SLIP RING CATALOG

ELECTRO-OPTIC, VEHICULAR, HELICOPTER, PROPELLER AND MINIATURE SLIP RINGS

MOOG

MOTION TECHNOLOGY CATALOG INDEX

Moog Inc. is a worldwide designer, manufacturer, and integrator of precision control components and systems. Moog's high-performance systems control military and commercial aircraft, satellites and space vehicles, launch vehicles, missiles, automated industrial machinery, marine and medical equipment.

Moog's Power and Data Sector, headquartered in Blacksburg, Virginia, is an innovative provider of power and data transfer solutions, motion control, and electronic products that are designed and manufactured to meet the demanding technical and environmental requirements of the defense and space markets.

Moog products can be found on mission critical applications:

- Armored vehicle turrets, IR and EO systems
- Missile seeker gimbals and inertial systems
- Helicopter de-ice systems, EO / IR trackers and target systems
- Fixed-wing aircraft - EO / IR trackers, fire control systems, surveillance systems and targeting systems
- Missile counter measures
- Space - solar array mechanisms
- Shipboard / submersible - navigation systems and fire control radar
- Surveillance systems

More information about Moog is available at **www.moog.com**.

Note: Products listed herein are subject to U.S. Export Regulations and may require export licensing. Contact Moog to obtain specific export control requirements.

HOW TO SPECIFY A SLIP RING

Many of the more than 10,000 slip ring designs are available for use in their existing configuration or they may be modified to meet your specific requirements. New designs can also be created to meet the most demanding specifications.

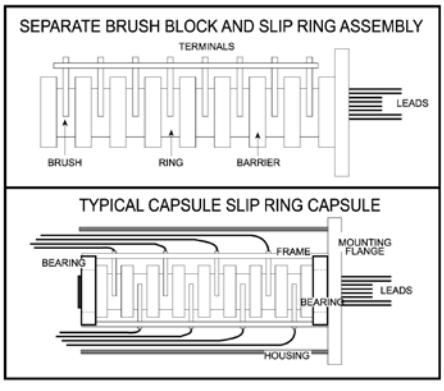
Our engineers are experienced in a wide range of slip ring applications. A very active in-house quality program solicits the best inputs from all of our many concurrent engineering groups, from start to finish.

This section is designed to guide you through the process of specifying a slip ring. We've outlined below the major considerations that a slip ring engineer will need to know about your application.

Basic Slip Ring Design

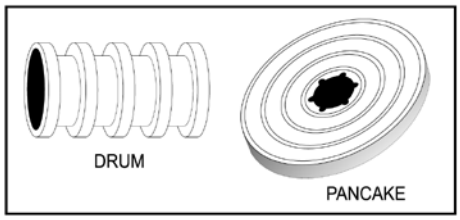
Throughout these pages, you will see three basic terms used for slip rings:

1. Slip Ring Capsule - A fully integrated unit with a housing and bearings.
2. Slip Ring Separates - Separate slip ring rotor and brush blocks for mounting in your system.
3. Twist Capsule - A limited rotation device used typically in scanning applications where continuous rotation is not required.



There are two basic slip ring configurations to consider based on space allocation in your system:

1. The more common drum approach where each ring is adjacent to the next along the centerline, somewhat like the threads on a bolt and
2. The platter approach where the rings are concentric with one another like the grooves on a flat surface. The pancake approach is used when length is at a premium but diameter is less restrictive.



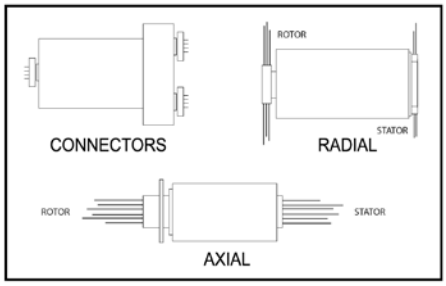
Defining the Mechanical Envelope

The envelope is, of course, largely dictated by the space available in the system. The slip ring engineer should be given the maximum space available in the system so all existing candidate designs can be considered. It is imperative that the space required for the slip ring be specified in the early stages of the system design and that it be consistent with the structural and electrical demands.

Defining System Interface Requirements

The slip ring engineer will need to know these system interface considerations:

1. Can the slip ring mount directly on the center line or is a through-bore required in the slip ring? A through-bore can be used to mount the slip ring on a shaft or used for routing hydraulic lines, pneumatic lines, fiber optic rotary joint, wave guide. etc.
2. How will the slip ring attach to the system? A slip ring must be mounted with a flexible coupling on one side of the unit. Hard mounting on both the rotor and stator will cause the slip ring to fail prematurely by translating system load into the slip ring bearing structure.
3. How should the electrical connections to the slip ring be made? Is it desirable to have connectors integral with the slip ring on both the rotor and stator, or would flying leads on one or the other ends be desirable? And if flying leads are preferred, should they exit the rotor / stator in a radial or axial direction, and what length should the leads be?



Defining Electrical Requirements

The specified current enables the slip ring engineer to propose a unit with the appropriate cross-sectional area of the rings, brushes and lead wires. The specified voltage dictates the spacing between adjacent rings and brushes. It is helpful in achieving the most cost effective and smallest practical envelope not to rate all circuits at the maximum level. For example, if you need 20 circuits total, three of which must carry ten amps, designate three for high current. Don't insist on 100% functional interchangeability by specifying that all 20 circuits carry ten amps. And, if ten amps is a surge current with a continuous current of only two amps, tell us that, too. There is no reason for you to pay for ten amps continuous capacity when you only need two amps.

Be aware that voltage surges and spikes are the major cause of system slip ring failures. Moog uses a conservative approach to circuit design, however, it is not uncommon in some power supply systems to see voltage spikes ten or more times the normal operating voltage. We strongly recommend surge protection on all power supplies.

Most smaller slip rings will satisfactorily conduct signals to 50 megabits / sec. Special slip rings can be used to pass broadband signals from DC to 1 gigahertz and data rates of 500 megabits or even higher. Cross-talk, insertion loss and bit error rate information can be projected, if tested for actual values, when data rates, formats and impedances are defined. The appropriate shielding techniques will be incorporated to meet the system requirements.

Defining Mechanical Requirements

1. Operating speed (rpm) is an important design parameter. Almost any slip ring can operate successfully at speeds to

HOW TO SPECIFY A SLIP RING

100 rpm although many applications only require operation at a few rpm. Slip rings are routinely used to instrument test jet turbine engines operating at speeds in excess of 20,000 rpm. The operating speed, in conjunction with the diameter, dictates the surface speed of the ring relative to the brush and hence the internal design approach and material selection.

2. What rotational life is necessary for your application? Will the unit oscillate or rotate at a continuous speed?

Defining the Environment

The environment in which the slip ring must survive is a key factor. Operating temperature range is important in specifying the proper lubricant. And if the slip ring will operate exposed to the elements or to a hostile environment, integral seals must be included in the design. Any unusual shock or vibration should also be specified.

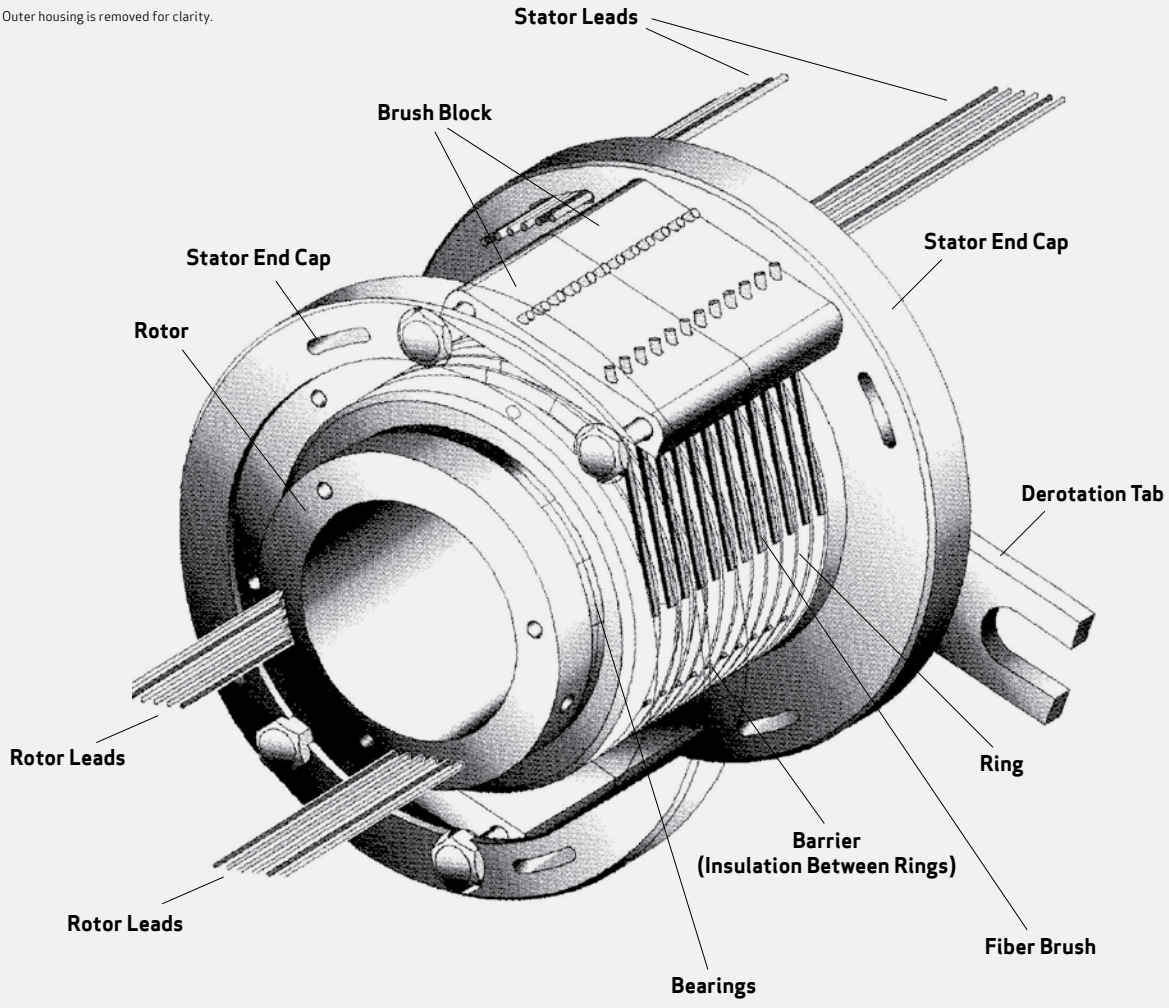
Your Slip Ring Requirements

For assistance on your slip ring requirements, please complete the Slip Ring Application Specification Sheet located on page 6, you can either fax or call and speak with one of our engineers about your optimum slip ring solution.

Many of the slip ring designs and manufacturing processes described are proprietary and are covered under one or more U.S., European or Japanese patents. The information provided is intended to assist the system engineer in initial discussions and is not intended as a specification.

COMPONENTS OF A SLIP RING

Note: Outer housing is removed for clarity.



SLIP RING APPLICATION SPECIFICATION SHEET

Please provide as much information as possible, enter NA for those questions that are not critical or important to you. Do not be concerned if you do not have all of the specifications that are requested, we are happy to work with as little or as much information as you can provide. However, the more complete your response, the more thorough our analysis.

COMPANY INFORMATION

Company Name _____ Contact _____

Division _____

Address _____

❑ Buyer

❑ Engineer

❑ Other _____

City _____ State/Country _____ Zip/Post Code _____

Phone _____ FAX _____ E-mail _____

1) Description of Application: _____

❑ Commercial
❑ Industrial
❑ Military
❑ Other

2) Type of Slip Ring ❑ Capsule ❑ Separate Brush Block ❑ Other _____
❑ Separate Slip Ring ❑ Poly-Twist (for ± °) _____

3) This Application is: ❑ New ❑ Retrofit / Replacement Type of Application: _____

Current Supplier: _____ Part Number: _____

4) Estimated Annual Quantity: _____ Price Target: _____ Production Start Date: _____

Estimated Life of Program: _____ Tooling $ Available: _____

5) Size Constraints - Mechanical and additional requirements (i.e. resolver, motor, hydraulics, pneumatics, optical channel, etc):

_____

_____

6) Specifications:

Number of Rings: _____

Size: Length _____

Diameter _____

Bore _____

Wear (Life): Hours (or Yrs) _____

at Duty Cycle _____

Operating Temp Range (°C):

Min _____ Max _____ Norm _____

Pressure: Norm _____ Min _____

Vibration: ____g's @ ____Hz Shock ____g's

Sealing: ❑ None ❑ Dust & Splash
❑ Water Spray ❑ Submersion

Rotational Speed: Norm _____

Oscillatory Motion: Yes _____ No _____

Torque: Max Starting _____ gm-cm

Weight (Max): _____

Lead Length: Rotor _____ Stator _____

Connectors: Rotor _____ Stator _____

Lead Exits: Rotor Axial _____ Radial _____
Stator Axial _____ Radial _____

Circuit Function	No. Ring	Current (amps)		Working Volts	Data Protocol	Digital Risetime* or Freq. (Hz)	Crosstalk Isolation (dB)
		Normal	Max				

*If unknown please specify protocol or data rate.

SLIP RING PROGRAM MATRIX

PROGRAM MATRIX	
Program	**Description**
Bradley Fighting Vehicle	Commander's Independent Viewer AZ Slip Ring
	A3 Turret Slip Ring, EL Poly-Twist
	A2 Turret Slip Ring
Advanced Targeting Pod	Pitch Axis Slip Ring
	Roll Axis Slip Ring
AH-64A / D Apache Longbow Attack Helicopter	Slip Ring RF Rotary Joint Assembly
AH64 Apache	Tail Rotor De-ice
Avenger Air Defense System	Turret Slip Ring Capsule
Blackhawk and Seahawk	Main Rotor
	Tail Rotor
F-14 / 15 / 16 LANTIRN	Main De-roll Slip Ring
Sentinel Radar	Pedestal Slip Ring Capsule
V-22 Osprey	Main Prop Rotor Slip Ring De-ice and Flight Controls
Stryker IAV Mobile Gun System	Turret Slip Ring Assembly
F35 Joint Strike Fighter	EOTS Roll Slip Ring
S92 Helicopter	Main Rotor De-ice Slip Ring
	Tail Rotor De-ice Slip Ring
AWACS	Main Power and Signal Transfer Slip Ring / RF Rotary Joint
	Main Power and Signal Transfer Slip Ring / RF Rotary Joint

SIG CKTS = Signal Circuits (Rings)
PWR CKTS = Power Circuits (Rings)

ELECTRO-OPTIC SYSTEMS

The dramatic increase of sophisticated gimbaled electro-optic sensor systems that provide battlefield information has led to major developments in supporting hardware. These EO systems require an enormous amount of data to be transmitted across the rotating axes as well as power and other signals. Moog has always been one step ahead of these requirements with the development of high bandwidth slip rings, twist capsules, fiber optic rotary joints and multiplexing technologies.

Moog has participated in the development of many of the major airborne and ground-based EO systems The Abrams Tank Commander's Independent Thermal Viewer (CITV) has used our slip ring assembly to allow continuous rotation on the azimuth axes since the program's inception. The Bradley armored vehicle also uses Moog's slip ring on the azimuth axis of its Commander's Independent Viewer (CIV); in addition the CIV uses a Moog's twist capsule on the elevation axis.

Moog slip rings and twist capsules are used extensively in airborne EO systems. The latest upgrade to the F-18 Hornet's EO sensor suite, Advanced Targeting Forward Looking Infrared (ATFLIR), utilizes a Moog slip ring to allow continuous rotation in the roll axis and a twist capsule for scanning, or limited rotation, in the elevation and yaw axes. The Low Altitude Navigation and Targeting Infrared for Night (LANTIRN), and its successor Sniper, pods used for EO targeting and navigation on the F-16 uses Moog slip rings and twist capsules exclusively. The Predator UAV, LAMPS helicopter, and Apache helicopter all "see in the dark" because Moog hardware transmit data and power reliably.

FEATURES

- Multiple contact technologies suited for the application
  - Monofilament wire brush
  - Multiple precious metal fiber brush
  - Composite brush
- Environmental sealing
- EMI Shielding
- FEA structure analysis
- High shock and vibration capabilities
- Wide operating temperature envelope
- Vertical integration of position sensors and ancillary products
- High frequency bandwidth
- High reliability and life
- Redundant bearing designs

TYPICAL APPLICATIONS

- Blade de-ice
- Blade position
- Tip lights
- Flight controls
- FLIR systems
- Target acquisition systems
- Weapon stations

ELECTRO-OPTIC SYSTEMS SLIP RING DESIGNS

Low Profile Azimuth Slip Rings

System height is often the primary concern of the EO gimbal designer. Moog has the solution with its patented broadband platter slip ring design. This broadband technology allows the slip ring designer to package multiple high speed data lines on slip ring platters, and then "stack" these platters with their accompanying brush blocks into a very low profile design. Power rings as well as discrete signals and video can also be placed on these slip ring platters. This has led to a dramatic decrease in typical slip ring height or length over traditional slip ring "drum-style" designs.

High Speed Data

The dramatic improvement in image quality, the use of multi-sensors, and increased communication requirements have driven the need for EO Systems to significantly increase transmission speeds of data channels with every generation of upgrade. We have EO slip rings that handle as many as two dozen data channels at over 400 Mbps each, for an aggregate bandwidth of 12 Gpbs. Slip ring/fiber optic rotary joint hybrid designs contain both copper lines for power and signals, as well as fiber lines for fiber optic signals.

Design and manufacturing techniques have been developed and patented that increase signal bandwidth while controlling crosstalk and EMI/EMC. A arrange of solutions is available to handle data channels such as GigE, Fibre Channel, and IEEE1394 to name just a few. These high speed data solutions are being used in existing EO system as well as turret, radar, and other advanced technology applications.

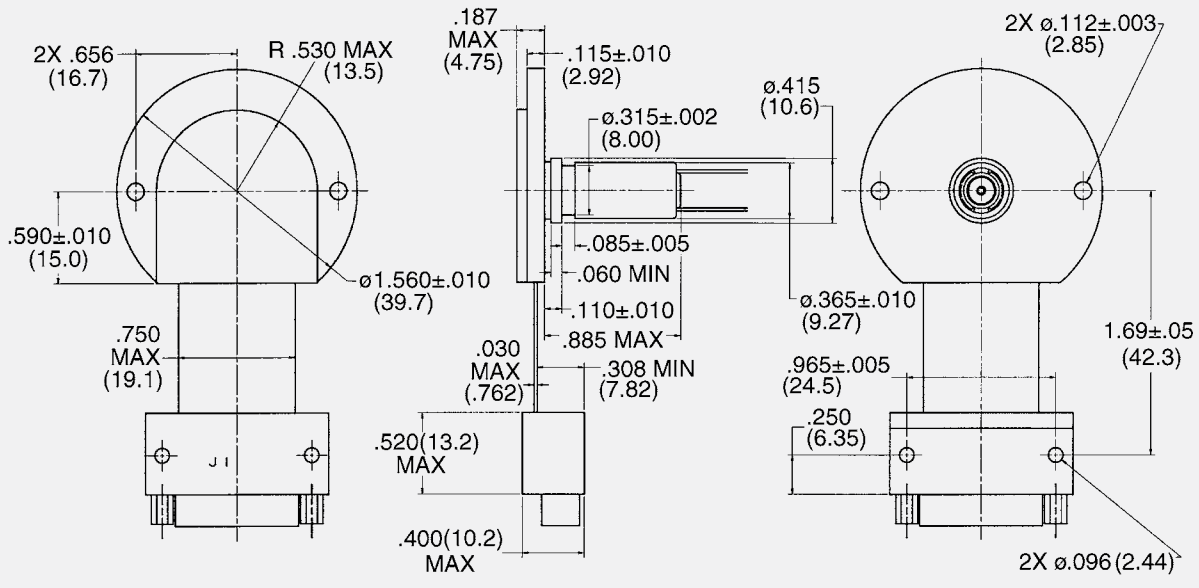
Poly-Twist or Twist Capsules

In most cases gimbaled EO systems require continuous, unlimited rotation on just one axis, typically the azimuth or roll axis. In this case slip rings are the ideal solution for transmitting signals across the rotating interface. Normally the other axes (pitch, elevation, or yaw), require only limited rotation, i.e., less than 360 degrees. This allows the use of a Poly-Twist to transmit electrical power and signals. By the use of wrapping flexible circuits , the Poly-Twist designer is able to increase circuit density, decrease weight, and improve system reliability over traditional cable wraps. The long life, low and consistent torque, and the small size make Poly-Twists the best solution for scanning, or limited rotation axes in EO systems.

Poly-Twists — How They Work

Poly-Twists resemble slip ring assemblies in size and appearance and provide multiple turns of rational freedom. They operate by winding and unwinding flexible circuit tapes wrapped around a central shaft in a configuration resembling a clock spring. The central shaft is generally supported by ball bearings, but bearing-less assemblies are available. One end of the shaft is fastened to the shaft, with lead wires extending from the shaft either axially or radially. The other end of the tape is fastened to the Poly-Twist frame, which is usually considered stationary. Stator lead wire terminations may also be either axial or radial. The flexing element is the key to the low torque and long life of the Poly-Twist. The stress on the flexible circuit is well below its endurance stress limit producing very low torque levels and very long operational life.

ELECTRO-OPTIC SYSTEM SLIP RING DESIGN DIMENSIONS INCHES (MILLIMETERS)



VEHICULAR SLIP RINGS

RELIABLE SIGNAL AND POWER COUPLING IN THE MOST RUGGED BATTLEFIELD CONDITIONS

The increasing complexity of modern military vehicles demands slip rings that provide reliable electrical interfaces between the stationary and rotating parts of these vehicles. Moog slip rings have been chosen to operate on numerous vehicular programs to meet these challenges. M1 / A2 and M60 tanks, A2 / A3 Bradley Fighting Vehicles, Stryker, Light Armored Vehicles (LAVs), and V150 Commando Vehicles are just a small sample of these vehicular programs.

Technological developments have yielded stabilized gun systems, laser target acquisition and fire control systems, and high bandwidth data communications that create unique demands for vehicular slip rings. We meet all of these challenges effectively and economically. A sampling of our many active vehicular slip ring designs are shown on the following pages, or our engineering department can tailor a slip ring for your vehicular application, often within the existing envelope. Contact us with your requirements.

FEATURES

- Supports modern data communication technologies
- Full environmental sealing capabilities
- EMI shielding available
- Range of operating voltages compatible with any vehicular system
- Hydraulic rotary joint options
- Gold-on-gold contacts for signal and data integrity
- Meets military shock and vibration requirements
- Speed, torque and frequency characteristics designed for specific vehicular applications
- High power capability to support present and future vehicular system needs
- High frequency coax channels available
- Through-bore designs
- Cam-operated microswitches
- Vertical integration with resolvers, fiber optics, fluidic interfaces, hydraulics, pneumatics and motors
- Filtered air transfer for chemical, biological and radiological (NBC) requirements and / or electronics cooling and pneumatic rotary joint options for crew station breathing and electronic cooling
- High speed data capabilities

TYPICAL APPLICATIONS

- Tanks
- Light armored vehicles
- Armored personnel carriers
- Retrievers
- Armored field artillery vehicles
- Brigade command vehicles
- Reconnaissance vehicles
- Mobile missile launchers
- Independently rotating commander stations
- Forward-Looking-Infra-Red systems (FLIRs) or viewers

VEHICULAR SLIP RING DESIGN CRITERIA

Electrical slip rings are used in vehicles such as tanks, retrievers, light armored vehicles, mobile missile launchers, and armored personnel carriers. A typical vehicle might contain slip rings in the turret, the commander station and the infrared sight. In each of these systems, slip rings have provided reliable signal and power coupling under the most rugged battlefield conditions.

In addition to producing compact slip rings where minimal space is available, we have provided units that combine conventional electrical slip rings with resolvers, encoders, fiber optics, pneumatics and hydraulics rotary joints.

Design

Moog can offer the most valuable design assistance by being involved early in the development of the vehicle. The internal design of the slip ring capsule will be driven by the circuit requirements and the space available for mounting the slip ring capsule. From our vast product line, we can pull from the following design criteria:

- use of existing designs
- single drum
- concentric drums
- single pancake
- stacked pancakes
- combination of designs
- clear through-bore to allow another device to occupy the centerline
- connectors – case mounted or attached to cables
- mechanical support – on either side of the rotating interface

Power Circuits

Theoretically, there is no limit to the amount of power that can be transferred by the slip ring capsule. Most hull-to-turret slip ring capsules are capable of transferring 150 amps continuously. It is important that the power duty cycles (including surge currents) be accurately defined as early as possible in the design stage. (Requiring the slip ring capsule to operate at continuous current levels that will not be encountered in the field takes space that could be more effectively used for signal requirements.) If the space available for the slip ring capsule is limited, it may be advantageous to transfer the power at higher voltages and lower currents. The power ground can be made through the case of the slip ring capsule or insulated from case ground.

Signal Circuits

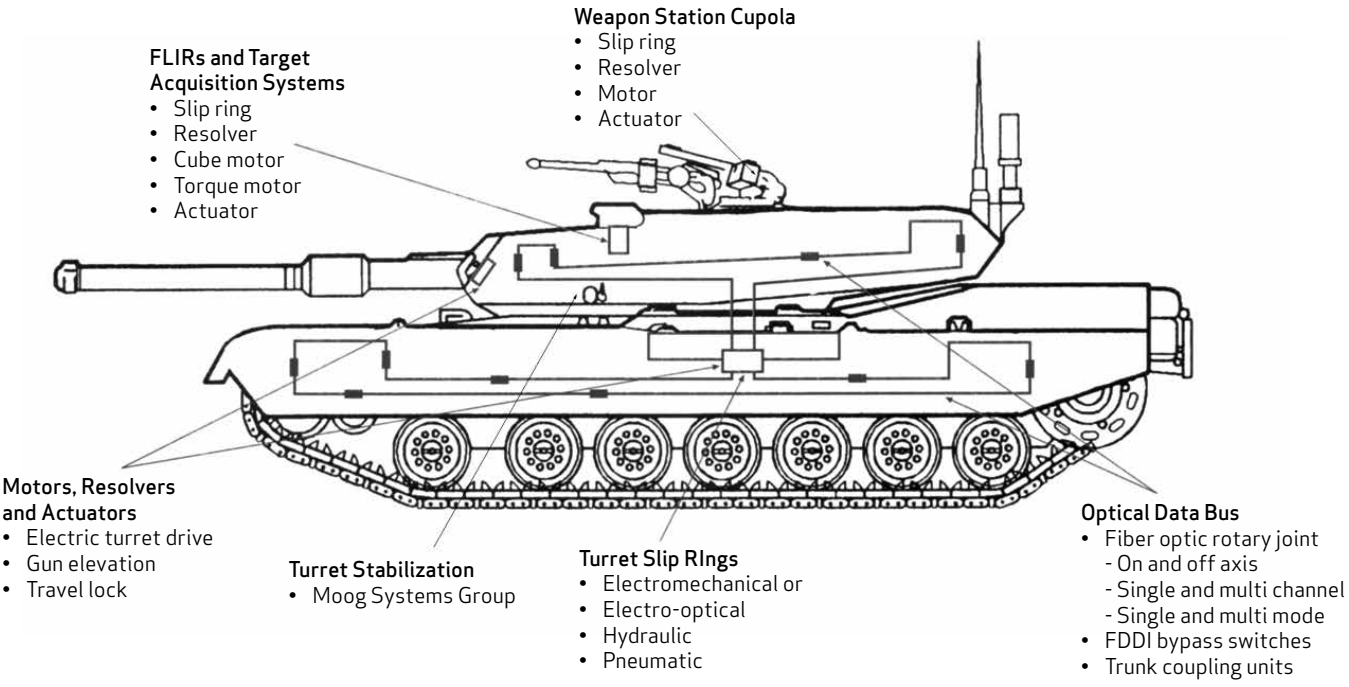
Signal requirements for vehicular slip ring capsules continue to be increasingly demanding. The circuit functions and electrical isolation requirements have a significant impact on the design of the slip ring capsule. A typical vehicular slip ring will include circuits for powering electronic equipment, video circuits, and analog and digital control circuits.

Sometimes it is important that sensitive circuits have additional isolation from other circuits to meet heightened sensitivity requirements. Circuit isolation requirements are more easily addressed early in the design stages.

Slip Ring Expertise

Vehicles such as tanks, retrievers, mobile missile launchers, light armored vehicles and armored personnel carriers pose a variety of challenges. Hydraulically-actuated equipment in the turret may require the combination of conventional electrical slip ring with a hydraulic joint to form an electro-hydraulic slip ring, thereby providing reliable fluidic interfacing. The threat of a NBC environment may require pneumatic channels through the slip ring to provide filtered air to crew members' face masks. The introduction of an independently rotating commander station or cupola may require a slip ring large enough in diameter to encompass the station, yet very thin in cross section to minimize space requirements. These advances in military technology, plus many others, have challenged the capabilities of the slip

COMPONENTS FOR VEHICULAR SYSTEMS



VEHICULAR SLIP RING DESIGN CRITERIA

ring industry, demanding equally sophisticated solutions for reliable vehicle operation.

Moog consistently meets these challenges successfully and economically. For more than 50 years we have been involved in the design, development, and production of quality slip rings for many diverse applications. Recognized as leaders in slip ring research and testing, our team of engineers, scientists, and manufacturing personnel have focused their total resources toward one goal—providing you with the best possible product.

To that end, we have:

- Established a complete Research & Development team, conducting numerous on-going studies in such areas as tribology — the science of friction, wear and high bandwidth communication.
- Studied the effect of environmentally-induced contaminants on slip ring contacts and made substantial progress in making slip rings more tolerant of hostile environments.
- Consolidated all of the functions of product design, tool design, manufacturing, and product testing into a well-integrated in-house operation certified to AS9100 Rev. C ISO 9001-2008.
- Combined field-proven slip ring designs with high-volume tooling techniques resulting in high quality hull-to-turret slip rings at attractive unit prices.
- Presented technical papers dealing with the field of electrical contacts and the applications of our technology to a diverse marketplace.

In view of our many years of applications experience and proven performance, it is easy to understand why our slip rings have been chosen to be used on numerous vehicular programs, including:

- APC
- 8x8
- M60 A1 and A2
- M728 CEV
- HSTV
- Centurion
- M2 and M3 Bradley
- Commando V150
- Leopard
- Stryker
- M48
- AAV
- LAV
- Bionix

The following table presents a cross-section of our vehicular designs. These products are for reference purposes only. Please contact the factory concerning your requirements. Tooling charges may apply.

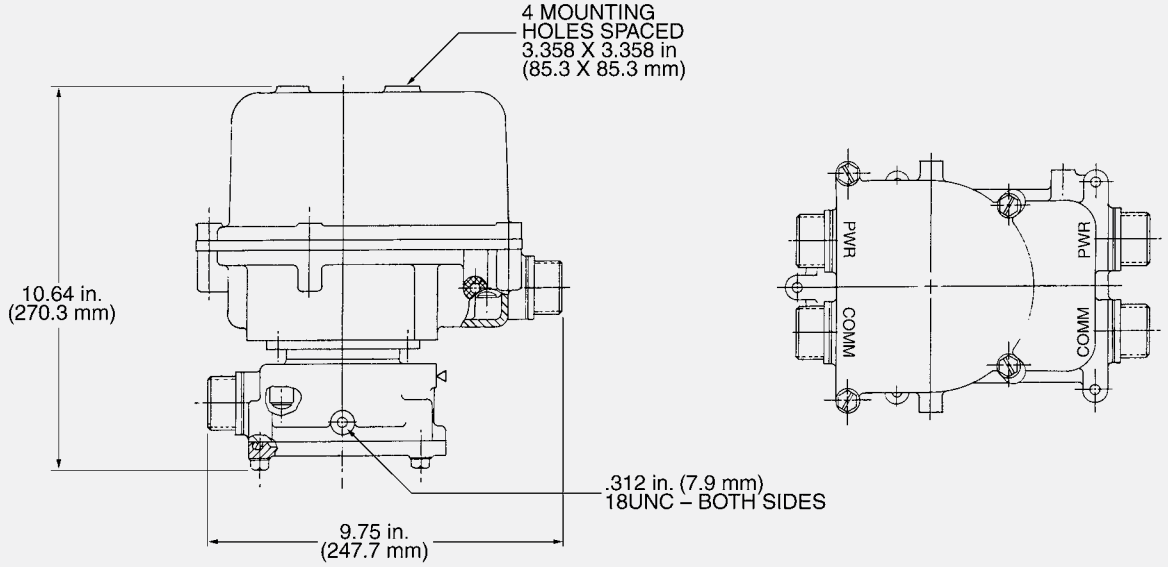
VEHICULAR AND TURRET SLIP RING SPECIFICATIONS

	POWER			SIGNAL			
Vehicular Slip Ring	No. of Circuits	Cont. Current Rating	Voltage Rating	No. of Circuits	Gauge or Type	Intended Signal	Comments
AC3497	1	150 amps	Ground	12	Control	5 amps, 150 V	2 cam design for dual fire control Variations available
AC6033	1	150 amps	Ground	18	Control	5 28 VDC	Dual cam NBC air channel Variations avai able
VSR-3733	2	200 amps	24 VDC	42	20 AWG	3 amps, 28 VDC	NBC air channel Size similar to VSR4994
VSR-4906	2	200 amps	24 VDC	61	20 AWG	3 28 VDC, 28 VDC	NBC air channel Size similar to VSR4994
VSR-4994	4	200 amps	24 VDC	86	24 AWG	2 - 4 amps, 28 VDC	NBC air channel (2) 1553 Data-bus (8) RS-170 Video
VSR-6057	2	250 amps	18 - 37 VDC	238	24 AWG	2 - 4 28 VDC, 28 VDC	EMI features concentric rings and high isolation
VSR-6772	2	450 amps 75 amps	28 VDC	150	28 AWG	100 Mbit Ethernet	Contains resolver, R to D network, power distribution network and pneumatic and hydraulic rotary joint
VSR-2000	2	50 amps	250 VDC	12 or 24		10 amps, 250 VDC	High current and alternate signal configurations available
VSR-7001	2 4 4 11	150 amps 120 amps 80 amps 13 amps	20 - 33 VDC	32 18 6 13 4	22 AWG 24 AWG 28 AWG Twinax MIL-C-17 / 94 28 AWG Twinax	5 amps, 20 - 33 VDC 3 amps, 20 - 33 VDC Serial Data RG-179 Gigabit Ethernet	Gigabit ethernet channels Immersible to 1 meter (2) RS-170 video Air channel

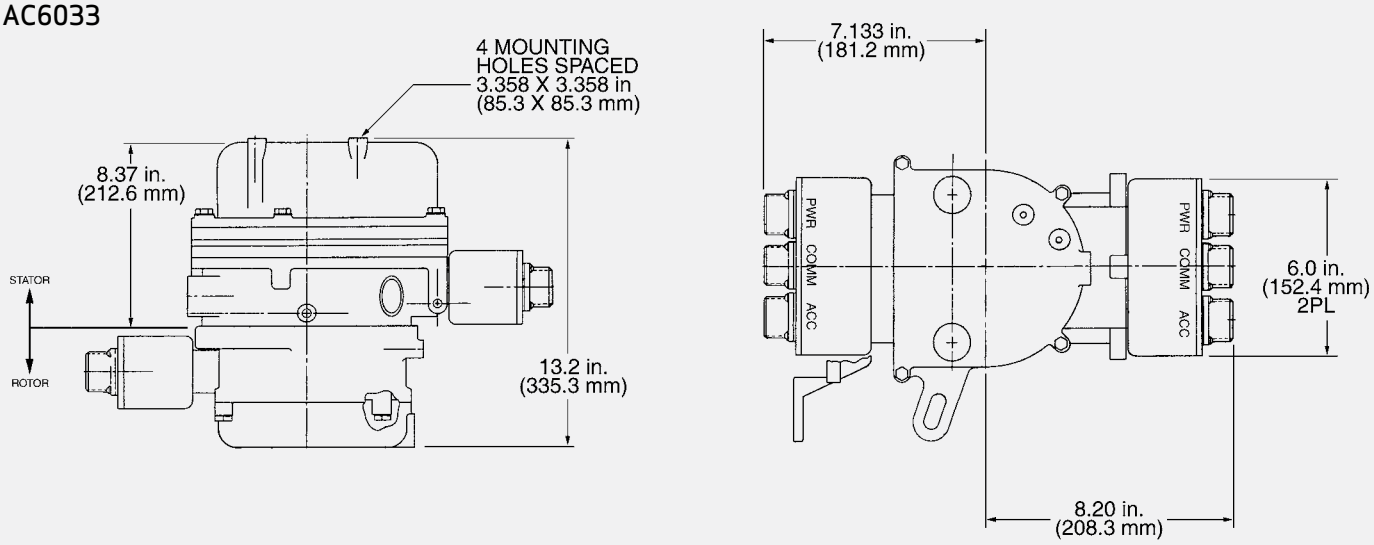
VEHICULAR SLIP RING DESIGN CRITERIA

MECHANICAL DIMENSIONS INCHES (MILLIMETERS)

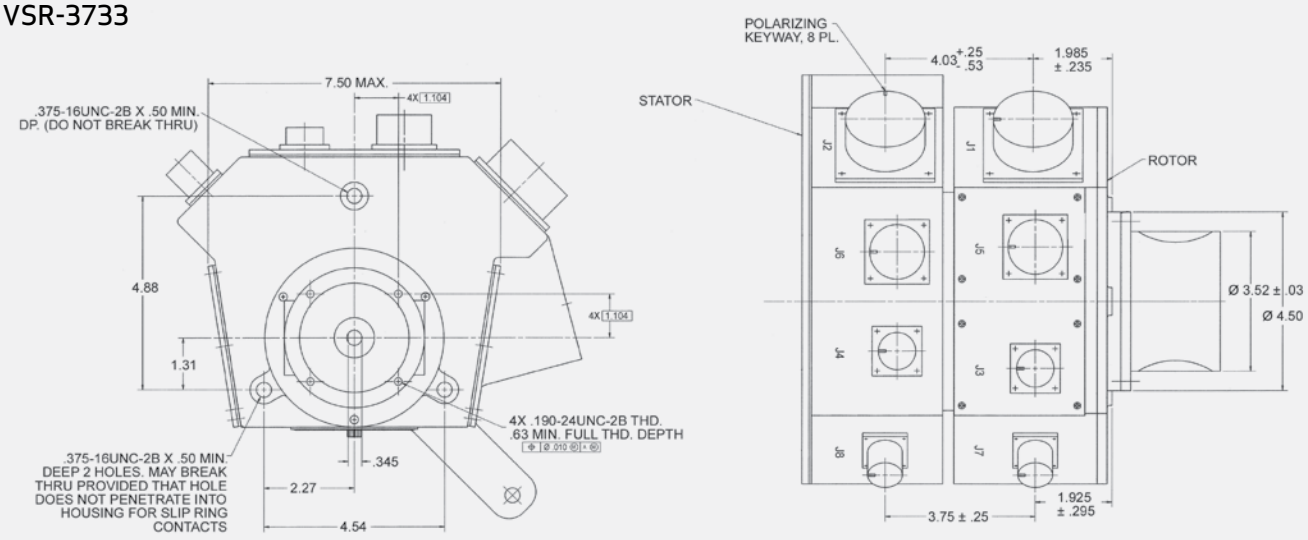
AC3497



AC6033



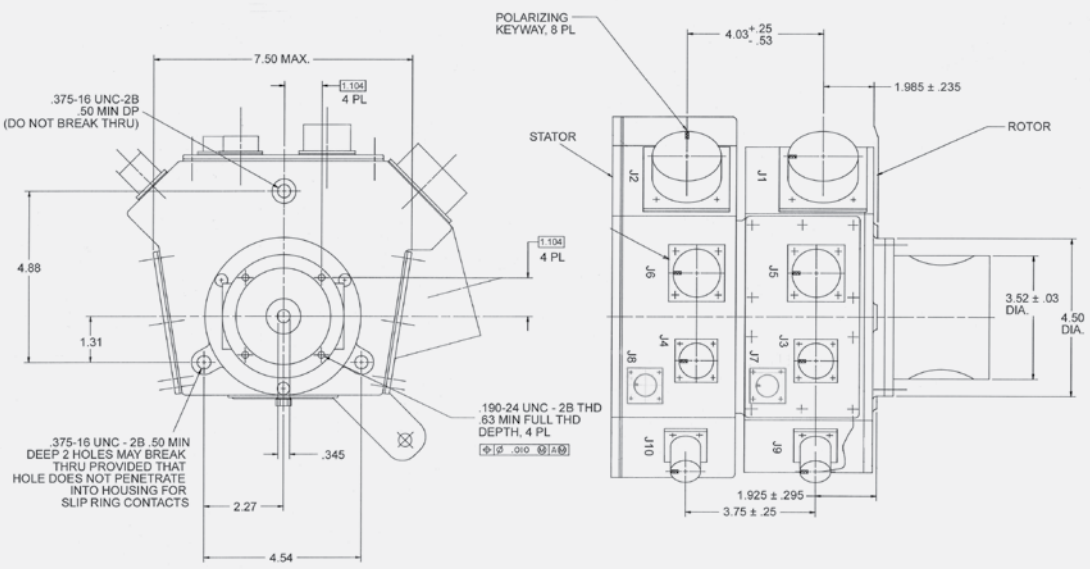
VSR-3733



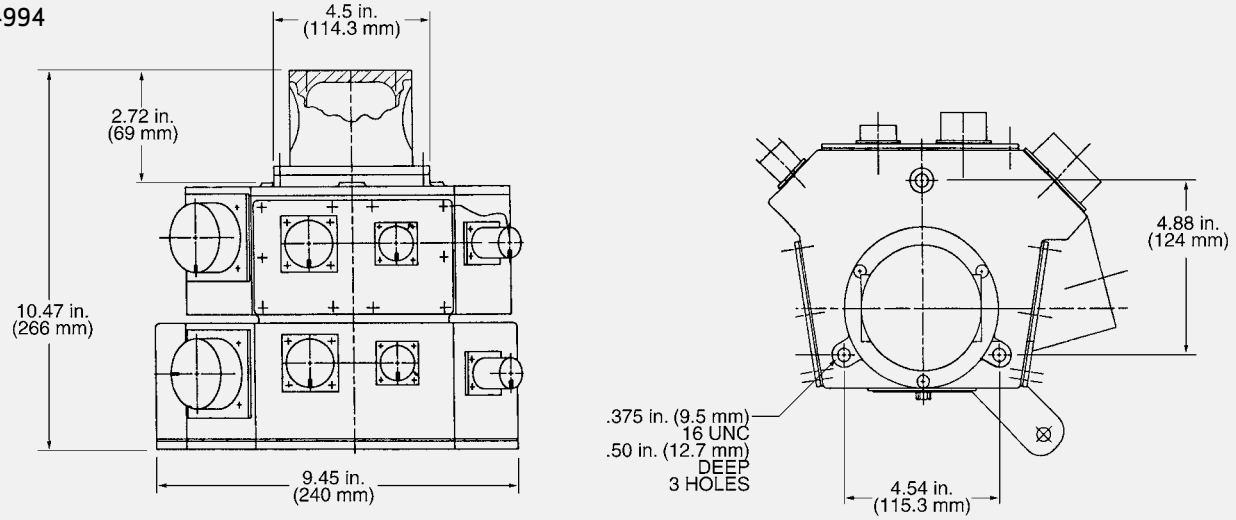
VEHICULAR SLIP RING DESIGN CRITERIA

MECHANICAL DIMENSIONS INCHES (MILLIMETERS)

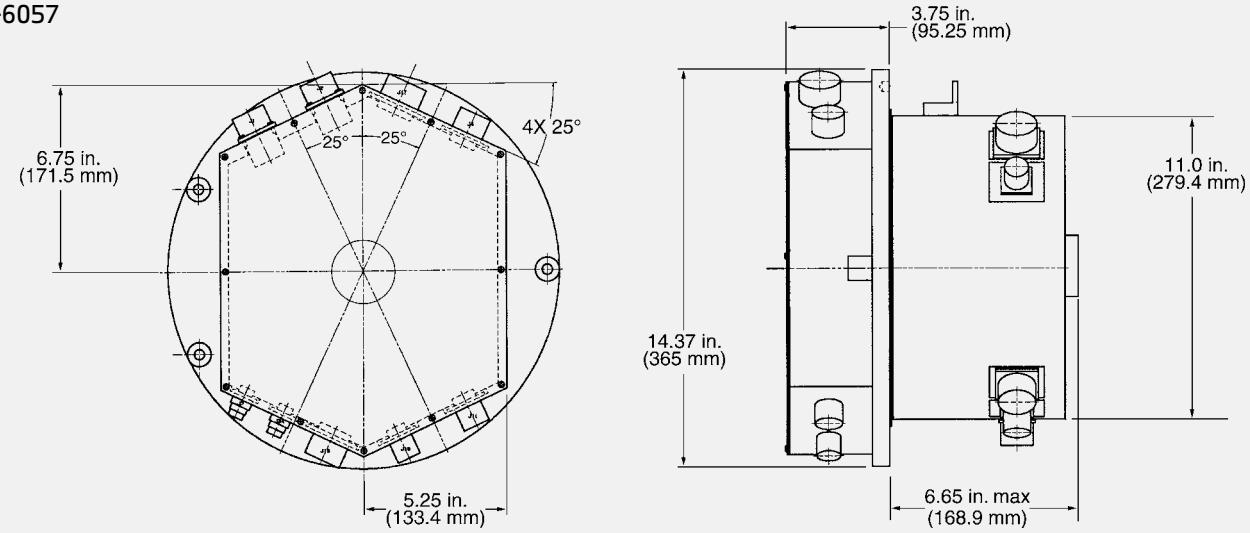
VSR-4906



VSR-4994



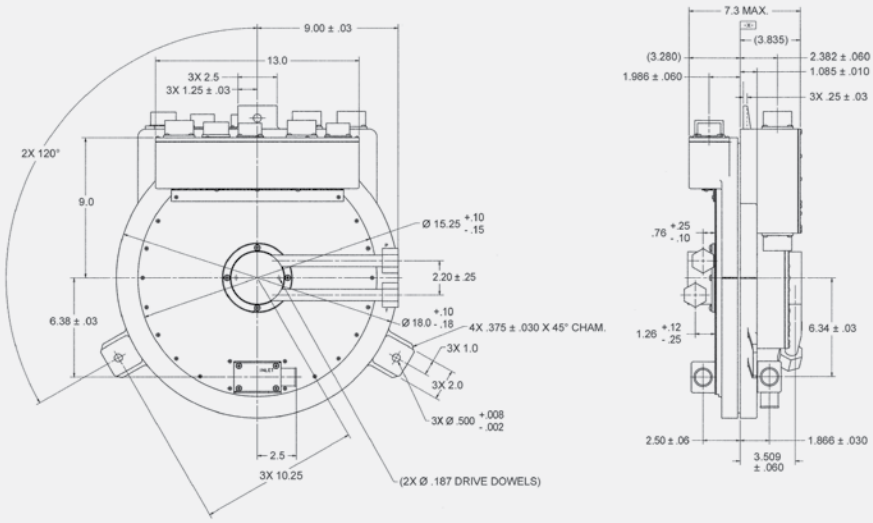
VSR-6057



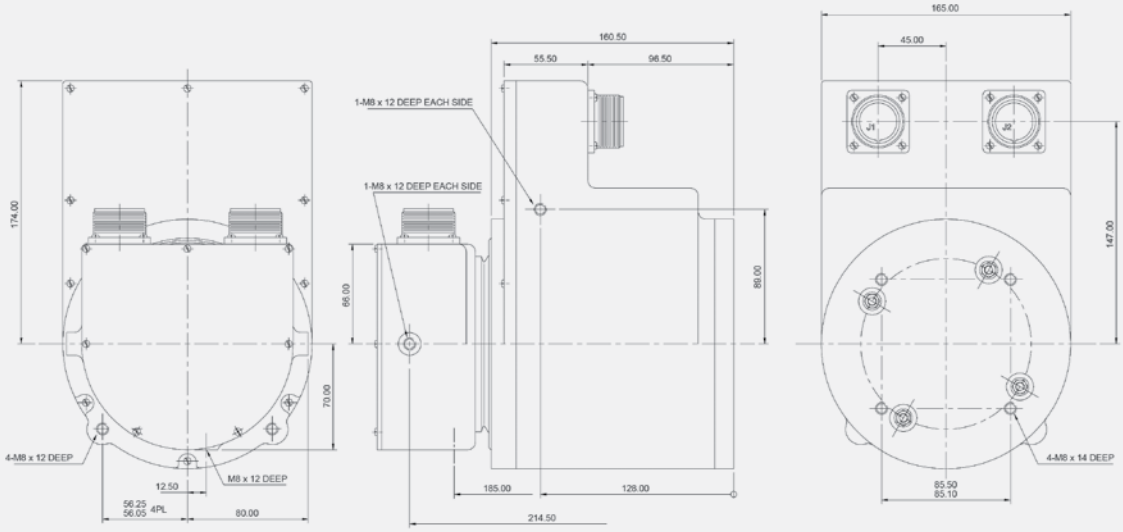
VEHICULAR SLIP RING DESIGN CRITERIA

MECHANICAL DIMENSIONS INCHES (MILLIMETERS)

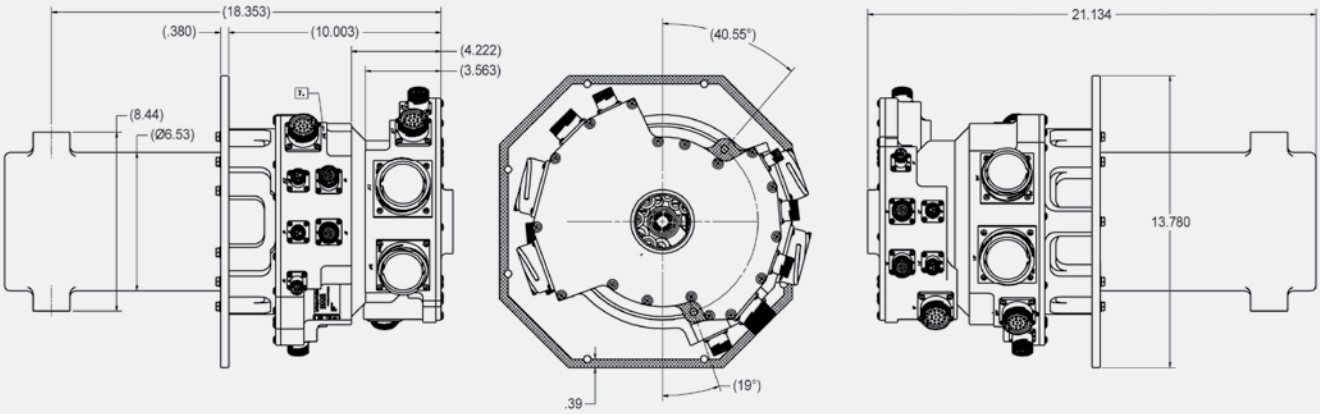
VSR-6772

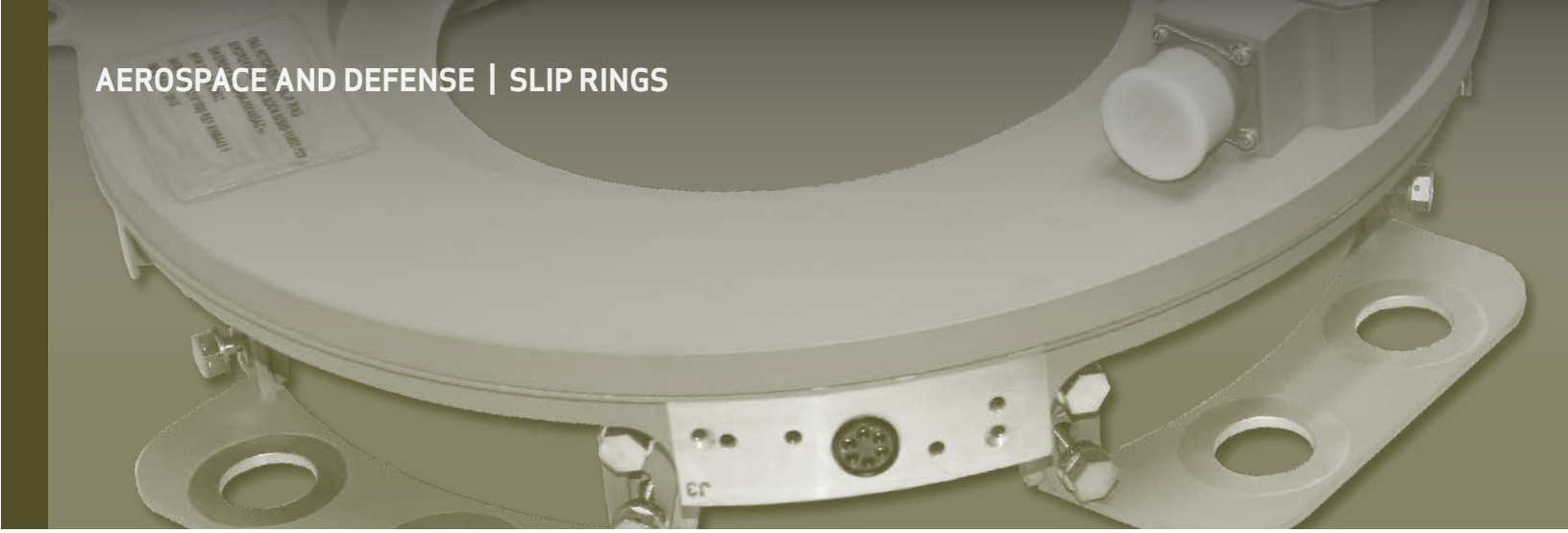


VSR-2000



VSR-7001





HELICOPTER SLIP RINGS

PROVEN RELIABILITY IN THE MOST DEMANDING OF APPLICATIONS AND ENVIRONMENTS

Today's rotorcraft applications place unique demands on slip ring technology because of equipment requirements and environmental conditions. From de-ice applications (with their need for high rotational speed, exposure to weather conditions and high vibration) to weapon stations and electro-optic sensor systems (with high bandwidth signal transmission), helicopter slip rings must perform in a highly reliable mode with the latest product advancements.

Our many years of experience in this arena has allowed Moog to be a leader in slip ring technology for rotorcraft applications. Employing a combination of precious metal fiber and composite brush technology for signal and power transfer, we are qualified to meet the most demanding applications effectively and economically. Contact us with your requirements so we can help you find a solution.

FEATURES

- Multiple contact technologies suited for the application
  - Monofilament wire brush
  - Multiple precious metal fiber brush
  - Composite brush
- Environmental sealing
- EMI Shielding
- FEA structure analysis
- High shock and vibration capabilities
- Wide operating temperature envelope
- Vertical integration of position sensors and ancillary products
- High frequency bandwidth
- High reliability and life
- Redundant bearing designs

TYPICAL APPLICATIONS

- Blade de-ice
- Blade position
- Tip lights
- Flight controls
- FLIR systems
- Target acquisition systems
- Weapon stations

HELICOPTER SLIP RING DESIGN CRITERIA

Electrical slip rings are used in helicopter, tilt-rotor and rotorcraft applications for a variety of applications. Historically, slip rings were initially intended for use in blade de-ice and tip-light applications where electrical power was required for the main and tail rotor blades. Today, with the advent of tilt-rotor aircraft, slip rings are transmitting flight control and blade position data. Reliability and data integrity has never been more important.

Advanced aircraft now carry infrared and electro-optic sensors, target acquisition systems and weapon stations requiring unrestrained rotation. As a result, slip rings (and our related motion technology components) play a much broader and important role.

In addition to producing compact, light weight and highly reliable slip rings, we have provided units that combine conventional electrical slip rings with resolvers, encoders, fiber optic rotary joints and other commodities.

Design

Moog can offer the most valuable design assistance by being involved early in the development of the aircraft and related subsystems. The internal design of the slip ring capsule will be driven by the circuit requirements, need for ancillary products and the space available for mounting the slip ring capsule. We can offer the following design criteria:

- Use of existing designs
- Single drum
- Concentric drums
- Single pancake
- Stacked pancakes
- Combination of designs
- Clear through-bore to allow for another device or bearing structure
- Connectors – case mounted or attached to cables
- Mechanical support – on either side of the rotating interface including the stand pipe

Power Circuits

Theoretically, there is no limit to the amount of power that can be transferred by the slip ring assembly. Most rotorcraft de-ice slip rings carry less than 100 amperes of current. It is important that the power duty cycle be defined as early as possible in the design stage. Thermal design requirements can affect other design parameters. If the space available for the slip ring capsule is limited, it may be advantageous to transfer the power at higher voltages. Power can be grounded either through the case of the slip ring or insulated from the case.

Signal Circuits

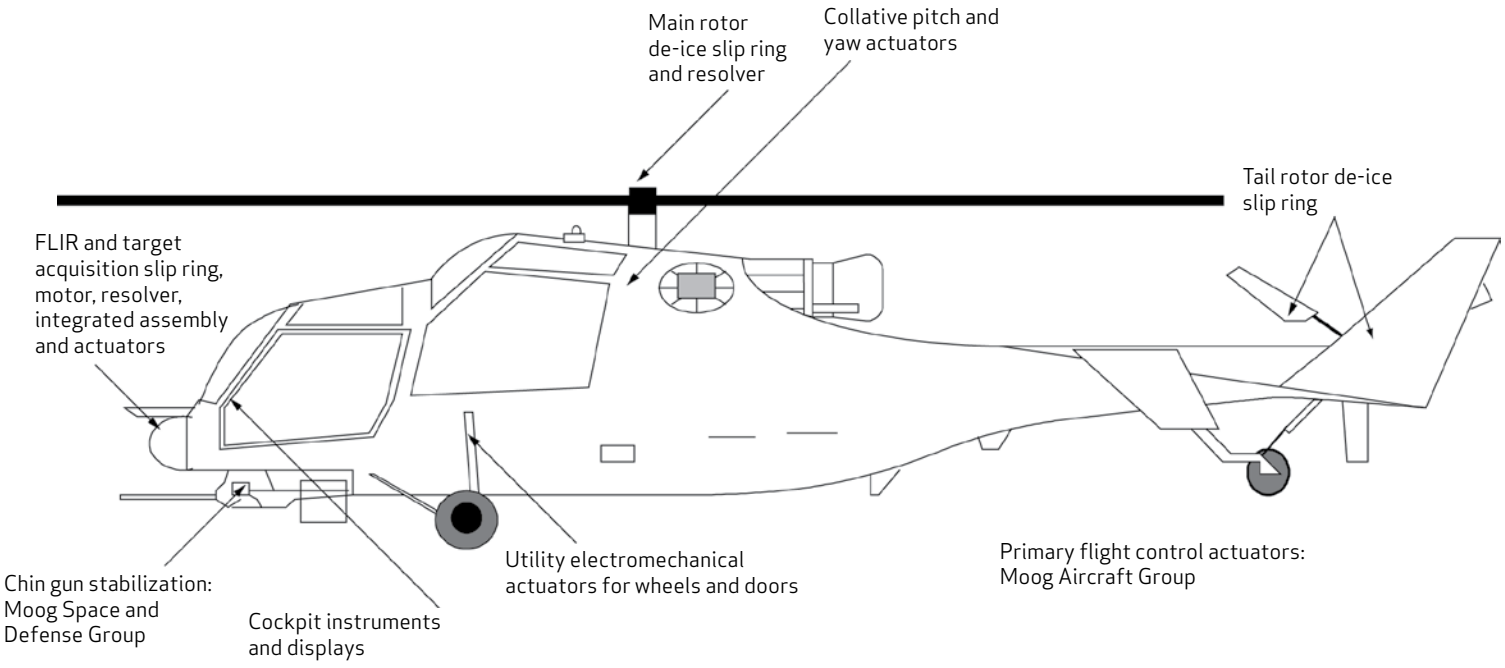
Signal requirements for a rotorcraft slip ring capsule continues to be increasingly demanding, particularly with the advent of tiltrotor aircraft, electro-optics and target acquisition systems. The circuit functions and electrical isolation requirements have a significant impact on the design of the slip ring. While a de-ice system has few signal requirements, tiltrotor aircraft require flight control circuitry and electro-optic sensors often requiring high-bandwidth video, analog and digital control circuitry.

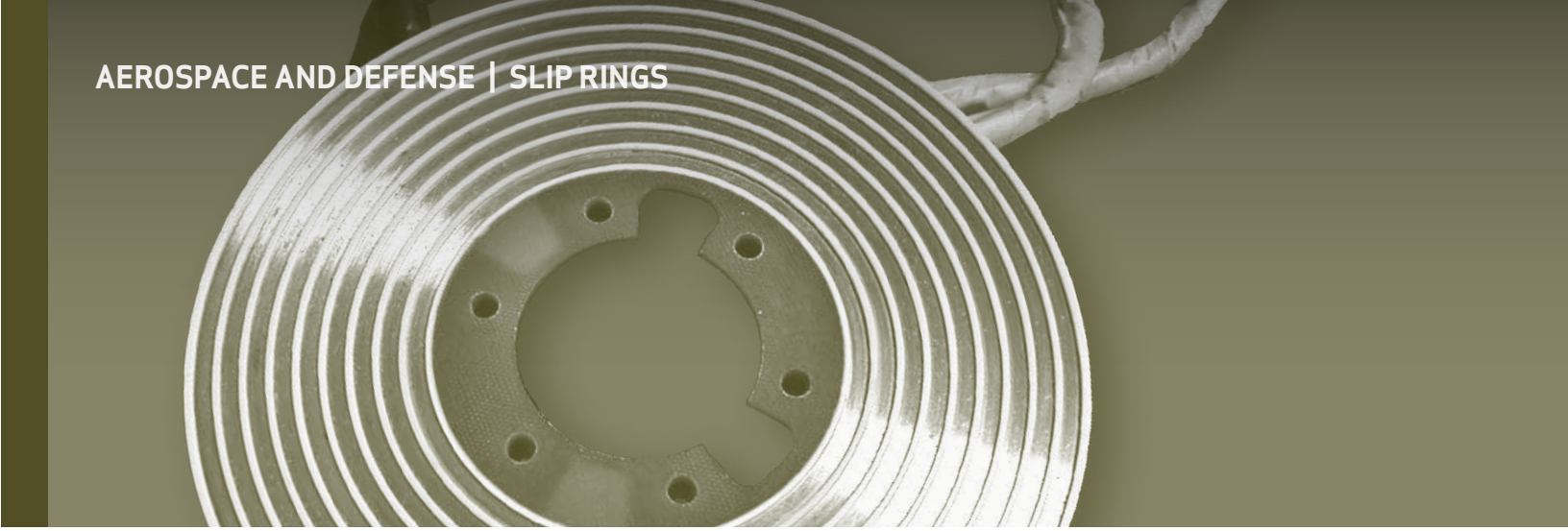
It is often important that sensitive circuits have additional isolation from other circuits and impedance matching for high bandwidth. Such requirements can be much better addressed early in the design stages.

Slip Ring Experience

Rotorcraft applications pose a variety of design challenges. High vibration, harsh environments and high reliability demands products from a proven supplier. Moog has a long history of supplying slip ring and motion technology (motors, resolvers, fiber optic and subsystem) products to the rotorcraft industry. Current fielded systems include Apache, Blackhawk, Seahawk, EH-101, S-92, V-22, CV-22 and BA-609 to name a few. Let us put our experience to work for your next rotorcraft application.

COMPONENTS FOR HELICOPTER SYSTEMS





PROPELLER SLIP RINGS

Fixed wing propeller aircraft use special de-icing slip rings to pass electrical power from the airframe generators to the rotating propellers. These propellers are heated to avoid the build up of ice either in flight or on the ground in difficult weather conditions.

The correct choice of materials for the rings and brushes, together with a very fine surface finish on the rings themselves, ensure the optimum life of the unit in operation. The life time is generally in excess of 1500 hours at 1200 rpm – equivalent to >100 million revolutions, with only a simple maintenance operation to change the brushes and brush block.

Units are designed for each application in conjunction with the customers' requirements.

Typically these slip rings are supplied to the Propeller system manufacturer.

Moog pedigree extends over many years and the following programmes are examples of where our products are used :

- Jetstream
- Fokker 50
- SAAB 340
- Grumman
- SAAB 2000
- De Havilland Dash 8
- Lockheed Martin C130J
- ATR42
- Airbus A400M

FEATURES

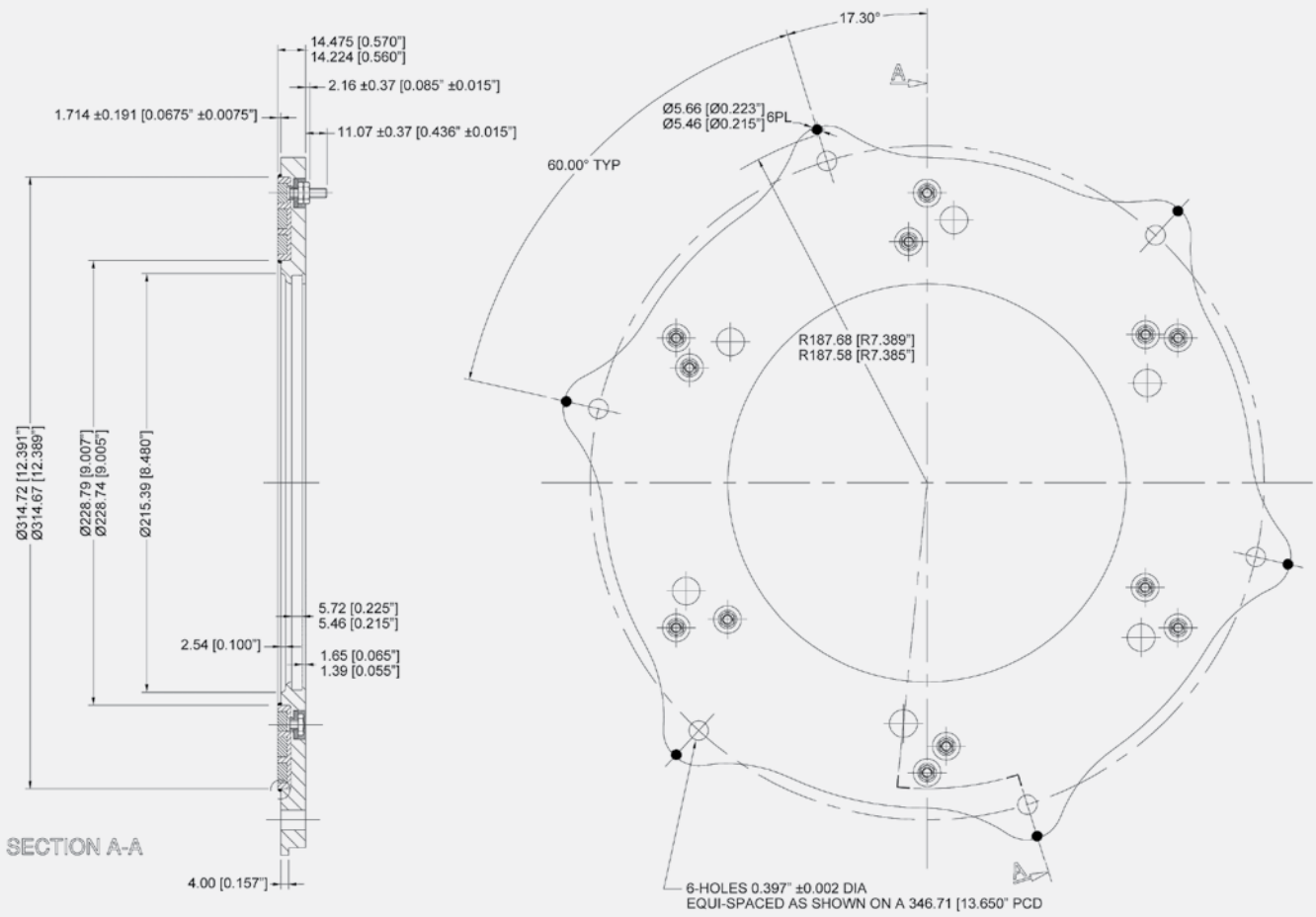
- Low brush wear
- Integrated rings and housings
- Beryllium free design
- Low maintenance solution, replaceable brushes
- Diamond turned finish on the slip ring

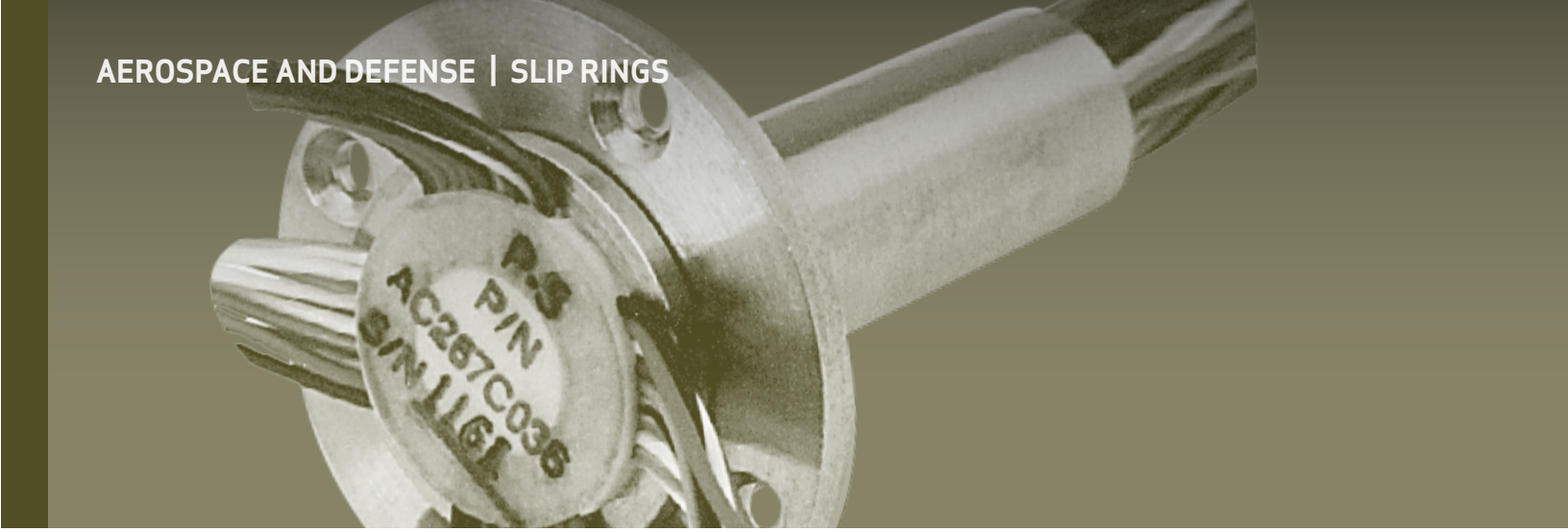
TYPICAL APPLICATIONS

- Blade de-ice

PROPELLER SLIP RING DIMENSIONS

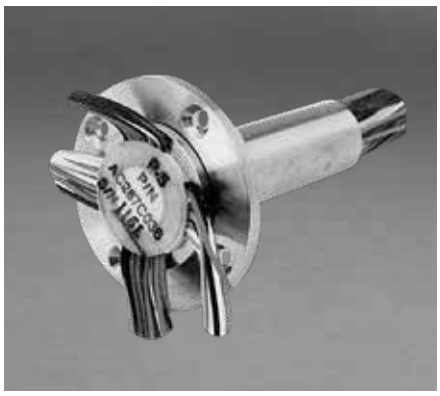
TYPICAL PROPELLER SLIP RING DIMENSIONS MILLIMETERS (INCHES)





MODEL AC264 / AC267 MINIATURE SLIP RINGS

MINIATURE CAPSULES IN VARIOUS CIRCUIT CONFIGURATIONS



A slip ring capsule can be used in any electromechanical system that requires unrestrained, intermittent or continuous rotation while transferring power and / or data.

Miniature slip ring capsule assemblies economically address both critical space and weight limitations. Each assembly includes the rotor, brush blocks, frame, ball bearings and dust cover. Existing designs are available or we can custom design slip rings to meet your specific requirement.

Although originally designed for commercial uses, the miniature slip ring capsule is well suited for many military applications.

FEATURES

- Rugged stainless steel housing
- Up to 60 rings can be packaged in a self-contained envelope 1.957 inch long and .50 inch barrel diameter
- Gold-on-gold sliding contact technology
- Up to 100 rpm operation
- Low noise; as low as 25 milliohms
- Long life. Several million total revolutions at speeds up to 60 rpm have been obtained.

TYPICAL APPLICATIONS

This slip ring provides high speed performance and is successfully serving in various applications such as:

- Gimballed pitch, roll and yaw axes of inertial navigation systems
- Unmanned Aerial Vehicles (UAV)

BENEFITS

- Precise, tight packaging capabilities for meeting stringent design criteria
- Proprietary plating techniques provide improved reliability, longer life and increased efficiency
- Unique signal handling performance to minimize noise and increase speed
- Configuration flexibility allows for packaging from 16 to 60 circuits

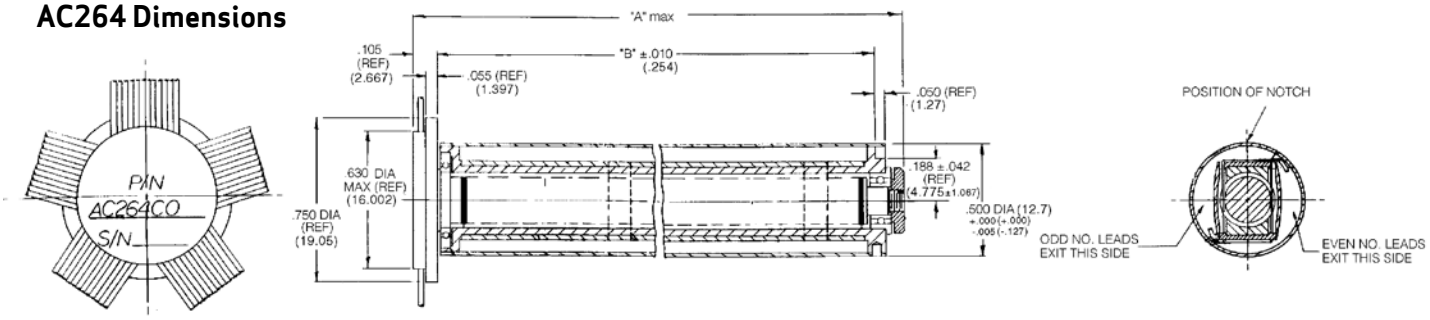
AC264 / AC267 SPECIFICATIONS

AC264 SPECIFICATIONS

Modular	"A" Inches
Current Rating	.8 amp per circuit
Lead Size	30 AWG
Dielectric Strength	500 VAC (test)
Insulation Resistance	1000 mohms @ 500 VDC
Circuit Resistance	265 mohms with 12 in. leads both ends
Starting Torque	2 grams-centimeters max. per circuit
Noise	50 mohms tested @ 5 rpm test current 50 MA

No. of Circuits	"A" Dimension	"B" Dimension
20	1.04 (26.3)	0.757 (19.2)
30	1.34 (33.9)	1.057 (26.8)
40	1.64 (41.5)	1.357 (34.5)
50	1.94 (49.1)	1.657 (42.1)
60	2.24 (56.8)	1.957 (49.7)a

AC264 Dimensions



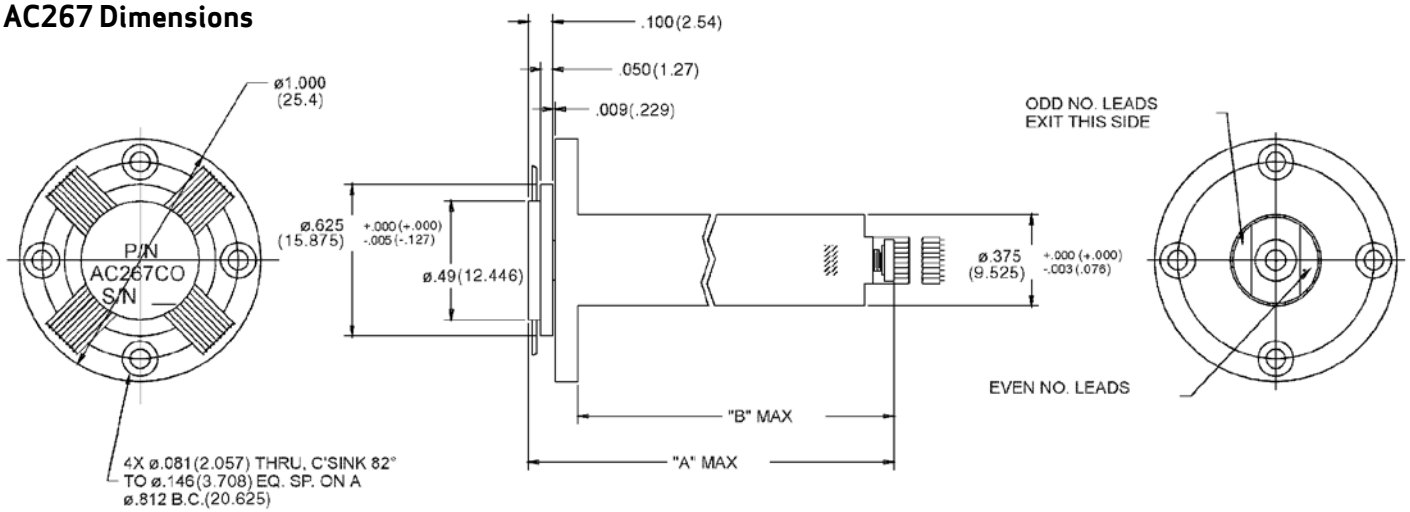
Dimensions in inches (millimeters)

AC267 SPECIFICATIONS

Modular	"A" Inches
Current Rating	.8 amp per circuit
Lead Size	30 AWG
Dielectric Strength	500 VAC (test)
Insulation Resistance	1000 mohms @ 500 VDC
Circuit Resistance	270 mohms with 12 in. leads both ends
Starting Torque	1.5 grams-centimeters max. per circuit
Noise	25 mohms tested @ 5 rpm test current 100 MA

No. of Circuits	"A" Dimension	"B" Dimension
16	1.04 (26.3)	0.757 (19.2)
20	1.34 (33.9)	1.057 (26.8)
24	1.64 (41.5)	1.357 (34.5)
28	1.94 (49.1)	1.657 (42.1)
32	2.24 (56.8)	1.957 (49.7)a
36	1.51 (38.4)	1.31 (33.2)

AC267 Dimensions



Dimensions in inches (millimeters)

RE4815 MINIATURE SLIP RING CAPSULE

A slip ring capsule can be used in an electromechanical application to transfer low power and data over a continuous rotary interface, eliminating the need for wrapped cables. The RE4815 provides highly compact packaging to 32 conductors in a very small 1/2 inch diameter housing with an overall length of less than 1-3/8 inches.

FEATURES

- Compact for ease of incorporation in small mechanisms
- 32 rings with excellent signal handling properties as well as low power transfer
- Gold-on-gold contact technology
- Up to 600 rpm operation
- Low electrical noise

BENEFITS

- Highly compact to keep mechanisms small
- Outstanding signal handling capability to transfer the most demanding communication protocols
- Proprietary plating techniques and materials for high performance and reliability
- Rugged stainless steel housing for demanding environments

TYPICAL APPLICATIONS

- Gimbal systems
- UAV camera systems
- Positioning tables
- Laboratory equipment

RE4815 SPECIFICATIONS

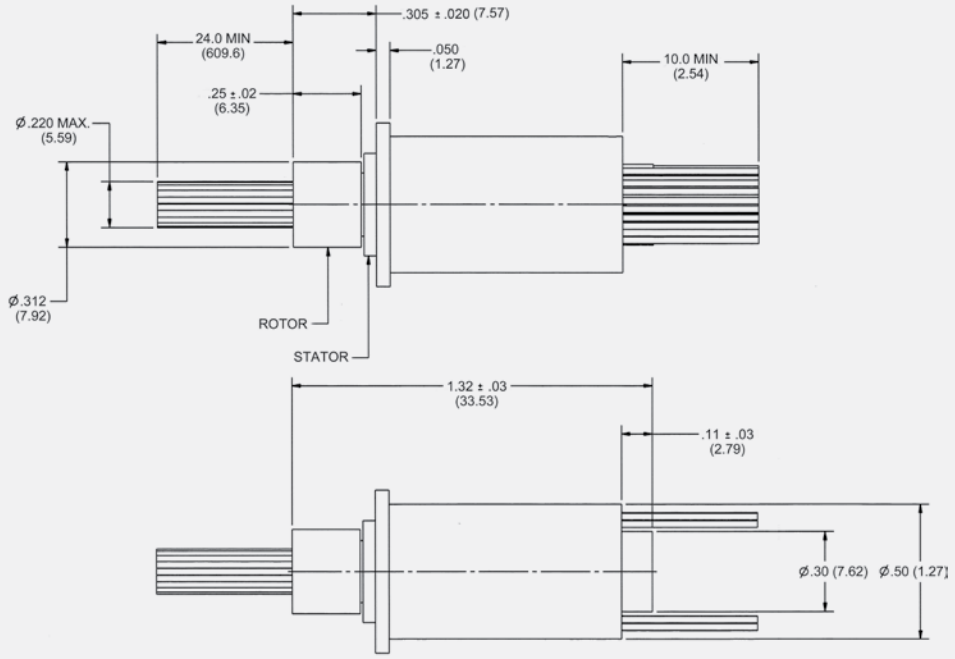
MOTOR CHARACTERISTICS

Specification	Units
Current Rating	1 A per circuit
Operational Voltage	50 VAC / VDC
Lead Size	30 AWG (19 / 42 SPC, Teflon® insulation)
Starting Torque	50 gm cm
Electrical Noise	50 milliohms maximum tested @ 6 VDC 50 milliamps when running @ 130 rpm
Operational Temperature	80°C maximum
Rotational Speed	600 rpm
Circuit Resistance	900 milliohms maximum
Enclosure	Stainless steel

LEAD COLOR CODES

??	??	??	??	??	??	??	??
1	BLK	9	GRY	17	WHT/BLU	25	WHT/BLK/BLU
2	BRN	10	WHT	18	WHT/VIO	26	WHT/BLK/VIO
3	RED	11	WHT/BLK	19	WHT/GRY	27	WHT/BLK/GRY
4	ORN	12	WHT/BRN	20	WHT/BLK/BRN	28	WHT/BRN/RED
5	YEL	13	WHT/RED	21	WHT/BLK/RED	29	WHT/BRN/ORN
6	GRN	14	WHT-ORN	22	WHT/BLK/ORN	30	WHT/BRN/YEL
7	BLU	15	WHT/YEL	23	WHT/BLK/YEL	31	WHT/BRN/GRN
8	VIO	16	WHT/GRN	24	WHT/BLK/GRN	32	WHT/BRN/BLU

MECHANICAL DIMENSIONS (INCHES)



AC6292 MINIATURE SLIP RING CAPSULE

A slip ring capsule can be used in any electromechanical system that requires unrestrained, occasional or continuous rotation while transferring power and / or data.

Miniature slip ring capsule assemblies economically address both critical space and weight limitations. Each assembly includes the rotor, brush blocks, frame, ball bearings and dust cover.

These slip rings can be configured with spacing between rings of 0.006 inch and brush diameters no larger than a human hair. Existing designs are available or we can custom design slip rings to meet your specific requirement.

FEATURES

- Center-to-center adjacent ring spacings as small as 0.015 inch can be obtained
- 80 rings packaged in a self-contained envelope 2.0 inches long and .68 inch barrel diameter
- Gold-on-gold sliding contact technology
- Up to 40 rpm operation
- Low noise; as low as 15 milliohm per circuit pair
- Long life; several million total revolutions have been obtained

BENEFITS

- Precise, tight packaging capabilities for meeting stringent design criteria
- Proprietary plating techniques provide improved reliability, longer life and increased efficiency
- Unique signal handling performance to minimize noise and increase speed
- Other configurations are available from 16 to 95 circuits
- We also manufacture commercial slip rings from 6 to 56 circuits

TYPICAL APPLICATIONS

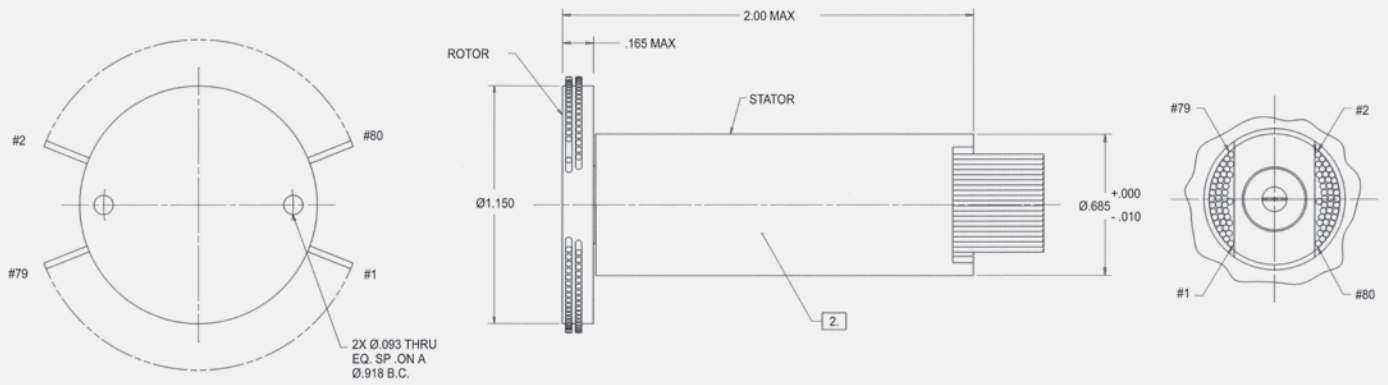
- Gimballed pitch, roll and yaw axes of inertial navigation systems
- Unmanned Aerial Vehicles (UAV)
- Airborne camera platforms

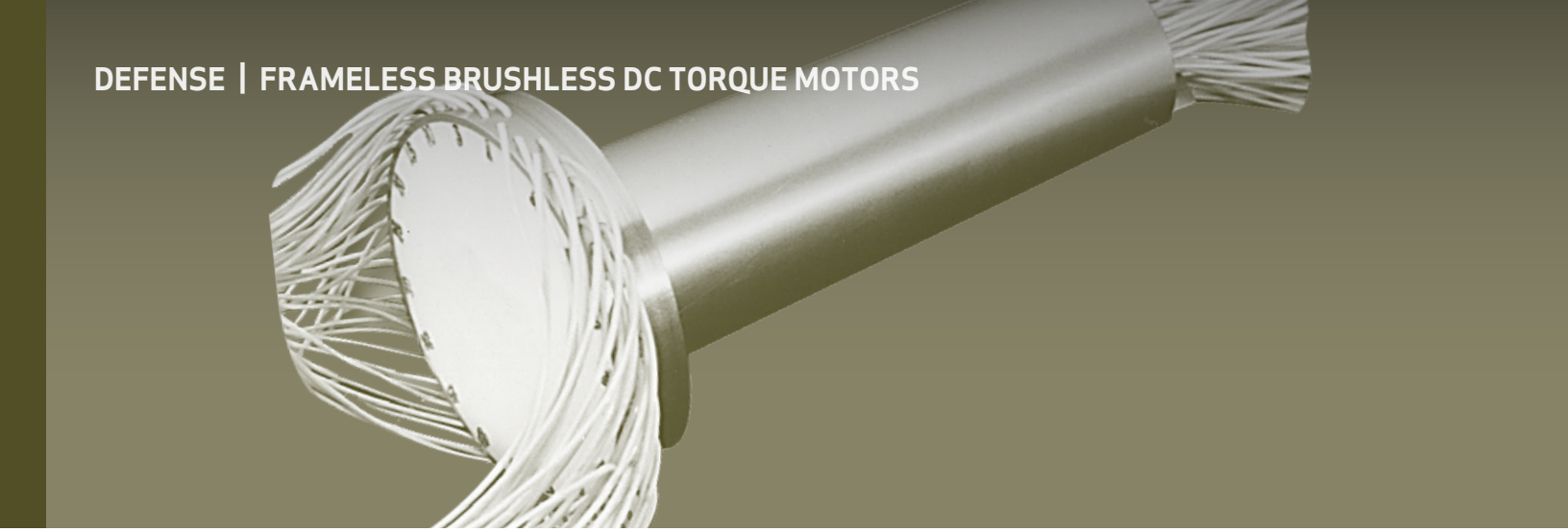
AC6292 SPECIFICATIONS

MOTOR CHARACTERISTICS

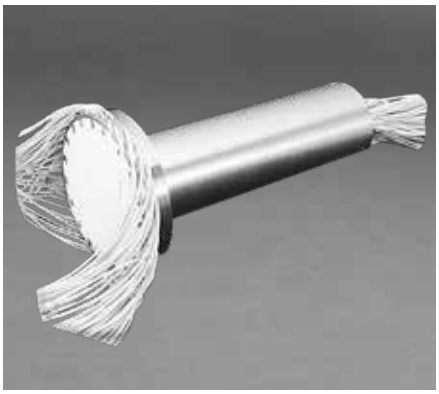
Specification	Value
Lead Size	30 AWG / 26 AWG
Dielectric Strength	500 VAC (test)
Insulation Resistance	1000 megohms
Circuit Resistance	0.54 ohms (leads @ 24 in.)
Starting Torque	240 gm cm
Noise	30 milliohms max.
Rotational Speed	40 rpm max.
Lead Length	24 inches each end

MECHANICAL DIMENSIONS (INCHES)





RK4288 MINIATURE SLIP RING CAPSULE



A slip ring capsule can be used in any electromechanical system that requires unrestrained, occasional or continuous rotation while transferring power and / or data.

Miniature slip ring capsule assemblies economically address both critical space and weight limitations. Each assembly includes the rotor, brush blocks, frame, ball bearings and dust cover.

These slip rings can be configured with spacing between rings of 0.015 inch and brush diameters no larger than a human hair.

Existing designs are available or we can custom design slip rings to meet your specific requirement.

FEATURES

- Center-to-center adjacent ring spacings as small as 0.015 inch can be obtained
- 95 rings packaged in a self-contained envelope 3.3 inches long and 1.5 inch barrel diameter
- Gold-on-gold sliding contact technology
- Up to 40 rpm operation
- Low noise; as low as 15 milliohm per circuit pair
- Long life; several million total revolutions have been obtained

BENEFITS

- Precise, tight packaging capabilities for meeting stringent design criteria
- Proprietary plating techniques provide improved reliability, longer life and increased efficiency
- Unique signal handling performance to minimize noise and increase speed
- Other configurations are available from 16 to 80 circuits
- We also manufacture commercial slip rings from 6 to 24 circuits

TYPICAL APPLICATIONS

This slip ring provides high speed performance and is successfully serving in applications such as:

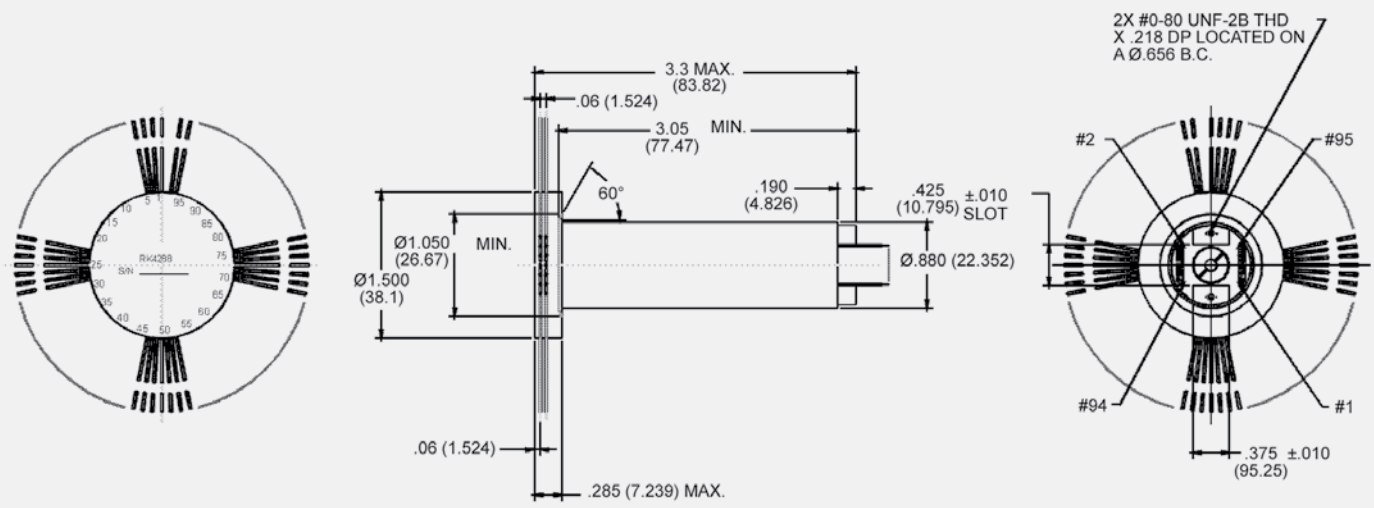
- Gimballed pitch, roll and yaw axes of inertial navigation systems
- Satellite de-spin assemblies
- Deep earth drilling projects
- Unmanned Aerial Vehicles (UAV)
- Airborne camera platforms

RK4288 SPECIFICATIONS

MOTOR CHARACTERISTICS

Specification	Value
Current Rating	0.8 amp per circuit
Lead Size	30 AWG
Dielectric Strength	500 V (test)
Insulation Resistance	1000 Mohms @ 500 VDC
Circuit Resistance	0.54 ohms (leads @ 24 in.)
Starting Torque	240 gm cm
Noise	30 milliohms max.
Rotational Speed	40 rpm max.
Lead Length	24 inches each end

MECHANICAL DIMENSIONS (INCHES)



RK4288 SPECIFICATIONS

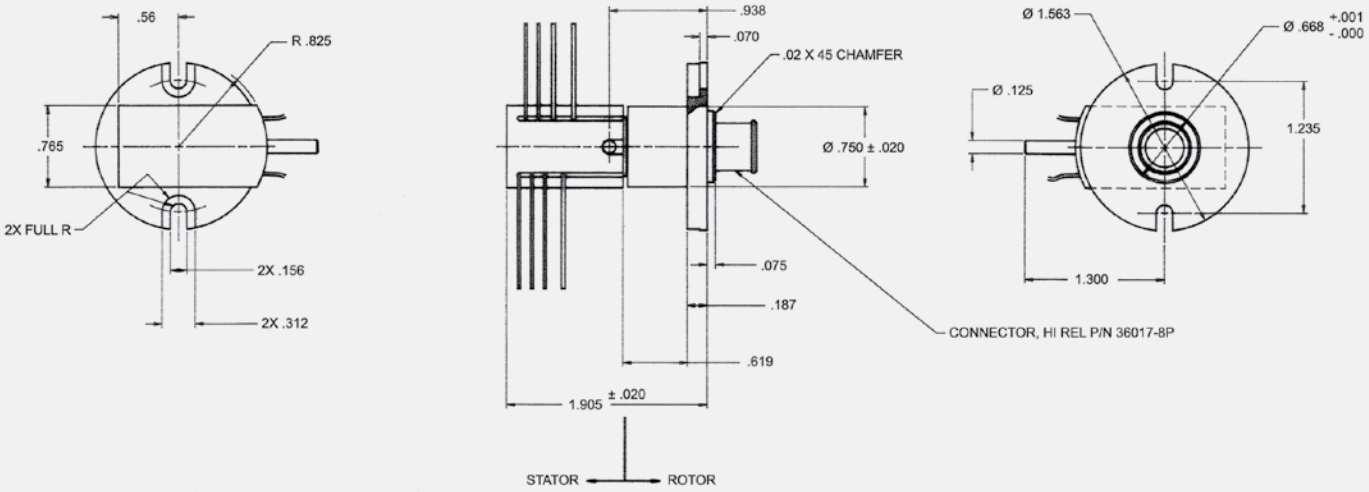
LEAD COLOR CODES

Part Number	No. of Ckts.	Signal	Power	Length (inch)	O.D. Housing (inch)	O.D. Flange (inch)	Other
RT4922	5	5 @ 1A	0	1.10	0.47	0.87	1 segmented circuit
SJ4834	8	5 @ 1A	3 @ 4A	1.90	0.75	1.56	Integral rotor connector
JJ6095	15	15 @ 1A		1.1	1.0	1.4	O'ring, sealed bearing, fiber brush
GS2725	29	23 @ 0.5A	6 @ 2A	0.83	0.39	1.24	Lead length is 11 in. min.
RE4815	32	32 @ 1A	0	1.32	0.50	0.60	Lead length is 24 in. rotor & 12 in. stator
GS2388	38	38 @ 1A	0	1.0	0.41	1.26	Rotor leads: 12 in.; brush block leads 8 in.
BB3199	39	39 @ 1A	0	1.03	0.59	0.65	24/12 in. lead length
BB2759	45	45 @ 1A	0	1.03	0.59	0.65	Rotor leads: 24 in.; brush block leads 12 in.
NH3302	60	60 @ 1A	0	2.24	0.50	0.75	Lead length is 12 in.
BB2871	65	65 @ 1A	0	1.28	0.65	0.64	Higher voltage on 5 ckts
AC6449	74	66 @ 1A	8 @ 3A	1.26	1.75	2.25	Concentric unit
AC6292	80	57 @ 1 A	23 @ 2A	2.00	0.68	1.15	COTS - export w/out license
RK4288	95	95 @ 1A	0	3.3	0.88	1.50	Lead length is 24 in.

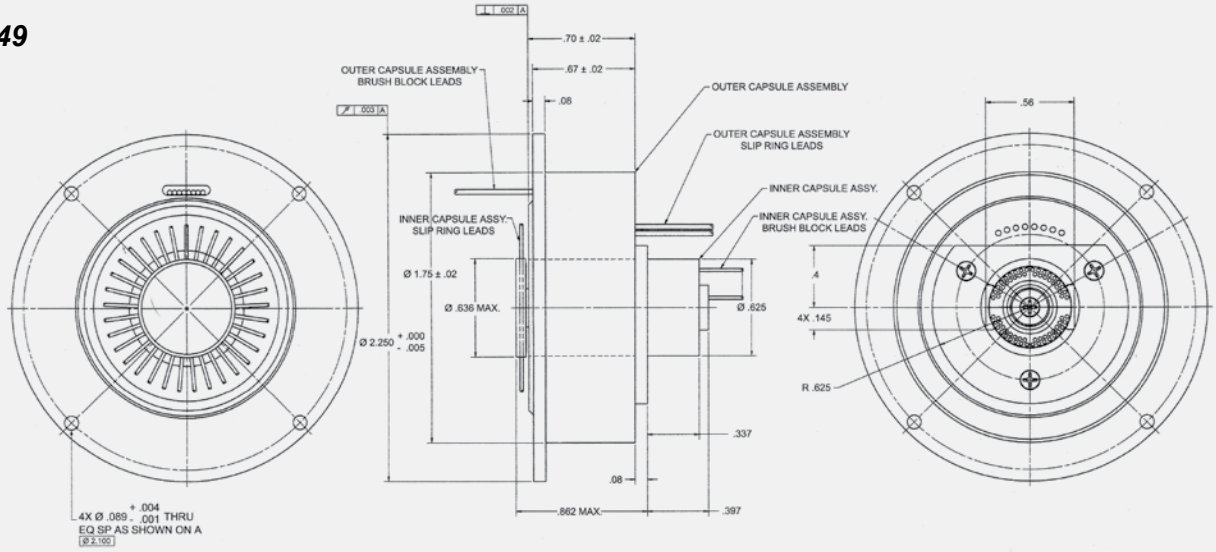
RK4288 SPECIFICATIONS

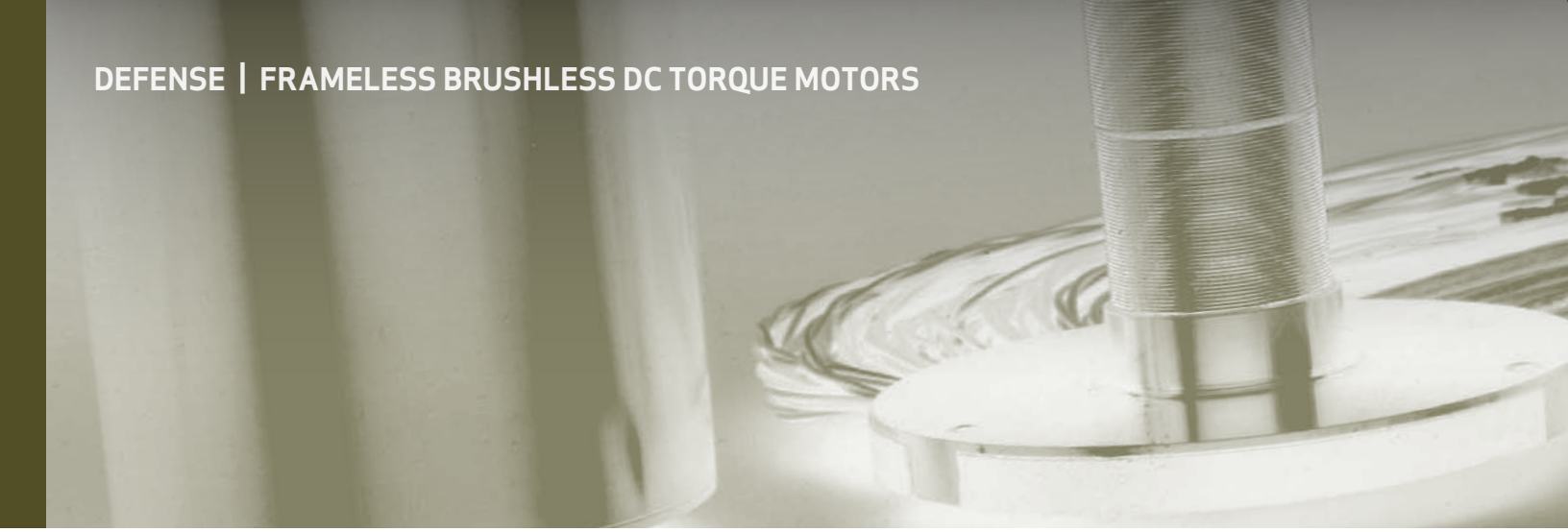
TYPICAL MINIATURE SLIP RING CAPSULE MECHANICAL DIMENSIONS (INCHES)

SJ4834



AC6449





M SERIES SLIP RING CAPSULES

The M series of slip ring assemblies were developed for a wide variety of applications and environments. The M series is an ideal choice for limited space applications. As many as 120 separate circuits are accommodated in a 2.7 inch diameter OD envelope and in less than 5.50 inches long. These slip ring assemblies are a quick turn solution for your application. Off the shelf components allow for a delivery which meets your needs.

FEATURES

- Ideal for limited space applications
- Modular construction for up to 120 circuits
- All circuits 60 V / 2 A each
- Continuous bidirectional rotation up to 1,000 rpm
- Dust-proof cover standard
- Flange mounting
- Superior signal quality
- 24 inch flying leads, optional wiring and harnessing available
- #26 AWG lead wire

TYPICAL APPLICATIONS

- Surveillance equipment

M SERIES SPECIFICATIONS

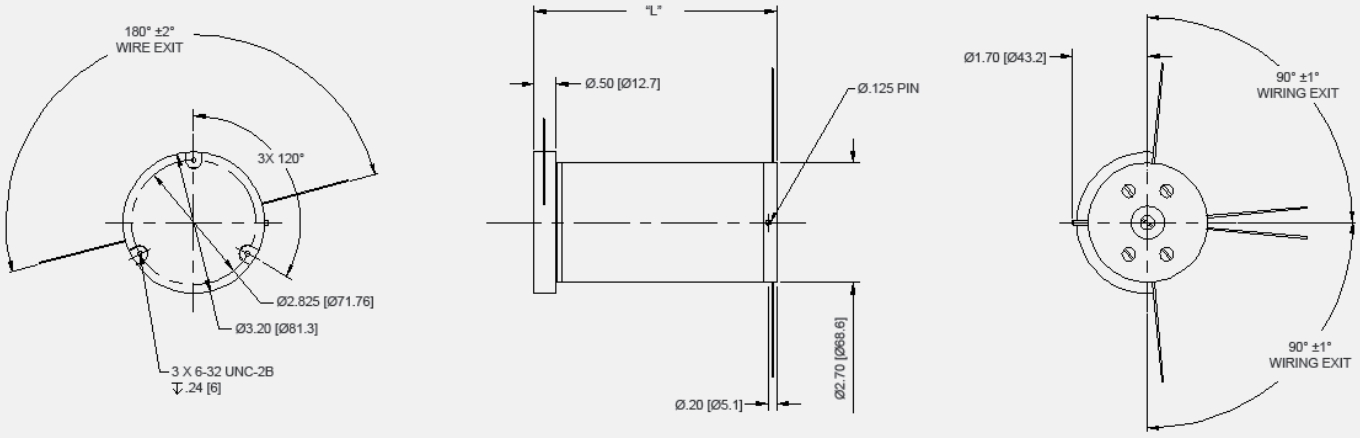
MOTOR CHARACTERISTICS

Specification	Value	Options
Circuits	Up to 120 circuits: 2 A / 60 volts	• Longer leads • Special wiring • Fiber optic rotary joint • High voltage option to 120 V
Maximum Speed	1000 RPM	
Terminals	#26 AWG flying leads	
Mounting	Flange mounting	

MOTOR CHARACTERISTICS

Part Number	Number of Circuits	"L"
1021202-1	40	2.80
1021202-2	80	4.15
1021202-3	120	5.50

MECHANICAL DIMENSIONS INCHES (MILLIMETERS)



INTEGRATED MECHANISMS

Moog's unique product offering of motion technology (slip rings, motors, resolvers, drives and actuators) and fiber optic and multiplexing products provides the capital assets and engineering capabilities to design, manufacture and integrate these discrete products into an integrated gimbaled mechanism. In today's business environment where many corporate strategies are to focus on core competencies, let Moog take the design and integration of these discrete components into fully functional and tested subassemblies that are ready for installation into the end-item assembly. Should your strategy be to outsource these assemblies on a build-to-print or build-to-spec basis, we are ready to apply our resources so you can achieve those goals too.

Our integrated assemblies range from simple combinations of motors and resolvers to sophisticated electro-mechanical assemblies including the slip ring, brake, drive electronics, fiber optic rotary joints, hydraulic and pneumatic swivels and RF rotary joints. We also offer and provide fully integrated servo and utility actuators complete with precision gearing, clutches, brakes and closed-loop control electronics.

Our business strategy is simple, let Moog focus on what we do best so our customer can focus on what they do best. This strategy provides our customers with many measurable benefits.

Optimized systems that operate at peak performance

Tolerance stack up can rob magnetic and electromechanical designs of their intended performance capabilities. Maintaining air gap and mechanical tolerances are critical in precision electromechanical mechanisms. Even though the discrete components fall within specified tolerances, tolerance stack up may result in system performance problems. The end result is costly system redesign, component matching or assembly shimming for each item produced.

When a single manufacturer of these magnetic and electromechanical components has this responsibility, these issues are mitigated by careful attention to processing of the discrete components, thus ensuring a final assembly, that is electrically and mechanically aligned and fully tested.

System design can often be verified when a single manufacturer is able to conduct trade studies of the various components. Within a given mechanical envelop, space can be minimized, total component count reduced and structures sculpted with an end result of increased MTBF and reduced end-item weight.

Resource Optimization

This approach ensures system engineers are focused on the system, not its components. By focusing engineering resources, program risks are minimized, schedules maintained and costs reduced. Additionally, overhead costs are reduced by eliminating the manpower of soliciting multiple contractors and resulting contract administration, multiple incoming inspections of discreet components and the resulting expenses of pulling and distributing component kits. Additional program costs are saved by eliminating the need of holding multiple design reviews at different locations, multiple qualification tests and the review and approval of their related documents.

Accountability

You are assured that all system components are integrated properly and a fully tested end-item assembly is delivered. And, in the rare case that a technical problem should occur, you know exactly who to call for immediate help.

With all military and aerospace programs, a heritage of program success is essential. Moog has successfully provided integrated mechanisms to many mission critical programs including the following:

MILITARY MARKET

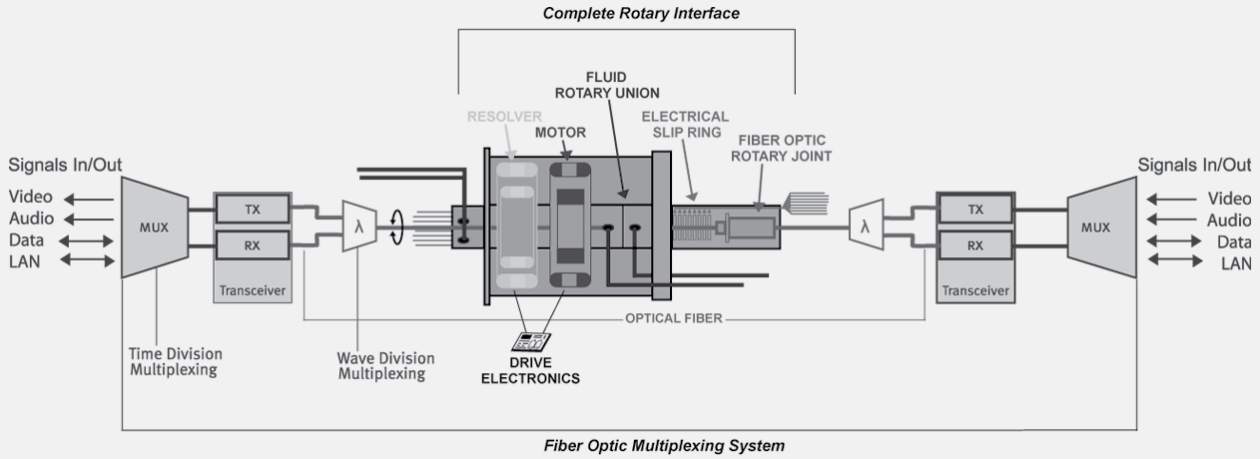
Platform	Integrated Assembly	Status
Helicopter	Slip ring, resolver and RF rotary joint	Production
Helicopter	Twist cap and resolver	EMD
Rotorcraft	Slip ring, resolver and monopole sensor	Production
Armored Vehicle	Slip ring, resolver, R-to-D network, hydraulic and pneumatic swivel, and power distribution	Production
Armored Vehicle	Slip ring, encoder and pneumatic swivel	Production
Radar	Slip ring, motor, resolver, motor control and drive electronics, and 2-channel FORJ	EMD
Radar	Slip ring, digital resolver, motor and bull-gear	EMD
Radar	Servo actuator, motor and drive electronics	Production
Radar	Slip ring, FORJ and FRU	Production
Naval Towed Arrays	Slip ring, FORJ and FRU	Production

SPACE MARKET

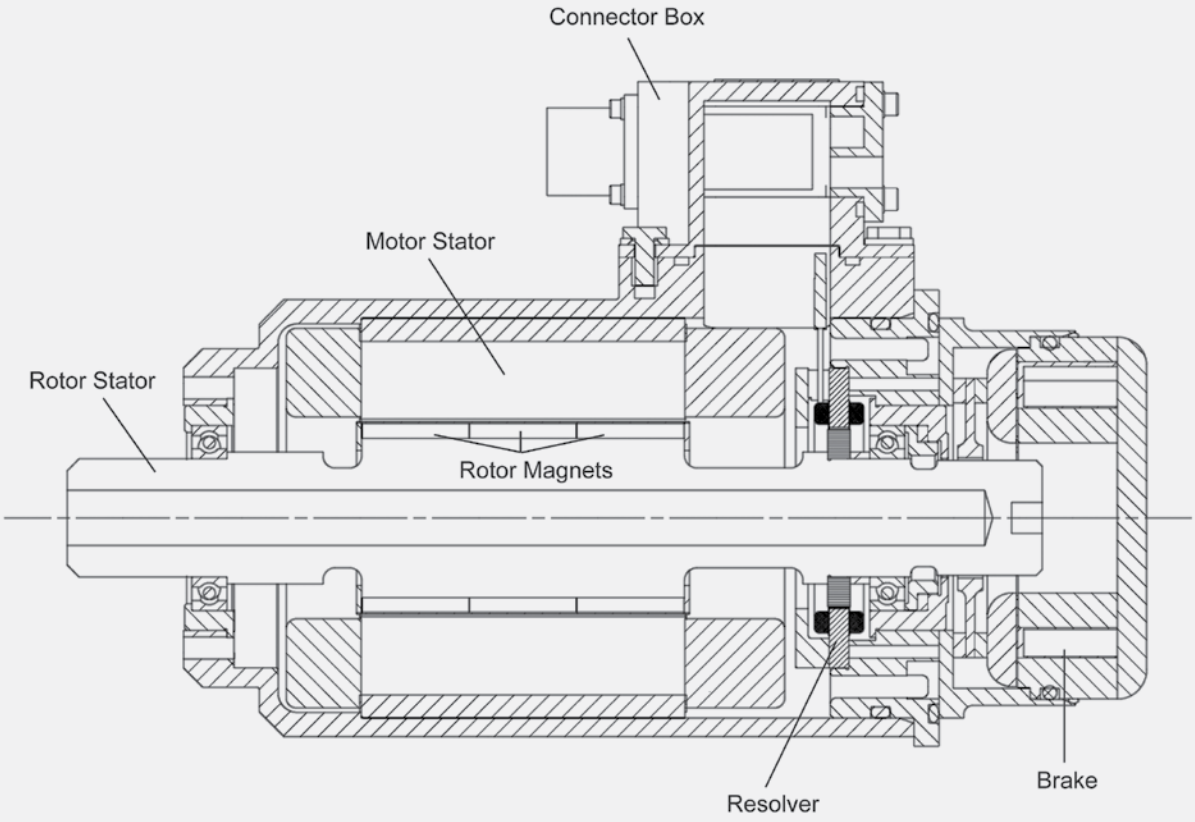
Platform	Integrated Assembly	Status
Solar Array Drive	Slip ring, motor, harmonic drive and potentiometer	Flight
Solar Array Drive	Slip ring, motor and resolver	To-be-flown
Satellite Mechanism	Motor, ball screw and balanced weight	Flight

INTEGRATED MECHANISMS

EXAMPLES OF INTEGRATED MOTION TECHNOLOGY



PRIMARY FLIGHT CONTROL SURFACE DRIVE ASSEMBLY



Moog looks forward to applying our design and manufacturing resources to your program's integrated assembly needs.

TECHNICAL INFORMATION

Introduction

As the analog world gives way to the digital in more and more applications, design engineers are faced with replacing traditional analog components with their digital equivalents. Nowhere is this more evident than in the electro-mechanical world. Analog resolvers are being replaced by digital encoders and digital drive circuitry has become commonplace for motor control. When part of the system has to rotate, and a rotary connection for power and digital data is required, what does the designer do? Can the traditional slip ring with its sliding electrical contacts handle the job?

The Problem

Slip rings were originally designed to carry AC and DC power from a rotating platform to a stationary structure, or vice versa. Many applications also required, and still require, the transmission of relatively low bandwidth analog and digital control signals. In this environment, the traditional slip ring performs extremely well. Modern control systems now also require the transmission of high bandwidth analog and digital signals through the slip rings. Typical examples are analog and digital video signals. Until recently, bandwidths measured in the tens of megahertz were generally adequate. Today, and in the future, bandwidths will be required that are orders of magnitudes higher.

Basic Slip Ring Configuration

A basic slip ring, shown schematically in Figure 1, is composed of four elements, or components:

- A ring assembly that provides one or more circuit paths. Each ring is electrically conductive and provides a circuit path over a full 360 degrees of rotation of the ring assembly.
- Brushes provide electrical contact between the rotating (usually the ring) and the stationary parts of the assembly. The brushes ride on the ring, and are mounted in a brush block assembly, usually on the stationary structure.
- Input and output leads that connect the ring and brushes to the outside world.
- Connectors that connect to the slip ring assembly wiring. Connectors are optional, and are often specified by the customer.

Factors Affecting Slip Ring Performance

The following factors will determine the data rate that can be transmitted through a slip ring:

- The frequency response, or insertion loss, of the rings and brushes.
- The impedance, as a function of frequency, of the assembly.
- The differential time delay, as a function of frequency, through the device.
- Crosstalk between circuits.
- Frequency response of the leads and connectors.

The primary factor is frequency response, or bandwidth. Digital data streams will begin to suffer errors from insufficient bandwidth when the digital signal is attenuated, or distorted, to such an extent that the digital receivers cannot properly recognize the received signal.
A digital signal is composed of a fundamental frequency at the basic signaling rate, as well as the odd harmonics of the fundamental.
The required bandwidth of the slip ring may be several times the data rate.

For example, a 1 MHZ square wave may require a bandwidth of 5 or 7 MHz (5th and 7th harmonics). As the data rate is increased, eventually the harmonics is matched to the external system input and output impedances. Using transmission line theory, the designer will vary ring geometry, spacing, and dielectric material, to obtain the needed impedance. Often a ring and brush impedance of 70 to 150 ohms is obtainable, which should be well suited for many of today's digital systems. As a rule of thumb, a smaller diameter ring will result in a higher data rate. For very high data rates and / or large ring diameters, multiple taps and multiple brushes are often used to minimize signal path lengths.

For optimal performance, high frequency digital signals should be driven differentially, and connected to the slip ring using twisted pair, shielded cable such as CAT5 or CAT5e. This same wiring, including the shield, should be continued through the slip ring. Ideally, the internal slip ring wiring would also be twisted pair shielded cable, however, this may not always be possible due to physical constraints. Connectors, if used, must also be designed, or chosen, to have an impedance and frequency response consistent with system requirements.

Crosstalk between sensitive circuits will also be minimized by proper lead routing and shielding. Sensitive circuits (victims) should be routed within the slip ring as far away from noisy circuits (sources) as possible. Also, all unused circuits should be terminated in the characteristic impedance of the cables used.

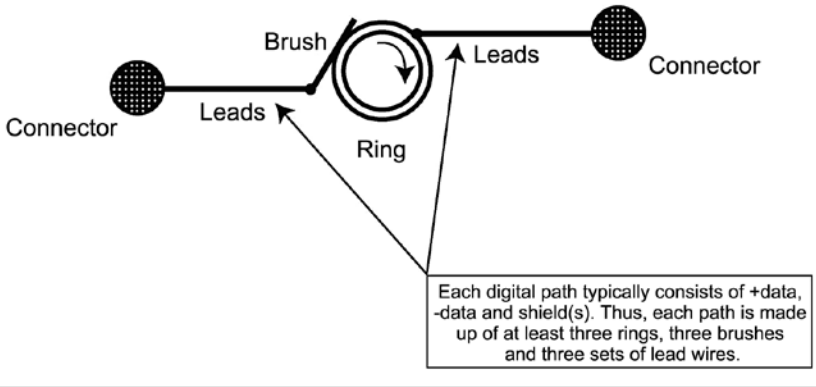
Specifying a High Performance Slip Ring

This article has attempted to make users aware of factors that determine slip ring performance, and of the limitations imposed by the total system in which the slip ring must operate. It is no longer adequate to simply request a device "that will transmit 50 mbs." The best solution is obtained when the entire system is known and understood, and usually requires a compromise between performance, size, weight, number of circuits, external factors, and cost.

The following parameters should be specified to assure satisfactory operation in a specific application:

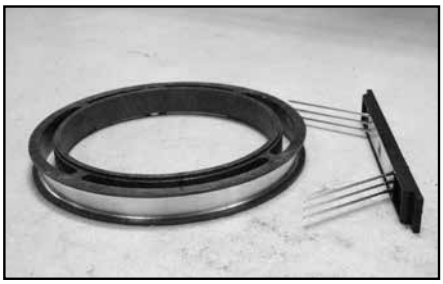
- Data bus used to transmit data, i.e. Profibus, Ethernet, Firewire
- Cable type used to connect to the slip ring
- Maximum cable length between transmitter and receiver
- Maximum data rate
- Maximum error rate that can be tolerated

Figure 1 - Basic Slip Ring



TECHNICAL INFORMATION

Commercial Separate Products
These products are highly configurable to meet your requirements with readily available products.



In addition to these enclosed slip ring capsules we also provide fiber brush separates. When a "self-contained" capsule is not practical due to system size or cost constraints, fiber brush separates are an excellent alternative. These separates are available in the following configurations:

Bore Size	Current
1.8"	2 amps
2.8"	5 amps
	10 amps
	30 amps
	50 amps
4.0"	10 amps
	30 amps
	50 amps

Properly mounted and aligned, fiber brush separates provide the same exceptional performance characteristics of our self-contained capsule designs.

Our Staff
Our staff includes electrical, mechanical, manufacturing and software engineers, metallurgists, chemists, physicists and materials scientists. Our emphasis on research and product development has provided us with the expertise to solve real-life manufacturing problems. Using state-of-the-art tools in our complete analytical facility, our capabilities include a full range of environmental test, calibration and inspection services. We have recognized expertise in tribology (the science of friction and wear), precision gearing, magnetic circuit design, PWM amplifier design and in the supporting materials sciences.

Our engineers can work from your designs, or create a custom design for you.

Consistent Quality
Moog Components Group places a continuing emphasis on quality manufacturing and product development to ensure that our products meet our customer's requirements as well as our stringent quality goals. We have committed to the Total Quality Management Program with a policy of "Do It Right the First Time" and a goal of "Zero Defects". We are ISO 9001 Certified to ensure the consistent quality and reliable performance of our products.

The newest initiative of our division is Demand Flow® Technology (DFT). DFT is a demand driven manufacturing flow system that economically manages in-process inventory. The concept operates with a "line-of-sight" premise which provides visibility for all in-process work. This concept has helped the division be more efficient and flexible to customer schedule changes, reduced inventories and improved organizational operations. Benefits include streamlined processes to accommodate jobs with a quick turn-around, reduced cycle time to cut costs, and greater customer responsiveness.

[1]Roberts E.W., Sliding Electrical Contracts in Space: Observations on Existing Technology and New Trends in Low-Speed Applications, European Space Tribology Laboratory.

Demand Flow® is a registered trademark of the J_C-I-T Institute of Technology, Inc.

COMPARISON OF SLIDING ELECTRICAL CONTACTS FOR SPACE APPLICATIONS

Composite Brushes **Ag / MoS_2 / Graphite**	**Monofilament Brushes** **Lubricated**	**Fiber Brushes** **Unlubricated**
Most flight history	Considerable flight history	Growing flight history
Meets outgassing requirements	Does not meet outgassing requirements	Meets outgassing requirements
Self lubricating contacts (solid lubricant in brushes)	Requires liquid lubricant on contact surface	No oil or dry film lubricant application required
Requires largest ring-to-ring axial pitch	Requires smallest axial pitch (50% of composite brush pitch)	Requires less axial pitch than composites (70% of composite brush pitch)
Manufacture subject to greatest number of process variables	Manufacture subject to few process variables	Manufacture subject to few process variables
Greatest amount of wear debris generation (approximately 100 times the wear rate of fiber or monofilament brushes)	Much smaller amount of wear debris generation than composite brushes	Smaller amount of wear debris generation than composite and monofilament brushes
High electrical noise if operated in humid environment	Low electrical noise in air and vacuum	Low electrical noise in air and vacuum
Must operate in vacuum or dry inert atmosphere	Operational in air or vacuum with lubricant present	Operational in air or vacuum
Wide operating temperature range	Viscosity limited operating temperature range	Wide operating temperature range
Wide range of surface speeds	Limited range of surface speeds	Wide range of surface speeds

TECHNICAL INFORMATION

- Maximum size, i.e. diameter and length
- Number of circuits and their ratings, i.e. voltage, current
- Maximum operating speed of rotation
- Operating environment

Moog has thousands of slip ring designs, including many standard "off the shelf" designs. Our engineering staff is available to modify an existing design or to provide a completely new design, if required. However, customers are encouraged to evaluate a standard design before requesting modifications that may not be needed.

We have tested many of our standard designs for high data rate performance. Devices with through bores of up to six inches have been tested. Testing has included insertion loss, frequency response, bit error rates, differential time delay, and impedance over frequency. In some cases we have identified, and implemented, design modifications to significantly improve performance. As a general statement, all devices that have been tested will support digital data rates of at least 50 mbs. This verifies that our standard units will operate successfully in a wide variety of standard data systems in use world-wide. These include, but are not limited to: Device Net, CAN Open, Profibus, and Ethernet 10Base T. Additionally, several models tested are suitable for Ethernet 100Base T, and Firewire at 400 mbs.

SLIP RING FUNDAMENTALS

A standard slip ring has four elements, or components:

- A ring assembly provides one or more circuit paths. Each ring is electrically conductive and provides a circuit path over a full 360° of rotation of the ring assembly.
- Brushes provide electrical contact between the rotating (usually the ring) and the stationary parts of the assembly. The brushes ride on the ring, and are mounted in a brush block assembly, usually on the stationary structure.
- Input and output leads connect the ring and brushes to the outside world.
- Connectors link to the slip ring assembly wiring. They are optional and often specified by the customer.

For the most demanding applications, we have integrated single channel and multiple channel fiber optic rotary joints (FORJs) into our standard slip ring assemblies. The FORJ is used to carry the very high data rate signals, or those circuits requiring very low cross talk or high noise immunity, while conventional slip ring technology is used for transmitting power and other control signals. We can also provide the hardware to perform the electrical- to optical- back to electrical conversion.

Applications

Industrial and Commercial

- Semiconductor equipment
- Industrial machinery
- Robotics
- Medical equipment
- Packaging machines
- Cable reels
- Laboratory equipment
- CCTV camera mounts
- Lighting
- Rotary index tables
- Rate tables
- Medical CT scanners
- Amusement rides
- Flight simulation

Aerospace and Military

- Inertial navigation systems
- Missile weapon systems
- Satellite assemblies
- Unmanned aerial vehicles
- Airborne camera platforms
- Shipboard communication systems
- Radar
- Tanks
- Light armored vehicles
- Helicopters
- Aircraft

Marine

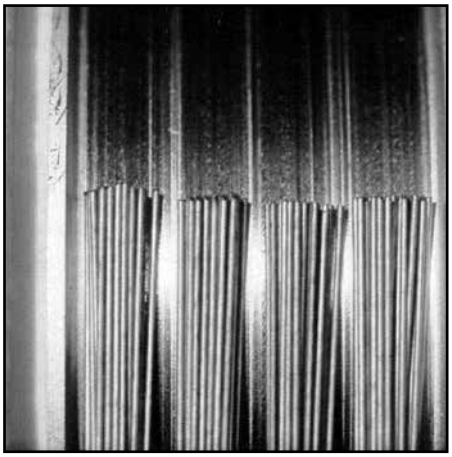
- Remote operated vehicles (ROV)
- Seismic surveying
- Oceanographic winches
- Subsea communications and control
- Floating production, storage and offshore loading (FPSO)
- Diving
- Marine instrumentation
- Downhole / wire logging and drilling

Moog fiber brush contact technology was initially developed to solve a critical problem in military / aerospace applications. With many years of successful performance in highly critical slip ring applications, the fiber brush technology is available in commercial products as well.

Fiber Brush Technology For Commercial / Industrial Applications

For many years the traditional design for rotary contact slip rings used either a lubricated monofilament brush or a self-lubricating composite brush. While these traditional approaches have proven to be successful through testing and field experience, improved performance is always desirable. To that end, we developed the fiber brush technology. A chart comparing the advantages of different contact technologies is shown on page 30.

Today's industrial / commercial equipment slip ring requirements are becoming more and more demanding. High operational speeds, long life, no maintenance, and data transfer capability, are the general expectations in slip ring performance. Taking advantage of the developments done in our Advanced Materials Research and Development Department, we have transferred the fiber brush technology to cost effective commercially available products to address today's critical applications.



Military / aerospace applications require slip rings that provide minimal debris generation, low electrical noise, both high and low current transmission capabilities, low outgassing and a long operational life. They must also operate flawlessly in a wide operating temperature range, and at a variety of brush ring surface speeds, as well as in air or vacuum conditions.

TECHNICAL INFORMATION

Fiber Brush Contact Technology
Fiber brush is the term for a particular design of sliding electrical contacts. Fiber brushes are simply a group of individual metal fibers (wires) that are collimated by and terminated into a metal tube as illustrated in the photo on the left. In this cantilevered design, the free, unterminated end of the fiber brush bundle rides in a groove on the ring surface.

Many Advantages
Fiber brushes have many distinct and measurable advantages over conventional slip ring contacts in military / aerospace applications:

- Multiple points of ring contact per brush bundle
- Ability to perform in ambient conditions as well as in vacuum conditions
- Contact surfaces that do not require lubrication
- Long life
- Low contact force per fiber
- Low contact wear rates
- High power circuit density
- Low dynamic contact resistance (noise)
- High and low current carrying abilities
- Low outgassing
- Very little debris generation
- Wide operating temperature range
- Wide range of brush / ring surface speeds

Proven Performance
As an alternative to traditional sliding contact designs, Moog fiber brush was developed to meet the increasing demands of slip ring performance. The technology has been used in many demanding applications such as:

- CT Scan systems
- High speed testing
- Robotic welding systems
- High-speed, in-line inspection systems
- Radar platforms

A Growing History
Moog started in 1953 as a supplier of high reliability slip rings to the military and aerospace community. Over the years we have developed a reputation as a quality and precision supplier for space, weapons, aircraft and other mission critical program requirements. It is this stringent quality and technology that has now carried over to our commercial products group. We have adapted technology designed and produced for defense applications for use in our growing line of standard commercial products.

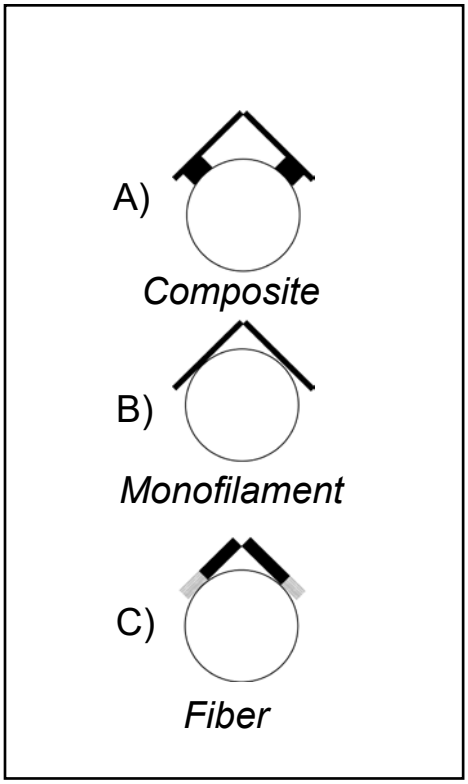
All of our experience and expertise helps our customers in a very real measurable fashion. We make a point to fully understand our customers' applications and by teaming with our customers we are able to efficiently coordinate their needs with our engineering and production departments. We have for years had a Commercial Slip Ring Team that provides focus allowing us to slash lead times and develop special designs fast and accurately.

Technology Comparison
Generally, aerospace slip rings and brushes (sliding electrical contacts) are designed using traditional contact technologies such as lubricated monofilament wire brushes or self-lubricated composite brushes. These approaches have been proven successful many times through testing and actual flight experience. There are, however, some disadvantages to these approaches.

Composite Brushes
Unlike monofilament brushes, composite brushes provide their own lubrication through the addition of an embedded solid lubricant to the composition of the brush. The nature of this lubrication mechanism requires that the brush must experience wear to transfer the lubricant from the brush to the ring. This wear results in some amount of electrically conductive debris being generated within the slip ring. While small amounts of this debris can generally be tolerated if proper design procedures are followed, the extended life requirements of new aerospace slip rings could result in the generation of intolerable amounts of this conductive debris.

Also, the contact materials used in composite brush slip ring designs can be contaminated by absorption of airborne gasses. The principal form of this contamination is silver sulfide, which appears as tarnish. When exposed to temperatures of less than 178° C, these films have semiconducting properties (increase in electrical conductivity with increased temperature). The presence of silver sulfide films at low temperatures may cause unacceptably high contact resistance on low current circuits. Below is a chart that summarizes the characteristics of the different types of contact technologies.

Monofilament Brushes
Aerospace rated monofilament brushes depend on intentional lubrication of the contact surfaces to perform properly. Many of the liquid lubricants used will not meet NASA outgassing requirements, and the ones that do typically have poor viscosity characteristics at low temperatures. Designs using this contact technology must be analyzed to ensure that sufficient lubrication is maintained throughout the system life requirements.



Materials Choices
One of the most important features of any military or aerospace design is the choice of component materials. Materials must be carefully chosen to reduce outgassing, control dissimilar thermal expansions, reduce galvanic corrosion, and provide nuclear hardening, among other concerns. Materials choices for fiber brush slip rings are much the same as used in traditional slip ring designs with the major exception of the contacts. Fiber brush contacts (fiber and ring surfaces) can be manufactured using alloys of copper, gold, silver and palladium. The actual choice of contact materials depends largely on the electrical requirements of the slip ring. Moog Components Group controls all materials and materials suppliers to verify and ensure consistent quality.

Commercial Fiber Brush Products
Our commercial fiber brush products include a variety of products with power capabilities up to 100 amps and down to low level data transfer, all within the same housed design. These products are highly configurable to meet your requirements with readily available products.

DEFENSE PRODUCTS

ROTARY JOINTS AND SLIP RINGS

These high performance products are used in systems that require unrestrained, continuous rotation while transmitting power, data and media from a stationary device to a rotating structure. High bandwidth options include Ethernet, high definition video and other industry standard formats. Moog also has solutions including fiber optic rotary joints, fluid rotary unions and position sensors.

DIRECT DRIVE DC TORQUE MOTORS AND ALTERNATORS

Frameless torque motors are used in defense applications that require high power density and quick accelerations. The motors are optimized to minimize input power for maximum efficiency. Alternators in the same mechanical configuration can be used for mobile power generation.

RESOLVERS

Moog offers rugged resolvers that provide accurate positioning and velocity feedback, as well as commutation of brushless motors. These models withstand the shock and vibration levels often encountered in aerospace and military applications. They are used for vertical integration with motors and slip ring assemblies.

ACTUATORS

Multi-purpose electromechanical actuators are available in both rotary and linear configurations and are standard building blocks in a variety of systems. Some of our actuators integrate servo electronics. These actuators are used on air, ground and unmanned applications.

HIGH SPEED DATA COMMUNICATIONS

Moog provides innovative components and communication sub-systems for both copper and optical fiber based systems used in harsh environments. Moog meets the demanding high speed and secure networking equipment requirements of todays modern defense systems. The product range includes electro-optical transceivers, link extenders, Ethernet media converters and switches, data aggregators and multiplexer/de-multiplexer solutions.

INTEGRATED MOTION ASSEMBLIES

Our higher level solutions range from simple combinations of individual products to sophisticated electromechanical assemblies including the motor, drive electronics, slip ring, fiber optic rotary joint, fluid / pneumatic swivel and RF rotary joint. Moog's single-axis gimbal stage supports most payloads, and all the rotary components are integrated into one assembly. This design reduces set-up time and simplifies the installation process.

NOTES

NOTES

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