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HERITAGE AND CAPABILITIES
ARMORED VEHICLE SLIP RINGS

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Introduction

In 2005 the two largest armored vehicle slip ring suppliers in the world merged. The first of these two, Poly-Scientific, was acquired by Moog, Inc. in 2003 and became Moog Components Group (MCG). In 2005 MCG acquired Electro-Tec, the second of the two. In addition, IDM Electronics, a leading European slip ring supplier and Focal Technologies, the world's largest supplier of fiber optic rotary joints and multiplexers were added to MCG. The combined heritage and capabilities of these organizations, with regards to Armored Vehicle slip rings, is addressed in this application note.

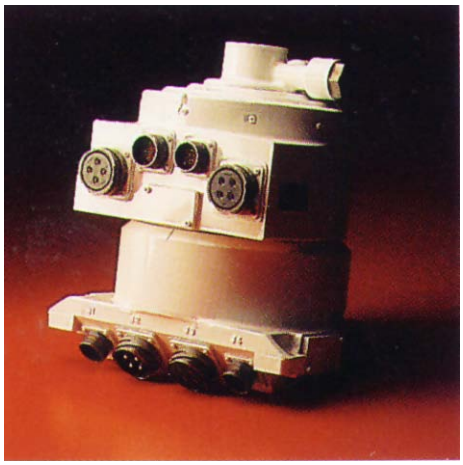

Figure 1. Abrams Turret Slip Ring

Armored Vehicle Tradition

MCG has played a key role in armored vehicle programs since rotating turrets first used slip rings (as highlighted in Table 1). MCG's legacy program has been the Abrams turret slip ring (Figure 1) that has been produced in quantities approaching 10,000 units. Production slip ring programs for the U.S. Army's M60 Tank and Bradley vehicles, the U.S. Marine's Light Armored Vehicle (LAV), the United Kingdom's Warrior, and the Korean K1 Main Battle Tank have given MCG experience with high volume, high reliability armored vehicle programs. The experience with the production volume, logistics support, and configuration management places MCG in a unique position to support new armored vehicle design, production and support requirements.

Because of MCG's armored vehicle experience and continued research, MCG has been selected as the slip ring supplier for most major armored vehicle upgrade programs in the last 10 years. For example, MCG has provided turret slip rings for the Abrams M1A1 to M1A2 upgrade as well as the Bradley A2 to A3 upgrades. MCG also participated with the Army and GDLS to upgrade the Abrams slip ring to address unique environmental issues discovered during Desert Storm.

Figure 2. Stryker Turret Slip Ring

MCG has been putting the technology in place to support the Armored Vehicle of the future, recognizing that the digital battlefield is putting tremendous pressure on the bandwidth capability of traditional slip rings. MCG has worked with the V-SIL lab of TARDEC (TACOM) on projects to demonstrate various high-speed digital data link capabilities for tank VETRONICS. This research demonstrated that slip rings could be used to support a number of the most advanced VETRONICS data speed requirements. This technology was subsequently inserted into several new armored vehicle upgrade programs. MCG has demonstrated the ability to provide high speed data lines that meet stringent bit error rate (BER), EMI/EMC/ and environmental requirements.

Table 1. Key Programs Using MCG's Slip Rings/Twist Capsules

APPLICATION	PROGRAM	CUSTOMER
ADVANCED ARMORED VEHICLE TURRET SLIP RINGS	Abrams Main Battle Tank (M1, M1A1, M1A2)	GDLS
	AAAV, EFV	GDAMS
	M2/M3 Bradley A2 & A3	BAE
	IBCT Stryker	GDLS
	(Light Armored Vehicle) LAV	GDLS
	M113 APC	
	M60 Patton	
	M48 Patton	
	M728 Combat Engineer Vehicle (CEV)	
	AAVP7A1 Amphibious Assault Vehicle	
	IBCT Anti-Tank Guided Missile Vehicle (ATGM)	
	Warrior (UK)	BAE
	CV 90	BAE
ELECTRO-OPTIC SYSTEMS (ARMORED-VEHICLES)	Bradley CIV	Raytheon
	CITV	Raytheon
	HTI Thermal Viewer	Raytheon
	Stryker Thermal Viewer	GDLS
	SGTS/ KEOTS	Raytheon
	Korean K-1	Raytheon

The recent the addition of Focal Technologies, the world's largest supplier of FORJs and Multiplexers, to Moog Components Group has been a significant addition to the already extensive high speed data capabilities of MCG. In addition, MCG's fiber brush technology offers significant weight, size, and reliability advantages over traditional electrical contact, and advanced design solutions for fluid rotary unions provide long life rotary fluid connections.

The breadth of experience that Moog Components has with armored vehicle turret slip rings is further augmented by the leadership role they have played in the development of slip rings and twist capsules for electro-optic systems used by these same armored vehicles. For example, MCG has provided all the slip rings for the Commanders Independent Thermal Viewer (CITV) used on the Abrams A2 as well as all the slip rings (azimuth axis) and twist capsules (elevation axis) for the Commanders Independent Viewer (CIV) for the Bradley A3. These designs further highlight MCG's capability to provide high data rate solutions in environmentally robust and size efficient packages.

Figure 3. Bradley Turret Slip Ring

To support the design and production capabilities of slip rings for Armored Vehicles, MCG has made significant investment in design tools and production equipment. The tables below show some of these capabilities.

Table 2 shows the design tools available to MCG engineers. 3-D solid modeling for mechanical design work is supported by finite element, fluid flow, statistical, and reliability modeling capabilities. Electrical analysis capability is provided by both high voltage modeling and transmission line modeling (for high data rate lines). Optical modeling software is used in the case of fiber optic transmission lines.

Table 3 shows a sample of the test equipment available to MCG engineers to evaluate new designs. An extensive array of data transmission line test equipment allows MCG engineers to characterize and analyze the capability of new designs to provide acceptable signal quality. The MCG Materials Lab provides expertise for both process control and problem analysis. The environmental and mechanical test equipment allow a wide range of design verification and qualification testing as well as environmental stress screening (ESS) and HALT/HASS evaluation.

Table 2: Modeling and Simulation Capabilities

Function	Modeling Capability	Description
Weight and size reduction	Finite Element Analysis (FEA)	FEM software will be critical in the size and weight reduction effort. Models will be developed and analyzed to optimize material properties and design features.
Mechanical Design and 3-D Modeling	IDEAS	3-D solid modeling software.
Optical wave path simulation	ZEMAX	Allows optical components to be modeled and performance parameters predicted.
Model high voltage fields	Coulomb	Coulomb allows the modeling of high voltage fields to determine risk of corona or high voltage arcing.
Optimize high speed data performance of transmission lines	Zeland IE3D Electromagnetic Simulation Software	This is a method of moments field solver (Maxwell's Equations) that is used for modeling standard and non-standard electrical transmission lines to optimize high frequency performance.
Analysis of high frequency transmission lines	HyperLynx GHz	HyperLynx allows the analysis of signals ranging from megabit to gigabit speeds. This capability allows impedance, radiated emissions, eye diagram analysis and crosstalk analysis to be performed and optimized before any fabrication is started.
Perform frequency domain analysis on slip ring structures	PSpice	SPICE is a general purpose analog circuit simulator that is used to verify circuit designs and to predict the circuit behavior.
Statistical modeling	Minitab	Minitab is used for six sigma design analysis to ensure that reliability goals are factored into tolerance analysis.
Reliability Modeling	Relex Reliability Modeling	An integrated set of reliability analysis tools for performing reliability and maintainability analyses.
Fluid Flow	Custom Spreadsheet Solution	This program allows designers to model fluid flow through FRUs and determine critical performance parameters.

Table 3: Test Equipment

High Speed Data and Communication Test Equipment

Manufacturer	Model	Equipment Type
Anritsu	MP1632C	Bit Error Test Set
Synthesis Research	7500A	BERTscope
Tektronix	CS7404	Communication Signal Analyzer
Tektronix	404	Communication Signal Analyzer
Tektronix	GigaBERT 1400	Generator
Tektronix	GigaBERT 1400	Analyzer
Ando	AQ6317B	Optical Spectrum Analyzer
Anritsu	MS96A	Optical Spectrum Analyzer
Tektronix	CS8200	Communication Signal Analyzer
Hewlett Packard	3762A	Data Generator
Hewlett Packard	3763A	Error Detector
Tektronix	TDS 460A	4 Channel Digitizing Oscilloscope
Hewlett Packard	33120A	Function Generator
Tektronix	147A	NTSC Test Signal Generator
Tektronix	520	Vectorscope
Tektronix	1425R	NTSC Video Waveform Monitor
Tektronix	1430	Random Noise Measuring Set
Tektronix	VM700A	Measurement Set
Agilent	81619A	Lightwave Multimeter
Agilent	81612	Lightwave Multimeter Plug-in
Agilent	8720ES	20 GHz Vector Network Analyzer
Agilent	86100	20 GHz DCA/Oscilloscope

Materials Analysis Equipment

Manufacturer	Model	Equipment Type
Physical Electronic Industry	Model 550	Scanning Auger Electron Spectroscopy and X-ray Photoelectron Spectroscopy
Nicolet	Impact 400	Microscopic Fourier Transform Infrared Spectrometer
ISI	Super 3A	Scanning Electron Microscope and Energy Dispersive X-ray (SEM/EDS
Veeco	XRF-5200L	X-ray Fluorescence Spectroscopy
TA Instruments	DSC 2010	Differential Scanning Calorimeter (DCS)
Perkin-Elmer	2380	Atomic Absorption Spectrometer
SRI	8610C	Gas Chromatograph (GC)
		DC-1000Hz Automatic Magnetic Hysteresisgraph (AMH)
Micrometer	22	Dage Micro Tensile Tester
Brookfield	DV-II+	-20C to 150C Cone and Plate Viscometer
Instron	1123	Universal Testing Machine

Chemical Analysis Laboratory

Environmental and Mechanical Test Equipment

Manufacturer	Model	Equipment Type	Functional Capability
Thermatron, 2×	SE600-6-6	Environmental Chamber	10%-90%RH -70C – +170C
Thermatron	PR-CH-5-5-AC	Environmental Chamber	-70C – +170C
Thermatron	S-1.2	Environmental Chamber	-70C – +170C
Thermatron	S-1.2	Environmental Chamber	-70C – +170C
Thermatron	S-16-3800	Environmental Chamber	-70C – +170C
Thermatron	S5.5	Environmental Chamber	-70C – +170C
Cincinnati Sub Zero	ZH-32-3-3-H/AC	Environmental Chamber	to 100% RH -70C – +170C
Tenney	8TS		-70C – +170C
Blue M	WSP-109BMF3		Cold: -75C – 0C Hot: +85C – +200C
Starrett	HGDC242418	CMM	3 Axis: 24”×24”×18”
Starrett	RCS402824	CMM	3 Axis: 40”×28”×24”
Ram Optical Instrument	OMIS III	Optical Vision Measurement System	3 Axis: 12”×12”×16”
UnHoltz Dickie		Vibration System	3300 lbf, Random 4000 lbf, Sine
LDS		Vibration and Shock System	7000 lbf, Random 8000 lbf, Sine
Custom Built		ESS Chamber Connected to Liquid Nitrogen	12C/minute ramp rate
Custom Built, 5×		Vacuum Chambers	10E-6 torr; -50C – +170C
Polytec	Model 5000	Laser Vibrometer	10 m/s