



ENGINEERING DATA for Gearheads and Speed Reducers

CHOOSING PRECISION GEARHEADS FOR HIGH RELIABILITY APPLICATIONS

Since servomotors operate most efficiently at much higher speeds than are actually required to drive transducer loads, practically all electromechanical instrument servomechanisms use reduction gearing between the servomotor and which it actuates. This natural association of servomotor and gearing makes it practical to combine motor and gearhead in a single compact assembly with resultant simplification in servomechanism packaging as well as gains in reliability and cost reduction. The advantages of standard motor gearheads are summarized Table 1.

The advantages indicated in Table 1 have led to the almost universal practice in the design of miniature servomechanisms of employing gearheads which generally match the frame sizes of the standard Bureau of Ordinance servomotors. Thus, a Size 11 gearhead couples to a Bureau of Ordinance Size 11 servomotors and may be mounted in the standard manner. This practice extends also to motor tachometers.

General Construction of a Gearhead

Two jig-bored parallel bearing plates provide the bearing seats for the various gear shafts in the gearhead. The shaft centers are symmetrically located on a circle concentric with the axis of the gearhead. Gear clusters are selected to give the required ratio, always using the same shaft centers.

Flanged bearings provide true alignment of shafts. The pinions and gears may be fabricated from materials having different grades and hardnesses, such as 416 and 303 stainless steels, to obtain the best combination for required wear characteristics.

Aluminum is the most commonly used gear housing material. A gearhead motor with an aluminum housing mounted on a aluminum heat sink plate (a typical installation) has a much lower temperature rise than a similar unit with a steel housing. This is because the aluminum housing is much more efficient at conducting heat to the heat sink than a comparable steel housing.

Gearheads often incorporate slip clutches to protect the output shaft against a stalled condition where damaging shaft torques might be developed.

The following sections will consider in turn the factors of importance in specifying the performance characteristics of gearheads required for specific applications.

TABLE 1
ADVANTAGES OF STANDARD GEARHEADS

1. Simplify design and packaging of servomechanisms and systems.
2. Achieve more uniform performance, saving much costly and complex assembly.
3. Lower cost as a result of mass production and standardization of gearhead.
4. Proven performance, based on use of standard item.
5. Environmentally tested, frequently in diverse applications. Closed construction affords convenient protection.
6. Changes, including ratio changes, may be readily accomplished in early stages of prototype testing.

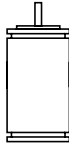


TABLE II
GEAR RATIO SELECTION

1. When the reference signal varies at a relatively constant speed, the gear ratio should permit following at this speed;
2. When the reference signal experiences sudden increments (high acceleration) the gear ratio should be selected to achieve maximum torque-to-inertia ratio at the output.
3. Where static accuracy or slow smooth following is a principal consideration, the gear ratio should amplify motor torque so that the output torque is capable of maintaining the error within allowable limits. This gear ratio is usually inefficient in terms of power transfer to the load.
4. When there are special requirements such as the ability to maintain simultaneously a specified velocity and acceleration, or the need for rapid reversal, or the requirements of minimum time to come up to speed, or a maximum allowable braking time, the gear ratio must be determined accordingly.
5. When a specified friction load is to be carried at a given speed, (either a constant friction or a linear speed-varying drag), the gear ratio should suitably match the motor maximum power output point to the load speed.

Gearhead Friction

Gearhead friction is undesirable for two reasons: (1) it may result in appreciable power loss in the gearhead, particularly where the load draws high power, and (2) it reduces the sensitivity of the servo loop, often directly affecting the static accuracy. In precision instrument servo loops, friction torque amounting to only several thousandths of an ounce-inch assumes significance.

Higher gear friction than would ordinarily be acceptable may be unavoidable in applications where heavy grease is used perhaps to meet some very high temperature requirement. Such greases often introduce disturbing amounts of friction at very low temperatures, and the selection of grease must be made with great care, often with experimental verification of the low temperature starting characteristics of the motorgearhead assembly. Sometimes a permissible warm-up time is specified, during which the grease temperature increases as a result of heat generated by the servomotor until the required starting no-load speed characteristics are achieved.

Inertia

The inertia introduced by the gearhead should be inappreciable by comparison with servomotor inertia if the motor's acceleration characteristics are to be utilized. This is usually not a difficult design problem and is best solved by using a pinion cut directly in the motor shaft as the input drive, and by avoiding large ratios in the first stage or two of the train. The slower shafts contribute practically nothing to the overall reflected inertia at the motor shaft.

Miscellaneous Application Factors

Where application requirements call for accuracies, torque ratings or special mechanical features not included in the standard gearhead construction, it is general practice to provide additional gearing driven by the gearhead output shaft. These gears are larger than the gears within the gearhead, although for ease of installation their diameter rarely exceeds the gearhead diameter.



These larger additional gears may be designed for exceptionally high accuracy, high torque capacity, or tightness of mesh. Spring loaded gears may be installed if required. Ultimate positioning accuracy of +1 minute may be achieved to drive resolvers and single-turn potentiometers. Slip-clutches as well as mechanical and electrical limit stops are often conveniently located in a separate gearing subassembly. Often all that is required are idler gears for coupling the parallel shafts of an array of rotating devices. In summary, where particularly severe gearing specifications must be met, it is often simplest to provide most of the required reduction ratio in the gearhead, and to provide a last stage or two of special gearing to meet the required specifications.

Many construction variations occur in practice to meet specific installation requirements, or to substitute for older models, designed before standardization came to the gearhead industry. Special mountings are common. Occasionally found is an offset shaft construction where the output gear meshes with an external gear train and the mesh is adjustable merely by rotating the whole motor-gearhead assembly.

In the following sections of this catalog Superior Electromechanical Components Service, Inc. has presented data on a wide range of gearheads and speed reducers for use with standard Bureau of Ordnance motors. All types shown can be modified or redesigned to suit new applications. SECS' Engineering Department is available for consultation on particular requirements and will be pleased to recommend specific designs to meet user specifications.

In addition to the standard types offered in this catalog, SECS also provides complete design, fabrication and production facilities for fast delivery of special units to meet the most rigid customer specifications.

Some of the important design and construction features that make the SECS' standard gearheads outstanding for critical servomechanism applications are listed below:

Precision Postless construction assures maximum rigidity of gearhead and accurate alignment of gear centers.

Bearing and pilot holes uniformly bored to 0.0002" maximum variation of center distance for minimum backlash.

Low starting torque and inertia.

Precision stainless steel ball bearings used throughout.

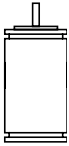
All gearing is A.G.M.A Quality 12 or 14

PERFORMANCE FACTORS IN GEARHEAD SELECTION

The performance characteristics of a gearhead are best established by comparing the required characteristics with those of a hypothetical ideal gearhead. The ideal gearhead would provide an out put shaft speed exactly proportional at any instant to input shaft speed, the proportionality factor being the gear ratio. There would be no friction (other than reflected load friction) at the input shaft, nor would the gear train introduce any inertia. Resilience of shafts and gear teeth would be negligible and backlash would be zero. And these idealized features would be retained at full output load over the life of the unit.

Gear Ratio

The choice of gear ratio is made by the servomechanism designer. The important consideration here is whether the ratio is selected on the basis of matching motor to load, or whether ratio is determined by considerations of loop gain. Table II summarizes some of the factors influencing the choice of gear ratio. Ample margin should be provided to account for variations in servomotor characteristics.



Once the overall ratio is established, the gearhead manufacturer matches this as closely as possible with one of his standard models. For this reason some tolerance is necessary on the specified ratio. An "exact" ratio requirement, calling for a not standard gear design, costs more than an approximate yet suitable ratio. Timing devices driven by synchronous motors, and integrating motor tachometers, however, often require exact ratios.

Backlash

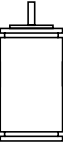
In general, it is the backlash at the output shaft of the gearhead that is of interest to the designer. It is here that backlash may be most readily related to the feedback transducer (control transformer, potentiometer, etc.). In effect backlash introduces a kind of time delay in that portion of the servomechanism between the servomotor and the response signal of the transducer. As with all time delays, backlash tends to introduce an instability factor in the servomechanism loop which the design engineer is often apt to overlook. A servomechanism which on paper appears to be perfectly stable may exhibit the characteristic high-frequency low amplitude oscillation or "buzz" resulting from backlash. Even though backlash oscillations may be very small in amplitude, perhaps well within permissible accuracy limits, they may introduce excessive equipment wear, particularly on the gear teeth. Gearheads with backlash of 30 minutes or less generally satisfy most requirements in practical servomechanisms.

It is unfortunate that the tendency to oscillate is greatest in those servomechanisms having the least static friction, namely those where highest sensitivity is required. Static friction is probably the best deterrent to backlash oscillations even though it is not a reliable or effective means to employ systematically. It would be a mistake to tighten gear meshes so as to introduce excessive static friction (as well as static inaccuracy) since the meshes will eventually loosen as a result of wear. Also, because of eccentricities which inevitable occur in the most accurate gears, some mesh points will always be looser than others, which may lead to sporadic oscillations. Similar remarks might be made about the intentional use of excessively preloaded bearings.

The best way to deal with backlash is to provide accurate gear meshing together with a means of damping sufficient to assure that oscillations do not occur when servo gain is increased to the required design value. Inertially damped motors are particularly effective in critical backlash situations.

The factors which must be considered in setting a specification for backlash are:

1. Backlash at the feedback transducer must be consistent with overall accuracy requirements.
2. Backlash must be small enough so that the tendency to oscillate is eliminated. Servos with high velocity constants and long motor time constants are most sensitive to backlash as are also high-sensitivity servos where static friction is an absolute minimum;
3. Backlash may be relatively unimportant in servomechanisms which drive a friction load at a uniform or slowly varying velocity;
4. Backlash is of less importance where the output transducer swings through a wide angle (such as with a multi-turn potentiometer).



Speed and Torque Ratings

These ratings are of course determined by requirements of wear and life. In many applications, loads are negligible and life of several thousands of hours is readily achieved under the more common military environments. In such instances it is necessary only to make certain that loading is not introduced as a result of improper gear installation; for example, cocking, eccentricity, or similar misalignments may cause heavy wear, even without output-shaft load.

At the input end, coupled to the drive motor, little difficulty is encountered at speeds to 12,000 rpm. Fortunately most 400-cycle servo motors have no-load speeds under 7,000 rpm, or occasionally 10,000 rpm. Sixty-cycle motors have much slower speeds. D-C motors occasionally will reach speeds of 18,000 rpm, and care must be exercised to insure adequate life, especially if appreciable torque loads occur. Because of the high speed and low torques encountered at the motor end of the gear train, relatively loose meshes and fine pitch gearing are commonly employed.

At the low speed end, on the other hand, substantial torques may occur, even in very low power systems. A Size 8 motor with a rated stall torque of 0.25 ounce-inches will generate approximately 75 ounce-inches through a rather typical 300:1 reduction ratio. Under running conditions the teeth must withstand surface fatigue and bending stresses for the required life of the unit. The choice of gear materials and their heat treatment as well as the selection of pitch and face width determine the loading capacity. The gears must be cut accurately, aligned properly and permanently fastened to their shafts to insure full use of their inherent load-carrying capacity.

Bearings

The gearhead designer is quite restricted by packaging design in his choice of bearings. Generally speaking, Class 5 and Class 7 stainless steel ball bearings provide best life as well as best performance. Their major disadvantage is their high cost, especially in gearheads with multiple meshes and hence, many bearings.

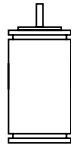
If price is of importance and the application requirements somewhat less critical, sleeve bearings may be profitably used. These generally exhibit high friction and poorer life than ball bearings, particularly under extreme temperature conditions. To be useful, sleeve bearings must be machined to extremely close tolerances and carefully installed, otherwise wear becomes excessive and premature failure occurs.

Lubrication

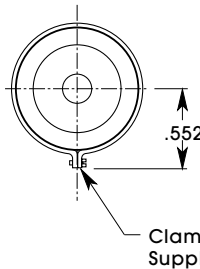
The problem of lubrication applies to gearhead bearings just as it applies to servomotor bearings. Lubricates must be selected on the basis of ability to operate at extreme temperatures without introducing excessive viscous friction even at low temperatures, where the servomotor gearhead combination must still respond readily to small signals.

GEARHEADS AND SPEED REDUCERS

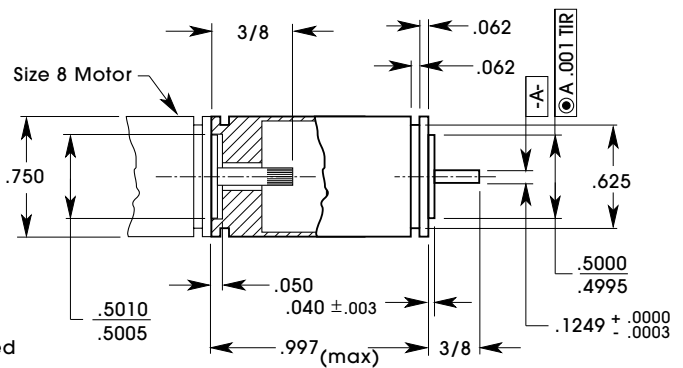
Precision—Size 8
 Ratios 8.11—1970.17



Type GHH 8
 Unless Otherwise Specified
 Decimal Dimensions $\pm .005$
 Fractions $\pm 1/64$

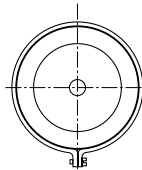


Clamp Supplied

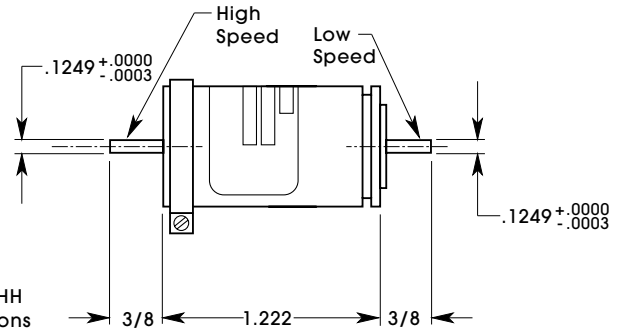


Motor Pinion Data

Number of Teeth	13
Diametral Pitch	120
Pressure Angle	20°
Pitch Diameter .....	.1083
Measurement Over .016 Wires .....	.1316/.1311
Outside Diameter .....	.1247



Type SR 8
 See Type GHH
 for Dimensions
 Not Specified



SPECIFICATIONS

Backlash at Output Shaft:	30 min. Max. with a 1 oz-in Reversing Load
.....	45 Min. Max Ratios 8.11 thru 99.28
Maximum Continuous Output Torque:	5 oz-in
Maximum Momentary Output Torque:	25 oz-in
Breakaway Torque at High Speed Input: .....	.005 oz-in
Moment of Inertia at High Speed Input: .....	.005 gm-cm ²
Shaft Radial Play: .....	.002 inch per inch Max. with 4 oz. Gage Load
Shaft End Play: .....	.004 inch Max. with 1 Pound Gage Load in Axial Direction
Operating Temperature:	-55°C to +125°C
Lubrication:	per MIL-L-6085A and MIL-S-823827
Military Specification:	Applicable Sections of MIL-S-81963
Gear Tolerance:	A.G.M.A. Quality 12 or Better
Bearings:	Precision Stainless Steel
Materials:	Passivated Stainless Steel Gear Clusters and Bearing Plates
.....	Stainless Steel Housing and End Cap
Friction Slip Clutch:	Available on Request. Specify Setting

RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
8.11	1	SAME	GHH8-8.11	SR8-8.11
11.71 17.71 21.62 24.32	2	REVERSE	GHH8-11.71	SR8-11.71
			GHH8-17.71	SR8-17.71
			GHH8-21.62	SR8-21.62
			GHH8-24.32	SR8-24.32
31.23 37.23 57.65 64.86 72.97	3	SAME	GHH8-31.23	SR8-31.23
			GHH8-37.23	SR8-37.23
			GHH8-57.65	SR8-57.65
			GHH8-64.86	SR8-64.86
			GHH8-72.97	SR8-72.97

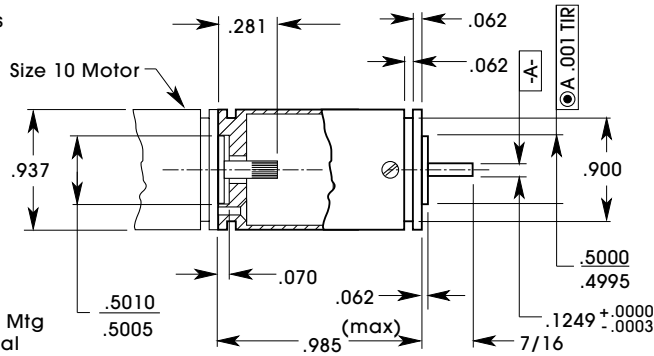
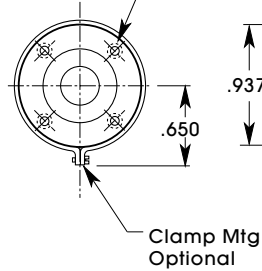
RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
82.28 99.28 123.56 153.74 172.96 194.58 218.91	4	REVERSE	GHH8-82.28	SR8-82.28
			GHH8-99.28	SR8-99.28
			GHH8-123.56	SR8-123.56
			GHH8-153.74	SR8-153.74
			GHH8-172.96	SR8-172.96
			GHH8-194.58	SR8-194.58
			GHH8-218.91	SR8-218.91
264.74 329.74 410.00 518.89 656.72 878.54	5	SAME	GHH8-264.74	SR8-264.74
			GHH8-329.74	SR8-329.74
			GHH8-410.00	SR8-410.00
			GHH8-518.89	SR8-518.89
			GHH8-656.72	SR8-656.72
			GHH8-878.54	SR8-878.54
1093.33 1383.00 1556.67 1970.17	6	REVERSE	GHH8-1093.33	SR8-1093.33
			GHH8-1383.00	SR8-1383.00
			GHH8-1556.67	SR8-1556.67
			GHH8-1970.17	SR8-1970.17

Specials: Specifications, Ratios and Dimensions may be Changed to Meet Customer Requirements on Request.

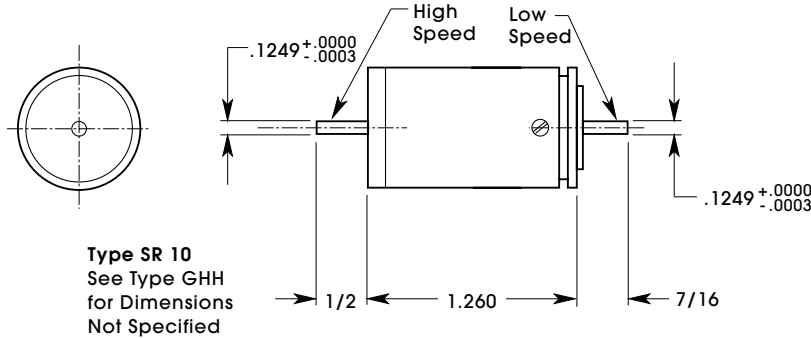
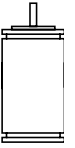
GEARHEADS AND SPEED REDUCERS

Precision—Size 10
Ratios 12.69—9412.32

Dr. No. 47(.078) C'Sink
82° to .145 dia. 4 Holes
Eq. Spaced on
.700±.002 Dia.



Type GHH 10
Unless Otherwise
Specified Decimal
Dimensions ±.005
Fractions ±1/64



Motor Pinion Data

Number of Teeth	13
Diametral Pitch	120
Pressure Angle	20°
Pitch Diameter .....	.1083
Measurement Over .016 Wires .....	.1316/.1311
Outside Diameter .....	.1247

SPECIFICATIONS

Backlash at Output Shaft:	30 min. Max. with a 2 oz-in Reversing Load
.....	45 Min. Max Ratios 12.69 thru 91.53
Maximum Continuous Output Torque:	15 oz-in
Maximum Momentary Output Torque:	50 oz-in
Breakaway Torque at High Speed Input: .....	.005 oz-in
Moment of Inertia at High Speed Input: .....	.0095 gm-cm ²
Shaft Radial Play: .....	.002 inch per inch Max. with 4 oz. Gage Load
Shaft End Play: .....	.004 inch Max. with 1 Pound Gage Load in Axial Direction
Operating Temperature:	-55°C to +125°C
Lubrication:	per MIL-L-6085A and MIL-S-823827
Military Specification:	Applicable Sections of MIL-S-81963
Gear Tolerance:	A.G.M.A. Quality 12 or Better
Bearings:	Precision Stainless Steel
Materials:	Passivated Stainless Steel Gear Clusters and Bearing Plates
.....	Black Anodized Aluminum Housing and End Cap
Friction Slip Clutch:	Available on Request. Specify Setting

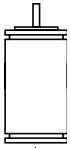
RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
12.69	1	SAME	GHH10-12.69	SR10-12.69
24.40 47.59	2	REVERSE	GHH10-24.40 GHH10-47.59	SR10-24.40 SR10-47.59
91.53 133.27 178.49	3	SAME	GHH10-91.53 GHH10-133.27 GHH10-178.49	SR10-91.53 SR10-133.27 SR10-178.49

RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
198.32 224.67 256.28 373.15 499.76 699.32	4	REVERSE	GHH10-198.32 GHH10-224.67 GHH10-256.28 GHH10-373.15 GHH10-499.76 GHH10-699.32	SR10-198.32 SR10-224.67 SR10-256.28 SR10-373.15 SR10-499.76 SR10-699.32
961.08 1399.33 1874.10 2510.00	5	SAME	GHH10-961.08 GHH10-1399.33 GHH10-1874.10 GHH10-2510.00	SR10-961.08 SR10-1399.33 SR10-1874.10 SR10-2510.00
3604.04 5247.48 7027.32 9412.32	6	REVERSE	GHH10-3604.04 GHH10-5247.48 GHH10-7027.32 GHH10-9412.32	SR10-3604.04 SR10-5247.48 SR10-7027.32 SR10-9412.32

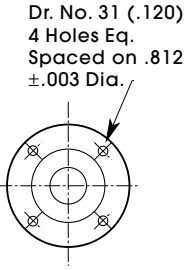
Specials: Specifications, Ratios and Dimensions may be Changed to Meet Customer Requirements on Request.

GEARHEADS AND SPEED REDUCERS

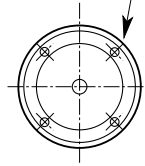
Precision—Size 11
 Ratios 14.46—11,105.28



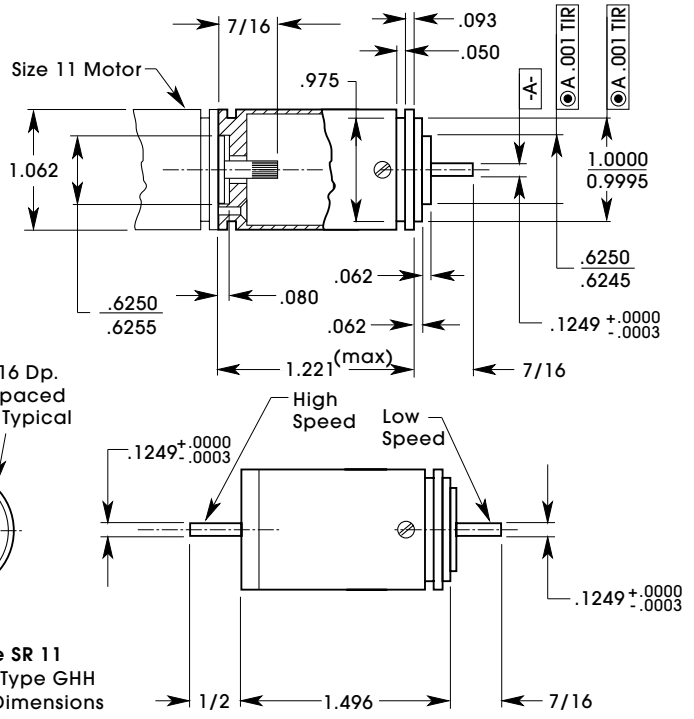
Type GHH 11
 Unless Otherwise Specified
 Decimal Dimensions ±.005
 Fractions ±1/64



No. 4-40 NC-2x3/16 Dp.
 4 Holes Equally Spaced on .812 ±.003 Dia Typical



Type SR 11
 See Type GHH for Dimensions Not Specified



Motor Pinion Data

Number of Teeth	13
Diametral Pitch	120
Pressure Angle	20°
Pitch Diameter	.1083
Measurement Over .016 Wires	.1316/.1311
Outside Diameter	.1247

SPECIFICATIONS

- Backlash at Output Shaft: 30 min. Max. with a 3 oz-in Reversing Load
- Maximum Continuous Output Torque: 45 Min. Max Ratios 14.46 thru 100.54
- Maximum Momentary Output Torque: 25 oz-in
- Breakaway Torque at High Speed Input: 100 oz-in
- Moment of Inertia at High Speed Input: .005 oz-in
- Shaft Radial Play: .011 gm-cm²
- Shaft End Play: .002 inch per inch Max. with 4 oz. Gage Load
- Operating Temperature: .004 inch Max. with 1 Pound Gage Load in Axial Direction
- Operating Temperature: -55°C to +125°C
- Lubrication: per MIL-L-6085A and MIL-S-81963
- Military Specification: Applicable Sections of MIL-S-81963
- Gear Tolerance: A.G.M.A. Quality 12 or Better
- Bearings: Precision Stainless Steel
- Materials: Passivated Stainless Steel Gear Clusters and Bearing Plates
- Friction Slip Clutch: Black Anodized Aluminum Housing and End Cap
- Friction Slip Clutch: Available on Request. Specify Setting

RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
14.46	1	SAME	GHH11-14.16	SR11-14.16
24.10 43.38 57.84	2	REVERSE	GHH11-24.10 GHH11-43.38 GHH11-57.84	SR11-24.10 SR11-43.38 SR11-57.84
72.30 100.54 130.14 152.50 173.52 199.24 231.36	3	SAME	GHH11-72.30 GHH11-100.54 GHH11-130.14 GHH11-152.50 GHH11-173.52 GHH11-199.24 GHH11-231.36	SR11-72.30 SR11-100.54 SR11-130.14 SR11-152.50 SR11-173.52 SR11-199.24 SR11-231.36

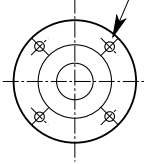
RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
249.03 270.29 332.08 390.42 520.56 694.08 925.44	4	REVERSE	GHH11-249.03 GHH11-270.29 GHH11-332.08 GHH11-390.42 GHH11-520.56 GHH11-694.08 GHH11-925.44	SR11-249.03 SR11-270.29 SR11-332.08 SR11-390.42 SR11-520.56 SR11-694.08 SR11-925.44
1029.26 1171.26 1561.68 2082.24 2776.32 3701.76	5	SAME	GHH11-1029.26 GHH11-1171.26 GHH11-1561.68 GHH11-2082.24 GHH11-2776.32 GHH11-3701.76	SR11-1029.26 SR11-1171.26 SR11-1561.68 SR11-2082.24 SR11-2776.32 SR11-3701.76
4117.04 4685.04 6246.72 8328.96 11,105.28	6	REVERSE	GHH11-4117.04 GHH11-4685.04 GHH11-6246.72 GHH11-8328.96 GHH11-11,105.28	SR11-4117.04 SR11-4685.04 SR11-6246.72 SR11-8328.96 SR11-11,105.28

Specials: Specifications, Ratios and Dimensions may be Changed to Meet Customer Requirements on Request.

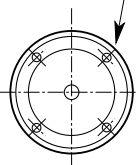
GEARHEADS AND SPEED REDUCERS

Precision—Size 15
Ratios 15.30—14,429.85

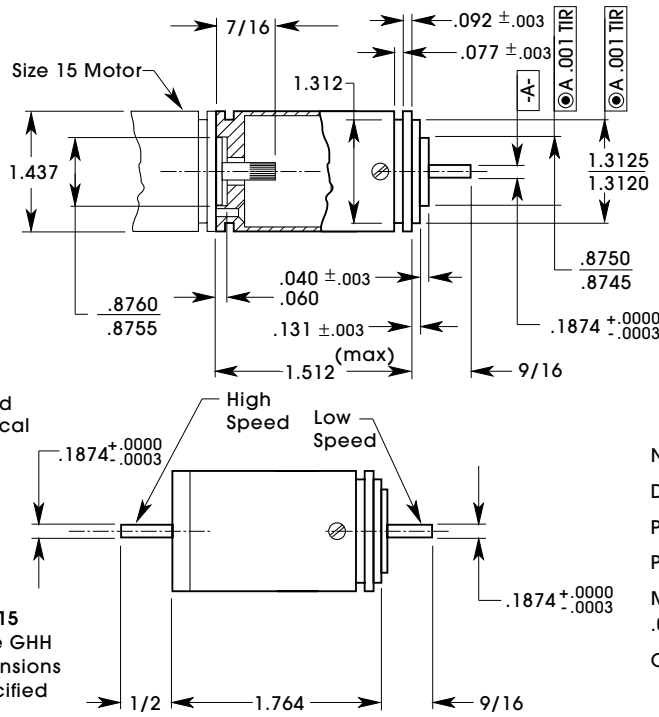
Dr. No. 30 (.128)
4 Holes Eq.
Spaced on
1.100 ±.003 Dia.



No. 4-40 NC-2x.125 Dp.
4 Holes Equally Spaced
on 1.100 ±.003 Dia Typical



Type SR 15
See Type GHH
for Dimensions
Not Specified



Type GHH 15
Unless Otherwise
Specified Decimal
Dimensions ±.005
Fractions ±1/64

Motor Pinion Data

Number of Teeth	15
Diametral Pitch	96
Pressure Angle	20°
Pitch Diameter .....	.1562
Measurement Over .018 Wires .....	.1791/.1786
Outside Diameter .....	.1765

SPECIFICATIONS

Backlash at Output Shaft:	30 min. Max. with a 5 oz-in Reversing Load
Maximum Continuous Output Torque:	35 oz-in
Maximum Momentary Output Torque:	100 oz-in
Breakaway Torque at High Speed Input: .....	.008 oz-in
Moment of Inertia at High Speed Input: .....	.045 gm-cm ²
Shaft Radial Play: .....	.002 inch per inch Max. with 4 oz. Gage Load
Shaft End Play: .....	.004 inch Max. with 1 Pound Gage Load in Axial Direction
Operating Temperature:	-55°C to +125°C
Lubrication:	per MIL-L-6085A and MIL-S-23827
Military Specification:	Applicable Sections of MIL-S-81963
Gear Tolerance:	A.G.M.A. Quality 12 or Better
Bearings:	Precision Stainless Steel
Materials:	Passivated Stainless Steel Gear Clusters and Bearing Plates Black Anodized Aluminum Housing and End Cap
Friction Slip Clutch:	Available on Request. Specify Setting

RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
15.30	1	SAME	GHH15-15.30	SR15-15.30
23.53 30.60 40.80 47.81 56.82 68.85	2	REVERSE	GHH15-23.53 GHH15-30.60 GHH15-40.80 GHH15-47.81 GHH15-56.82 GHH15-68.85	SR15-23.53 SR15-30.60 SR15-40.80 SR15-47.81 SR15-56.82 SR15-68.85
81.60 105.85 137.70 158.24 183.60 215.15 255.72 309.82	3	SAME	GHH15-81.60 GHH15-105.85 GHH15-137.70 GHH15-158.24 GHH15-183.60 GHH15-215.15 GHH15-255.72 GHH15-309.82	SR15-81.60 SR15-105.85 SR15-137.70 SR15-158.24 SR15-183.60 SR15-215.15 SR15-255.72 SR15-309.82

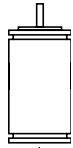
RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
367.20 422.28 489.60 573.75 681.94 826.20	4	REVERSE	GHH15-367.20 GHH15-422.28 GHH15-489.60 GHH15-573.75 GHH15-681.94 GHH15-826.20	SR15-367.20 SR15-422.28 SR15-489.60 SR15-573.75 SR15-681.94 SR15-826.20
1049.14 1147.50 1319.62 1652.40 1900.26 2203.20 2581.87 3206.64 3717.90 4356.84 5178.42 6273.85	5	SAME	GHH15-1049.14 GHH15-1147.50 GHH15-1319.62 GHH15-1652.40 GHH15-1900.26 GHH15-2203.20 GHH15-2581.87 GHH15-3206.64 GHH15-3717.90 GHH15-4356.84 GHH15-5178.42 GHH15-6273.85	SR15-1049.14 SR15-1147.50 SR15-1319.62 SR15-1652.40 SR15-1900.26 SR15-2203.20 SR15-2581.87 SR15-3206.64 SR15-3717.90 SR15-4356.84 SR15-5178.42 SR15-6273.85
9652.08 12,547.70 14,429.85	6	REVERSE	GHH15-9652.08 GHH15-12,547.70 GHH15-14,429.85	SR15-9652.08 SR15-12,547.70 SR15-14,429.85

Specials: Specifications, Ratios and Dimensions may be Changed to Meet Customer Requirements on Request.

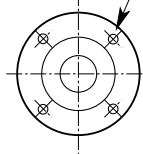
GEARHEADS AND SPEED REDUCERS

Precision—Size 18
Ratios 17.00—16,033.16

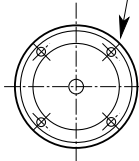
Dr. No. 31 (.120) C'Sink 80°
x .250 Dia. Opposite Side 4
Holes Eq. Spaced on
1.1250 ±.003 Dia.



Type GHH 18
Unless Otherwise
Specified Decimal
Dimensions ±.005
Fractions ±1/64



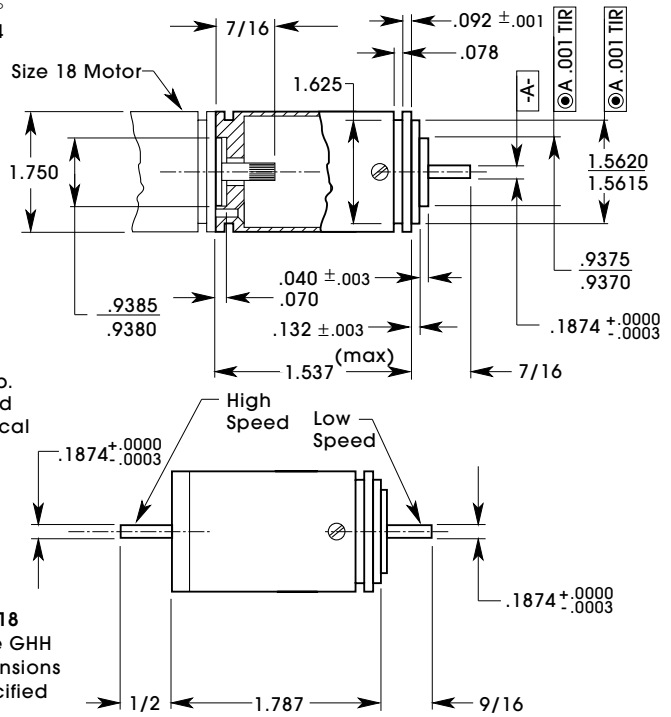
No. 4-40 NC-2 x .250 Dp.
4 Holes Equally Spaced
on 1.250 ±.003 Dia Typical



Motor Pinion Data

Number of Teeth	15
Diametral Pitch	96
Pressure Angle	20°
Pitch Diameter .....	.1562
Measurement Over .016 Wires .....	.1791/.1786
Outside Diameter .....	.1765

Type SR 18
See Type GHH
for Dimensions
Not Specified



SPECIFICATIONS

Backlash at Output Shaft:	30 min. Max. with a 5 oz-in Reversing Load
Maximum Continuous Output Torque:	65 oz-in
Maximum Momentary Output Torque:	150 oz-in
Breakaway Torque at High Speed Input: .....	.010 oz-in
Moment of Inertia at High Speed Input: .....	.050 gm-cm ²
Shaft Radial Play: .....	.002 inch per inch Max. with 4 oz. Gage Load
Shaft End Play: .....	.004 inch Max. with 1 Pound Gage Load in Axial Direction
Operating Temperature:	-55°C to +125°C
Lubrication:	per MIL-L-6085A and MIL-S-23827
Military Specification:	Applicable Sections of MIL-S-81963
Gear Tolerance:	A.G.M.A. Quality 12 or Better
Bearings:	Precision Stainless Steel
Materials:	Passivated Stainless Steel Gear Clusters and Bearing Plates Black Anodized Aluminum Housing and End Cap
Friction Slip Clutch:	Available on Request. Specify Setting

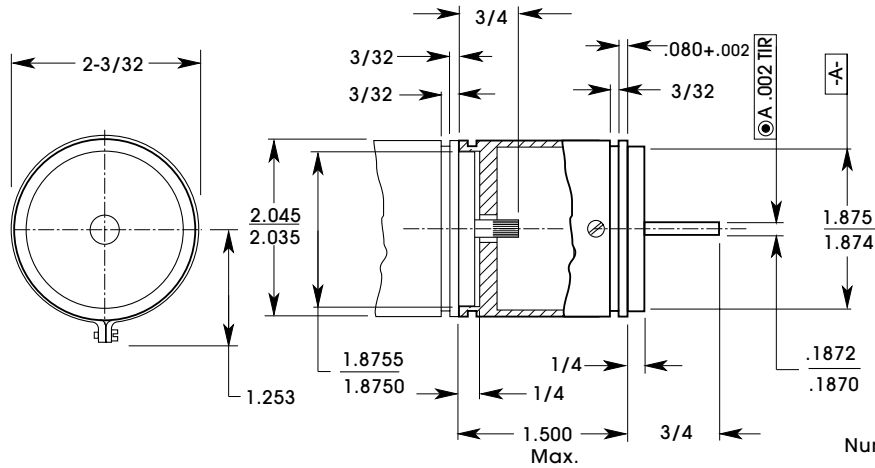
RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
17.00	1	SAME	GHH18-17.00	SR18-17.00
26.14 34.00 45.33 53.12 63.33 76.44	2	REVERSE	GHH18-26.14 GHH18-34.00 GHH18-45.33 GHH18-53.12 GHH18-63.33 GHH18-76.44	SR18-26.14 SR18-34.00 SR18-45.33 SR18-53.12 SR18-63.33 SR18-76.44
90.66 117.61 153.00 175.82 204.00 239.05 284.13 344.24	3	SAME	GHH18-90.66 GHH18-117.61 GHH18-153.00 GHH18-175.82 GHH18-204.00 GHH18-239.05 GHH18-284.13 GHH18-344.24	SR18-90.66 SR18-117.61 SR18-153.00 SR18-175.82 SR18-204.00 SR18-239.05 SR18-284.13 SR18-344.24

RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
469.20 544.00 637.50 757.71 918.00	4	REVERSE	GHH18-469.20 GHH18-544.00 GHH18-637.50 GHH18-757.71 GHH18-918.00	SR18-469.20 SR18-544.00 SR18-637.50 SR18-757.71 SR18-918.00
1165.57 1275.00 1466.20 1836.00 2111.40 2448.00 2868.74 3562.93 4131.00 4840.90 5753.80 6970.94	5	SAME	GHH18-1165.57 GHH18-1275.00 GHH18-1466.20 GHH18-1836.00 GHH18-2111.40 GHH18-2448.00 GHH18-2868.74 GHH18-3562.93 GHH18-4131.00 GHH18-4356.84 GHH18-5753.80 GHH18-6970.94	SR18-1165.57 SR18-1275.00 SR18-1466.20 SR18-1836.00 SR18-2111.40 SR18-2448.00 SR18-2868.74 SR18-3562.93 SR18-4131.00 SR18-4356.84 SR18-5753.80 SR18-6970.94
10,724.53 13,941.89 16,033.16	6	REVERSE	GHH18-10,724.53 GHH18-13,941.89 GHH18-16,033.16	SR18-10,724.53 SR18-13,941.89 SR18-16,033.16

Specials: Specifications, Ratios and Dimensions may be Changed to Meet Customer Requirements on Request.

GEARHEADS AND SPEED REDUCERS

Precision—Size 21L
 Ratios 5.83—8928.57



Motor Pinion Data

Number of Teeth	13
Diametral Pitch	96
Pressure Angle	20°
Pitch Diameter .....	.1354
Measurement Over .016 Wires .....	.1680/.1678
Outside Diameter .....	.1560

SPECIFICATIONS

Backlash at Output Shaft:	30 min. Max. with a 10 oz-in Reversing Load
Maximum Continuous Output Torque:	80 oz-in
Maximum Momentary Output Torque:	150 oz-in
Breakaway Torque at High Speed Input: .....	.005 oz-in
Moment of Inertia at High Speed Input: .....	.060 gm-cm ²
Shaft Radial Play: .....	.002 inch per inch Max. with 4 oz. Gage Load
Shaft End Play: .....	.003 inch Max. with 1 Pound Gage Load in Axial Direction
Operating Temperature:	-55°C to +100°C
Lubrication:	per MIL-L-6085A and MIL-S-81963
Military Specification:	Applicable Sections of MIL-S-81963
Gear Tolerance:	A.G.M.A. Quality 12 or Better
Bearings:	Precision Stainless Steel
Materials:	Passivated Stainless Steel Gear Clusters and Bearing Plates Black Anodized Aluminum Housing and End Cap
Friction Slip Clutch:	Available on Request. Specify Setting

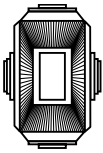
RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
5.83 13.57	1	SAME	GHH21-5.83 GHH21-13.57	SR21-5.83 SR21-13.57
32.91 50.00 77.63 96.87 125.00	2	REVERSE	GHH21-32.91 GHH21-50.00 GHH21-77.63 GHH21-125.00	SR21-32.91 SR21-50.00 SR21-77.63 SR21-125.00
155.26 200.00 250.00 265.00 484.37	3	SAME	GHH21-155.26 GHH21-200.00 GHH21-250.00 GHH21-265.00 GHH21-484.37	SR21-155.26 SR21-200.00 SR21-250.00 SR21-265.00 SR21-484.37

RATIO	NUMBER OF CLUSTERS	DIRECTION OF OUTPUT SHAFT ROTATION WITH RESPECT TO MOTOR PINION	CATALOG NUMBER	
			GEARHEAD	SPEED REDUCER
733.19 776.32 1000.00 1250.00 1494.57 1696.43 1940.79 2421.87 3125.00	4	REVERSE	GHH21L-733.19 GHH21L-776.32 GHH21L-1000.00 GHH21L-1250.00 GHH21L-1494.57 GHH21L-1696.43 GHH21L-1940.79 GHH21L-2421.87 GHH21L-3125.00	SR21L-733.19 SR21L-776.32 SR21L-1000.00 SR21L-1250.00 SR21L-1494.57 SR21L-1696.43 SR21L-1940.79 SR21L-2421.87 SR21L-3125.00
5000.00	5	SAME	GHH21L-5000.00	SR21L-5000.00
8928.57	6	REVERSE	GHH21L-8928.57	SR21L-8928.57

Specials: Specifications, Ratios and Dimensions may be Changed to Meet Customer Requirements on Request.

PRECISION DIFFERENTIALS

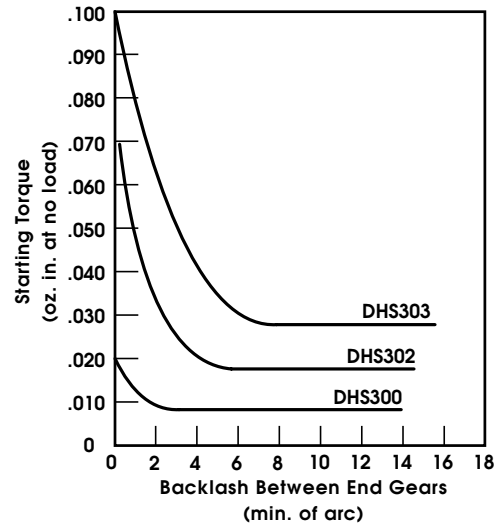
Solid Shaft • Hollow Shaft • Single End



The SECS differentials are engineered for high accuracy in additive and subtractive operations and have primary applications to angular velocity, sums, differences, sequence, and other functions. Their design features include: high speed rotation, minimum backlash and low breakaway torque, simple shaft lock for easy installation or removal of the unit from a gear train without disassembly of unit or instrument and easy pinion gear adjustment for desired backlash starting torque and adjustment for wear.

Features:

- Minimum Backlash.
- Easy Adjustment For Desired Backlash, Starting Torque, or Adjustment for Wear.
- Simple Shaft Lock for Easy Installation or Removal.
- Versatile hollow shaft eliminated stocking of custom shaft lengths
- Hardened (RC 26-32) type 416 Stainless steel construction throughout
- Precision stainless steel ball bearings
- 2 Point contact with spider gears
- Light weight—low inertia
- End gears will be quoted on request.
- Engineering assistance is available on their selection and application.



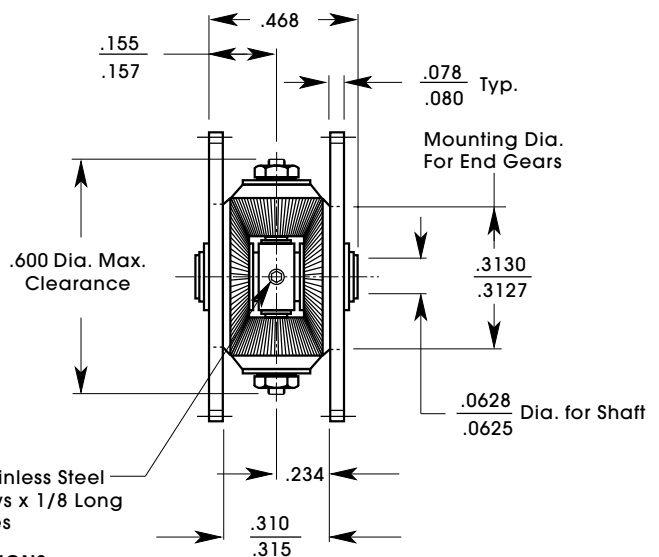
36T-24T • Pitch 96

Shaft 1/8

Hollow Shaft

CATALOG NUMBER	DHS300
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

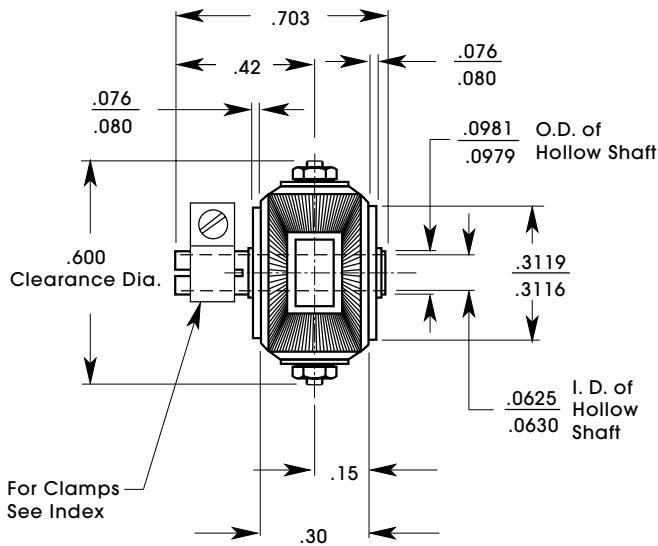
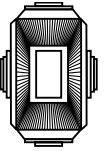


SPECIFICATIONS

Backlash Between End Gears:	0-10 Min. of Arc
Maximum Recommended Shaft Speed:	1000 RPM
Shaft Diameter:	1/16
Clearance Diameter: .....	.600
Maximum Recommended Load Rating:	7 oz. in.
End (Sun) Bevel Gears-Straight:	36 Teeth 96 Pitch
Pinion Bevel Gears-Straight:	24 Teeth 96 Pitch
Weight:	185 oz.
Method of Attachment:	Two Opposed Set Screws (#1-72)
Ball Bearings:	Precision Stainless Steel

PRECISION DIFFERENTIALS

48T-24T • Pitch 96
Shaft 1/16
Hollow Shaft



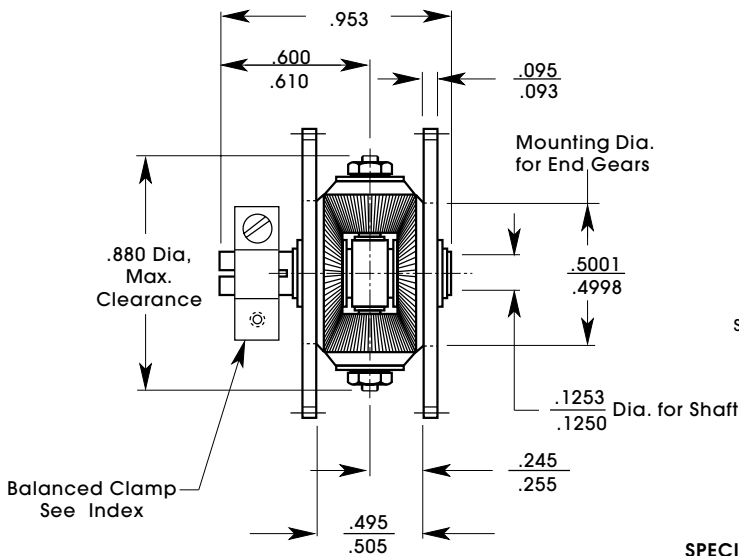
CATALOG NUMBER	DHS301
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Shaft Speed: 1000 RPM
 Shaft Diameter: 1/16
 Clearance Diameter:600
 Maximum Recommended Load Rating: 7 oz. in.
 End (Sun) Bevel Gears-Straight: 48 Teeth 96 Pitch
 Pinion Bevel Gears-Straight: 24 Teeth 96 Pitch
 Weight:580 oz.
 Method of Attachment: Balanced Clamp
 Ball Bearings: Precision Stainless Steel

40T-24T • Pitch 64
Shaft 1/8
Hollow Shaft



CATALOG NUMBER	DHS302
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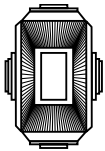
Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Shaft Speed: 900 RPM
 Shaft Diameter: 1/8
 Clearance Diameter:880
 Maximum Recommended Load Rating: 10 oz. in.
 End (Sun) Bevel Gears-Straight: 40 Teeth 64 Pitch
 Pinion Bevel Gears-Straight: 24 Teeth 64 Pitch
 Weight:638 oz.
 Method of Attachment: Balanced Clamp(Standard)
 Two Opposed Set Screws (#2-56) (Special)
 Ball Bearings: Precision Stainless Steel

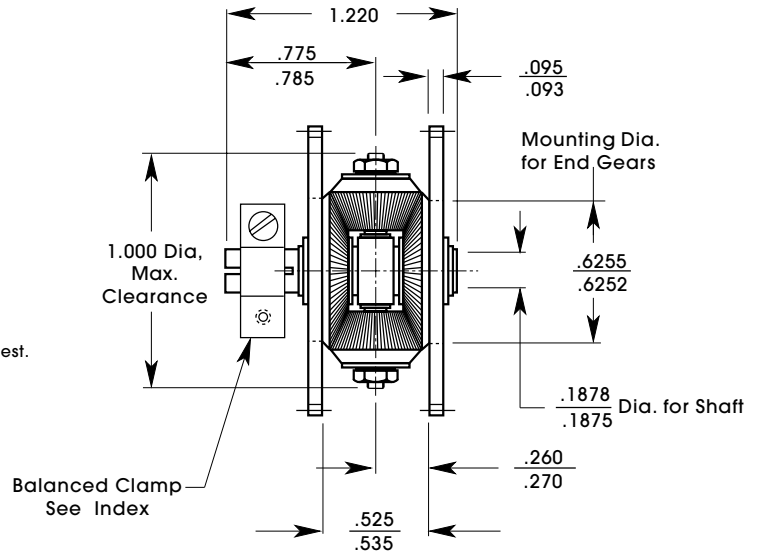
PRECISION DIFFERENTIALS

48T-28T • Pitch 64
 Shaft 3/16
 Hollow Shaft



CATALOG NUMBER	DHS303
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Special Differentials Designed to Your Requirements Available on Request.
 End Gears Available on Request.



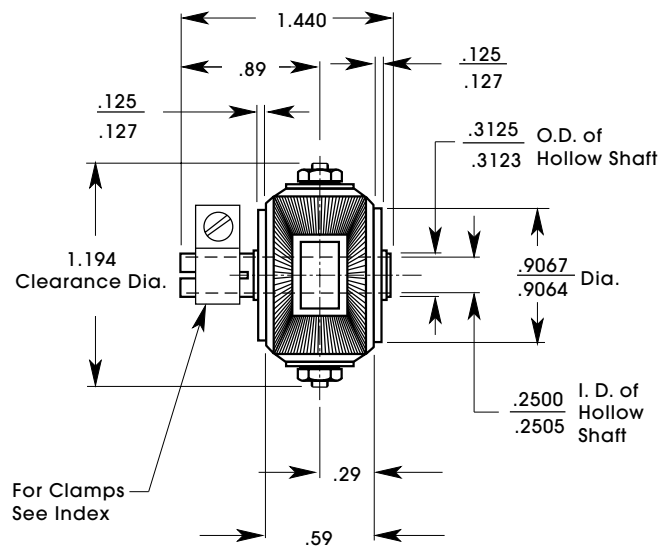
SPECIFICATIONS

Backlash Between End Gears:	0-10 Min. of Arc
Maximum Recommended Shaft Speed:	800 RPM
Shaft Diameter:	3/16
Clearance Diameter:	1.000
Maximum Recommended Load Rating:	12 oz. in.
End (Sun) Bevel Gears-Straight:	48 Teeth 64 Pitch
Pinion Bevel Gears-Straight:	28 Teeth 64 Pitch
Weight: .....	.911 oz.
Method of Attachment:	Balanced Clamp(Standard) Two Opposed Set Screws (#4-40) (Special)
Ball Bearings:	Precision Stainless Steel

64T-32T • Pitch 64
 Shaft 1/4
 Hollow Shaft

CATALOG NUMBER	DHS304
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Special Differentials Designed to Your Requirements Available on Request.
 End Gears Available on Request.

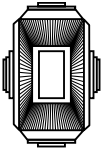
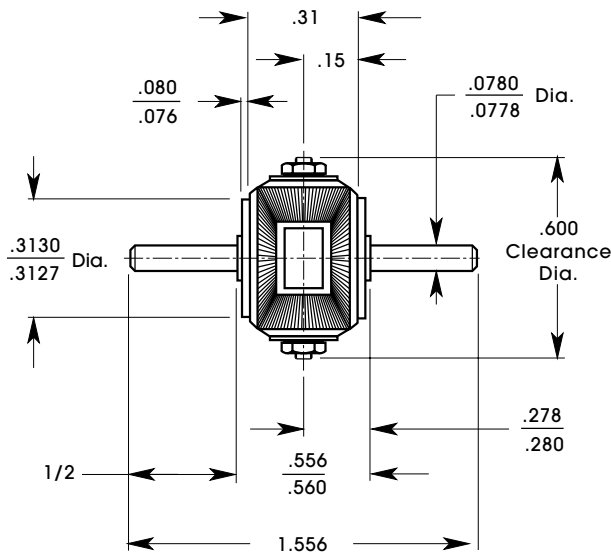


SPECIFICATIONS

Backlash Between End Gears:	0-10 Min. of Arc
Maximum Recommended Shaft Speed:	800 RPM
Shaft Diameter:	1/4
Clearance Diameter:	1.194
Maximum Recommended Load Rating:	25 oz. in.
End (Sun) Bevel Gears-Straight:	64 Teeth 64 Pitch
Pinion Bevel Gears-Straight:	32 Teeth 64 Pitch
Weight:	1.70 oz.
Method of Attachment:	Balanced Clamp
Ball Bearings:	Precision Stainless Steel

PRECISION DIFFERENTIALS

36T-24T • Pitch 96
Shaft 5/64
Solid Shaft



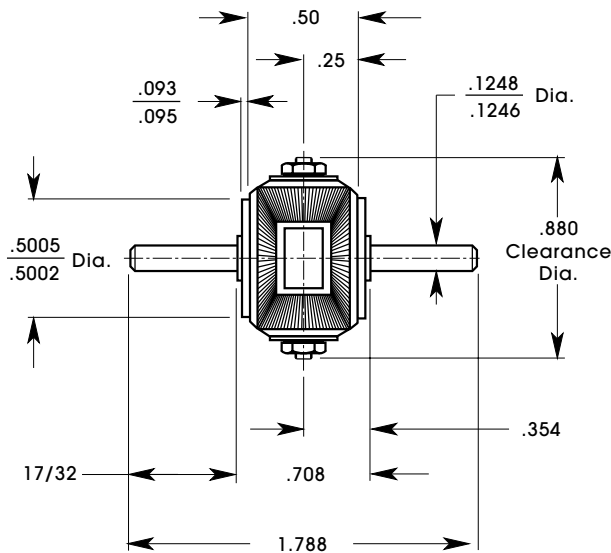
CATALOG NUMBER	DSS305
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Shaft Speed: 1000 RPM
 Shaft Diameter: 5/64
 Clearance Diameter:600
 Maximum Recommended Load Rating: 10 oz. in.
 End (Sun) Bevel Gears-Straight: 36 Teeth 96 Pitch
 Pinion Bevel Gears-Straight: 24 Teeth 96 Pitch
 Weight:600 oz.
 Ball Bearings: Precision Stainless Steel

36T-28T • Pitch 64
Shaft 1/8
Solid Shaft



CATALOG NUMBER	DSS306
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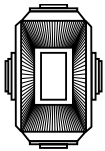
Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Shaft Speed: 1000 RPM
 Shaft Diameter: 1/8
 Clearance Diameter:880
 Maximum Recommended Load Rating: 19 oz. in.
 End (Sun) Bevel Gears-Straight: 36 Teeth 64 Pitch
 Pinion Bevel Gears-Straight: 28 Teeth 64 Pitch
 Weight:500 oz.
 Ball Bearings: Precision Stainless Steel

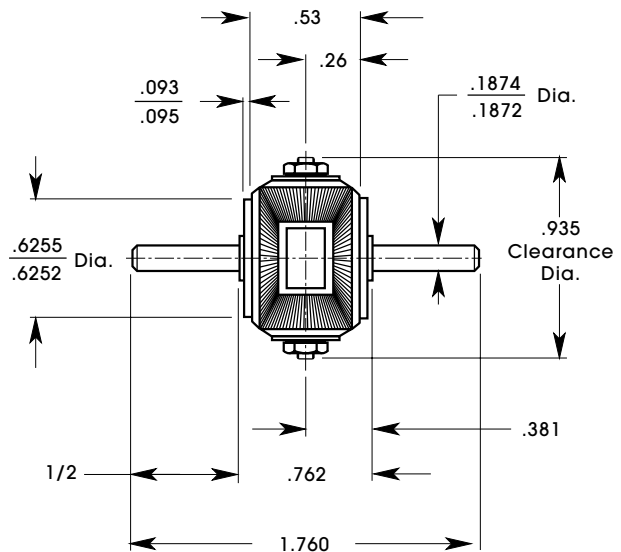
PRECISION DIFFERENTIALS

48T-28T • Pitch 64
 Shaft 3/16
 Solid Shaft



CATALOG NUMBER	DSS307
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Special Differentials Designed to Your Requirements Available on Request.
 End Gears Available on Request.



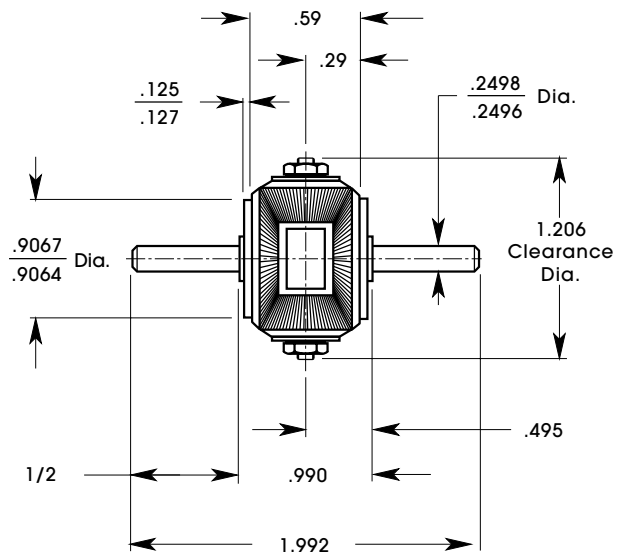
SPECIFICATIONS

Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Shaft Speed: 1000 RPM
 Shaft Diameter: 3/16
 Clearance Diameter:935
 Maximum Recommended Load Rating: 20 oz. in.
 End (Sun) Bevel Gears-Straight: 48 Teeth 64 Pitch
 Pinion Bevel Gears-Straight: 28 Teeth 64 Pitch
 Weight:800 oz.
 Ball Bearings: Precision Stainless Steel

66T-32T • Pitch 64
 Shaft 1/4
 Solid Shaft

CATALOG NUMBER	DSS308
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Special Differentials Designed to Your Requirements Available on Request.
 End Gears Available on Request.

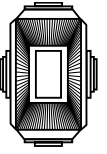
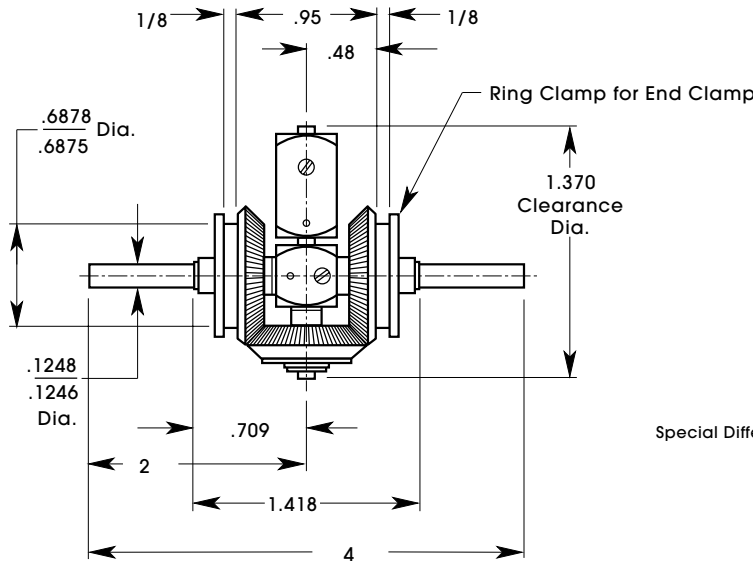


SPECIFICATIONS

Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Shaft Speed: 1000 RPM
 Shaft Diameter: 1/4
 Clearance Diameter: 1.106
 Maximum Recommended Load Rating: 30 oz. in.
 End (Sun) Bevel Gears-Straight: 66 Teeth 64 Pitch
 Pinion Bevel Gears-Straight: 32 Teeth 64 Pitch
 Weight: 1.90 oz.
 Ball Bearings: Precision Stainless Steel

PRECISION DIFFERENTIALS

Pitch 72
Shaft 1/8
Solid Shaft



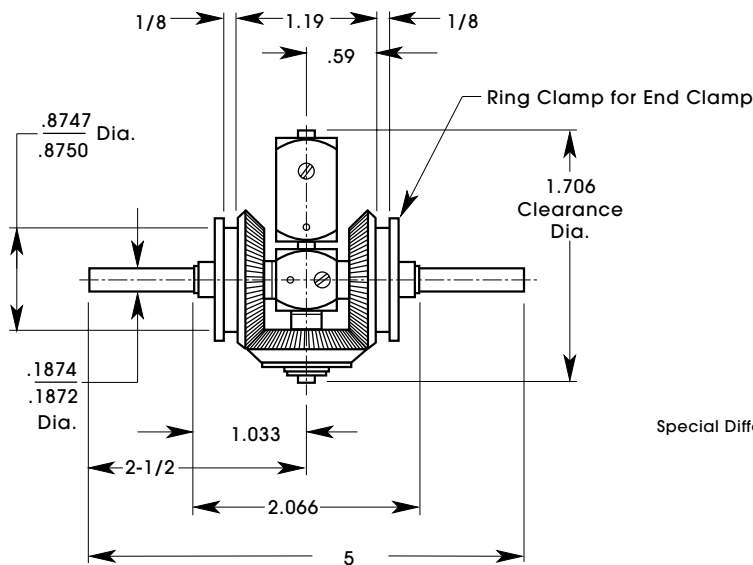
CATALOG NUMBER	DSS309
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Maximum Recommended Load Rating: 40 in. oz.
Backlash Between End Gears: 0-10 Min. of Arc
Maximum Recommended Operating Speed: 600 RPM.
Starting Torque:2 in. oz.
Weight: 2.3 oz.
Ball Bearings: Precision Stainless Steel
Bearings in Bevel Gears: Double
Bearings Pinion Gears: Double

Pitch 64
Shaft 3/16
Solid Shaft



CATALOG NUMBER	DSS310
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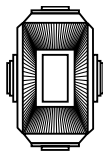
Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Maximum Recommended Load Rating: 80 in. oz.
Backlash Between End Gears: 0-10 Min. of Arc
Maximum Recommended Operating Speed: 2400 RPM.
Starting Torque:2 in. oz.
Weight: 5.2 oz.
Ball Bearings: Precision Stainless Steel
Bearings in Bevel Gears: Double
Bearings Pinion Gears: Double

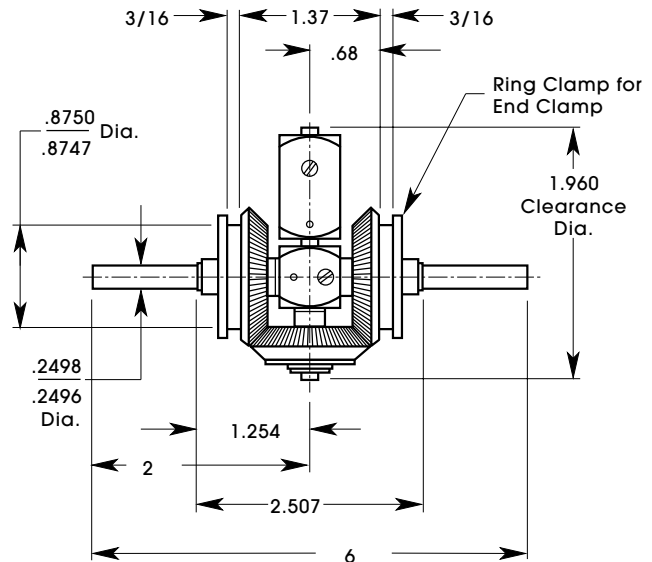
PRECISION DIFFERENTIALS

Pitch 48
Shaft 1/4
Solid Shaft



CATALOG NUMBER	DSS311
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.



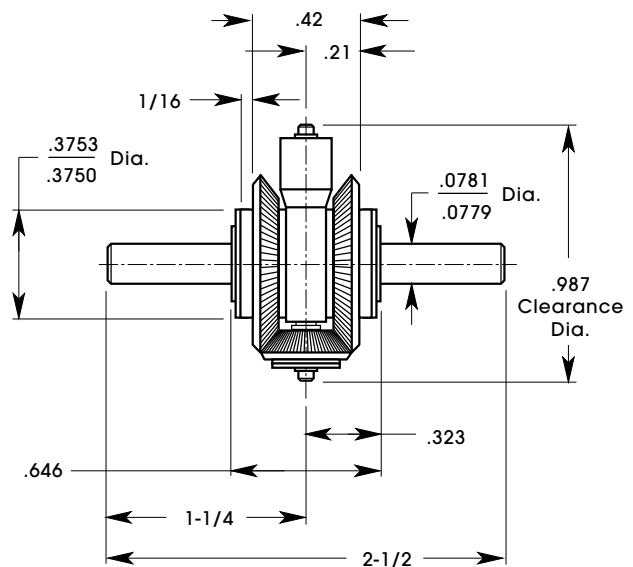
SPECIFICATIONS

Maximum Recommended Load Rating: 80 in. oz.
 Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Operating Speed: 2400 RPM.
 Starting Torque:1 in. oz.
 Weight: 7.5 oz.
 Ball Bearings: Precision Stainless Steel
 Bearings in Bevel Gears: Double
 Bearings Pinion Gears: Double

Pitch 96
Shaft 5/64
Solid Shaft

CATALOG NUMBER	DSS312
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

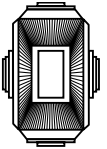
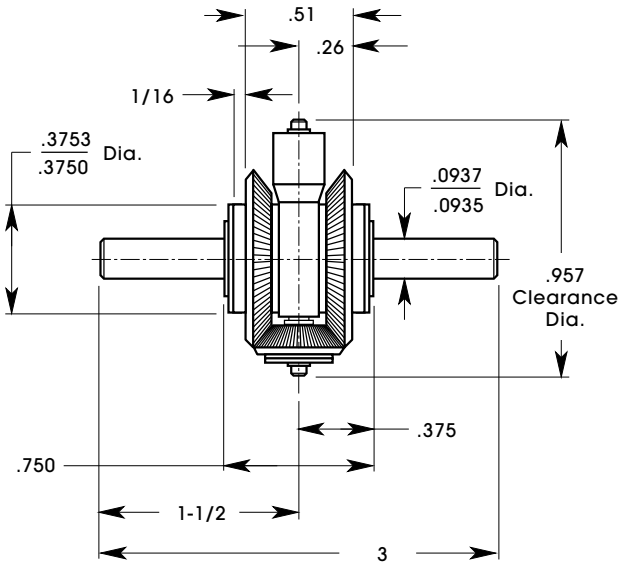


SPECIFICATIONS

Maximum Recommended Load Rating: 20 in. oz.
 Backlash Between End Gears: 0-10 Min. of Arc
 Maximum Recommended Operating Speed: 1100 RPM.
 Starting Torque:05 in. oz.
 Weight:5 oz.
 Ball Bearings: Precision Stainless Steel
 Bearings in Bevel Gears: Double
 Bearings Pinion Gears: Double

PRECISION DIFFERENTIALS

Pitch 96
Shaft 3/32
Solid Shaft



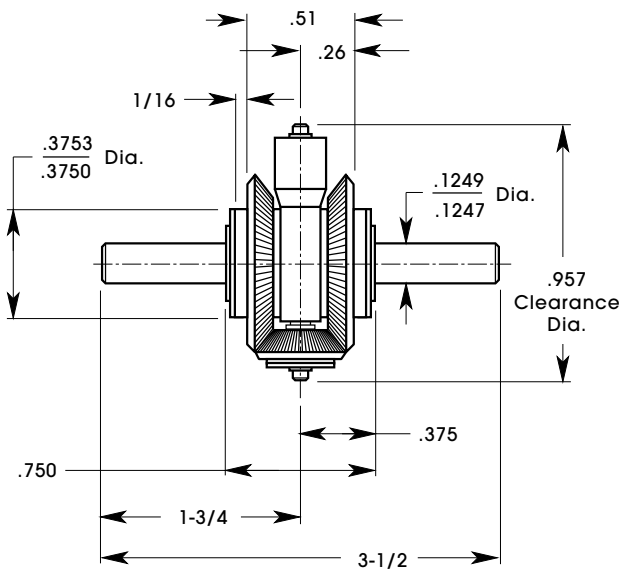
CATALOG NUMBER	DSS313
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Maximum Recommended Load Rating: 20 in. oz.
Backlash Between End Gears: 0-10 Min. of Arc
Maximum Recommended Operating Speed: 1100 RPM.
Starting Torque:05 in. oz.
Weight:6 oz.
Ball Bearings: Precision Stainless Steel
Bearings in Bevel Gears: Double
Bearings Pinion Gears: Double

Pitch 96
Shaft 1/8
Solid Shaft



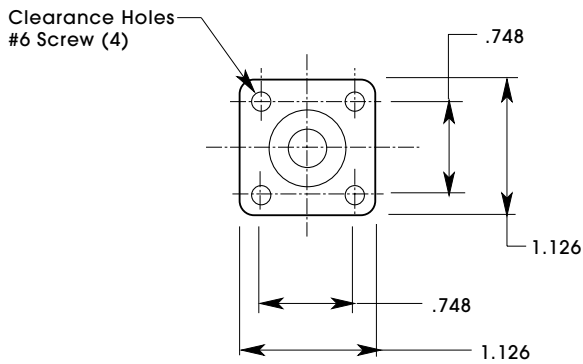
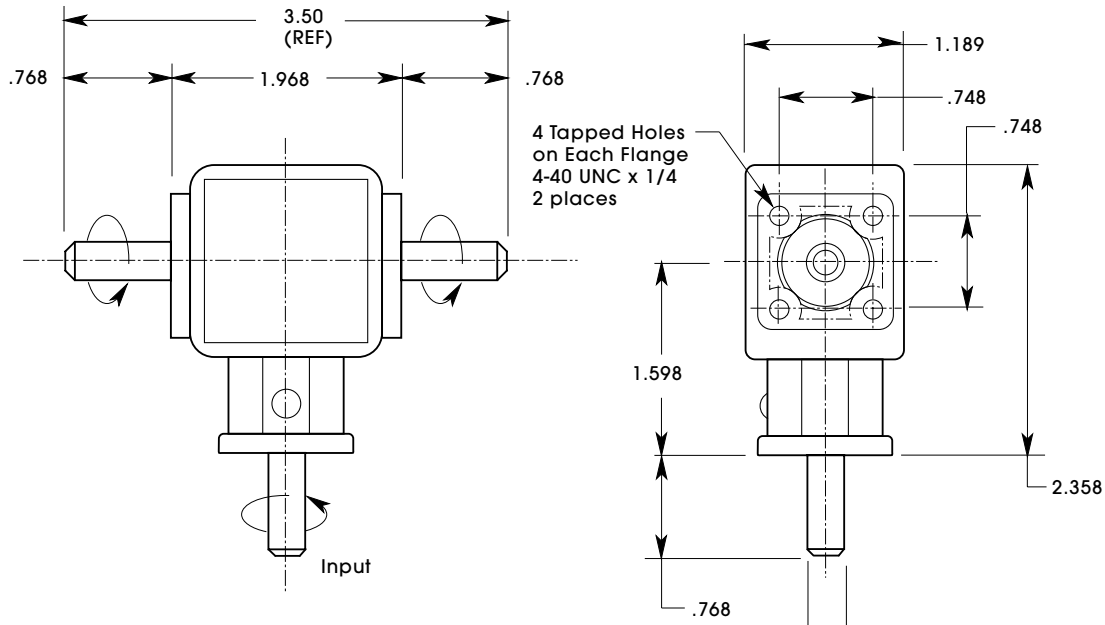
CATALOG NUMBER	DSS314
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Special Differentials Designed to Your Requirements Available on Request.
End Gears Available on Request.

SPECIFICATIONS

Maximum Recommended Load Rating: 17 in. oz.
Backlash Between End Gears: 0-10 Min. of Arc
Maximum Recommended Operating Speed: 1100 RPM.
Starting Torque:05 in. oz.
Weight:7 oz.
Ball Bearings: Precision Stainless Steel
Bearings in Bevel Gears: Double
Bearings Pinion Gears: Double

BEVEL GEAR BOX



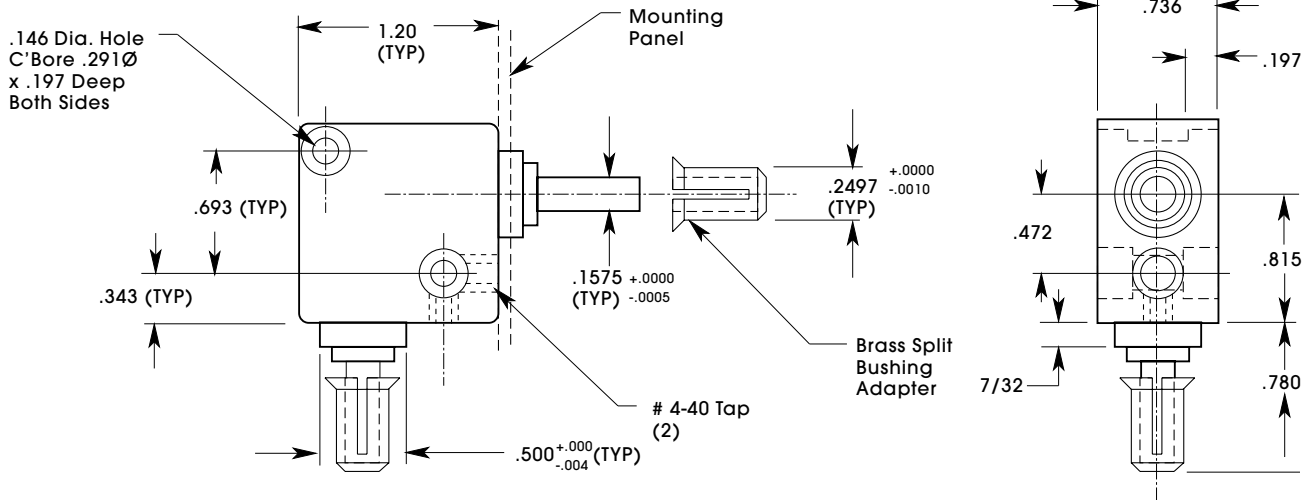
Material :

Molded Plastic *Housing*
 Case Hardened *Gears*
 Surface Hardened, Corrosion Resistant *Shafts*
 Lubricated for Life

RATIO	RPM MAX	OPERATING TORQUE	BACKLASH MAX	CATALOG NUMBER
1.1	1500	48 OZ. IN.	2°	SE61XM-16
1.2	1500	96 OZ. IN.	2°	SE71XM-17

MINIATURE MITER GEAR BOX

1/4 SHAFT • 4 MM SHAFT



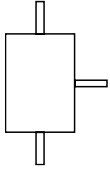
RATIO	RPM MAX	OPERATING TORQUE	GEAR MATERIAL	CATALOG NUMBER
1:1	1000	98 OZ. IN.	HARDENED STEEL	SE41XM-14

Material :

Black Acetal *Housing*
 Sintered Bronze *Bearings*
 Ground Hardened Steel *Shafts*
 Lubricated for Life

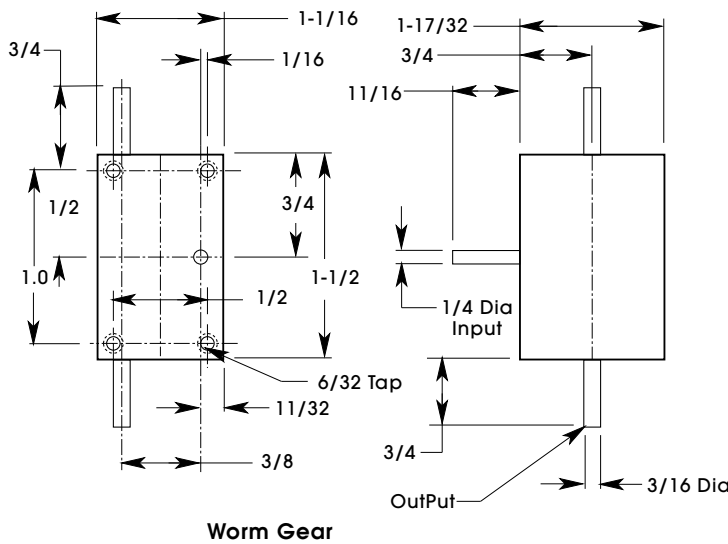
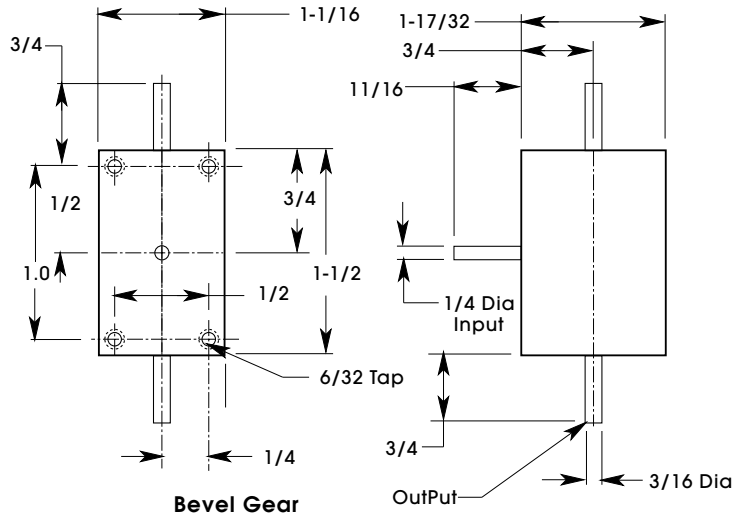
RIGHT ANGLE RATIO DRIVE

Bevel Gear Type
Worm Gear Type



Bevel Gear

RATIO	CATALOG NUMBER
1:1	RAD4
2:1	RAD5
3:1	RAD6

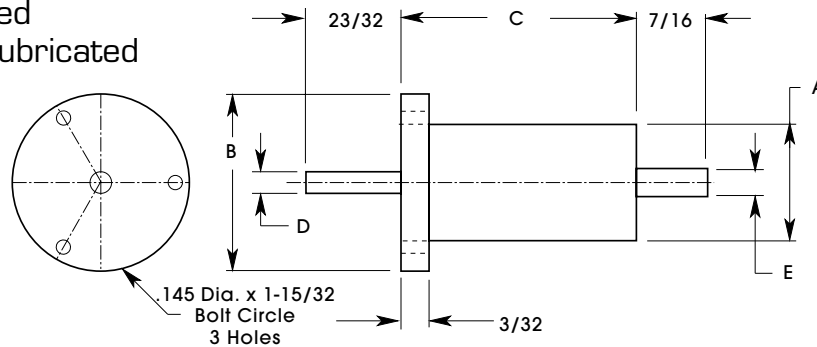
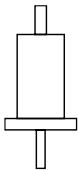


Worm Gear

RATIO	CATALOG NUMBER
5:1	RAD1
10:1	RAD2
20:1	RAD3

RATIO DRIVES

- Compact
- Ball Bearing Type
 - Permanently Sealed
 - Permanently Lubricated



RATIO	A	B	C	OUTPUT D	INPUT E	BOLT CIRCLE	CATALOG NUMBER
266:1	1-1/8	1-13/16	1-3/32	1/4	3/8	1-15/32	SRC1
7.08:1	1-1/8	1-13/16	1-1/2	1/4	3/8	1-15/32	SRC2
18.80:1	1-1/8	1-13/16	1-1/2	1/4	3/8	1-15/32	SRC3