# DIY HP-IL Cable

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## Introduction

Hewlett Packard designed the Interface-Loop (HP-IL) to use unique cables with specifically designed connectors. Whether this was a necessity or not can be discussed, but it produced links of the very high HP-quality. On the other hand this makes it impossible to find cables or connectors from third party manufacturers. Used HP-IL cables are offered from time to time on auction platforms in the internet but may be expensive or not of the desired length.

Building your own cables has been discussed several times over the last years but I have not seen any results. If you want to build your own cables you absolutely need the correct male and female pins, a housing and the wires. All this has to be sourced or designed and assembled.

This document shows how to create your own HP-IL cable. It is not easy or cheap, but a possibility which gives you the ability to create any desired length of cable.

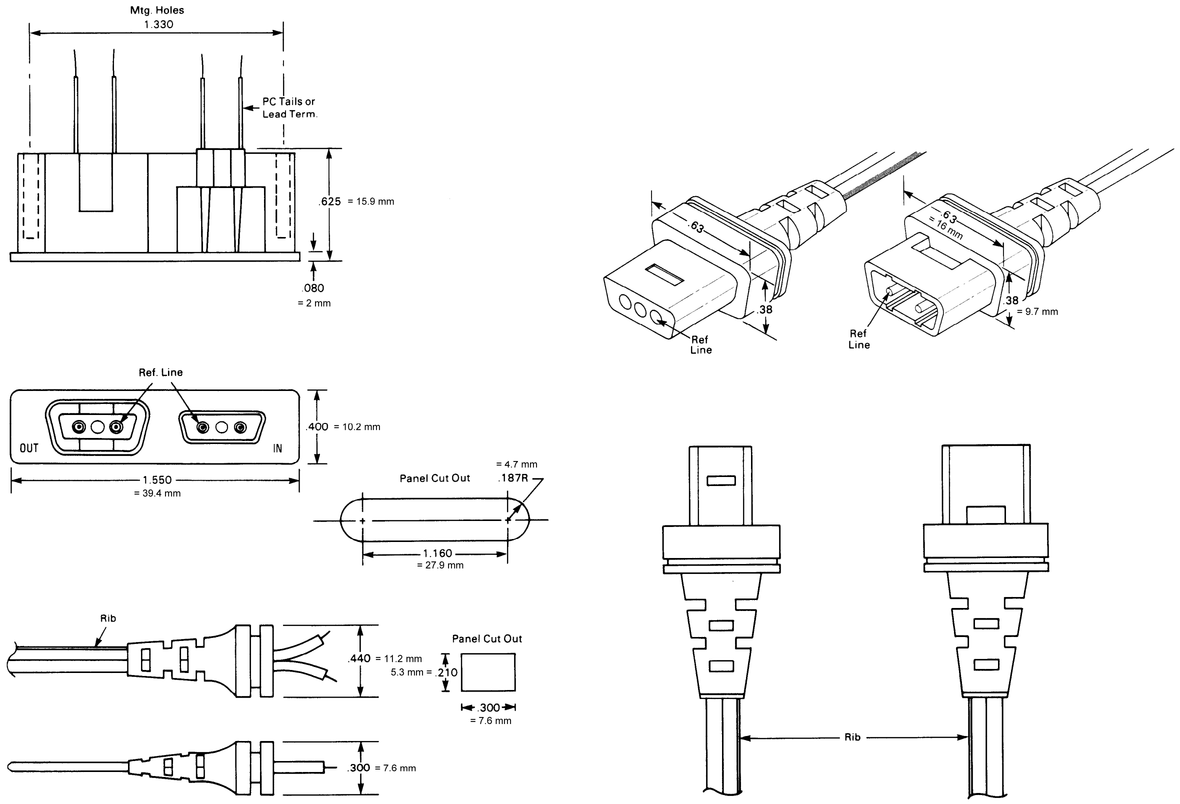


**Figure 1: Mechanical specification of the HP-IL connectors taken from [1] but error corrected and metric dimensions added. Note that no detailed dimensions for the housings are given in the original specification.**

# Design and Materials

## Motivation and Costs

Initially the idea was to avoid excessive eBay prices, which typically range between $40 and $60 per cable. Another motivation was to create cables of any desired length and to create experimental cables for tinkering e.g. with IL-USB boxes, Arduinos and similar toys. For this purpose I did not want to destroy original cables.

The following table shows that the self-made cables are not exceptionally cheap. One reason is the high costs of the precision pins which come down only when bought in large quantities (I bought just 20 pairs and the shipping costs were about the same as for the pins themselves).

| | |
|---|---|
| Two male/female pin pairs | 10€ |
| One set of 3D-printed parts | 6€ |
| Twin wire | 1€ |
| Time and profit | 0€ |
| **Total** | **17€** |

**Table 1: Parts list and costs for a typical cable.**

## Do it Yourself

If you follow this description, you can build your own cables. However, please note the following points:

- The building process takes some time – do not try to hasten or to do too many things at the same time. Plan each step before executing it.
- You need a good eye and calm hands. If you have already soldered small electronic parts in the past you might qualify for this project.
- You need the usual equipment: a small soldering iron (e.g. 12V/6W), insulation stripper, small drill bits (1.6 mm, 0.8 mm), needle file, pointed tweezers or needles, toothpick and probably more.
- You should know how to work with Epoxy glue. I used 5 minute quick-set Epoxy – if you need more time, use a slower (e.g. 15 to 30 minutes) Epoxy which gives you more time to work more careful. Do not use any liquid glue – this may seep into the connected pins.
- If you have experience with small parts and all this, this description may be a bit lengthy at times. It was intended to allow a less experienced user to obtain a satisfying result.
- Everything you do is your own responsibility and your risk. If you burn your fingers, or even kill the cat – blame yourself, not me.

## The Wires

For the cable you need a thin twin “zip” cable. The copper strands must be thin enough to fit into the tiny pins. The original wires were specified as 24 AWG (made from 26 strands of 38 AWG). For civilized people who use the metric system, this amounts to a cross section area of 0.205 $mm^2$ composed of 26 strands of 0.0080 $mm^2$ each. Such a cable can be found e.g. at Mouser but the spool has a length of 150 meters which is slightly more than I needed.

Luckily I had a twin cable for small earplugs with a cross section area of about 0.14 $mm^2$ at hand. So I used this cable with success. Shielded wires would be useful if you want to exploit the maximum allowable (per HP specification) length of 100 m. The specification also allows for a third center pin, which was intended to carry the shield, but this was never used in any product that I know of.

**Figure 2: Such a cheap set of headphones or similar earphones provides a low cost source for the cable.
There is a risk for a family conflict if you check out the stuff of your children or spouse. Note that I can take no responsibility for slammed doors or worse reactions.**

## The Pins

Each cable contains two small male and two female pins. These pins were still available commercially in 2016. For one cable you need two each of Cannon-ITT 031-9540-000 and 030-9542-001. If bought in small quantities (say, less than 1000) the pins seem to be quite expensive. However, they are of very high quality and are obviously used in avionics, which explains the high costs. I have seen 3-row connectors with about 3x25 pins being offered for about $100. Comparing with the well-known mass produced D-Sub connectors, the HP-IL pins are much more delicate. The wire design of the male pins provides some self-cleaning action when inserted or unplugged. Maybe you can lift a few from the avionics bay of your private Airbus or Boeing.

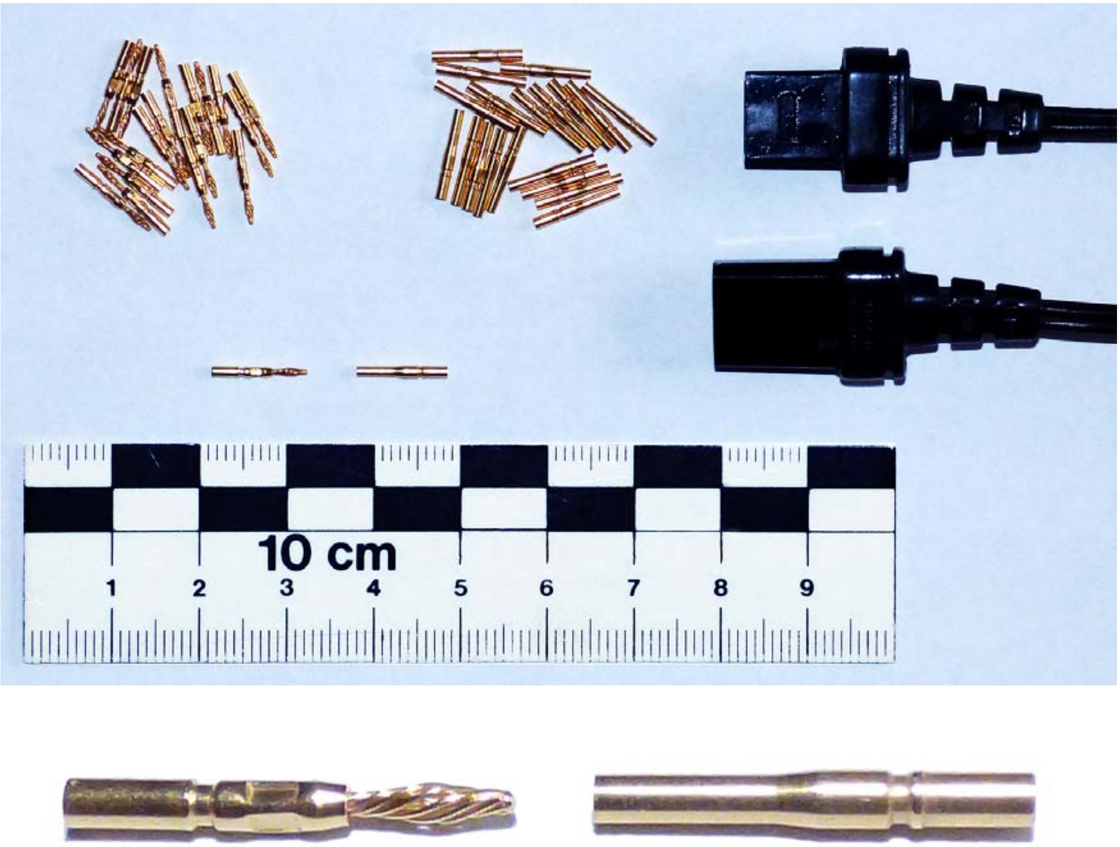


**Figure 3: What I got for 60€ - twenty smallish pairs of very delicate pins. Note the male pin which is made from fine wires. Also note the taper on the female plug which leads to the narrower front end. The rear part of each pin with the retention groove will be glued into our housings. Of course all pins are gold plated to survive any economic crisis.**

## The Housings

The original housing was injection molded from polycarbonate complete with the wires and an additional flexible end cap. This of course required complex and expensive multi-part molds good for making hundreds of thousands of parts. For our hobby project several options came to mind: machining from solid plastics, casting the housings with resin in silicon molds taken from original plugs, and finally, using the 3D-printing technology.

Several sheets of paper later and out of curiosity I decided to try the 3D-printing technology. 3D-printers for hobby purposes can be bought in a price range from $500 to more than $2500. While this would open up an interesting new hobby I found it too expensive to produce just a few plugs. Also, following the technology over more than one year and reading through publications, user forums and manufacturer service boards I found that these hobby machines need a lot of experience (aka trial and error) and do not always deliver what is promised. So I decided to try a commercial 3D-printing service which required no upfront investment and allowed to test different materials and manufacturing methods.

After carefully designing the plug parts using a CAD program with manufacturability and assembly in mind I produced the required STL files (not too large but with sufficient resolution of all details). As no dimensions were given in the specification, measurements were taken from an original cable.

Finally I ordered two sets of housings from a commercial 3D printing service. One set made from laser sintered Polyamide powder (also known by the names NYLON or PERLON) and the second made from layers of hot extruded ABS. Two weeks later the parts arrived. The Polyamide parts have a slightly rough and porous surface (like very fine sand) while the smooth ABS parts clearly show the individual layers. The ABS parts have the advantage that they can be glued together using a solvent based plastic model cement, while the polyamide parts can probably only be glued together using formic acid, which is not compatible with the copper wires. However, in both cases Epoxy glue works fine due to the surface roughness. On the other hand the sintered Polyamide parts are mechanically more robust and less brittle than the ABS parts. The sintered parts may have remains of the fine Polyamide powder in small openings while the ABS parts are perfectly clean. The sintered parts have the dimensions closer to the design, while the ABS parts show higher tolerances due to shrinking. For practical application both materials are suitable.

After obtaining the first set of parts and reworking them to fit, some small refinements of the CAD model were made to take the increased tolerances into account. Nevertheless some rework will almost always be required due to the manufacturing tolerances.

**Figure 4: Intended assembly of the connectors with wires and pins.**

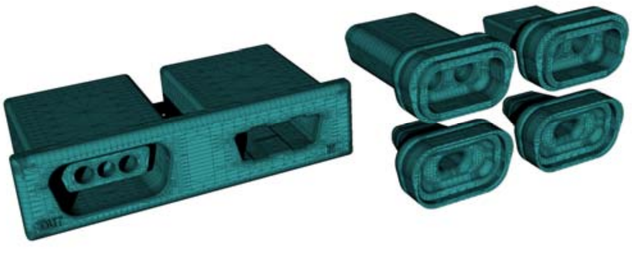

**Figure 5: Set of STL parts created from CAD models for the connectors and a device connector panel.**

# How to Build Your Cable

## Step 1: Fit the 3D-Printed Parts

The 3D-printing process is not as accurate as injection molding. Depending on the operator and the material each batch may be slightly different. Tolerances may be as large as 0.2 to 0.5 millimeter.

Therefore is necessary to test whether the new connectors fit original HP-IL connectors. For this you should have another original cable and also a device panel with molded HP-IL connectors for testing.

- First check the male plug parts. The two holes for the pins must be 2 mm in diameter and 6 mm deep. Be careful when you try to plug the 3D printed part into an original female connector. If the holes are less than 2 mm you may damage the female pins in the original connector. The hollow pins of the female connector must nicely fit into these holes. This may require some drilling with a fast spinning drill press. If you don't have one use a Dremel like tool, if possible secured to your desk. The connector should nicely fit into the female plug with a slight snap. Then make sure that the rear part of each pin hole which will later hold the male pin has a diameter of 1.4 to 1.5 mm. With the help of tweezers or a needle, you should be able to push each male pin from the rear into the hole.
- Now the check the female connector. Again make sure that the plastic parts fit over an original male connector. It should be a tight fit, but not too tight. If necessary widen the interior of the part with a needle file. Also check whether each pin hole which will later hold the female tube has a diameter of about 1.5 mm. With the help of a needle, you should again be able to push the hollow female pin from the rear into the hole.
- If necessary, enlarge the hole for the passage of the twin wires in each end cap with a small file or a 1.5 mm drill bit. Test by inserting your wires.
- Finally test whether the rear cover parts fit the front parts of the plugs. Again, some work with the needle file may be needed. In case of ABS parts you can achieve a “Lego-like” snap-in-place fit.

The more careful you are at this stage, the less problems you will have later.

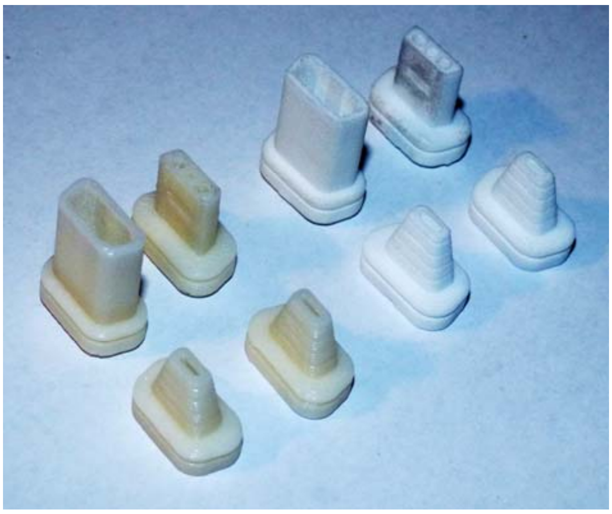

**Figure 6: 3D-printed plastic parts. The cream colored parts on the left are made from extruded ABS while the white parts on the right are sintered polyamide.**

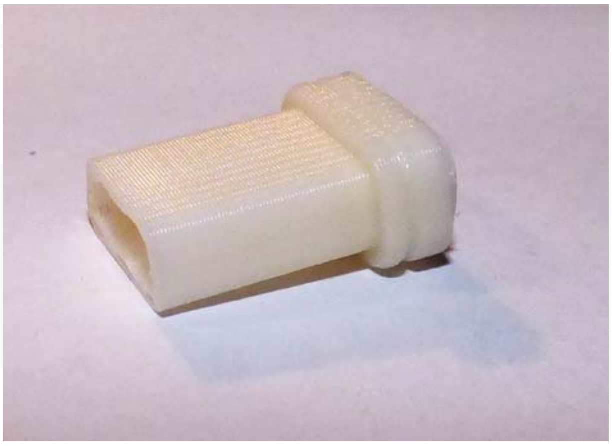

**Figure 7: The extruded ABS plug clearly shows the individual layers which have been melted on top of each other.**

## Step 2: Prepare the Wires

A length of 10 mm at the ends of each wire should be stripped of insulation. Ideally you would use a matching crimp tool to connect wires and pins, but these tools are expensive. If you crimp, you should not tin the wires. Lacking a crimp tool, I pre-tinned the wire ends after twisting the copper strands. Then I used a small cutter to trim the tinned wire ends to the same length of about 5 mm.

## Step 3: Mate the Wires and Pins

Insert the wire into its corresponding pin. In case of a female pin double-check that you are mounting into the correct (slightly larger diameter) end.

Use a small soldering iron to solder the wire into the pin with a very small amount of additional solder. Normally the pre-tinned wire should carry enough solder for a good connection and the additional solder serves mostly as a flux carrier. Do not use too much solder, but make sure that the connection is nice and shiny. There is a risk to fill the female connector with solder. To reduce this risk you can pinch the middle part of the pins with a pair of pointed pliers so that the wire end is trapped and no lead can flow to the front opening. You could also insert a thin cylindrical piece of wood (toothpick or hard balsa wood) into the tube to avoid flooding. Holding the pins vertical with a wooden block also helps to keep the solder from creeping too deep into the pin. Even if you partially filled the hollow female pin with too much solder, you can use a small handheld drill (0.8 mm diameter) to remove the solder.

After soldering test the connection with the corresponding pin respectively plug. Use tweezers to insert and remove the pins and avoid pulling the wires.

**Figure 8: The wires soldered to male pins. The lower pin receives too much solder which had to be removed to fit the assembly into the housing. Note: if you have a suitable crimp tool, use this instead of soldering.**

## Step 4: Position the End Caps

Slip the end caps onto your cable so that they form an exact mirror image of each other. This means that the wider side of the trapezoidal shape must be on the same side when placed flat on the table. The wires must pass straight through from the male to the female connector – they must not be twisted. If you would connect the two ends of the cable, each wire should connect to itself. With twisted wires the system won't work and you would later have to cut the cable and crosslink the wires.

## Step 5: Mount the Pins

First insert the empty housing into a mating male respectively female plug from an original cable or any other peripheral if you don’t have a cable. Then insert the wires with the pins into the housing and push them into the housing so that their rear end is 0.5-1.0 mm deep in the recess (see Figure 10). Make sure that the pins are at their intended depth and if necessary use a needle or pointed tweezers to push them forward. If necessary, take apart and rework the holes in the housing. If everything fits, carefully remove the cable with the pins from the housings. Note the trapezoidal shape of the end caps and the housings and make sure that they match.

Now we are ready to glue the pins into the housings. Do one connector first, then the second, but do both pins of each connector at the same time. Add a small amount of 5-minute Epoxy to the center part of each pin (see Figure 9). Ensure that the glue is nicely spread around the perimeter of each pin.

Note: when mixing Epoxy mix at least 0.5 to 1 $cm^3$ as smaller batches are difficult to measure and may not harden properly. If your Epoxy is supplied in a twin syringe feeder, you should have no problems with mixing small amounts. Stir for at least 30 seconds to make sure the mixture is good.

**Figure 9: Male connector pins with fresh Epoxy applied, seconds before being inserted into the housing. Be careful to avoid the application of Epoxy to the part of the connector pins forward of the conical section.**

Now insert both pins into the housing. Use the needle or tweezers to push both far enough into their holes (about 0.5 to 1mm below the surface). They will line up with their counterparts in the mating connector. Do this in one smooth operation and never pull the connectors back. If you soldered the pins as short as shown above the insulation of the wires should just contact the housing. Be careful not to break the wires – try to push on the pins only.

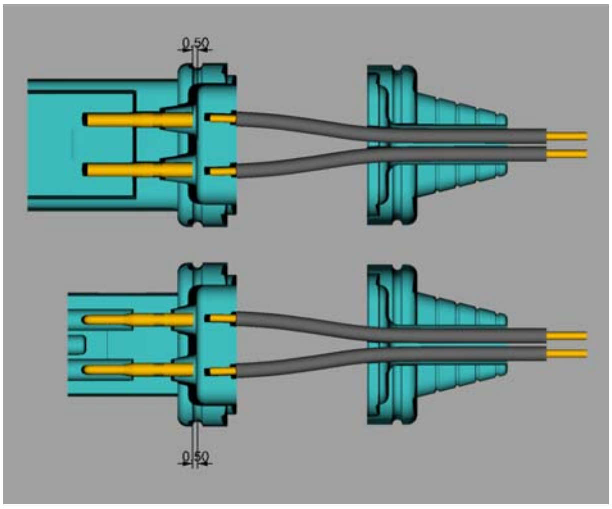


**Figure 10: Assembly of the housings with wires and pins. Note that the pins go into the housings about 0.5 to 1 mm below the surface of the bathtub recess.**

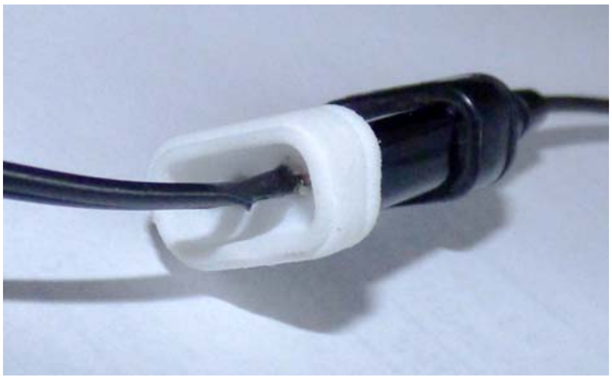

**Figure 11: Male pins glued into the housing. Only a small amount of glue is used at this stage.**

You can wait until the glue has set and recheck everything. If you are sure that everything is fine you can also continue directly to fill the bathtub recess with the remaining resin following Step 6: Complete the Front Housings.

## Step 6: Complete the Front Housings

Mount the housings in a fixture (e.g. a small vise) so that they are in a vertical position with the rear open end pointing up. Cast a generous amount of 5-minute Epoxy around the pins so that they and the wires are safely embedded in the Epoxy. Avoid trapped bubbles of air by using a wooden toothpick. You should fill the front part of each housing flush with the rim so that the pins as well as the wires are safely embedded in the resin. Keep the rim clean so that the end cap will later fit easily. You can apply a second coat of epoxy later when you add the end caps. Put aside and let the Epoxy set over night.

**Figure 12: Housing with pins and cable completely filled with epoxy. Do not overfill as the end cap volume is limited. The upright position allows filling the recess to properly grab the insulation of the cable.**

## Step 7: Test

Before finishing the housing it makes sense to test your cable. At this stage you may still be able to take it apart with the help of a drill and some heat. Carefully remove the mating plugs and inspect everything. Test the cable with an Ohm-Meter to make sure that the connections are good and the wires are not twisted.

Attach the new cable to an HP-IL-loop, being careful not to break the glue joints. Test the loop with your new cable. If everything works, proceed. Otherwise throw your hands up in disgust and recheck the connections.

**Figure 13: Both ends are ready to be mated to their end caps. I keep the original HP-IL cable attached for aligning the pins as long as possible – even the 5-minute Epoxy needs about 24 hours to cure completely.**

## Step 8: Add the End Caps

If necessary add some more epoxy first to make sure that the wires are well held in place and no load is ever introduced into the connection to the connector pins.

For this final step you can again use Epoxy (for the polyamide parts) or a plastic model glue (if the plastic parts were made from ABS). Attach the rear part and hold in place with some adhesive tape until the glue has set. If you want, you can later add another layer of glue around the joint but normally this is not necessary.

**Figure 14: The finished cable.**

Note: Depending on 3D print service you can obtain different colors for the plastic parts. It is also possible to dye the Polyamide material by immersing in colored ink jet ink for several days if you want to do it yourself.

Another option might be to redesign the rear end cap to be made from a flexible material, which will not be glue-able and therefore must then be mechanically anchored inside the front part.

### The Device Connector Parts

The same technique can be used to build a device connector block. I built one of these for my PIL-Box, a HP-IL to Serial resp. USB interface.

In this case I tried a different print service which used a hobby-type printer. The individual layers were more visible. To obtain a smooth exterior finish I sanded the flange part using wet sand paper and water going from 200 grade paper to 500 grade paper. The result was a shiny, smooth surface, similar to an injection molded part. The inner surfaces which mate with the cables HP-IL connectors had to be smoothed with a small needle file. No big deal, but it takes some time. In order to simplify manufacturing the STL parts are in two parts. After fitting the parts they can be glued together using solvent based model aircraft plastic cement.

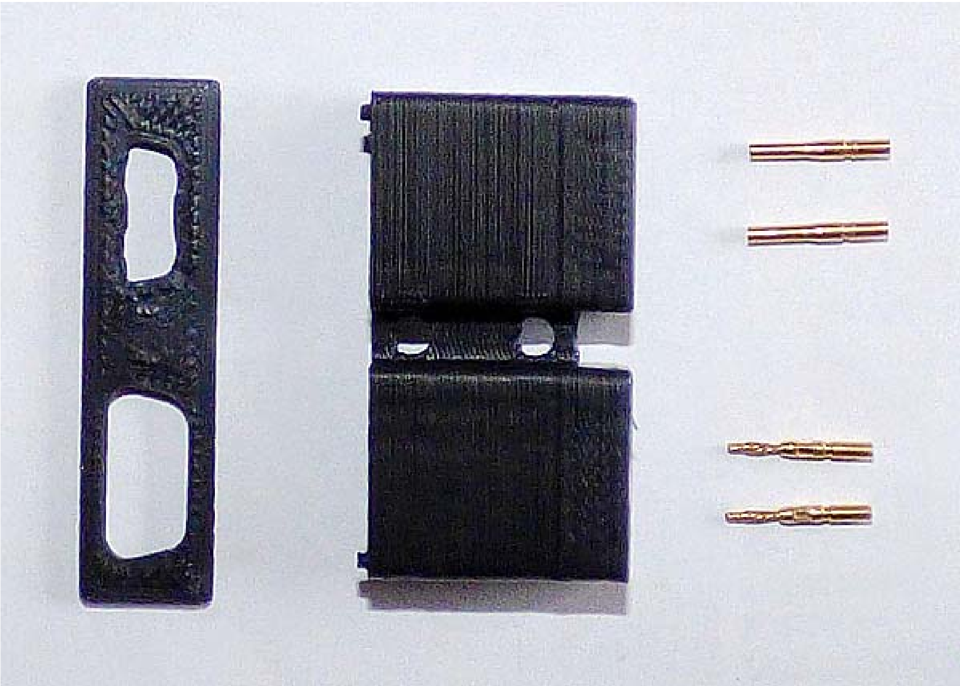

**Figure 15: These parts make a device connector. This sample had been printed on a hobby-type 3D printer and shows a relatively coarse surface structure.**

## About 3D Printing

All printing services need the CAD geometry in form of STL files. These contain the objects in the form of small pyramids and tetrahedra so that they are only an approximation of the objects. However most CAD programs allow specifying the tolerances e.g. by defining the maximum allowable distance between a true curved surface and its polygonal approximation. Thus it is possible to create the parts with the desired relatively smooth shape.

In case of the sintering methods the orientation of the part is not important as it is always supported by the surrounding powder bed and thus thin parts cannot sag or bend.

If the filament deposit method is used (common for ABS or PLA) the orientation of the parts should be chosen so that no large overhangs occur. Some manufacturers automatically generate support structures, but I tried to design the parts so that these are not necessary. The web interface offered by my supplier had the option to reorient the parts by rotating them in 90 degrees steps. I oriented the plugs so that they stand on their wire end and the free plug points up. For the end caps the orientation is similar: here the narrow wire end points up and the connector side down. As all four parts are in one STL model there is only one way to orient them all.

| Description | File Name | File Size |
|---|---|---|
| Cable connector set (4 parts) | HP-IL-Housings.stl | 12.8 MB |
| Device connector (2 parts) | HP-IL-TwinHousing.stl | 5.7 MB |

**Table 2: The STL files and their content.**

Note:

I learned that the tolerances from batch to batch vary. While the first print was an almost perfect fit, the second batch was considerably (say about 2/10 mm) smaller resp. thinner. This made the connectors match less well than the first set of prints. This is probably something we have to live with as long as you do not have your own 3D printer and can control the whole process yourself. One means to fix this small variation on nylon sintered parts is to add a thin layer of super-glue to the outer surface and put some super-glue-gap-filler powder on the liquid glue. Any excess can later be removed with a small file. Even if the super glue does not chemically bond with nylon, it infiltrates the porous surface and creates a mechanical bond. Remember that we are talking about variations in the 1/10 mm range, so it is not necessary to pile up a thick layer of filler.

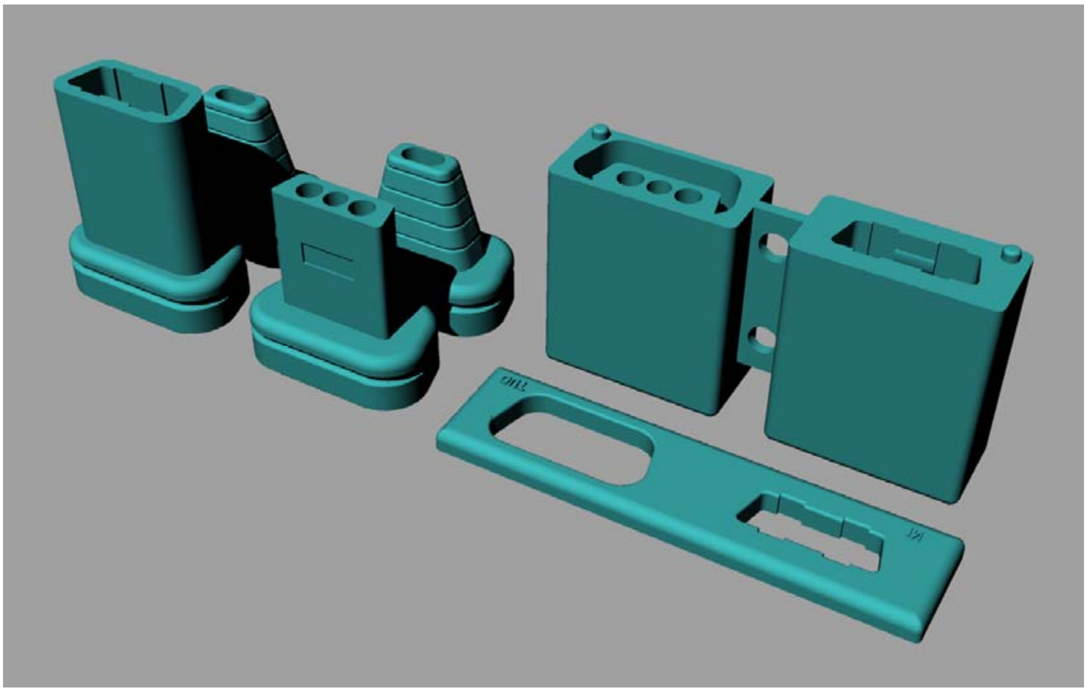

**Figure 16: The STL parts oriented so that their support side is down and the free ends point up. The STL file "HP-IL-Housings.stl" contain the male/female plug parts together so that they can be**

**printed in one batch. The two device connector parts are contained in “HP-IL-TwinHousing.stl”.**

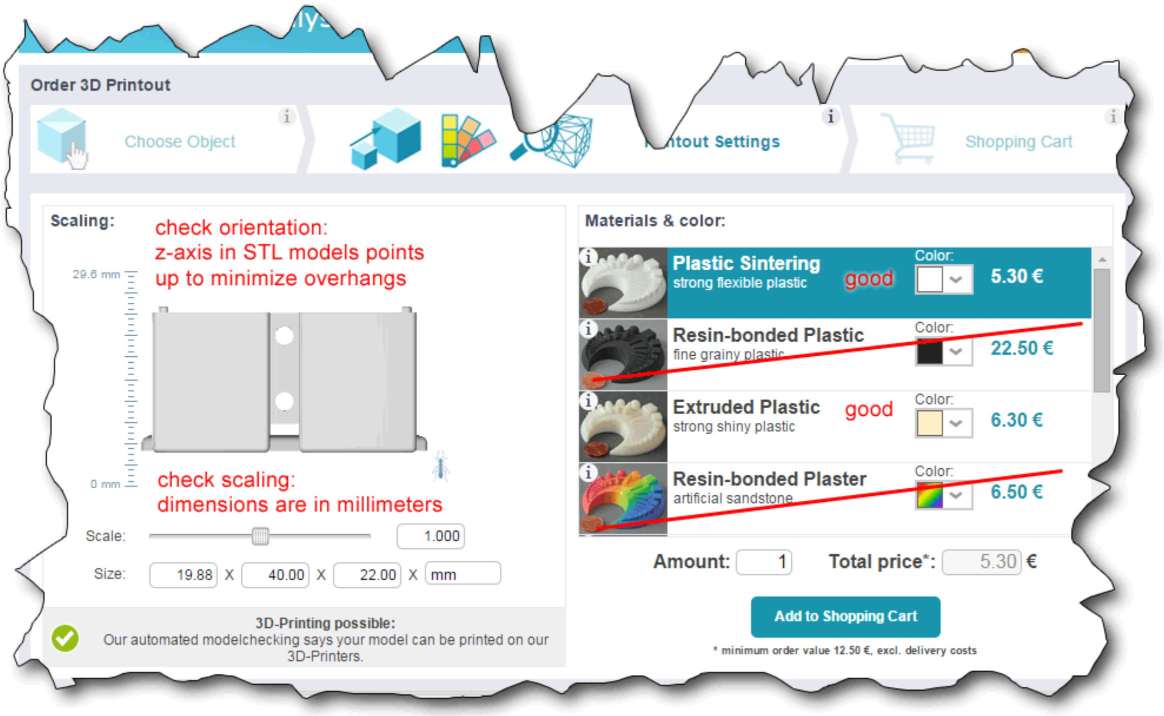


**Figure 17: The web interface of most 3D-printing service providers can be used to check the orientation and the scaling of the parts. Please note that the units in my STL parts are millimeters.**

# Materials and Sources

The table lists the suppliers I had chosen. I am not affiliated with any of the listed sources and there will be other sources. If you find other local suppliers, I am happy to add them to this document.

| Component | Country | Supplier | Internet | Comment |
|---|---|---|---|---|
| 3D Printed Parts | Germany | trinckle 3D GmbH | www.trinckle.com | simple and easy |
| Connector Pins | USA and UK | PEI-Genesis Ltd. | http://www.peigenesis.com | shipping costs! |

# References


[1] “The HP-Il Interface Specification”, Document 82166-90017, Hewlett-Packard, 1982.