1. Preamble

This document is intended to explain and to help understanding certain terms and relations between them.

The explanations are only related to technical devices like power supplies, electronic loads or battery chargers which can be found in the EA product portfolio. It may occur that common thoughts and definitions are dissenting from what is explained below.

2. Resolution and step width

2.1 General

The term „resolution“ is, on one hand, related to the various displays on technical devices which will values and, on the other hand, related to the number of values or steps that are available to adjust set values like voltage, current, power or resistance. It is very common nowadays to control electronic devices by microcontrollers and thus terms like resolution and step width become relevant to the output/input values.

2.2 Resolution of input and output values (actual values, set values)

The ***resolution*** of a set value primarily depends on a so-called digital-to-analogue converter (DAC) and the ***resolution*** of measured (actual) values primarily depends on a so-called analogue-to-digital converter (ADC). The DAC creates analogue signals from digital values, which are adjusted by the user manually on the device or sent to the microcontroller (and thus DAC) via digital communication from a PC. The ADC measures actual analogue values and converts them into digital equivalents, which may be brought to display by the microcontroller or sent to the PC upon request via digital control. Both components have an ***ideal resolution*** and a ***true resolution***. Every electronic component has an error, so the ideal ***resolution*** can not be achieved in most situations and a device manufacturer won‘t thus guarantee it. The manufacturer will, if at all, specify a ***resolution*** which the device can always achieve as minimum.

An example: a 12 bit DAC generates the set values for current, voltage and power of a power supply. 12 bit means 4096 values of possible resolution. This is only the ***ideal resolution*** of the DAC. Due to the errors of the DAC and other components, the ***true resolution*** is reduced. Additionally, the full range of the DAC is not used, due to design. This will vary from device to device and can thus not be determined exactly. Data, measured during end tests of units from running production, can be used to extract the minimum average ***resolution****,* that is achieved by a certain device series. If the specification says, a device has a ***resolution*** of minimum 10 bits, then the 1024 steps of the DAC are spread over the range of the particular output values.

2.3 Resolution of displays

The devices feature various displays (LED or LCD) to show set values and actual values. With older device series from EA, values in the display always have 4 digits and the number of decimal places changes from model to model. With newer series, the displayed values can have 3 to 5 digits. For example, the EL 9080-200 electronic load displays the actual voltage as 00.0 V and the current as 000.0 A. This also defines the manually adjustable ***resolution***, which has to be expedient for the 80 V input, displayed as 80.0 V. If the ***resolution*** would be 10 mV, then the adjustment range would have 8000 steps and with 100 mV resolution it would be 800 steps. When considering the ideal ***resolution*** of a 12 bit DAC being 4096, then 8000 steps would be much too high and 800 steps quite low. The specified step width is thus a compromise, in this case it is 100 mV. Further information in section 2.5.3.

2.4 Relation between resolution and step width

The ***step width*** is a value that results from the true resolution of a device‘s DAC. It defines the minimum difference between two set values, like of the voltage, that can be achieved on the DC input/output when adjusting. Usually, the true and measurable ***step width*** is lower than the specified one. But it is also not exactly determinable and can only be specified as an average value, built from n measured samples along the whole range of a value. The adjustable step width depends on the way of adjusting a set value (manual, digital, analogue).

As an example, let‘s consider the approximate ***step width*** that can be achieved on a PS 8720-15 2U. This model offers 720 V max. output voltage, 15 A max. current and 3000 W power. With the effective resolution of ~3700 steps it would be 720 V / 3700 = ~ 0.19 V per step. For power and current it is similar. The max. 15 A of the example model results in a current ***step width*** of 15 A / 3700 = ~4 mA. For the power of 3000 W it results in a power ***step width*** of 3000 W / 3700 = ~ 0.8 W. But the actual step widths for manual adjustment with this model are 0.1 V, 10 mA and 1 W and are thus either finer or coarser than the measurable step width on the output.

What does that mean in the end?

A device will only be able to achieve a DAC depending step width for adjustment, no matter how many steps the user can adjust manually on the device or how many different values can be sent through digital communication.

Why is that?

Because you can not map any set or actual value to the true or ideal resolution of a DAC or ADC. Because analogue remote control is set up for common ranges of 0...10 V and for digital remote control there has to be a system that fits best.

Assumed that any set value would be transmitted as 32 bit value in dig. remote control and in millivolt or milliampere format, etc. It would allow to send even a value like 566.455 V for a model with high voltage, like the 720 V. That would be 566455 mV or 720000 mV for the maximum and would require to use at least a 24 bit converter in order to set a value like this. Instead, this value is usually downsized by the microcontroller to match the resolution of the 12 bit DAC, that does not allow more than 4096 different values.

The resolution of the set value that the user can send to the device is much higher than the true resolution. *If the resolution and/or step width of a value is not given in the technical specifications of an electronic device, the user might assume the resulting resolution of output values is identical to the possible resolution of set values. But this is wrong!*

2.5 Resolution of the various forms of input

2.5.1 Input by digital interface

Older series up to 2012:

Set values that are sent via digital communication have a max. resolution of 25600 steps. The true step width on the output of the device is the one that can be achieved by the DAC. It is approx. 3700 steps. Interfaces which use the command language SCPI allow to send values with multiple decimal places, just because the SCPI format makes it possible. These values are internally converted and rounded to achieve a step width that matches the minimum output step width.

Newer series since 2014:

Set values that are sent via digital communication have a max. resolution of 52428 steps. The true step width on the output of the device is the one that can be achieved by the DAC. It is 26214 steps. A 16 bit converter is used here, where the full range is referenced as 0...125% for set values and actual values, plus the values can be signed. Thus the effective resolution reduces to 2^15 * 0.8 = 26214 for 0...100%.

Interfaces which use the command language SCPI allow to send values with multiple decimal places, just because the SCPI format makes it possible. These values are internally converted and rounded to achieve a step width that matches the minimum output step width.

2.5.2 Input by analogue interfaces

Set values, as given by analogue interface, are actual values with resolution X to the device‘s microcontroller in the first place. For EA devices, ADC‘s generally use 14 bit (ideal). Because they‘re measured by the ADC and microcontroller, then converted and set with the DAC, the input resolution of the sampling ADC is irrelevant. But a higher input resolution helps to already minimize errors coming from the sampling procedure and thus minimize the overall error.

2.5.3 Input by manual adjustment on the device’s panel

Manually adjusted values are bound to definite adjustment step widths, which result from the display format.

Devices series from EA **up to 2012** use 4-digit values for display and a **12 bit converter**.

Examples: 4.000 A, 80.00 V, 1000 W, 15.00 kW

Normally, the minimum adjustment step width would be the last digit. For a device with 80 V nominal voltage that‘d be 10 mV. This makes 8000 steps and is not achievable with a 12 bit DAC. The user would either only see a reaction on the output with every 2-4 steps or the minimum step width is increased to 20 mV or 50 mV.

Doing so will reduce the number of steps to 4000 resp. 1600 for the 80 V example. The number of steps would then match the DACs capabilities.

For other set values, like for example 1500 W, it can be vice versa. This is defined as 1500 steps of 1 W, while the DAC could provide double the steps. Here, the manual adjustment step width is bigger than for digital or analogue adjustment, because there 0.5 W steps are possible.

With newer series, as **from 2014**, values with 3 to 5 digits and a **16 bit converter** are used

Examples: 20.000 A, 80.00 V, 3.50 kW

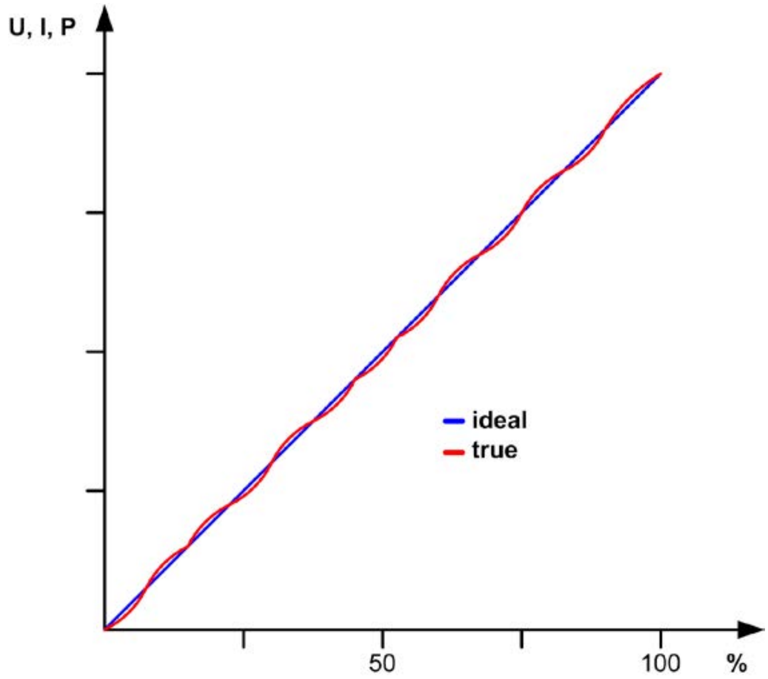
Due to the higher resolution (see 2.5.1), a range of 0...20 A with display format 20.000 and thus 20000 steps fits quite well the effective resolution on the DC input/output. Here too, every value has a certain error on the DC input/output.

3. Accuracy

Accuracy is the complement of an error. Every output value has an error and this error is given in the technical specifications as maximum error resp. minimum accuracy. The true error has to be smaller than given, the accuracy can be better or higher than stated.

The error of an output value is always related to the nominal value. A specification of „≤ 0.1%“ for an 80 V model means, the output value may have an error (or deviation) of up to 80 mV compared the set value, no matter what set value between 0% and 100% was set. With small set values, this deviation is more significant than with high set values.

For the user it show like this: a set values is adjusted on the device and the output value is measured with a multimeter. The output value (or actual value) differs from the set value, either in negative or positive direction. This is normal. Important is, if the deviation in within the allowed range or not.



Example: an 80 V power supply with 0.1% max. voltage error is adjusted to 5 V. When measuring the output voltage with a multimeter (which also has an error we will ignore for the moment), it will display values around 5 V usually with three decimal places and may show 5.035 V. It‘s a deviation of 35 mV from the set value and thus acceptable, because up to 80 mV are allowed.

The actual-to-set value deviation is, unfortunately, not constant over the whole output value range of 0...100%. In fact, the output value with its error represents an unlinear curve (see figure above).

If an application requires very exact output value adjustment, the user is asked to use an external and very exact multimeter in order to adjust correctly, because a power supply or electronic load is <u>no measuring device</u>.