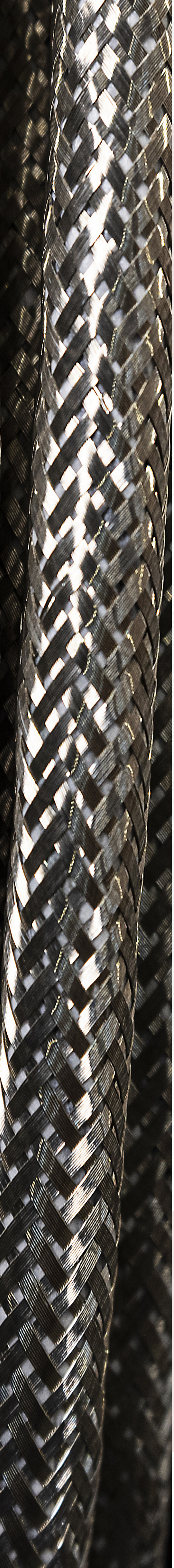
MOTIONEMC IEC 61800-3

OPTIMIZING SHIELDING EFFECTIVENESS FOR MAXIMUM OPERATIONAL REACH IN INDUSTRY-STANDARD PROTOCOLS.



MOTION**CABLES**: LEADING THE WAY IN **SPECIAL CABLE SOLUTIONS**

MOTION**CABLES** specializes in the design, manufacturing, and qualification of high-performance special cables, particularly focusing on applications requiring constant movement, extreme environmental resistance, and maximum data integrity.

Our mission goes beyond mere compliance; we provide products validated to operate reliably under the most severe real-world conditions, including combined and extreme stress scenarios.

This commitment is rooted in MOTION**TECHCORE**, our dedicated Research & Test Centre, where an engineering-driven approach ensures that every cable is tested and classified before shipment.

By subjecting our cables to over 60 rigorous tests, from dimensional checks and material analysis to dynamic movement (e.g., drag chain, torsion) and system-level validation, we guarantee a product that maintains its performance throughout its planned operational life.

MOTION**CABLES** thus acts as a technical partner, providing not just components, but verified solutions that directly enhance system reliability and reduce the overall total cost of ownership (TCO) for the customer.

KEY ADVANTAGES OF MOTIONCABLES

MOTION**CABLES** leverages its MOTION**TECHCORE** research centre to deliver verified, high-performance special cables, offering the following key benefits:

GUARANTEED LONG-TERM RELIABILITY

Products are qualified through accelerated aging and dynamic testing (millions of cycles) to ensure stable performance over the full operational life, minimizing unscheduled downtime.

PERFORMANCE CLASSIFICATION

Cables are objectively categorized into four classes (Electrical, Dynamic, Environment, Safety) based on real-world test data, enabling quick and precise selection for specific application needs.

SYSTEM FUNCTIONALITY ASSURANCE

Validation includes the entire system (Drive–Cable–Motor), confirming reliable performance and compatibility within the customer's actual industrial environment.

SUPERIOR ENVIRONMENTAL RESISTANCE

Proven resistance to oils, chemicals, temperature extremes, UV, and salt fog, ensuring cable integrity in harsh and contaminated settings (e.g., machine tools, offshore).

REDUCED TOTAL COST OF OWNERSHIP (TCO)

High durability, predictable life expectancy, and validated technical parameters simplify design and maintenance, leading to fewer failures and lower inventory costs.

CONTENTS

THE **EMC MANDATE** & THE MOTIONCABLES **SYSTEM THINKING** APPROACH

In the modern landscape of industrial automation, **Electromagnetic Compatibility** (EMC) is no longer a mere regulatory hurdle—it is the lifeline of system reliability. As switching frequencies increase and cabinet footprints shrink, the risk of Electromagnetic Interference (EMI) grows exponentially.
At MotionCables, we recognize that a cable is more than a conductor; it is a critical component of a complex ecosystem. Our testing philosophy is built on two pillars:

- **Preventative Analysis**: Testing materials and geometries before assembly.
- **System-Specific Validation**: Ensuring finished cables meet the stringent requirements of specific drive and feedback systems like Siemens DRIVE-CLiQ, Heidenhain EnDat, and One Cable Solutions (DSL).

Our goal is simple: To provide the lowest possible transfer impedance to **guarantee the maximum operational length** of your system without signal degradation.

PHASE 1
PRE-PRODUCTION, TESTING MATERIAL SCIENCE AND SHIELDING GEOMETRY

Before a single meter of cable is jacketed, MotionCables conducts rigorous analysis of the shielding components. The efficiency of a shield is determined by its ability to reflect and absorb interference, which we evaluate through:

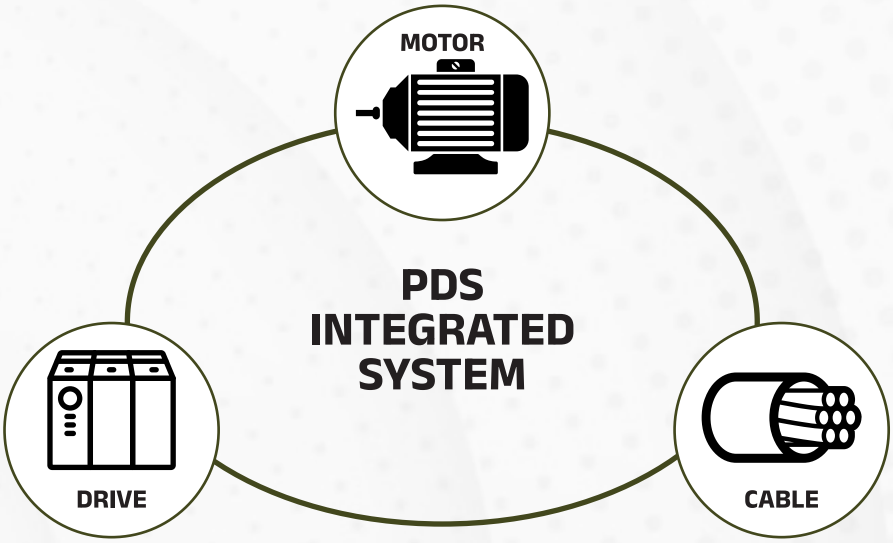
- **Coverage Factor Analysis**: We utilize high-precision optical and mathematical models to ensure optical coverage exceeds 85% for high-flex applications, preventing "windowing" effects during bending.
- **Braid Angle Optimization**: For dynamic applications, the angle of the braid must balance mechanical flexibility with electrical screening. We test various braiding densities to find the "Sweet Spot" where EMI protection remains stable even after millions of cycles.
- **Surface Transfer Impedance (Z_T)**: Initial testing of the shielding material to ensure the Z_T values are within the milli-Ohm range, providing a low-resistance path to ground for induced currents.

PHASE 2 – FINISHED CABLE VALIDATION

The Triaxial Cell and the Absorbing Clamp
Once the cable is manufactured, it undergoes a battery of tests in our specialized laboratory to verify its real-world performance.

1. **Screening Attenuation (a_s).**
   We measure the difference between the power fed into the cable and the power radiated out.
   For feedback cables in high-noise environments, we aim for Class A or A+ performance.
2. **Transfer Impedance (Z_T).**
   This is the most critical metric for industrial cables. Using the Triaxial Method, we measure the voltage drop along the shield relative to the current on the outside. A lower Z_T indicates a superior shield that prevents internal signals from escaping and external noise from entering.
3. **Long-Term Dynamic EMC Stability**
   Unlike static cables, MotionCables' products are built for motion. We re-test EMC parameters after the cable has undergone millions of cycles in our torsion and drag-chain test rigs to ensure that mechanical wear hasn't compromised the shield's electrical continuity.

These are test endured only for the cables, but MotionCables has extended the classification and evaluation to the whole PDS: a **Power Drive System (PDS)**, according to the EN/IEC 61800-3 standard, is not merely the sum of individual components but **an integrated system** comprising the **drive**, **motor**, **cable**, and **sensor**.
The individual EMC compliance of each component does not guarantee system stability when the components interact.
Electromagnetic emissions and interference propagate throughout the entire system: cables, motors, filters, and shielding interact in a complex manner. The EN/IEC 61800-3 standard mandates that **EMC tests must be performed at the system level, not on the individual component**.



MOTIONCABLES **SYSTEM THINKING** APPROACH

MOTION**CABLES** applies the principle of **SYSTEM THINKING**, considering the cable not as an isolated element, but as an integral part of the drive system's EMC behaviour.

WHAT WE ANALYSE DURING TESTING

- PWM switching up to 16 kHz.
- Cable lengths from 5 to 100 m.
- Different shielding methods (360°, single ended, floating).
- Environments with strong radiated fields or conducted disturbances.

TESTING OBJECTIVES

- To **evaluate** the **actual immunity** of th industrial system.
- To **measure** the **effect of disturbances** on digital signals (DSL, EnDat, EtherCAT P, Hiperface DSL, MOVILINK DDI).
- To **ensure communication continuity** even under EMC stress.

WHY SYSTEM-LEVEL TESTS ARE CRUCIAL

The transmission of power and data within the same conductor bundle (One Cable Technology, OCT) generates non-linear EMC phenomena:

- PWM waves can couple with signal conductors, generating **common-mode currents and crosstalk**.
- Impedance differences between shields and terminals cause **reflections or synchronization errors**.
- Shield or grounding discontinuities alter the HF (High Frequency) return path, **increasing emissions and susceptibility**.

By testing cables under real-world conditions, MOTION**CABLES** verifies:

- **Stability** of the digital communication link.
- **Functional resilience** to EMC disturbances (Burst 4 kV, Surge $\pm$4 kV, RF 10 V/m).
- **Compliance** with conducted and radiated emissions for industrial categories C3 and C4.

SYSTEM-SPECIFIC OPTIMIZATION

Maximizing Cable Lengths

The "Maximum Operational Length" of a cable isn't a fixed number; it is a variable defined by the system's sensitivity to capacitance and noise. We tailor our shielding designs to the specific requirements of the world’s leading drive systems (some examples):

SYSTEM REFERENCE	CRITICAL EMC FACTOR	MOTIONCABLES ENGINEERING APPROACH
Siemens (S210)	High-speed data integrity	**Low-capacitance insulation paired with high-density tinned copper braiding.**
Sick (DSL HYPERFACE)	Power/Signal crosstalk	**Advanced hybrid shielding to isolate power cores from sensitive feedback pairs.**
Heidenhain (EnDat)	Signal precision	**Precision-wound shields to minimize phase errors over long distances.**

By optimizing the shield to these specific protocols, we allow our customers to push the boundaries of their machine layouts, extending the distance between the drive and the motor without the need for signal repeaters or expensive filters.

OCT ONE CABLE TECHNOLOGY: THE **EMC CHALLENGE**

OCT PRINCIPLE

Integrates power, control, and data into a single cable, reducing space, weight, and installation complexity.

EMC Challenge:
PWM power lines generate magnetic fields and common-mode currents that **can interfere with data lines**.

MOTION**CABLES** SOLUTIONS

- **Optimized conductor geometry** (twist + concentric shielding).
- Insulating materials with a **low dielectric constant**.
- **Multi-layer shielding** (foil + copper braid).
- **360° low HF impedance terminations**.

KEY PERFORMANCE OF MOTIONHYBRID OCT CABLES

- Controlled characteristic impedance: 100 / 120 Ω, S210, EtherCat, EnDat 2.0, EnDat 3.0
- Minimal crosstalk and stable propagation: 4.8-5 ns/m.
- Shielding effectiveness up to 1 GHz.
- Supported lengths: 50 - 100m.
- EMC compliance and integrity of high-speed digital signals.

TEST PROCEDURES

Complete drive + motor + cable systems, real-world conditions, PWM up to 16 kHz, 360° shielding.

EMISSION RESULTS

TEST TYPE	C3 LIMIT	MOTIONCABLES VALUE	Margin	Observations
Conducted Emission	73 dBµV	58dBµV	+15 dB	20% reduction compared to standard cable.
Radiated Emission	40 dBµV/m	36 dBµV/m	+4 dB	No interference in the 30–300 MHz range.

IMMUNITY RESULTS

DISTURBANCE TYPE	Level	OUTCOME	NOTES
Burst (FTB)	4.55 kV@10 kHz	OK	No errors on DSL link.
Surge	±4 kV CM ±2 kV DM	OK	No loss of synchronization.
Radiated RF	10 V/m	OK	Stable signal, jitter <1%.

INTERPRETATION

The combination of foil + braid shielding and correct terminations ensures signal continuity even under extreme disturbances.

COMPARATIVE ANALYSIS

Compared to a non-optimized standard cable:

- Conducted emissions reduced by up to -18 dBμV/m.
- 30% higher immunity.
- Zero signal degradation.

TEST CONDITIONS SUMMARY

- **Test configuration**:
  PDS consisting of industrial drive, motor with digital encoder, MotionCables EMC cable (length 100 m.).
- **Installation Setup**:
  Cable routing and grounding according to Motion Cables installation guidelines; 360° shield termination at both ends.
- **Test Method:**
  EMC immunity tests performed according to IEC 61800-3 and IEC 61000-4-x.
- **Instrumentation:**
  Jitter analyser, encoder error counter, drive diagnostic monitoring.
- **Acceptance Criteria:**
  - No Encoder errors.
  - No Communication losses.
  - No Drive Alarms or performance degradation during and after the test.

FUNCTIONAL SAFETY - SAFETY READY

Safety functions (SOS, SLS, SLP, SLA) depend on the signal continuity across the drive–cable–sensor chain.

MOTION**CABLES** Safety-Ready:

- Design compliant with IEC 61800-5-2 / IEC 61508.
- Cables qualified with certified encoders (Heidenhain, Sick, SEW, Siemens).
- Controlled delay and attenuation for a mission time of > 20 years.

Principle: Functional safety is not only measured on the test bench but must be maintained over time and under movement.

EMC AND SAFETY INSTALLATION GUIDELINES

To maintain stated performance:

- Terminate shields **on both sides** (360°).
- Separate power/signal paths by ≥ 200 mm.
- Minimum bending radius ≥ 7.5 times Ø (Diameter).
- Low impedance PE (Protective Earth) connections (< 100 mΩ @ 10 MHz).
- Beyond 25 m: evaluate filters or dedicated topologies.
- Avoid unshielded cables near PWM lines.

ADDITIONAL BEST PRACTICES

- Connect motor side to local ground.
- Avoid loops or twists in cable carriers (drag chains). Use non-metallic cable ties.
- Always document the installation path.

MISSION TIME AND DYNAMIC FLEXING TESTS

Testing on dynamic cable carriers **up to 10 million cycles**, monitoring:

- Temperature
- Insulation resistance
- Conductor continuity

After mechanical stress, the cable is re-tested for EMC: zero performance loss is confirmed, verifying reliability in robotics, machine tools, and handling equipment.

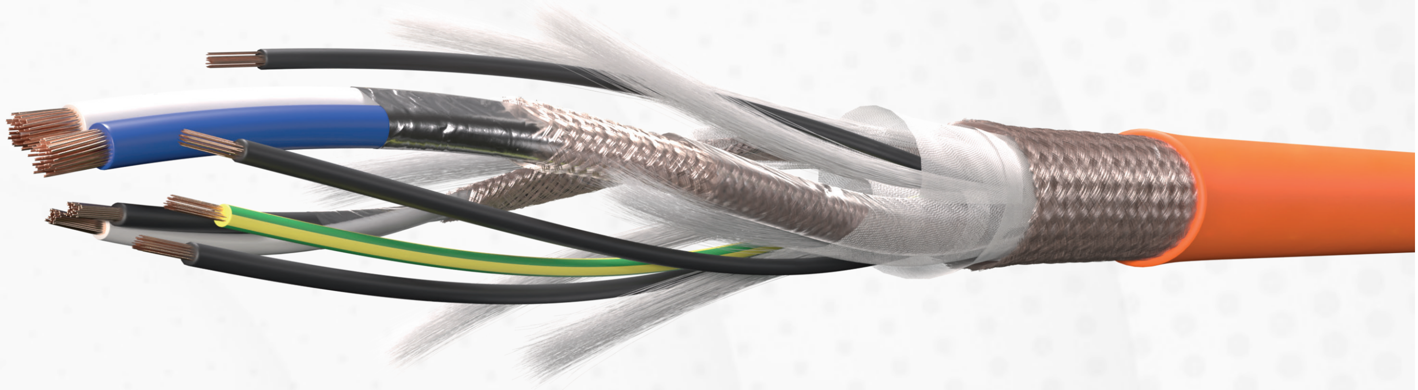
MAIN APPLICATIONS

- **Machine Tools and CNC:**
  Digital feedback, mission time test > 20 years.
- **Robotics and Handling:**
  High-flexibility OCT hybrid cables, post-fatigue EMC testing.
- **Process Automation and Packaging:**
  100 MHz deterministic data transmission, C3/C4 environments.
- **Logistics and Intra-logistics:**
  Conveyors, AGVs, reinforced cables, mechanical durability testing.
- **Energy and Renewable:**
  Drive tracking, UV and thermal resistance.

In Summary: Wherever power and signal coexist, MOTION**CABLES** ensures stability, compliance, and durability.

The above combo-image depicts the overall testing area where the case study explained in the incoming pages has been performed. As you can see the test follows the "system thinking" approach, having all the aspects (drive, motor and cable) wrapped in a Power Drive System (PDS) for a complete evaluation.

CASE STUDY: **MOTIONCABLES DSL PROTOTYPE**



CASE STUDY OBJECTIVE

The MOTION**CABLES** **DSL prototype** was developed to validate the performance of OCT (One Cable Technology) cables under real-world conditions for high-speed data transmission combined with PWM power signals up to 690V. The goal was to demonstrate:

- Integrity of the bidirectional digital signal (DSL, EnDat, Hiperface DSL).
- EMC resilience in the presence of Burst and Surge disturbances.
- Compatibility with high-speed industrial protocols.
- Mechanical reliability over long distances and repeated cycles.

TEST CONFIGURATION

- **System Tested**: Drive + asynchronous/brushless motor + prototype DSL cable + digital encoder.
- **Cable Lengths**: 5 -100 m.
- **Drive PWM Frequency**: Up to 16 kHz
- **Shielding**: 360° on both sides.
- **Main Digital Protocol**: Hiperface DSL, EnDat 2.2 and 3.

TEST PROCEDURES

- **Full System EMC Testing**:
  - > Application of Burst disturbances up to 4.55 kV@ 10 kHz.
  - > Surge over-voltages ± 4 kV CM / ± 2 kV DM.
  - > Radiated RF fields up to 10 V/m, 80 MHz – 1 GHz.
- **Digital Signal Monitoring:**
  - > Real-time error counter and jitter analyser.
  - > Verification of synchronization and absence of erroneous packet transmission.
- **Mechanical Post-Fatigue Analysis:**
  - > Cable laid in a dynamic cable carrier, 10 million cycles.
  - > Checking insulation resistance, conductor continuity, shield integrity.
  - > Repeated EMC testing to evaluate the effect of wear.

TEST TYPE	REGULATORY LIMIT (C3)	MOTIONCABLES DSL VALUE	Margin	Interpretation
Conducted Emission	73 dBµV	58dBµV	+15–18 dB	Significant reduction compared to standard cables; stable cable in heavy-duty industrial conditions.
Radiated Emission	40 dBµV/m	36 dBµV/m	+4 dB	Foil + braid shielding and symmetric geometry reduce common-mode currents.

TECHNICAL INTERPRETATION

The data demonstrates that the geometrical design and the shielding combination ensure:

- Signal continuity even in the presence of high-frequency disturbances.
- Genuine immunity up to the maximum levels generated by testing instruments.
- A superior EMC margin, which is critical for C4 industrial environments.

MECHANICAL INTEGRITY AND MISSION TIME TESTS

- 10 million cycles of continuous movement.
- Zero degradation in impedance or crosstalk.
- Post-EMC testing confirms the integrity of the digital signal and resistance to disturbances.

TECHNICAL CONCLUSION OF THE CASE STUDY

According the tests provided, we can state that the MOTION**CABLES** DSL prototype:

1. Withstands extreme EMC stress (Burst/Surge/Radiated RF) without loss of functionality.
2. Maintains the integrity of digital protocols (DSL, EnDat, Hiperface DSL) even in the presence of high PWM power.
3. Guarantees mechanical durability and a mission time exceeding 20 years.
4. Confirms the **System Thinking** approach: testing the cable, motor, and drive as an integrated system produces real and reliable data.

DESIGN IMPLICATIONS FOR OEMS AND INTEGRATORS

- Reduced risk of communication errors in robotics and CNC applications.
- Increased EMC safety margin in heavy industrial installations.
- Functional verification of the drive-cable-sensor chain for SIL2/SIL3.
- Comprehensive technical documentation for system certifications.

We don't just test the cable; we test the system that moves your machine.

TECHNICAL SUMMARY

The tests conducted on MOTION**CABLES**, particularly on OCT (One Cable Technology) systems and the DSL prototype, demonstrate that every developed product is capable of ensuring:

- **Integrity** of digital and power signals in complex industrial environments.
- **Genuine EMC compliance**, verified at the complete system level according to IEC 61800-3 and IEC 61000-4-x.
- **Functional safety verified** according to IEC 61800-5-2, maintaining the SIL level up to SIL3.
- **Durability and mechanical reliability** over a mission time exceeding 20 years, even in high-frequency dynamic applications.

MOTIONCABLES ADDED VALUE

1. ADVANCED SYSTEM THINKING

Every cable is tested as an integral part of the drive + motor + sensor system. We do not limit ourselves to measuring the nominal compliance of the cable: we evaluate the system stability under real operating conditions.

2. RIGOROUS AND CERTIFIED EMC TESTING

- Burst tests up to 4.55 kV @ 10 kHz.
- Surge± 4 kV CM / ± 2 kV DM.
- Radiated RF fields 10 V/m.

All tests are monitored in real-time, with analysis of the digital signal, jitter, and industrial protocol continuity.

3. ADVANCED OCT CABLE DESIGN

- Optimized conductor geometry
- Multi-layer foil + braid shielding
- Low HF impedance 360° terminations
- Supported lengths up to 100m without signal degradation.

4. SAFETY-READY FUNCTIONAL SAFETY

Our cables maintain integrity and immunity even for critical functions like SOS, SLS, SLP, and SLA. The result: a complete drive–cable–sensor chain compliant with SIL2/SIL3, proven in the laboratory and reliable in the field.

5. VALIDATION ON MISSION TIME AND DYNAMIC FLEXING

Every cable is subjected to extreme dynamic cycles (up to 10 million) simulating real industrial conditions. Post-test, the cable maintains low emissions, high immunity, and digital signal integrity.

BURST	Rif. IEC 61800-3 Test Description	Time	Allarm Drive
None	On rotation enabled ± 3000 rpm	5 min.	None
1 kV @ 5 kHz	LEVEL 2 (minimum for signal cables ± 3000 rpm)	7 min.	None
2 kV @ 5 kHz	LEVEL 3 (minimum for power cables ± 3000 rpm)	6 min.	None
4 kV @ 5 kHz	LEVEL 4 (± 3000 rpm)	8 min.	None
4,5 kV @ 10 kHz	Maximum level allowed by the instrument	21 min.	None

TEST CONDITIONS

- Drive enabled to give power to the motor
- Speed controlled motor at different speeds as indicated in the table
- Reverse speed of the motor axis are controlled
- Operating parameters:
  > Pr16 = 80.
  > Pr17 = 400
  > Pr19 = 200

The different levels of immunity to disturbances is shown in the above table.
With the configuration indicated above we have then supplied power to the circuits of the three-phase drive then to the motor. After we have launched an immunity test against noises.
The first part of the cable, at about 1 meter from the drive, has been coupled with a capacitive clamp to the FTB (Fast Transient Burst) type disturbances generator.

The communication is established regularly during the initialization phase. The encoder parameters are read regularly as expected and the initialization sequence is completed without errors. The encoder position - gained by reading the channel incremental - occurs regularly every 128μs without faults of any kind are reported.

The following are the values of the DSL master DSL obtained:

- SUMMARY = 0
- EDGES = not verified
- DELAY --> RSSI = 8/10 (67%... 83%)
- Line Delay = 6 (60...70 m)

In all the different tests, without applying power to the motor, is not detected neither a communication error nor a fault messages of the position value read by the master DSL. All the error counters remain permanently at zero:

- DSL_link_err_cnt = 0
- DSL_prst_rst_cnt = 0
- DSL_FastPos_NV_cnt = 0
- DSL_AbsPos_NV_cnt = 0
- DSL_vrt_err_cnt = 0
- DSL_acc_NV_cnt = 0

Different starts have been made, all of which have been without errors. The tests have been performed at different encoder temperatures between 21.5 and 91.8 °C, measured at every restart.

Master DSL Register					Error Counter						Result
Event H	SUM	QM	RSSI	Delay	Link Error	Prst Rst	Fast Pos Error	Abs Pos Error	VRT Error	Acc NV	
0 x 00	0 x 00	0 x 8F	8	5	0	0	0	0	0	0	OK
0 x 00	0 x 00	0 x 8F	8	5	0	0	0	0	0	0	OK
0 x 00	0 x 00	0 x 8F	8	5	0	0	0	0	0	0	OK
0 x 00	0 x 00	0 x 8F	8	5	0	0	0	0	0	0	OK
0 x 00	0 x 00	0 x 8F	8	5	0	0	0	0	0	0	OK

SYSTEM-LEVEL VALIDATION APPROACH:
Validation performed on the complete Power Drive System (PSD), not on the cable alone, ensuring rilable EMC performance under real industrial operating conditions.

TEST OVERVIEW - EMC IMMUNITY AND FUNCTIONAL PERFORMANCE

Test Category	Scope of Validation	Reference standards/ parameters	Outcome
EMC immunity (EFT / Burst)	Immunity of encoder signal and drive operation under fast transient burst	IEC 61000-4-4 up to ± 4 kV	No Encode errors No Drive alarms
EMC immunity (Surge)	System robustness against surge disturbances	IEC 61000-4-5 up to ± 2 kV	Continuous operation maintained
Radiated EMC immunity	Resistance of the complete PDS to radiated RF fields	IEC 61000-4-3 10 V/m ; 80 MHz-1 GHz	Stable signal transmission
Functional start-up validation	Drive and Encoder behaviour during repeated start-up cycles	Multiple start sequences under EMC stress	No disturbances detected
Cable length verification	Signal integrity and EMC behaviour at increasing cable lengths	50 m / 75 m / 100 m	No measurable signal degradation
Signal integrity monitoring	Encoder signal quality during all EMC and functional tests	Jitter analysis; error counter monitoring	No variation vs baseline
Mechanical stress validation	Electrical and functional stability after dynamic mechanical stress	Bending, torsion, continuous motion	No performance degradation

CONCLUSIONS: MOTION**CABLES** **RELIABILITY AND PROFESSIONALISM**

WHY CHOOSE MOTIONCABLES

MOTION**CABLES** doesn't just produce cables: it creates reliable and certified connection systems, designed for the modern industrial reality.

- Every cable is a strategic component of the Power Drive System.
- Every EMC test is conducted at the system level.
- Every cable is designed to coexist in C3/C4 environments with high electronic density.
- Every solution ensures functional continuity, safety, and durability.

By choosing MOTION**CABLES**, the customer gains proven reliability, genuine EMC margins, and certified functional safety, with complete documentation for OEM and integrator certifications.

With us, the cable is no longer just a wire: it is the reliable heart of your automation system, tested, certified, and ready to withstand the most demanding industrial conditions.

We are partners in your drive systems, from design to certification, with expertise, experience, and a dedicated in-house laboratory.

MOTION**CABLES**
DRIVE. CONNECT.
SECURE.

MOTION**CABLES**

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