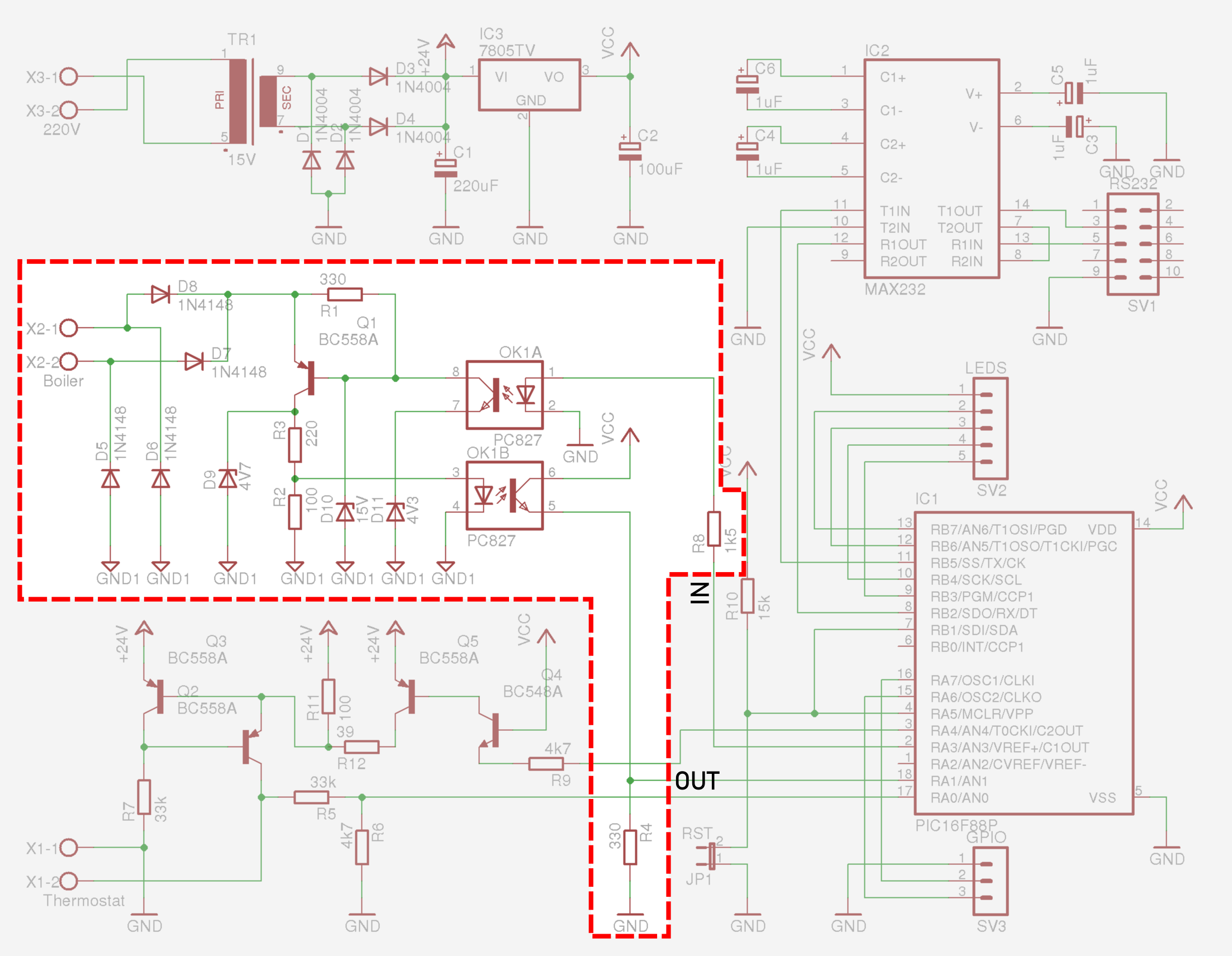
I want to create a new version of my room thermostat, and this time I want to order an assembled PCBA at JLCPCB. Eventually I also want to add a USB-C connector, power supply and ESP32 to the board, but to try out if my KiCad skills are sufficient, I first created a very simple board, which only consists of the redlined area of the schematic below:



I copied this schematic from: [otgw.tclcode.com/schematic](https://otgw.tclcode.com/schematic.html#schematic)

I needed to transfer the components list:

* Conrad numbers are provided, where I need JLCPCB part numbers
* I need to substitute through-hole components by surface mounted devices

The original parts list is (only the relevant parts):

| **Reference** | **Description** | **Value** | **Conrad** | **Detailed description from Conrad** (Dutch) |
| --- | --- | --- | --- | --- |
| **OK1** | Dual opto-coupler | PC827 | [140235-89](https://www.conrad.nl/zoeken?search=140235-89) | Broadcom Optocoupler fototransistor ACPL-827-000E DIP-8 Transistor DC |
| **Q1** | PNP Transistor | BC558A | [1262971-89](https://www.conrad.nl/zoeken?search=1262971-89) | Diotec Transistor (BJT) - discreet BC558A TO-92 PNP |
| **D5**, **D6**, **D7**, **D8** | Diode | 1N4148 | [162280-89](https://www.conrad.nl/zoeken?search=162280-89) | Diotec Ultrasnelle Si-diode 1N4148 SOD-27 75 V 150 mA |
| **D9** | Zener Diode | 4V7 | [180084-89](https://www.conrad.nl/zoeken?search=180084-89) | Diotec Zenerdiode ZPD4.7 Behuizingssoort (halfgeleider) DO-35 Zenerspanning 4.7 V Vermogen (max.) P(TOT) 506 mW |
| **D10** | Zener Diode | 15V | [180203-89](https://www.conrad.nl/zoeken?search=180203-89) | Diotec Zenerdiode ZPD15 Behuizingssoort (halfgeleider) DO-35 Zenerspanning 15 V Vermogen (max.) P(TOT) 518 mW |
| **D11** | Zener Diode | 4V3 | [180076-89](https://www.conrad.nl/zoeken?search=180076-89) | Diotec Zenerdiode ZPD4.3 Behuizingssoort (halfgeleider) DO-35 Zenerspanning 4.3 V Vermogen (max.) P(TOT) 505 mW |
| **R2** | 1/4 Watt 5% Resistor | 100 | [1417639-89](https://www.conrad.nl/zoeken?search=1417639-89) | Yageo CFR25J100RH CFR-25JT-52-100R Koolfilmweerstand 100 Ω Axiaal bedraad 0207 0.25 W 5 % 1 stuk(s) |
| **R3** | 1/4 Watt 5% Resistor | 220 | [1417693-89](https://www.conrad.nl/zoeken?search=1417693-89) | Yageo CFR25J220RH CFR-25JT-52-220R Koolfilmweerstand 220 Ω Axiaal bedraad 0207 0.25 W 5 % 1 stuk(s) |
| **R1**, **R4** | 1/4 Watt 5% Resistor | 330 | [1417730-89](https://www.conrad.nl/zoeken?search=1417730-89) | Yageo CFR25J330RH CFR-25JT-52-330R Koolfilmweerstand 330 Ω Axiaal bedraad 0207 0.25 W 5 % 1 stuk(s) |
| **R8** | 1/4 Watt 5% Resistor | 1k2 | [1417712-89](https://www.conrad.nl/zoeken?search=1417712-89) | Yageo CFR25J1K2H CFR-25JT-52-1K2 Koolfilmweerstand 1.2 kΩ Axiaal bedraad 0207 0.25 W 5 % 1 stuk(s) |

My new schematic looks like this:

A white screen with red and green lines and numbers

Description automatically generated

I installed a library of JLCPCB components and footprints from <https://github.com/CDFER/JLCPCB-Kicad-Library.git>, but found that some components are missing. I tried to find equivalent SMT components on [https://jlcpcb.com/partdetail](https://jlcpcb.com/partdetail/). Typically, several versions of a component exist, and specifications are slightly different from the original through-hole part.

Starting with D1, D2, D3 and D4 in the new bill of materials, this is the original 1N4448 from the Conrad part:

A white sheet with black text and numbers

Description automatically generated

In JLCPCB, I sorted on available stock and started at the top:

A screenshot of a computer

Description automatically generated

Here is a sample of the datasheet of the Xzt 1N4448W, LCSC# C5805633:

A white and black text on a white background

Description automatically generated

Comparison:

| **Property** |  | **1N4448**  **Conrad** | **1N4448W**  **JLCPCB** | **Suitable** |
| --- | --- | --- | --- | --- |
| Reverse voltage | VR | 75 V | 100 V (?) | OK |
| Repetitive peak reverse voltage | VRRM | 100 V | 75 V | NOK |
| Max. average forward rectified current, R-load | IFAV | 150 mA | ? | ? |
| Repetitive peak forward current | IFRM | 500 mA | ? |  |
| Non-repetitive peak forward current, tp = 1 µs | IFSM | 2000 mA | 2 A | OK |
| Power dissipation | Ptot | 500 mW | 500 mW | OK |

To know if the JLCPCB version is suitable for this application, I would need to reverse-engineer the circuit based on the OpenTherm specification. **What kind of due diligence is common when designating alternative components?**

So just to make sure I retrieved [the specification of the OpenTherm protocol](http://files.domoticaforum.eu/uploads/Manuals/Opentherm/Opentherm%20Protocol%20v2-2.pdf):

A diagram of a line voltage

Description automatically generated

The units are Volts horizontally and mA vertically. The boiler can send signals to the controller by changing the current, the controller can send signals by changing the voltage. It is backwards compatible with old-style hydrogen-drop-in-glass-bead Honeywell thermostats, since if the circuit is closed or open for longer periods of time, the boiler starts or stops boiling at full load.

Without external load, the voltage emitted by the boiler is 42 V.

I requested ChatGPT to reverse-engineer the schematic:

This schematic shows an interface circuit designed to handle communication between an OpenTherm-compatible boiler and a microcontroller, using optocouplers for isolation. Let’s go through how it works:

*Overview*

* Left Side (Boiler Side): This side is connected to the boiler, which uses the OpenTherm protocol. OpenTherm uses current modulation to communicate, and this circuit translates those signals into voltage levels suitable for the microcontroller.
* Right Side (Microcontroller Side): This side interfaces with a microcontroller that sends and receives data to/from the boiler.

*Detailed Functionality*

Input Protection (Diodes D1, D2, D3, D4):

* D1 and D2 are reverse protection diodes ensuring that the input is protected against reverse polarity.
* D3 and D4 provide additional protection and voltage clamping to safeguard the circuit.

Zener Diodes D5 and D6:

* D5 (4.7V): Sets a reference voltage. If the voltage across D5 exceeds 4.7V, it clamps the voltage, protecting the circuit.
* D6 (15V): Provides over-voltage protection, clamping any excessive voltage above 15V.

Transistor Q1 (BC858):

* Acts as a switch. When the voltage at its base (controlled by the boiler current) is sufficient, it allows current to flow from collector to emitter, effectively controlling the optocouplers.

Optocouplers U1 and U2 isolate the boiler side from the microcontroller side:

* U1: The LED inside U1 is activated when the transistor Q1 conducts. The phototransistor on the microcontroller side will change its state, indicating a signal from the boiler to the microcontroller.
* U2: Works in the opposite direction. When the microcontroller sends a signal on pin 2 of J2, it lights up the LED inside U2, which then modulates the current going back to the boiler.

Resistors:

* R1 (220Ω): Limits the base current to Q1, ensuring proper operation.
* R2 (100Ω) & R3 (330Ω): Form a voltage divider to bias Q1 correctly.
* R4 & R5 (330Ω and 1.5kΩ): Current-limiting resistors for the LEDs in the optocouplers.

Zener Diodes D7 (4.3V):

* Provides another layer of voltage protection to ensure that voltage levels sent to the boiler do not exceed the protocol limits.

*Communication Direction:*

* Microcontroller to Boiler (Pin 2 of J2): The microcontroller sends a signal via U2. When pin 2 of J2 is high, it activates the LED in U2, which modulates the current to the boiler, signalling data.
* Boiler to Microcontroller (Pin 3 of J2): The boiler modulates the current, which is sensed by the base of Q1. This turns on/off Q1, which in turn activates/deactivates U1. The microcontroller reads this as data on pin 3 of J2.

*Summary:*

This circuit effectively uses optocouplers to interface the microcontroller with the boiler in a safe and isolated manner, converting current modulation from the boiler to voltage signals for the microcontroller, and vice versa. The use of Zener diodes and resistors ensures that the voltage and current levels are within safe limits for both devices.

I calculated 4 cases:

|  |  |
| --- | --- |
| Boiler current 9 mA  Output of microcontroller low | Boiler current 9 mA  Output of microcontroller high |
| Boiler current 23 mA  Output of microcontroller low | Boiler current 23 mA  Output of microcontroller high |

My conclusions:

* Open collector, the circuit should be able to handle 50 V without load.
* Current will remain below 25 mA
* To handle 18 V and 23 mA with some headroom, the circuit should be able to handle 500 mW

I assumed the JLCPCB part is suitable.

The part was not in the library, so I modified the values of a generic diode to match the C5805633. **Is that also common, or are there clever ways to obtain the part and footprint?**

As part of this, I had to choose a footprint. JLCPCB specifies an SOD-123 footprint looking like this:

A screenshot of a computer

Description automatically generated

KiCad offers three flavours of SOD-123 footprint:

A computer screen shot of a diagram

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A screen shot of a computer

Description automatically generated

A screen shot of a computer

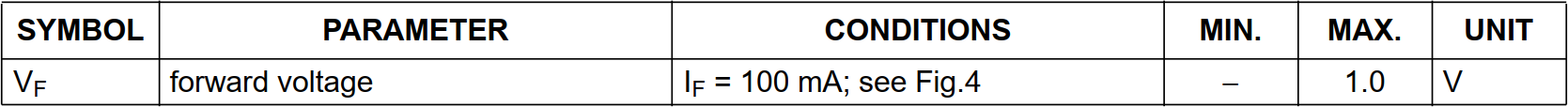
Description automatically generated

I more or less randomly opted for the third one since it is specified as SOD-123\_... instead of SOD-123F\_... **Could I have made a more elaborate decision there?**

Next is D5, the 4.7V Zener diode. The Conrad datasheet (BZX55-C4V7) specifies:

A white sheet with black text and black text

Description automatically generated



A screenshot of a computer

Description automatically generated

Again, sorting on stock level, I chose the first one with a power dissipation of 500 mW, the ZMM4V7 from Slkor, a.k.a. C707193:  
A close-up of a white background

Description automatically generated

A table with numbers and symbols

Description automatically generated

| **Property** |  | **BZX55-C4V7**  **Conrad** | **ZMM4V7**  **JLCPCB** | **Suitable?** |
| --- | --- | --- | --- | --- |
| Continuous forward current | IF | 250 mA | no spec. | ? |
| Non-repetitive peak reverse current | IZSM | 6 A | no spec. | ? |
| Total power dissipation | Ptot | 400..500 mW | 500 mW | Yes |
| Non-repetitive peak reverse power dissipation | PZSM | 30..40 W | no spec. | ? |

I decided that this component is probably unsuitable, so I chose the next in line, the BZT52C4V7S, a.k.a. C5190168. However, according to the datasheet the power dissipation is limited to 200 mW instead of 500 mW, so I moved on to the MM1Z4V7, a.k.a.. C22379458.

| **Property** |  | **BZX55-C4V7**  **Conrad** | **MM1Z4V7 JLCPCB** | **Suitable?** |
| --- | --- | --- | --- | --- |
| Continuous forward current | IF | 250 mA | no spec. | ? |
| Non-repetitive peak reverse current | IZSM | 6 A | no spec. | ? |
| Total power dissipation | Ptot | 400..500 mW | 500 mW | Yes |
| Non-repetitive peak reverse power dissipation | PZSM | 30..40 W | no spec. | ? |

Although it feels like a significant leap of faith since so little is specified, I decided to go for the MM1Z4V7 because the ZMM4V7 has a LL-34 package which looks odd.