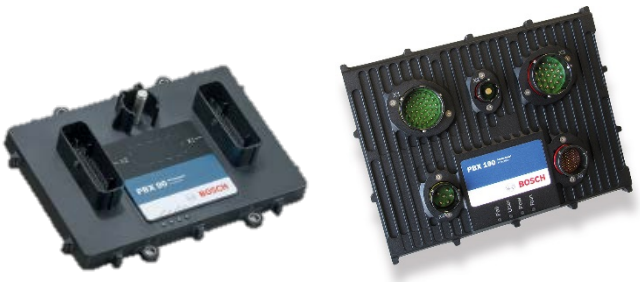
Technical Bulletin
PowerBox – Wiring Harness Design Recommendations

ABSTRACT

The PowerBox is an intelligent control and distribution unit for the electric grid in a modern racing car which is seamlessly integrated into the Bosch Motorsport system architecture. It is capable of replacing all conventional relays, fuses and circuit breakers. It simplifies wiring harnesses and provides diagnostic capabilities.

Due to the PowerBox's high current capabilities, it is necessary to take care of its mounting location in the complete system.



PowerBox PBX 90 and PBX 190

TECHNICAL DETAILS / SPECIFICATIONS

A simplified system overview is shown on the picture on the right. The input of the PowerBox is connected via main switch to the battery. The outputs of the PowerBox are used to supply or control the actuators.

First, let have a look at the wiring harness, especially the input cable**.** The following points are equally relevant for output cables although currents in these cables are lower.

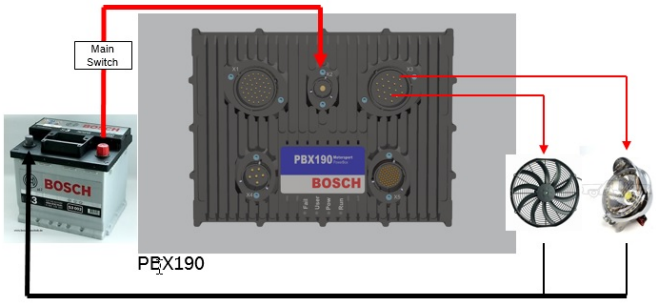
The sum current of all actuator currents flows through the input cable and also the PowerBox itself. This current is limited to 250A (200A over connector X2, 50A over connector X4) for PBX 190. Due to this, high input current it is necessary to choose the correct wire diameter to minimize voltage drop and power loss of the cable. It is recommended to use 35mm^2 cable cross section for X2 at a high permanent input current. Undersized cables lead to an increase of temperature rising due to some basics of physics:

- **Higher ohmic resistance**
  A smaller diameter of the cable leads to a higher ohmic resistance and the power loss over the cable increases.

- **Higher voltage drop**
  A higher ohmic resistance will cause a higher voltage drop across the cable, which results in lower output voltage. To compensate the voltage drop the current must increase to get the same output power. This higher current through the cable also causes more power loss in the cable.

- **Higher thermal resistance**
  Another aspect is the lower thermal conductivity of an undersized cable. The surface of the cable is smaller and therefore the cable's ability to transfer heat is reduced.

- **Increase of temperature results in increase of ohmic resistance**
  The three points above show that an undersized cable will get warmer than a cable that fits the requirements. This also causes an additional temperature rise, because the temperature coefficient of copper is positive. That means the resistance of the cable increases when the temperature rises.



Simplified system architecture

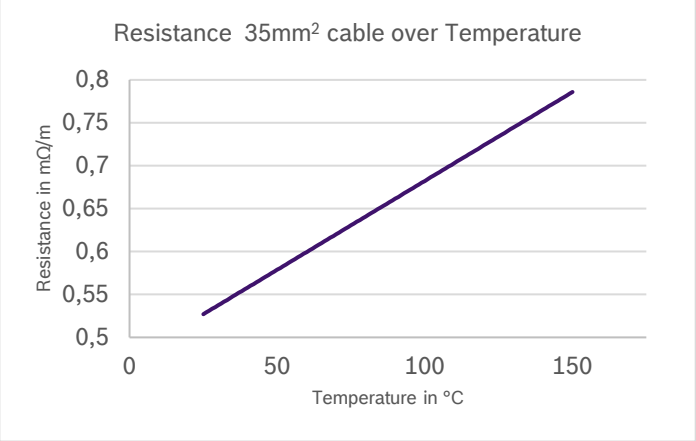
All these facts show that is very important to use the correct cable size. In the table on the next page some important cable parameters are shown. The resistance of the cable (R) is normally given in the datasheet. P_v is the power loss over the cable and ΔT is the estimated temperature rise of the cable. I_{max} shows the max.

current through the cable recommended by Bosch Motorsport (max. temperature rise of cable about 50°C).

RADOX 155 Battery cable parameters				
Cable size	R (@20°C)	P_v @200A (1m cable)	ΔT @P_V	I_{max} (ΔT= 50°C)
16mm²	1.16 mΩ/m	46.4W	183 °C	100A
25 mm²	0.74 mΩ/m	29.7W	75 °C	150A
35 mm²	0.53 mΩ/m	21.1W	38 °C	220A

As you can see in table on next page the temperature rise of the cable is strongly dependent on its cable diameter, because a thicker cable has a smaller wire resistance and a better thermal conductivity.

In the graph bellow the resistance of a 35mm² cable over temperature is shown. You can see that at 130°C the resistance of the 35mm² cable is the same as of an 25mm² cable at 20°C (table above shows R @20°C = mΩ/m for 25mm² cable).



Now let's have a look at the PowerBox itself. The PowerBox has a power loss due to connector pin resistance, internal wiring and the resistance of the output power stages. To decrease this resistance it is helpful at higher currents to link two output stages rather than leaving it unused in the car. This reduces the resistance of pin, wiring and output power stages by half. It is also helpful to use power outputs on all connectors to spread the power losses over the whole device and to minimize thermal hotspots.

All these resistances inside the PowerBox are also temperature dependent and increase with a temperature rise. For example the resistance of the output power stages will be nearly doubled when junction temperature reaches 150°C instead of 25°C.

The conductivity of the housing is very good and also the housing has a high thermal capacitance, but it is the costumers own responsibility to use a mounting location where the housing can transfer the heat to the environment efficiently. An average air speed of 2m/s is recommended for 250A total input current.

HINTS / SOLUTIONS

Some hints to avoid a thermal incident of the PowerBox and to have an efficient and robust operation:

- Use correct cables for input and output. Be sure that the resistance of the cable is low enough, also rated over the peak temperature which could be reached during operation.
- Especially the input cable should be as short as possible, because a high current flows through this cable. A longer cable causes a higher voltage drop and therefore higher power losses.
- A mounting location in a colder area of the vehicle is recommended for the PowerBox and also for the wire harness. This minimizes the power loss and provides the possibility to use thinner cables if cooling is sufficient to maintain a low temperature.
- For high total output current it is necessary to have an airflow over the housing of the PowerBox. Check that the PowerBox is mounted correctly so that the air flows in parallel to the fins. Otherwise the effect of the airflow can be reduced.
- Use the feature of linking outputs for high output currents to reduce power loss in the PowerBox.
- Spread the outputs and use power output stages on different connectors to minimize hotspots on the PCB.

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