WHAT IS REGULATION AND REPEATABILITY?

# APP Note 509

## Regulation and Repeatability

The terms regulation and repeatability are often used to describe the same phenomena in capacitor charging power supplies. They should not be confused with similar terms for continuous DC power supplies where they have a different definition.

Repeatability is a measure of a power supply's ability to charge a load capacitor to the same voltage from one charge cycle to the next. It is also termed pulse to pulse repeatability or regulation. Repeatability is expressed as a percentage variation relative to the rated output voltage of the power supply. Figure 1 below illustrates a typical repetitive charge cycle.

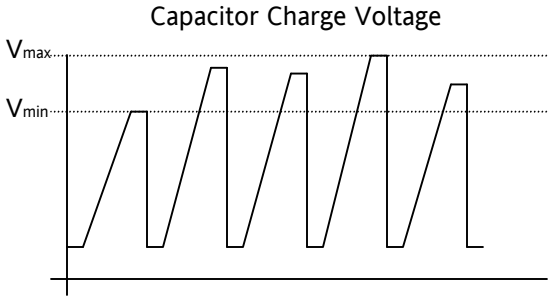


Figure 1. Typical Repetitive Charging Waveform

The figure shows that the charge voltage reached from one pulse to the next has slight variations (the variations are exaggerated for illustrative purposes). Repeatability is calculated from maximum delta of the charge voltage variation over a period of time ($V_{max}$-$V_{min}$) divided by the rated voltage of the unit.

## Why do I get charge voltage variations?

When a capacitor charging power supply is used to charge a capacitor it acts as a constant current source until the programmed output voltage is reached, then the supply shifts into voltage regulation mode. The current output from the supply is formed by multiple consecutive charge 'buckets' that are continuously delivered to the load until regulation mode is reached. The size of the charge buckets is determined by the output current capability of the power supply, and the switching frequency. The power supply can only deliver whole charge buckets, and the size of this charge bucket determines the regulation limit of the supply. Figure 2 shows the approximate form of a charge bucket.

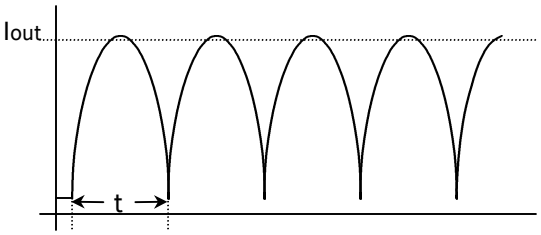


Figure 2. Approximate output current for a capacitor charging power supply

## Output Current Waveform

Figure 2 shows a typical output current waveform for a capacitor charging supply. The time t (on figure 2) is half of the inverter switching period or the inverse of 2 times the switching frequency. The charge in a single charge bucket can be approximated from the product of t and $I_{out}$. Every charge bucket delivered to the load raises the potential on the load capacitor by a small voltage dV given by equation 1;

$$dV = \frac{I_{out} \times t}{C_{load}} \quad \text{..... equation 1}$$

This voltage dV is the smallest change in output voltage for a given supply and load so this is the absolute best case repeatability possible for a given supply and load configuration.

## Example.

A 10kV rated model 802 power supply is used to charge a 900nF load capacitor. What would be the minimum pulse to pulse repeatability?
Iout for a 10kV rated model 802 is 1.8A. The inverter switching frequency is 40kHz so t=12.5µs.

$$dV = \frac{1.8 \times 12.5 \times 10^{-6}}{900 \times 10^{-9}} = 25V$$

$$\text{Regulation \%} = \frac{dV}{V_{rated}} = \frac{25}{10000} = 0.25\%$$

## Simple approximation method

A first order approximation of the % repeatability can be calculated from equation 2, which is derived from the equation 1 above.

$$\text{Repeatability \%} = \frac{1}{2 \times \text{switching frequency} \times t_c} \quad \text{. . . equation 2}$$

Where $t_c$ is the charge time for the load
switching frequency = 40kHz (typical)

## High performance applications

In most capacitor charging application repeatability of 1% is typical, however in certain applications such as Excimer lasers, the repeatability requirements can be extreme (0.1%) and are made more challenging with small load capacitors and high repetition rates. ALE has a range of power supplies that employ both frequency and phase shifting techniques to achieve repeatability as low as 0.1% at repetition rates to 2kHz. Details on these techniques can be found in reference 1. If you have an application that requires very low pulse to pulse repeatability (<0.2%) at high repetition rates (above 100Hz) then please contact the factory to discuss your exact requirements in more detail.

Reference 1. Capacitor Charging Power Supply Design For High Pulse To Pulse Repeatability Applications. G. L. Bees and A. Tydeman. IEEE Pulsed Power Conference 1999.



 

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