

***USING THE ULTIMOD TO CHARGE
CAPACITORS FOR LASER DRIVING
APPLICATIONS***

REPORT

Version *1.0*

02/06/2017

VERSION HISTORY

Version #	Implemented By	Revision Date	Approved By	Approval Date	Reason
1.0	<i>Tommy O'Brien</i>	<i>02/06/2017</i>			<i>First Draft</i>

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1 INTRODUCTION

1.1 PURPOSE

This document describes the elements required to use the Ultimod power supply to charge capacitors in Laser Driving Applications.

2 REQUIREMENT OVERVIEW

2.1 DRIVING LASER APPLICATIONS

A laser is an example of coherent light source, that is a source of light of a single wavelength (which means of a single colour), and whose waveforms are all in step or in phase. This coherent light can be focused in a very small area and at a very high intensity and can therefore be used as a means of energy transfer. At a high enough intensity this laser light can be used to cut or weld materials with an intense heat.

This ability to superheat, cut or weld / cauterize tissue means that lasers can be used in a wide range of medical and cosmetic applications. They can also be used to target the melanin in hair follicles to destroy the follicle, removing the hair.

Many of these applications use pulsed laser devices that produce pulses of high intensity light with a very short pulse width and low duty cycle. Pulsing the laser is desirable as it obtains the optimal effect on a targeted tissue while minimizing the effect on surrounding tissue. This means that the power requirement to drive this laser has a similar pulsed profile.

A pulsed power requirement (pulsed high peak power with a very low duty cycle) can be difficult to supply efficiently. If the power supply is sized for the peak power there is a lot of wasted power capacity when the load is not drawing power. If the power requirement can be “smoothed” or averaged out, a power supply with a lower peak rating can be used which would be more compact and more cost effective. This can be achieved with a capacitor bank that delivers energy during the pulse while storing energy during the idle time.

However, charging a capacitor bank also presents a number of challenges for a power supply.

2.2 CHARGING CAPACITOR BANKS

A capacitor is a passive device that stores energy in its electric field. It is made up of two conducting plates separated by an insulating material or dielectric. During the charging process, electrons flow from the negative terminal of the power supply to one plate of the capacitor and from the other plate to the positive terminal of the power supply.

The formula for the current charging a capacitor is given by the formula:

$$I = \frac{V}{R} e^{-\frac{t}{RC}}$$

If charging with a constant voltage, the instant the voltage is applied to the capacitor t is zero and the exponential term resolves to 1. Now all that is limiting current flow into the capacitor is R (the capacitors ESR). For large capacitors the ESR is quite low ($<1\Omega$), so the initial inrush current is very high. As the capacitor charges up, the charging current decreases. The initial inrush current can overload and damage a power supply if precautions are not taken.

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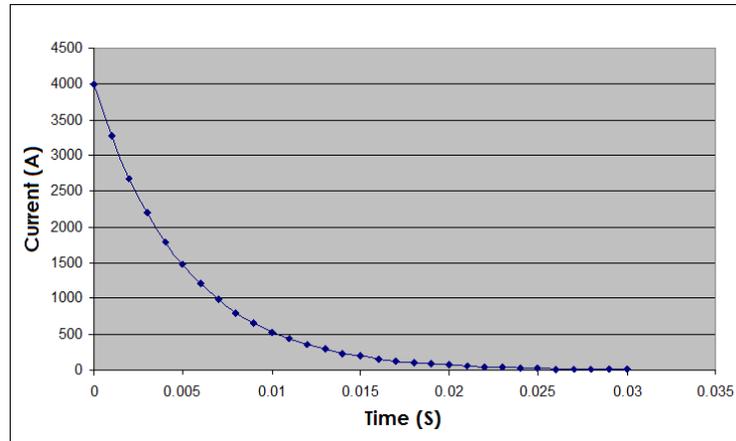


Figure 1. Typical Constant Voltage Capacitor Charge Curve

The Ultimod power supply offers a more controlled charge method. Since the Ultimod gives you access to the modules current limit via the Itrim pin, it can be configured as a constant current source by applying a voltage reference to the Itrim pin (this can also be achieved by applying a resistance between Itrim and $-V_{out}$). Charging capacitors with a constant current ensures that the power supply is not stressed. The formula for rate of change of capacitor voltage when charged with a constant current is given by the formula:

$$I = C \frac{dv}{dt}$$

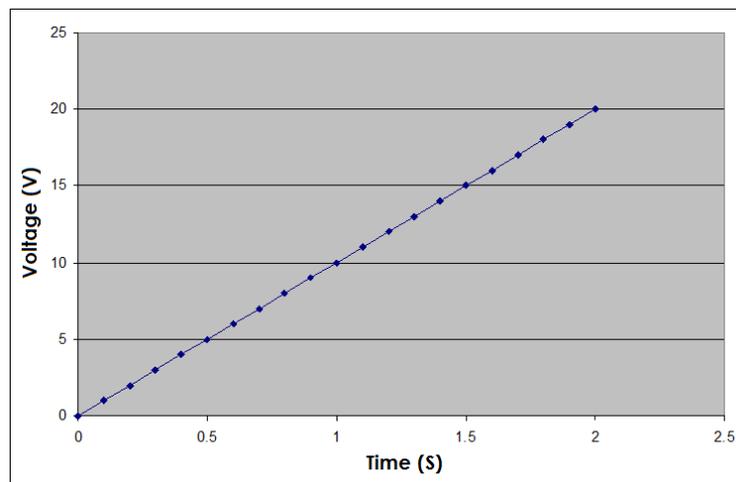


Figure 2. Typical Constant Current Capacitor Charge Curve

Like many power supplies the Ultimod modules also incorporate short circuit protection (SCP) that causes a hiccup when a short circuit is detected in order to protect itself from

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excessive current. As we have seen above, switching into a discharged capacitor can be very similar to switching into a short circuit!

All Ultimod modules have an overcurrent protection (OCP) circuit that limits the maximum output current of the module by controlling the duty cycle of the output buck converter. If the load is such that the voltage drop across it at this maximum OCP current is less than a set reference voltage (known as the SCP voltage) the module considers this to be a short circuit condition and will shut itself down for a set period of time (around 45 ms). The module then auto recovers and after around 10 ms once more checks that the output voltage is above the SCP voltage. If the voltage is below the SCP voltage the module shuts down for another 45 ms and the process repeats. This is known as hiccupping.

So, what does that mean for the Ultimod and capacitors? Taking the Xg4 module as an example, the Xg4 module threshold is set at 6.8 V, while the OCP current is 11 A. This means that when the Xg4 is used to charge a capacitance greater than 16 mF it will go into short circuit hiccup protection:

$$C = I \frac{dt}{dv}$$
$$C = 11 \frac{0.01}{6.8}$$
$$C = 16 \text{ mF}$$

The module will continue to hiccup until the voltage of the capacitor (being charged during the 10 ms on time of the hiccup) reaches 6.8 V.

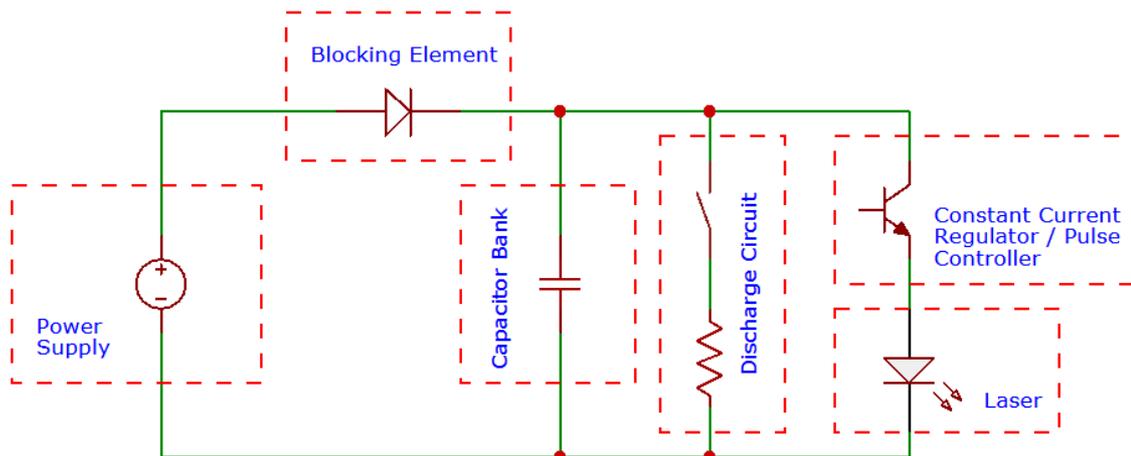
To improve this performance Excelsys have introduced Wide-trim modules (XgM-XgQ). Wide-trim modules have been designed to operate over a much wider voltage range, operating safely down to 1 V. In the majority of capacitor charging applications these modules will not hiccup at all. They are ideal for charging capacitors for laser driving applications, but they do require a number of other elements to be implemented to provide a complete solution.

3 OVERALL TOPOLOGY

3.1 HIGH LEVEL OVERVIEW

There are a number of elements required when using the Ultimod in Laser Driving / Capacitor charging applications:

- Power Supply
- Blocking Element
- Capacitor Bank
- Capacitor Discharge Circuit
- Constant Current Regulator / Pulse Controller
- Laser



3.2 ELEMENT DESCRIPTION

3.2.1 Power Supply

As discussed previously, Wide-trim modules (that operate down to 1 V out) should be used when charging large capacitances to allow for safe, extended use at the low output voltage that is required at the beginning of the capacitor charge cycle.

In addition, the output current should be limited using the Itrim pin in order to ensure that the output power does not exceed the rating of the module and to allow for a linear controlled charge. The configuration tools available at the following link can be used to calculate the required voltage signal / resistor needed to set the output current:

<https://www.excelsys.com/technical-support/power-supply-weight-calculator/>

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The output current of the Ultimod should be selected so that the energy discharged from the capacitor bank during the current pulse of the application can be replaced during the idle time. The output current of the Ultimod will also impact the initial charge time of the capacitor bank

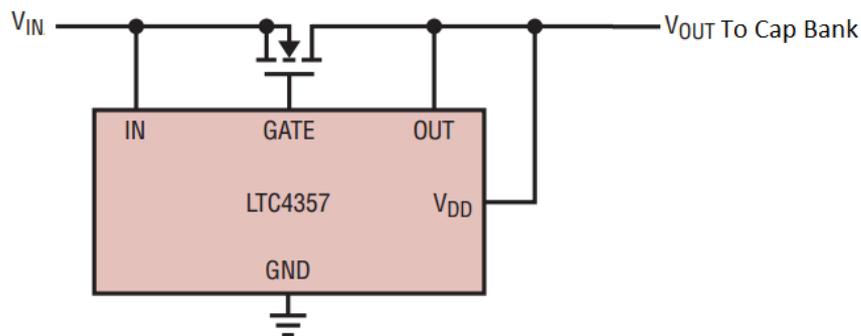
Remember that since the Ultimod is a modular power supply, the output current of the Ultimod can be increased by adding modules in parallel. Please contact Excelsys for advice on the recommended Ultimod configuration for your application.

3.2.2 Blocking Element

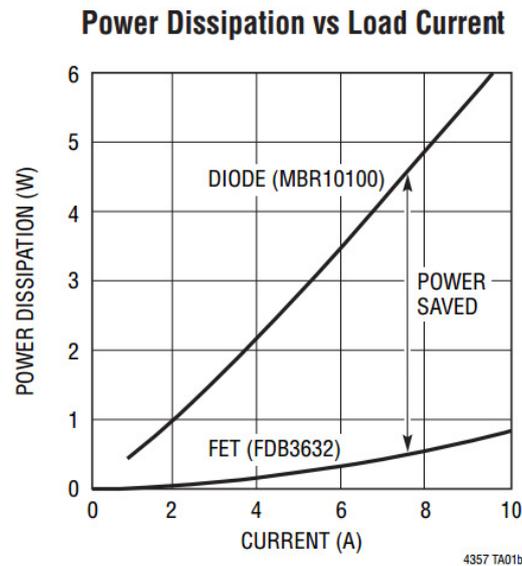
A blocking element must be placed between the power supply output and the capacitor bank to ensure that there is no back EMF during shutdown (this can cause damage to the modules). The simplest solution is to use a blocking diode, but this of course has an associated power loss during forward conduction.

A better option is to use an Oring FET solution. There are ICs specifically made to control MOSFETs to be turned on when conducting in the forward direction and off if it detects any back EMF. One such IC is Linear Technologies LTC4357:

<http://www.linear.com/product/LTC4357>



The MOSFET used should be rated for the output current of the Ultimod modules. Using an Oring FET solution greatly reduces power loss and associated thermal issues.



3.2.3 Capacitor Bank

The sizing of the capacitor bank and choice of capacitor type is very important in these applications, and there are a number of factors that determine capacitor selection.

1. What is the voltage requirement of the application – the capacitor bank voltage rating must meet this requirement
2. What is the peak drive current requirement of the application – the capacitor bank current rating must meet this requirement
3. What is the pulse length and maximum voltage dip during the pulse – the capacitor bank must be sized large enough to supply the pulse energy
4. Lifetime of the capacitor – please note that this is very temperature dependant
5. Charge / discharge cycle life of the capacitor

There are two types of capacitor that are suitable for use in these types of applications, Aluminium Electrolytic capacitors and Ultracapacitors.

Aluminium Electrolytic capacitors came in a wide range of output voltage ratings. They are the first choice in high voltage applications (> 70 V) but can also be used in lower voltage applications but it may be necessary to connect multiple capacitors in parallel to meet the energy storage requirements.

Ultracapacitors are high capacity capacitors with capacitance values much higher than Aluminium Electrolytic capacitors but have much lower voltage limits (around 3 V). This means that multiple ultracapacitors must be connected in series to reach a suitable voltage rating. This means that they may need a balancing circuit to be used to balance the voltage across each capacitor in order to maximize their lifetime (this could be a passive circuit like a resistor chain or an active circuit). Ultracapacitors typically store 10 to 100 times the energy per unit volume of Aluminum Electrolytic capacitors.

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3.2.4 Capacitor Discharge Circuit

Due to the amount of energy stored in the capacitor bank there may be a requirement (to meet the Safety Standards of the final application) to implement a discharge circuit in order to dissipate this energy during system shutdown (this circuit may be as simple as a switch and an appropriately sized resistor). The AC Fail signal of the Ultimod PowerPac may be used to switch in this circuit if required. The specification of this circuit will be heavily dependant on the discharge time allowed by the safety standard.

3.2.5 Constant Current Regulator / Pulse Controller

The last element required is the Pulse Controller. This can be as straightforward as a switch to apply the capacitor voltage to the load, but it is advisable to also control the current through the load during the pulse using a power MOSFET or transistor pass element. Controlling the current flowing through the Laser load will maximize its usable lifetime.