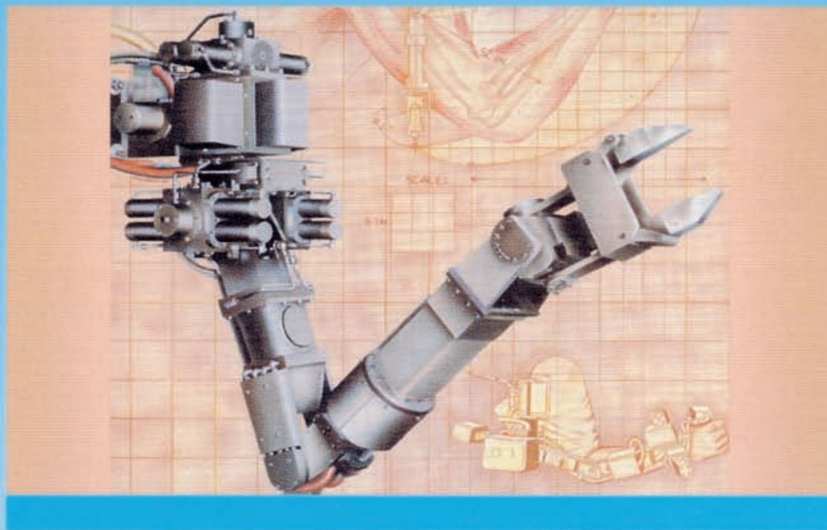
ROTARY TRANSDUCER APPLICATION DATA



CDA InterCorp

CDA InterCorp

INTRODUCTION

This application manual defines the performance capabilities of CDA InterCorp's Rotary Transducer Product Line for feedback systems to sense position, velocity and acceleration with rugged, reliable performance hardware.

The design data contained herein reflects the continuous demand for improved performance, efficiency, and reliability, while simplifying drive techniques, and minimizing size and weight. CDA InterCorp's rotary transducers are designed to operate under the most demanding requirements of MIL-STD–810, while maintaining robust, reliable damping characteristics. These transducer products are used in aerospace, outer space, defense, commercial aviation, "down hole", robotic, nuclear, and high reliability industrial control applications.

With over 35 years in the industry, CDA InterCorp's core philosophy of modular standardization has withstood the test of time. Each module design utilizes the same inventoried piece part standards, materials, processes, and construction techniques. Inherent in our standard modules are unequaled reliability and ruggedness, while maintaining flexibility in providing custom transducer requirements and extremely responsive prototype and production deliveries.

CDA's quality system is certified to ISO-9001:2000. A government quality representative is available to provide source inspection, as required.

For responsive support for your specific requirements , please write, phone, fax, or e-mail CDA InterCorp directly. CDA's system application engineers are available to visit your facility to assist in the design and selection of the proper Rotary Transducer Assembly for your specific application.

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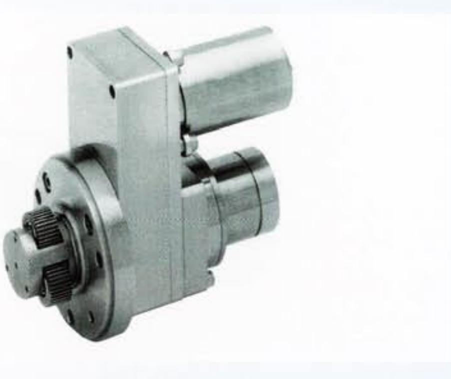


Rotary Transducers

CDA InterCorp's Rotary Transducers provide high accuracy outputs for angular position, velocity, and acceleration requirements in today's advanced systems. These components deliver precise output performance in small size and weight. High grade stainless steel construction, class H220 insulation system, and brushless design assures reliable performance under the most severe operating conditions. Additional features include wide operating range of -80° C to +220° C, high vibration and shock capacity, high velocity and high acceleration capacity, high signal to noise ratio, continuous rotation, and a wide selection of output formats.

Applications for these sensing devices include aircraft antenna positional feedback, primary and secondary control surface indicators, servo stability requirements, servo control demand information, velocity servos, aircraft wheel velocity information, and virtually any system where velocity, position, force, or acceleration information is required.

CDA InterCorp has the ability to provide these components with integrally mounted geartrains, or combine components to provide "multi-function sensing", or cascade components in tandem or cluster format to provide redundancy. Additionally, CDA InterCorp may provide these devices mounted to a motor or actuator to provide reliable servo performance in a compact package. All components have been qualified to the most demanding requirements of MIL-STD-810. Historical data has proven that CDA InterCorp's rugged construction components perform reliably in extreme application environments.

POSITION TRANSDUCERS

With the advancement of digital electronics, and increased demand for high reliability, high accuracy systems, high frequency brushless position sensors are replacing brush-type synchros, resolvers, and optical encoders, for these applications. Small size, light weight, rugged construction, and ease of implementation make CDA InterCorp's line of Brushless Resolvers, and Brushless RVDT's, ideal for control and positional information in advanced systems.

CDA InterCorp's standard line of position sensors are tabulated on pages 3 through 8.

VELOCITY TRANSDUCERS

Velocity sensors are extremely useful for position and velocity control applications. AC Tachometers are designed to accommodate specific rate signal needs, to improve inner loop stability, and provide overall system damping, which is essential for closed loop control systems. Velocity control systems can benefit from high signal to noise ratios, high accuracy, and stable performance over temperature and time.

Another velocity sensor option is the Permanent Magnet Alternator (PMA). PMA's produce an output where the frequency and magnitude of voltage vary in direct proportion to the angular velocity. These devices are useful where dynamic angular positional information can also be derived by "EZing" the PMA in the system. Additionally, "Zero Crossing" information of the output voltages is a simple method of determining positional and velocity information.

CDA InterCorp's standard line of velocity sensors are tabulated on pages 8 through 11.

ACCELERATION TRANSDUCER

Acceleration feedback offers a "higher" order effect on servo and stepper motor operation than other forms of rate feedback. A major advantage of our Rotary Accelerometers (RA's) is that they do not require excitation or demodulation to provide a DC output voltage in proportion to the angular acceleration ($Vp/rad/Sec^2$). Particularly useful in closed loop servo applications or operating a stepper motor in the slew mode, the accelerometer may be mounted directly to a motor, or sold as a stand alone module.

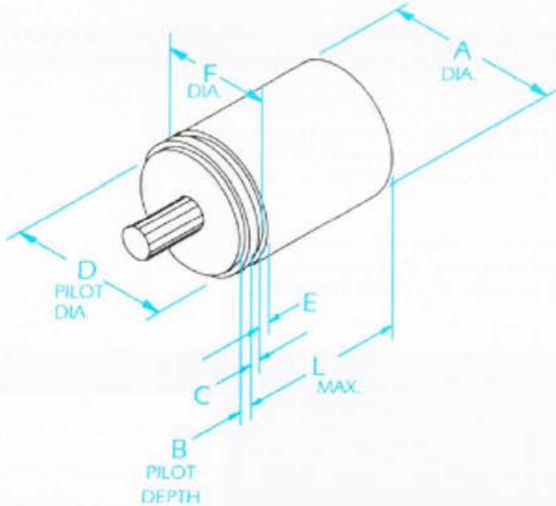
More detailed information on the description and applications of RA's are detailed on pages 12 through 15.

INDEXING GEARING

CDA may provide precision "index gearing" with our transducer models to increase field of operation, or increase resolution of sampling information. Indexing gears are specifically designed to adapt to our precision rotary transducers, to provide high accuracy, low transmission error operation. As with all of CDA's products, our indexing gearing is constructed with matched CTE's for wide temperature operation. See page 16 for indexing gearing options.

Geared Brushless Resolver Assembly

Resolver & RVDT Mechanical Data



IMPERIAL UNITS - In Inches												
TYPE	A	B	C	D	E	F	SINGLE			TANDEM		
							L	INERTIA Oz-In-sec²	WEIGHT Oz.	L	INERTIA Oz-In-sec²	WEIGHT Oz.
03BRX	0.750	0.040	0.062	0.6875	0.062	0.691	1.240	1.5×10^{-5}	1.75	2.553	5.1×10^{-5}	3.6
03RVDT	0.750	0.040	0.062	0.6875	0.062	0.691	0.887	9.0×10^{-6}	1.30	1.660	1.9×10^{-5}	2.8

SYSTEM INTERNATIONAL - In mm												
TYPE	A	B	C	D	E	F	SINGLE			TANDEM		
							L	INERTIA kgm²	WEIGHT kg	L	INERTIA kgm²	WEIGHT kg
03BRX	19.1	1.02	1.58	17.463	1.58	17.55	31.50	1.06×10^{-7}	0.050	64.85	3.60×10^{-7}	0.102
03RVDT	19.1	1.02	1.58	17.463	1.58	17.55	22.53	6.40×10^{-8}	0.037	42.16	1.34×10^{-7}	0.080

Notes:

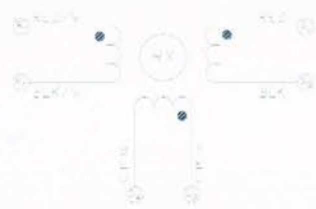
1. Pilot to pinion concentricity = 0.0007 inches [0.018 mm] TIR.
2. Mounting surface to pinion perpendicularity = 0.0007 inches [0.018 mm] TIR.
3. Other mounting and shaft configurations are available on request.
4. Standard size 08, size 10 or size 11 mounting configuration available on request.
5. Operating temperature range: -80° C to + 225° C.
6. Cryogenetic temperatures available on request.
7. See pages 4 & 5 for Brushless Resolver (BRX) performance data.
8. See pages 6 to 8 for RVT & RVDT performance data.
9. See pages 16 & 17 for precision gearing configuration and options.

Brushless Resolver Performance Data

BRUSHLESS RESOLVER - TRANSMITTER (RX)

Description / Application:
Resolver Transmitters are utilized in translating angular rotor position into orthogonal (sine-cosine) components. The two wire rotor (R_{12}) is excited with a fixed voltage and frequency, and the stator (S_{13} & S_{24}) output voltages vary sinusoidally with the rotor position.

With the advancement of Resolver to Digital converters, these devices are becoming very popular in control and position sensing requirements, in advancing high reliability systems.



	TYPE —>	08BRX2.5
Excitation Voltage (Rotor)	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.019
Tuned Current	Amps RMS	0.009
Tuning Capacitor	μF	0.100
Output Voltage (Stator)	Volts RMS	10.0
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.030
Accuracy	Arc-Min	3.0
Output Impedance (Z)	Ohms	1600
Output Load	Ohms	100,000

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Other accuracies available upon request.
3. See page 16 for precision gearing data.
4. See page 3 for mechanical data.
5. Impedances for optimum RX-RC combination available upon request.

BRUSHLESS RESOLVER - CONTROL (RC)

Description / Application:
Like the RX, the Control Resolver (RC) is useful in orthogonal axis translation. However, the RC is stator excited (S_{13} & S_{24}) with sine-cosine voltages, and the rotor output varies sinusoidally with rotor position. The RC may be driven off of an RX, or off a system gyro with sine-cosine components.

RC's are particularly useful in servo-control applications, where the rotor output is used for amplifier signal input, in closed loop motor contorl systems.

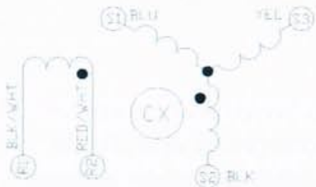
	TYPE —>	08BRX2.5
Excitation Voltage (Stator)	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.005
Tuned Current	Amps RMS	0.003
Tuning Capacitor	μF	0.018
Output Voltage (Rotor)	Volts RMS	10.0
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.030
Accuracy	Arc-Min	3.0
Output Load	Ohms	100,000

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Other accuracies available upon request.
3. See page 16 for precision gearing data.
4. See page 3 for mechanical data.

Brushless Control Performance Data

BRUSHLESS CONTROL - TRANSMITTER (CX)

Description / Application:
Control Transmitters (CX) are ideal components utilized in the remote control of precise servo applications. Typically used as axis sensing components, the Control Transmitter's output signal is often used to drive a Control Transformer (CT). However, with today's Synchro to Digital converters, CX's are finding more applications in other position feedback applications.



Viewing shaft end, output positive for CCW rotation from EZ shown when S_1 and S_3 tied

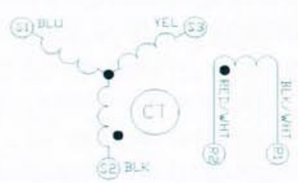
	TYPE —>	08BCX2.5
Excitation Voltage (Rotor)	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.016
Tuned Current	Amps RMS	0.008
Tuning Capacitor	µF	0.082
Output Voltage (Stator)	Volts RMS	10.0
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.030
Accuracy	Arc-Min	3.0
Output Impedance (Z)	Ohms	450
Output Load	Ohms	100,000

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Other accuracies available upon request.
3. See page 16 for precision gearing data.
4. See page 3 for mechanical data.

BRUSHLESS CONTROL - TRANSFORMER (CT)

Description / Application:
Like the RX, the Control Resolver (RC) is useful in orthogonal axis translation. However, the RC is stator excited (S_{13} & S_{24}) with sine-cosine voltages, and the rotor output varies sinusoidally with rotor position. The RC may be driven off of an RX, or off a system gyro with sine-cosine components.

RC's are particularly useful in servo-control applications, where the rotor output is used for amplifier signal input, in closed loop motor contorl systems.



Viewing shaft end, output positive for CCW rotation from EZ shown when S_1 and S_3 tied

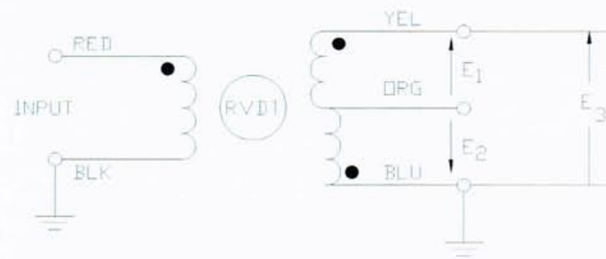
	TYPE —>	08BCT2.5
Excitation Voltage (Stator)	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.005
Tuned Current	Amps RMS	0.003
Tuning Capacitor	µF	0.018
Output Voltage (Rotor)	Volts RMS	10.0
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.030
Accuracy	Arc-Min	3.0
Output Load	Ohms	100,000

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Other accuracies available upon request.
3. See page 16 for precision gearing data.
4. See page 3 for mechanical data.

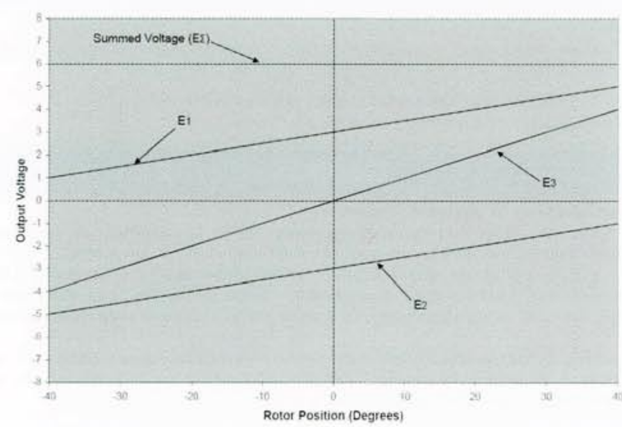
ROTARY VARIABLE TRANSFORMERS AND ROTARY VARIABLE DIFFERENTIAL TRANSFORMERS

The Rotary Variable Transformer (RVT) and the Rotary Variable Differential Transformer (RVDT) are effective solutions for high reliability position sensing applications. These components offer low friction, infinite resolution, and linear output.

The input voltage is an AC signal ranging in frequency from 400 Hz to 5,000 Hz. The output voltage is also an AC signal at the same frequency as the excitation, whose magnitude varies in proportion to the angular position of the shaft. The output voltage scale factor (mV/Deg) may be modified as required to meet system application needs.



The RVDT provides a linear voltage output across E_3, over a limited angular range from electrical zero. The outputs E_1 and E_2 are typically used for functional testing purposes as Built In Test (BIT). When the **absolute** outputs of E_1 and E_2 are summed together, a constant voltage (E) is produced over the angular range. This voltage (E) may be used to verify the integrity of the rotary transformer, as well as the excitation voltage supply line.



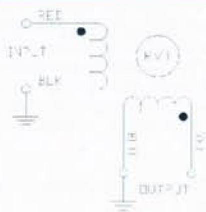
If monitoring of the summed output voltage (E) is not required, it is recommended that a RVT be specified for the application. The RVT may provide the same output scale factor as the RVDT, but the elimination of the summed output feature reduces the number of terminations, and simplifies the design. Either option is a standard product offered by CDA InterCorp.

RVT Performance Data

ROTARY VARIABLE TRANSFORMER (RVT)
TWO CYCLE

Description / Application:
The Rotary Variable Transformer (RVT) produces a linear voltage output over a limited angular displacement of the rotor. The RVT has no brushes or rotary windings, and has the capability of unlimited rotation. The single winding repetitive output, limits the two cycle useful operating range to ±40°.

Precision gearing is available to extend the useful angular operating range. See page 16 for gearing information.



Viewing shaft end, output positive for CCW rotation from EZ shown

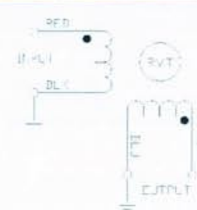
	TYPE ——>	2XRVT2.5
Excitation Voltage	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.023
Tuned Current	Amps RMS	0.005
Tuning Capacitor	μF	0.1
Scale Factor	mV/Degrees	100
Temperature Coefficient	%/°C	0.007
Range	Degrees	±40
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.015
Linearity ±40°	%	0.50
Output Load	—	50,000Ω

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Offset range of 0° to +80°.
3. See page 3 for mechanical data.

ROTARY VARIABLE TRANSFORMER (RVT)
SINGLE CYCLE

Description / Application:
The Rotary Variable Transformer (RVT) produces a linear voltage output over a limited angular displacement of the rotor. The RVT has to brushes or rotary windings, and has the capability of unlimited rotation. The single winding repetitive output, limits the single cycle useful operating range to ±80°.

Precision gearing is available to extend the useful angular operating range. See page 16 for gearing information.



Viewing shaft end, output positive for CCW rotation from EZ shown

	TYPE ——>	1XRVDT2.5
Excitation Voltage	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.035
Tuned Current	Amps RMS	0.007
Tuning Capacitor	μF	0.22
Scale Factor	mV/Degrees	100
Temperature Coefficient	%/°C	0.007
Range	Degrees	±80
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.015
Linearity ±80°	%	0.50
Output Load	—	50,000Ω

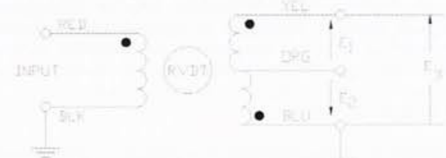
Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Offset range of 0° to +160°.
3. See page 3 for mechanical data.

RVDT Performance Data

ROTARY VARIABLE DIFFERENTIAL TRANSFORMER (RVDT)
TWO CYCLE

Description / Application:
The Rotary Variable Differential Transformer (RVDT), like the RVT, produces a linear voltage output over a limited angular displacement of the rotor. The differential output provides a constant sum voltage when E_1 and E_2 are summed absolutely. See expanded description on page 3. The Two Cycle RVDT provides a linear output over a ±40° range.

The advantage of the RVDT includes simple implementation and high reliability.



Viewing shaft end, output E_3 positive for CCw from EZ shown

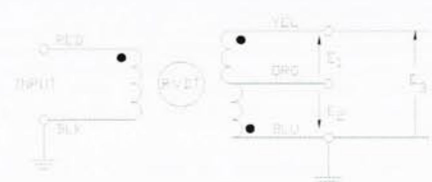
	TYPE —>	2XRVDT2.5
Excitation Voltage	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.023
Tuned Current	Amps RMS	0.005
Tuning Capacitor	μF	0.1
Scale Factor	mV/Degrees	100
Temperature Coefficient	%/°C	0.007
Range	Degrees	±40
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.015
Linearity ±40°	%	0.50
Output Load	—	50,000Ω

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Offset range of 0° to +80°.
3. See page 3 for mechanical data.
4. See page 16 for precision gearing.

ROTARY VARIABLE DIFFERENTIAL TRANSFORMER (RVDT)
SINGLE CYCLE

Description / Application:
The Rotary Variable Differential Transformer (RVDT), like the RVT, produces a lenear voltage output over a limited angular displacement of the rotor. The differential output provides a constant sum voltage when E_1 and E_2 are summed absolutely. See expanded description on page 3. The Single Cycle RVDT offers a wider angular range over the two cycle.

The advantage of the RVDT includes simple implementation and high reliability.

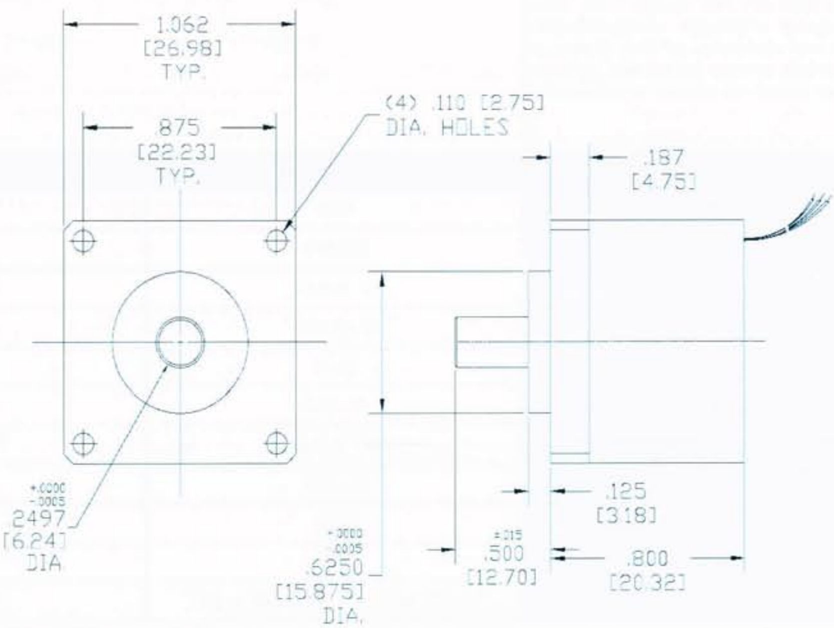


Viewing shaft end, output positive for CCw rotation from EZ shown

	TYPE —>	1XRVDT2.5
Excitation Voltage	Volts RMS	10.0
Frequency	Hertz	2500
Untuned Current	Amps RMS	0.035
Tuned Current	Amps RMS	0.007
Tuning Capacitor	μF	0.22
Scale Factor	mV/Degrees	100
Temperature Coefficient	%/°C	0.007
Range	Degrees	±80
Phase Shift	Degrees	0
Null Voltage	Volts RMS	0.015
Linearity ±80°	%	0.50
Output Load	—	50,000Ω

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. Offset range of 0° to +160°.
3. See page 3 for mechanical data.
4. See page 16 for precision gearing.

Velocity & Acceleration Transducer Mechanical Data



Type	L		Weight		Inertia	
	Inches	mm	Oz	kg	Oz-In-Sec^2	kgm^2
Damping Tach	0.765	19.40	2.20	0.063	$1.7 * 10^{5}$	$1.2 * 10^{7}$
Rate Tach	1.000	25.40	2.90	0.082	$4.6 * 10^{5}$	$3.2 * 10^{7}$

Notes:

1. Other mounting and shaft variations available on request.
2. Concentricity of output shaft to pilot: 0.0007 T.I.R. (0.018 mm).
3. Perpendicularity of output shaft to mounting surface: 0.0007 T.I.R. (0.018 mm).
4. Operating temperature range: -80^0 C to $+225^0$ C.
5. High grade stainless steel construction.
6. Tachometer performance and electrical data tabulated on page 10.
7. Tachometers may be provided integrally mounted to a motor assembly, or as a stand alone item as shown.

AC Tachometer Performance Data

TACHOMETERS - DAMPING

Description / Application:
The Damping Tachometer is ideal for high accuracy closed loop position applications where inner loop stability and high forward loop gain are critical.

The Damping Tachometer produces an AC output at the excitation frequency. The output voltage magnitude varies in proportion to the rotational velocity of the output shaft. This information may provide inner loop damping for a position servo, or it may be used to close a velocity loop.

	TYPE —>	11S2.5	11S0.4
Excitation Voltage	Volts RMS	10	26
Frequency	Hertz	2500	400
Untuned Current	Amps RMS	0.065	0.016
Tuned Current	Amps RMS	0.043	0.012
Tuning Capacitor	μF	0.3	0.16
Output Voltage	Volts/1000 RPM	0.50	0.25
Phase Shift	Degrees	5° Lag	10° Lag
Temperature Coefficient	%/°C	0.10	0.25
Total Null Voltage	mVrms	20	020
In Phase Null Voltage	mVrms	10	10
Output Load	—	100 kΩ // 0.0082 μF	100 Ω

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. See page 8 for mechanical data..

TACHOMETERS - RATE

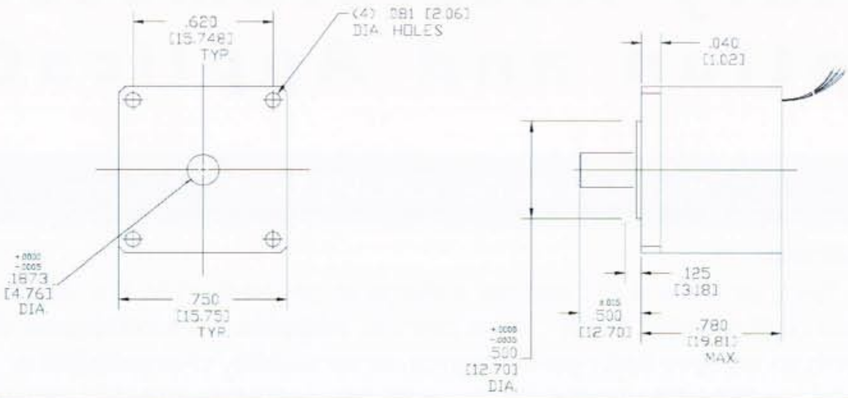
Description / Application:
The Rate Tachometer is ideal for high accuracy closed loop velocity applications where consistent performance over temperatures are critical.

The Rate Tachometer produces an AC output at the excitation frequency. The output voltage magnitude varies in proportion to the rotational velocity of the output shaft. This information may used to close a velocity loop, or it may be used for inner loop damping in position servo applications.

	TYPE —>	11M2.5	11M0.4
Excitation Voltage	Volts RMS	10	26
Frequency	Hertz	2500	400
Untuned Current	Amps RMS	0.510	0.135
Tuned Current	Amps RMS	0.240	0.055
Tuning Capacitor	μF	1.0	1.90
Output Voltage	Volts/1000 RPM	0.50	0.60
Phase Shift	Degrees	0°	5° Lag
Temperature Coefficient	%/°C	0.02	0.04
Total Null Voltage	mVrms	20	020
In Phase Null Voltage	mVrms	10	10
Output Load	—	100 kΩ // 0.0082 μF	100 Ω

Notes:
1. Other voltages, frequencies, and performance data available upon request.
2. See page 8 for mechanical data..

Permanent Magnet Alternator Performance Data



Notes:
1. Other mounting and shaft variations available on request
2. Concentricity of output shaft to pilot: 0.0007 T.I.R. (0.018 mm)
3. Perpendicularity of output shaft to pilot mounting surface: 0.0007 T.I.R. (0.018 mm)
4. Weight: 1.3 oz (0.037 kg)
5. Operating temperature range: -80° C to +225° C
6. High grade stainless steel construction
7. Rotor inertia: $9.2 * 10^{-6}$ Oz-In Sec^2 ($6.5 * 10^{-8}$ kgm^2)
8. Sinusoidal output voltages

PERMANENT MAGNET ALTERNATOR (PMA)

Description / Application:

Permanent Magnet Alternators (PMA's) have the distinct advantage of requiring no excitation voltage. PMA's produce an output voltage whose magnitude and frequency vary in proportion to the rotational velocity of the output shaft. Dynamic angular position may be derived by "counting" the zero crossings of the output voltages. Precision gearing may be incorporated to increase velocity sampling rate.

PMA's may be used for system damping, velocity servos, or dynamic response applications.

Type	1PMA1	1PMA2	1PMA3	2PMA1	2PMA2	2PMA3	3PMA1	3PMA2	3PMA3
Electrical Cycles Per Revolution	1	2	3	1	2	3	1	2	3
Volts Per 1000 RPM (Vrms)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
# Windings	1	1	1	2	2	2	3	3	3
Electrical Angle Between Phases	N/A	N/A	N/A	90°	90°	90°	120°	120°	120°
Rated Load Resistance	10kΩ	10kΩ	10kΩ	10kΩ	10kΩ	10kΩ	10kΩ	10kΩ	10kΩ

Notes:
1. Other voltages available upon request.
2. See page 16 for precision gearing data.

Rotary Accelerometer Description and Applications

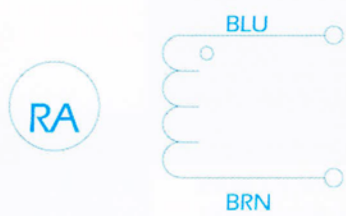
ROTARY ACCELEROMETERS

Description / Application:

Rotary Accelerometers (RA's) provide a DC output voltage in proportion to the phase and magnitude of the rotary acceleration of the motor shaft. These devices **require no excitation or input power**. RA's are ideal components to achieve high performance servo stability characteristics. The acceleration signal may be used alone, or the voltage may be op amp integrated to provide velocity damping plus acceleration information. Feedback can eliminate limited cycle oscillation in geared servo systems, and allow high forward loop gain through response shaping networks (PI OR PID), in digital or analog signal processing systems.

RA's may also be used in stepper motor applications, to determine the step "crossover" of the motor rotor during operation. This information is useful to determine optimum stepping pulse rate in high load inertia applications, or the stepper motor pulse rate may be dynamically controlled to step at the crossover point. This allows the motor to operate in the higher efficiency slew region of performance while maintaing step count. Since the permanent magnet Rotary Accelerometer provides a DC signal, the output may be directly used to determine step to step integrity of the stepper motor in critical pointing mechanisms, where step integrity is paramount.

The data included herein provides greater detail of the benefits and application information of RA's in stepper and servo motor applications.

	TYPE —>	03ACC	Schematic
Output Voltage	V/100kRAD/sec^2	0.60	
Output Load	Ohms	50,000	
Added Length (when integrated to motor)	Inches [mm]	0.622 [15.8]	
Accelerometer Diameter	Inches [mm]	0.750 [19.1]	
Added Inertia	Oz-In-sec^2 [kg-m^2]	6.6 E-05 [4.6 E-07]	
Added Weight	Oz [kg]	0.750 [0.021]	

Notes:

1. The information above is tabulated for an RA mounted directly to a CDA InterCorp motor assembly.
2. Tabulated performance at +25° C.

Rotary Accelerometer Applications for Stepper Motor Actuators

Rotary Accelerometers (RAs) have many practical uses for stepper motor applications. CDA InterCorp's RAs do not require excitation, and provide a DC output in proportion to the motor rotor acceleration. There is no need for external power input or output demodulation to process the signal. With excellent output gain, RAs provide high signal to noise ratio giving robust feedback signals. Typical benefits or applications with stepper motors include: step crossover switching, unit step integrity feedback, inertial compensation, and dynamic speed vs. torque operation.

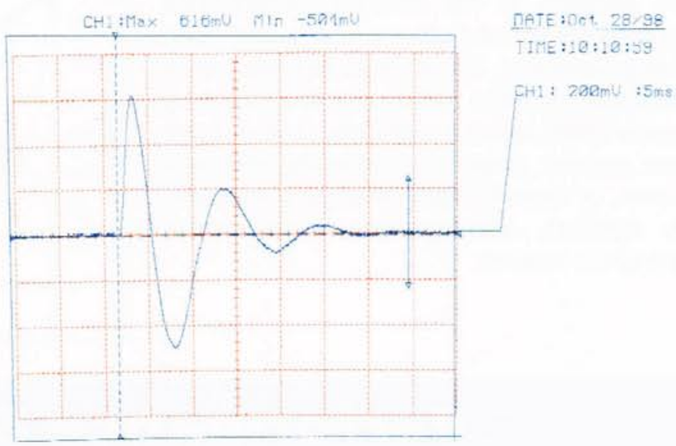
Crossover Switching is used to operate the stepper motor in the high speed slew region of performance. The output of the RA can be used to detect the crossover, or step angle, of the stepper motor. When the accelerometer output goes to zero, the unit step angle has been achieved, and the unit may be pulsed to the next step. Quite simply, set the "clock" input of the stepper motor to step when the accelerometer output goes to zero, this allows the motor to be stepped at the optimum pulse rate while maintaining pulse count, and eliminating overshoot oscillations.

This type of stepper motor control may offer many benefits to the performance of a stepper motor. This technique automatically slews the motor to the maximum allowable pulse rate for a given torque load, or it may also be "clocked" to limit the pulse rate to a specific limit. One disadvantage of conventionally driven stepper motors is the fact that if pull out torque capacity is reached in an application, the motor will lose all torque capacity and fall out of operation. However, with Crossover Switching, if the pull out torque capacity is reached at a specific pulse rate, the motor does not lose torque capacity, but rather simply reduces pulse rate automatically - significantly increasing torque margin capacity of a motor without increasing power input.

Unit Step Integrity feedback may be obtained by looking at the magnitude of the output of the RA. For each given step output, the RA will produce an output signal in response to each pulse. This information is useful in determining whether or not the motor has stepped in response to the pulse. Additionally, this may be used in indexing, or initializing, a stepper motor against a stop in order to "zero" the motor step count. An RA can provide the information to determine if steps have been missed, or if an end stop has been reached.

Inertial Compensation may be derived by feeding the acceleration signal back to a power stage amplifier, to minimize the effect of overshoot and resonant situations. If current feedback is available in the stepper motor controller, the RA's output may be used as feedback into a current loop, which may eliminate high inertial load resonances and torque reduction areas. For a simpler approach, RA's may be used to determine optimum stepping rate for a specific application. By analyzing the accelerometer output, it can be easily determined where the ideal stepping rate is, within a given range, by assuring that the motor is stepping in the proper region of operation. With the characteristic overshoot and bounce inherent in stepper motors, there are some pulse rates which result in an increase in torque capacity, and some pulse rates which result in a reduction of torque capacity. It is easily determined from the output of an RA where these operational pulse rates occur. This information is very beneficial for minimization of power consumption, or system simulation purposes.

Below is an actual scope trace which shows the output of a type 03ACC RA, on the back of a type 16-2P6-20 stepper motor. This is a classic acceleration profile for a single step of a stepper motor. From this direct output you can determine crossover time, overshoot, settling time, desired optimum pulse rate for maximum dynamic torque, and unit step integrity. For performance critical applications , the RA output may be utilized to determine mechanism integrity through the acceleration output. There will be a direct indication from the RA if torque or friction levels of the load or mechanism increases. The brushless DC output provides the ultimate in simplicity, reliability, and effectiveness.



Dynamic Speed vs. Torque Operation may be obtained with a stepper motor with RA feedback. As mentioned under the Crossover Switching section, a stepper motor with RA feedback may obtain dynamic speed vs torque characteristics. Without the RA, stepper motors are usually driven at a fixed operational clock, or pulse rate. Once the pull out torque capacity of such a stepper motor is reached for a given pulse rate, the stepper motor will not continue to run, and the motor will loose all torque capacity. Conversely, with the RA feedback, once the pull out torque capacity has been reached, the motor simply slows down to a lower pulse rate, rather than pull out of operation. This increases torque margin and capacity tremendously, as the stepper motor now performs more like a servo motor, without the complicated electronics. The following information shows the benefits of Dynamic Speed vs. Torque Operation for specific examples, and other performance enhancing characteristics of an RA.

Rotary Accelerometer Applications for Stepper Motor Actuators

The following performance data comparison and performance curves display the benefits which may be realized when an RA is incorporated on a stepper motor actuator. The following scenarios compare a CDA InterCorp Type 16-2P6-20 Stepper Motor, with a 100:1 Type CA gearbox, and a load inertia of 0.125 Oz-In-sec^2. This specific combination results in an inertia factor of 38. These results reflect actual test data. Refer to CDA InterCorp's Stepper Motor Application Data design manual for performance data, equations, and glossary of terms.

Figure 1 shows this motor driven with a conventional "open loop" stepper motor controller. Figure 2 is the identical actuator's dynamic speed vs. torque performance when using RA Crossover Switching.

In addition to the obvious performance enhancement of higher torques and operating velocities, the RA also provides other tangible benefits. With the RA, pulse by pulse information is available. That is, there are no lost steps. Additionally, resonant areas, or unstable performance is inherently nullified, and dynamic speed versus torque is realized.

Figure 1 - Motor Code 16-2P6-20 with 100:1 Gearhead
Inertia Factor = 38 - **Conventionally Driven**

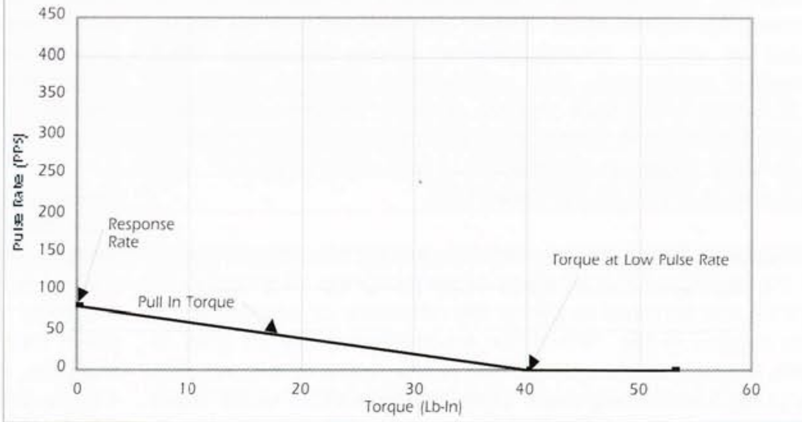
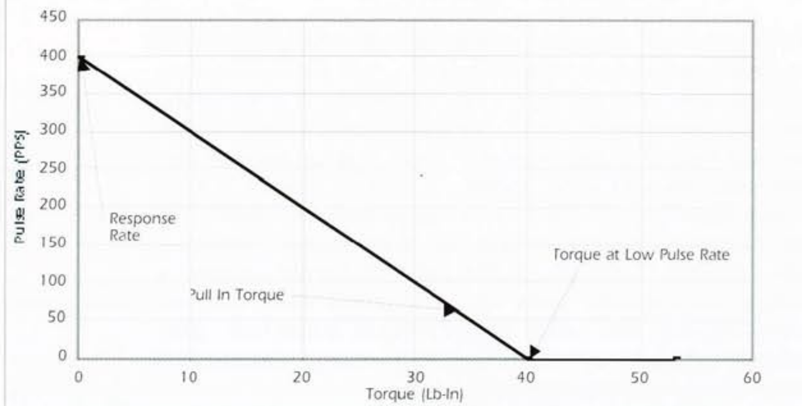


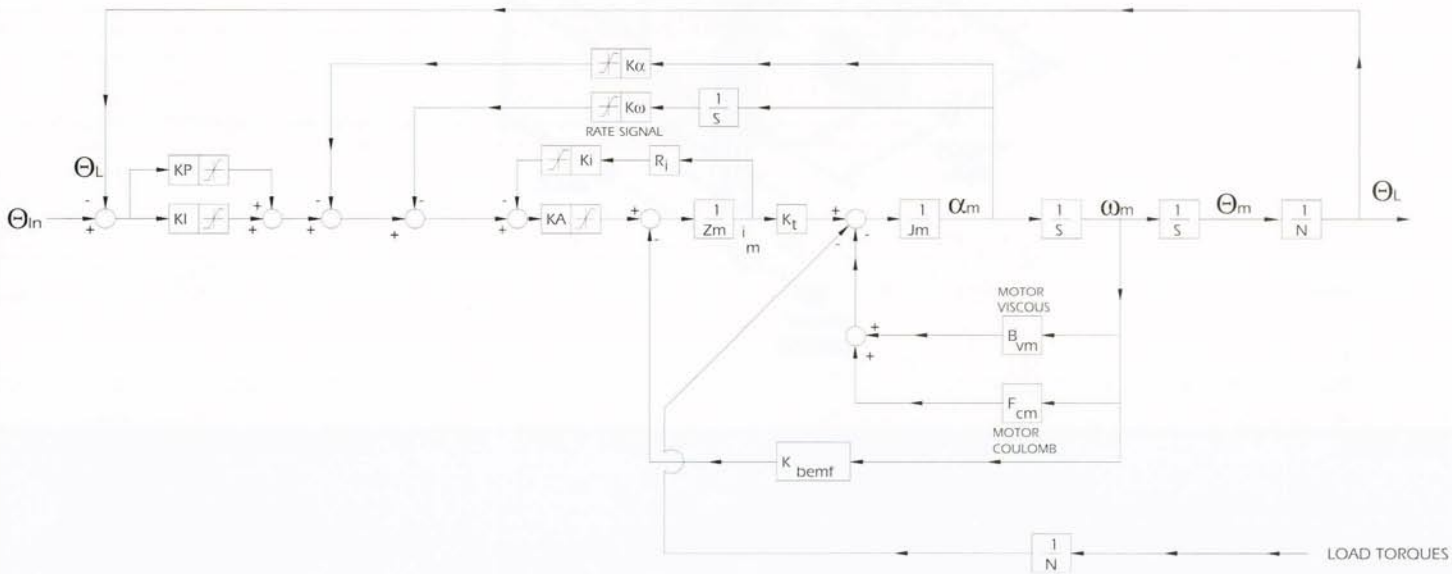
Figure 2 - Motor Code 16-2P6-20 with 100:1 Gearhead
Inertia Factor = 38 - **RA Crossover Switching**



Performance Data Comparison

Parameter			RA Drive Performance	Conventional Drive Performance
Response Rate	Pulses Per Second		**400**	80
Pull In Torque at 60 PPS	Lb-In [Nm]		**34 [3.8]**	10.5 [1.2]
Maximum Power Output Performance	Torque	Lb-In [Nm]	**25 [2.8]**	25 [2.8]
	Speed	Pulses Per Second	**200**	40
Continuous Stable Operation			**Yes**	No
Step Count Verification			**Yes**	No

Functional Block Diagram
Brushless Permanent Magnet Servo Motor with Rotary Accelerometer Feedback and Integrated Velocity Damping



Where:

KP = Proportional Gain of Error Signal

$K\alpha$ = Acceleration Signal Gain

K_i = Current Feedback Gain

R_i = Current Sense Resistor

K_t = Motor Torque Constant

B_{VM} = Motor Viscous Damping

K_{bemf} = Motor Back emf Constant

i_M = Motor Current

α_M = Motor Acceleration

θ_M = Motor Position

θ_{IN} = Load Position Command

KI = Integration Gain of Error Signal

$K\omega$ = Velocity Signal Gain

KA = Power Amplifier Gain

Z_m = Motor Impedance (Ro+jwL)

J_M = Motor Inertia

F_{CM} = Motor Coulomb Friction

s = Laplace Operator

N = Gearhead Ratio

ω_M = Motor Velocity

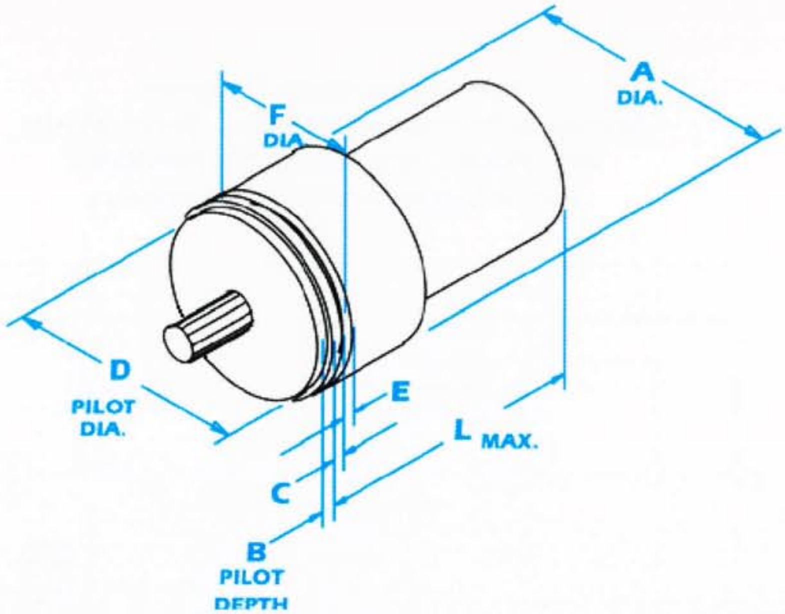
θ_L = Load Position

J_L = Load Inertia

The Rotary Accelerometer (RA) is an extremely useful component in high performance and / or high load inertia servo actuator systems. Since the RA requires no excitation or demodulation, the DC output may be directly Op-Amp integrated for an angular rate damping signal of the motor. This information, along with the angular acceleration signal, provides tremendous flexibility in contouring the system response, and controlling the transfer function.

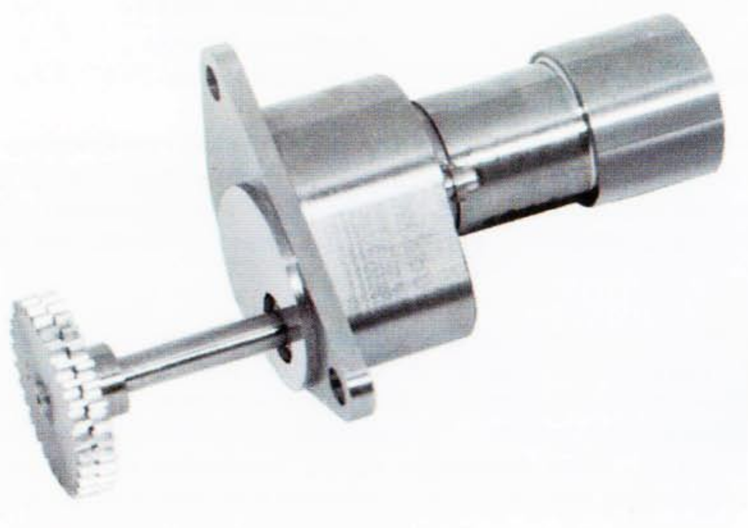
The RA can make the motor rotor inertia electronically "look" larger or smaller through this feedback technique. This electronic technique is like adding a variable electronic "flywheel" to the system, and provides a higher order effect, as compared to electronic damping through tachometer feedback. This may provide high forward loop gain, while maintaining a stable servo system. The electronic flywheel may be controlled to provide these characteristics dynamically in the system. Other advantages include acceleration control, and disturbance attenuation. Contact CDA InterCorp's engineering department for additional information on RA benefits in servo systems.

INDEXING GEARING OPTIONS



Notes:

1. Other mounting configurations available upon request.
2. Concentricity of output shaft to pilot: 0.0007 T.I.R. (0.018 mm)
3. Perpendicularity of output shaft to mounting surface: 0.0007 T.I.R. (0.018 mm)
4. Operating temperature range: -80° C to +225° C.
5. High grade stainless steel construction.
6. Position transducer performance and electrical data tabulated on pages 3 through 8.
7. Speed Down ratios up to 1:2500 available in this configuration. Higher ratios available upon request.
8. Speed Up ratios of up to 2500:1 available in this configuration. Higher ratios available upon request.



IMPERIAL DIMENSIONS (Inches)

SPEED DOWN GEARING

DEVICE	A	B	C	D	E	F	WEIGHT (Oz.)	LENGTH (Inches)
Resolver or Synchro	1.000	0.062	0.093	0.9375	0.062	0.875	4.1	2.052
Tandem Resolver or Synchro	1.000	0.062	0.093	0.9375	0.062	0.875	5.8	3.453
RVT, RVDT, or PMA	1.000	0.062	0.093	0.9375	0.062	0.875	3.6	1.592
Tandem RVT or RVDT	1.000	0.062	0.093	0.9375	0.062	0.875	4.8	2.537

SPEED UP GEARING

DEVICE	A	B	C	D	E	F	WEIGHT (Oz.)	LENGTH (Inches)
Resolver or Synchro	1.000	0.062	0.093	0.9375	0.062	0.875	3.8	2.000
Tandem Resolver or Synchro	1.000	0.062	0.093	0.9375	0.062	0.875	5.5	3.400
RVT, RVDT, or PMA	1.000	0.062	0.093	0.9375	0.062	0.875	3.3	1.500
Tandem RVT or RVDT	1.000	0.062	0.093	0.9375	0.062	0.875	4.5	2.445

SYSTEM INTERNATIONAL (mm)

SPEED DOWN GEARING

DEVICE	A	B	C	D	E	F	WEIGHT (kg)	LENGTH (mm)
Resolver or Synchro	25.4	1.58	2.36	23.81	1.58	22.23	0.116	52.20
Tandem Resolver or Synchro	25.4	1.58	2.36	23.81	1.58	22.23	0.165	87.70
RVT, RVDT, or PMA	25.4	1.58	2.36	23.81	1.58	22.23	0.102	40.44
Tandem RVT or RVDT	25.4	1.58	2.36	23.81	1.58	22.23	0.136	64.44

SPEED UP GEARING

DEVICE	A	B	C	D	E	F	WEIGHT (kg)	LENGTH (mm)
Resolver or Synchro	25.4	1.58	2.36	23.81	1.58	22.23	0.108	50.80
Tandem Resolver or Synchro	25.4	1.58	2.36	23.81	1.58	22.23	0.156	86.36
RVT, RVDT, or PMA	25.4	1.58	2.36	23.81	1.58	22.23	0.095	38.10
Tandem RVT or RVDT	25.4	1.58	2.36	23.81	1.58	22.23	0.128	62.10

Speed Down gearing features the position transducer rotating SLOWER than the ouput. This allows the sensor to rotate in unison with the load axis, while not mounted directly on the axis of rotation. Featuring Anti-Backlash Gearing and AGMA 12 Gears, these components are useful in applications for linear actuation sensing, where "Ball Screw" rotation is an accurate means of sensing linear position.

Speed Up gearing features the position transducer rotating FASTER than the ouput. This allows the sensor to rotate in unison or at greater rates than the load axis, while being mounted away from the axis of rotation. Featuring optional Anti-Backlash Gearing, and AGMA Quality 12 Gears, these components are ideal for systems where high sampling rates of the load is desired.

CDA InterCorp Products

Motor Modules:
- Brushless Permanent Magnet Motors
- AC Induction Motors
- Stepper Motors
- Square Wave Driven AC Motors
- Damped Rotary Switches
- Housed Limited Angle Torquers
- Synchronous Motors

Eddy Current Dampers:
- Rotary
- Linear
- In Line or Right Angle
- Damping "enable" option

Gearing Modules:

Rotary:
- High Torque Planetary
- Right Angle Gearing
- High Accuracy Zero Backlash Gearing
- Precision Indexing Drive Gearing

Linear:
- Ball Screw Actuation
- ACME Lead Screw Actuation
- In-line, Right-angle, or U-drive

Brakes:
- DC Friction Brakes
- Permanent Magnet Detent Brakes
- DC Hysteresis Brakes

Transducers:

Position Transducers:
- Brushless Resolvers
  - Single Speed
  - Multiple Speed
  - Tandem or Cluster Redundant
  - With or without Gearing
  - *OnAxis* Resolvers
- RVDT's
  - Tandem or Cluster Redundancy
  - With or without Gearing
  - *OnAxis* RVDT

Velocity Transducers:
- AC Tachometers
  - Damping Tachs
  - Rate Tachs
- Permanent Magnet Alternators
  - Single Speed
  - Multiple Speed
  - With or without Gearing

Acceleration Transducers:
- Brushless DC Rotary Accelerometers
- DC Excited Rotary Accelerometers

CDA InterCorp can combine these standard modules into multi-function integrated actuators and assemblies. Call CDA InterCorp directly for application engineering assistance, or to request a complete set of application data brochures.

CDA INTERCORP

450 Goolsby Boulevard
Deerfield, FL 33442-3019
TEL (954) 698-6000 ▪ FAX (954) 698-6011
http://www.cda-intercorp.com