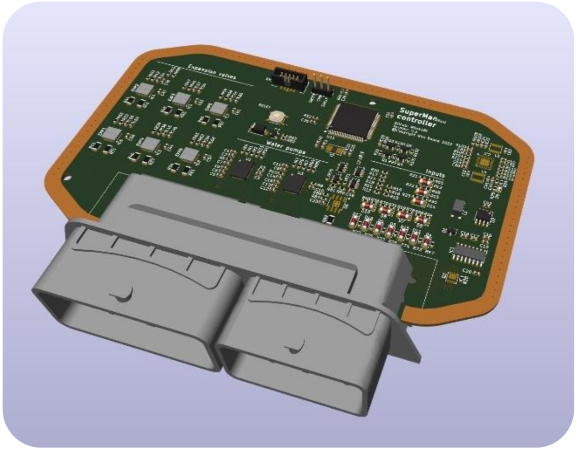
TESLA HEATPUMP CONTROLLER

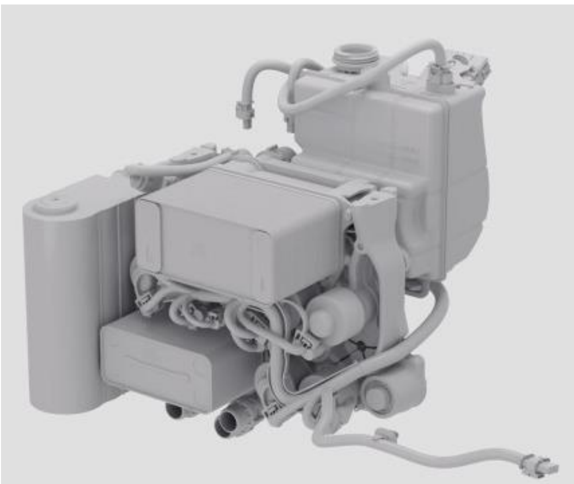
GENERAL DESCRIPTION

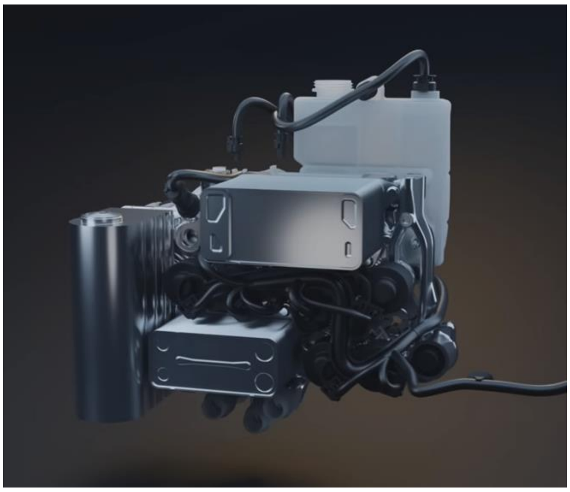


This controller is specifically designed to control the complete heat pump system used in modern Tesla vehicles (2020-present).

It plugs directly into the original wiring harness of the heatpump manifold. The controller can be controlled via the 48 pin CMC header. It has digital and analog inputs.

PROPERTY	VALUE	UNIT
Dimensions	177 x 111 x 42	**mm**
Weight	300	**gram**
Connector	64 (heatpump), 48 (interface)	**pins**
Operating temperature	-20 to + 100	**°C**
Supply voltage	9 to 15	**V**
Max load current	15 (must be fused at 20A)	**A**
No load current	150	**mA**
Sleep mode	~	**mA**





INTERFACE

INTERFACE:

- 1x CAN 500kbps
- USART for ESP8266/ESP32 Wi-Fi chip (OpenInverter Webserver)
  (Internal UEXT connector)

OUTPUTS:

- 1x PWM 5V for radiator shutter servo (optional)
- 1x PWM 12V for radiator fan motor control

DIGITAL INPUTS:

- T15 wake-up signal
- Enable AC compressor
- Enable water pumps
- Battery heat request
- Battery cooling request
- Cabin cooling request*
- Cabin left heating request
- Cabin right heating request

ANALOG INPUTS:

- 6x Temperature sensors
  - Cabin left
  - Cabin right
  - Outside
  - Radiator
  - Battery
  - Drivetrain
- 2x Potentiometer
  - Cabin left temperature control
  - Cabin right temperature control

* *The tesla heatpump manifold only supports cooling on both sides at the same time. Unlike heating which can be done individually.*

PINOUT (48 PIN MOLEX CMC HEADER)

C1	+5V for servo
C2	12V PWM for radiator fan
D1	GND for servo
D2	5V PWM for servo
E1	Temperature sensor: Outside
E2	Temperature sensor: Radiator
E3	Temperature sensor: Battery
E4	Temperature sensor: Drivetrain
F1	Potentiometer: Cabin left
F2	Temperature sensor: Cabin left
F3	Potentiometer: Cabin right
F4	Temperature sensor: Cabin right
G1	Enable: GPI1
G2	Enable: Heat cabin right
H1	Enable: Cool cabin
H2	Enable: Heat cabin left
J1	Enable: Cool battery
J2	Enable: Heat battery
J3	CAN low
J4	CAN high
K1	T15 key on
K2	Enable: Water pumps
M1	+12V
M2	GND

MAXIMUM RATINGS

Temperature sensor: Internal 10k pullup to 3.3V, Connect thermistor only between GND and input.

Potentiometer: 0-5V input range. Do not exceed!

Enable: 9-15V for logic HIGH. Internal pulldown in microcontroller.

CAN-bus: Withstands -4V to +16V on both CANL & CANH.

PWM output: Short circuit to GND protected. Not protected against overvoltage!

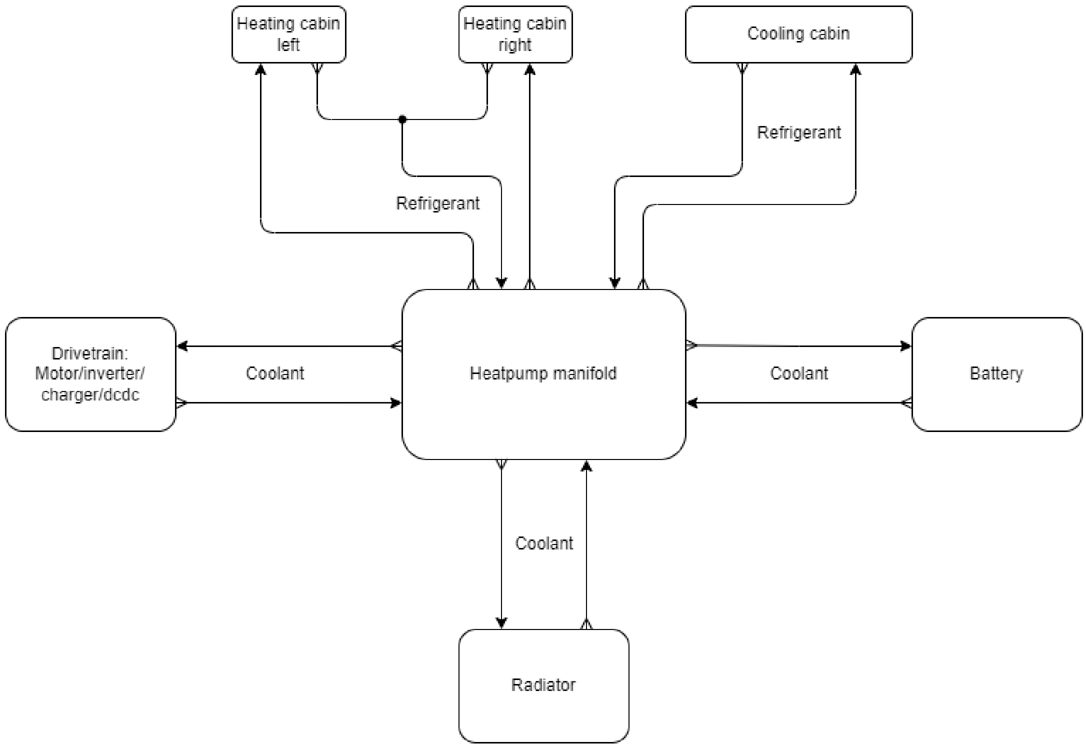
5V output: Max. 1.5A. Protected against overcurrent but used by other sensors as well so do not exceed!

12V supply: Max. 15V supply. Short circuit and polarity protected. 20A external fuse required.

OPERATION

The basic idea of the entire thermal management system is that heat energy can be moved between the 6 individual loops as shown in the diagram below. As it is always more efficient to move heat from where you don't need it to where you need it instead of creating new heat!

- Coolant loops
    - Battery
    - Drivetrain
    - Radiator
- Refrigerant loops
    - Cabin heating left
    - Cabin heating right
    - Cabin cooling



To control this effectively, the following assumptions are made:

- The cabin has priority in what is requested. The rest of the system has to deal with whatever limits exist. For example when it's very hot outside, the battery has just been fast charged, the motor is warm and you want to cool the cabin, it becomes rather difficult to reject heat. It will sacrifice motor performance by prioritizing to keep the cabin cool. And than with whatever power it has left try to cool the battery and motor.
- The drivetrain always produces heat which must be rejected somewhere.
- The battery generally doesn't need heating or cooling. Only when the temperature exceeds a certain range. Though it can absorb or reject heat in the normal range of operation if another loop can use this effectively.
  For example when you want to heat the cabin. If the temperature outside is lower than the battery,

and the battery is still within normal operating temperature range. It is more efficient to take heat from the battery than outside. This works for cooling the cabin as well.

- The radiator can either reject or absorb heat.

BATTERY

The battery is automatically controlled and thus requires a feedback sensor for the battery temperature. The thermistor can be simply placed on the coolant return line or directly on a cell for more accuracy. The default source for this value is a thermistor on the analog input. But can also be configured to be sent via CAN-bus. The controller requires a temperature range outside of which the battery needs to be heated or cooled. By default, this is set as heating under 5 degrees Celsius and cooling above 40 degrees Celsius. But can be configured via the webserver.

DRIVETRAIN

The drivetrain is also automatically cooled, though by default not actively. This means that by default the heat from the drivetrain goes to the radiator, or the battery or cabin if necessary. The drivetrain also needs a thermistor in the coolant return line. Via the webserver you can set a temperature above which the drivetrain needs active cooling. This will use the AC compressor to take heat from the drivetrain and reject it to the radiator. This allows for a higher rejection temperature and thus more effective cooling.

CABIN INTERFACE: CLASSIC MODE

This is the default and most basic mode of operation. It works like any conventional heating/cooling of the cabin.

The user inputs in this mode are AC enable, heat enable, knob cabin left, knob cabin right. The knobs simply control the amount of heating or cooling and do not necessarily amount to a certain temperature.

CABIN INTERFACE: CLIMATE CONTROL MODE

This mode works as the name suggests like most other climate control systems you find in modern vehicles.

The user inputs in this mode are enable AC compressor, Temperature knob cabin left and temperature knob cabin right. The knob is a potentiometer that sets the temperature in degrees Celsius. The range is by default 15-30 degrees Celsius. But can be configured through the webserver. This mode requires feedback temperature sensors in the cabin left and right for the control algorithm.

INSTALLATION

To actually install the heatpump in an EV conversion there are multiple options. To start, the components below are required.

- Superman controller
- Tesla Heatpump manifold
- Tesla AC compressor

To connect everything up to the manifold you need to either buy the coolant connector adapter kits or source the original coolant hoses from salvaged vehicles. For the condenser and evaporator cores in the cabin, you can either buy the entire cabin heater core from a salvaged vehicle or buy a refrigerant connector adapter kit. This allows you to connect your own condenser and evaporator. If you do not need the split cabin left and right heating, you can simply plug of cabin left and disable that output from the webserver.

Optional, if not using all original Tesla parts:

- Coolant connector kit
- Refrigerant connector kit
  or:
- Tesla cabin heater core.

CAN-BUS PROTOCOL

Every physical analog or digital input can also be sent via CAN. On top of that the Superman Controller also broadcasts the status of various parameters on the CAN-bus. This allows for optimal wiring and more custom control and integration. The webserver allows you to select the source for every value, be it GPIO, CAN-bus or LIN.

CAN ID'S:

For all sensor temperatures: Unit: Celsius (Val:0 = -50°C, Val:255 = 205°C)

For all temperature setpoints: Unit: Celsius, 0,5C precision, divide by 2 (Val:99 = 49,5°C)

For all pressures: Unit: bar, 0,2 bar precision, divide by 5 (Val:99 = 19,8 bar)

0x731 Received Setpoints for controller Length: 6

B0	Actual battery temperature
B1	Battery temperature setpoint
B2	Actual cabin left temperature
B3	Cabin left temperature setpoint
B4	Actual cabin right temperature
B5	Cabin right temperature setpoint

0x732 Transmitted Heatpump values msg 1 Length: 8 Interval: 100ms

B0	Temperature pressure sensor 1
B1	Temperature pressure sensor 2
B2	Temperature pressure sensor 3
B3	Pressure sensor 1
B4	Pressure sensor 2
B5	Pressure sensor 3
B6	Waterpump A flow
B7	Waterpump B flow

0x733 Transmitted Heatpump values msg 2 Length: 8 Interval: 100ms

B0	Temperature battery inlet
B1	
B2	
B3	
B4	
B5	
B6	
B7	

LIN-BUS PROTOCOL

WORK IN PROGRESS!

If you are integrating the Superman Controller in a more modern vehicle. Chances are that it already has an existing climate control system. These often communicate via LIN with the AC compressor and various other things like valves and temperature sensors.

As this will vary per car, you will have to do your own reverse engineering on your car. But in the software a basic example is already provided and is tested and actively used in a BMW 3 series E90 conversion.