# US Dynamics Rate Gyroscope Interface Brief

**Scope:**

*This applications note discusses in brief, the typical input signals to and output signals from a US Dynamics miniature spinning mass Rate Gyroscope. Since there are several variations of rate gyroscopes, the signals exemplified here represent those typical of the Model 475 Rate Gyroscope, a common design. The aim of this note is to give system designers and engineers some basic insight as to how to plan for the design and implementation of the necessary rate gyroscope operation support functions.*

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**Typical Rate Gyroscope Input/Output Explained in Brief**

*Rate Gyroscope Inputs*

The US Dynamics miniature spinning mass *Rate Gyroscope*, as a minimum, requires the following inputs:

1.  Spin motor excitation.

Spin motor excitation provides the electrical power required to start and maintain the speed of the gyroscope spin motor, which is a synchronous induction, hysteresis type. Required here is a two phase AC signal, where the two phases are 90 electrical degrees displaced, such that there is a leading phase and
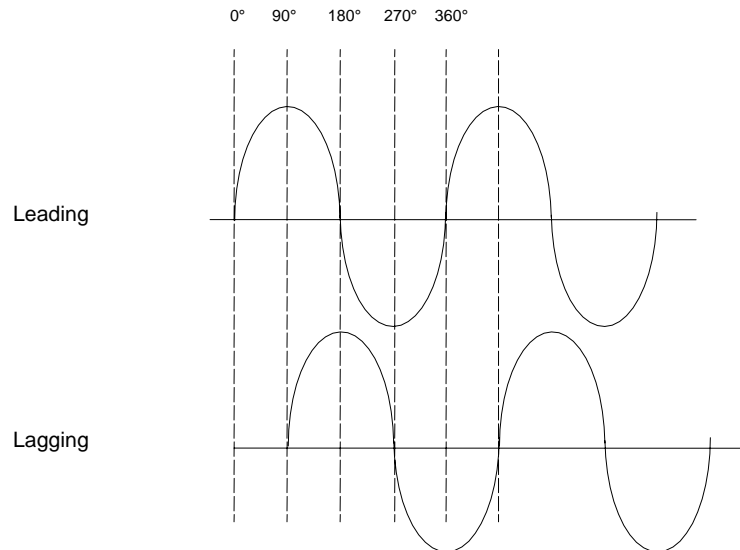


**Figure 1 - Spin motor excitation phase relationship**

a lagging phase. This signal then must be amplified to assure that adequate voltage and current is available to satisfy the requirements of the motor. Refer to figure 1. The 90° offset *(quadrature)* phase relationship is necessary in a synchronous induction hysteresis motor to set up a *rotating* magnetic field. The rotation of the field then allows an *attractive* material, such as that incorporated in the rotor, to spin with the field. In

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the hysteresis induction motor, the rotor will eventually (usually within a minute) lock into the same rotation rate as the field. The rate of rotation of the magnetic field is governed by the following relationship:

r.p.m. = (120 * f) / p

> where: f = excitation frequency
> p = number of motor poles
> r.p.m. = the rotation rate

The system designer may note that the excitation waveform shall not necessarily be restricted to a sinewave. Square waves in quadrature may also be used in some cases, however this preference must be noted at the time of gyroscope design or specification to verify compatibility. The waveform must however, be *bi-polar* (true AC).

The close regulation of gyro wheel speed in a spinning mass gyroscope is of great importance to the accuracy of the angular rate measurements received from the rate gyro. Therefore, the oscillator used to generate the motor excitation should be as frequency stable as practical for the intended application.

2.  Pickoff excitation.

The rate gyroscope pickoff (output signal generator) excitation provides the electrical input to the *primary side* of the pickoff. This is a single phase AC signal. The pickoff operates as a differentially wound variable transformer, similar to an LVDT. That is, it is a phase sensitive, variable *rotary* transformer. In many cases, the motor frequency and pickoff frequency is specified to be common. Therefore, only one *master* oscillator would be required. This could greatly simplify an overall system design.

Usually, the pickoff *primary* winding is of sufficiently low impedance as to require current levels higher than typical signal level current. Current levels exceeding 40mA are not uncommon requirements. As such, an appropriate amplifier would be used to increase the current as well as provide convenient signal conditioning opportunities, such as phase correction, if needed.

As with the spin motor, the pickoff waveform requirement is not limited to pure sinewaves. Although sinewave excitation for the pickoff is generally preferred, in some cases square wave pickoff excitation may be permitted by the particular design of a given gyroscope.

### Rate Gyroscope Outputs

The rate gyro pickoff output (output signal generator) provides a *phase sensitive*, variable voltage which when scaled by the rate gyro scale factor, gives a direct indication of the rate of turn input that the gyro is experiencing. The scale factor is a ratio of pickoff output voltage to rate of turn (in degrees per second), and is usually given in mV per degrees per second. Therefore, if the pickoff is outputting 1.45 Volts, that voltage divided by the scale factor will provide the rate of turn the gyro is experiencing, in degree per second.

For example, if the rate gyro scale factor is 40mV/deg/sec, and the output of the pickoff secondary is 1.45 Volts, divide 1.45 Volts by .040V, to find 36.25°/sec. Some typical output waveforms of a rate gyro pickoff are shown below:
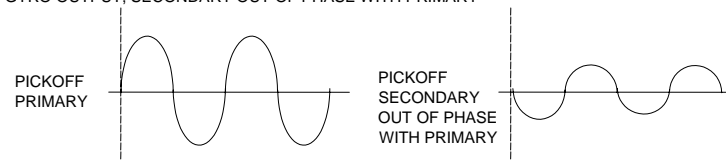
A. GYRO OUTPUT, SECONDARY IN PHASE WITH PRIMARY

PICKOFF PRIMARY

PICKOFF SECONDARY IN PHASE WITH PRIMARY
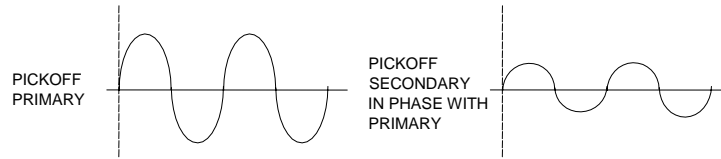
B. GYRO OUTPUT, SECONDARY AT NULL

PICKOFF PRIMARY

PICKOFF SECONDARY AT NULL
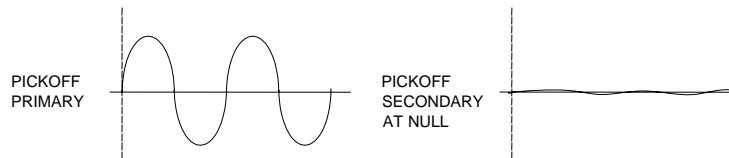
C. GYRO OUTPUT, SECONDARY OUT OF PHASE WITH PRIMARY

PICKOFF PRIMARY

PICKOFF SECONDARY OUT OF PHASE WITH PRIMARY

**Figures 2A thru 2C- Typical pickoff output waveforms**

Figure 2A shows the pickoff output waveform when sensing a clockwise rotation rate. The output waveform is noted to be *in phase* with the primary excitation waveform. Figure 2B shows the pickoff output waveform at the *null* position, where no rotation rate is sensed. A negligible null voltage is present under those conditions. Figure 2C shows the pickoff output waveform when sensing a counterclockwise rotation rate. The output waveform is noted to be *out of phase* (180°) with the primary excitation waveform. Therefore, the phase relationship between the pickoff primary and the pickoff excitation waveform can give insight as to the direction of the rotation rate sensed by the rate gyro.

The output of the rate gyro pickoff then requires *demodulation* if the output of the gyro is to provide direction of rotation rate output in addition to the absolute magnitude of rotation rate. In other words, the output of the pickoff could simply be monitored with a true RMS voltmeter (reading AC) to give the *magnitude* only of the rotation rate sensed by the gyro, as a voltage. However, most applications do require the sensed rotation rate direction as well, and would therefore require a phase sensitive demodulator.

Demodulation accomplishes two tasks to resolve the output of the rate gyro. First, it rectifies the AC output voltage into a DC voltage. Second, it compares the phase of the pickoff output to the phase of the pickoff excitation to determine rotation rate direction. Demodulation therefore, also provides a sign (+/-) to the DC voltage output. The result is a positive or negative DC voltage, indicative of the magnitude *and* direction of the rotation rate sensed by the rate gyro.

*Other Possible Interface Requirements*

1. Gyroscope Heater Power.

Some rate gyroscope designs require a heater to maintain a constant temperature at the gyroscope. A constant temperature eliminates the effects of temperature swings on the performance of the gyro. The damping ratio factor of the rate gyro is a prime example.

The damping ratio primarily depends on the damping provided by the gyroscope fill fluid. As this *viscous* fluid is heated or cooled, the viscosity index of the fluid changes as well. This would invariably cause a change in the damping ratio of the gyro. In extreme cases, this could lead to instability and subsequently to errors. Some gyro designs include a temperature sensitive compensator that adjusts the damping during temperature changes.

A well controlled heater that maintains a constant temperature at the gyroscope can accomplish the same effect. For example, the temperature can be maintained above the highest expected operating ambient temperature condition (but well below any damage threshold). Then for any ambient temperature up to the heater temperature can be held to a constant by adjusting the energy input to the heater.

2.  Gyroscope Gimbal Torquer Power.

Ordinarily, gimbal torquers (a device which serves to position the gimbal in the absence of an input rate or torque) are not associated with rate gyroscopes. However, some rate gyro designs require a self-test feature to enable a system to check the ability of an individual rate gyro to be up to its task. Here, a (typically) DC current is supplied to the torquer device, or torque motor, to rotate the gyro's gimbal a prescribed amount (resolved in degrees or radians). Then, the gyro pickoff output can be monitored to determine if the gimbal was free to move the prescribed amount, thereby verifying the condition of the gyro via the self test.
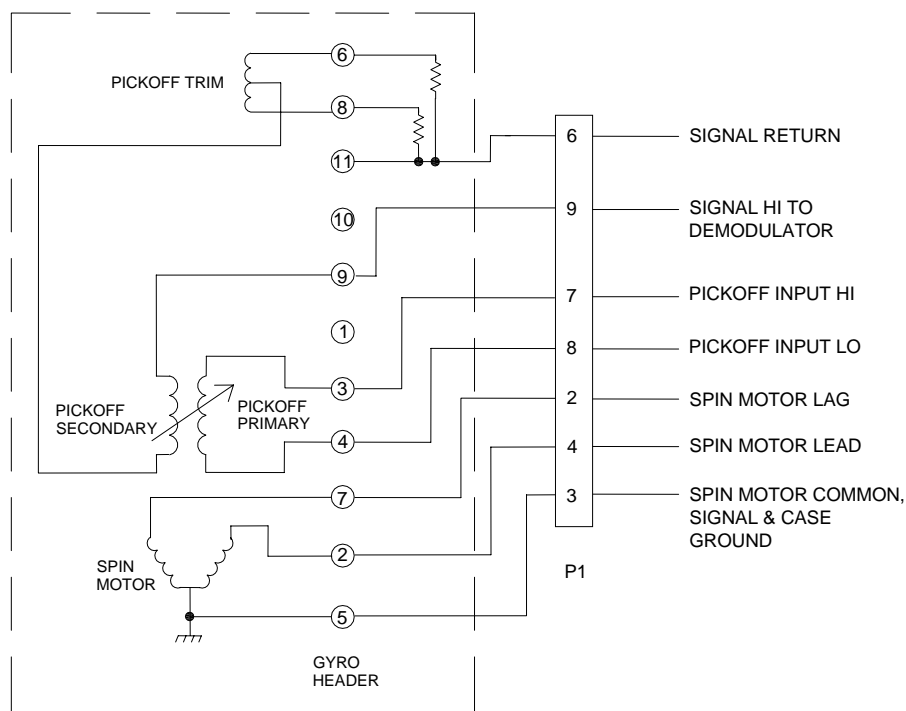
**Model 475 Rate Gyroscope Wiring Diagram**



**Figure 3 - Model 475 Type Rate Gyro wiring diagram**

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Shown above in figure 3 is the interface wiring diagram for the US Dynamics Model 475 Rate Gyroscope. It can be considered as the minimum interface required for a miniature spinning mass rate gyroscope. Through the P1 connector, the gyro is provided with spin-motor and pickoff excitation. In addition, the pickoff output is available to the user for demodulation, or for measurement otherwise.

<u>**Summary**</u>

System designers and engineers may review the information presented in this brief to become familiar with the basic rate gyroscope interface requirements.

As a minimum, gyroscope spin motor excitation and gyroscope pickoff (output signal generator) excitation are required inputs to most miniature spinning mass rate gyroscopes such as the US Dynamics Model 475. In addition, the rate gyroscope pickoff output made available to a phase sensitive demodulator is typical. These minimum basic input/output requirements are necessary to allow a user to test or to use a rate gyroscope for accurately and directly determining the precise rate of turn of an object such as a telescope gimbal mount or an antenna platform.

Subsequent US Dynamics applications notes will present the basic topics discussed here in more detail. In those more specific notes, there will be presented some basic interface circuits in more detail for those familiar with circuit design to expand upon and customize for use in their own applications.