1. Preamble

This note is intended to help understand the working principle of an electronic load, as well as some certain, indispensable given facts. For users which experience inexplicable or allegedly illogical behaviour, this document shall be a help to solve the problems by understanding the relations and situation of problems, which are often caused just by the lack of appropriate knowledge.

2. Questions and answers

2.1 What is an electronic load at all?

An electronic load is a device that simluates an ohmic resistor with transistors. It is considered as a power sink. Typically, input power and input current are adjustable, as well as voltage and resistance. To load a connected DC voltage/current source (battery, power supply, capacitor, turbine), either the input current is adjusted and the internal resistance changes or the internal resistance is adjusted and the input current changes accordingly. Input power adjustment is a higher priority feature, affecting the input current in dependency of the input voltage by formula P = U * I, no matter what current or resistance the user has adjusted. So the user can adjust input current, input power and internal resistance. This leads to few important insights:

- The adjusted set values determine the behaviour of the e-load and the regulation mode it works with (CC, CP, CV, CR). It means, once the adjusted current is flowing in, the device will be in CC (constant current) mode and as soon as the adjusted inout power matches the adjusted power, it will switch to CP (constant power) mode. In case of a EL3000 or EL9000 switching modes between CC, CP etc. either just preselects the corresponding set value for adjustment or enables a certain feature (CV, CR). There is no „CC only mode“ or similar.
- Only the set values determine which regulation mode (CV, CC, CP, CR) the load will operate in. If the input current reaches the adjusted current, the load changes to CC (constant current). If the input power reaches the adjusted max. power, the load will change to CP (constant power). In case of the electronic load series EL 3000 and EL 9000, switching the mode switch between CV, CC etc. is actually just a selection of the corresponding set value, in case of CV it also enable the voltage set value for adjustment and in case of CR, it enables the resistance value for adjustment.
- Only one of the four regulation modes can be in control. CP has the highest priority, then comes CC and then CR and CV.
- CV (constant voltage) is a special case. The load is an energy sink which can take a limited power. The power source (or voltage source) usually holds the voltage constant. In CV mode of the load, the user can also adjust a voltage. If this voltage value is adjusted higher than the voltage coming from the voltage source, the load will drain no current. If adjusted lower, the load will try to bring the input voltage down to the adjusted level by draining so much current from the voltage source so that the voltage collapses. This can only work if the voltage source can not provide more current than the load can drain. A battery, for example, can provide a high current, but will discharge over the time and the battery voltage will sink, eventually lower than the adjusted voltage value. In CV mode, the load would then stop discharging the battery. If the voltage would be set too low, the battery could be deeply discharged and thus even destroyed.

2.2 Relation of input voltage to input current

In situations where the input voltage of the load is very low, the load can not drain full current. Why is that?

Section 2.1 describes that an electronic is basically nothing more than a variable resistor, realised with transistors. Those transistor have a resistance that can not go down to zero, though it is very small and can also not be determined exactly. With an input voltage on, for example, a load with 80V and 2400W nominal values, the load will not be able to drain full current because of Ohm‘s law R = U / I or I = U / R. Thus there is a mimimum input voltage for every model where the load can drain full current and this minimum voltage varies with every model. It can be determined by a simple test: connect a variable voltage source to the load which can provide at least the current the load can drain and adjust the voltage slowly up from zero. When the actual input current of the load has reached the maximum, the actual voltage on the load‘s display is that minimum input voltage for max. current.

However, even with input voltage below that minimum, the load will work normal and reliable. It is just not possible to achieve a certain input current or adjusted resistance in this situation.

2.3 Internal resistance in dependancy of U and I, Genauigkeiten

All adjustable values of voltage, current, power etc. are not 100% precise. It means, if someone would calibrate them with very high precision instruments, he/she would see small differences between adjusted values (i.e. set values) and input values (i.e. actual values). This is based on the nature of things and is called accuracy or tolerance or error. Actual values, as shown in the display, are measured by the load and will always have a certain error. Also set values, as adjusted by the user, will have an error. What‘s the effect? In constant current operation, only the error of the current is effective. In constant power operation, the errors of voltage <u>and</u> current are effective, they multiply according to formula P = U * I.

For the internal resistance it is similar, but more problematic. The user adjusts the desired resistance which the load shall simulate. Depending on the voltage that is put in, a certain current has to flow, which is calculated by the load according to I = U / R. This division will bring, that...

- a high input voltage and a small adjusted resistance would result in a high current, which calculated valued could exceed the adjusted or even the maximum current of the load, so that the actual resistance could not be achieved
- a small input voltage and a high adjusted resistance could result in a very small calculated current. This current could be set by the load, but the global error of the current could cause a big deviance at the same time and the load could not achieve the desired resistance

Both situations can not be circumvented. What to do? They can be avoided by only working in the middle range of the load‘s values, like for example between 10% and 90%.

2.4 Regulation speed

The electronic load has an internal control circuit, consisting of electronic components. The circuit‘s speed is not infinite. In case of a set value change, for example a different current, the control circuit will regulate the new value as fast as possible to the input. Several factors are impacting here, like the characteristics of the voltage source, the internal temperature of the load, the difference of the set value change and eventually distorting noise. Thus it is impossible to determine a definite regulation time/speed.

2.5 Current rise

Also see item 2.4. The speed of the regulation circuit also affects the current rise. Electronic loads of the series EL 9000 are very fast regarding the speed of current rising, so that the input current could rise from 0 to 100% within microseconds, which will stress the source accordingly. This can lead to unwanted side effects like oscillation, when using capacitive or inductive voltage sources. Oscillation is not uncommon and can be suppressed by the user by applying certain measures.

2.6 Transient times

The transient time of control signals or commands sent via digital interface can be important for some applications. Based on the construction of the EL 3000 and EL 9000 devices, those transient times are not constant. It means, the time it takes for a unit to react on a signal like on the analogue interface, for example „Rem-SB“, varies. This basically applies to every control signal from outside, no matter if analog or digital. Due to this, there are no exact transient times, only minimum and maximum, whereas both, min. and max., also differ for every signal.

2.7 Hysteresis when stopping the battery test

In battery test mode there is an adjustable low voltage threshold, called Ulow. This is used by the load to determine when to stop the battery test automatically. Usually, the voltage of the source (in this case a battery) is quite stable, but also may fluctuate. During the test with the battery voltage being almost Ulow, it might fluctuate very shortly, causing the load to stop the test. Small voltage fluctuations are not critical, so the test should not stop. Thus the load will start a test when the battery voltage falls the first time below threshold Ulow. It checks if the input voltage remains below Ulow. Unless the battery voltage does not exceed the threshold again, the battery test will stop after five seconds. This may cause problems for batteries where the battery voltage changes quite fast due to high-current discharge, because during those five seconds, the battery test continues. Ths five seconds test time is not adjustable. Thus the battery test is only recommended for slow and insensitive batteries with high capacity, like lead-acid.