Slip rings connect reliably CAN bus-lines

Especially in construction machine and equipment, slip rings are used to transfer data signals and power to rotating cabs. Intermittent open or high resistance needs to be avoided, to guarantee a reliable signal transmission.

There are slip rings available, which enable CAN communication with bit-rates up to 1 Mbit/s and above. They achieve this with an excellent Bit Error Rate (BER) over the life of the system. When we refer to BER, we are speaking the "language" of data reliability. A stable, well-formed eye pattern is the most important element of low BER and reliable data transmission. But in the case of electrical contacts, bit errors can also be caused by intermittent open circuits in the transmission line as a result of high (or even open) resistance between the contacting members of electrical contacts. These resistance changes are often called contact noise or sometimes "microcuts." For example, fretting wear/corrosion can cause resistance in electrical connector pins to go high enough to create intermittent open circuits (bit errors). Slip rings are constructed with sliding electrical contacts where conducting brushes, or wipers, slide along circular conductive ring surfaces to allow electrical contact during rotation.

Slip rings in construction equipment

Reliable data transmission through slip rings requires control of the conditions that cause closed eye patterns as well as intermittence opens or high resistance. Proper materials, good electrical design, and environmental protection of the sliding contacts accomplish this control. It is important to understand that many of these design aspects are also crucial for the reliable transfer of power, as well as data. For example, the transfer of power on sliding electrical contacts is very dependent upon an enclosure that protects the contacts from the environmental effects of contamination and most especially moisture.

Proper contact materials and contact design

CAN data transmission through electrical contacts has had a significant impact on the contact materials used to transfer the data. Some contact materials that have been used successfully in the past cannot transmit error-free digital data because of unreliable contact resistance. Contaminants produced by wear debris and surface films can produce high resistance events that produce bit errors. Noble metal electrical contacts should be used for electrical contacts transmitting digital data. These un-reactive (i.e., noble) metals resist corrosion and surface filming thereby providing consistently low contact resistance.

The reliability of electrical contacts is greatly improved with redundancy. Figure 2 shows a ring with a

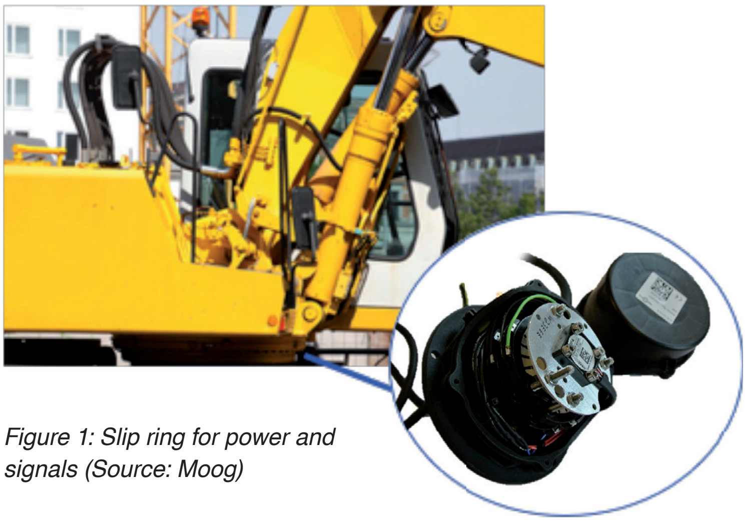


Figure 1: Slip ring for power and signals (Source: Moog)

brush assembly with six independent precious metal contact elements per ring. This redundant contact arrangement virtually eliminates the potential for an anomaly (e.g., contaminating particle) to effect all brushes simultaneously resulting in very low BER (10^{-12} or better). Proper brush design must also take into account the shock and vibration environment found on construction equipment. Again, redundancy is important as is the contact force and the relative mass of the brush in order to keep the resonant frequency of the brush well above operating excitation frequencies.

Electrical design for RF

It is generally believed that resistive contact noise (intermittent high resistance events) is the primary limit to slip ring bandwidth. But just as important to reliable data transfer is proper electrical design that does not filter the high frequency components of a digital signal (see Figure 3). Any component (slip ring, connector, relay, etc.) inserted into a digital data transmission line will have an effect on the BER of the data transmission because of the impedance discontinuity or mismatch placed in the data path. The magnitude of the impact on the signal transmission is a function of the length and magnitude of the impedance mismatch as well as any phase imbalance introduced into the transmission line. Connector selection, lead and shield termination, ring and brush impedance, as well as a number of other design and manufacturing considerations, have a significant impact on data reliability. Slip ring engineers who design slip rings to handle communication data must ▷

Figure 2: Ring brush assembly showing six contact elements (Source: Moog)

specify proper internal design features to control the amplitude and length of the impedance mismatch as a function of the data speed and type.

Crosstalk can also be problematic in slip ring design. Placing a number of power and data circuits in relative close proximity in a housing requires careful attention to the isolation of noise sensitive channels from noise producing channels. Careful physical spacing and shielding accomplish this.

Environmental protection

Slip rings require a protective housing to protect the sliding electrical contacts from environmental contamination like the one in Figure 4. One of the leading causes of slip ring failure is a breakdown in this environmental protection thereby exposing the exposed electrical contacts to external contamination. Contamination from sand and dust, humidity, or hydraulic oil (to name just a few) can result in failure of data channels. Lack of or degradation of the structural stiffness of the housing can also expose the contacts to excessive amplified vibration levels. Proper slip ring mechanical housing design is just as important to

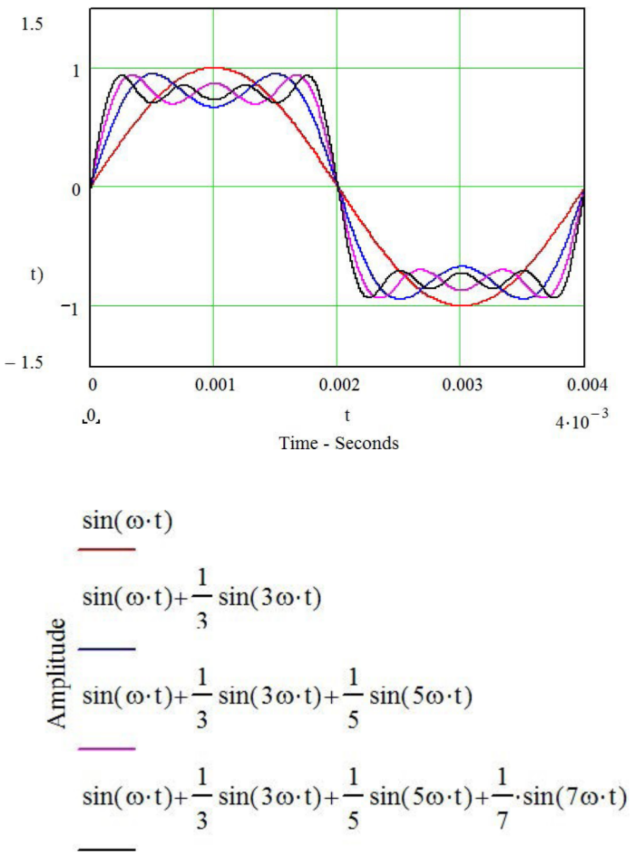


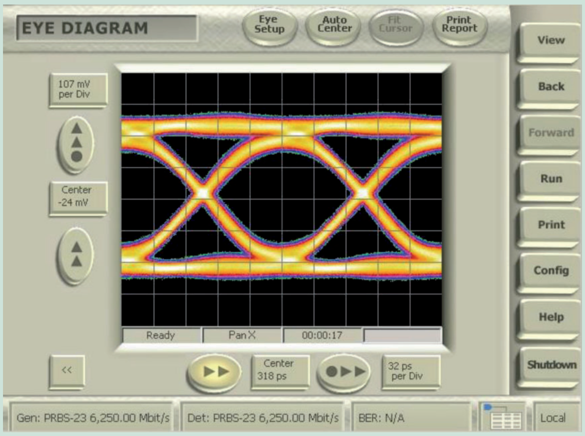
Figure 3: The ability of the transmission line to pass higher order harmonics improves the quality and reliability of the digital data being transmitted (Source: Moog)

data reliability as the design of the electrical contacts or the electrical design. The construction equipment environment can be harsh in terms of shock, vibration, contaminating fluids/sand/dust, and temperature extremes. Critical features of the housing must include:

- The electromagnetic environment should also be considered. "Contamination" from conducted or radiated electromagnetic noise can result in spurious data coupling onto digital data channels. Proper electromagnetic shielding is an important slip ring feature.
- An external housing that is rugged and stiff, but not excessively heavy as well as corrosion and fungus resistant.
- Environmental sealing to the appropriate IP standard, which is normally IP65- or IP66-rated depending on the operating environment
- A maintenance-free bearing design to survive all environmental requirements
- The ability to operate within a temperature range of -40 °C to +80 °C and a humidity range between 0 % and 100 %.
- The housing must survive the shock and vibration levels imposed by construction equipment without significant degradation.

Bit Error Rate (BER)

Bit Error rate is the best metric of quality of digital data and values on the order of 10^{-9} are normally required for acceptable data transmission, i.e, one bit out of every 1 billion is "bad" or one bit error every 10 seconds for data transmitted at 100 Mbit/s. A signal can be assessed for potential data quality by looking at its eye pattern. The figure shows the eye pattern of a 100 Mbit/s square wave. "Stacking up" all the pulses on a transmission line on top of each other forms the eye patterns, to clearly see the pulse amplitude and phase variation. The open part, or eye, can be equated to a BER value. Smaller eyes equal higher BERs, or poorer data quality. Eye patterns show the quality of the transmission line being used to transmit the signal and are a very good indicator of the impedance mismatch in the transmission line.



Eye diagram (Source: Moog)

CAN communication

There is a wide range of protocols or formats used to communicate between devices. Classical CAN is the most commonly used network technology in construction equipment. With a maximum data rate of 1 Mbit/s, data is transmitted differentially on a twisted pair (balanced) from which it derives its robust noise immunity and fault tolerance. The nominal line impedance of CAN is 120 Ohm and the slip ring should be designed with this impedance in mind. Low latency is critical with CAN, but since slip rings are passive devices, they do not contribute to system latency. A variety of multi-pin, environmental connectors can be used as the interface to the CAN channel(s). Properly designed slip rings can reliable transmit CAN data with BER rates of greater than 10^{-12}. The same can be said for CAN FD with a data rate 10 Mbit/s or less.

Figure 4: Slip ring protective housing (Source: Moog)

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