The Advantage of Tantalum Capacitors in Detonation Systems

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For modern detonation systems, molded tantalum (MnO_2) capacitors offer two key advantages. First, unlike aluminum electrolytic capacitors, they provide high capacitance in a small form factor (CV) as required by these compact systems. Second, unlike multilayer ceramic chip (MLCC) capacitors, tantalum devices offer very stable performance under applied voltage, temperature, and mechanical stress. Vishay offers a complete portfolio of molded solid tantalum chip capacitors with capacitance from 0.1 µF to 1 mF and voltages from 2 V to 75 V in a wide range of case sizes.

INTRODUCTION

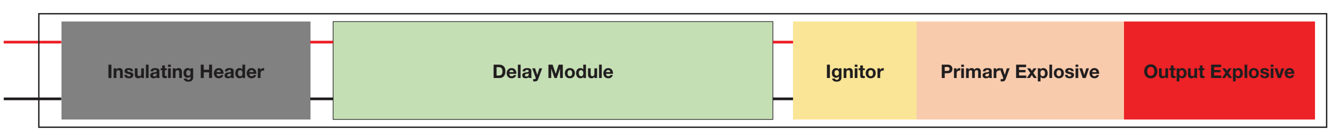
Detonation systems are critical components for mining, demolition, and quarrying. For decades, traditional blast tubes have been the go-to solution. Although reliable and relatively inexpensive, these systems have distinct disadvantages, including long set-up times, and they could pose a safety risk for users and manufacturers alike if improperly deployed. With new technological advancements, electronic mining detonation systems have been developed that will drastically reduce set-up times and improve safety. Under development are the next generation of detonation systems that will be fitted with the same wireless technology that allows submarines to communicate hundreds of meters below the ocean. These next-generation systems remove the constraints of having a physical connection and can reliably deliver initiation signals wirelessly through rock, water, and air.

As with any electronic device, an internal power source is needed to power the system controller (MCU) and charge an ignition capacitor. To ensure a properly timed, reliable detonation, a capacitor is used as an energy storage device for the initiation element. Due to their ability to hold a charge (low DC leakage) and their high energy density relative to other capacitive technologies, molded tantalum (MnO_2) capacitors are the best choice for electronic detonation systems, providing more time and releasing more voltage to ensure proper ignition. For companies that develop and manufacture electronic detonation systems for mining applications, this paper will outline why tantalum capacitors are the best technology to use.

DETONATOR DESIGN

A modern electronic detonator consists of a delay module to produce an accurate and consistent detonation for a variety of explosive applications. As the level of controllability increases, so does the level of safety by triggering at the optimal time.

A simplified wired electronic detonator structure is shown below.



The structure of an electronic detonator consists of an insulating header to protect against external or transient voltages that could accidentally ignite the primary explosive; a delay module that provides the ignition signal from the main controller; and a detonation system formed by an ignitor, primary explosive, and output explosive.

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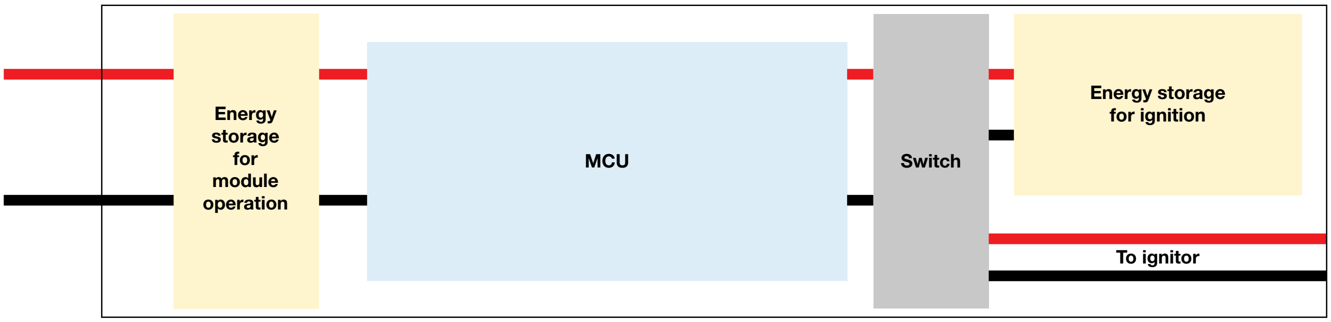
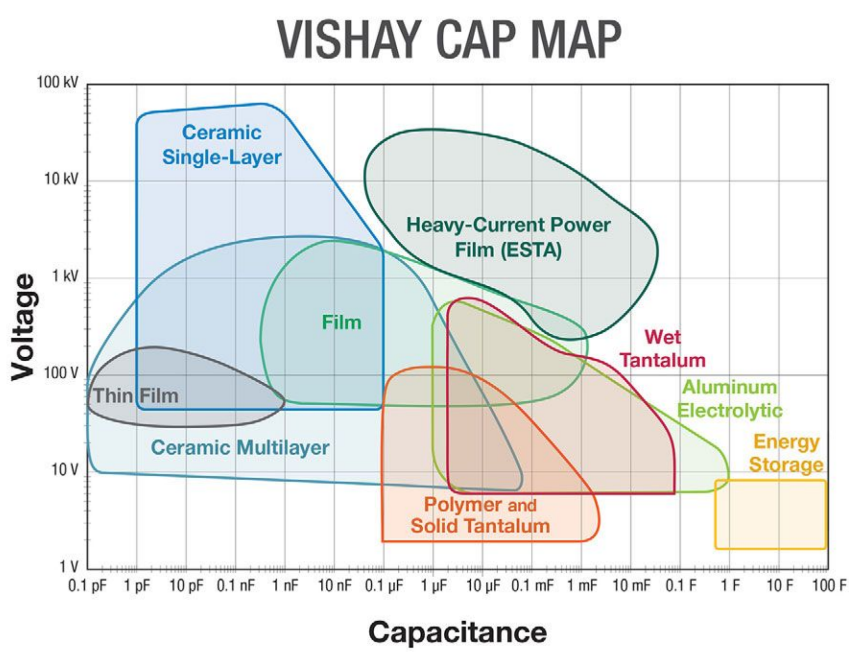
Inside the delay module, an MCU directs a signal to each capacitor to trigger the ignition.



Depending on the design, one or two energy storage capacitors provide ignition. Thus, the capacitor plays an important role. However, with a variety of capacitive technologies available, which is the best for electronic detonators?

CAPACITOR SELECTION

Since it would be impractical to use a bulky DC/DC converter to convert a high voltage (28 V or higher) to a low voltage (3.3 V to 5 V) for the MCU's operation, a capacitor is the ideal option. Due to size, cost, and / or stability concerns, technologies such as aluminum, thin film, heavy current power film, and wet tantalum are not the best options. Therefore, only two capacitor technologies are most suitable: solid tantalum or multilayer ceramic chip (MLCC) capacitors. Refer to Vishay's Capacitance Map to compare the voltage to capacitance range for each technology.



Although MLCCs offer a variety of capacitance values and a small form factor, their capacitance to voltage (CV) volumetric efficiency is not sufficient to support a typical detonator application.

In addition to high CV, a tantalum capacitor's capacitance value remains stable across the entire operation voltage and temperature range, which means the DC voltage output remains consistent. Tantalum also offers robust mechanical shock performance.

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Lastly, low DC leakage (DCL) is another characteristic that makes tantalum the most suitable option. By comparison, in a 12 V application, an MLCC's leakage could be almost double that of an equivalent tantalum capacitor, depending on the material and capacitance.

Taking a 25 V, 22 μF capacitor as an example - the largest CV an MLCC can achieve - and with Ohm's Law, DCL(I) = V / IR (R).

The MLCC will perform as outlined below.

The insulation resistance (R) of the MLCC: 50 Ω*F ÷ (22 x 10^{-6} F) = 2.27 MΩ

DCL(I) = V / IR (R) = 12 V ÷ 2.27 MΩ = ~ 5.2 μA

For a low leakage tantalum capacitor:

DCL(I) = 0.005CV = 0.005 x 12 V x (22 x 10^{-6} F) = 1.3 μA

These calculations are based on the commercial material properties and an insulation resistance of 50 Ω*F to 1000 Ω*F.

CONCLUSION

Although there are many factors to consider when selecting a capacitor for an application, when it comes to electronic detonators Vishay tantalum capacitors offer the best performance compared to other capacitor technologies.