

## Speed Measurement and Control with the AD2S83, a "Silicon Tachogenerator"

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### INTRODUCTION

Continuous and precise control of speed with long-term stability and good transient performance is an important feature of machine control. At the present time, the most popular speed transducer used in the industry is still the mechanical dc tachogenerator, which has the advantages of small size, simple connections and good linearity. But its mechanical commutator is often undesirable because of the regular maintenance required. Mechanical tachogenerators normally use silver-graphite brushes for commutation. They usually have quoted life time of  $10^9$  revolutions in industrial conditions, which is equivalent to 347 days life with a motor running on average at 2000 rpm. When interruptions of the operation cannot be tolerated or when the transducer is used in inaccessible locations, constant maintenance is difficult; conversely, brushless resolvers have a robust rotor construction which permits reliable maintenance-free operation at a wide speed range. Because the resolver is an absolute position device, it intrinsically provides velocity information.

### SILICON TACHOGENERATOR CONFIGURATION

The block diagram of a typical type II tracking R/D converter is shown in Figure 1. With the resolver shaft moving at a constant speed  $v$ , the VCO output will correspond exactly to the update rate which is equal to the rate of change in  $\theta$  per unit of time where instantaneously  $\theta = \phi$ . This infers that  $d\phi/dt$  always tracks the velocity of the input  $d\theta/dt$  with zero velocity error (also, without a position error), i.e.,  $d\phi/dt = d\theta/dt = v$ . The signal  $d\phi/dt$  is used to represent accurately the resolver shaft rotating speed. Theoretically, the only error in this process is the momentary errors during acceleration or deceleration. How fast the transient error settles usually depends on the dynamics of the tracking converter, which are determined by external passive components (set by user) on some modern monolithic converters. Traditionally monolithic RDCs were optimized for position information outputs only. The AD2S83, based on the AD2S80A, can now provide a very high quality velocity signal with a linearity error as low as  $\pm 0.15\%$  of its nominal value.

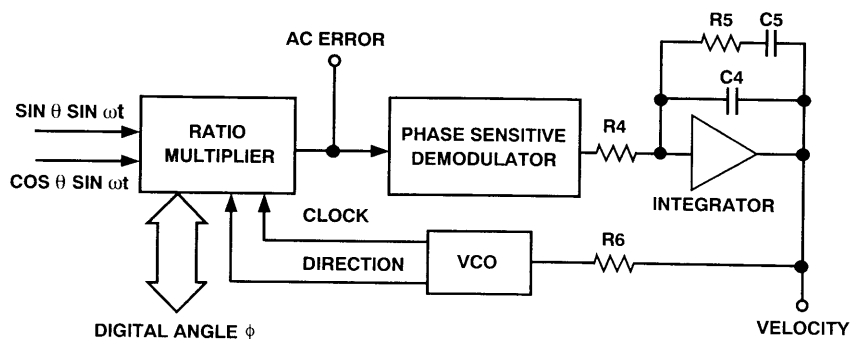


Figure 1. Tracking Resolver-to-Digital Converter Block Diagram

Practically, there are several error sources in the R/D converter velocity signals.

1. Static errors caused by resolver inaccuracies including resolver phase shift and transformer ratio mismatch;
2. An ac component of  $2\times$  reference frequency superimposed on the dc velocity signal output, which has the amplitude (rms value) ranging from several millivolts to a hundred millivolts depending on the converter loop bandwidth set by user;
3. LSB rate ripple caused by least significant bit update noise, which usually has a magnitude of approximately sub-millivolt peak if the VCO gain is correctly scaled.

These errors can be minimized with careful consideration in the sizing of resolvers and other passive components. The combination of resolver and R/D converter provides a suitably high quality velocity signal for high precision motion control.

Other advantages of using a resolver with an AD2S83 in speed control include the infinite velocity resolution compared to an encoder system, high speed ratings due to its brushless structure, and offering a cost competitive solution.

#### AD2S83 AND MECHANICAL TACHOGENERATOR PERFORMANCE TEST

In this performance test, we randomly picked a dc tachogenerator and a size 11 brushless resolver, with the following key specs which are typical of industrial applications:

Tachogenerator: 0.1% linearity, 0.25% reversion error and 3% ripple, over 0–3600 rpm  
Brushless resolver: size 11, 7 arc min accuracy and 0.015 V null voltage. Excitation frequency is 5000 Hz.

The resolver-to-digital converter used is the AD2S83. It has 8 arc min position accuracy and has been specifically designed for applications requiring a high quality velocity signal. The resolution of the position data is 10-, 12-, 14- and 16-bit user selectable, and the converter dynamics are set by external passive components. In the test, the resolution was set to 12 bits with a bandwidth of 520 Hz. Maximum velocity tracking rate in 12-bit mode is 15,600 rpm. To guarantee the accuracy of the test results, two velocity transducers are coaxially connected via a precision gearbox (with minimal backlash). Any velocity error from either the drive or gearbox will be common to both devices and, therefore, only the relative accuracy is compared. The hardware configuration of the testing system is shown in Figure 2. The velocity source is guaranteed to have overall 0.05% accuracy during the test. The test data is detailed in the curves shown in Figure 3 (percentage linearity error), Figure 4 (percentage reversion error) and Figure 5 (ac ripple content). From the comparison curves, it could be clearly seen that the performance of a resolver plus AD2S83 R/D converter is superior to that of a dc tachogenerator.

For resolver plus R/D, the test curve can be extended to its full range of 15,600 rpm, if the velocity source permits. The 0–3,000 rpm range was chosen for the test as tachogenerators usually have limited linear speed range, typically 0–3,000 rpm.

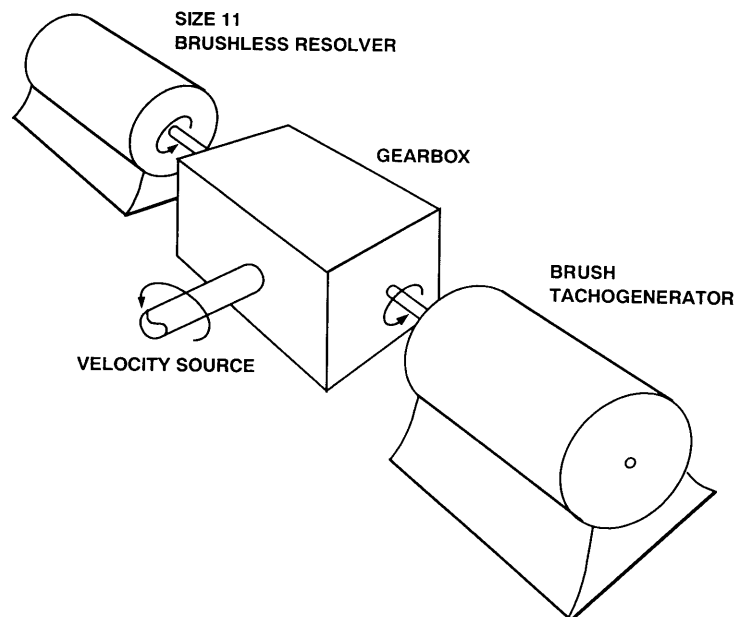


Figure 2. Hardware Configuration

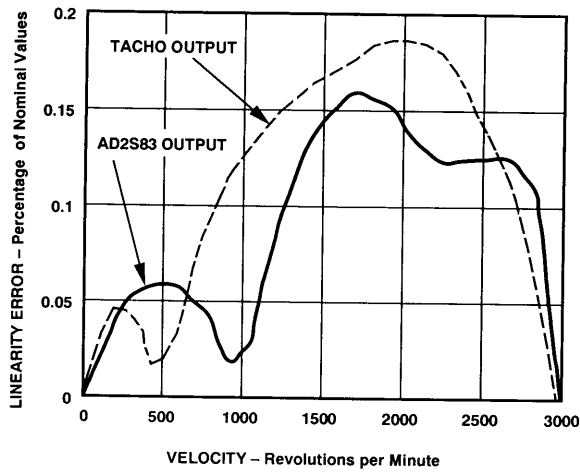


Figure 3. Linearity Error Comparison Curve

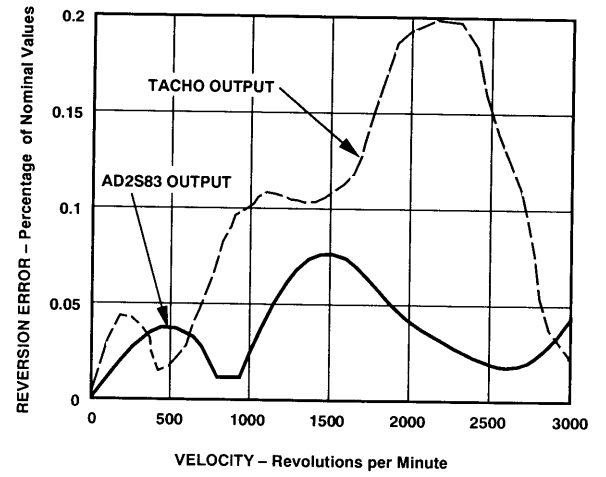


Figure 4. Reversion Error Comparison Curve

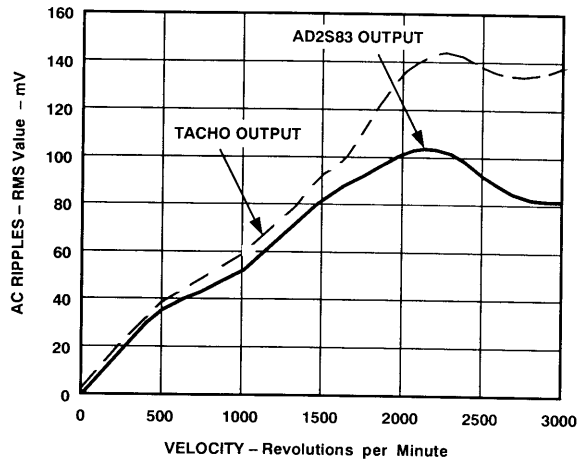


Figure 5. AC Ripple Content Comparison Curve