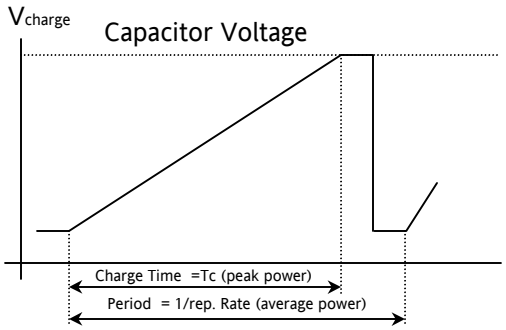
APP Note 500

Using Power Ratings

A capacitor charging power supply has two power ratings expressed in Joules per second (J/s), the peak power and the average power. The peak power rating is used when calculating the charge time, and the average power is used to determine maximum repetition rates or charge voltages. The sketch below illustrates a typical capacitor charge/discharge cycle.



Calculating Charge Time (Tc)

Using the peak power rating of the power supply, charge time Tc can be calculated using equation 1 below.

$$T_c = \frac{0.5 \times C_{load} \times V_{charge} \times V_{rated}}{P_{peak}} \quad \text{..... equation 1}$$

Where;
T_c is the load charge time in seconds
P_{peak} is the unit peak power rating
C_{load} is the load capacitance in Farads
V_{charge} is the load charge voltage in volts
V_{rated} is the power supply rating in volts

In many applications the load charge voltage (V_{charge}) and the power supply rated voltage (V_{rated}) will be the same, but it is important to use equation 1 if the load is charged to a voltage less than the power supply rating, otherwise an incorrect charge time will be calculated.

Example:
A 1µF load capacitor is charged to 15kV using a 20kV rated model 802 power supply. Using equation 1, and the peak power rating of 9000J/sec for the 802;

$$T_c = \frac{0.5 \times 1 \times 10^{-6} \times 15000 \times 20000}{9000} = 16.7\text{ms}$$

Calculating Peak Power Rating (P_{peak})

If the required charge time and load capacitance is known, then equation 1 can be rearranged to determine the power supply peak rating required. See equation 2 below.

$$P_{peak} = \frac{0.5 \times C_{load} \times V_{charge} \times V_{rated}}{T_c} \quad \text{..... equation 2}$$

Example:
A 5µF load capacitor requires charging to 5kV in 30ms. Using equation 2, the peak power required can be determined.for a 5kV rated power supply

$$P_{peak} = \frac{0.5 \times 5 \times 10^{-6} \times 5000 \times 5000}{30 \times 10^{-3}} = 2083\text{ J/sec}$$

The closest peak power rating available is 2250J/sec for the model 202A, so this would be the best choice. Note that if Vrated and Vcharge are not the same the appropriate values must be used to calculate the correct rating.

Calculating Average Power rating (P_{av})

If the repetition rate, charge voltage, and load capacitance is known then it is possible to calculate the average power rating using equation 3 below.

$$P_{av} = 0.5 \times C_{load} \times V_{charge} \times V_{rated} \times \text{Rep rate} \quad \text{..... equation 3}$$

Where;
Rep rate is the number of charge cycles per second in Hz

Example:
A 20nF load capacitor requires repetitive charging to 40kV at a repetition rate of 200Hz.

$$P_{average} = 0.5 \times 20 \times 10^{-9} \times 40000 \times 40000 \times 200 = 3200\text{J/sec}$$

The closest average power rating available is 4000J/sec for the model 402, so this would be the best selection.

Calculating Maximum Repetition Rate *

If the charge voltage, rated voltage, average power available and load capacitance for a specific circuit is known then it is possible to calculate the maximum possible repetition rate using equation 4.

$$\text{Rep rate} = \frac{P_{av}}{0.5 \times C_{load} \times V_{charge} \times V_{rated}} \quad \text{..... equation 4}$$

Example:
A 2µF load capacitor is to be charged to 15kV using an LC1202-20kV power supply. What is the maximum possible repetition rate? (LC1202 average rating is 12,000 J/sec)

$$\text{Rep rate} = \frac{12000}{0.5 \times 2 \times 10^{-6} \times 15000 \times 20000} = 40\text{Hz}$$

Using Output Current

Although the output current for a capacitor charging power supply is not normally quoted, it can be useful when calculating charge times. Capacitor charging power supplies have fixed constant output current, that can be calculated from the peak power rating and output voltage rating. Equation 5 shows the relationship between peak output current, rated voltage and peak power.

$$I_{out} = \frac{2 \times P_{peak}}{V_{rated}} \quad \text{..... equation 5}$$

Where;
I_{out} is the peak output current in Amps
P_{peak} is the unit peak power rating
V_{rated} is the power supply rating in volts
Note: The output current for a capacitor charging power is two times that from a similarly rated continuous DC power supply.

*For repetition rates above 500Hz contact the factory.

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Example:
What is the peak charge current for a 10kV rated model 303 power supply. Using equation 5, and the peak power rating of 37500J/sec for the 303;

$$I_{out} = \frac{2 \times 37500}{10000} = 7.5 \text{ Amps}$$

Calculating Charge Time Using Current

Given that the output current has been determined using equation 5, and as long as the required charge voltage and load capacitance is known then it is possible to calculate charge time using equation 6 (the charge balance formula).

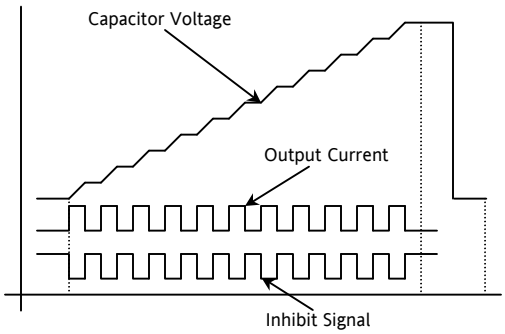
$$T_c = \frac{C_{load} \times V_{charge}}{I_{out}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{ equation 6}$$

Example:
What is the charge time with a 7.5A rated power supply, charging a 20µF load to 15kV.

$$T_c = \frac{20 \times 10^{-6} \times 15000}{7.5} = 40\text{ms}$$

Calculating Charge For Large Load Capacitors

Lambda EMIs ALE range of capacitor charging supplies are designed primarily for short charge time repetitive load applications. When used to continuously charge a large capacitive load over a long period of time, a load fault condition will occur. The power supply load fault circuitry determines whether the load voltage has reached the programmed voltage within a preset time (typically 1.5 seconds). To avoid this condition and achieve a repeatable and predictable charge time it is recommended that an external inhibit signal is used to limit the average power. The inhibit signal can be a 50% duty cycle square wave with a frequency ideally between 20 and 100Hz, that is applied to the inhibit input of the remote control interface. This will limit the average output power and prevent damage to the supply when used to charge a large load capacitor. Typical output voltage and current waveforms are shown in the following sketch.



The sketch shown exaggerates the voltage steps to illustrate power supply operation. When operating with a reasonably high frequency inhibit signal and long charge times, the charge voltage ramp will appear linear.

Equation 6 can be used to determine load charge time in this mode of operation however the peak output current calculated for the specific supply used should be divided by 2 to give the correct charge time.

Summary

This APP Note presents a number of different equations useful in capacitor charging applications. Below is a brief summary of the equations shown and how they are best used and applied.

What is the best equation to use?

Want to know: load capacitor charge time.
Already know: load capacitance, the charge voltage, the power supply rated voltage, power supply peak power rating.
Equation to use: 1

Want to know: supply peak power required for my application.
Already know: load capacitance, the charge voltage, the power supply rated voltage, desired charge time.
Equation to use: 2

Want to know: supply average power required for my application.
Already know: load capacitance, the charge voltage, the power supply rated voltage, and the repetition rate.
Equation to use: 3

Want to know: maximum repetition rate possible in my application*.
Already know: load capacitance, the charge voltage, the power supply rated voltage, and the supply average power rating.
Equation to use: 4

Want to know: peak charge current for a given supply.
Already know: the power supply rated voltage and peak power rating.
Equation to use: 5

Want to know: load capacitor charge time.
Already know: the load capacitor charge voltage, the load capacitance, peak charging current.
Equation to use: 6

Want to know: load capacitor charge time for a large load.
Already know: the load capacitor charge voltage, the load capacitance, peak charging current.
Equation to use: 6 but half the peak charge current used

If you are unsure about any of the data presented in this APP Note then do not hesitate to contact the factory or your local representative.

*For repetition rates above 500Hz contact the factory.

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