AOZ18101DI Soft Start and Output Capacitor Selection Guidance

By Kevin Kim

Introduction

AOZ18101DI is a current-limiting over-voltage protection eFuse targeting applications that require front end protection at the input line. Both VIN and VOUT terminals are rated at 22V absolute maximum. There is a programmable soft-start feature that controls the inrush current for highly capacitive loads. It also has Input Under-Voltage Lock Out (UVLO), Input Over-Voltage Protection (OVP), and Thermal Shut Down Protection (TSD). It features an internal current-limiting circuit that protects the supply from large load current. The current limit threshold can be set externally with a resistor.

AOZ18101DI has soft-start feature to control the in-rush current during the startup. It also has startup SOA control to protect internal MOSFETs by avoiding violation of Safe Operating Area (SOA) of the internal MOSFETs. During startup, the voltage at VOUT linearly ramps up to the VIN voltage over a period of time. This ramp time is referred to as the soft-start time and is typically in milliseconds. The soft-start time (t_{ON}) can be programmed by externally through SS pin with a capacitor C_{SS} to control in-rush current. The following formula provides the estimated 10% to 90% ramp up time.

$$t_{ON} = \frac{(C_{SS}+0.07)\times VIN}{1.067} \qquad (1)$$

where C_{SS} unit is in nF and t_{ON} unit is in ms.

During this soft-start time, there will be large voltage across the power switch. Also, there will be current, I_{SW} through the switch to charge the output capacitance at VOUT pin. In addition, there may be load current to the downstream system as well. This total current during soft-start time is calculated as:

$$I_{SW} = C_{OUT}\left(\frac{dVOUT}{dt}\right) + I_{LOAD} \qquad (2)$$

In the soft-start condition, the power MOSFET as a power switch is operating in the linear mode and power dissipation is high. The ability to handle this power dissipation is largely a function of the power MOSFET linear mode SOA and good package thermal performance $R_{\theta JC}$ (Junction-to-Case) as the soft-start ramp time is in milliseconds.

AOZ18101DI has current limit control for SOA during the soft start time. Figure 1 illustrates an example of the current limit values with VOUT percentage to VIN during the startup. Since the voltage drop between VIN and VOUT is large at the beginning of startup, the current limit value is small to limit the power consumption. As the VOUT increases during the startup, the current limit increases to make power consumption within SOA range.

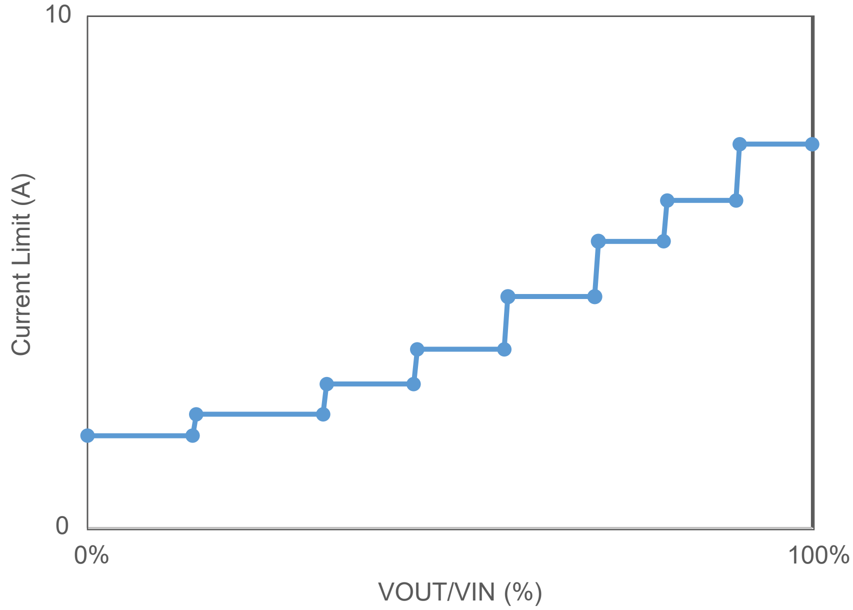


Figure 1. Current Limit vs. VOUT During Startup

The soft start capacitor needs to be selected properly based on output capacitor and load current for successful startup without violating SOA of the internal MOSFET and reaching the current limit. Please refer to following Figure 2 for proper selection of C_{SS} capacitor and C_{OUT} capacitor with various output load current conditions. It shows recommended C_{SS} and C_{OUT} area in color with the different load current values. The recommended area has upper limit and lower limit of C_{SS} values in the diagram.

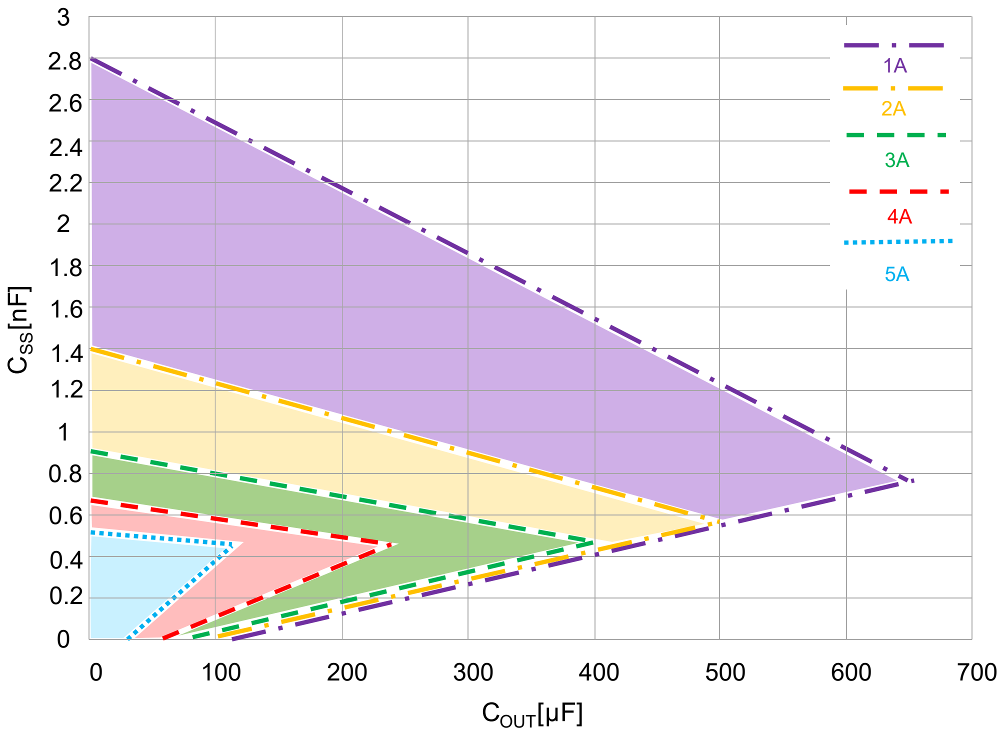
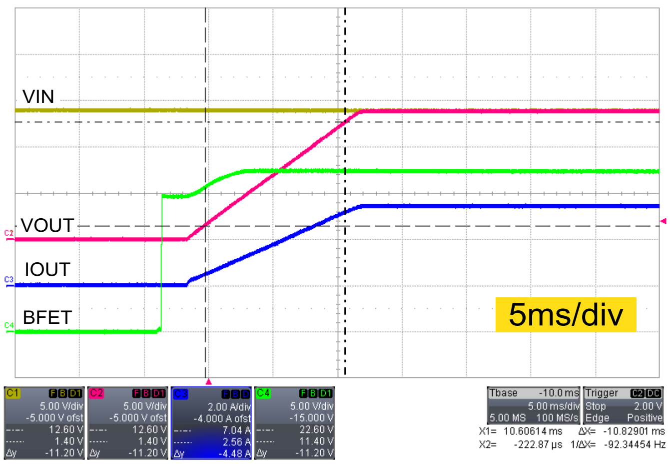


Figure 2. Recommended C_{SS} and C_{OUT} Area With Various Load Current Conditions

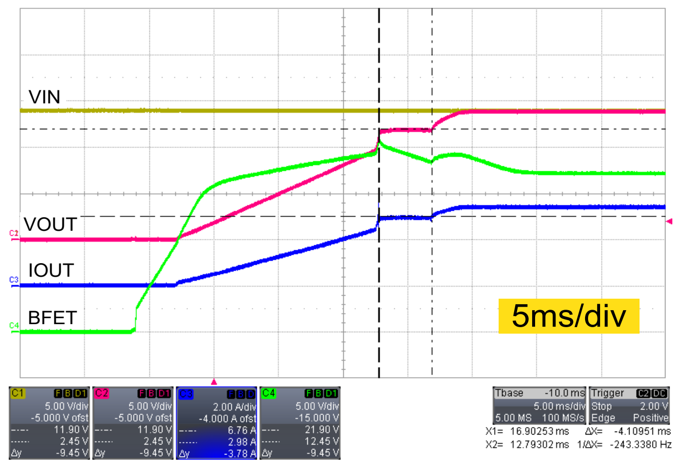
Long soft start time makes total energy during the soft start beyond the SOA and can damage the device. In order to avoid the SOA damage due to the high energy during startup, the load current, output capacitor and startup time should be limited within the recommended area shown in the Figure 2.

The upper limit of the recommended C_{SS} area is defined by SOA. The total energy during the startup beyond the SOA damages the device. The lower limit of the recommended area is defined by the current limit control of the device. If the current during the soft start is larger than current limit for 512µsec, the device is shut down to protect the internal MOSFETs from the damage. The current limit profile during soft start is illustrated in Figure 1.

Figure 3 shows startup waveforms with two different C_{SS} capacitor values with 14V input, 100µF output capacitor and 3A load. Figure 3(a) is normal startup waveform with C_{SS}=0.78nF capacitor since C_{SS} capacitor is within the recommended area as shown in Figure 3(c). Figure 3(b) is abnormal startup waveform with C_{SS}=1.5nF since C_{SS} capacitor is out of the recommended area as shown in Figure 3(c). In this case, the energy during the soft start time is large enough to damage the device. In the next startup sequence, the device is damaged. Figure 3(c) shows recommend C_{SS} and C_{OUT} area in color under load resistance of 3A condition.

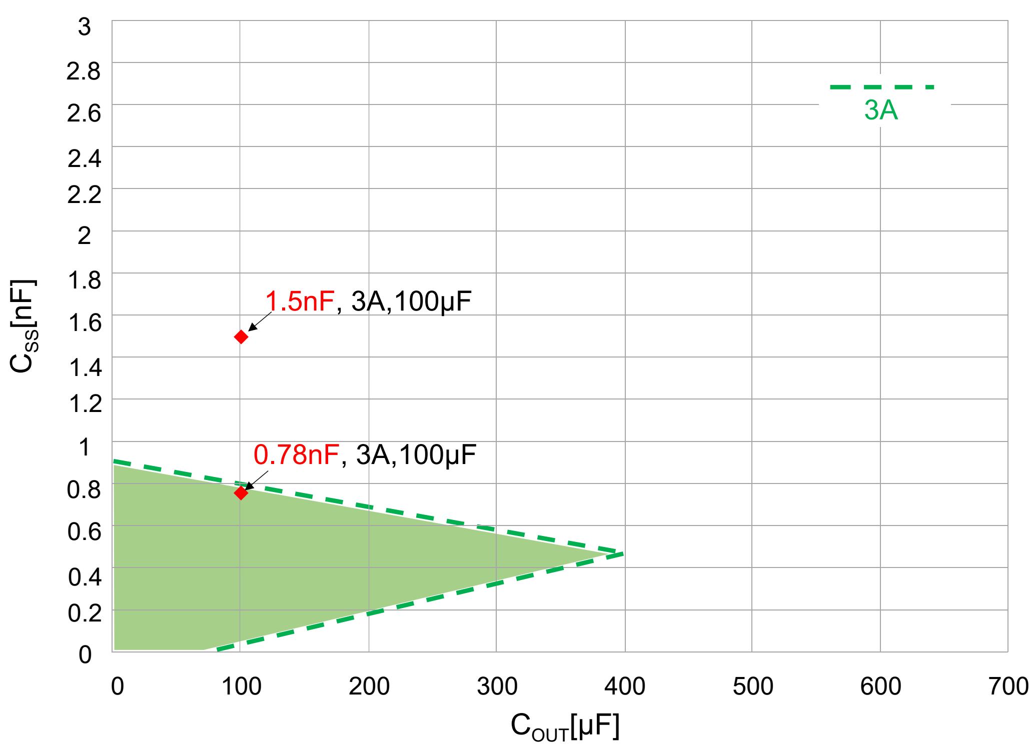


(a) C_{SS}=0.78nF



(b) C_{SS}=1.5nF

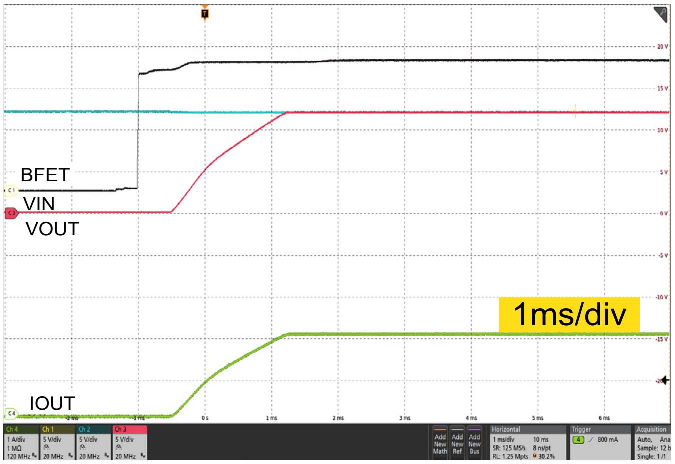
Ch1: VIN(5V/div), Ch2: VOUT(5V/div), Ch3: IOUT(1A/div), Ch4: BFET(5V/div)



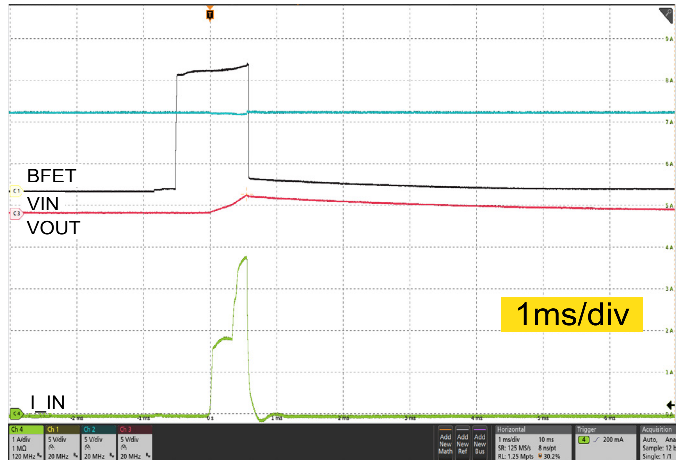
(c) 3A Load Recommend Area With Waveform (a) & (b) Conditions

Figure 3. Startup Waveform With Different C_{SS} (VIN=14V, CIN=300µF, C_{OUT}=100µF, I_Load= 3A)

Figure 4 shows startup waveforms with different output capacitor C_{OUT} values with 12V Vin, 6Ω resistor load (=2A load current) and 0.18nF C_{SS} capacitor. Figure 4(a) is normal startup waveform with C_{OUT}=100μF since C_{OUT} is within the recommended area. Figure 4(b) is unsuccessful startup waveform with C_{OUT}=680μF since C_{OUT} is out of recommended area. Since the in-rush current is large due to the large C_{OUT}, current is limited by current limit control for 512μs. The device is shut down and latched off without finishing startup. Figure 4(c) shows recommended C_{SS} and C_{OUT} area in color under load resistance of 2A condition.

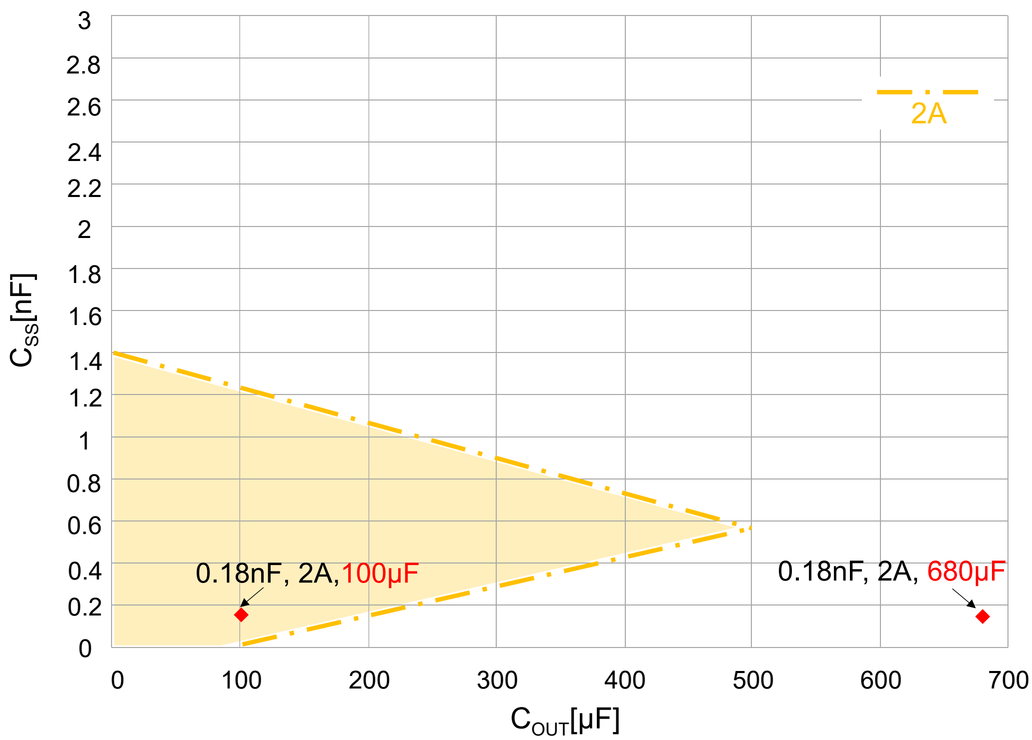


(a) C_{OUT}=100μF



(b) C_{OUT}=680μF

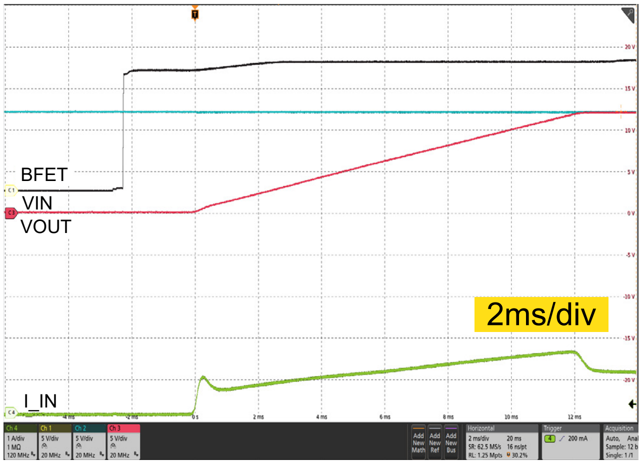
Ch1: BFET(5V/div), Ch2: VIN(5V/div), Ch3: VOUT(5V/div), Ch4: IOUT/IIN(1A/div)



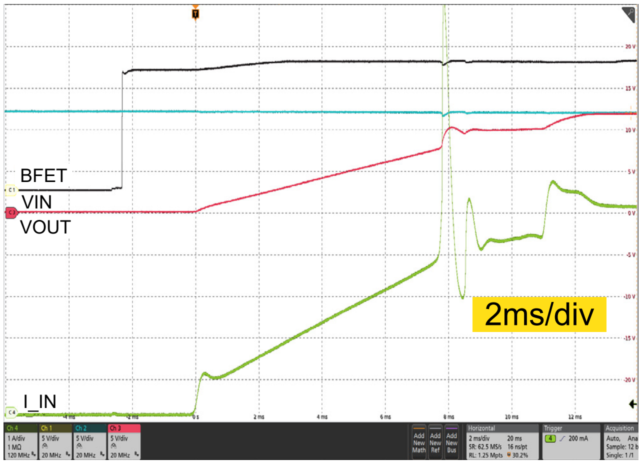
(c) 2A Load Recommended Area With Waveform (a) & (b) Conditions

Figure 4. Startup Waveform With Different C_{OUT} (VIN=12V, CIN=300μF, R_Load=6Ω, C_{SS}=0.18nF)

Figure 5 shows startup waveforms with different resistor load condition with 12V Vin, 570μF output capacitor and 1nF C_{SS} capacitor. Figure 5(a) is normal startup waveform since the condition of C_{SS} and C_{OUT} is within the recommended area of 1A load. Figure 5(b) is abnormal startup waveform since the condition of C_{SS} and C_{OUT} is out of recommended are of 5A load. In the next startup sequence, the device is damaged. Figure 5(c) shows recommended areas in colors under 1A and 5A conditions.

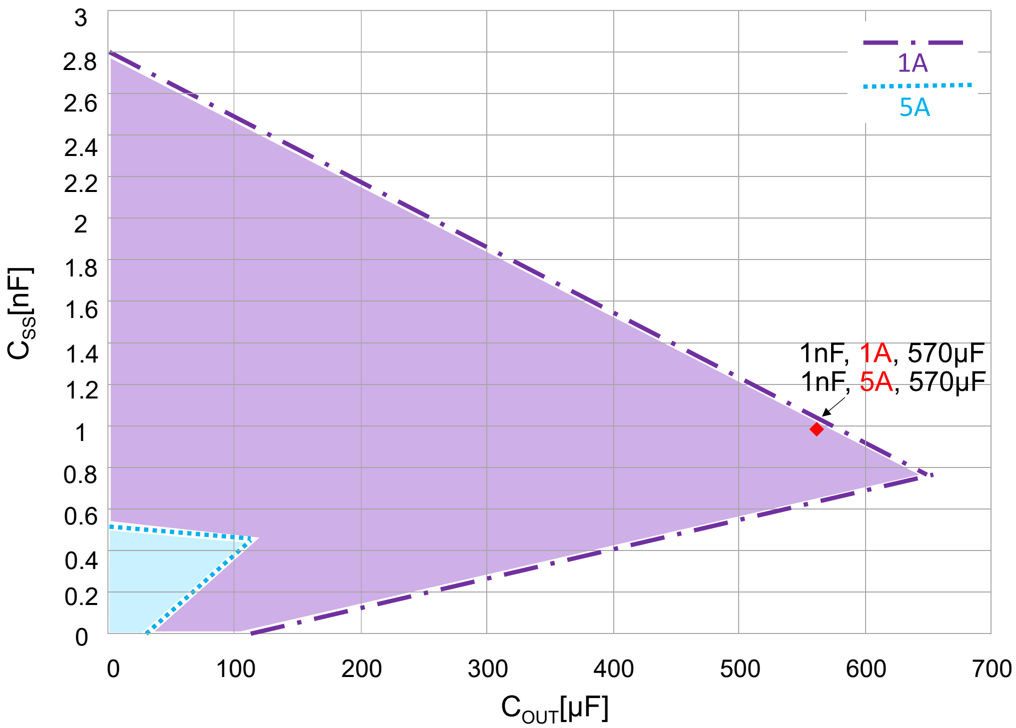


(a) R_LOAD=12Ω (I_LOAD=1A)



(b) R_LOAD=2.5Ω (I_LOAD=5A)

Ch1: VIN(5V/div), Ch2: VOUT(5V/div), Ch3: IOUT(1A/div), Ch4: BFET(5V/div)



(c) 1A & 5A Recommended Areas With Waveform (a) & (b) Conditions

Figure 5. Startup Waveform With Different Load (VIN=12V, CIN=300μF, C_{OUT}=570μF, C_{SS}=1nF)

For the evaluation of AOZ18101DI, pure resistor load is recommended instead of electronic load. Since the electronic load has controlled current sources inside to emulate the load, it may interact with current limiting circuitry of AOZ18101DI and cause an oscillation during the start up.

Example: VIN=12V, C_{OUT}=100μF, Load current = 3A

Since the load current 3A, user can find out recommended soft-start capacitor values on 100μF C_{OUT} in the Figure 2. The recommended C_{SS} is 0.05nF to 0.8nF. By applying these C_{SS} values into equation (1), user can calculate the soft-start time, Ton from 1.35ms to 9.78ms.

In summary, there are three major parameters to determine the SOA area. Each parameter's impact to the SOA area was tested and provided as examples. A guidance of AOZ18101DI SOA area is shown in Figure 2. A design tool is available to provide SOA guidance as well.

LEGAL DISCLAIMER

Applications or uses as critical components in life support devices or systems are not authorized. Alpha and Omega Semiconductor does not assume any liability arising out of such applications or uses of its products. AOS reserves the right to make changes to product specifications without notice. It is the responsibility of the customer to evaluate suitability of the product for their intended application. Customer shall comply with applicable legal requirements, including all applicable export control rules, regulations and limitations.

AOS' products are provided subject to AOS' terms and conditions of sale which are set forth at:
http://www.aosmd.com/terms_and_conditions_of_sale

LIFE SUPPORT POLICY

ALPHA AND OMEGA SEMICONDUCTOR PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.

2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.