

Slip rings

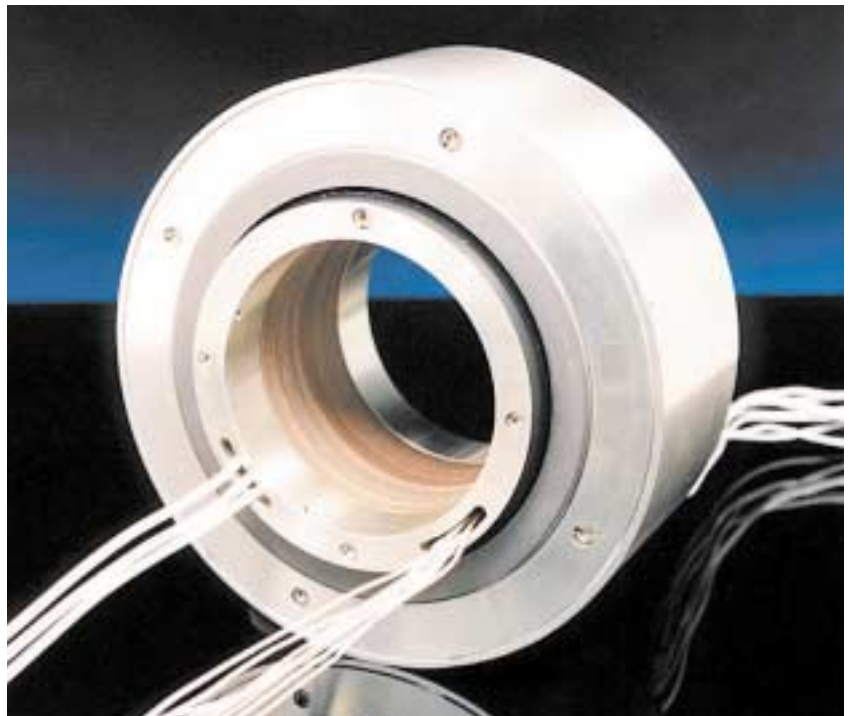
go digital

Transmit power *and* digital data through rotary connections without compromising performance.

Barry Brown

Manager, Motion Technology
Products Engineering
Poly-Scientific
Blacksburg, Va.
www.polysci.com

As the analog world gives way to the digital in more applications, integrators face replacing traditional analog components with digital equivalents. Nowhere is this more evident than in the electromechanical world. Digital encoders are superseding analog resolvers, and digital drive circuitry has become commonplace for motor control. But, the electronic revolution has met physical challenges. For instance, when part of a system has to turn and a rotary connection for power *and* digital data is required, what should a designer do? Can the traditional slip ring with its sliding electrical contacts handle the job?



In general, standard slip rings should support digital data rates of at least 50 Mbyte/sec.

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, relatively low-bandwidth analog and digital con-

trol signal transmission. In this environment, the traditional slip ring performs extremely well. More advanced control systems now also require transmitting high bandwidth analog and digital signals through the slip rings. A typical example is

Slip rings help robotic vehicles do another 180

Thanks to slip rings, ground robotic vehicles from General Dynamics Robotic Systems, Westminster, Md., can see what's coming from every direction.

The robots have a multiple-signal sensor suite, including stereovision video cameras, infrared cameras, and lidar, housed inside a pan-tilt head. For the most effective operation, the robots need a 360° view of their environment on a continuous basis at power and data rates to 200 Mbytes/sec. This constant data transmission tells the robots what's around them — at distances of 500 m in some cases — so they can navigate, detect intruders, and assess inventory.

Using direct cable connections, GDRS was able to accomplish a continuous 180° sweep of the environment, but they wanted to advance the robots' perception capabilities further. To do that, they needed 360° rotation of the pan-tilt head.

To gain the other 180°, GDRS turned to Poly-Scientific slip rings. The slip rings ensure reliable circuits of multiple signal types, including shielded video and high-speed data signals. The slip rings' compact packaging helped meet weight and space restrictions, as well as the required number of signals.

receivers. Reduced bandwidth results directly from poor impedance control.

With a standard slip ring, at any time two different signal paths exist between the brush and ring pick-off points. As the ring rotates, the two path lengths continually increase and decrease. Therefore, the output signal is the summation of two signals that have traveled different distances. Due to the differential path lengths, the signals may add or subtract at the point of summation, resulting in further output distortion. This factor can usually be ignored if the path length is small compared to

the quarter wavelength of the 3rd harmonic. If this condition is met, the difference in path lengths is insignificant at the frequencies of interest.

Another cause for concern in digital data transfer is cross coupling between adjacent circuits, i.e. crosstalk. Coupling can occur between adjacent rings and brushes and within the wiring itself. When power is coupled from one circuit to another nearby, this power never makes it to the load. With proper

analog and digital video signals. Until recently, bandwidths measured in the tens of megahertz were generally adequate. Today, and in the future, systems will require bandwidths on orders of magnitudes higher.

Performance factors

The following factors determine the slip ring data transmission rate:

- The rings and brushes' frequency response, or bandwidth
- Assembly impedance, as a function of frequency
- 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. Insufficient bandwidth can attenuate and distort digital signal until receivers no longer recognize them. 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 may be several times the data rate. For example, a 1-MHz square wave may require a bandwidth of 5 or 7 MHz (for the 5th

and 7th harmonics). As the data rate increases the fundamental's harmonics are attenuated, resulting in a slower rise time for the signal appearing at the receiver. This causes a reduced binary signal bit width, which eventually makes the error rate unacceptable for proper system operation.

Performance also depends on the slip ring's characteristic impedance. For optimum performance, the slip ring impedance matches the system, including cables, line drivers, and



Slip rings with a capsule design can be used in any electromechanical system needing unrestrained, intermittent, or continuous rotation while transferring power or data.

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.

(sources) as possible. Also, terminate all unused circuits in the cables' characteristic impedance.

Specifying slip rings

No longer is it adequate to simply request a device "that will transmit 50 Mbyte/sec." For the best solution, the entire system must be known and understood, and usually requires a compromise between performance, size, weight, number of circuits, external factors, and cost.

Specify the following parameters to assure satisfactory operation in a specific application:

- Data bus used to transmit data, i.e. Profibus, Ethernet, Firewire
- Cable type for connection to the slip ring
- Maximum cable length between transmitter and receiver
- Maximum data rate
- Maximum error rate that can be tolerated
- Maximum size, i.e. diameter and length
- Number of circuits and their ratings, i.e. voltage, current
- Maximum operating speed of rotation
- Operating environment

Always check that a manufacturer has tested standard designs for high data rate performance. Testing should include insertion loss, bandwidth, bit error rates, differential time delay (skew), and impedance over frequency.

For demanding applications, single and multiple-channel fiber optic rotary joints (FORJs) have been integrated into some standard slip ring assemblies. The FORJ carries the highest data rate signals, or those circuits requiring low crosstalk or high noise immunity, while conventional slip ring technology transmits power and other control signals.

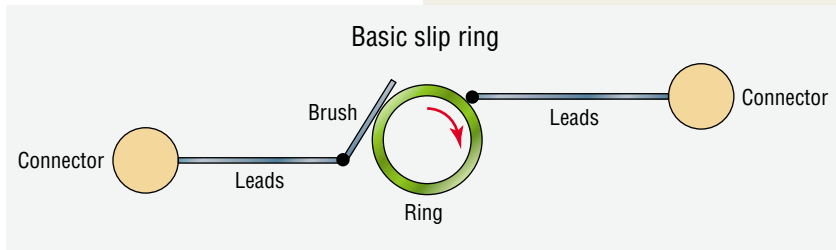
lead dress and unused circuit termination, crosstalk is usually a minor contributor to error rate in a digital system. Circuit isolation of 40 dB is common, and values greater than 60 dB have been achieved.

At higher frequencies, wiring and connectors can increase crosstalk and contribute to decreased bandwidth, unless they have been chosen specifically to provide reliable high-frequency performance.

Digital design tips

Once performance-limiting factors are properly understood, several design techniques can be applied to obtain the required performance for a given application.

As mentioned previously, controlling and matching impedance over the frequency range of interest is important. The goal: make the slip ring appear as a wide-band transmission line that is matched to the external



system input and output impedance. Using transmission line theory, designers should vary ring geometry, spacing, and dielectric material. Often a ring and brush impedance of 70 to 150 Ω is obtainable, which should suit many digital systems. As a rule of thumb, a smaller diameter ring will result in a higher data rate. For very high data rates or large ring diameters, multiple taps and multiple brushes are often used to minimize signal path lengths.

One tip for optimal performance: drive high-frequency digital signals differentially and connect to the slip ring with twisted pair, shielded cable such as CAT5 or CAT5e. This same wiring, including the shield,

In the basic slip ring setup, each digital path typically consists of + data, - data, and shields. So, each path has at least three brushes and lead wire sets.

should continue through the slip ring. Ideally, the internal slip ring wiring is also twisted pair shielded cable; however, this may not always be possible due to physical constraints. Connectors, if used, must also have an impedance and frequency response consistent with system requirements.

Proper lead routing and shielding also minimizes crosstalk between sensitive circuits. Route sensitive circuits (victims) within the slip ring as far away from noisy circuits