



Cable and Wire Selection for Pulsed Power Applications

Executive Summary

Pulsed power systems, including directed energy weapons, high-power radar, and electromagnetic launchers, demand precise electrical and mechanical performance from their cabling infrastructure. Selecting the appropriate wire and cable for these applications is critical to achieving reliable energy delivery, minimizing losses, and preventing catastrophic failure in high-voltage, high-current, and high-speed pulsed environments. This white paper explores the pivotal considerations in selecting wire and cable for pulsed power applications, including conductor construction, insulation materials, thermal performance, shielding strategies, termination practices, and understanding **dielectric stress, heating effects, and failure mechanisms**. It also examines compliance with relevant standards such as MIL-STD-810, MIL-STD-461, MIL-PRF-85045, and AS9100, offering guidance to procurement and engineering teams seeking dependable, mission-critical solutions.

Introduction

Pulsed power applications require short bursts of high energy delivered over very short durations. The extreme electrical and mechanical stresses in these systems impose unique challenges on cable and wire design. Factors such as **dielectric stress, transient over voltages, Joule heating, skin effect, and surge currents** must be carefully considered. Unlike continuous power systems, pulsed power wiring must withstand repeated high-energy cycles without degradation. Mismanaged dielectric stress or inadequate thermal handling can result in insulation breakdown, arcing, or catastrophic connector failure, compromising both system performance and safety.

High-reliability environments, such as military and aerospace platforms, necessitate rigorous adherence to AS9100 quality management principles and Mil-Spec standards. This guarantees that cables meet performance specifications, maintain traceability, and survive extreme environmental conditions including vibration, thermal cycling, and electromagnetic interference.



Technical Considerations

Conductor Construction

- **Solid vs Stranded:** Stranded conductors are preferred in high-current pulsed applications for flexibility and improved skin effect performance at high frequencies. Solid conductors offer lower resistance but are more prone to mechanical fatigue under repeated flexing.
- **Material Selection:** Copper remains the industry standard due to its high conductivity, but silver-plated copper or copper-clad aluminum can be used where skin effect mitigation or weight reduction is critical.

Insulation Materials

- **Dielectric Strength and Stress:** Pulsed power systems may operate at voltages exceeding tens of kilovolts, producing significant **dielectric stress** on insulation materials. Insulation must withstand both instantaneous voltage peaks and repetitive stress cycles without degradation.
- **Thermal and Heating Effects:** Short-duration high-current pulses generate localized **Joule heating**, which can accumulate over repeated cycles, leading to thermal stress. Materials must maintain integrity under these spikes to prevent melting, carbon tracking, or partial discharge.
- **Failure Mechanisms:** High-energy pulsed environments can lead to insulation breakdown, corona formation, and micro-arcing. Selecting materials with high dielectric strength, thermal stability, and resistance to partial discharge is essential for long-term reliability.
- **Material Recommendations:** Crosslinked polyethylene (XLPE), polyimide, and high-performance fluoropolymers (FEP/ETFE) are suitable for managing both dielectric and thermal stresses while resisting radiation or chemical degradation.

Shielding and EMI Management

- **Electromagnetic Shielding:** High-current pulses can induce EMI affecting nearby electronics. Braided, foil, or hybrid shielding may be required depending on system sensitivity.
- **Grounding and Termination:** Proper grounding of shields and use of 360-degree terminations prevent voltage surges, minimize dielectric stress, and maintain signal integrity.



Mechanical Considerations

- **Flex Life:** Repeated high-current pulses generate mechanical stresses; stranded conductors with high strand counts increase durability.
- **Abrasion and Environmental Resistance:** Sleeving, jacketing, and conduit protect cables from mechanical wear, chemical exposure, and UV degradation, essential for long-term mission reliability.
- **Bend Radius:** Maintaining proper bend radius reduces stress on insulation and conductor interfaces, preserving integrity under dynamic deployment conditions.

Connector and Termination Practices

- **High-Current Contacts:** Pulsed power connectors must handle extreme transient currents without localized heating or arcing, which can increase dielectric stress at termination points.
- **Backshell Integration:** Strain relief via backshells or molded terminations reduces mechanical fatigue and helps prevent insulation failure under repeated high-energy cycles.

Testing and Quality Assurance

- **HI-POT Testing:** Assures dielectric withstand under high-voltage stress.
- **Pull Testing:** Confirms mechanical integrity of terminations under load.
- **Spark Testing:** Detects micro-defects in insulation prior to assembly, identifying potential **failure mechanisms** early.
- **Traceability:** Compliance with AS9100 and MIL-PRF-85045 promotes documentation of material sources, test results, and production lineage.

Recommended Selection Guidelines

Parameter	Recommendation for Pulsed Power Systems
Conductor	Stranded copper or silver-plated copper for high-current pulses
Insulation	XLPE, polyimide, FEP, ETFE – high dielectric & thermal stability



Parameter	Recommendation for Pulsed Power Systems
Jacket/Sleeving	Abrasion-resistant fluoropolymers, aramids, or hybrid composites
Shielding	Braided or foil shields; 360-degree terminations for EMI suppression
Connector/Termination	High-current, high-voltage rated; backshells for strain relief
Testing	HI-POT, pull test, spark test; full AS9100 traceability

Conclusion

Selecting the right wire and cable for pulsed power applications requires a meticulous balance of electrical, mechanical, and environmental considerations. Managing **dielectric stress, heating effects,** and potential **failure mechanisms** is critical to maintaining insulation integrity, connector reliability, and overall system safety. Conductor construction, insulation material, shielding, flex life, and termination practices must all be optimized to withstand extreme transient currents, high voltages, and mechanical stresses. Adherence to MIL-STD and AS9100 standards establishes reliable performance, safety, and traceability across mission-critical platforms. By applying the selection guidelines outlined in this paper, engineering and procurement teams can confidently implement cabling solutions that meet the rigorous demands of modern pulsed power systems, maintaining both system longevity and operational success.