Power and Voltage Ratings
for Connectors

Before reading this third instalment on connector specifications, you can catch up with the first two in these blog posts:

- **Derating Curves, Power Ratings, Maximum Current Ratings**
- **The Secrets of Temperature Ranges**

We're now reaching the specifications that confused me when I first started designing connectors. Don't worry, the excellent Harwin Design Team has double-checked this article!

High Power or High Current?

One item we need to address is the interchangeable problem with Current and Power in the connector industry – we're guilty of this ourselves, but it's widely accepted.

When you see a connector referred to as "High Power", strictly speaking we mean "High Current" – i.e., the connector contacts can carry a reasonably high level of current. The use of 'power' in this context seems to have come from the source of the high current – the power supply. Therefore, a high current connector is capable of transferring current delivered by a power supply and used to power the device (as opposed to data signals).

Power from Voltage Rating – or not?

The confusion comes when engineers try to apply that well known formula for calculating power:

$P = V \times I$	P = Power (Watts) V = Voltage (Volts) I = Current (Amps)

Connectors do not heat up enough to keep your cat/dog warm

Let's add in some figures for our newest range of power connectors – Kona. At first glance, with a current rating at 60A, and a maximum voltage of 3,000V... we have a power rating at 180kW!

In your head, you compare this to the heat that comes off a 1kW bar heater – and you get worried. Well, I did the first time I worked it out!

Don't Panic

What we're not taking into consideration here is Resistance, and the function of the connector. Let's take a step back and check out what we're expecting from the connector.

Connectors should take no active part in a circuit. They are designed to pass current with as little interference as possible. Their function is to provide a convenient re-usable separation point in the circuit; to help with portability, manufacture, maintenance, or upgrade. If everything was permanently wired or printed tracks, it would be much trickier (or impossible) to assemble. Imagine if everything electrical in your house had no plugs and was hard-wired to the power grid!

To the current passing through it, the connection pair should look the same as the wires or tracks – just a conduit for electrons. So, like the solid copper wires or tracks, a nice low resistance in the materials and at the connection point is most desirable.

What if we used the connector resistance (given as Contact Resistance in specifications) to calculate power?

$$P = I^2 \times R$$

P = Power (Watts)
I = Current (Amps)
R = Resistance (Ohms)

Back to Kona: $60A^2 \times 0.002Ohms$ gives us 7.2W – that sounds a lot more reasonable! So what's going on here? How have we got two wildly different Power figures?

Transferred Power or Dissipated Power

Here's where context is important in understanding these calculations. Voltage is a measure of Electromotive Force (EMF), which is the pushing force behind the electric flow. It's also a measure of Potential Energy, the difference between the two poles of the power source.

Now, for this 3,000V figure to be relevant to the connector alone, it would have to lose all that potential energy just across the connector. In other words, the voltage reading on one side of the connector would be 3,000V, and on the other side it would be 0V. Now you can see where you might get 180kW of energy!

But as we know the connector's purpose is absolutely NOT to lose any of that voltage if at all possible. We want all that power to be transferred power – transferred from one side of the connector to the other, with minimal interference.

Transferring power from wall socket to charging cable

So that first calculation is irrelevant for a connector – and the second calculation now makes more sense. It gives us the potential energy or power lost (Dissipated Power) as the electron flow passes through the connector.

Don't forget, we're still talking worst case. Contact resistance figures for connectors are always maximums, so in practice it's likely to be much lower.

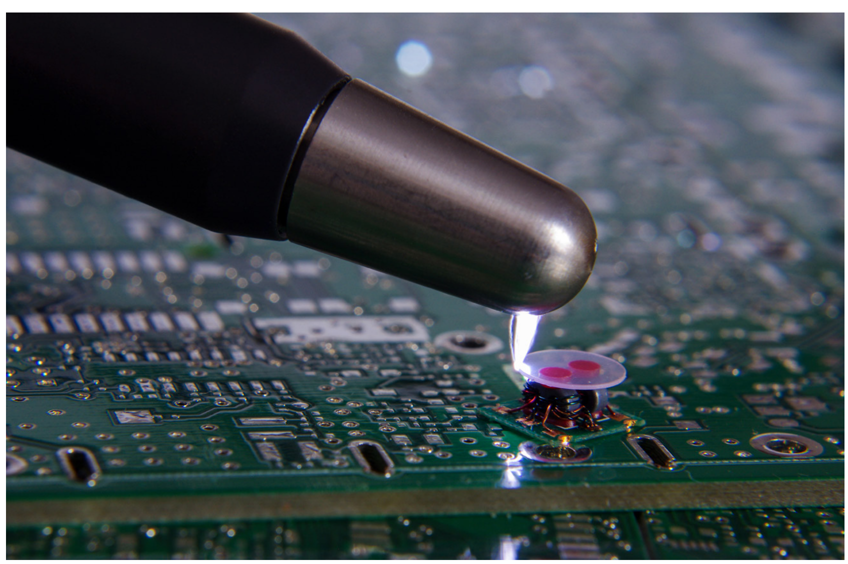
Coming round in a full circle

And here's where it all comes back round to the previous article – that same resistance and power loss is what heats up the connector. That takes us back to the current derate curve, and the effect of heating on your maximum current carrying capacity.

The derate curve is generally more useful for circuit and equipment designers, so you won't see power loss ratings on normal connectors.

Maximum Voltage Ratings

So, what's the voltage rating for? If it's not to calculate a power rating, what's it telling us? Well, that EMF can sometimes push electrons out of the conductor and across the gap to the next nearest conductor. That might be a piece of fixing hardware, a metal shield, or the outer enclosure. With a connector, it's normally the next nearest contact. We call this a flash-over, as in the worst cases you'll see a spark or flash as the electron flow jumps the gap. Lightning and Tesla Coils are lovely examples of this, but in an electrical circuit it's really undesirable. You might also see it called Breakdown voltage, as the insulation between the two conductors has broken down and allowed current to pass.



Flashover due to electrostatic discharge – voltage build-up from static

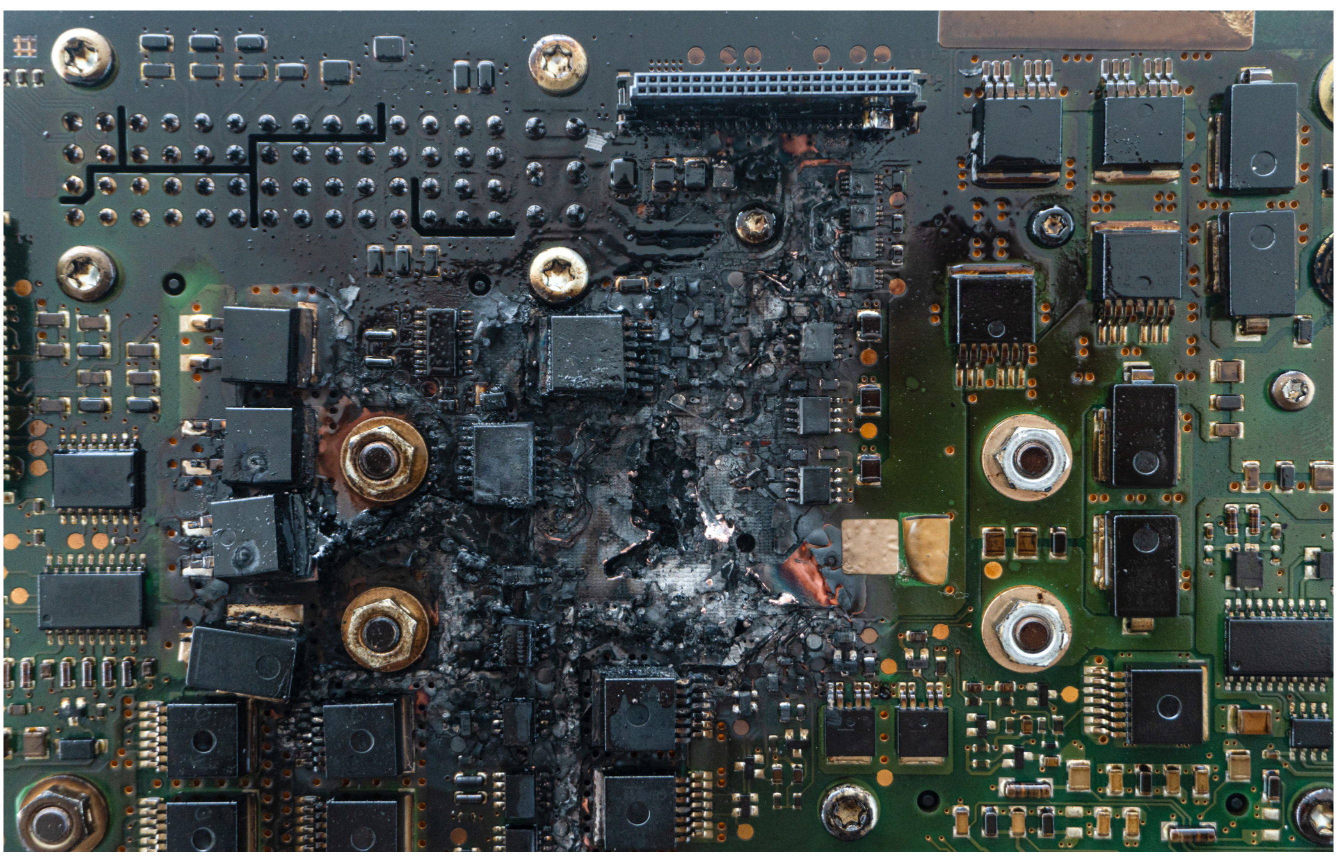
The amount of force (or voltage) needed to achieve this will depend on a) the insulation resistance of the gap between the contacts and b) the distance between the contacts. This is not always a simple calculation, as the complex shape of housings and the amount of air between contact make it difficult to know the exact insulation resistance in the gap.

So maximum voltages are established by laboratory testing. There are various standards that detail the method, but they all involve monitoring the voltage level across a connector. As the voltage level from the power source is increased, at some point the measured voltage across the connector will start to drop. The electron flow is starting to leak out of the measured conductor into the next nearest conductor.

The maximum voltage is then set at a nice round figure safely below this level. You might see this specification given a variety of names:

- Maximum Voltage Rating
- Voltage Proof
- Dielectric Withstanding Voltage

There are some minor differences in these definitions, but in practice they mean the same thing – stay below this voltage to avoid flashover.



Working Voltage Ratings

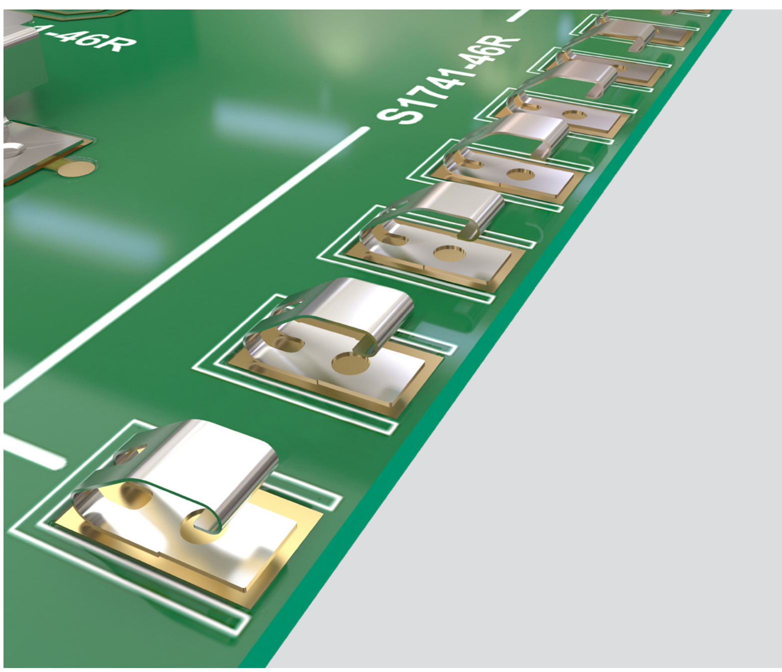
Once you've got the maximum for your voltage recommendation, you can then set a working voltage level. There are no specific rules on setting the working voltage. You'll see versions set at one-third, one-half, or two-thirds of the maximum voltage.

If you're specifying for a significant voltage level, make sure you check both working and maximum voltage specifications. Also check the stability of your power source, to evaluate the risk of fluctuations and surges.

These robot arms can be under the control of higher-level systems, but often have their own control package for standalone operation.

Voltage Ratings for Single Contacts

One frequently asked question we see is "why does this terminal pin not have a voltage rating?" The answer should now be obvious – we don't know where your next nearest conducting element is placed!



Your system layout will determine the distance to any metal or other conductor, and what insulation (or free air) is between these two points. Just like we test our maximum voltage, you'll need to do the same.

Congratulations

You've made it – hopefully now with a better understanding of some of the most important specifications for determining your best connector choice.

At Harwin, we publish this specification information in a couple of places:

- On the Technical Drawing for the individual product – available from a product page under Downloads;
- In the Component Specification, valid for a range of connectors – available from a product page under Downloads, or listed on the Design Resources page.

Our technical team are ready to take you through any aspect of your connector needs, and our possible solutions – book a consultation today.