App Note 505 - Charging Units as Continuous DC Supplies

Introduction

TDK-Lambda's ALE series capacitor charging power supplies are designed for operation in two modes. In their most common format they are used as constant current Capacitor Charging Supplies which will reliably charge High Voltage capacitors and Pulse Forming Networks (PFNs) in lasers and modulator circuits. However, they can also operate as constant voltage, continuous output DC power Supplies for powering RF generators and other continuous DC loads.

Capacitor Charging vs DC Supplies

Capacitor charging power supplies are designed and rated such that they are actually capable of delivering greater than 2 x their average output power for durations of a few milliseconds, and under certain output conditions.

If a standard capacitor charging supply is operated in the continuous DC mode, an internal Load Fault detection circuit will shut down the output after approximately 500ms, and then cycle the output on and off in 500ms intervals to prevent power supply and load damage.

For reliable operation in continuous DC applications the output current of a capacitor charging supply is factory de-rated so that the average DC power rating of the unit can never be exceeded. In addition the function of the load fault circuit; that is no longer useful; is disabled.

All of TDK-Lambda's ALE series capacitor charging power supplies can be factory adjusted in this way for operation in continuous DC applications without exceeding their average power ratings. A power supply modified in this way usually contains -DC in the part description, for example 500A-1kV-POS-DC, or 303S-12kV-NEG-DC.

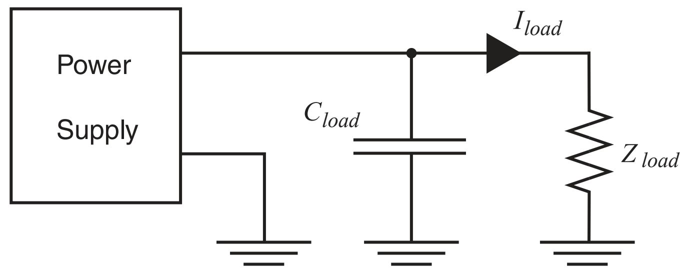
Output Filter Capacitance

One other feature of the capacitor charging power supply that needs to be addressed in continuous DC applications is the output filter capacitance. Due to the nature of capacitor charging applications, the power supply only requires a very small internal filter capacitor. A large filter capacitance in the unit is unnecessary, and can lead to significant losses in high repetition rate applications.

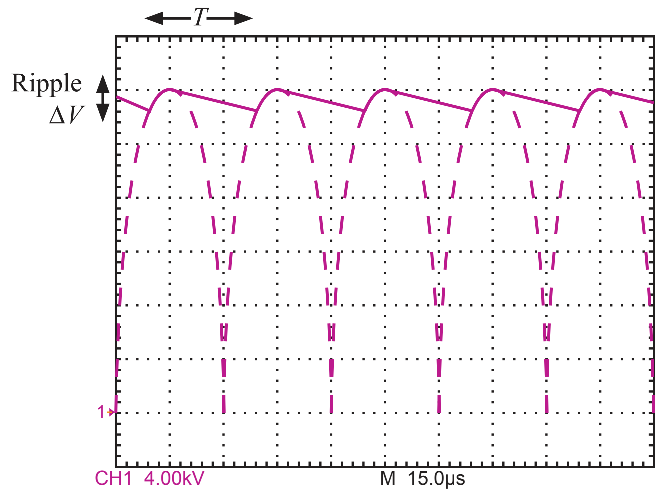
The low output filter capacitance results in poor 'out of box' ripple performance in many continuous DC application, however ripple can be easily improved by the addition of a **customer supplied external filter capacitor** in the load circuit. Output ripple in the region of 1% can be achieved with the addition of a simple and relatively small filter capacitor in the load circuit. If ripple requirements are <0.1% peak-peak then a more complex pi type LC output filter may be required. Recent ALE system designs have achieved better than 0.015% peak to peak ripple with LC filtering. Please contact the factory for further guidance and support.

Calculating Load Ripple

Load ripple is a key requirement for many high power DC circuits. For example voltage ripple across certain RF tubes results in output frequency ripple which can degrade system performance. It is relatively simple to approximate voltage ripple as long as a few circuit parameters are known. Consider the simple capacitive filter illustrated opposite.



Although the exact load waveform is quite complex, it can be approximated by the solid line shown in the sketch below.



In this case it is simple to determine the voltage ripple by considering the discharge rate of the capacitor. If the dc current drain on the capacitor is assumed to be constant (I_{load}), then the voltage loss can be determined using equation 1;

$$I_{load} = \frac{\Delta Q}{T} = C\frac{\Delta V}{T} \quad \text{equation 1}$$

Solving for ΔV gives equation 2.

$$\Delta V = \frac{I_{load} \times T}{C} = \frac{I_{load}}{2 \times f \times C} \quad \text{equation 2}$$

Where

- f - switching frequency of the power supply in Hz
- I_{load} - load current in Amps
- C - load capacitance in Farads

Equation 2 can be re-arranged to give the required capacitance for a defined load ripple.

$$C = \frac{I_{load}}{2 \times f \times \Delta V} \quad \text{equation 3}$$

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Example:
A 1kV rated model LC1202-DC supply is operated with a 12A load and is required to give 10V peak to peak ripple, what filter capacitance is required? (Note: the switching frequency of the LC1202 is approximately 40kHz)

Solution:
Use equation 3 to determine the capacitance required.

$$C = \frac{12}{2 \times 40 \times 10^3 \times 10} = 15\mu F$$

Example:
A 30kV model 303-DC supply is operated with a 1.5A load and a 50nF external filter capacitance. What would be the peak-to-peak load voltage ripple? (Note: the switching frequency of the 303 is approximately 30kHz)

Solution:
Use equation 2 to determine the load ripple.

$$\Delta V = \frac{1.5}{2 \times 30 \times 10^3 \times 50 \times 10^{-9}} = 500V$$

Some suggested filter capacitor manufacturers are listed at the end of this application note.

Application Examples
Capacitor charging power supplies work very well in broad range of continuous DC applications simply with the addition of an external filter capacitor for acceptable ripple. Some examples of successful loads include;

- Microwave Tubes
  - Inductive Output Tube (IOT)
  - Klystron amplifier
  - Magnetron
  - Gyrotron
  - Travelling Wave Tube (TWT)
- X-ray tube burn-in
- DC bus generation
- Precipitators
- Grid bias
- Tetrode Screen power
- Plasma Generation
- General research
- High power RF amplifiers
- Inverter test
- Radar

DC versions of our capacitor charging power supplies provide power for the Space Shuttle Tracking Radar, Proton beam therapy accelerators, Naval radar systems, precision thermal instruments, and directed energy weapons.

Compared with conventional switchmode and linear DC power supplies, an end user will often find that TDK-Lambda's ALE series high voltage DC rated products present significantly smaller and lower cost alternatives.

DC Power Ratings
The DC power ratings and typical switching frequencies for ALE DC supplies are shown in the following table. This data can be used to determine appropriate filter capacitors using equations 2 and 3.

Model	DC Power Rating	Switching Frequency
500A	500W	40kHz
102A	1,000W	40kHz
152A	1,500W	40kHz
202A	2,000W	40kHz
402	4,000W	30kHz
XR802	6,000W	40kHz
802	8,000W	30kHz
LC1202	15,000W	40kHz
203	30,000W	30kHz
303	50,000W	30kHz

High Power Parallel Systems
For applications requiring in excess of 50kW average power, it is possible to operate multiple supplies in a parallel DC system. Care must be taken to ensure effective load sharing between units, and the best way to achieve this is to use a system controller. TDK-Lambda's ALE team have a great deal of experience with extremely high power DC systems based primarily around our 303 series supplies using a central system controller. These systems employ sophisticated control topologies which deliver excellent ripple, regulation, stability, combined with low stored energy.

Some example system parameters are highlighted below;

- Average power to 1MW
- Ripple better than 0.015% p-p
- Output stored energy less than 10J
- Stability better than 10ppm/°C
- Regulation better than 0.0001%
- Efficiency of 90%
- Arc response faster than 50μs

Learn more online at:
http://www.us.tdk-lambda.com/hp/product_html/HV_systems.htm

High Voltage Filter Capacitor manufacturers
NWL
Snow Hill, NC - T: 252-747-5943 x2425, BKropiew@nwl.com
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If you have any questions or comments regarding this or any of our Application Notes or products, please contact Andy Tydeman at the factory, we are here to help.

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