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Application Note

HIGH SPEED DATA AND COMMERCIAL SLIP RINGS

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INTRODUCTION

Many commercial applications require rotary platforms and slip rings to carry electrical power and signals to and from the rotating system. Standard slip ring technology involves forming an electrical path with rotating rings contacted by a stationary sliding contact or brush. In the world of analog signals, analog video, and low speed digital data, the specification of a slip ring for a set of signals and power involved specifying the voltage and current required for the electrical signals and or/power. However, in the new world of digital video, high speed data, and networking, slip ring design issues have move out of the DC regime and the requirements involve bandwidth. The good news is that there are slip ring options available for digital video and high speed data.

This application note is intended to assist the reader in specifying slip rings from Moog's commercial slip ring offering that are appropriate for specific high speed data applications. Application Note 227, *Critical Parameters for High Speed Data on Slip Rings* is a helpful companion document to this application note and will provide some background for the calculations and estimates made for the Commercial slip ring products.

DATA RATES OF MOOG COMMERCIAL SLIP RINGS

A review of the Moog Line of Commercial slip rings will show three basic configurations:

1. Miniature capsule
2. Thru-bore assembly
3. Platter Assembly

Each of these configurations has its own guidelines for data transmission. Typically the configuration choice made for specific applications is based on mechanical considerations, i.e., space available, or sometimes on power required.

Miniature Capsules

Miniature capsules have been produced by Moog for over 50 years and their evolution from analog to digital transmission devices has been gradual over this period. These slip rings are less than 1 inch in diameter, usually less than 6 inches long, and typically contain less than 80 rings or circuits. The advantage of these capsules in handling digital data is their small diameter: less than 1 nanosecond of equivalent electrical path or, using the ¼ path length approximation, at least 1 GHz of bandwidth. The disadvantage of this small capsule design with respect to digital data is the difficulty in terminating controlled impedance cable close to the rings and brushes. This means that the electrical path length of the impedance discontinuity becomes longer by the length of the uncontrolled termination. Additionally, crosstalk is difficult to control within the small capsule. However, using sound lead termination practices and carefully spacing high speed data circuits in the capsule has produced capsules that are capable of handling high speed data of around 600-800 Gbps (as shown in Figure 8—0.0 bore) in special custom designs. The more normal maximum operating range is 200-400 Mhz in standard commercial miniature sip rings.

Figure 1: AC 6292 Miniature capsule

Thru-bore slip rings

The most common commercial slip ring, the drum-style ring (see Figures 2 and 3) with a thru-bore, has the advantage of increased size for improved lead termination techniques but the increased size has the obvious disadvantage of reducing the bandwidth due to the increased electrical path of the impedance discontinuity of the ring. Figure 4 gives conservative estimates of bandwidth of commercial slip rings using the bandwidth estimate techniques outlined in

Application Note 227. It should be pointed out that these are analyses for thru-bore slip rings with approximations made for internal cable termination lengths close to rings and brushes.

Figure 2: AC 4598 1.5 inch through bore

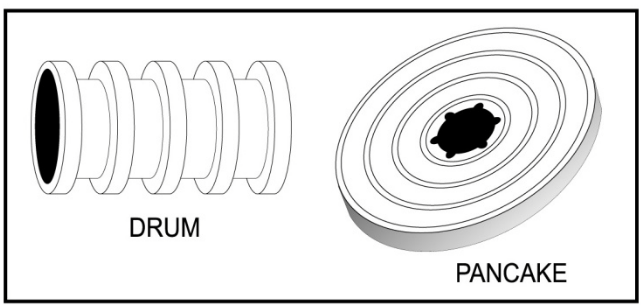

Figure 3: Platter and Drum Style Slip Ring Design

It is often more convenient to buy a commercial slip ring off-the-shelf and simply splice cable to the standard slip ring wire. It is important to understand the impact of this termination technique on the ability to handle high speed data. The effect of longer cable terminations is shown in Figure 5. The 0.0 bore slip ring is the miniature capsule design. Moog has multiple test data to verify that the estimates in Figure 4 and 5 are conservative values

Broadband Platter Slip Rings

The slip ring design that is optimized for high data rate is the Broadband platter design. The ability to match the impedance of the rings to the transmission line and insert ground planes for crosstalk control allow bandwidths of the broadband platter to extend to 200 MHz for data transfer of up to 300 Mbps. The larger diameter of the broadband design allows improved cable termination strategies and connectorization. The higher bandwidth and the crosstalk control of the Broadband platter allows this slip ring design to be used for multiple high data rate channels, and it is an ideal design for Gigabit Ethernet data transfer. Custom designs of the broadband platters are available that transmit data in excess of 800 Mbps.

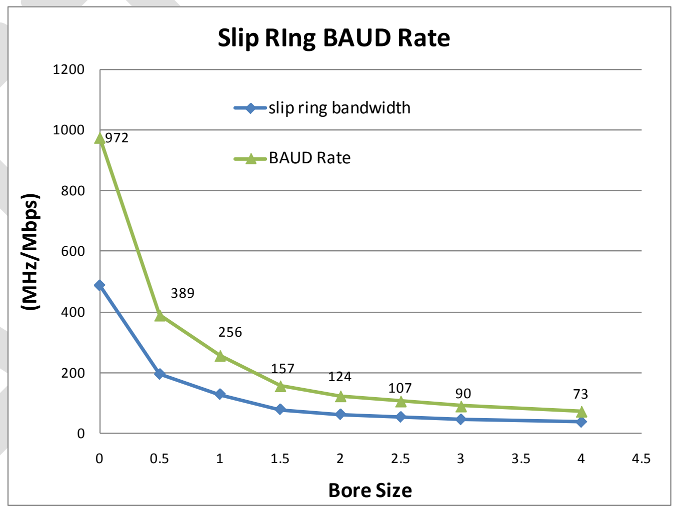

Figure 4: Bandwidth and baud Rate Guidelines for Drum Style Slip Rings

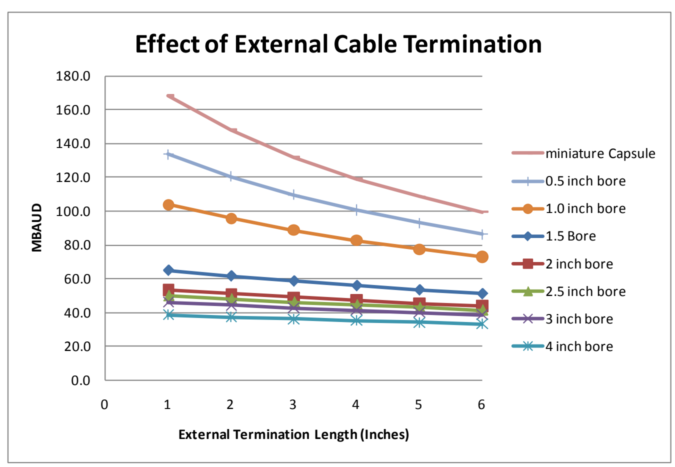

Figure 5: Effect of Cable Termination Outside the Slip Ring Housing

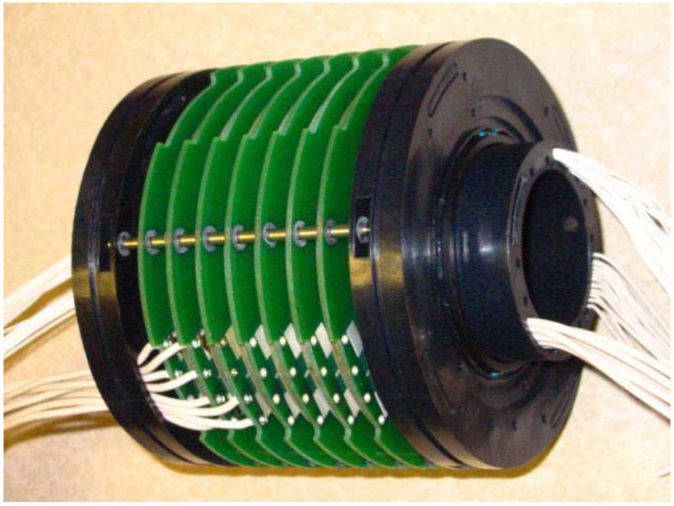

Figure 6: AC 6815--Broadband platter construction

The AC 6815 is the platter slip ring designed by Moog with digital data communication in mind. It is available with interface connectors (as shown in Figure 7) for all commercial data buses and is able to pass all the communication data of Table 1

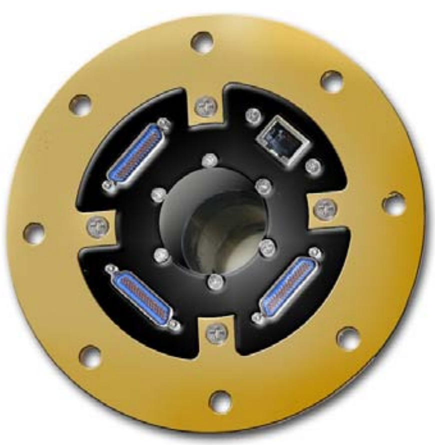

Figure 7: AC 6815 with connectors

Guidelines for Data Transfer through Slip Rings

There are several of questions that should be asked when installing a slip ring into a data transmission line.

1. Does the slip ring have the bandwidth to transmit the baud rate?

First we should take a look at the baud rate requirements for most commercial data bus formats. It is very important to note that the data rate shown in Figure 1 is the actual data rate transmitted on the cable; with encoding, the actual data transmission rate can be different.

Table 1: Industrial Data Bus Speeds

Bus	baud rate
Device Net	500 Kbps
CAN Bus	1 Mbps
Control Net	5 Mbps
Profibus	12 Mbps
10 BaseT Ethernet	10 Mbps
100 BaseT Ethernet	25 Mbps
1000 BaseT Ethernet (GigE)	125 Mbps

Table 2 provides guidelines for the commercial slip rings in the Moog Slip Ring catalog. The data rate estimations contained in the first column (terminations inside) assume that the system wiring (controlled impedance cable) can be terminated inside the assembly within 1 inch of the rings and brushes (This is the value shown in Figure 8). The second number given (terminations outside) assumes that cables are terminated within 1 inch of the end of the assembly, outside the assembly. So in the case of products with 1.5 inch bore similar to AC 4598, the effective baud rate that can be transferred when system cable is terminated inside the slip ring is 150 Mbaud and if cable is terminated outside the slip ring is 60 Mbaud. It can be seen that this effect is most significant on the smaller diameter slip rings.

Table 2: Data rate of Moog Commercial Slip RIngs

Product	Mbps(terminations inside)	Mbps(terminations outside)
AC 6355 (0.0)	400	150
AC 6438 (0.5)	300	100
AC 6349 (1.0)	200	80
AC 4598 (1.5)	150	60
AC 6815 (1.5) Broadband	300 Mbps	
AC 6275 (2.75)	100	40
AC 6098 (4.0)	70	35

Techniques used to control the bandwidth of the slip rings have the secondary effect of controlling the crosstalk performance and EMI/EMC. And of course the phase delay, jitter, and attenuation concerns of each of the data specifications is also captured in the bandwidth The data rates listed in Table 2 can be used to determine if a specific slip ring design will transmit the data shown in Table 1.

It can be seen that with proper wiring all the Moog commercial slip rings up to 4 inches in diameter have the bandwidth capability to transmit almost all of the industrial buses with the exception of Gigabit Ethernet. Gigabit Ethernet can be transmitted on the miniature capsules and the 0.5 in. bore products when a custom wired design is specified, and the AC 6815 Broadband product when the Ethernet connector options is specified. As discussed earlier, bandwidth is not the only criteria for evaluation. It is important to specify shield rings (if necessary) for providing continuity of the cable shields and internal ring shielding, determine where the cables are terminated (internal or external) and how, and carefully separate noisy circuits from sensitive ones. Moog slip ring applications engineers can assist with these details.

2. *How close to the rings and brushes can the system wiring be terminated?*

Ideally the slip ring design can accommodate terminating the shielded cable inside the slip ring body close to the rings, but in the case of miniature capsules this is frequently impossible. It is also more convenient to use a standard-wired slip ring and splice on wires external the slipring. The chart below gives estimates of maximum baud rates for various slip ring sizes that have cables terminated outside of the slip ring. Notice that the effect is more pronounced with smaller slip rings.

Although it can be seen that this style of cable termination does have a significant effect on slip ring bandwidth, there is still sufficient baud rate capabilities with external cable termination for most commercial data bus formats.

3. *Can the Broadband platter design (AC 6815) be utilized?*

The AC 6815 design and its derivatives allow the maximum number of data channels within a size efficient volume. The bandwidth and crosstalk are controlled by the use of ground planes and controlled impedance rings. Connectorization is provided to allow good practices for cabling to minimize the length of the cabling mismatches. The 150 Mbps eye pattern of Figure 10 shows a very open and low-jitter (540 pS) eye. Other tests have shown a very acceptable eye pattern up to 300 Mbps. Crosstalk is less than -30 dB up to 300 Mbps.

The AC 6815 can be provided with connectors to interface with all standard industrial buses. These remove the uncertainty of lead termination. The AC 6815 is a good option for 1000 Base-T (GigE) data since it can be provided with a standard Ethernet connector (RJ 45). It has been tested with a standard Ethernet tester and showed not bit errors.

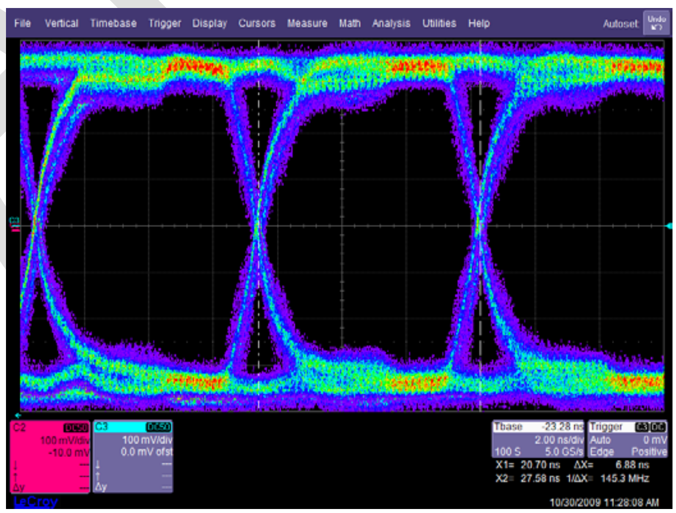

Figure 10: AC 6815 Eye Pattern at 150 Mbps