness screw must be adjusted 'carefully and accurately', although the actual speed of this adjustment is not very critical. A single-pole stepper motor with reduction gearing meets these requirements perfectly. The type used, with 2400 steps per revolution, will operate the richness screw of your precious engine gently and accurately. The stepper motor is connected to the CBRM board via six wires. Look at the April 2009 article [2] for details of this connection. Instead of a long-winded explanation, **Figure 6** will guide you in building the bracket and coupling between the richness screw and the stepper motor. Check that the supply jumper JP11 is in the VHV position. Once fitted and connected, test the operation of your project using the encoder knob on the terminal. The motor should turn in the same direction as the encoder. Rotating the encoder anticlockwise should make the stepper motor turn in such a way as to open the needle valve. If this is not the case, correct the motor wiring. If the motor doesn't turn at all, check that jumper JP3 is not fitted. If it is fitted, remove it.

Glow-plug supply

Traditionally, model enthusiasts power their engine's glow-plug by means of a 'glow clip' — a sort of removable connector that works a bit like a syringe. This connector is hooked onto the engine by hand at the moment of starting. This method is perfectly suitable when you're starting before taking a flight or going for a lap of the circuit, depending on whether the model is a plane or a car. But in a running-in situation, the model-maker generally has to start the engine several times.

Repeatedly handling a glow clip close to a moving propeller is not very convenient and certainly dangerous. The CBRM board looks after powering the glow-plug for you, so you can leave the glow clip in place permanently, or replace it, as we have, with a little rubber connector specially intended for the purpose (**Figure 7**). A cheaper alternative to this connector is a simple electrician's choc-block, stripped of its insulation, which will connect the + pole of the glow-plug to its supply cable, which should have a cross-section of around 0.5 mm². Don't forget to connect the engine mount to ground, using an eyelet terminal and wire of the same gauge as the wire to the glow-plug. These two wires will be connected to connector K11 on the board. The glow-plug supply battery (not more than 2 V!) will be connected in the same way to connector K13. Make sure you observe the power source polarity correctly!

A polarity error won't cause any damage, but the glow-plug will be powered all the time, which is **very dangerous**, as the engine may start unex-

Basic precautions

Using i/c model engines does require some basic precautions.

Mechanical mounting of the engine

It is vital to make provision for a sturdy, reliable mechanical mount, as these engines vibrate a lot and produce a tractive force that can reach several tens of newtons. This point is particularly important, as it's not hard to imagine the damage and injuries that an engine fitted with its propeller could cause if it came adrift from its mounting at full speed! ***Don't use vices or G-clamps for holding the engine.***

Fuel supply

The bench's fuel tank must be designed to hold methanol-based fuel and include a pressurization point. The fuel tank must be positioned in such a way that the level of the engine carburettor is half-way up the fuel tank. What's more, you should take care to fit the fuel tank as close as possible to the engine, to minimize the length of piping. An unsatisfactory fuel supply will cause difficulties in starting and erratic running of the engine. This type of fuel tank, holding around 500 ml, is readily available form model shops. They'll also be able to supply the silicone 'hose', the pump for filling the fuel tank, and of course, the right sort of fuel for your dear little gem…

Exhaust

Model engines running on methanol operate with a fuel containing around 20% oil. This oil, mainly unburnt, gets into the exhaust gases. No need to point out that unless certain 'health' precautions are taken, this oil ends up invading everything around the exhaust outlet, with the unpleasant consequences that can be imagined. To make matters worse, during running-in, the engine operates with a very rich mixture, increasing the emission of oil very significantly.

Figure 7. Detail of the glow-plug.

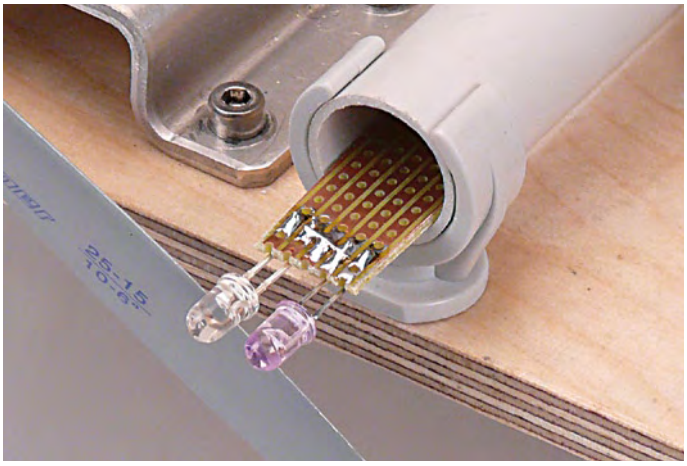


Figure 8. The speed detector, consisting of a phototransistor and an infrared LED inside a PVC tube.

pectedly while you are priming it! Test the proper operation of the glow-plug several times using the pocket terminal. To do this, you can temporarily connect a glow-plug to the connector and ground and check that it glows and goes out clearly according to your commands.

When the glow-plug is on, LED D15 on the CBRM board lights. If the LED doesn't light, check that jumper JP3 is not fitted. If it is fitted, remove it. The glow-plug power system must be totally reliable, or else the running-in sessions will become a real nightmare!

Speed detector

The speed detector consists of a phototransistor and an infrared LED. Fit these two components side by side on a small, rectangular piece of prototype board, just the right width to fit inside the 16 mm PVC tubing (**Figure 8**). Depending on the ambient lighting, the extra (invisible) light provided by the LED may not be needed, or may actually be a nuisance. By crimping both a 3-pin connector and a 2-pin connector to the end of the cable, you can choose whether or not the LED is powered, according to which connector is connected to the CBRM board A 5 cm length of PVC tubing provides effective mechanical protection for this detector.

Once it is in place, wave a sheet of white paper rapidly in front of the detector. The terminal display should indicate a speed of a few hundred RPM, varying. Tip: The 'camera' function of your mobile phone will let you see the infrared light from the LED. If it is not visible in the form of a white dot on the screen of your phone, check the polarities and quality of the wiring to the detector and LED.

Engine temperature detector

The KTY81-210 temperature detector is easy to use, as it comes in a standard 2-pin TO92 package, and is thoughtful enough not to be polarised. After connecting it to a 2-core cable and insulating the joints with heatshrink sleeving, plug the detector onto connector K17 and test it by checking the plausibility of the temperature it shows on the terminal. If you grasp it with your fingers, the temperature indication should change. Then cut off a short length (approx. 3 cm) of 5 mm inside diameter brass tubing. Flatten one end of the tube and drill it with a 3 mm hole. Check that you can easily fix this bit of tube under one of the engine block screws (**Figure 9**) to ensure very good thermal contact. Once the mechanical

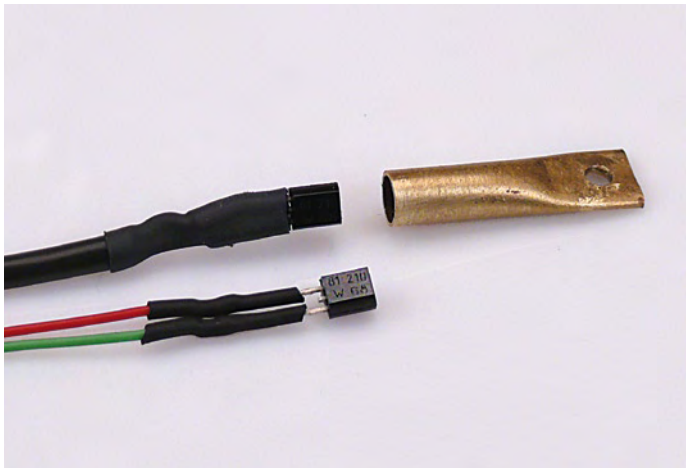


Figure 9. The temperature detector and its brass fixing.

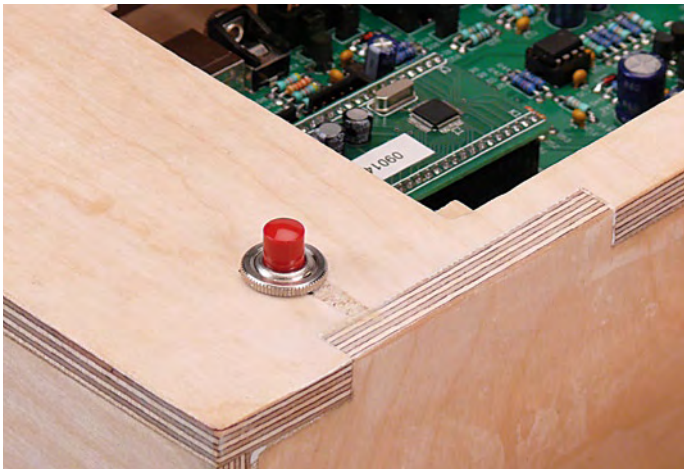


Figure 10. The emergency stop button needs to be accessible!

assembly is finished, insert the detector all the way into the tube and stick it in place with epoxy resin.

Emergency stop push button

It's vital to fit our magnificent bench with a control that will let us shut off the engine throttle control quickly in the event of a problem. Cutting the power to the bench is not a good idea, as the throttle servo will stay in its last position at the moment of losing power and the engine will continue to run.

The system we've adopted has the merit of being simple and effective. The emergency stop button (refer to **Figure 10** for fitting) is simply connected in parallel with the CBRM board reset button, via connector K4. As soon as you release the button, the microcontroller will restart, and will lose no time putting the throttle servo into the 'throttle closed' position, thereby stalling the engine. You should use a simple normally-open (NO) push button, sturdy enough to withstand 'beefy' pressing. A locking industrial-type 'emergency stop' button will not be suitable for this use, as it locks into the contact closed position and the microcontroller won't reboot until the button is unlocked, which is unacceptable here. Check that this button works properly before carrying out your first trials with an engine running.

Figure 11. A solid panel of wood lets you fix the bench onto trestles.

Mounting the bench

We recommend mounting your bench on a solid panel of 19 mm thick chipboard so you can rest the bench on two trestles during your trials. You can use four sturdy G-clamps to hold the bench firmly on the trestles.

First trials with an engine

After you have checked several times that all the detectors and actuators of your new bench operate correctly, we recommend getting used to it by doing some trials with an engine that's already been run-in. The terminal will let you control its settings manually without 'sticking your fingers in'. So handy!

To be continued…

Next month, we'll be rounding off this 3-part article with the description of the automatic program.

(081187-I)

Acknowledgements

The author would like to thank Guillaume and Dominique Dobler for designing and building the mechanical part of the bench.

Internet Links

[1]. www.elektor.com/081187

[2]. www.elektor.com/080253